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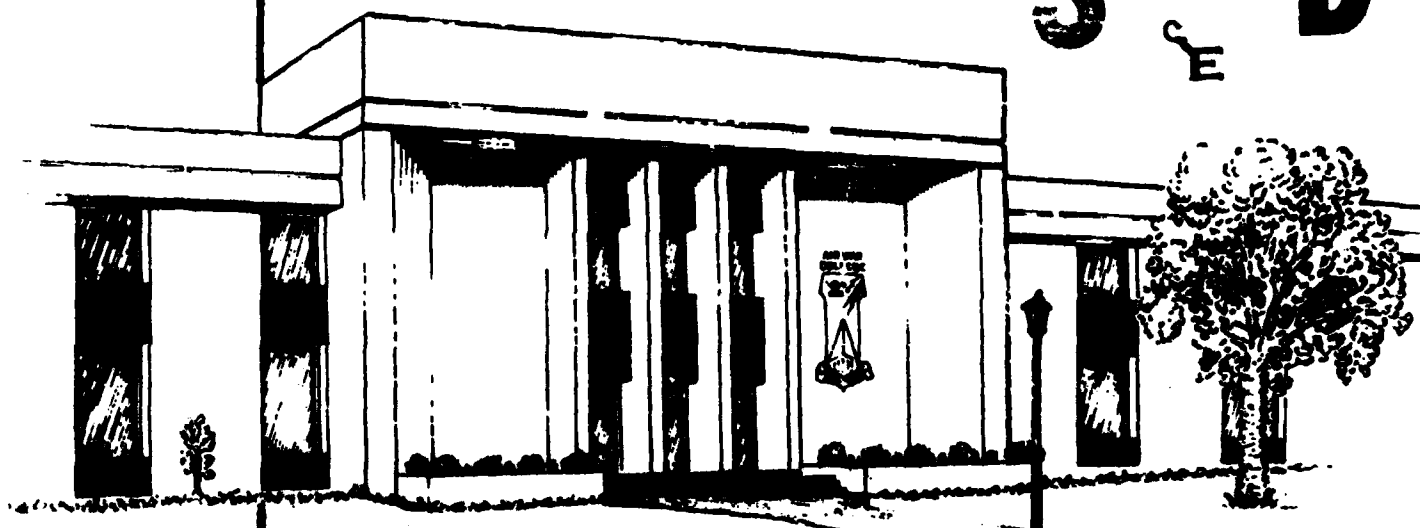
RESEARCH REPORT

WEAPON SYSTEM WARRANTIES: IS THE AIR
FORCE ON TRACK?

LIEUTENANT COLONEL JUAN G. MENDEZ

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WEAPON SYSTEM WARRANTIES:
IS THE AIR FORCE ON TRACK?

by

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A RESEARCH REPORT SUBMITTED TO THE FACULTY
IN
FULFILLMENT OF THE RESEARCH
REQUIREMENT

Research Advisor: Dr. Jim Winkates

MAXWELL AIR FORCE BASE, ALABAMA

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AIR WAR COLLEGE RESEARCH REPORT ABSTRACT

TITLE: Weapon System Warranties: Is the Air Force on Track?

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This thesis describes weapon system warranties and examines the corporate Air Force approach to integrating warranties into the acquisition process. The paper is broadly focused on warranties within the framework of four issues. The issues are: (1) Congressional intent; (2) the warranty as part of the acquisition process; (3) the warranty's relationship to reliability and maintainability; and (4) administration of warranties. The author briefly traces the history of warranty law and compares the 1984 and 1985 warranty laws. Warranty concepts are discussed with examples of incentive and assurance warranties. Confusion between commercial and military warranties is shown to be a cause of misunderstanding within the Air Force. The paper illustrates where assurance and incentive warranties are used and establishes a linkage between warranties and reliability and maintainability. Policy guidance is examined as a possible source of confusion about warranties. The paper examines how the Air Force is organized to administer warranties and looks at the adequacy of data systems. The author finds generally poor understanding and confusion about warranties in the Air Force. Reliability and maintainability are found to be inadequately linked to warranties and administratively the Air Force is found in need of structural changes and completion of a warranty data management system.

BIOGRAPHICAL SKETCH

Lieutenant Colonel Juan G. Mendez (B.S. Mississippi State University and M.S. Abilene Christian University) has served as a C-130 and C-5 aircraft commander and has been a maintenance officer for both aircraft. His career includes experience in a variety of line, staff and command jobs. He has seven years in the rated supplement maintenance business and just prior to attending Air War College he served as the commander of the 1605th Military Airlift Support Squadron at Lajes Field Azores. Lieutenant Colonel Mendez is a graduate of Squadron Officer School and Air Command and Staff College.

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CHAPTER I

INTRODUCTION

The end of the Reagan era brings with it a period of fiscal constraint, which is getting the attention of everyone in the Air Force who manages a budget funded with federal dollars. The federal budget's deficit growth has resulted in budget cuts that are being felt in every area, especially the world of weapon system acquisition. This is driving the Air Force acquisition and logistics communities to seek more combat effectiveness for the weapon system dollar.

Since 1985 there has been extensive discussion of one of the most controversial defense subjects to emerge in years: warranties. Concern about the rapidly rising cost of weapon systems combined with concern about reliability resulted in congressional action. Numerous people in the Congress and Department of Defense (DOD), believed warranties would improve reliability and control quality-related costs. As a result, in 1985 Congress enacted legislation requiring inclusion of performance warranty provisions in production contracts.

The new law requires a cost benefit analysis to preclude wasting money. Although it appears to be having some beneficial effects, warranties as an integral part of acquisition is in its infancy. Following passage of the 1985 law, the Air Force was given only two months to integrate warranties into the acquisition process; however, at this point there are still more questions than answers about how to proceed. In an attempt to comply with the law, we have developed warranty clauses for everything from a small "black box" to an entire

aircraft, such as the F-15E. The Air Force is now faced with a large group of complex and fast moving acquisition programs which urgently require warranty administration and we are not prepared to do it.

Several studies have been completed which focus on narrow aspects of the warranty issue rather than the United States Air Force (USAF) corporate approach. This study is broadly focused on the warranty issue from USAF corporate perspective, examining the Congressional mandate and the Air Force approach to warranties within the framework of four specific issues. The issues are: (1) Congressional intent; (2) the warranty as part of the acquisition process; (3) the warranty's relationship to R&M; and (4) administration of warranties.

CHAPTER II

BACKGROUND

The History of Warranty Law

The US military has a long tradition of warranting weapon systems. It began in 1796 with a simple warranty on a purchase of cannons. (9:1) Today, the Defense Department spends billions of taxpayer dollars on weapon systems. Warranties as an integral part of the acquisition process have emerged as part of a continuing defense effort to exact more combat capable and reliable products from defense contractors. During the early 1970's the Air Force used an incentivized approach called the Reliability Improvement Warranty (RIW) for the F-16 program. (7:6) During that time, the Assistant Secretary of Defense for Administration and Logistics issued a memorandum entitled "Trial Use of Warranties in the Acquisition Process For Electronic Subsystems." (4:1) The RIW is one of a class of what the Air Force calls product performance agreements (PPA's). The RIW provides incentives to the contractor to achieve performance levels exceeding minimum contract values. Typically, the PPA adds a distinct identifiable cost to the contract.

Although warranties have been used in industry for many years, their use with military weapon systems has been very limited because of the more demanding environment associated with the way military weapon systems are used and other factors such as technical risk. However, prior to the 1960's, there was wide use of short-term agreements covering latent manufacturing defects in "material and workmanship."

During 1981, then Deputy Secretary of Defense Frank Carlucci published a set of 31 "acquisition initiatives" some of which were targeted specifically at "supportability." Mr Carlucci's initiative 16 proposed contractor incentives to improve reliability and support. (7:6) The Air Force developed other warranty and product performance agreement contract vehicles designed to induce contractors ultimately to produce weapon systems, subsystems, and equipment with better reliability and maintainability and/or with lower support costs. (4:1)

During 1981 Air Force Systems Command (AFSC) and Air Force Logistics Command (AFLC) in a continuing effort to integrate contractor guarantees* and product performance incentives into the acquisition process, established the Product Performance Agreement Center (PPAC). Its purpose is the creation of a repository for warranty data and a source of assistance to Air Force acquisition activities in applying and administering warranty and RIW contracts. (4:1)

In 1983 North Dakota U.S. Senator Mark Andrews asked, "If we can get warranties on TV sets, washing machines, and air conditioners, why can't we get them when we buy the machinery to protect our freedom?" Senator Andrews reasoned that warranties are a common-sense approach to buying weapon systems. He did not expect his constituents to buy a tractor or pick-up without a warranty, nor the government to buy a tank or an airplane without one. Senator Andrews brought this philosophy to defense procurement and in 1984 Congress enacted section 794 of the 1984

*The words "warranty" and "guarantee" are used interchangeably in the taxonomy on warranties.

DOD Appropriations Act (Public Law 98-212), which required the DOD to obtain warranties in major weapon system production contracts. (9:3)

Two laws were passed in successive years, 1984 and 1985.

The laws originally emerged from "concern that weapon systems often failed to meet their military missions, were operationally unreliable, had defective and shoddy workmanship, and could endanger the lives of U.S. troops." (5:7-8) Congress felt warranties would improve reliability and quality of weapon systems by making contractors more accountable. The 1984 law provoked strong criticism from DOD and industry officials who felt it was impractical and unworkable. Warranties in the context of the 1984 law were thought to potentially be more expensive because of the increased risk imposed on the contractor. Congress responded to these concerns and in 1985 the law was replaced by Section 2403 of the 1985 DOD Authorization Act (Public Law 98-525), which modified the terms of the 1984 law. (5:8)

Warranty Laws Compared

The 1984 law specified that funds could not be obligated or expended to procure a weapon system unless the contractor guaranteed "that the system and each component thereof were designed and manufactured so as to conform to the Government's performance requirements as specifically delineated in the production contract...", (5:8-9) and "that the system and each component thereof, at the time they are provided to the United States, are free from all defects (in materials and workmanship) which would cause the system to fail to conform to the government's performance requirements...." (5:9)

Contract breaches obligated the contractor to "bear the cost of all work promptly to repair or replace" the parts needed to meet the "required performance requirements." Contractors not performing could be required to pay for the parts procured from a different source. (5:9)

The 1985 law added Section 2403 to Title 10, United States Code, which says that each prime contractor must guarantee that (1) "The item provided under the contract will conform to the design and manufacturing requirements specifically delineated in the production contract..." (2) "The item provided under the contract, at the time it is delivered to the United States, will be free from all defects in materials and workmanship;" and (3) "The item provided under the contract will conform to the essential performance requirements of the item as specifically delineated in the production contract...." The law also provides remedies to the Government if the above guarantees are breached; the contractor will at the election of the Secretary of Defense, or as otherwise provided by the contract:

"(A) Promptly take such corrective action as may be necessary to correct the failure at no additional cost to the United States" or

"(B) Pay costs reasonably incurred by the United States in taking such corrective action." (5:10)

TABLE 1 SUMMARY OF 1985 WARRANTY LAW (1:2-4)		
Factor	Definition	Description
Coverage	Weapon systems	Used in combat missions; unit cost is greater than \$100,000, or total procurement exceeds \$10,000,000.
Warrantor	Prime contractor	Party that enters into direct agreement with U.S. to furnish part or all of weapon system.
Warranties	Design and manufacturing requirements	Item meets structural and engineering plans and manufacturing particulars.
	Defects in materials and workmanship	Item is free from such defects at the time it is delivered to the Government.
	Essential performance requirements	Operating capabilities or maintenance and reliability characteristics of item are necessary for fulfilling the military requirements.
Exclusions	GFP, GFE, GFM (Government furnished parts, equipment and material)	Items provided to the contractor by the Government.
	Essential performance requirements for items not in mature full-scale production	The first 1/10 of the total production quantity or the initial production quantity, whichever is less.
Waivers	Necessary in the interest of national defense; warranty not cost-effective	Assistant Secretary of Defense or Assistant Secretary of the Military Department is lowest authority for granting waiver; prior notification to House and Senate committees required for major weapon system.
Remedies	Contractor corrects failure at no additional cost to U.S.; contractor pays for reasonable costs for U.S. to correct	Other remedies may be specified; contract price may be reduced.
Tailoring	Exclusions, limitations, and time duration	Specific details to be negotiated.
	Dual-source procurements	Relieve second source from guaranteeing essential performance requirements for initial product delivered.
	Extensions	Extend coverage and remedies as deemed beneficial.

A comparison of the two laws reveals that the primary difference is in the area of what is referred to as essential performance requirements (EPR's). The first two provisions of the 1985 law require

guarantees that the weapon system or item will be built and delivered to the United States according to the specifications delineated in the contract, and that there will be no defects in materials and workmanship. The third provision is significantly different in that it requires the weapon system meet specified performance criteria that have been determined essential to the mission effectiveness of the weapon system or unit.

Congressional Intent

The intent of Congress for the application of warranties appears to extend well beyond the literal interpretation of the wording of section 2403* of the law. (9:6) For example, Subsection (f) states the law applies to weapon systems in full-scale production, yet there is no prohibition of warranting weapon systems not yet in full-scale production and the law encourages those warranties by requiring a Secretary of Defense waiver for systems with no warranty that are not in full-scale production. Subsection (g) states that warranties may be used in more cases than required by the law and that remedies may be more comprehensive. (9:6) Some aspects of the law's definitions and requirements exceed commonly accepted use of commercial warranties and ignore the lessons the services have already learned in dealing with warranties. (9:6) For example, the services had learned that simple and explicit contractor remedies and incentives contributed to effective warranties; however, many warranties prescribed complex remedies which

*A complete copy of Title 10, Section 2403, of the United States Code is included in the Appendix.

tended to pose more risk than the contractor was willing to accept.

(6:61)

The intent of the Congress was further amplified in a Senate Appropriations Committee report which describes the basic purpose of the law in terms of dissatisfaction with the reliability of US weapon systems. The report published in part in a General Accounting Office (GAO) audit on Department of Defense (DOD) warranties, highlights the committee's concern that Congress has been preoccupied with appropriating funds to correct defective and shoddy workmanship in weapons systems. It further states that tax dollars should not be expended for military weapons that are operationally unreliable, do not meet the military mission, task and threat, and may imperil the lives of troops on the front lines of defense. It is the committee's belief that Congress must demand that those weapons work as intended. (5:38)

The Congress, distraught with weapon systems which did not work or hold up well after delivery, clearly intended to motivate the contractor to produce a quality product with reliability which assured agreed upon performance in the field. They wanted more combat effective weapon systems and in the same sense they did not want to continue paying defense contractors to modify or repair a weapon system that had been bought and paid for, but did not do what it was supposed to do.

Congress specified warranties apply to combat weapon systems costing more than \$100,000 each, or more than \$10,000,000 total procurement cost. They specifically excluded commercial items sold in large quantities to the public. Next, Congress specified the "prime

contractor" be held responsible and accountable for the contract provisions. Congress specified weapon systems be built exactly in accordance with agreed to engineering plans with precise control and quality assurances as to materials, measurements, tolerances and product tests. Finally, Congress intended that the weapon system execute reliable technical performance and that it be maintainable to an extent which does not impair military mission. (9:4)

CHAPTER III

THE WEAPON SYSTEM WARRANTY

Warranty Concepts

Warranties within the framework of the weapon system acquisition today fall within two concepts, "assurance warranties" and "incentive warranties." The "assurance warranty" is used when the intent is to assure that minimum design, quality and performance criteria are met. In assurance warranties, the Government is seeking only minimum contract specifications, and, therefore, the contract does not provide incentives to the contractor for improved performance. However, the "assurance warranty," which is now mandated by 10 USC 2403, invokes penalties for the contractor on failure to meet contract specifications. This is in stark contrast to the de facto penalty the Government paid when, prior to the law, a weapon system did not meet contract specifications.

The "incentive warranty" is not mandated by law and provides the contractor incentives to exceed minimum contract specifications for design, quality or performance. Incentive warranties are structured so that risks of failing to achieve minimum criteria, combined with the improved profit potential for exceeding minimums, will motivate contractors to work toward exceeding minimum values. (1:3-2)

The distinction between assurance and incentive warranties is exemplified in the following example. A hypothetical warranted equipment item has a required fielded Mean Time Between Failure (MTBF) of 1000 hours and is expected to operate a total of 200,000 hours during the warranty period. Therefore, to satisfy the warranty requirement, we

say the expected number of failures is $200,000/1,000$ which equals 200, i.e., the item must operate for a total of 200,000 hours with a MTBF of 1000 hours and not more than 200 failures.

To illustrate the concept of the "assurance warranty," we state the terms of the contract so that all failures exceeding 200 which occur during the warranty period must be repaired by the contractor at no additional cost to the Government. (1:3-2) In addition, the EPR of a 1000 hour MTBF must be met or the contractor incurs a penalty which may involve repair, replacement, or redesign and retrofit, at no additional cost to the Government. In this example, the contractor does not realize a profit margin increase by exceeding a 1000 hour MTBF. (1:3-2) He could, however, increase his profit by reducing the repairs he makes under the contract.

In our second example, the contractor of the same equipment is to provide depot repair service at fixed contract priced over the period of the warranty. (In both examples the warranty period is the same.) The contractor recognizes the fixed price means if he can reduce failures he will increase profit by having fewer repairs to make. This motivates the contractor to invest in design, production, and quality assurance to reduce the number of future failures. (1:3-2) This type of warranty is called a reliability improvement warranty (RIW) because of its incentivizing features. There is some point beyond which the contractor may not wish to go in seeking improvements because of the risk associated with the extra expense and the attendant diminishing returns.

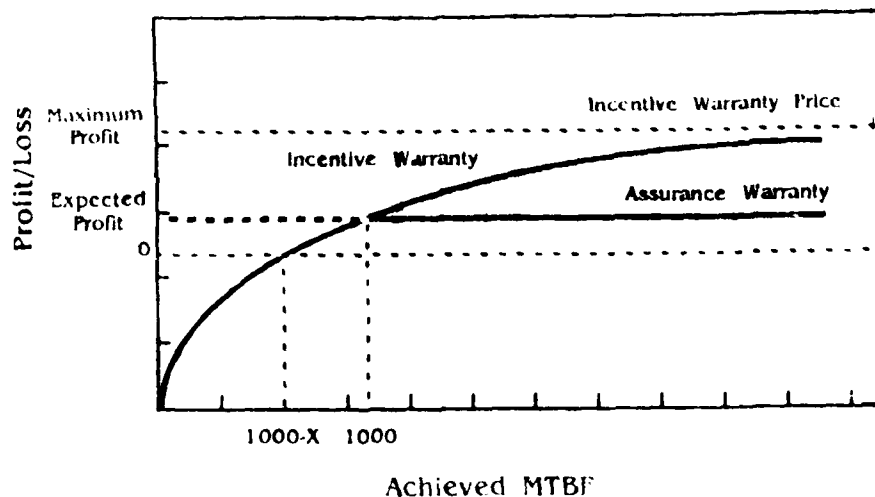


Figure 1
Contractor Profit - Assurance Versus Incentive Warranty (1:3-3)

Figure 1 depicts the relationship between profit and level of MTBF achieved. The contractor will lose profit with both assurance and incentive warranties if MTBF is less than 1000 where X represents the decrease in MTBF from 1000 hours "covered" by the warranty profit/risk dollars in the contract price. Conversely, the contractor will increase profit with the incentive warranty if he exceeds the 1000 hour MTBF. The contractor can make no more than the expected profit with the assurance warranty whereas he can theoretically make substantial additional profit in the incentive warranty. The only costs he would incur with MTBF well above minimum values, are those associated with warranty administration. Table 2 provides additional clarification of the differences between assurance and incentive warranties.

TABLE 2 COMPARISON OF ASSURANCE AND INCENTIVE TYPES OF WARRANTIES (1:3-4)		
Factor	Assurance Warranty	Incentive Warranty
Basic Intent	Meet minimum performance and R&M levels.	Exceed minimum levels.
Warranty Price	Expected to be minimal, from 0 up to 1 or 2 percent per year of hardware price.	May be significant, up to 7 or 8 percent per year of hardware price.
Warranty Duration	Limited -- generally 1 year or less.	Can be extensive -- 3 or more years.
Technology Factors	Warranted item is well within state of the art (SOA), or SOA is so severely "pushed" that only limited warranty protection is realistic.	Warranted item pushes SOA, so there is need to protect against failure and there is opportunity for growth.
Contractor	Contractor has limited opportunity to control and improve performance prior to and during warranty.	Contractor has significant opportunity to control and improve performance.
Competition	Should not reduce future competitive climate.	May significantly reduce competitive climate.
Administration	Generally not a severe burden.	May require complex procedures.

Warranties Defined

A military warranty as defined by the Federal Acquisition Regulation (FAR) subpart 46.701 is "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 contract." (6:30) This definition is both broad and vague and consequently is of little use in understanding military warranties. During the research for this paper, the author found a disturbing lack of consensus among knowledgeable people on just what is represented by a

military warranty. Frequently people who were involved with the weapon system and in some cases the administration of warranties had an incomplete or hazy understanding of the warranty process. (6:5) A 1987 Rand study found workers and officials involved in warranties did not agree on objectives of warranties, how incentives of warranties were supposed to work, or on criteria for the ultimate evaluation of warranty or program performance. (6:5)

There appear to be several reasons for this. Clear concise guidance is not yet available at all levels. Equally important is that people involved with the warranty process do not communicate effectively on the subject of warranties. This is due both to association with commercial warranties and vague definitions which result in differing interpretations of what a military warranty represents. We should therefore clarify both points, beginning with the distinction between commercial and military warranties and subsequently expanding the general definition of a warranty.

Although the Air Force buys some products which, like commercial products, have very low risk, the majority of military weapon systems are complex and involve much higher levels of risk. While low-risk systems may be well suited to commercial warranties, the higher risk systems are incompatible with commercial warranties for the following reasons:

- 1) Complex systems with attendant higher levels of risk must have warranties specifically tailored to the weapon system to account for the way the military uses the system. This tailoring involves

contractual language which differs from that found in commercial warranties.

2) The acquisition of major military weapon systems involves tight DOD service control and supervision over product development. The contractor therefore is often not in a position to assume full responsibility for the design.

3) The fundamental organization of the Air Force acquisition system results in weapon system production start occurring before R&M (warranty) testing and validation can be completed. (6:3)

The purpose of a commercial warranty is to limit the seller's obligations to the buyer rather than protect the buyer; as such, these warranties are narrowly focused on specific terms. The most important conditions of the warranty are established by the seller and are not negotiated with the buyer as is done with military warranties. The autonomy of the manufacturer in commercial endeavors contrasts sharply with a defense acquisition in which government engineers establish design parameters, life expectancy requirements, technical performance, and reliability requirements. (9:11) In those cases where the design specifications, technical performance, or reliability criteria have not been proven in previously built systems, risk is introduced as a function of uncertainty. (9:11) Therein lie the major differences between the commercial and military warranty environments.

The degree of risk associated with a weapon system acquisition is a function of the level of technology involved, the urgency of the production schedule, and the level of performance being sought. Risk is

an inherent part of weapon system acquisition which can be minimized, but not eliminated, with good management. The warranty transfers risk from the Government to the prime contractor. The transfer or sharing of risk is a fundamental characteristic of warranties. (6:19) The warranty clearly is not undertaken without risk to both the government and the contractor. This risk can be mitigated by appropriate acquisition phase activities which must include precise tailoring of warranty contractual language. (1:3-14) A 1986 ARINC study showed that when the warranty was well planned and integrated into the weapon system acquisition, there was no instance where the warranty seriously disrupted system deployment or threatened the reliability of the contractor. Therefore, it is clear that despite some problems, there is ample evidence that workable warranties can be obtained which benefit both the Government and the contractor. The Government takes the position that the penalty or incentive features of the warranty will ensure product performance requirements are met, while the contractor believes the warranty money paid will be retained as profit. (1:3-14)

In the presence of sound pricing strategies, good quality and performance can yield a positive outcome for both parties. A constructive coalition between the Government and the contractor is needed. This "win-win" strategy is achievable in the absence of unacceptable risk, which experience has proven would flaw the acquisition strategy with or without the warranty. The risk associated with the warranty process can be minimized by including the warranty as a part of the total acquisition strategy. Criteria for selecting the

appropriate form of warranty (assurance, incentive or combination) must be developed and the acquisition strategy must address the elements of risk. The Air Force Product Performance Agreement Center currently has a computer-based decision support system which is well suited to this and other aspects of warranty development. Finally, a warranty cost benefit analysis must be performed. (1:3-14) Tables 3 and 4 list possible risks involved and recommendations for developing warranties. (1:3-15)

TABLE 3 WARRANTY RISKS	
Factor	Risk
Characteristic Addressed Under Warranty	The "wrong" characteristic may be selected, thereby focusing effort incorrectly.
Price	It is difficult to estimate expected field performance, which is a basic measure for realistic pricing.
Operational factors	Field stresses may be difficult to estimate, because of many unforeseen circumstances.
Self-Sufficiency	Contractor repair, if part of the warranty, can reduce military self-sufficiency for wartime-critical items.
Equipment Design	Contractor may design equipment more suitable for meeting the warranty commitment than for meeting the military maintenance environment.
Transition	If required, transition from contractor maintenance to military maintenance can introduce serious administrative and logistics problems.
Administrative Complexity	Procurement and logistics procedures may have to be developed to implement the warranty effectively.

TABLE 4 RECOMMENDATIONS FOR WARRANTY DEVELOPMENT	
Do	
Do involve the contractor, user, support agency, Defense Contract Administration Services (DCAS), and other affected functional elements in the planning process.	
Do consider life-cycle cost as one measure for evaluating warranty alternatives.	
Do simplify time measurement, termination, and price adjustment to the maximum extent possible.	
Do check and double-check to ensure that concepts, terms, and conditions are clearly and fully understood.	
Do structure terms and conditions to be consistent with operations and support procedures.	
Do develop adequate back-up approaches if the warranty cannot be negotiated or implemented.	
Don't	
Don't commit the contractor to warrant elements beyond its reasonable control.	
Don't dilute the fixed-price essence of a warranty essentially to a time-and-materials contract.	

Clearly from the above discussion there are differences in commercial and military warranties which must not be confused. Primarily, the environment surrounding the commercial product development manufacturing and market process provides the seller with autonomy which does not exist in most military acquisitions. The products developed for the general public are generally much less complex and the seller has more control over what will be warranted. In specific cases the military has exacerbated the complexity problem by adding technical requirements which have marginal value to military capability (goldplating), but which significantly increase cost and

risk. Finally, the risk involved in a weapon system acquisition must be managed through precise tailoring of contractual language specific to the system in question.

The remaining issue in the definition of the military warranty concerns the vague way in which it is defined by the FAR subpart 46.701. An alternative definition is proposed which brings much clearer meaning to the term warranty.

A contract between the Government and the prime contractor which specifies the characteristics warranted, the period of coverage, responsibilities of the Government and the prime contractor, the remedies available to the Government should the product fail to meet contract provisions and incentives (if any) to the contractor should the product exceed contract provisions. The contract should also specify claim procedures and such provisions as lost arrangements for spares, and transportation. (9:3)

A general definition similar to the one above could help promote better understanding and better communication for people involved in the warranty process.

Warranties: A Part of the Acquisition Process

Appraising warranties is a complex undertaking at best. The wide variety of warranty applications, conditions and operational circumstances require very specific tailoring of each warranty to the weapon system. Warranties are perhaps best understood by distinguishing between the different types of warranties in the context of the acquisition cycle. Additionally, since warranties bring both advantages and disadvantages to the acquisition process, they are more clearly understood when presented in light of their contribution to a variety of weapon systems. Figure 2 provides one useful framework for appraising military warranties.

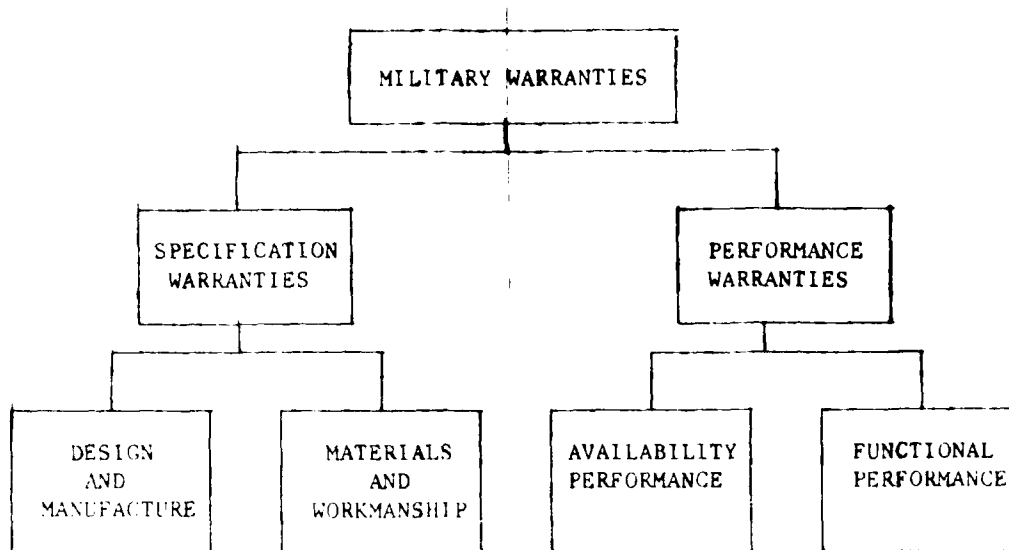


Figure 2
Depiction of Military Warranties (6:31)

Military warranties as shown in Figure 2 can be viewed as specification or performance guarantees. The 1985 law requires the contractor to design and build the weapon system according to the specifications in the production contract. These specifications are broken out into two specific areas, first design and manufacturing and second materials and workmanship. Specifications warranties are an alternative method for accomplishing the functions of the "correction-of-defects" (COD) clause and the "standard inspection" clause found in most government contracts. (6:32) Their use as a warranty however, is not entirely duplicious; they serve to supplement such clauses when they define the time limit for discovering defects and reduce the inspection requirements now performed by the Government. (6:32) The key characteristic of a specification warranty lies in its

contribution to facility of measurement and/or verification. Design and manufacturing requirements can usually be verified by a one-time process completed early in production with periodic quality audits to follow. The warranty against defects in materials and workmanship is directed at controlling "latent defects" by specifying a discovery period which often runs the duration of the warranty on "essential performance requirements." (1:2-4) Both types of specification guarantees have historically been provided for through standard contractual clauses other than warranty clauses.

The performance warranty mandated by the 1985 law potentially offers the greatest improvement to weapon system acquisition. The performance warranty provides an assurance to the Government that the weapon system will provide specified levels of performance while the system is in ordinary use. (6:32) The term "ordinary use" differentiates a performance warranty from other forms of acquisition contracts. (6:32) Moreover, this is the area of weapon system acquisition most affected by the 1985 congressional warranty mandate. The performance warranty aims at the heart of the warranty issue, the essential performance requirements (EPR's) which consist of the operating capabilities and maintenance and reliability characteristics of the weapon system. These EPR's are specifically linked to the system's capability to perform its military mission as determined by the Secretary of Defense. The "performance" clause represents a major change in acquisition approach by extending the contractor's liability

into the arena of performance, including reliability and maintainability (R&M). (1:2-5)

Traditional approaches to acquisition have always included cost, schedule and performance as the major determinants of success or failure in a major weapon system program. The inclusion of R&M on a co-equal basis is a wholly new approach which focuses on a category of performance not previously considered worth pursuing. Three developments have altered this view. The first is the rising cost of weapon systems, the second is the need for a reliable and maintainable (combat effective) weapon system cost notwithstanding, and the third is technological advances in computer-aided design and manufacturing which make improved R&M achievable.

The performance warranty focuses on the EPRs of the fielded weapon system. Unlike specification warranties, performance warranties are mandated only in "mature production lots," that is, those produced after the first one-tenth of the total production or after the initial production quantity, whichever is less. The aspect of the performance warranty that is similar to the specification warranty and that is "operational or functional performance," which like specification characteristics, can typically be validated during such events as development tests, initial operational tests, or acceptance tests upon delivery. This leaves only the R&M characteristics of the weapon system which cannot be validated in the early stages of production. It is precisely these characteristics upon which performance warranties mandated in the 1985 law may have the most significant impact.

Functional performance, which can typically be validated during development tests, or other validation tests at or before delivery, does not benefit equally from warranties because such performance has typically been covered in other kind of contractual language. Reliability and maintainability are unique in that both reliability and maintainability bear a relationship to combat effectiveness which can only be validated while the weapon system is fielded and operated under routine military conditions involving Air Force organic (Air Force "Blue Suit" Personnel) support systems rather than contractor support. A study performed by the Rand Corporation indicated warranties are possibly the only method for ensuring the contractor meets the R&M specifications of the contract. (6:33) This condition exists in contrast to interim contractor support (ICS) which is often used during the early phases of production (and occasionally much longer) to support the weapon system until the Air Force has enough trained and experienced personnel to support the new system organically.

There are several examples of successful Air Force warranty approaches already on record. Two of the better examples are presented by the F-16 RLW and the C-17 reliability and maintainability demonstration. (3:2) Both these weapons system have warranties which are specific and carefully thought out for the benefit of government. The warranty concepts are integrated into the weapon system program strategy.

The C-17 program includes a requirement for demonstrations of system reliability and maintainability after delivery. (3:5) Among the

more innovative aspects of the C-17 warranty is the requirement for the Initial Operation Capability (IOC) complement of production aircraft to meet pre-defined performance criteria during an Operational Readiness Evaluation (ORE) conducted soon after delivery of the initial complement of aircraft. (3:5)

A study of Reliability Improvement Warranties completed at the Air Force Acquisition Logistics Center (AFALC) assessed eight programs which used the RIW.

The eight programs are listed below:

Klystron Electron Tube	Sep 75 - Sep 79
AN/ARN 118 TACAN	Dec 75 - Apr 82
AVU - 8C/A Airspeed Indicator	Apr 76 - Apr 81
Omega Navigation System	Apr 76 - Nov 82
Carousel Inertial Navigation System (INS)	Apr 77 - Apr 81
F-16 Avionics	Jan 79 - Jan 83
A-10 Inertial Navigation Unit (INU)	Dec 80 - Dec 85
ALCM Inertial Navigation Element (INE)	Nov 81 - Nov 86

Five of the eight programs were assessed as moderately cost effective based on analysis of all available data. In this study and others, the F-16 RIW is consistently cited as an effective and successful warranty code. The non-cost effective programs were the Klystron Electron Tube, Omega Navigation System and the Airspeed Indicator. The benefits included temporary transfer of risk to the production contractor(s) for fielded reliability of the equipment, deferred Government investment in maintenance resources, and better R&M than could have been achieved without such a warranty. All eight programs were plagued with management and administration problems which require correction. Typically, warranties were voided by using organizations through poor knowledge and ineffective communication.

Symptomatically this was manifested in what should have been no-cost engineering change proposals (ECPs) erroneously charged against the Correction of Deficiencies (COD) clause, inadequate provisions for excessive non-verified failures, and configuration control problems associated with large numbers of design changes. Administration problems were shown to reduce the effectiveness of the RIW in each of the eight programs examined. (11:3-5) Clearly the problems associated with managing and administering warranties have detracted from their effectiveness as a tool for improving the acquisition process and ultimately the combat effectiveness of weapon systems.

Warranties: Linking R&M to
Combat Effective Weapon Systems

Military warranties in general and more specifically performance (assurance) warranties have a definite relationship to R&M and therefore to combat effective weapon systems. This paper gives exceptional weight to the synergistic role of warranties linking R&M to an acquisition process aimed at reliable combat effective weapon systems for optimum cost.

Reliability drives how long a system will operate without repair while maintainability reflects the speed and ease of returning the system to operational status - the combination R&M translates into increased combat effectiveness or warfighting capability at lower cost and reduced manpower. In the past when compared with cost, schedule and operational (functional) performance, R&M considerations have been given lower priorities. In the words of General Larry Welch, Chief of Staff, USAF, "it's past time now to correct that situation." (8) Reliability

and maintainability have risen to prominence in the acquisition process and now stand as the highest ranking factor among the traditional cost, schedule and performance parameters. (8) Performance warranties according to Rand appear best suited to assure R&M goals are met for new weapon systems. (6:67) The Air Force acquisition system has typically been successful in achieving acceptable levels of functional performance through standard inspection and testing contract clauses. However, R&M has frequently failed to meet expectations and left the Air Force with only expensive alternatives to attain acceptable R&M levels. General Welch's comments reflect Air Force recognition and acceptance that combat effectiveness can be maximized only when the proper balance has been achieved between functional performance and R&M. The relationship between functional performance, R&M (availability),* and combat effectiveness is shown in a 1987 Rand study on warranties. In Figure 3 below, devised by Rand, the vertical dimension represents a measure of functional performance for a hypothetical weapon; and the horizontal dimension represents some composite measure of its availability (R&M). Both types of performance contribute to the combat effectiveness of the weapon system, and each can be traded off to some extent against the other. For example, an attack aircraft needs both speed and availability to be effective, and the lack of speed on a particular type of aircraft can be offset at least somewhat by increased reliability or

*The term R&M, meaning reliability and maintainability, is often used interchangeably with availability. For purposes of discussion R&M constitutes a major part of availability because a weapon which is both highly reliable and maintainable will be available for use.

maintainability, which enables more aircraft to be in combat at a given time. Similarly, to be effective, ICBMs require both accuracy and availability (R&M).

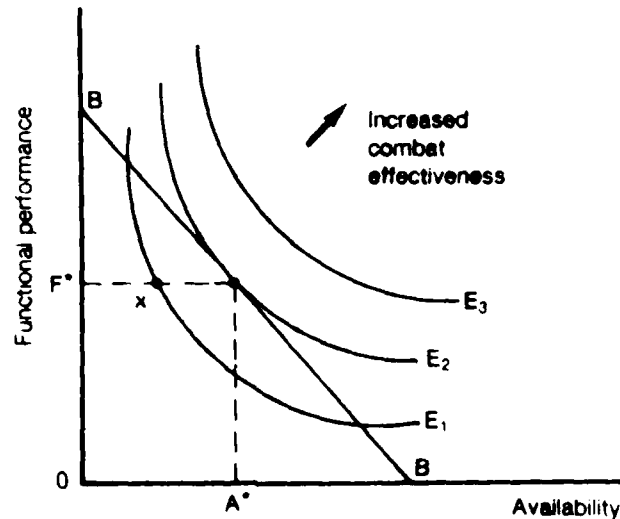


Figure 3
Tradeoffs Between Functional Performance and Availability
(R&M) in a Hypothetical Weapon (6:69)

The curves E_1 , E_2 , and E_3 , in Figure 3 represent increasing levels of combat effectiveness at different combinations of functional performance and availability. The BB line represents the cost constraint for the weapon; only combinations of functional performance (F) and availability (A) on or to the left of this line are permissible within cost. The point at F^* and A^* then represents the highest level of combat effectiveness available within the cost constraints. (6:70)

Typically cost, schedule, and functional performance reflect reality to the program manager and hence have historically been the

bench marks of success. Recent thinking which has made R&M co-equal with functional performance has altered the balance of these criteria. This is because experience has shown that the most advanced functional performance cannot compensate for poor R&M. Let us imagine for example a hypothetical weapon system which is so unreliable it requires 50 percent more of them to do the mission. Similarly, imagine maintenance time (down time) of 50 percent greater than was expected to produce enough weapon systems to perform the mission. In both cases required availability can only be achieved through extraordinary measures which involve exceptional expense, such as more weapon systems or more manpower and spares. At this point it becomes clear that poor R&M can outweigh any high-tech advantages which produce even the most exceptional levels of functional performance. Conversely, as R&M are improved we need fewer weapons and less expensive resources to achieve desired availability, and with it combat effectiveness.

Because of the exceptional importance of R&M to the acquisition of new weapon systems and the modification of old weapon systems, warranties should be structured to reinforce the effort underway to integrate R&M totally into the weapon system acquisition process. In the words of General Welch, "the future operational effectiveness of our weapon systems will be strongly driven by how well we integrate Reliability and Maintainability into the design process." The "performance warranty" provides the acquisition and logistics communities with a statutory tool to leverage R&M provisions through constructive contractual language. The process of developing the

specifics of warranty language is very complex and involves many players. The process is beyond the scope of this paper but is covered in detail in the Warranty Handbook listed as reference 1 to this paper. The state of the art technology which exists today has provided the technical basis for significant R&M improvements as targets or goals for developing military warranty clauses of weapon system contracts.

Examples of this technology are abundant in today's high-technology Air Force. The F-16 uses over 260 technical orders which are long, cumbersome, and slow to use at best. (8) An automated system is under development which would ease the technician's job by facilitating faster, easier access to the technical data required to repair the aircraft. (8) The time and money savings translates to improved maintainability and increased combat effectiveness. A similar technical data reference requirement is easily within the scope of contractual warranty language under maintainability provisions. Similarly, the F-16 engine requires an oil servicing cart and two people to service oil in a critical and error prone time and manpower intensive operation. (8) A small error in oil servicing can induce a malfunction requiring an engine change. Future fighter aircraft design should assure a less critical oil level requirement, and routine maintenance which can be performed quickly by one person with little or no servicing equipment. Performance (R&M) warranty clauses are ideal for such requirements. To perform maintenance on the F-16 weapon stores panel, 45 minutes are required just to gain access to the panel. Increasing the length of a single wire bundle would have reduced the job to five minutes. (8) Clearly, although this

is a design problem, the maintainability is affected and properly structured warranty language (redesign or maintainability clause) would put the responsibility on the contractor to correct this. The F-16 bore-sighting procedure (required to establish weapons delivery accuracy) required two people using special tools and equipment from six to eight hours. This situation is exacerbated by the requirement to use a technician with "long thin arms" to reach the nearly inaccessible equipment.

The effect of this poor design in a combat environment is obvious. There are virtually limitless examples of such design incompatibilities. Warranty provisions enforcing R&M features can have a positive effect on many of the problem areas which prompted the Air Force to seek better R&M through such concepts as the RIW and ultimately prompted Congress to pass assurance warranty legislation. In today's increasingly austere environment, turnaround time, alert requirements, fewer total systems, multiple sortie requirements and cost prohibit difficult to maintain or unreliable systems. (8) Performance warranties, if developed as part of a total acquisition strategy, have the potential for increasing the combat effectiveness of the fewer weapon systems that will be fielded in the future.

Unlike defects in material and workmanship, availability (R&M) characteristics of a weapon system typically are not fully demonstrable during the development process. Aspects of R&M which are analytically derived without thorough testing may turn out to be significantly in error thus creating a situation wherein the contractor is judged not to have met contract specifications. An example of the effect of this pro-

process is evident in the Navy's F-14 aircraft which uses a radar specified at 1600 hours mean time between failure (MTBF). The actual MTBF achieved was 94 flying hours. (7:5) Acquisition programs frequently lack sufficient time for complete demonstration of R&M characteristics. Moreover, these tests often demonstrate inherent R&M under "ideal" conditions or using interim contractor support (ICS) under the watchful eye of the contractor rather than typical field conditions. (7:4) The C-17 warranty is structured to preclude this by evaluating key R&M provisions during an Operational Readiness Exercise (ORE) using Air Force organic support.

The specifics of the warranty include:

(a) a warranty of contractual specification conformation, design integration, and material and workmanship; (b) a warranty of fleet reliability, maintainability, and availability; (c) a warranty for the installation of parts; and (d) a warranty of design information.

The remedies for the (a) and (b) warranty clauses include correction, repair, rework, replacement, or redesign; for (b) in particular this includes changes in the design and production procedures for all aircraft in production or still to be produced and retrofit of those (up to 16) already delivered; for (c) it includes reinstallation and the assumption of the parts vendor's warranty; and for (d) the correction of the information and the repair, rework, or replacement of any damage it caused.

Defects must be discovered no later than 180 days after initial operational capability, which is defined as the delivery of 12 production-configured aircraft and their supporting equipment and data. The basis for the incentive fee for availability, reliability, and maintainability achievement will be a highly structured 30-day mini-squadron evaluation that is scheduled to take place in the early 1990s. (6:72)

The relatively short time since the 1985 law has not been adequate to assess the acquisitions brought on board under its provisions. Table 5 lists selected systems warranted under the 1985 law. (6:56)

TABLE 5
CHARACTERISTICS OF SELECTED 1985 LAW WARRANTIES (6:86)

Timing and System	Type of Warranty				
	Performance				
	Specifi- cation	Avail- ability	Reli- ability	Maintain- ability	Func- tionality
Signed before FSD					
SINCGARS airborne radio	F		L	D	
Initial Production					
F100 engine (F-15/F-16)	F		\$	D	
Avionics & electronics					
NAVSTAR user equipment	F			D	
STD PA INU	F		L	D	
STD and F-15 RLG INU	F		L	D, L	
SCPS-2 protection system	F	?	?	?	?
SCDAC air data computer	F	?	?	?	?
MX Peacekeeper ICBM					
Support equipment	F			D	
Ops support equipment	F			D	
Follow-on Production					
F-15 (1985 buy)	F	?	?	?	?
IR-1/U-2R aircraft	F	?	?	?	?
AGM-65D Maverick missile	F	?	?	?	?
MHU 196	F	?	?	?	?
FWWS update	F	?	?	?	?
MX Peacekeeper ICBM					
Third-generation gyro	F		D		D
Stage I and FIOS	F	L		D	
Stage III	F	E, D			
Ordnance initiation system	F			D	

- D The contractor performs depot maintenance and usually incurs some penalty (money or the provision of spares) if turnaround time targets are not achieved.
E Engineering redesign (often including reproduction, reinstallation, and the provision of interim spares) is required if targeted performance is not achieved.
F Specification warranty (now required by law) (fix or replace).
\$ A bonus or penalty, dependent on performance.

Initial assessments are generally positive, expressing optimism for the potential of assurance warranties to make significant contributions to the combat effectiveness of future major weapon system acquisitions; there are, however, some important concerns. New warranties are generally more lengthy. Engines and certain other items which may

be procured in annual lots have contracts which are similar to but longer than those written before the 1985 law. (6:57) Functional performance and availability (R&M) appear to be covered under the same specifications and "essential performance requirements" (EPRs) appear to be buried in major sections of documents. (6:57) Both Rand and the GAO indicate warranties have been written which are not explicit on remedies. (6:58)(5:30) Pre-1985 warranties were typically written in significant detail which enabled both the Government and the contractor to know what was expected if objectives were not achieved. Some newer warranties are more general, leaving perhaps too much room for interpretation. (6:60)

It is clear that assurance warranties have the potential to improve combat effectiveness in our weapon systems if properly integrated into the acquisition process. Warranties used to enforce R&M can bring better weapon systems to the Air Force. The Air Force is still in the early stages of learning how best to employ warranties, and borrowing from the words of General Welch, it is time now to do something about that.

CHAPTER IV

WARRANTY ADMINISTRATION

Air Force Formal Guidance

Since the Congress passed 10 USC Section 2403, the Air Force has been working to prepare the formal written guidance needed to integrate warranties into the acquisition process. When the law was passed as a part of the Defense Procurement Reform Act of 1985, the Air Force was already in the warranty business and had established the Product Performance Agreement Center (PPAC) to serve as a focal point for warranty-related activities. In February 1985 PPAC published the Product Performance Agreement Decision Support Handbook, designed to assist the analyst by providing a framework for selecting, analyzing and structuring product performance agreements. (11:11) While this publication is thorough, it is intended for use primarily by the contract analyst. During April 1986, Headquarters Air Force published the Warranty Administration Plan to establish a system for acquisition and logistic organization to track and administer warranties for fielded systems. (4:1) The guidance provided in this plan was exceptionally general and vague in many areas reflecting primarily the Air Force's lack of knowledge and in experience with the new assurance warranties. On 20 October 1987, Headquarters Air Force SAF/AQC distributed a printed draft copy of Air Force Regulation (AFR) 800-47, "Weapon System Warranties," for final review. The relatively lengthy period of time involved in finalizing this document is attributable to the wide variety

of opinions expressed within the Air Force acquisition and logistics communities.

While it is not within the scope of this paper to investigate these views completely, it is worth noting that one of the major problems the Air Force has with warranties stems from the lack of consensus on numerous warranty-related issues, some of which are fundamental. For example, the definition of a warranty in AFR 800-47 is so general and vague that it is not useful in clarifying the concept or theory of a warranty as it applies to a military weapon system. There is great concern among the Air Force maintenance community about portions of the regulation which require data collection and reports by aircraft mechanics. (13:1) Headquarters Air Force LE-RD has expressed concern that Air Force policy should require "no-cost" warranties rather than allow a contractor to price a warranty which may ultimately be a hidden maintenance support contract rather than a warranty. In their words, "a pricing policy based on minimum number of random or predicted failures turns the warranty into an interim contractor support agreement." The "no-cost" concept supports the theory that one of the fundamental purposes of a warranty is to shift risk from the Government to the contractor and that only carefully developed pricing strategies will indemnify the government against cost benefit reversal. (12:1-2) In another example, there is concern that the wording of AFR 800-47 related to "remedies" appears to focus on contractor repair/replacement with inadequate concern for the "loss of combat capability" associated with failure to achieve essential performance requirements. (12:2)

The formal guidance prepared to date, while it outlines the policies and requirements in regulatory language, does not do enough to make the incredible complexity at the weapon system warranty issue more understandable and workable for those who must develop, manage and administer warranties for the Air Force. Moreover, the lack of consensus on fundamental aspects of Air Force warranty philosophy is symptomatic of endemic organizational problems. Clearly AFR 800-47 should be reconciled and finalized at the earliest possible time. Additional steps are needed to ensure a more thorough understanding of the Air Force warranty program at all applicable levels.

The 1987 Rand study on warranties indicated a need for policy guidance improvements in five important areas. First, DOD should clarify and disseminate to warranty project personnel the possibilities and options available for using performance warranties to increase the probability of achieving specific ~~Availability~~ goals. Second, there is a need for improved evaluation criteria and procedures for cost-benefit analyses. (6:87) This author found during several interviews with knowledgeable people that cost-benefit studies are receiving only perfunctory attention in most cases. The reason most often given was lack of any detailed criteria and procedures. It is worth noting that the Warranty Handbook listed as a reference for this paper contains substantial specific guidance for cost benefit studies and the Air Force PPAC has a computerized dial up program designed specifically to aid with cost benefit studies. However, neither of these aids are

considered policy guidance, rather their use depends on the resourcefulness of warranty program personnel.

A third area cited involved the need for policy guidance on waivers, exclusions, and the tailoring of warranties. The RAND study found few allowable Secretary of Defense waivers, but a large amount of uncoordinated tailoring of individual warranties, which appeared to have tacit approval by higher authorities. Guidance is needed on when second-source producers and others should be exempt from performance, but not specification, warranties. This guidance should specify what type warranties may be waived, which may be tailored, and which apply to all acquisitions. (6:67) The fourth area cited deals with the timing of warranties. Policy guidance should relate the weapon system program objectives (and therefore warranty objectives) to methods of achieving those objectives, specifically, the timing of opportunities and the incentives available during the different phases of the acquisition. (6:67) The final area cited involves the need for policy guidance in the area of risk sharing. Since warranties are contracts, they can serve to provide structured motivation for the contractor but they cannot alter the technical uncertainties and risks involved in advanced weapon development and acquisition. Rand maintains the warranties serve as a tool for managing these uncertainties and risks but that in major ventures involving significant risk, the Government must continue to bear a substantial portion of the risk. (6:68)

There is a need for publications and training for personnel directly involved in the warranty process. The Defense Systems

Management College has published a Warranty Handbook which covers the warranty subject in significant detail. This publication warrants dissemination throughout the Air Force communities involved in warranties. However, this publication is not explicit enough by itself; the Air Force working people need a brief simple educational pamphlet which lays out the basics of warranties. While these steps are being taken, something more fundamental is in order. The Air Force must develop a consensus on fundamental aspects of warranty philosophy. We must clarify more precisely where and how warranties fit within the Air Force acquisition process, and organize to achieve success in this endeavor. In so doing, we will elevate the process to the priority assigned by the Chief of Staff. That is the first priority in the source selection process.

Air Force Warranty Program Organization

The Air Force is working vigorously to develop effective organizational approaches to warranties. Beginning with the first initiatives in the 1970's, the Air Force has used warranties in an attempt to improve product reliability. As with any new system, the Air Force is experiencing certain growing pains developing a corporate approach to warranties. The author's research indicates one of the most fruitful areas for change may be in the organizational or structural approach to warranties within the acquisition system. Depending on the complexity of the acquisition program for which the warranty applies, the procedures and organization needed to administer the warranty may vary substantially. Small programs with low technical risk may involve

only a simple warranty where administration is confined to reviewing a checklist to ensure the Government has no tasks to perform before fielding the weapon system and concluding with some simple evaluations at the conclusion of the warranty. Major programs such as the C-17, B-1B, and Advanced Tactical Fighter require much more complex warranties which may involve incentive provisions and substantial elements of risk. The programs involve large complex Government and contractor organizations and require very substantial resources and procedures to administer. Administrative tasks should be kept to a minimum when the warranty is developed, and knowledgeable logistics and user personnel should be intimately involved in the warranty development to ensure it can be administered and will be an effective tool for guaranteeing a reliable, combat effective weapon system.

Multiple interviews within the acquisition and logistics communities revealed fundamental problems with the warranty program. People working at various levels typically lacked a thorough understanding of warranties and warranty concepts. This was especially prevalent at the using command and unit level. Technicians and managers of various levels described warranty losses and warranty invalidations resulting from difficulty in determining what was warranted. Poor training appeared to be the culprit in most cases. Knowledgeable people associated with policy making are concerned about the avalanche of warranty administration problems about to occur because of the B-1B, B-2, C-17, and Advanced Tactical Fighter.

The GAO report on warranties, published July 1987 indicated warranties might be difficult to administer for the following reasons:

- (1) Warranties were not always clear about the validation of warranted performance;
- (2) Warranties did not always specifically state contractor responsibilities for redesign;
- (3) Warranties did not always specify the effect of storage time on the warranty period;
- (4) Warranties did not always address coverage on repaired or replaced parts; and
- (5) Warranties did not specifically require warranted items to be marked to aid in identification. (5:31)

The warranty program is organized within the acquisition system to require the program manager to exercise responsibility for integrating warranties into the acquisition process while making Reliability and Maintainability co-equal partners with the traditional cost schedule and (functional) performance. Typically, most program offices appear to need help with the development integration and administration of congressionally-mandated warranties into a major weapon system program. According to a report produced by the Air Force Product Performance Agreement Center (PPAC), it is a complex process involving personnel from a variety of functional areas, during which the appropriate form of warranty or Product Performance Agreement (PPA) must be selected, tailored to match program objectives, equipment characteristics and operational criteria, analyzed for cost-effectiveness and finally assessed to ensure it can be administered and enforced without excessive mission capability degradation. (16:1) An interview with PPAC staff members revealed this process is not done with equal

success in all program offices. They indicated although PPAC is staffed and organized to assist program offices, they must await a request for assistance before becoming involved. (15) A policy change restructuring this arrangement could potentially strengthen the contribution of warranties within the acquisition process.

In a letter sent by the Tactical Air Command (TAC) LG to Headquarters US Air Force, SAF/AQC on 10 June 1987, potential problems in warranty administration were highlighted. The TAC LG forwarded comments from the LGM who said:

Warranties should not be an administrative burden on maintenance, supply, transportation, and other personnel supporting the weapon system. The way some Product Performance Agreements (PPAs) are currently written (e.g., F-100, F-100-220 engine warranties), their administration has caused a tremendous burden on the field that is labor intensive. For example, the F-110 engine has approximately 8,000 warranted items. AFLC has dictated (IAW T.O. 00-35D-54) a warranty deficiency report will be submitted on every warranted item that fails. This policy will place a tremendous burden on field units not only in deficiency report generation, but also the tracking and shipment of warranted parts. As more and more warranted weapon systems and engines enter the Air Force inventory, this administrative burden will continue to grow. . . .

The personnel responsible for the PPAs within the AFSC System Program Offices (SPOs) need to be more sensitive to the way warranties are written and how they will affect field units. SPO personnel may write an excellent agreement enforcing contractor product quality IAW the contract -- thus saving the Air Force millions of dollars, but the PPA may not be cost effective if it generates a labor intensive warranty administration program.

. . . Parts identification ideas have ranged from bar coding and label identification, to technical order listing. Tracking system ideas have also varied, but currently no definitive procedures have been decided on how all these thousands of warranted parts will be identified and administratively controlled.

Warranted administration has the potential to devastate field units with an administrative burden well beyond their current resources. We do not oppose PPAs on our weapon systems, but it is time for AFSC, AFLC, and Air Staff managers to realistically review the consequences the warranty administration program is having on field units. (18)

The research for this paper revealed Air Force operators (users), maintainers, suppliers, and finally contractors do not speak a common language where warranties are concerned. The coordination process which must include all these disciplines from the using command, supporting command (AFLC) and implementing command (ASD/ESD), appears to be ineffective because it is frequently circumvented. One of the most common complaints heard during research interviews was that people at various levels of the process do not talk to each other on important matters which should have been coordinated. The result is warranty contract language which cannot be effectively and efficiently administered after the weapon is fielded. These problems exist after program management responsibility transfer (PMRT) at both the supporting command (AFLC) and the using command. The position taken by the using command is that an aircraft mechanic is supposed to repair aircraft and if he spends a large portion of this time filling out warranty paperwork, that time is lost for maintaining the weapon system. Manpower constraints preclude additional people being hired to perform this warranty paperwork.

The effect of poor coordination during warranty development can be seen in the F-15/F-100-PW-220 Engine Warranty. Headquarters Tactical Air Command (HQ TAC) logistics staff indicated during an interview, that the biggest complaint was that it takes "six engine technicians" to prepare many multiple-page service reports associated with the failures on the engines. Some of the reports are in addition to those required by TO-00-35D-54, but an administration system designed to support the

warranty on the 220 engine is driving the requirement. Despite the presence of a contractor representative at Eglin AFB, Aeronautical Systems Division must provide disposition instructions before parts can be shipped for repair, and it takes up to 120 days (60 days average) to return the repaired parts. (14)

The HQ TAC Logistics Staff feels a need exists for better communications between the using command (TAC) and the implementing command (ASD). (14) The examples cited above are not new, however, as the Air Force continues to obtain warranties for new weapon systems, parts of weapon systems and modifications to weapon systems, the problems associated with their development and administration continue to grow. There are two important points to be made concerning these problems. First, warranties are being developed which are difficult to administer and therefore may cost more than they are worth. In many cases these costs are not recognized as being associated with the warranty. Second and perhaps most importantly, the symptoms described above are indicative of a more fundamental problem, that is the institutional structure of the Air Force warranty program.

The numerous symptoms of disorganization seen within the warranty process suggest that senior Air Force leadership may not be convinced of the utility of warranties in producing more combat effective weapon systems. The potential of warranties for contributing to improved combat effectiveness is too important for the Air Force to flounder in search of the answer. This author's research strongly suggests that the Product Performance Agreement Center (PPAC) is the

most appropriate Air Force agency to assume the central leadership role for the warranty process. The center maintains an extensive complement of resources designed for warranty development and analysis, as well as archival preservation of lessons learned. Their role today, however, is primarily passive advocacy; they have inadequate authority, and typically they must wait for warranty managers to seek them out. The center needs much more authority, staff augmentation, and more funding. To accomplish this in the austerity of today's environment demands difficult and perhaps painful priority adjustments that are essential to keeping warranties on track. Program managers may perceive an erosion of their "turf" which is not the intent. In fact, they must continue to be responsible for their programs, but Air Force cannot reinvent the warranty wheel with each new weapon system program. A reasonable and prudent middle ground is possible wherein the Air Force profits from the "corporate knowledge" and expertise which exists today in the Product Performance Agreement Center. In addition to the need for "corporate view" orchestration, there exists a critical need for a central Air Force approving authority with responsibility and accountability for the warranty process and printed product. The Product Performance Agreement Center appears to be the best candidate. Additional manning and funding, while important to a strong PPAC, need not prevent important progress toward developing the needed reforms. One eventual possibility is to identify manpower positions for transfer from within both the acquisition and logistics communities. Funding certainly involves difficult and even painful tradeoffs, but the offset resulting from

warranty process improvements can result in cost savings which justify the new priorities. One need only consider the dollars lost in today's ineffective warranty process to see this. Steps can be taken now to improve the process, pending additional manpower and funding. Senior Air Force leaders should decide now to initiate bold measures in warranty reform. Immediate measures could include placing a colonel in the director's position with marching orders aimed at developing specific recommendations for increased PPAC involvement. Talented and experienced people in overmanned logistics and acquisition billets throughout the Air Force should be sought to increase the staff pending permanent manpower changes. The Product Performance Agreement Center is already actively pursuing initiatives in the training and education arena that have strong potential to improve the warranty process. The point is the Air Force has a corporate agency well suited to a stronger role in the warranty process; what they need now is corporate support to bring it to fruition. Their formal role in the warranty process deserves another look to determine how an active PPAC, with strengthened authority, renamed the Air Force Warranty Center, might help warranties achieve their full potential in achieving more combat effective weapon systems.

Air Force Data Management Systems

One of the key questions surrounding the warranty issue evolves from the requirement for the Air Force to be able to administer them. The question in its simplest form is, does the Air Force have the data systems it needs to manage warranties? The Air Force has data systems

in various stages of development which will be capable of data collection and management for warranty administration when those systems are complete. The difficulty arises from the ongoing creation of warranties with the concurrent development of data systems to administer them, which at their inception were needed to manage weapon systems but not warranties. Many of the data systems in use today at field and Major Air Command (MAJCOM) level were designed as maintenance or supply information management systems. These systems have evolved over several years and until recently there was no formal requirement for these systems to have the capability to manage data for purposes of warranty administration. The requirements however, have changed as weapon systems have come to fruition with companion warranty administration requirements. The Air Force now finds itself in a position of urgently needing a data system which is capable of both managing the weapon system and administering an oncoming avalanche of warranties which resulted from the 1985 law. Current budget cuts significantly increased the problem. The change has occurred so rapidly that the requirement for a warranty administration data system, has outgrown Air Force capability. This is complicated by a tendency for major acquisition programs to develop unique data systems for the management of the warranty.

The Air Force is taking steps to reduce the proliferation of new data systems because they are expensive and present overwhelming integration problems for warranty administration after PMRT. The supporting command (normally Air Force Logistics Command) must assume

responsibility for most of the weapon systems in the Air Force inventory following PMRT and they must have warranty data flow to them in a form which is compatible with their organic data management capability. The proliferation of data systems, which are not compatible with standard Air Force data systems, places at risk the supporting commands ability to administer the warranties after PMRT.

Clearly at issue is the question of how to design a common data system which meets the needs of the various users. The system must have the capability to track data sets/parameters selected by the user and agreed upon by the contractor for use in assessing contractual warranty obligations.* The system must have enough data capacity to capture and store the raw data and desired parameters. It must have the flexibility to accept the algorithms required to convert raw data into usable or normalized measurements, which can then be used to determine if

*To be an effective part of any warranty, the criteria used must be measurable and compatible with standard USAF data systems. For example, reliability must in some way be measurable. Basic reliability parameters address the frequency of failure or malfunction which impacts mission accomplishment or creates a need for maintenance. (19:10) Assume now that a parameter called Mean Time Between Maintenance (MTBM) is required to enforce certain reliability provisions of the warranty. The Air Force routinely tracks a variety of maintenance codes which are compatible with standard data systems and from which MTBM can be determined. Among these codes are "type maintenance codes," "action taken codes," and "how malfunctioned" codes. These and others must be collected. It is important to ensure that warranty authors and developers do not include a requirement for data which is not normally collected to manage the weapon system. This requires effective coordination during the development process but it ensures compatibility with standard USAF data systems and eliminates one of the areas of greatest concern in the field, i.e., mechanics inappropriately involved in collecting warranty data. Moreover, it prevents the proliferation of data systems by eliminating the need for a special system to support warranty administration.

essential performance requirements are satisfied. It must be simple and sufficiently automated to enable data input quickly and efficiently (minimum manpower) at the unit level. Finally, it must be compatible for use by the using command (SAC, MAC, TAC) and the supporting command (AFLC).

During several field interviews this author conducted, the needs and concerns of the using command and supporting command were discussed. There is a consensus that the system at the unit level must be simple to use and "transparent" to the technician. This might translate for example, to as few computer key strokes as possible, and the technician goes back to work repairing aircraft. The use of bar code or chip technology for parts marking may prove to be feasible, such that identification is simplified at the unit level. Tutorial interface between the technician and the computer is essential to provide any instructions associated with disposition of warranted items. The bottom line for field users is a process which does not involve the technician to a greater extent than his normal day to day routine, but which has adequate safeguards to preclude mismanagement of warranted items. The system must also meet the needs of the supporting command. The using command system absolutely must be compatible with the supporting command system. The warranty manager for example can receive on his terminal all the information needed to administer the warranty. This implies the data input by the using command (base level) satisfies the assessment requirements established during warranty program development. Another key point here is the requirement for the author of the warranty

language to fully understand base level procedures and capabilities to ensure requirements are not established which are incompatible with base level input capabilities.* Warranty language must be standardized to the extent possible. While it is true that each weapon system has unique requirements, a significant amount of warranty language can be standardized. The Air Force Product Performance Agreement Center can play a major role in standardizing warranties. The center maintains on file generic warranty clauses which can be used to tailor a warranty to a specific weapon system. (10:B-1) Finally great concern was expressed about including a data system format to input all deficiency data as required by Air Force Technical Order 00-35D-54. Such a capability will simplify and enhance the base level capability to comply with their part of warranty administration.

The Air Force is working to build a data system which will be effective in the warranty administration role for most weapon systems. The base level warranty system is built on the currently existing weapon system management system called the Core Automated Maintenance System

*The amount of data managed for a warranty can cause substantial amounts of tracking work. For example between January and September 1987 one F-15 wing prepared a total of 419 reports of which 240 were exclusively warranty-related. The several man-hours expended for each report translates to a very substantial workload for base level personnel. The effort requires the capability for serialized tracking of warranted elements. In addition, program office requirements for the F100-PW-220 engine specify a lengthy service report must be prepared for each failure which occurs prior to PMRT. The B-1B aircraft data system base contains several million elements of information and the warranty administration requirement is constantly growing as programs like the ATF, B-2 and C-17 continue development. The Air Force is moving rapidly on a variety of fronts to cope with the requirement to manage weapon systems and administer warranties. Unfortunately not everyone is moving in the same direction.

(CAMS). CAMS runs on the base level Sperry 1100 computer using a variety of terminal and interface devices. CAMS was not bought with warranty administration included and therefore the Air Force must buy a special software addition to achieve this new capability. In addition, a system called Reliability and Maintainability Information System (REMIS) must be bought for the supporting and implementing command to provide the capability for data input at base level to be processed upline by warranty managers charged with actual administration of warranties. Finally some form of connectivity between the two systems must be established to enable data from base level to flow to upline warranty manager systems. Headquarters U.S. Air Force is advocating a common system (CAMS/REMIS) for use by all using commands. The current and forecast budget constraints support this approach for cost savings reasons. The Air Force cannot afford to fund several different data systems. Using commands are taking steps to alter whatever systems they currently have to make them CAMS/REMIS compatible. This is an essential step for the corporate Air Force in the quest for warranty administration capability.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

The U.S. Air Force is engaged in a substantial effort to integrate congressionally-mandated warranties into the acquisition process. That effort, which has been on-going since the early 1970's, has accelerated in light of the 1985 law. This study shows that warranties do have a beneficial effect on weapon system acquisition if managed properly. The Air Force is clearly making progress and is doing many of the right things. There are, however, improvements and adjustments needed if the real potential of warranties (reliable, combat effective weapon systems at optimum cost) is to be achieved.

The Air Force has not done enough to educate its personnel about warranties. As a result, warranties and the warranty process within the Air Force are poorly understood. There is a major disconnect between warranty authors in the program offices, and the field. This is reflected in contracts written but unenforceable because the Air Force cannot properly administer them. Much better coordination is needed between users and warranty authors. Warranty authors need a much better understanding of base level capabilities and limitations and base level personnel need a better understanding of what warranties are and how they apply to weapon systems being supported. An aggressive effort designed to educate and train people engaged in warranty related work will help prepare the Air Force for the flood of warranties that are coming. We must prepare and disseminate widely educational materials like the "R&M 2000 Process" booklet and Warranty Handbook cited as

references to this paper. Simple, explicit guidance and policy is needed at levels from HQ USAF through base level.

The Air Force senior leadership has gone only half way in establishing the linkage between warranties and more combat effective weapon systems. It has been clearly established and accepted that only those weapon systems that are demonstrably free of R&M problems, provide adequate combat effectiveness. What is not well understood is that performance warranties give the Air Force the statutory leverage to assure R&M goals are met and, therefore, there is a compelling and synergistic indirect linkage between warranties and combat effective weapon systems. The intent of Congress in passing the 1985 law was better R&M and more combat effective weapon systems. The Air Force senior leadership should direct action now to establish clearly, how warranties can contribute to better R&M and thereby, to more combat effective weapon systems. One possibility is the production of a videotape introduced by the Chief of Staff, USAF, similar to one referenced in this paper. In this way everyone who sees and hears the message will understand the philosophy and importance of warranties.

The Air Force is not using the Product Performance Agreement Center optimally in the warranty process. The center founded solely for working with product performance agreements has evolved into a "passive advocacy" role, but now an active orchestration role is urgently needed. The Product Performance Agreement Center should be elevated to a more active role in the warranty process. The Air Force senior leadership should boost PPAC authority and make their involvement a matter of

policy to capitalize on the importance of warranties to Air Force combat capability. Parochial concerns, however valid, that are blocking such a reform, should be held secondary to vitally needed process improvements.

The Air Force does not have the data systems it needs to administer warranties effectively. Progress is being made toward implementing the CAMS/REMIS systems; however, many warranties are in the field now or will be soon for which there is inadequate data management capability. This system must be funded and fielded in a timely manner to enable the Air Force to administer warranties now and in the near future. The Air Force senior leadership must make the necessary budget adjustments to ensure this system is fully funded because we simply cannot afford the alternative of not having the capability to administer warranties mandated by law.

The recommendations proposed by this paper address substantial areas of concern from a corporate perspective. Each recommended action is needed to enable the Air Force to continue to integrate warranties into the acquisition process, for the purpose of building reliable and combat effective weapon systems. Initial steps can and should be taken right away, to ensure warranties achieve their full potential toward improving combat effectiveness of Air Force weapon systems.

APPENDIX

TITLE 10, SECTION 2403, OF THE UNITED STATES CODE

§ 2403. Major weapon systems: contractor guarantees

(a) In this section:

(1) "Weapon system" means items that can be used directly by the armed forces to carry out combat missions and that cost more than \$100,000 or for which the eventual total procurement cost is more than \$10,000,000. Such term does not include commercial items sold in substantial quantities to the general public.

(2) "Prime contractor" means a party that enters into an agreement directly with the United States to furnish part or all of a weapon system.

(3) "Design and manufacturing requirements" means structural and engineering plans and manufacturing particulars, including precise measurements, tolerances, materials, and finished product tests for the weapon system being produced.

(4) "Essential performance requirements", with respect to a weapon system, means the operating capabilities or maintenance and reliability characteristics of the system that are determined by the Secretary of Defense to be necessary for the system to fulfill the military requirement for which the system is designed.

(5) "Component" means any constituent element of a weapon system.

(6) "Mature full-scale production" means the manufacture of all units of a weapon system after the manufacture of the first one-tenth of the eventual total production or the initial production quantity of such system, whichever is less.

(7) "Initial production quantity" means the number of units of a weapon system contracted for in the first year of full-scale production.

(8) "Head of an agency" has the meaning given that term in section 2302 of this title.

(b) Except as otherwise provided in this section, the head of an agency may not after January 1, 1985, enter into a contract for the production of a weapon system unless each prime contractor for the system provides the United States with written guarantees that—

(1) the item provided under the contract will conform to the design and manufacturing requirements specifically delineated in the production contract (or in any amendment to that contract);

(2) the item provided under the contract, at the time it is delivered to the United States, will be free from all defects in materials and workmanship;

(3) the item provided under the contract will conform to the essential performance requirements of the item as specifically delineated in the production contract (or in any amendment to that contract); and

(4) if the item provided under the contract fails to meet the guarantee specified in clause (1), (2), or (3), the contractor will at the election of the Secretary of Defense or as otherwise provided in the contract—

(A) promptly take such corrective action as may be necessary to correct the failure at no additional cost to the United States; or

(B) pay costs reasonably incurred by the United States in taking such corrective action.

(c) The head of the agency concerned may not require guarantees under subsection (b) from a prime contractor for a weapon system, or for a component of a weapon system, that is furnished by the United States to the contractor.

(d) Subject to subsection (e)(1), the Secretary of Defense may waive part or all of subsection (b) in the case of a weapon system, or component of a weapon system, if the Secretary determines—

(1) that the waiver is necessary in the interest of national defense; or

(2) that a guarantee under that subsection would not be cost-effective.

The Secretary may not delegate authority under this subsection to any person who holds a position below the level of Assistant Secretary of Defense or Assistant Secretary of a military department.

(e)(1) Before making a waiver under subsection (d) with respect to a weapon system that is a major defense acquisition program for the purpose of section 1552a of this title, the Secretary of Defense shall notify the Committees on Armed Services and on Appropriations of the Senate and House of Representatives in writing of his intention to waive any or all of the requirements of subsection (b) with respect to that system and shall include in the notice an explanation of the reasons for the waiver.

(2) Not later than February 1 of each year, the Secretary of Defense shall submit to the committees specified in paragraph (1) a report identifying each waiver made under subsection (d) during the preceding calendar year for a weapon system that is not a major defense acquisition program for the purpose of section 139a of this title and shall include in the report an explanation of the reasons for the waivers.

(f) The requirement for a guarantee under subsection (b)(3) applies only in the case of a contract for a weapon system that is in mature full-scale production. However, nothing in this section prohibits the head of the agency concerned from negotiating a guarantee similar to the guarantee described in that subsection for a weapon system not yet in mature full-scale production. When a contract for a weapon system not yet in mature full-scale production is not to include the full guarantee described in subsection (b)(3), the Secretary shall comply with the notice requirements of subsection (e).

(g) Nothing in this section prohibits the head of the agency concerned from—

(1) negotiating the specific details of a guarantee, including reasonable exclusions, limitations and time duration, so long as the negotiated guarantee is consistent with the general requirements of this section;

(2) requiring that components of a weapon system furnished by the United States to a contractor be properly installed so as not to invalidate any warranty or guarantee provided by the manufacturer of such component to the United States;

(3) reducing the price of any contract for a weapon system or other defense equipment to take account of any payment due from a contractor pursuant to subclause (B) of subsection (b)(4);

(4) in the case of a dual source procurement, exempting from the requirements of subsection (b)(3) an amount of production by the second source contractor equivalent to the first one-tenth of the eventual total production by the second source contractor; and

(5) using written guarantees to a greater extent than required by this section, including guarantees that exceed those in clauses (1), (2), and (3) of subsection (b) and guarantees that provide more comprehensive remedies than the remedies specified under clause (4) of that subsection.

(h)(1) The Secretary of Defense shall prescribe such regulations as may be necessary to carry out this section.

(2) This section does not apply to the Coast Guard or to the National Aeronautics and Space Administration.

(Added Pub L. 98-523, Title XII, § 1234(a), Oct. 10, 1984, 98 Stat. 2801.)

Prior Provisions. Provisions similar to this section were contained in Pub L. 96-512, Title VII, § 704, Dec. 8, 1979, 97 Stat. 1456 (set out as a note under section 1304 of this title) prior to repeal of the section by section 1234(b)(1) of Pub L. 98-523, effective Jan. 1, 1985.

Legislative History. For legislative history and purpose of Pub L. 98-523, see 1984 U.S. Code Cong. and Adm. News, p. 4174.

LIST OF REFERENCES

1. Balban, Harold S., Tom, Kenneth B., Harrison, George T. Jr., Warranty Handbook. Defense Systems Management College, Fort Belvoir, Virginia, June 1986.
2. Bradney, James M., Capt USAF, Perkins, Mark M., Capt USAF, Proposed Criteria for Evaluation of the Reliability Improvement Warranty Concept, Masters Thesis, School of Systems and Logistics, Air Force Institute of Technology, Wright-Patterson AFB, OH, 11 June 1980.
3. Miller, Thomas B., Major USAF, Warranties and Acquisition Strategies, Air Command and Staff College, Air University, Maxwell AFB, AL, April 1986.
4. United States Air Force Warranty Administration Plan, Directorate of Maintenance and Supply, DCS/Logistics and Engineering, HQ USAF, 11 April 1986.
5. DOD Warranties, Improvements Needed in Implementation of Warranty Legislation, United States Government Accounting Office, Report to the Chairman, Committee on Armed Services, U.S. Senate, Report No. 87-122, July 1987.
6. Stucker, James P., Smith, Giles K., Warranties for Weapons, Theory and Initial Assessment, A report sponsored by Deputy Chief of Staff/ Research Development and Acquisition, HQ USAF, Rand Corporation, Santa Monica, CA, April 1987.
7. Curtis, Lewis E., III, Colonel USAF, Strategies for the Use of Product Performance Agreements to Enhance Supportability, Air War College, Air University, Maxwell AFB, AL May 1984.
8. Combat Support in the Air Force - The AFLC Perspective, Aerospace Audio Visual Service Product Number PAN F3205-87-0034.
9. Zeigler, Timothy R., Major, USAF, Consumer Warranties Are Not the Answer, National Defense University, Armed Forces Staff College, Norfolk, VA, April 1986.
10. Guenther, Michael A., Lt Col, USAF, Assessment of the Reliability Improvement Warranty (RIW), Air Force Product Performance Agreement Center, Wright-Patterson AFB, OH, 12 July 1985.
11. Allen, B. J., Bardenstein, R. L., Fritz, A. L., Product Performance Agreement Decision Support Handbook, The Analytical Sciences Corporation under Contract to the Air Force Product Performance Agreement Center, Wright-Patterson AFB, OH, 1 February 1985.

12. HQ USAF/LE-RD Letter to SAF/AQCS, Final Review of Draft AFR 800-47, Weapon System Warranties, Washington, D.C., 8 December 1987.
13. HQ TAC, LGX Letter to SAF/AQCS, Draft AFR 800-47, Weapon System Warranties, Langley AFB, VA, 9 December 1987.
14. Interview with HQ TAC LGM Staff, Langley AFB, VA, 3 February 1988.
15. Interview with Director, Product Performance Agreement Center, Lt Col William A. Cunningham, Wright-Patterson AFB, OH, 5 February 1988.
16. Task Force Report, Cost-Benefit Analysis of Warranties, Air Force Product Performance Agreement Center, Wright-Patterson AFB, OH, January 31, 1986.
17. Interview with Mr. George Baum, AFLC/MMA, Wright-Patterson AFB, OH, 4 February 1988.
18. HQ TAC, LG Letter to SAF/AQC, 10 June 1987.
19. Hentges, Kenneth M., Major, USAF, A Guide to System Level Warranties/Incentives: An Approach for Assuring Aircraft Readiness, Air Command and Staff College, Maxwell AFB, AL, March 1983.
20. USAF R&M 2000 Process, Headquarters, United States Air Force Office of the Special Assistant for R&M, Washington, D.C., October 1987.