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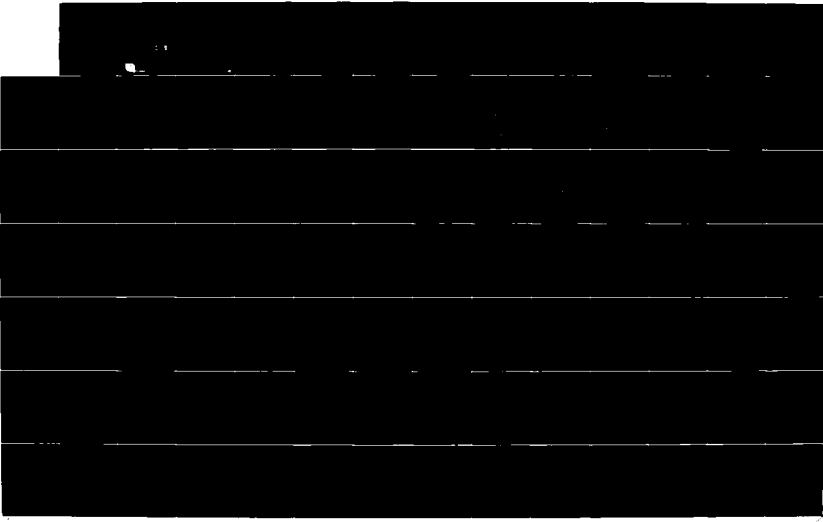
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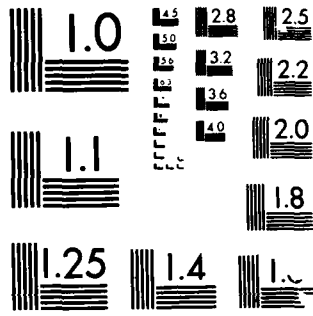
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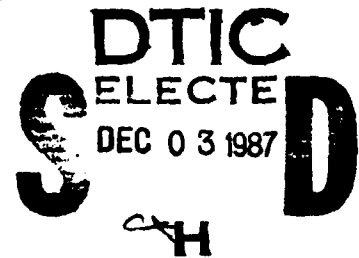
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WARRANTIES IN WEAPON SYSTEM PROCUREMENT:
AN ANALYSIS OF PRACTICE AND THEORY

Robert E. Kuenne
Paul H. Richanbach
Frederick R. Riddell
Rachel Kaganoff

April 1987



Prepared for
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19. ABSTRACT (Continue on reverse if necessary and identify by block number) Congressional legislation requires that all major weapon systems contracts signed after January 1, 1985, contain three types of written warranties: design-manufacture, materials-workmanship, and essential performance requirements. This study reviews the specifics of the law, its legislative history, and Congressional intent revealed in relevant hearings. Through analysis of recent weapon system contracts from all the Services, supplemented by field interviews with contracting personnel, the study ascertains the changes in contractual warranty provisions effected by the mandate. Research is then directed more deeply into the functions of weapon systems warranties and their economic appropriateness in a Department of Defense context.				
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INSTITUTE FOR DEFENSE ANALYSIS

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PREFACE

During the recent period of intense attention to Department of Defense procurement policy by Congress, the department itself, and the military services, few aspects have received as much review as weapon system warranties. Congressional action has mandated their inclusion in contracts for such equipment and has moved both their content and goals away from traditional directions. It is not clear to what extent the contracting community has understood or conformed to these innovations, nor, indeed, is Congressional intent unambiguous. In a normative vein, few guidelines exist in the literature for determining efficient employment procedures for these instruments.

This study seeks to remedy some of these deficiencies and to analyze the content and aftermath of recent legislation affecting warranties. It employs both empirical and theoretical means to investigate current practices and their conformance to legislative dictates as well as efficiency principles. Because Congressional mandates were issued so recently, the availability of extensive data on relevant warranty usage has been limited; thus extensive field interviews with the Services' contracting personnel were conducted.

The project, therefore, is deeply indebted to these personnel who gave their time so ungrudgingly in the midst of busy schedules, and who responded so candidly to inquiries. Their names are not listed here to protect the confidentiality of their interviews, but their contribution to the study must be acknowledged as fundamental.

The authors also are grateful for the assiduous work of the Eagle Research Group in assembling and analyzing the sample of contracts employed in the study and organizing the interviews. Don Binder and Bob Widder were the prime movers in these efforts.

Dr. Harry Williams and Mr. Stanley Horowitz reviewed an earlier draft of this paper, and the authors are grateful for their useful comments.

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GLOSSARY

AR	Army Regulation
ASD(I&L)	Assistant Secretary of Defense (Installations and Logistics)
ASPR	Armed Services Procurement Regulation
BFV	Bradley Fighting Vehicle
DAR	Defense Acquisition Regulation
DDR&E	Director, Defense Research and Engineering
DFARS	Defense Federal Acquisition Regulation Supplement
DM	Design/Manufacture (Warranty)
DoD	Department of Defense
EC	Engineering Change
ECP	Engineering Change Proposal
EPR	Essential Performance Requirement
EPWT	Essential Performance Warranty Test
FAR	Federal Acquisition Regulation
GCS	Guidance Control Section
GLLD	Ground Laser Locator Designator
GS	General Service
IDA	Institute for Defense Analyses
I&L	Installations and Logistics
IPT	Initial Production Test
LDR	Laser Designator Rangefinder
MLDT	Mean Logistic Down Time
MLRS	Multiple Launch Rocket System
MTBF	Mean Time Between Failure
MTBR	Mean Time Between Repair
M/W	Materials/Workmanship (Warranty)
NAVSEA	Naval Sea Systems Command
OC	Operating Characteristic
POMCUS	Prepositioning of Material Configured to Unit Sets
PVT	Product Verification Testing
RI	Reliability Incentive
RIW	Reliability Improvement Warranty
RMA	Reliability, Maintenance, and Availability
RMAC	Reliability, Maintenance, and Availability Characteristic

SECDEF	Secretary of Defense
TAT	Turnaround Time
TOT	Total Operating Time
UCC	Uniform Commercial Code
ULCE	Unified Life Cycle
USC	United States Code

EXECUTIVE SUMMARY

A. PURPOSE AND SCOPE OF THE STUDY

Recent Department of Defense (DoD) and Congressional concerns with defense procurement have resulted in a renewed emphasis upon the use of warranties, especially in major weapon system acquisition. In Section 794 of the Defense Appropriations Act of 1984, Congress mandated the use of written warranties from weapon system contractors to assure that such equipment met DoD's specified performance requirements. In the light of a substantial body of criticism of Section 794 from DoD and the contractor community, Congress superseded Section 794 a year later with altered provisions that became Title 10, Section 2403 of the United States Code (10 USC 2403). Section 2403 relaxed the more rigid provisions of Section 794, but retained the basic requirement for explicit warranties on most weapon systems.

This study was sponsored by the Director, Program Analysis and Evaluation to study the impacts of this legislation upon weapon system contracting to date, to draw upon existing economic theory for insights into the conditions for efficient usage of the warranty in defense contracting, and to derive guidelines for the cost-effective application of such guarantees based upon the empirical and theoretical analyses.

B. THE ROLE OF WARRANTIES IN DEFENSE PROCUREMENT

The following definition of a warranty within the DoD procurement context has been adopted in this study:

A legally binding guarantee - usually explicit but in certain cases implicit - whereby a contractor, with or without an explicit payment, agrees to remedy defects in design, manufacture, workmanship, materials, or performance existing at a specific time or emerging over a specific period in a weapon system. It may, in addition, provide positive incentives to exceed target specifications in these characteristics, or penalties if specified targets are not achieved.

1. The Emerging Framework for Weapon System Procurement

Since the end of World War II, weapon systems have become increasingly complex and expensive, and correspondingly greater and greater attention has been paid to the procurement process by Congress, DoD, and the military services. In the last few years a

distinctive "vision" of the process has emerged that treats the process as an integrated, seamless continuity from concept to research and development, design, testing, manufacturing, and support phases. Advances in computer hardware and software have made feasible the concept of Unified Life Cycle Engineering (ULCE), in which producibility and supportability characteristics of the weapon system are incorporated into the design with weights coordinate with that given performance. In the design phase explicit consideration can be given to manufacturing implications and testing requirements, with explicit trade-offs among configurations taken into account by the experts.

Warranties should be analyzed with this backdrop in view. They are tools and their optimal usage is determined by their contributions to furthering this goal of producing higher quality systems with minimal life cycle costs. Their potential roles rest upon the following characteristics of the acquisition process:

- a. *The forces of competition* are attenuated by the advanced technology necessary to participate. The number of highly specialized firms is small so DoD may wish to substitute other mechanisms for deficiencies in competition to assure quality and constrain price.
- b. Advanced technology results in the pervasiveness of *uncertainty* as to cost and performance of the systems. Explicit risk sharing between contractors and DoD becomes necessary, and instruments to perform this function must be defined.
- c. DoD cannot expect to be fully informed about the possibilities of state-of-the-art technology and the quality or performance characteristics of the delivered product. It may, therefore, find it advantageous to overcome by contractual arrangements the potential disadvantages springing from this *asymmetry of information*.
- d. Contractors may believe that efforts to meet or exceed specifications lessen profits, and may be reluctant to make such expenditures unless positive or negative incentives are provided by DoD. Efficient *incentivization* instruments may then prove useful to overcome this *moral hazard*.

2. The Functions of Warranties

Warranties are contractual instruments which can be used to aid DoD in coping with these characteristics. Their functions in the procurement process are conveniently classified as follows with these characteristics of the procurement process in mind:

- a. *Assurance-Validation*. This basic function is that of assuring DoD that the contractor delivers a product whose design and manufacture as well as materials and workmanship conform to contractual specifications. Implicitly assumed is the assertion that such defects can be avoided by

ordinary management prudence, and hence the costs of providing remedial actions should be borne by the contractor. Assurance-validation in the strictest sense ends at acceptance of the system with respect to patent defects and after some reasonable period with respect to latent defects.

- b. *Insurance.* Every warranty provides a measure of insurance against the risks of repair or replacement costs. This function becomes noteworthy or dominant when the warranty protects DoD against substantial contingent losses due to support costs or performance inadequacies in periods that extend extensively into the post-acceptance phase.
- c. *Incentivization.* All warranties also incentivize the contractor as a matter of course. However, this function becomes truly distinctive when guarantee provisions provide explicit penalties for failure to achieve target parameters and/or rewards for overachievement of such targets.

The manners in which these functions confront the reduced competitive aspects of DoD weapons procurement, the uncertainty of performance and its attendant costs, the asymmetry of information suffered by DoD, and the need to overcome or exploit moral hazard are self-evident. The analysis to follow classifies warranties by which of these three functions is *dominant*, given that the presence of all three is the general case.

Warranties, therefore, are potential contributors to the integrated procurement process and its goals of increasing product quality and producing weapon systems with more efficient resource expenditure. Certain caveats are in order concerning their potential contributions, however. They command a price, either explicitly as payments to the contractor or implicitly in the price of the contract, and those costs to DoD must be considered as offsets to their benefits. Moreover, they do not permit DoD to escape the real costs of uncertainty in the procurement process but only the risk of extreme *variations* in those costs. Their potential contribution to efficient resource allocation inheres rather in their forcing the interested parties to design and produce systems whose benefits truly exceed their real costs.

C. DoD WARRANTY POLICY IN THE PRE-MANDATE PERIOD

Although warranties have been used by the military departments prior to World War II, the modern period of warranty history may be dated conveniently from 1964. In that year Secretary McNamara initiated a campaign to unify warranty practices among the Services and to develop guidelines for proper usage by DoD contracting officers. In the mid-1970s this renewed interest was intensified by DoD's urging of the Services to experiment with incentive warranties in the procurement of electronic equipment. This led

to the development of the Reliability Improvement Warranty (RIW) which rewarded the contractor for assuming the depot repair of equipment over specified periods of time, and inflicted negative incentives for failure to achieve certain reliability, maintainability, or availability (RMA) targets. These two developments--the unification of practice through the establishment of guidelines and the fostering of incentivization warranties--were superimposed upon a body of regulations and practices that formed a kind of "common law" which continues in force today, especially in DoD procurement other than weapon systems. Its nature is indicated below.

1. The "Common Law" of Defense Warranties

The Uniform Commercial Code provides two implicit types of warranties to all purchasers of commercial goods, and DoD participates in this protection:

- a. *Merchantability*, or the assurance that the goods will pass in the trade as described and that they are fit for the ordinary purposes for which such goods are used.
- b. *Fitness for a particular purpose*, or the additional guarantee that the goods are fit for the *particular purpose* for which the buyer will use them when 1) the seller has reason to know of such purpose and 2) the buyer is relying upon the seller's expertise and judgment in their selection and provision.

When DoD contracts contain specific warranty provisions, however, these common law guarantees are nullified, and DoD's protections are based upon those explicit warranties and its right to inspect and formally accept goods. Numerous court and claims commission decisions have upheld the government's right to insist upon strict compliance with contractual specifications as long as they are reasonable and testing procedures are acceptable. However, once DoD accepts goods, unless warranties provide otherwise, it has no recourse to the contractor unless 1) latent defects emerge that were not discoverable by reasonable inspection at the time of acceptance, 2) fraud was present in the manufacture of the goods, or 3) gross mistakes that amount to fraud were committed.

Explicit warranties in DoD contracts other than weapon systems evolved from commercial practice and are usually paired:

- a. *Design and manufacture (D/M)*, which certifies that the product has been designed and manufactured to conform to the specifications of the contract.
- b. *Materials and workmanship (M/W)*, which guarantees that the materials used and the quality of workmanship will conform to the specifications of the contract.

In the past, it is important to note, these warranties were written and interpreted to be assurances that the goods met contract configurations and, except for potential latent defects, were fulfilled upon DoD acceptance. *They did not extend into the post-acceptance phase* (barring latent defects, fraud, or gross mistakes).

2. Warranty Provisions of the Federal Acquisition Regulations

Since the late 1970s, as a continuation of the McNamara initiative and as a response to Congressional concern about the procurement process, the executive branch of the federal government in general and DoD in particular have devoted great effort to unifying and formalizing warranty procedures. Most importantly, Part 46 (Quality Assurance), Subpart 46.7 (Warranties) and Part 52 (Solicitation Provisions and Contract Clauses), Subparts 52.246-17 through 52.246-21 of the Federal Acquisition Regulations (FARs) established ground rules for warranty usage in federal procurement. They are declared to be non-mandatory and are to be used only when the contracting officer deems them in the government's interest.

Most importantly, the FARs contain models of terms and conditions for five types of goods, and these models have been adopted by the military services with necessary modifications as the basic frameworks for warranties:

- supplies of a noncomplex nature,
- supplies of a complex nature,
- systems and equipment under performance specifications or design criteria,
- services, and
- construction.

As adapted to military use by the Defense Federal Acquisition Regulation Supplements (DFARS) and, in the case of weapon systems, as modified by recent legislation, military service contracts tend to contain warranty clauses closely modeled after the FAR schema for the third type of good listed above.

3. The Experience with Reliability Improvement Warranties

As noted above, at the behest of DoD, the military services began to experiment with the use of warranties as instruments to provide incentives. The most important form these assumed was the RIW as applied to the acquisition of electronic equipment. This type of equipment has a more predictable failure rate than mechanical types, and was therefore chosen for experimentation with the RIW. Because of the importance of avionics in Air Force acquisitions, this service used them most extensively.

The RIW in the narrow sense generally provided for contractor repair of failures in a given number of fielded units over a specific period of time. Frequently fee schedules were specified per item repaired. More broadly, the concept can be extended to include warranties that provided negative incentives for failure to achieve target parameters (e.g., mean time between failure (MTBF) goals) or positive incentive payments for exceeding them. The goals of the program were to improve the reliability, maintainability, availability characteristics (RMACs) of the equipment, and although sufficient data are not available to judge the cost-effectiveness of the RIWS the consensus of contracting officials is that they were a successful application of warranties.

It is important to distinguish between two types of performance characteristics that can be parameterized in warranty provisions:

- a. RMACs, as discussed above, which are concerned with the *downtime* of systems. Mean times between failure or repair, or measures based upon them, are frequent indices of downtime. The concern of RMACs is the proportion of the time equipment is available for field use.
- b. OCs, or operating characteristics, which are concerned with the performance of systems when they are operable. Such parameters might include the thrust or fuel consumption of aircraft engines, the range of radars, the speed of ships, and so forth.

As noted above, the RIW was concerned exclusively with RMACs.

D. DoD WARRANTY PRACTICE IN THE POST-MANDATE PERIOD

In specific weapon system warranty practice it was the policy of the military services to seek D/M and M/W warranties to protect themselves against patent and latent defects, but to self-insure against support or retrofit costs in the post-acceptance stages with the informal but frequently important contributions of contractors. These practices were changed abruptly with the passage by Congress of Section 794 and Section 2403 noted in

section A. These acts *mandated* written warranties on weapon systems and, with some ambiguity and outright confusion, seemed to extend warranties in two dimensions:

1. The notion of warranties as guarantees that systems conformed to contract configuration at acceptance was expanded to require conformance to performance requirements for indefinite periods after fielding.
2. The performance requirement most frequently used in warranty provisions--RMACs--was deemphasized in favor of OCs.

Congressional intent was not clear in both regards, and confusion begat confrontation with the defense community.

1. Section 794 and Defense Guidance Interpreting It

Section 794 was a short, tersely-worded statute intended to provide basic requirements for warranties on weapon systems, with contractual provisions to be tailored by contracting officers to individual circumstances. There were three important types of mandates:

- a. *Scope. All weapon system contracts in the future were required to contain two written warranties from prime or "other" contractors. These were:*
 - *D/M. This constituted a guarantee that the system and each component conformed to the performance requirements stated explicitly in the contract or any other agreement relating to the production.*
 - *M/W. This guaranteed that at the time of delivery the system and each component was free of materials and workmanship defects that would cause nonconformance to specified performance requirements in the contract or any other agreement relating to production.*
- b. *Remedies Available to DoD. In the event of breach of either or both warranties "the contractor" was to bear the cost of repair or replacement of such parts as were necessary to attain the performance requirements. Failing such action, the contractor would be required to reimburse DoD for effecting the remediation.*
- c. *Waiver Procedures. The Secretary of Defense could waive the warranty mandates if 1) it was the interest of national defense, or 2) the warranties were not cost-effective and 3) he notified the armed services and the appropriations committees of both houses of Congress in writing and explained his reasons for the waiver.*

Upon passage of the act in December, 1983, DoD issued a blanket waiver of its provisions until the following March to minimize disruption of the acquisition process while it developed implementation instructions. It published a draft of proposed guidelines

in January which is valuable as a guide to its interpretation of Congressional intent. Briefly, it:

- a. attempted to define the term *weapon system*;
- b. excluded spare parts from the component category;
- c. narrowed "performance requirements" to *specified performance requirements* which were defined as mandatory requirements rather than expressed aspirations;
- d. stated that the specified performance requirements were to be in the form of a test or demonstration and deemed to be met upon successful completion of such events, when a first prototype or first production unit was involved;
- e. required that for other units, when the specified performance requirements were in the form of RMACs and the warranty extended over a period of time, conformity was to be interpreted in those terms;
- f. stipulated that breach of warranty for the first prototype or production unit required the contractor to perform all design and manufacture work necessary to assure conformance to the requirements at no increase in cost to DoD; and
- g. asserted that breach of warranty in other cases required redesign and remanufacture of the system and each component to meet requirements "and/or" repair or replacement of parts necessary for conformance, at no increase in cost to DoD.

The criticisms of Section 794 and its draft Defense Guidance (*the measures*) from the contracting community was immediate and included these important charges:

- a. The measures altered the classic application of warranties from conformance to contract specifications at the time of acceptance to a guarantee of performance requirements for an undefined time period in the post-acceptance phases. Moreover, those requirements seemed to emphasize OCs rather than RMACs.
- b. The all-inclusiveness of the warranty mandates prevented relevant specific circumstances to be considered, notably the degree of participation of the contractors in design and whether a cost-reimbursable contract was in force.
- c. The performance warranty placed large contingent liabilities upon firms which had no way of estimating such potential costs and, especially in the case of small businesses, had no financial base to meet such obligations.
- d. The act itself seemed to limit contractor responsibility to repair or replacement of parts, but the guidance document extended this to redesign and remanufacture responsibilities.
- e. The defense procurement base would be reduced and competition lessened if small business left defense work because of the act's provisions that they could be liable for breach of warranty for the system if their components malfunctioned.

2. The Provisions of Section 2403

In reaction to criticisms of this nature, Congress passed the measure which became 10 USC 2403. It introduces a great deal more flexibility into warranty design without eliminating the burden of performance guarantees. Significant relaxation of Section 794 requirements was revealed in the following provisions:

- a. The D/M and M/W warranties revert to their former role as requiring conformance to contract specifications.
- b. The performance requirement is limited to a third warranty--*essential performance requirements* (EPRs)--which were a specifically designated subset of performance parameters.
- c. The provisions do not apply to weapon systems that have a unit cost of less than \$100,000 or a total procurement cost of less than \$10 million.
- d. Written warranties are required from prime contractors only.
- e. It is explicitly permitted to define EPRs as RMACs as well as OCs.
- f. The EPR guarantees become effective only for weapon systems in "mature full-scale production," which is explicitly defined.
- g. The waiver provisions for major acquisition programs are retained, but for other programs DoD is required merely to report and explain their rationale annually.

The contracting officer is given a great deal of flexibility in negotiating warranties as long as the guarantee meets the general requirements of the act. One major power is the ability to limit the financial liabilities incurred by the contractor under the three required warranties.

Since January 1, 1985, all weapon systems contracts must conform to the provisions of Section 2403.

3. Ambiguities in the Interpretation of Congressional Intent

Study of the two acts discussed above, the hearings that concerned them, and the reactions of critics failed to reveal a clear, consistent Congressional intent. Advocates tend to urge the assurance-validation, insurance, and negative incentivization functions of warranties without clearly distinguishing them. Performance requirements seem to be most frequently envisaged by advocates as OCs, and Congressional intent seems to have been to institute them in the warranties. Yet DoD witnesses responded more frequently in terms of RMACs, especially with reference to RIW experience. Congress did consistently argue for

the need of contracting officers to tailor warranties to the specifics of contracts and has chided DoD for failing to do so. The great discretion given such officers in Section 2403 is the result of this desire by Congress.

4. Recent Contract Compliance With Warranty Legislation

In-depth analysis was undertaken of the warranty provisions of 13 recent contracts for major weapon systems spread about evenly over the three services. In addition, interviews were conducted with contracting officials in all services. The purpose of the empirical studies was to discern what changes in warranty practices, if any, had been instituted to comply with Section 2403.

The major conclusions of the analysis are the following:

- a. Warranties are currently being written to conform formally with the requirements of Section 2403. In almost every instance D/M, M/W, and EPR warranties are present.
- b. The assurance-validation function of warranties is dominant in the warranties examined and in the intentions of interviewed officials. This is reassuring in that this is the most fundamental function of such guarantees.
- c. The insurance function is absent from the warranties examined. That is, attempts to use the warranty predominantly to shift contingent liabilities in the post-acceptance phase to the contractor are not found in the sample of contracts. One reason for this is the cost of such warranties. Interviews with Army contracting personnel, however, revealed that the service intends to seek systemic defect warranties in the future for up to one-half service life. The dominant function of such warranties would be that of insurance.
- d. Given the favorable experience of the services with RIWs, a somewhat surprising finding was the rare use of negative and positive incentive warranties. In only one contract had it been employed in the recent past, but even in that case it had not been renewed in the FY 1985 contract. Also, as noted, liability ceilings granted contractors are so low as to be questionable sanctions. The reasons given in interviews for this nonuse were high costs; the expense and effort necessary to develop incentivization schedules; and the maturity of most of the systems currently in production and the consequent nonnecessity for incentives in steady state production.
- e. There is little evidence that Section 2403 has increased the duration of post-acceptance warranty periods. Army personnel did assert that an effort is currently in process to extend such durations. Cost is a barrier to such extensions as is the Services' desires to protect in-house repair capability.
- f. Evidence that the legislation has altered the structure of performance requirements between OCs and RMACs is mixed. A bias toward RMACs does appear in the partial list of EPRs available to the study.

- g. One notable feature of almost all the contracts examined is the failure to break out warranty price (if any) as a separate line item. It is incorporated in contract price. This is specifically permitted by DoD policy, but it seriously interferes with judgments of the cost-effectiveness of the warranties.**

E. A THEORETICAL ANALYSIS OF WARRANTIES IN WEAPON SYSTEM PROCUREMENT

Because of the paucity of data on weapon systems contracts under performance warranties, much reliance for their analysis has been placed upon economic theoretical frameworks. Four branches of economic theory have been drawn upon heavily: the economics of uncertainty, insurance theory, principal-agent theory, and vector maximization techniques. The conclusions from these analyses are summarized below:

- 1. Assurance-validation warranties are integral to the production and delivery of the systems, and their costs cannot be separated from the costs of production. DoD has the obligation to receive from the contractor at acceptance the system with a configuration that was agreed upon contractually, and no price should be paid for a warranty that guarantees such a product. To do so would be to pay twice for the risks that some redesign or part replacement might be necessary to qualify the system for delivery--once implicitly in the price of the contract and again explicitly in the price of the warranty. Care should be taken that such expenses are not duplicated by being rolled into sustaining engineering budgets.**
- 2. Use of the warranty as an insurance vehicle to shift all or a major portion of the risk of substantial losses in the post-acceptance phase to contractors is not cost-effective for DoD. This conclusion rests upon the relative risk-averseness of the parties to this type of warranty. In general, insurance is purchased by a party who is risk-averse. DoD, with its large financial resources and multifold projects over which risk can be spread must be viewed as much more capable of bearing risk than contractors. There is, therefore, a perverse element in the purchase by DoD of insurance from contractors who have been shown in empirical studies to be quite risk-averse.**

In practical terms, this implies two characteristics of such insurance warranties:

- a. even if the warranty could be purchased at a price that reflected the true probabilities of undesirable events in the post-acceptance phase, DoD's welfare would not increase much if at all with its possession of such protection, and**
- b. the contractor will not sell such insurance at the "fair price," but will load the price with a premium dictated by his risk aversion and administrative expenses.**

Hence, warranties that have a dominant function of insuring against large contingent liabilities are not recommended. Self-insurance by DoD is advisable.

3. The use of a warranty as an incentivization instrument is an efficient mechanism to encourage contractors to meet or, when in the interest of DoD, overfulfill target parameters. When used negatively, contracting officers should gauge the moral hazard they face with given contractors. When positive incentives are employed, contract personnel should gauge the degree of control a contractor has over the specific characteristics of the system in question as well as his readiness to respond to monetary incentive payments. The analysis develops a simple method of determining an optimal fee schedule for such positive incentives.
4. Because of the cost structures involved in procurement, theoretical analysis suggests that contractors will be biased toward definition of EPRs as RMACs and that DoD should be oriented toward their definition as OCs. The difficulty of negotiating compromises of these two pre-negotiation strategies suggests that DoD might employ incentivization schemes to overcome contractor reluctance to accept OCs as EPRs.

F. CONCLUSIONS

In addition to the conclusions derived from the empirical analysis outlined in Section D and the guidelines suggested by the theoretical analysis summarized in Section E, the following observations are in order:

1. Current weapon systems contracts are being written with D/M, M/W, and EPR warranties in accordance with Section 2403, but the warranty periods tend to be coterminous. Since D/M and M/W warranties are designed primarily to reveal latent defects that are usually discoverable rather quickly after fielding, and EPRs are focused upon defects occurring over a long time horizon, this practice can be questioned. Warranty price seems to be the dominant consideration in limiting the EPR warranty period.
2. Warranties currently written conform to the guidelines derived from theoretical analysis rather well. The dominant function revealed in them is assurance-validation, and such warranties are treated as implicitly included in the contract price. The insurance function is not an important feature in such warranties. However, the use of incentives via warranties is not employed as much as theoretical analysis suggests it should be. Several explanations may be relevant. Other forms of incentive contracting may be used. Current weapon systems are in greatest part mature and beyond the stage where the use of incentives is needed. And the cost of such features, both in determining fee schedules and the size of necessary fees, may be prohibitive in the current procurement environment.
3. A tentative conclusion, given the imperfect information available from the warranty clauses of the sample of contracts studied, but supported by key interviews, is that OCs are receiving less emphasis in the definition of EPRs

than Congress' interest in on-line performance warrants, to judge the intent spirit of Section 2403. RMACs seem to predominate in EPR definitions. The reasons for this inhere in their ease of definition, contractor reluctance to accept OCs, and the inertia of historical usage.

4. One practice which should be instituted is the requirement that the prices of insurance and incentivization warranties be listed as line items. Rational analysis of their usefulness for DoD purposes requires the availability and cost.
5. A continuing concern of Congress has been the failure of contracting officers to tailor warranties to fit the specifics of a given contract and weapon system. There is a marked tendency for contracts to follow slavishly the FAR model for equipment designed to specifications.
6. The flexibility given contracting officers in Section 2403 is being used most visibly to limit contractor liability under warranty clauses. The ceilings in general are so low, relative to the profit margins on the equipment, as to nullify negative incentives. Interviews in the field indicated that this resulted from the need to reduce the price of the warranties, especially when competition was absent, and from the pressures to commit funds imposed upon contracting officers.
7. In general, an accounting and administrative infrastructure to handle warranties is not sufficiently in place at contractors or in the Services to still suspicions that they are ineffective in achieving their goals. Widespread skepticism about their cost-effectiveness exists in the Services' contracting community on these grounds.
8. An early concern about the adoption of EPR warranties was that they would bias design in conservative rather than innovative directions. No evidence of this was uncovered in this study.
9. The length of the EPR warranty period is important in fulfilling its assurance-validation function. If it is too short, contractors will not find it economical to effect fundamental design changes, electing instead to repair defects until the expiration of the warranty. Periods of at least two years are recommended on these grounds. However, as noted above, the price of warranties escalates rapidly with time duration.
10. Electronic equipment is more amenable to post-acceptance warranties than mechanical equipment by virtue of greater malfunction predictability.
11. With the increasing complexity of modern weapon systems, prime contractors are becoming assemblers of components produced by subcontractors and suppliers. Warranties on such systems, as opposed to their components, may be increasingly difficult to enforce, especially if the prime contractor had a small role in system design.
12. A neglected effect of positive incentive warranties may be lessened competition, in that they may strengthen the position of sole-source contractors in subsequent bidding. Higher long-run prices may be the result.

I. THE PURPOSE AND SCOPE OF THE STUDY

A. MOTIVATION OF THE STUDY

The process of weapon system procurement, viewed as an integrated continuum from conceptualization, design, and development through production and support phases, is characterized by a number of features that distinguish it from commercial acquisition. One dominant distinction, of course, is the public interest concern that Department of Defense (DoD) assets be technologically state-of-the-art, reliable in performance, and available when necessary to protect national security. Less vital, but important, differences, include the costly nature of the hardware; the long time period necessary to field it; the lessened role of competition in source selection; the frequent need to incorporate design changes for technological currency; the uncertain but often hostile or punishing environment within which equipment must function; and an inability to specify with confidence the expected times and rates of usage.

All of these distinguishing characteristics contribute to the differential uncertainty and its contingent costs that inhere in weapons acquisition when compared with more conventional procurement. The analysis of the sources and implications for decision making of this uncertainty, especially with respect to alternative means of distributing its cost among parties to the contracting, assumes great importance in the attempt to improve defense management. This realization has been manifest in the renewed interest that DoD, the military departments, and Congress have shown in the use of warranties as a potential means of assuring conformance to contract specifications, shifting risk away from government, reducing life cycle costs, and improving the performance of such equipment.

This study is motivated by 1) the desire to gauge the extent to which present and recent past incorporation of warranties in weapon system contracts are attaining these ends, and 2) the hope that economic theory, especially as it applies to uncertainty, can be formulated to set forth some guidelines for policy emphasis in these respects. The focus of this research is the provision of guidance to DoD in tailoring warranties to achieve its ends in cost-effective ways under specific contract circumstances.

B. THE TASKS DEFINED

The Director, Program Analysis and Evaluation, Office of the Under Secretary of Defense, Research and Engineering, has tasked the Institute for Defense Analyses (IDA) in Task Order No. MDA903 84 C0031: T-Q6-400 to undertake this analysis and derivation of guidelines.

Three specific tasks are defined in the order:

Task 1. A review of economic literature that has relevance to warranties, product liability, and decision making under uncertainty to discern its potential relevance to warranties in DoD procurement.

Task 2. The conduct of field studies of DoD experience with product liability and warranties, including interviews with DoD and contractor personnel and the study of the literature concerned with this experience. This empirical analysis will be considered in conjunction with the theoretical results of Task 1 in the derivation of conclusions.

Task 3. The formulation of guidelines incorporating the results of Tasks 1 and 2 as they bear upon the design of cost-effective warranties in DoD procurement.

The results of these analyses are presented in the chapters that follow. Two constraints on the performance of the tasks were revealed early in the investigation and should be made explicit at this point.

The first concerns Task 1. A thorough search of the relevant economic literature was performed but very little material of *direct* relevance to the concerns of the study was uncovered. Government procurement in general is not a subject of widespread interest among economists interested in the indicated fields, and most of what is indirectly relevant is concerned with optimal bidding strategies in bid tenders or auctions. Product liability analysis is concerned almost exclusively with consumer welfare, which has restricted applicability to government warranties whose chief goal is quality assurance or improvement. The economics of insurance and incentive were more rewarding in relevance. Nevertheless, the body of existing literature with potential for contribution to the task is quite small and argues for active efforts to stimulate more academic interest in the area.

The second constraint concerns the paucity of contracts containing warranties of primary interest to the study that are far enough along or that contain necessary data to permit firm conclusions to be drawn about the cost-effectiveness of such clauses in accomplishing their goals. Strong encouragement of the military departments by DoD to experiment with the reliability improvement warranty did not start until 1976, and the mandated inclusion of performance warranties was finally instituted by Congress in 1985. A large body of documented experience does not exist, nor is there an effective apparatus for its collection and review in DoD or the military departments, and their lack has forced this study to rely much more on informal judgments of interested parties and on a smaller sample of contracts than would be desirable in the ideal.

C. THE STUDY APPROACH

The employment of warranties as a DoD lever is intended to affect every phase in the procurement sequence. Successful usage results in greater attention paid in the conceptualization, design, and production stages to the definition and attainment of essential performance requirements (EPRs) at the time of DoD acceptance of the system and their retention in the post-acceptance period, as well as to the incorporation of greater reliability, maintainability, and availability (RMA) over its life cycle. Ideally, the shifting of a portion of the risk for nonconformance to contractual specifications from government to contractor will result in benefits with respect to improved performance characteristics, greater readiness through heightened asset availability, and reduced support costs that exceed the increased expenditure for the warranty.

A functional approach toward a study of the economic appropriateness of warranties requires, therefore, a comprehensive framework. It must include the following considerations:

1. The desiderata--greater performance, readiness, and support economy at acceptable cost--can be sought from alternative incentive methods. Warranties are only one means. A requirement of cost-effectiveness analysis is that the alternatives be kept in view, and, to the extent practicable, be compared with warranties.
2. The impact of warranties upon each phase of the procurement process must be discerned if their effectiveness in achieving the desiderata is to be gauged accurately. For example, greater reliability and maintainability in the design phase may be obtained at the expense of reduced operating capabilities, or lower support costs in the post-acceptance stage may be achieved only by a

sacrifice of in-house maintenance capability in the post-warranty phase of support.

To the extent practicable within the constraints of time, budget, and data availability the study has attempted to maintain comprehensiveness in both of these dimensions. In addition to the straightforward *assurance-validation* warranty, which employs strictly negative sanctions against contract breach, and the *insurance* warranty to protect against monetary loss, the *incentive* contract (frequently in the guise of a warranty) is also analyzed. In the field studies some attention has been paid to assessing the effects alternative strategies have revealed at each stage of procurement.

In accordance with the task order, formal and informal analytical techniques of assessing warranties within this framework have been employed. Optimization techniques under uncertainty have been used to analyze the prenegotiation goal formulations of government and contractor in a warranty context. This approach has proved useful in deriving hypotheses about warranty provisions emerging in the negotiation phase insofar as they concern tradeoffs between operating capabilities on the one hand and reliability and maintainability on the other. The economic theory of choice under conditions of uncertainty and differential attitudes to risk bearing has been brought to bear upon the wisdom of the use of warranties by DoD as insurance instruments. The application of principal-agent theory has been employed to derive guidelines for designing incentive warranties. Extensive analysis of a sample of contracts containing warranties and discussions with interested parties to these contracts has been drawn upon for practical guidance in judging the cost-effectiveness of alternative warranty strategies and for validation of the deductions from the formal theories.

D. ORGANIZATION OF THE REPORT

The study report is organized in accordance with the tasks undertaken and the approach adopted as elucidated in sections B and C.

In Chapter II the weapon system production process is presented as a comprehensive and interdependent sequence of phases, and the role of assurance-validation, insurance, and incentive warranties in the process is defined. The function of warranties in the attainment of overall DoD equipment goals is discussed.

Chapter III presents a brief discussion of the role of warranties in DoD contracting prior to 1984. It features the emergence of the incentive warranty in the 1970s in the form of the *reliability improvement warranty* (RIW), the definition of the legal and regulatory background in the forms of a type of "common law" that has emerged from court decisions and the rulings of claims commissions over the years and the creation of a formal procedural law that has been codified in the Defense Acquisition Regulations (DARs) and the Federal Acquisition Regulations (FARs).

Chapter IV discusses in some detail the 1983 and 1984 legislation that mandated written warranties on major weapon system procurements and the FARs and DoD guidance they inspired. An attempt is made to judge Congressional intent with respect to these warranty provisions, especially with regard to the guarantee of operating capabilities (OCs). This post-1984 warranty environment is the one of dominant interest and relevance to the purposes of the study, but an attempt has been made to link the legislation to the prior usages and regulations discussed in Chapter III.

Chapter V contains a discussion of the empirical analyses of 13 recent weapon system contracts with warranties and of interviews in the field. The provisions of the warranties in these contracts in their pre-1984 versions are compared with their post-1984 forms to judge the practical effects of the Congressional mandates. Each of these contracts was discussed with contracting personnel of the relevant services to clarify questions that arose in their interpretation. These interviews also explored the broader experience of the services with the legislation, basic attitudes to the appropriateness of warranties in weapon system contracting, and the emphases accorded the three functions of warranties in weapon system contracting.

The formal analysis that supplements these empirical investigations is contained in Chapter VI. It draws upon the theory of insurance and principal-agent relationships to derive theorems concerning the cost-effectiveness potential of warranties in fulfilling the three functions isolated in Chapter II.

Finally, Chapter VII contains the hypotheses, conjectures, and conclusions of the study with respect to the cost-effectiveness of warranties in weapon system contracting. It contributes to the definition of conditions when assurance, insurance, and incentive warranties seem appropriate for use, and those in which they are not cost-effective or are less so than alternative approaches.

II. THE ROLE OF WARRANTIES IN ACHIEVING DESIRED PERFORMANCE AND ECONOMY

Weapon systems procurement is experiencing currently one of its periodic episodes of intense concern and policy innovation. The creation by Congress of the position of Under Secretary of Defense to oversee procurement and to introduce greater centralization into the process is the most important recent development. Steps by Congress, DoD, and the military services to enhance the competition in the awards process, to seek earlier second sourcing, to break out spare parts purchases by by-passing prime contractors, and to revise contract fee schedules in order to incentivize investment in new plants and equipment are further evidence of renewed concern. Not the least of these innovations was the Congressional mandating of written warranties in weapon system contracting by two separate pieces of legislation in 1983 and 1984.

Chapter IV will detail the provisions of these warranty acts, the Congressional intent that underlay them, the disputes they set off in the defense community, and later chapters will consider their appropriateness for the attainment of their objectives. Before addressing these narrower purposes, however, it is important to place warranties within the matrix of the overriding concerns which have given them prominence: *improved system performance and resource economy*.

These concerns are not new, of course: they emerged in the post-World War II era with the increasing complexity and expense of weapon systems and have been prominent at least since the McNamara era. What does have the appearance of creative novelty is the increasing realization of the need to view the procurement process in an *integrated* manner. Research and development, design, manufacture, and support are now viewed as one continuous effort whose trade-offs in performance and cost must be confronted at the start of conceptualization. Military specialist, design engineer, reliability and maintenance engineer, production specialist, logistics personnel, and budgeteer must have early and continuing roles in achieving the desired system. The warranty is but one tool available to assist the participants.

Section A expands upon the necessity of considering the weapon system process as an integrated entity with interdependent phases. Section B presents the potential role of

warranties in helping the process to achieve its goals of desired performance at acceptable social costs.

A. THE WEAPON SYSTEM PRODUCTION PROCESS: AN OVERVIEW

A weapon system is a capital structure designed to deliver services over its lifetime in cooperation with personnel and material inputs. Other weapon systems will be substitutes for it in performing its functions or will be complements that enhance its productivity. Depending upon its design, achievement of a given level of effectiveness can be obtained with more or less of its cooperating personnel and material factors. It can be engineered with more or less reliability and maintainability, with implied reduced or increased demands upon personnel and material inputs after fielding. The level of effectiveness can be varied over a broad spectrum of possibilities at the cost of expending more resources in its production, and that cost will depend in large part upon the manufacturing and technology bases for its production. Finally, as merely one input in a transformation function that converts potentially available weapon systems, personnel, and supporting materials into an effective military posture output, its design, numbers, and time of initial operating capability must be determined in the light of an overall national strategy.

The fielding of a given weapon system, therefore, is a suboptimizing procedure in the immensely complex implementation of a global military posture that affects every one of the system's relevant dimensions: the purposes of its design, its cost, its quantity, the time-phasing of its fielding, its need for support resources, the structure of its manufacturing facilities, and many others. As a practical matter, the planning for the weapon system must be detached from its place in the broad military posture tableau after receiving a basic placement within it, because consideration of feedbacks from the system to that posture would be unmanageable in an extensive application. However, modern computer and data management techniques are creating the opportunity for a thorough integration of the innovation of the weapon system itself in all the dimensions listed above.

Consider the succession of phases through which a new weapon system must progress. It begins as a conceptualization emerging from a perceived need to the stages of design and development, followed by testing and evaluation. Initial manufacture and initial operational capability are followed by mature production and large-scale equipment of field

units. These last phases give rise to a requirement to support the equipment over its lifetime.

Modern computer technology and optimization methodology offers the prospect of integrating these phases *ex ante facto* to capture the interdependence among the phases and permit its implications to affect the design, performance characteristics, manufacturing facilities, and support planning for the weapon system. If a particular operating capability is enhanced, what does data from similar systems or engineering functional relationships project about incremental cost? Does existing manufacturing capacity exist to permit its implementation? If not, what equipment at what cost would be required? What incremental burdens would be placed upon support costs over the life cycle of the system? What would the enhancement of this operating capability require in sacrifice of performance in other dimensions if costs were held constant at a specified level? How would its implementation affect the time phasing of the fielding of the system? What implications for the design of the system's physical characteristics--weight, size, materials composition--does the change imply and how would they impact other performance characteristics? Considering the many dimensions that must be taken into account in designing the system, and the relative importance of those dimensions, would such an incremental change move the system in the direction of an optimum or away from it?

The ability to confront such questions systematically in a formal framework supported by the extensive data, computation, and graphic capabilities necessary is emerging in modern engineering. The temporal sequence of the phases can be eliminated in planning, and movements among them in forward and backward directions made at will. Expertise in all relevant fields will have to be consulted simultaneously: design personnel, military specialists, reliability engineers, production specialists, logistic experts, and budget personnel will provide inputs to the procurement process from the beginning. And, as decisions are made and problems confronted in execution of the project, the same framework will be available to permit rational adjustments.

It is within this integrated weapon system procurement framework that warranties are called upon to make their contribution. What roles can they play in furthering the means of obtaining quality outputs and restraining resource costs?

B. THE POTENTIAL ROLE OF WARRANTIES

In the FARs, Subpart 46.701, warranties are defined formally in the following terms:

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 the contract.

Unfortunately, this encapsulation does not convey the legal status, content, or purpose of the warranties that are currently in use in DoD weapon system procurement. The following alternative definition is hazarded:

A legally binding guarantee--usually explicit but in certain cases implicit--whereby a contractor, with or without an explicit payment, agrees to remedy defects in design, manufacture, workmanship, materials, or performance existing at a specific time or emerging over a specific period in a weapon system. It may, in addition, provide positive incentives to exceed target specifications in these characteristics, or penalties if specified targets are not achieved.

The legal aspects of warranties and the evolution of their use in DoD contracting will be presented in Chapters III and IV. Their current applications will be discussed in Chapter V, and the economic implications of their employment form the substance of Chapter VI. At this point of the study it is desirable to perceive their functions against the backdrop of the production process presented in Section A.

1. Distinctive Economic Characteristics of the Weapon System Production Process

To the economist certain features of that process mark it as distinctive from standard commercial procurement environments:

- a. Advanced technology is quite frequently used in the design of the product. This implies that usually only a limited number of producers is capable of bidding on or negotiating a contract, given the large capital investments and dedication of human capital required. Normal *forces of competition* to constrain price and assure quality are not present. Supplementary mechanisms to seek these ends may be desirable from DoD's standpoint.
- b. The role of advanced technology and its rapid obsolescence in defense systems implies the presence of large amounts of *uncertainty* and *information asymmetry*.
 - The contractor may be engaging in the production of a system whose performance capabilities are not wholly foreseeable even in mature

production. Substantial risks of contract nonconformance may exist, especially if he must coordinate the production of assemblies, subassemblies, and parts from many subcontractors and suppliers.

- The financial risks of contract nonconformance in these circumstances normally cannot be shifted to a willing insurer via market processes. The contractor is led, therefore, to seek an insurer or coinsurer in DoD, and government contracting personnel must therefore couple the negotiation of risk-sharing to the usual pricing tasks of contract negotiation.
- The investment by the contractor in personnel and equipment in attaining a threshold in advanced technology--uncertain as its payoff may be in the production process--implies that information will be unequally distributed to the disadvantage of DoD at the time of contract negotiation. In all likelihood, given the importance of the learning process in such endeavors, that imbalance will grow over time. DoD, therefore, cannot expect to be as fully informed about the quality or performance characteristics of the system when delivered as is true for more standardized products. In certain civilian contracting areas where interests as vital to individual welfare as national security is to collective welfare are involved, a certain trust relationship is established (e.g., doctor and patient). This may exist to a greater or lesser extent in weapon system contracting, but DoD may judge that additional protection against this informational disadvantage may be needed.
- The capability of differential application of effort, uncertainty of outcome, informational asymmetry and the profit motive combine to make the contractor potentially subject to *moral hazard* in both a negative and positive sense. Used pejoratively, the term means that if he is fully protected against the contingent liabilities of failure to conform to contract, the contractor may be tempted to underachieve specifications or potentially achievable standards. In a positive sense, because contractor effort in excess of threshold specifications reduces his profit on a fixed-price contract, DoD may feel it desirable to incentivize such overachievement by offering rewards for success in the endeavor.

The economically distinctive features of weapon system procurement, therefore, find their source in 1) restricted competition, 2) pervasive uncertainty, and 3) information asymmetry. They manifest themselves in problems associated with 1) the need to negotiate contracts rather than rely on competitive bid prices, 2) the necessity of deciding the bases of risk-sharing, 3) DoD protection against deficiencies in or unsuitabilities of product characteristics, and 4) the potential desirability of incentivizing the design and manufacture of products that exceed minimum requirements.

2. Warranties' Functions in the Procurement Process

As developed in Section A one of the primary goals of reform in weapon system procurement must be the tighter integration of all phases of the process--design, development, production, and on-line maintenance and repair support. If greater reliability and maintainability is desired, it must be engineered into the product at the design stage and possibly researched even earlier. The tradeoff required for such RMA improvement in OC performance must be investigated. The manufacturing process must be more closely integrated by computer with the design stage, so that feasibility of design can be efficiently judged and deficiencies in production line capital can be corrected. To the *economic* problems discussed in Section 1 these *integration* problems must be added as areas in which warranties may contribute to improvement.

As will be developed fully in Chapter VI, warranties serve three functions in DoD procurement:

- a. An *assurance-validation* function, which, in requiring specifications to be met at delivery or in later on-line usage upon penalty of remediation, helps to protect DoD against moral hazard and the information disparity.
- b. The *insurance* function to protect DoD partially or wholly against the occurrence of extremely large money losses through contract nonconformance in the post-acceptance phase.
- c. The *incentivization* function to provide negative and positive incentives to meet or exceed contract specifications concerned with product quality.

Figure II-1 provides the complete categorization of DoD weapon system warranties that is employed in this study. The first classification dimension is that of function, defined above to be assurance-validation, insurance, and incentivization. The second dimension is the time period during which the warranty applies or the event which terminates the warranty. There are two basic types so-defined. The inspection-acceptance version terminates with DoD inspection and acceptance of the system. The alternative form is a warranty that extends into the post-acceptance phase.

A third categorization dimension defines the nature of the coverage. One type warrants the design and manufacture of the system, assuring that required specifications have been met. A second type--closely allied to the first--assures that materials and workmanship conform to standards that permit achievement of contract specifications. Typically, these warranties apply, as far as patent defects are involved, until DoD

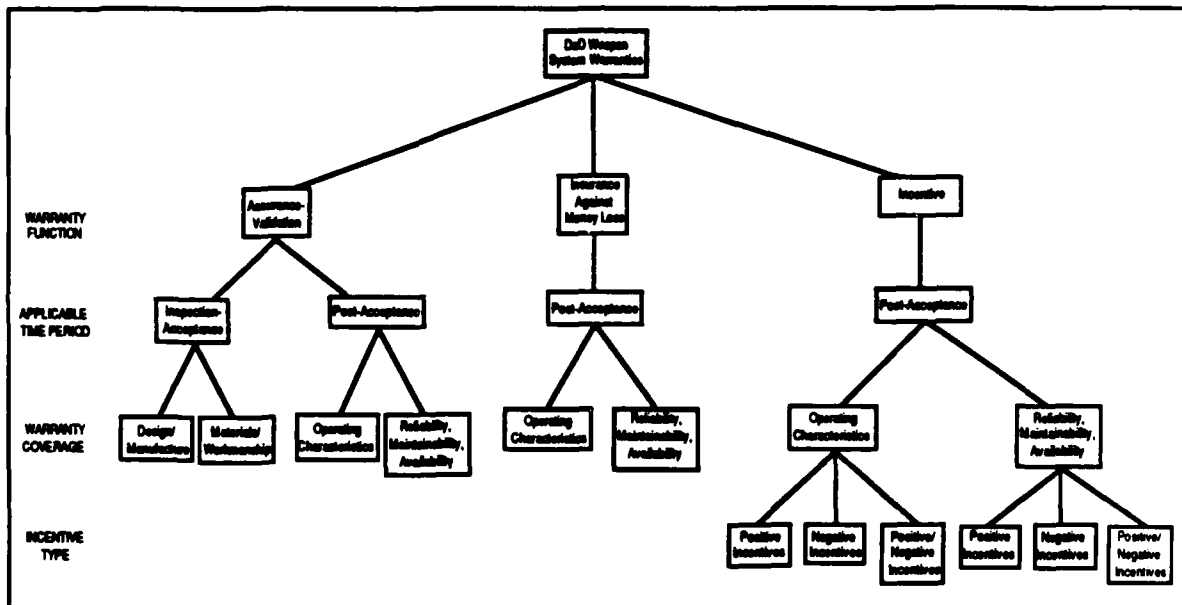


Figure II-1. A Categorization of DoD Weapon System Warranties

acceptance, with an extension into the post-acceptance phase for latent defects, or those that were not capable of discovery at time of inspection. Lastly, the performance characteristics warranty guarantees that certain operating parameters of the system will be met when the system is on-line and/or specified downtime parameters will not be exceeded. These two variants are termed *operating characteristics* and *reliability, maintainability, and availability characteristics* warranties respectively.

Finally, incentivization warranties are distinguished by the nature of the incentives. Negative incentive warranties punish the contractor for failing to achieve specified target parameters. Positive incentive warranties reward the contractor according to a fee schedule for exceeding target parameter values. Positive-negative warranties contain both features.

The general applicability of warranties in addressing the economic problems of Section 1 is self-evident. They provide substitutes for competition in reinforcing contractor dedication to quality, they cope directly with the problems arising from uncertainty in cost and quality concerns, and they confront the imbalance in information between the parties by a schedule of positive and negative sanctions.

The use of warranties as positive incentivization vehicles is an extension of their historical and their logical functions as *protectors* of a less knowledgeable or more vulnerable party to a contract. As a spur to overfulfillment of threshold quality standards they are really a form of incentive contracting.¹ This function has become so embedded in DoD warranty usage, however, that little is gained by making the distinction.

Before considering some of the narrower considerations that should enter the design of warranties to further the goal of improving weapon system performance and economy, their role in encouraging integration and interaction among the stages should be discussed. The use of warranties explicitly to require expensive contractor remedial actions if certain RMA goals like mean time between failures are not met has proved to be an effective means of intruding RMA into the design of the product. Hauter and Strempeke, [19], for example, in relating their experience from the contractor's viewpoint with the reliability improvement warranty (RIW) for the TACAN project--a short-range navigation

¹ Interestingly, reliability improvement warranties are specifically recognized as such by the Army (see Section 1-5a of [21]). They are therefore excluded from the consideration of the important weapon system mandates of current legislation by the Army.

system for aircraft--assert that it introduced a new concern in the firm's planning. Prior to the contract the typical avionics reliability engineer concerned himself wholly with successful passing of a qualification demonstration and some product sampling tests. Prior to the RIW no incentives or workable mechanisms for directing his attention to post-acceptance experience with the product existed. This changed when RIW forced a concern for the fielded equipment into the design phase of the product.

Such warranties put a renewed emphasis upon the need to gather data on field experience with equipment, extending the data base available for use in research, design, and manufacturing phases. They force both DoD and contractor into early consideration of facilities and manpower imposed by alternative designs in the maintenance phases, both during and after the period of the warranty. The necessity of contractors to give such guarantees forces them into closer review of government designs instead of waiting until the manufacturing stage to uncover deficiencies.

Warranties sensitize the contractor to the need for risk management, and by forcing decision-makers to look ahead at each phase, their provisions tie the process together more tightly. The need to measure performance accurately inspires managers to design test equipment simultaneously with the system itself. Increased attention must be also paid by contractor and DoD to life cycle costs, including maintenance.

The use of warranties provides substantial support, therefore, for the cultivation of the integrated vision of procurement that is increasingly demanded by the complexity of the systems and the phase-linkage made possible by computerization. Their more immediately perceived functions will remain economic, but their important contribution toward visualizing the whole before executing the part is worth stressing.

The use of warranties must be conditioned by the phase of the procurement process under consideration. As will be discussed in future chapters, they are not appropriate for the development phase. In the initial production stage, assurance-validation warranties should predominate, with perhaps some incentivization included. In early mature production as experience with fielded systems accumulates incentivization may become relevant and cost-effective. However, as production proceeds in the mature phase, a point is reached where incentivization warranties are no longer cost-effective and assurance-validation with the possibility of some insurance (given the increased possibility of estimating long-term performance of the system) will be appropriate. Warranty usage,

therefore, is a process over the lifetime of the weapon system that must be integrated into the time-phased planning of its program.

3. Resource Economy: Some Caveats

It may have surprised some readers that life cycle cost saving was not listed as one of the functions of warranties, for this is frequently cited as a potential contribution of the instrument.² This paper takes a skeptical view of the proposition that warranties make consistent contributions to cost reductions in the sense of a straightforward interpretation of the phrase: that is, the reduction in either the social cost or DoD cost *of producing a system with fixed capabilities* more cheaply. This does not deny the quite different proposition that their usage can result consistently in more efficient resource usage.

The simpler proposition seems to rest on several frequently implicit assumptions:

- a. The insurance feature of weapon systems warranties allows DoD to escape the costs imposed upon the production process by the unpredictable forces of uncertainty that affect technologically advanced systems.
- b. The written assurance-validation warranty introduces new economy features into the production process by forcing the contractor to give renewed attention to the inspection/acceptance phase of the contract at no cost to DoD.
- c. Negative incentives in the post-acceptance phase of the cycle, especially in the usage of RMA thresholds, provide DoD a costless means of assuring that the contractor will produce a product whose post-warranty support costs will be lower.

Close attention will be paid to the first assumption in Chapter VI. In anticipation of the results of that analysis, it is asserted that insurance is not a manner of escaping the social costs of uncertainty but rather is a means of escaping the potential variation of those costs. That is, the forces of uncertainty inflict costs in the manner of a probability distribution with a mean or expected value and a variance. An insured party always pays a premium which includes that mean cost: what he escapes thereby is the variance of the distribution. Hence, the insurance function of warranties does not reduce the costs of uncertainty to DoD: it shifts the risk of extreme deviations onto the contractor.

² See, for example, Arturo Gándara and Michael D. Rich, [15] and [16].

Moreover, that contractor's reluctance to accept these risks, his limited resources to bear such contingent liabilities, and the unavailability of willing parties to reinsure him, imply that the premium DoD pays in the form of a warranty price will be much higher than the mean value of the probability distribution over costs. And, finally, it will be demonstrated in Chapter VI that these "loaded" premiums will not improve and are likely to lessen the utility of the contract to DoD.

The second assumption can be challenged on grounds that the written assurance-validation warranty has been in effect in DoD contracting for some time, so that no new cost savings are likely to result. Further, the cost of producing a product that meets the warranty will have been fully covered in the cost of the contract, and no new pressures will exist on either side of the contract negotiation to alter costing procedures or bargaining strategies.

The introduction of negative incentives into the contract can admittedly lead the contractor to increase his efforts to improve quality and to protect DoD from the effects of moral hazard. Also, admittedly, it may result in lower costs to DoD in post-warranty support costs. But it cannot be assumed that the cost of the contract and/or the explicit warranty price will not absorb most or all of these potential DoD cost savings. Indeed, on the same grounds indicated in the discussion of the first assumption, the risk-averse contractor may extract a price for such guarantees that is much greater than the expected value of the reduction in DoD costs--even when the benefit of greater asset availability is monetized and added to support cost reduction.

The potential economy in resource usage inherent in warranty instruments is more sophisticated than the aspiration for a free lunch. It arises in the belief that by being forced to confront the total costs of weapon systems' performance characteristics--RMA and operating--and through study of the trade-offs among them, more efficient use of social resources will result in the production of national security readiness. If producing an aircraft with an added range of x kilometers will involve complexity that reduces MTBF by an average of 50 hours, is it a worthwhile trade-off? How much can the price of the performance requirement warranty or the incentivization fees be reduced if such incremental capability is sacrificed? How does the production engineer respond to the designer's request for a costing of the changes in the production process of effecting this incremental gain? How do contracting personnel perceive this potential cost increase impacting the

price of the performance requirements warranty? Is the benefit worth the cost, now that an apparatus is in place that forces such explicit economic questions to be asked and answered within an interstage, integrated decision-making framework?

These are the more sophisticated resource economy considerations to which warranties can make a contribution. They involve alternative weapon system configurations, trade-offs in their characteristics with respect to benefits and costs, and the improvement of weapon system force structure thereby.

III. DISCRETIONARY USAGE OF WARRANTIES IN DEFENSE PROCUREMENT: LEGAL AND REGULATORY BASES

The history of warranty usage in DoD weapon system contracting may be divided initially into the period of non-mandated usage that ended in 1984 and the period of mandated usage thereafter. In this chapter concern will focus upon the first period, and the body of regulations, practices, and "common law" that emerged from it or underlay it. This material is relevant to current DoD contracting practices for supplies other than weapon systems that conform to the criteria in current law (i.e., 10 USC 2403) as well as to the core of warranty structure that is conformant to that law.

A. A BRIEF HISTORY OF WARRANTY PROCUREMENT

A convenient year to date the origins of DoD's more recent concern with warranties is 1964, when Secretary McNamara initiated a campaign to unify warranty practices among the three services. Since 1952, military procurement had been regulated by the Armed Services Procurement Regulations (ASPRs). As a result of McNamara's initiative, a set of 1964 ASPRs, revised in October 1967, was written to define a set of guidelines for contracting officers' decisions whether warranties would be in DoD's interest in specific procurements.¹ The burden of the new regulations was that a long-term warranty on such acquisitions as weapons systems was to be an exception rather than the rule.²

This sentiment began to change as weapons continued to become more complex and costly. Among the first weapon systems to be supported by a post-acceptance warranty which went beyond a latent defects intent was the Navy's CN494A/AJB-3 gyroscope--the 2171 gyro. It had been developed by Lear Siegler in the late 1950s and brought into production for the A-4 and F-4 aircraft in the early 1960s. Some breakdown difficulties after fielding the unit led the Navy to negotiate a "failure-free" warranty with the contractor in 1967. It obligated the contractor to repair defects in a population of 800 units for 1,500 operating hours per unit or five years, whichever came first. The effectiveness of the

¹ See the October 1, 1967, Revision 25 to the 1964 ASPR, p. 120.12-4 through 120.18-1.

² Warranty Handbook, [4], p. 2-2.

warranty has been questioned,³ but it served as a model for the Air Force's warranty on the Lear Siegler gyro for the F-111 in 1969.

Experiences with these contracts and studies by the Air Force of commercial aircraft warranties initiated an interest in investigating more extensive uses for them in major procurements. In July 1973, the Air Force Logistics Command hosted a conference on the feasibility of using "commercial support/warranty concepts" on a variety of subsystems. The conclusions of the conference led the Air Force to be cautious in expanding warranty usage, the minutes stating that "due to the unique nature of the military market and nonavailability of secondary markets for the items involved, it would be difficult, if not impractical, to implement commercial support/warranty concepts in Air Force programs." They did conclude, however, that "it may be possible to explore their use on a case-by-case basis, particularly on items which have a commercial market."⁴

The result of this meeting was a suggestion by Assistant Secretary of Defense (Installations and Logistics) (ASD/I&L) Arthur Mendolia and Director of Defense Research and Engineering (DDR&E) Malcolm Currie to the service secretaries that "trial use of warranties in the acquisition process of electronic subsystems"⁵ be initiated. The memorandum requested each military department to appoint a representative to an OSD committee to establish a clearer policy for the use of warranties. This effort, therefore, was the second attempt to unify and formalize the employment of warranties in DoD procurement since the revitalization of the McNamara era.

In early 1974 the committee began functioning as the Reliability Improvement Warranty Committee, with representation from I&L, DDR&E, and the military departments. In July 1974, it completed a set of guidelines for the use of RIWs in defense procurement which are discussed in detail in Chapter V. Secretary Mendolia sent a memorandum on August 14, 1974 to the Assistant Secretaries (I&L) and Research and Development of the military departments explicitly urging trial usage of RIWs in the procurement of electronic systems and subsystems following the guidelines.⁶

³ Arturo Gandara and Michael D. Rich, [15], p. 45. See also Chapter V, section B below.

⁴ See [32], attached to minutes of July 17-18, 1973 meeting.

⁵ See [33].

⁶ See [33], with attached "RIW Guidelines."

The RIW generally provides that the contractor will perform depot repairs on defective supplies during the warranty period for a fixed price designated in the warranty. It may also have provisions concerning repair turnaround times and may be combined with a guaranteed mean time between failure provision.⁷ In this study the term will be applied more broadly to a family of positive and negative incentive features whose purpose is to incentivize reliability, maintenance, and availability characteristics (RMACs) of equipment.

The goal of this second unification drive in DoD was to encourage contractors to design and manufacture equipment with lower failure rates and support costs when fielded. Electronic gear was chosen as an early target because of the statistical predictability of its failure rates, as will be discussed in Chapter V. The use of the warranty to effect these improvements was to supplement its traditional function of assurance/validation with that of incentivization and to make of the instrument a form of incentive contract. The experience of DoD with RIWs will be discussed in detail in Chapter V, Section B.

The third wave of interest in warranties was initiated by Congress in 1983 and resulted in legislation in 1983 and 1984 that mandated written warranties for certain types of weapon systems. The sources of Congressional concern and the nature of its legislative intents will be discussed in Chapter IV. Suffice it to say at this point that there is some evidence that Congress wished to expand DoD's concern with the RMA incentivization through RIW warranties to include some attention to the operating performance of weapon systems when on-line.

Meanwhile, over this whole period from 1964 to 1984 a continuous contrapuntal concern in lower key, not independent of these three major movements but orchestrated in the most part by lower level contracting officials, is evident. It resulted in a codification of a "common law" of warranty usage by DoD drawn from civil commercial codes, court rulings, and claims commission findings. It evolved from the ASPRs through the DARs, instituted in 1978, through the FARs established in 1984 with their Defense Federal Acquisition Regulation Supplement (DFARS) and military department regulations as each of them addressed the subject of warranties.

Because, as noted, the focus of the second period of warranty action--the RIW--will be discussed in Chapter V, and the results of the third period--the mandated

⁷ See, for example, the Warranty Handbook, [47], pp. 3-6 - 3-7.

warranty legislation of 1983 and 1984--will be discussed in Chapter IV, the remainder of this chapter will be concerned with the remaining topics of this brief history. Section B develops the "common law" results of the first period of action as it was codified in the DARs. Section C reviews the current FARs insofar as they contain federal regulations for the writing of warranties on a variety of supplies.

B. THE "COMMON LAW" AS CODIFIED IN THE DEFENSE ACQUISITION REGULATIONS

A conventional warranty is an implicit or explicit guarantee by a seller that goods sold to a buyer conform to express or implied standards and subjects the seller to implicit or explicit contingent penalties if they do not. In ordinary commercial transactions the evolution of common law has resulted in the Uniform Commercial Code (UCC) governing goods other than services or construction. It provides a buyer with two implied warranties:

1. *Merchantability*, or the assurance that the goods will pass in the trade as described and that they are fit for the *ordinary purposes* for which such goods are used.
2. *Fitness for a particular purpose*, or the additional guarantee that the goods are fit for the *particular purpose* for which the buyer will use them when a) the seller has reason to know of such purpose and b) the buyer is relying upon the seller's expertise and judgment in their selection and provision.

This most general form of warranty is germane to this study because federal courts and boards of claims have turned to the UCC in interpreting the law of sales governing government procurement in the absence of more specific federal statutes or court rulings. Therefore, in theory, the federal government like all other buyers of tangible, movable goods is protected by these historically established obligations upon sellers.

In practice, however, these protections to the government are nullified if the standard inspection clause is included in the contract or if an explicit warranty provision is contained in the contract. Courts and boards have ruled that either type of clause eliminates the seller's liability under the law of sales. Because the inspection clause is almost universal in DoD contracting, and the explicit warranty clause is becoming more common, in practice the implicit warranty extension of common law is not operative in DoD contracting. In fact, the FARs provide that an explicit clause in federal contracts nullifies these implicit guarantees when the contractor gives required FAR-dictated guarantees.

Assurance, therefore, that DoD purchases conform to the ordinary or particular purposes for which they are intended is based fundamentally upon three explicitly defined provisions in DoD contracting. These concern the government's right to inspect and accept goods and its protection under explicit warranty clauses.

DoD contracts contain explicit specifications relevant to design, manufacture, materials, workmanship, and/or performance to which goods and services must conform, and specify as well the types of tests to which such goods will be subjected and the site of such testing. When contractual specifications are reasonable and unambiguous and when testing conforms to contract and reasonable standards, court and board rulings are extremely protective of DoD interests. They consistently require that contractors must comply strictly to contract specifications in supply contracts. The notion of substantial compliance is recognized only in construction contracts, and in them the concept does not relieve the contractor from responsibility for failure to comply with specifications. Duly performed inspection, therefore, and the contractor's obligation to conform in absolute fashion to contract specifications are standard protective devices in DoD contracts.

Once an authorized person has accepted goods for the government, however, the standard clause provides that the acceptance is conclusive except for a) latent defects hidden from sight and knowledge at the time of acceptance and not discoverable by reasonable inspection; b) fraud; c) gross mistake amounting to fraud; or d) other provisions in the contract.⁸ In general, once the government accepts contractor performance it cannot later reject or require replacement or correction of defective goods. Importantly, however, the contractor is responsible for correction of latent defects, and this binds him beyond the warranty period if a warranty applies. Of course, if explicit warranty provisions extend into the post-acceptance period, they must be honored.

Express warranty clauses in a contract increase the contractor's liability for defects in terms of scope of such defects and/or the period of liability. They must be expected, therefore, to raise the price of the contract to the government, and, in view of that, government policy had been, prior to the recent legislation concerning weapon systems, to include them only when in the best interests of the government.⁹ Regulations prohibited

⁸ Warranty clauses are the most frequent form of "other provisions."

⁹ DAR 1-324.2(a).

their use, for example, in cost reimbursement contracts¹⁰ because sufficient warranty aspects were deemed to be contained in their inspections clauses.¹¹ For fixed-price contracts DAR 1-324.3(b) listed 16 factors that were to be considered by procurement personnel prior to recent legislation in the determination of whether the best interests of the government were served by warranty clauses.

The basic assurance-validation warranty clause incorporates substantially the following wording:

Notwithstanding Government inspection and acceptance of supplies and services furnished under this contract...the contractor warrants that all [items] furnished under this contract will be free from defects in design, manufacture, material, and workmanship and shall operate in their intended environment in accordance with [accompanying exhibits governing specifications] for [a stated period of time].

The types of defects covered are both patent and latent.¹² However, courts and boards have ruled that warranty clauses must be strictly interpreted, and therefore that ambiguities are construed against the drafter. If the government wants a warranty of sufficient breadth to cover a product's total performance it must take care to draft one with requisite clarity. This is especially true for those clauses covering both design and performance which make the contractor liable for all defects other than government misuse or vandalism. Also, the contract must state the time at which the warranty period begins and the period within which notice of breach of the warranty must be given. Finally, the strictness of interpretation of warranty clauses has led adjudicating authorities to put the burden of proof for claims of warranty breach upon the government.

C. THE EXTENSION OF GENERAL WARRANTY PROVISIONS IN THE FEDERAL ACQUISITION REGULATIONS

Since 1982 an extensive program of rewriting, expanding, and reorganizing government policy with respect to warranties of all kinds has been instituted and incorporated in Part 46 (Quality Assurance), Subpart 46.7 (Warranties), and Part 52 (Solicitation Provisions and Contract Clauses), Subparts 52.246-17 through 52.246-21 of

¹⁰ DAR 1-324.2(b).

¹¹ See, for example, DAR 7-203.5. Exception was made in the case of contracts for technical data (DAR 1-324.11).

¹² DAR 7-105.7(a), para (a); 7-105.9(b); and 7-1904.5(c).

the FARs. Because these regulations as supplemented by DFARS and service regulations govern all DoD procurement it is important to review their major provisions in preparation for the analysis of major weapon system warranties to be conducted in Chapter V. The supplementary DFARS and Army regulations specific to weapon system warranties will be outlined in that chapter.

Interestingly, the FARs state that the principal purposes of warranties are to distribute the risks and costs of the assurance-validation function between contractor and government, and to incentivize quality performance. The insurance function in the post-acceptance stage is not explicitly mentioned. They assert that the warranty should provide for correction of defects notwithstanding any other clauses concerning acceptance for some explicit period of time or use after acceptance. Also, benefits must be commensurate with the cost of the warranty.

In general, therefore, the use of warranties in federal procurement is not mandatory, and the contracting officer is directed to consider five factors in determining their appropriateness in a contract: the nature and use of the supplies, the cost of the warranty, the ability of the government to administer and enforce it, whether the supply has a costless commercial warranty, and whether the cost of the warranty can be offset by government quality assurance testing cost reductions. Authority to include warranty clauses is vested in the agency issuing the contract.

The FARs apply certain constraints in the use of warranties. As a rule, subject to agency procedures, they should not be incorporated in cost-reimbursement contracts. The government has extensive rights to inspect supplies to protect itself against latent defects, fraud, or gross mistakes, as indicated in Section B: warranties must not restrict these provisions. And, with the exception of construction contracts the warranty clauses must provide protection notwithstanding inspection, acceptance, or other terms of the contract. Warranties, in short, are to be considered an addition to other standard protections.

The terms and conditions of a warranty must be stated with precision. Exact definitions of the item, components and characteristics guaranteed, the contractor's obligation if the warranty is breached, government's remedies, and the duration of the warranty are important.

Guidelines in writing these provision are given. The contractor's liability generally extends to all defects discovered in the warranty period except for damage caused by government. When government provides the design for an end item, the contractor's obligation is usually limited to materials/workmanship (M/W) defects and failure to conform to specifications. If the contractor is responsible for design, this broadens to include "usefulness" of the design. Express warranties nullify the merchantability and fitness-for-a-particular-purpose warranties of the UCC, and explicit recognition of this should be present in the contract.

Government remedies should permit contractor correction of defects at his expense or equitable adjustment of the contract price at government option. Government should retain the option to repair defects or have the contractor repair defects at their point of occurrence if it can be foreseen that movement of the item is impractical. The contractor-borne costs of repair should generally include transportation from some contract-specified place of delivery to contractor facilities and return, but his liability for such costs should not exceed the costs of the usual commercial method of shipment between these points.

The duration of the warranty should be related to the estimated useful life of the item, its shelf life (the storage time at which it must be checked for deterioration or replacement of parts), and usual trade practice. The period specified for discovery of latent defects should be a reasonable time after acceptance, and the warranty should specify a reasonable period after the discovery of a defect for government to notify the contractor.

The last guidelines specify the need to have contractors label the item as under warranty so that government personnel in the field will be informed, and the need for warranties to be consistent with other aspects of the contract, notably the specifications and inspection clauses.

Certain special situations with respect to warranties are given attention. When a fixed-price incentive contract is used, the contracting officer should roll the expected costs of compliance into the total final price, and after its negotiation, the costs of compliance must be borne by the contractor. Warranties on data must be written wholly in accordance with agency regulations. And warranties on commercial items may simply be the contractor's standard warranty, if deemed sufficient for the government's purposes, or the contracting officer may seek a more inclusive warranty if necessary for the government's best interest.

To give more explicit guidance to contracting officials, the FARs develop a set of model warranty clauses for applications to five different types of supplies, with the injunction that these models should not be followed slavishly but rather should be tailored to the specific supplies of a contract.

Before the outlines of these five models are presented, it will be useful to refer to five alternate clauses to those in the models that can be substituted in specific circumstances:

Alternate I. When a commercial product is being purchased, the warranty can incorporate clauses guaranteeing merchantability.

Alternate II. It may be appropriate to put the burden of transportation of defective items upon government rather than the contractor. If so, this clause revises the standard obligation.

Alternate III. If the contractor is the sole source of supply for the item, and if he does not agree that the defects are his responsibility to correct, this clause obligates him to remedy the defects subject to later price adjustment if the disputes process is ruled in his favor.

Alternate IV. This clause incorporates the guideline discussed above concerning the fixity of total final price of a fixed-price incentive contract.

Alternate V. When recovery of a warranted item requires large costs for disassembly and/or reassembly, this clause obligates the contractor to pay such costs.

In the discussions of the models, this list of alternate clauses will be referenced to present allowable standardized deviations from the standard clauses.

In all of the models, "acceptance" is defined as assumption of ownership by an authorized government representative, "correction" means elimination of a defect, and "supplies" are the end items furnished by the contractor.

1. Warranty of Supplies of a Noncomplex Nature

a. Contractor's Obligations.

(1) "Notwithstanding inspection and acceptance by the Government of supplies furnished under this contract concerning the conclusiveness thereof, the contractor warrants that for [time after delivery or occurrence that terminates the warranty period]": (*Override Clause*)

- i. Supplies are free of defects in materials and workmanship; (*M/W Warranty*)

ii. The preservation, packaging, packing, marking, and shipment preparation and method conform to requirements. (*Shipment Warranty*)

(2) The contractor will bear the cost of transportation and bear responsibility for warranted defective supplies in transit, but transportation charges cannot exceed those of the usual commercial shipment method. (*Contractor Transportation Obligation Clause*)

(3) Corrected supplies will bear the same warranties as initially delivered supplies. (*Corrective Warranties Clause*)

(4) Merchantability and fitness-for-a-particular-purpose warranties are excluded from the contract. (*Exclusion Clause*)

b. Remedies Available to the Government.

(1) The contracting officer must notify the contractor in writing of a breach of warranty within [specified period of time] of discovery. (*Notification Clause*)

(2) Within a reasonable time after such notification the contracting officer may (a) require correction or replacement of the defective supplies, or (b) retain the defective supplies and reduce contract price by an equitable amount. (*Replacement Clause*)

(3) If inspection requires sampling, the contracting officer's options in determining the procedure are specified. (*Sampling Clause*)

(4) The contracting officer may by contract or otherwise correct or replace defective supplies from another source and charge the cost to the contractor if the contractor (a) fails to redeliver returned supplies within the specified time or (b) fails to accept the returned supplies or make progress in their replacement within ten days of the contracting officer's notification of such failure. Further, if the contractor does not furnish timely disposition instructions, the contracting officer may dispose of defective supplies and deduct from the proceeds the costs of such actions. (*Noncooperation Clause*)

(5) The rights and remedies provided to the government by the warranty clause are in addition to and do not limit rights afforded it elsewhere in the contract. (*Preservation of Rights Clause*)

The FARs provide that the alternate clauses can be substituted for tailoring purposes:

1. When a commercial item is being acquired, Alternate I may be substituted for the Exclusion Clause.
2. When it is in the government interest, where, for example, the cost of the warranty otherwise might be prohibitive, Alternate II can be substituted for the Contractor Transportation Obligation Clause.
3. If the supplies are not available from other sources, Alternate III may be substituted for the Noncooperation Clause.
4. If a fixed-price incentive contract is used, Alternate IV can be added to the contract.
5. When assembly/reassembly costs in furtherance of a warranty are expensive, Alternate V may be added to the contract.

This model, with its indicated potential clause substitutions and additions, has become a "standard" form warranty for "nuts and bolts" logistics contracts in DoD. It is obviously inappropriate for use as a standard for more complex systems bought "off-the-shelf," such as construction machinery or fork-lift trucks. That suggested warranty form is considered next.

2. Warranty of Supplies of a Complex Nature

a. Contractor's Obligations.

(1) "The Contractor warrants that for [time after delivery or occurrence that terminates the warranty period]:

1. M/W Warranty.
2. The supplies will conform to the requirements of the contract. (*Specifications Warranty*)
3. The contractor's obligation with respect to government-furnished property is limited to proper installation unless he modifies it. (*GFP Disclaimer Clause*)

(2) Correction Warranties Clause.

(3) The contractor is relieved of the obligation to correct or replace supplies if the government does not provide him the necessary means (facilities, tooling, drawings, etc.) to do so. (*Remediation Nonsupport Clause*)

(4) The contractor is obligated to furnish the government data and reports on corrections of defects at no extra cost. (*Data Provision Clause*)

(5) Contractor Transportation Obligation Clause.

(6) Exclusion Clause.

b. Remedies Available to the Government.

(1) With a breach of warranty the contracting officer may at no increase in contract price (a) require the contractor to repair or replace defective supplies or (b) require the contractor to furnish parts and instructions for such correction. (*Repair/Replacement Clause*)

(2) If the contracting officer does not require correction of nonconforming supplies or the contractor is excused from the obligation by the Remediation Nonsupport Clause, the government will receive an equitable reduction in the contract price. (*Price Reduction Clause*)

(3) Notification Clause.

(4) After notification the contractor must submit within [a specified period of time] a recommendation for corrective action. (*Contractor Response Clause*)

(5) No more than [a specified period of time] after receipt of the contractor's recommendation, the contracting officer will notify him of action to be taken under the Repair/Replacement or Price Reduction Clauses. (*Government Response Clause*)

(6) The contractor is obligated to conform to the contracting officer's direction in the Government Response Clause, notwithstanding any disagreement about whether a breach of warranty has occurred. If later determination frees the contractor from obligation, the contract price will be adjusted equitably. (*Protest Procedure Clause*)

(7) Correction Warranties Clause.

Alternates I, II, IV, and V may be substituted or added under circumstances discussed above for the noncomplex good warranty model. Alternate III is not relevant because the contractor is required to furnish parts by the terms of the warranties.

This second type of warranty form does not yet capture the distinguishing characteristics of weapon systems which, in addition to their complexity, are produced in conformance with rigid design criteria and performance requirements. The third model incorporates provisions for these types of government supplies.

3. Warranty of Systems and Equipment Under Performance Specifications or Design Criteria

a. Contractor's Obligations.

(1) The warranty applies only to defects discovered by the government or contractor before [specific time or occurrence that terminates the warranty period]. (*Warranty Period Clause*)

(2) If the contractor detects before acceptance that a defect exists, he must correct it or notify the contracting officer. (*Contractor Disclosure Clause*)

(3) Notification Clause.

(4) Contractor Response Clause.

(5) The contractor must comply promptly with written direction from the contracting officer to correct or partially correct a defect at no increase in price. (*Finality of Government Decision Clause*)

(6) Data Provision Clause.

(7) Price Reduction Clause.

(8) Correction Warranties Clause.

(9) GFP Disclaimer Clause.

(10) Contractor Transportation Obligation Clause.

(11) Exclusion Clause.

b. Remedies Available to the Government.

(1) Preservation of Rights Clause.

(2) Override Clause.

(3) Government Response Clause directing correction, partial correction or noncorrection of defect.

(4) The time necessary to make corrections should not be used to extend contractual schedule obligations unless agreed to in a supplemental agreement. (*Schedule Clause*)

(5) The contracting officer will give written notice to the contractor specifying any failure of the contractor to conform to (a) the Contractor Response Clause, (b) the Finality of Government Decision Clause, or (c) the Data Provision Clause. This notice must specify a period of time after contractor receipt during which he must remedy the failure. (*Failure to Conform Clause*)

(6) If the contractor does not meet the conditions of the Failure to Conform Clause, the contracting officer may (a) obtain recommendations for corrective action and correct or replace the defective supplies, (b) obtain the necessary data and reports, and (c) charge the contractor for the costs of such actions. (*Government Recourse Clause*)

(7) No provision in this warranty shall be construed to oblige government to increase the contract price. (*Fixed Price Clause*)

Alternates II, IV, and V may be substituted in or added to the warranty. Alternate I is not relevant since the supplies are by their nature not commercial, and Alternate III is not applicable since the warranty requires the contractor to provide replacement parts.

This warranty model, modified to include the three mandated warranty types of recent legislation and such optional features as financial liability ceilings for contractors and the provision for dispute procedures, has become a prototype for the weapon system warranties currently being written by DoD. This will be demonstrated in Chapter V when 13 recent weapon system contracts are reviewed.

The distinguishing features of this warranty model from the first two models are the following:

1. It requires the contractor to act if a defect is discovered before government acceptance. He cannot legally put the responsibility for detection wholly on government during inspection.
2. The government's decision on corrective action and the conformance to warranty are final, with no indication of the ability of the contractor to appeal. This can be modified to include a disputes procedure, of course.
3. The nonexcusability of schedule slippages due to correction of defects.
4. The necessity of furnishing the contractor with a formal notice of failure to conform to warranty provisions, with a grace period to conform.

In general, these provisions strengthen the government's protections in implicit recognition of the greater expense of this category of supplies.

4. Warranty of Services

- (1) Override Clause.
- (2) M/W Warranty excluding materials.
- (3) Specifications Warranty.
- (4) Notification Clause, including a statement either that the contractor will correct or reperform the nonconforming services or that the government will not require this.
- (5) If correction or reperformance is required it will be at no cost to government and will be subject to the Correction Warranties Clause.
- (6) Refusal of the contractor to correct or reperform the services gives the government the option to have the work done by other parties at contractor expense.
- (7) Price Reduction Clause.

No alternate clauses are relevant.

A final warranty model is provided for construction.

5. Warranty of Construction

- (1) In addition to other warranties in the contract the contractor warrants the work performed is free of defects in equipment, material, design, and workmanship and conforms to contract specifications. These warranties extend to all work performed by subcontractors and suppliers at any time.
- (2) The warranty period is one year from date of final acceptance.
- (3) The contractor will remedy defects at his expense including damage to government-owned or controlled real or personal property when that damage is the result of failure to conform to specifications or defects in equipment, material, workmanship, or design.
- (4) Repaired work will receive a warranty for one year after its completion.
- (5) Notification Clause.
- (6) Government Recourse Clause.

(7) With respect to express or implied warranties from lower-tier suppliers, the contractor will obtain all normal commercial warranties, require warranties to be in writing if the contracting officer directs, and enforce such warranties for the government when directed by the contracting officer.

(8) If the one-year warranty has expired, the government has the right at its expense to bring suit to enforce a lower-tier warranty.

(9) *The contractor is not liable for repair of defects of material or design furnished by the government except for negligence on the contractor's part.*

(10) The government reserves the rights under inspection and acceptance clauses with respect to latent defects, gross mistakes, or fraud.

D. SUMMARY

The history of DoD warranty policy in the sense of applying a unified set of guidelines across the Services' acquisitions began in the McNamara era with its drives toward rationalization. As incorporated in the ASPRs and DARs this guidance drew heavily upon the legacy of commercial practices and the common law. As such it placed an emphasis upon the assurance-validation function of the guarantee.

In the mid-1970s an interest in improving the reliability of equipment when fielded resulted in extended experimentation with the RIW. It introduced incentives as an important supplementary warranty function. Under the urging of DoD all of the services experimented with the instrument.

Meanwhile, interest in unifying and codifying warranty guidelines and forms throughout government developed in the later 1970s and early 1980s. This led to Subpart 46.7 of the newly published FARs which established guidelines for general government procurement warranties to which DoD, of course, was required to conform. They are an extensive codification of prior governmental practices, emphasizing the assurance-validation function, wisely ignoring the insurance function, and completely excluding the potential incentive function of warranties. As such they could only provide a basic form of warranty guidance to a DoD whose military departments had by then an extensive experience with RIWs.

Nonetheless, the FARs did provide these basic forms in a variety of standard models that span the gamut of government purchases: noncomplex and complex standard supplies, designed-to-specification equipment, services, and construction. These forms were accompanied for the most part by alternate clauses to facilitate tailoring to contract specifics. They were rapidly adopted as "core" warranties by the military services, especially in providing a standard framework for weapon system warranties through adoption of the design-to-specification equipment prototype. One of the perceived potentials in doing so was, because of the strong emphasis of the model on assurance-validation and its nonincorporation of the incentive function, to eliminate the RIW provisions or other incentive clauses of prior contracts.

However, a third phase of DoD warranty policy was initiated in 1983 and finalized in 1984 in Congressional legislation that mandated written warranties for most weapon systems. The implications of this legislation for DoD procurement and the impacts it is exercising upon warranty provisions is the subject of ensuing chapters. This narrowing of the focus of the study will begin with the presentation of the history and content of the recent legislation in Chapter IV.

IV. CONGRESSIONAL MANDATING OF WARRANTIES IN DOD WEAPON SYSTEMS PROCUREMENT

The current phase of warranty policy in weapon systems procurement was initiated by Congress in response to rising public concern about performance deficiencies in major programs and the overpricing of some highly publicized components. A first legislative step was taken with the passage of Section 794 of the Defense Appropriations Act of 1984, and its intended implementation was clarified in a DoD Defense Guidance Memorandum. The provisions of these measures are discussed in Section A.

Section 794 and the Guidance Memorandum as a package set all-inclusive, inflexible, ambiguously worded, and potentially burdensome performance warranty mandates upon DoD and its contractors. A number of troublesome issues were raised in their wake that led to an important debate concerning the appropriateness, efficiency, and equity of this manner of attempting to improve weapon system quality and insure DoD against costly remediation of defective fielded systems. The issues in this exchange are reviewed in Section B.

This debate led Congress to replace Section 794 with a section of a new act--the Defense Procurement Reform Act of 1984, Public Law 98-525--which became 10 U.S. Code, Section 2403. It incorporated a great deal less stringency and more flexibility in the administration of the warranty provisions, making them more consistent with the existing practices discussed in Chapter III. It was implemented by FAR Supplement, Part 46 (Quality Assurance), Subpart 46.7 (Warranties). Both of these measures are discussed in Section C.

The evolution of Congressional dictates, as interpreted by DoD policy guidance, between the rigidities of the Section 794 process and the flexibilities of Section 2403 procedures, is of direct interest to the purposes of this study in judging Congressional intent as to the direction to be taken in warranty usage policy. Changes were instituted in direct response to the issues discussed in Section B, especially with respect to the discretion given heads of agencies in the writing of warranty clauses. These changes, with the policy guidelines that they have given contracting officers, are presented in Section D.

Because the question of which of the discretionary paths in the writing of mandated warranty clauses are being chosen by agencies can only be resolved by field studies, a

sample of important recent weapon systems contracts and the results of discussions with contracting personnel in DoD will be presented in Chapter V. The major discernible impacts upon contracting practice in weapon system procurement as a result of the Congressional mandates are discussed in that chapter. Preparatory to that analysis, Section E attempts to discern Congressional intent from the apparent and sometimes puzzling differences between these two pieces of legislation.

A. THE DEFENSE APPROPRIATIONS ACT OF 1984 AND DOD POLICY GUIDANCE

In 1983, Congress, acting in the wake of reported substandard performance in such weapon systems as the M1 tank, the Bradley Fighting Vehicle, and DIVAD, and in the belief that the existent warranty practices under the DARs (discussed in Chapter III) were insufficient, passed into law Section 794 of the Defense Appropriations Act of 1984 (Public Law 98-212), which was signed by the President on December 14, 1983. Its rather precipitate legislative genesis is indicated by the fact that it was passed as a Senate floor amendment to the appropriations act without hearings in either house. This marked the beginning of Congressionally mandated written warranties on weapon systems and an emphasis upon *guaranteed performance* in the sense of OCs as distinct from RMACs. The seeming attempt by the act to distinguish such performance warranties from more standard warranties and to define conditions for their appropriate use is a red thread of continuity linking the legislation, the DoD implementing guidelines, and the controversy that followed, and it is featured in the presentation to follow.

Section 794 is a short, tersely-worded statute which was meant to be fleshed-out by DoD policy guidance, but within severely restrictive limits.¹ The act required all weapon system contracts awarded after its enactment to contain two types of written warranties from the prime contractor "or other contractors":

1. *Design and Manufacture Conformance.* This constituted a guarantee that the system and each component conformed to *performance requirements* stated explicitly in the production contract or in any other agreement relating to such production.
2. *Defect-Free Materials and Workmanship.* This was a warranty that *at the time of delivery* the system and each component was free of materials and workmanship defects that would cause nonconformity to performance

¹ Section 794 is reproduced in Appendix A.

requirements explicitly stated in the production contract or in any other related agreement.

In the event the conditions of either or both warranties were not met for the weapon system or a component, the remedies placed one of two burdens upon "the contractor":

1. He was to bear the cost of all work necessary to repair or replace promptly such parts as were necessary to attain the performance requirements.
2. Failing such action on "the contractor's" part, as determined by the Secretary of Defense (SECDEF), he would pay all costs incurred by the U.S. to "produce such parts" from another source.

The conditions and penalties of nonconformance were specifically not applicable to government furnished weapon systems or components received by a contractor. Moreover, SECDEF could waive the conditions and penalties if:

1. He determined the waiver was necessary in the interest of national defense or the warranties would not be cost-effective, and
2. He notified the Armed Services and Appropriations Committees of both houses in writing of the waiver and explained his reasons for it.

The significant portion of the act was the requirement of the D/M warranty, and the distinctive phrase was *performance requirements*. This was seen as a significant departure from the standard design and manufacture warranty which was complied with if a contractor could show that the product met the design and manufacture *specifications* in the contract. Conventionally, if the system was in conformance with respect to specifications, but the system did not perform in accordance with expectations, the contractor was free from liability. The new terminology seemed to be extending contractor liability for an indefinite period after acceptance (and proof of conformity to specifications) to a meeting of performance requirements that were frequently expressed in the contract in the form of aspirations. The reluctance of contractors to accept this extension was closely coupled with the assertion that in most major weapon systems procurements the prime contractor did not have significant control over the design which he was required to guarantee.

On December 14, 1983, Deputy Secretary of Defense Thayer utilized the waiver provision of the Act to issue a blanket waiver of its requirements, explaining the action to the relevant committees as "necessary to minimize the disruption of the acquisition of weapons systems while the Department of Defense identifies implementation instructions to comply with the provision." A draft of such guidance was published in the Federal

Register on January 20, 1984, and written comments were solicited.² This document, which reflects DoD's interpretation of the act before revisions in the light of defense community reactions, is most valuable for its revelation of DoD's reading of Congressional intent and of the issues raised by performance warranties in principle. Consequently, a careful treatment of it is most rewarding.

Significant definitions in the draft Defense Guidance were the following:

1. *Weapon system* was defined as equipment used by the Armed Forces without substantial modification to carry out combat missions. It was sufficiently broad to include such support equipment as software, ground handling equipment, training devices, and test equipment.
2. *Components* were defined to exclude most spare parts.
3. *A specified performance requirement* was defined as any specifically delineated mandatory performance requirement set forth anywhere in a government production contract for a weapon system or in any other agreement relating to the production of such a system incorporated or referenced in the contract.

All contracts for production of a weapon system or components were required to contain the two guarantees of Section 794 and the remedies prescribed, unless they were waived. The design and manufacture conformance warranty was to be written in either of two ways:

1. For a first prototype or first production unit, the specified performance requirements were to be in the form of a test or demonstration and deemed met upon satisfactory completion of the test or demonstration. In the event of failure, the contractor was required to perform promptly "all design and manufacture work" necessary for conformance at no increase in cost to the government or in contract price.
2. Otherwise, when specified performance requirements were stated such as operation of the system without designated failures for a specified time period, in the event of nonconformity, at a minimum, the contractor was to be required, at no increase in cost to the government or in contract price, to design and manufacture the system and each component so as to conform "and/or" repair or replace parts necessary for conformance.

The defect-free materials and workmanship guarantee was to be interpreted as a second and independent warranty and to be valid for systems and components for a specified period of

² The draft Defense Guidance is reproduced in Appendix B along with a model guarantee.

time. Finally, in addition to these two Section 794 mandated warranties, other additional warranty and remedy clauses might be included when deemed appropriate.

B. ISSUES RAISED BY THE SECTION 794 MEASURES

With the passage of Section 794 and the publication of the DoD Draft Policy Guidance implementation, a number of issues centering upon interpretations, ambiguities of meaning, conflicts with existing laws or regulations, and potentially damaging public policy implications were posed by DoD and industry spokesmen. The diverse objections and questions that emerged are considered conveniently under five major categories and a miscellaneous grouping.

As noted in Section A, the overriding issue in the debate revolved around the major innovation of the legislation: the performance warranty. Both warranties in Section 794 referred to a *guarantee of all performance requirements*. A contractor who delivered a product conforming to design and manufacturing specifications at acceptance but which did not meet all *performance requirements* in some unspecified period after delivery was in breach of warranty. Similarly, a supplier of a component, however minor, which conformed to all specifications but whose furnished design was insufficient to permit performance requirements to be met at or after acceptance subscribed to an obligation to replace the redesigned part. .

1. Insensitivity to Relevant Particulars

The mandatory requirement of Section 794 and Guidance--Section 794 measures--that *all* weapons systems contracts (subject to the waiver provisions) contain written performance warranties evoked a number of objections based on its comprehensive nature. It forced DoD and contractors to ignore the nature of usage of the system or component, the maturity and source of its design, and the stage of production of the item. It reversed the long standing DoD policy of self-insurance at the weapon system level coupled with selective warranties at the subsystem and component level. And, it threatened to elevate costs significantly by ignoring in its blanket nature the prioritization of performance characteristics in the fulfillment of the system's functions.

Indeed, defense industry spokesmen challenged the applicability of performance warranties in any context where the contractor does not have substantial control over the

design of the system or component. In commercial warranty practice responsibility for remediation beyond materials and workmanship defects rests upon the designer of the product or component. In many, if not most, important weapon systems procurements, DoD furnishes major portions of the design.

Proponents of mandatory performance warranties on contracts with government-furnished design responded to such criticisms by asserting that these obligations forced the contractor to review government designs closely to determine feasibility before production. The implicit criticism was that in the absence of warranty responsibility contractors did not have a strong enough incentive to perform such review.³

Finally, with DoD encouragement, off-the-shelf components are meeting with increasing acceptance in weapons systems. Application of the measures, therefore, might discourage the greater usage of such components with attendant increases in cost, reduction of competition, and contraction of the procurement base.

2. Lack of Clarity or Precision

A second category of issues dealt with assertions that Section 794 was silent on crucial concerns, duplicated existing regulations unnecessarily, failed to define key concepts, and allocated too large an area of discretion to DoD guidelines. These latter, in consequence, it was asserted, as formulated in Guidance, defined requirements not explicitly contained in the Act and not intended by it; contradicted the Act's provisions; or failed to provide specific guidelines where the Act intended them to be written to conform to DoD requirements.

The provisions of Part 1.c seemed to imply that the intention of Section 794 was to limit contract liability to the costs of repairing or replacing parts necessary to achieve performance, which is akin to the obligation of replacing or repairing deficiencies in workmanship and materials. But Guidance went far beyond this interpretation in defining contractor liability. Section 5 implied that not only was the contractor liable for repair and replacement of parts at no increase in price or cost to the government, but was also responsible for redesign, redevelopment, retesting, and (more ambiguously) retrofitting.

³ See, for example, Senator Mark Andrew's testimony in [22], p. 10-12.

Most importantly, Section 794 contained no reference to a time period over which the design and manufacture conformance warranties were to apply. Guidance filled the gap by implying that this was a contractual provision arrived at through negotiation and that different time periods might be denoted in the same contract for different performance requirements.

The terse statement of Section 794 led to other dissatisfactions of critics because of similar failures to guide procedural policies. Its intentions with respect to subcontractor and supplier liability were unclear: was it meant to apply to prime contractors only? Section 794 referred simply to "weapon systems" and "components," with no attempt to define either. Guidance filled the gap with extremely broad definitions of both. These definitions became issues with industry and DoD critics who pointed to the pressures that would be exerted upon prime contractors to obtain written guarantees from suppliers of thousands of routine parts as a means of sharing the contingent liability on the system. The reluctance of small business to give such guarantees, it was asserted, could cause complications.

Section 794 and the Draft Guidance were also criticized for one-sidedness in the placement of responsibility on the contractor. Both measures, as well as the statements of supporting legislators in Congressional hearings, emphasized the insurance and negative incentive functions in the motivation of the legislation. The costs of design/manufacture nonconformity were to be borne fully by the contractor with no sharing of risk by DoD.

3. Contract Conflicts

The measures were explicit in applying their provisions to all weapon systems procurement contracts regardless of type, with some resultant contradictions of current contract policy and provisions and some confusion. As indicated in Chapter III, all DoD contracts are required to be of the fixed-price type unless specific conditions are met, in which cases exceptions are allowed and the cost-reimbursable contract may be used. In these respects, DAR 3-405.1(b) stipulated: "...the cost-reimbursable contract is suitable for use only when the uncertainties involved in contract performance are of such magnitude that cost performance cannot be estimated with sufficient reasonableness to permit use of any type of fixed-price contract." Their use is limited, therefore, to research, development, and test purposes.

The provisions of Section 794 would have forced current contract provisions to be violated. It required that the contractor bear the cost of all work incurred in fulfillment of the obligation. This would have forced the contractor with a cost-reimbursable contract to exceed his ceiling commitment, essentially forcing all such contracts to be written without such maxima.

4. Harmful Impacts Upon the Procurement Base

Vague though the intentions of the measures were in terms of the intended responsibility of subcontractors and suppliers for performance guarantees, the suggested extent of contingent liabilities in all likelihood would have forced prime contractors to pass through the obligations to these lower tiers of the procurement base. Small businesses generally lack the resource and diversification base over which a substantial deferred liability arising from a performance warranty could be distributed.

Guidance suggested that a common provision of weapons system contracts would void the warranty if repairs were made with unauthorized spare parts. Such a provision would discourage the current campaign to "break out" the supply of spares by by-passing prime contractors and buying from a wider supplier community, with the aim of enlarging the procurement base and heightening competition.

Finally, prime contractors, because of all of these complications involving suppliers, coupled with desires to protect themselves against liability for failure of systems to conform, might have been led to pull the manufacture of components in-house to control quality. This would accelerate the decline in the number of suppliers and the extent of competition.

5. Cost Implications

Besides the indirect bearing of potential declines in competition upon prices, opponents asserted that the measures might lead directly to more serious increases in the cost of weapons systems. Most importantly, a risk-averse prime contractor was required to deliver a wide-ranging guarantee for the performance of a system he may not have designed, containing components whose production he may not have been able to police, and which might be stored or handled improperly by the military services or used in environments or under conditions it was not designed to endure.

Also, critics suggested the measures did not provide for cases in which failure to attain performance requirements would not be rectifiable in cost-effective ways. For example, once a ship's design is locked into concrete form and it fails to meet speed specifications, there is probably no practicable way modifications can be made to obtain conformity. Current practices permit *objection trade-offs* by which flexibility exists to accept overperformance in some dimensions as offsets to underperformance in others. Were Section 794 to be enforced rigorously in these circumstances, costs could mount astronomically.

A cost impact that was demonstrated in previous warranty experiments by DoD was that of educating service personnel to an awareness of the existence of such guarantees and the potential for DoD to benefit from them. DoD without such consciousness of its rights at the operating level, might find that it was paying large prices for the warranties but obtaining much less benefit than their existence seemed to provide on paper and prospectively.

6. Miscellaneous Issues

Several other important issues that deserve discussion were raised by critics. A first was that in the face of such large potential liabilities and their reflected value in the price of performance warranties, both contractor and government might opt to reduce performance requirements and remain technologically with more certain, achievable ambitions. Risk aversion might, therefore, act through such warranties to lessen the proficiency of weapons systems. Proponents of the legislation, on the other hand, argued that forcing the expected costs of uncertain technology into the price of such systems was a means of capturing their true costs and insuring they would be matched against prospective benefits.

Appraisal of the risks imposed by performance warranties, opponents asserted, especially if they had to be estimated component by component, would add more time to the bid and proposal cycle--a cycle many already criticize for being overly long.

Finally, Section 794 required that all cost of rectification be borne by the contractor. Sometimes, however, the military services wish to train personnel for in-house maintenance capability in the post-warranty period, and perform the labor of repair during the period themselves.

C. THE DEFENSE PROCUREMENT REFORM ACT OF 1984

In reaction to the criticisms contained in Section B, and as part of a wide-ranging effort to reform DoD acquisition policies, Congress changed substantially the provisions of Section 794 in Public Law 98-575, the Defense Procurement Reform Act of 1984. The relevant provisions became codified in 10 United States Code 2403, and were implemented in FAR Supplement, Part 46 (Quality Assurance), Subpart 46.7 (Warranties).⁴ The law will be referred to henceforth as "Section 2403" and, when considered together with the FAR implementation, the "Section 2403 measures."

In broad perspective, Section 2403 substantially reduces without eliminating the burden of performance guarantees upon contractors in several important dimensions. In brief summary, these are:

1. Of the three types of warranties required, the first two--design/manufacturing and materials/workmanship--revert to former DoD policy in requiring conformance to contract specifications, and the third limits performance guarantees to those specifically designated "essential performance requirements" (EPRs).
2. It restricts the applicability of the act to weapon systems whose unit cost is in excess of \$100,000 or whose total procurement cost will exceed \$10 million.
3. It legislates that contracts signed after January 1, 1985, contain written guarantees from prime contractors only. It is silent concerning subcontractors and suppliers.
4. It explicitly permits--but does not require--DoD to define EPR as maintenance and reliability characteristics as distinguished from operating characteristics. This permits "performance" to be interpreted in terms familiar in RIW contracts.
5. It limits the need for the mandatory written EPR guarantee to weapons systems in "mature full-scale production," which is explicitly defined.

These and other provisions of the act must be elaborated in greater detail. When compared with Section 794 the act reveals a great deal more precision of definition. The term "weapon system" excludes ancillary equipment implicitly, off-the-shelf items explicitly, and items whose cost is below the monetary constraints stated above. Similarly, "components," "prime contractor," "design and manufacturing requirements," and "head of

⁴ 10 USC 2403 is reproduced in Appendix C.

an agency" are given straightforward and clear meaning. Through such definitions Congress sought to meet some of the criticism that Section 794 was unclear in its use of terms and left too much leeway to Defense Guidance to define its intent.

Terms that are novel with respect to Section 794 and that support the innovative features of Section 2403 are of even greater interest. The act defines EPRs as *either* the operating capabilities *or* maintenance and reliability characteristics of a weapon system determined by SECDEF to be necessary for it to fulfill its military requirements. As noted above, this gives DoD the potential for defining "performance" in terms of reliability and maintenance, thereby retreating from some of the more threatening potentials in the novel and much-criticized features of Section 794. Rather surprisingly, as will be discussed below, DoD seemed initially to have unnecessarily tied its own hands in the FARs in this regard and denied itself this option, but later amended the requirement to include it.

The EPR warranty need be required only for weapon systems in "mature full-scale production." This is defined to mean the lesser of (1) all units after the manufacture of the first one-tenth of eventual total production or (2) the number of units contracted for in the first year of full-scale production. The intent, of course, is to permit the contractor to obtain some production experience and perhaps field use before facing the penalties for nonperformance. Presumably, costs for modifications, redesign, retesting, and repair on these initial noncovered items will be borne by DoD self-insurance. The feature, therefore, is a bow in the direction of risk-sharing.

Two provisions, however, may limit the relief provided to contractors under this clause. First, the act does not hinder the head of an agency who is negotiating a contract for a weapon system not yet in mature full-scale production from including the EPR warranty clause. And second, when such a warranty is not to be included in a contract for a *major* defense acquisition program (as defined in 10 USC 139a) not yet in mature full-scale production, SECDEF must notify the four relevant committees of Congress of his intention and provide an explanation of the reasons for the exclusion.

In the event of failure to comply with one or more of the three mandated written warranties, the contractor is required at the election of SECDEF to take necessary corrective action to remedy the failure at no additional cost to DoD or pay reasonable costs incurred by the U.S. in taking corrective action. Remedies open the contractor to standard clause actions plus the performance clause requirements.

The waiver provisions for reasons of national defense interests or non-cost-effectiveness grounds are the same as in Section 794 for major acquisition programs, but for other weapon systems need merely be reported with supporting reasons once a year to the relevant four Congressional committees. This latter relaxation of prior requirements relieves SECDEF from seeking permission for such waivers.

Finally, agency heads charged with contract negotiation are given a great deal of flexibility in the act. Specifically:

1. They may negotiate specific details of a guarantee, including reasonable exclusions, limitations, and time durations, as long as the guarantee meets the general requirements of the act.
2. Although they may not require any of the three warranties from a prime contractor for a system or component furnished by the U.S. to the contractor, they may require its installation in a manner that would not invalidate any warranty given by its maker.
3. Collection of remediation costs may be made by agency heads by reducing the price of a contract.
4. They may excuse a dual-source contractor from the EPR warranty for the first one-tenth of his eventual production.
5. They may demand written warranties and remedies that are more comprehensive than required by the act.

These specific grants of negotiating power to contracting officers were inspired by Congressional disappointment with the Services' failure under Section 794 to tailor warranties more carefully to the specific circumstances of the contracts.⁵ Legislative history indicates Congressional concern that the military departments simply applied a standard performance warranty clause to all contracts mechanically, contrary to legislative intent. The new powers granted explicitly to agency heads were designed to encourage this case-by-case tailoring.

Two major criticisms of Section 794 were not explicitly dealt with by Section 2403, but implicitly their parent problems were meliorated. First, cost-reimbursable contracts were not excused from the provisions of the act. However, the legislative history indicates the intent of the legislators to consider each case on its own merits, and that waiver authority was seen as a means of excluding them when appropriate. Moreover, the "mature full-scale production" clause may eliminate most of such efforts that involve weapons

⁵ See [39] for explicit expression of this view.

systems from the purview of the act. Second, the act does not relieve prime contractors who have had no substantial control over design from the necessary warranties, except for the discretion given agency heads with respect to follow-on procedures. In the legislative history, however, legislators indicated their belief that agency heads had been given sufficient flexibility in the new act to judge the degree of accountability.⁶

With the intent of Congress taken into account, the provisions of Section 2403 were incorporated in FAR Supplement Subpart 46.7 to provide guidance to DoD contracting officials. This discussion will deal with the more noteworthy of those guidelines and regulations in 46.770, which deals with warranty usage in weapon system procurements.

Most surprising, in view of DoD's desire for greater flexibility in the use of performance warranties, was the initial definition of EPRs in Subpart 46.770-1. Where the statute defined them as "operating capabilities *or* maintenance and reliability characteristics of a weapon system" the FAR Supplement substituted *and* for *or*. This eliminated DoD's ability to interpret performance requirements in more conventional warranty terms. The clause was changed later to *and/or* and the flexibility restored.

Subpart 46.770-2 modifies the defects in workmanship and materials warranty clause in the act to hold at the time of "acceptance or delivery" instead of "delivery."

Subpart 46.770-3 expands upon Congressional intent for greater tailoring of warranties to contract specifics by discussing the nature of contracting officers' powers in negotiation. Most importantly, it specifically permits the officers to limit the contractor's financial liability under the warranties if necessary to make it cost-effective, and to negotiate the duration of performance warranties. They are encouraged to broaden the scope of the guarantees where appropriate, but also to narrow them when it would be inequitable to require that they hold in full force, as, for example, when a contractor did not have full control over design.

Subpart 46.770-8 requires contracting officers to conduct a cost-benefit analysis of warranties, including a study of life cycle costs with and without the warranty. Where such analysis indicates the warranty is not cost effective, the officer should initiate a waiver request.

⁶ *Ibid.*

D. THE CHANGES EFFECTED BY SECTION 2403 MEASURES

A comparison of the provisions of the Section 2403 measures with the issues raised by the Section 794 measures reveals that most of the criticisms have been confronted and their causes eliminated or impacts softened. A checklist would include the following:

1. The weapon systems covered have been narrowed from *all* such systems to expensive systems in mature full-scale production. Further, the definition of weapon system no longer includes ancillary equipment.
2. The nature of the warranties has been drastically altered in the direction of specification guarantees and away from sweeping performance guarantees. D/M and M/W warranties are no longer interpreted in the latter fashion, and performance warranties are limited to explicitly defined *essential* characteristics. These performance characteristics may be interpreted in terms of reliability and maintainability. In the application of these remaining performance warranties, lead and follow-on contractors are permitted some early noncovered production to gain experience with the systems.
3. Discretion in the design of warranties on the part of contracting officers is more explicitly encouraged in the 2403 measures, both in the direction of stricter provisions when required and relief where warranted. Importantly, contingent liability assumed by a contractor may be capped and lack of design responsibility may be reflected in lessened warranty obligations. The time duration of a performance warranty is also explicitly a matter of negotiation, although the new act, like Section 794, is silent concerning it.
4. Section 2403 continues the applicability of mandating written warranties on weapons systems produced under cost-reimbursable contracts. However, the price-of-systems constraints on applicability, the mature full-scale production condition, and the greater discretion given contracting officers virtually assure that few of the small number of such contracts issued for weapons systems will be affected.
5. Remedies specified by the Section 2403 measures call for correction of failures to conform to the three guarantees, with reduction of contract price a new option in the event of irremediability. Together with a potential financial limit on liability, the new measures permit much more flexible approaches to nonconformance in much less stringent types of warranty.
6. Only prime contractors are addressed by the new legislation, although all components in a system are included in the warranties. Hence, the new legislation does not address the criticisms concerning the relations of primes to subs and suppliers, the impact of contingent liabilities upon small businesses, and the effects upon competition and the procurement base. However, the reduction of the role of performance warranties does have the effect of substantially lessening the potential losses of suppliers and moving DoD policies closer to existent and familiar practices.
7. The waiver process is somewhat less burdensome under Section 2403 measures for systems which are not major acquisition items. Annual notice

to the four Congressional committees instead of case-by-case notification is now possible for many waivers. Nonetheless, the burden of seeking and supporting waivers remains a costly one for DoD.

8. Concern over the impact of performance warranties upon choices of technology remain, if somewhat lessened by the softening of the warranty requirement provisions and the greater discretion given contracting officers. Some bias toward selection of more predictable technologies probably remains, for good or for evil.
9. The increase in the duration of the bid-negotiation cycle and the imposition of significant price-of-warranty and administrative costs remain as implications of the new legislation. The cost enhancement will be less, given the flexibility and lessened stringency of the new act, but contract delays may be increased because of the heightened role of negotiation.

This reduction of rigidities in the new legislation seems to have substantially dampened criticism by DoD and industry spokesmen. Very little time has elapsed since its passage and experience is still limited, but the tempered nature of community reactions is marked. Nonetheless, several issues have emerged.

As of November 1985, only one waiver had been sought by DoD--on communications equipment for Army helicopters. DoD procurement officials have argued that the new legislation gives contracting officers sufficient flexibility to choose essential performance characteristics, time duration of the warranty, and limits on contractor liability to make all warranties cost effective. Cost analyses are performed on every warranty application, but in the absence of a data base very simple analytics are applied.⁷

The failure of DoD to seek waivers has raised several conflicting fears in the thoughts of interested parties. Congressional concerns center upon a feeling that contracting officers are using their new flexibility to reduce the costs of warranties by reducing requirements and/or excusing contractor liability. Contractors, on the other hand, assert that the potential need to defend waivers before Congressional committees effectively forecloses waivers as a policy available to contracting officers, even when appropriate. Hence, they urge, these officers are not using the flexibility available and are forcing all contracts into a rigid mold. Increasingly, rigid rules are encountered, they argue: a warranty price should be no more than x percent of the contract price, the warranty period

⁷ See the testimony of James P. Wade, Jr., Assistant Secretary of Defense (Acquisition and Logistics) in [25].

should be y years, the warranty ceiling liability should be greater than the contract profit and not less than a z multiple of the contract price, and so forth.

Finally, service procurement officers are taking rather mild exception to the remaining warranty rigidities in the legislation. The Air Force, especially, finds that warranties are frequently inappropriate to their systems and serve to heighten cost unnecessarily and increase procurement time. For example, once satellites are deployed, warranties on defects in materials and workmanship cannot be invoked. Similarly, EPR conformity cannot usually be judged for dormant systems. Other means for attaining quality assurance are more appropriate, they argue.

Resolution of such charges can only be sought by interviews with knowledgeable parties in the field and by analysis of the limited data available. These tasks will be performed in Chapter V. Before that survey, however, the implications of these two significant pieces of legislation for the role that Congress envisions for warranties in procurement policy will be discussed in Section E.

E. THE AMBIGUITIES IN CONGRESSIONAL INTENT

It is difficult to discern from the warranty legislation discussed above, the hearings that concerned it, and DoD's reaction to both a consistently clear, closely argued, majority-adopted Congressional intent. Attempts to find thoughtful statements of focused goals for these instruments in procurement, continuity in emphases among the integrating and economic functions isolated in this study, or persistent pressure to force DoD policy in ardently desired directions have been disappointing. The legislation appears to have been the product of an ardent minority, acting hastily to enact a concern rather than well-thought-out cure, and achieving a narrow legislative result by virtue of a broadly-based discontent with DoD acquisition policies. A search for consensus must be based upon impressionistic evidence, therefore, and its conclusions qualified by its subjectivity.

In the hearings, Congressional advocates of warranties tend to urge the assurance-validation, insurance, and negative incentive functions of warranties. The concerns that weapons systems are not performing up to the standards the nation has a right to expect, that the taxpayer is being burdened by the costs of remediation, and that contractors should be forced to face up to underperformance by the exaction of penalties are dominant.

Seldom is there an expression of sympathy for the use of warranties as positive incentives to improve performance.

These worries are apparent in the Section 794 legislation, with its emphasis upon written guarantees, the attainment of performance requirements, and the insistence that all remediation be costless to the government. It has been softened in the 10 USC 2403 legislation, with its retreat toward specifications guarantees and its narrowing of performance requirements' warranties to a specified subset. Further, its granting to contracting officers explicit freedom in tailoring warranty durations and setting financial liability ceilings indicates a lessening of Congressional attachment to the insurance motive.

Another perceived accent in the legislation and hearings is upon the performance requirement defined as an *operating characteristic* rather than a *reliability, maintainability, and availability characteristic*. Section 794's two warranty requirements are written explicitly in terms of performance requirements rather than specifications, and advocates and committee members tend to stress the perceived failure of systems in their OCs in hearings.⁸ DoD witnesses tended to respond to questions or to volunteer testimony in ways that stressed their experience with RIWs with their strong RMA content. This DoD viewpoint seems to have achieved a compromise in Section 2403, which permitted essential performance requirements to be defined in OC and/or RMAC terms. However, it is suspected that Congressional intent remains closer to the inclusion of the former rather than the latter. There is a persistent resentment by members of Congress with contractors' "oversell" of OC capabilities that is linked with the defenses of the warranty provisions, and an expressed hope that the definition of "essential" performance requirements will correct some of this hyperbole.

Another concern that pervades the hearings is the well-being of small business. The liability burdens that Section 794 placed upon the subcontractor were essentially unanticipated by Congress, and were speedily corrected in Section 2403. The warranty provisions were meant to be means of disciplining prime contractors rather clearly, and currently are restricted to them explicitly.

⁸ See, for example, the exchanges between witnesses and House Armed Services Committee members in explicitly attempting to provide a legislative history on Congressional intent in the wording of Section 794 in [23], pp. 74-75. Senator Mark Andrew's testimony in [22], pp. 3-27, is also instructive in this regard.

Advocates of the legislation object to the assertion that Section 794 was too rigid in its requirements by urging that DoD was encouraged to tailor warranty provisions to the peculiarities of specific systems. This defense has a good deal of merit, since in the informal guidance provided by the hearings supporters pointed to their belief that only DoD procurement officers were qualified to optimize the provisions on behalf of the government. As noted above, Congressional criticisms of DoD enforcement of the legislation include a concern that little imagination is being demonstrated in these matters. Part of the willingness of Congress to grant contracting officers the flexibility they were given in Section 2403 sprang from this desire. In future Congressional oversight of warranty mandates, therefore, it is to be expected that DoD will be granted a great deal of discretion in their administration.

V. AN ANALYSIS OF RECENT WARRANTY PRACTICES

Current warranty procedures by the military departments in weapon system contracting date from January 1, 1985, when Title 10, United States Code, Section 2403 became effective. Its policy codification in FAR Subchapter G, Part 46, Subpart 46.7 - Warranties; in DoD FAR Supplement Subpart 46.7; and in the military departments' regulations which relate to the foregoing measures is governing contract policy presently in these respects.

Experience with the new procedures, therefore, is not extensive, and the opportunity to judge whether important changes from past practices have been instituted has been limited. This chapter attempts nonetheless to examine the record by study of recent weapon system contracts and by interviews with contracting personnel at the Service level to give at least tentative answers to questions concerning new contracting departures.

Section A presents the FAR and DFARS background for weapon system warranty guidance, supplemented by U.S. Army regulations. Section B presents the history of usage of the Reliability Improvement Warranty which is the most extensive experience available for DoD application of an incentive warranty. In the Annex to this chapter Sections A, B, and C present a sample of recent past and current weapon system contracts for the Air Force, Army, and Navy respectively, with the primary goal of studying changes instituted by Section 794 and Section 2403 measures. Finally, Section C of the main body of the chapter provides conclusions concerning the impacts that Congressional actions have had upon the Services' warranty practices as revealed by the analysis of the sample contracts as well as interviews in the field.

A. CURRENT DOD REGULATIONS AND GUIDANCE

1. Provisions of the DFARS

In Chapter V, the FARs that govern federal government contract warranties in general, and by implication, DoD warranties on acquisitions other than weapon systems, have been discussed in detail. As noted in Chapter IV, Section 2403 requires that written warranties on weapon systems be mandatory unless waivers are authorized. Therefore, in

the DFARS, Subpart 46.7, it was necessary to alter FAR 46.703, which asserts that the use of warranties in government procurement is not mandatory, to accommodate the change with respect to weapon systems. The policies and procedures in effect for them, as prescribed by Section 2403, are presented in detail in DFARS 46.770.

In 46.770-1, definitions are given that are essentially repetitions of Section 2403 definitions (see Appendix C) with a few alterations and elaborations. In brief:

1. "At no additional cost to the United States" means
 - a. For a firm fixed-price contract at no increase in price.
 - b. For fixed-price incentive contracts, the provisions of FAR 46.707 must be followed. It requires that in the pricing of these types of contracts all costs of the equipment, including the expected costs of conforming to warranty provisions, be included. Once a price is negotiated on the basis of such costs, it cannot be changed because of unforeseen costs arising from the warranties.
2. "Design and manufacturing requirements" are defined exactly as in the statute. Broadly, they are the structural and engineering blueprint particulars, along with specified tolerances, materials, and tests in the contract.
3. "Essential performance requirements" alters the statute's wording significantly, as pointed out in Chapter IV. In this definition they are OCs *and/or* reliability characteristics, whereas in Section 2403 they are defined as OCs *or maintenance* and reliability characteristics. In the first version of DFARS the phrase was *and*, which limited DoDs ability to exclude either type from EPRs. The elimination of the word *maintenance* from DFARS does not have a clear rationale. It was not recommended by the DAR Warranties Subcommittee which proposed many of the changes to the original version.¹ The EPRs are those OCs and/or RMACs determined by SECDEF (or, in an extension in the DFARS, his delegee) to be necessary to fulfill the military requirements for which the system is designed.
4. "Initial production quantity" is the number of units contracted for in the first (program) year of full-scale production. The parenthesized word was added in DFARS.
5. "Mature full-scale production" retains its statutory definition as the lesser of (a) initial production quantity or (b) one-tenth of the eventual total production quantity.
6. "Prime contractor" meaning is retained as a party who enters into an agreement directly with the United States *to furnish a system or a major*

¹ See [12] for these suggested changes.

subsystem. In Section 2403, the wording is "to furnish part or all of a weapon system." DFARS wording tends to broaden this definition to contracts not limited to weapon systems but to narrow application to major subsystems rather than any part of a system.

7. "Weapon system" is defined in somewhat different terms in DFARS from those used in the statute. As a first departure, the restriction to items that have a unit cost in excess of \$100,000 or eventual total procurement cost of more than \$10 million is dropped. The term "item" in Section 2403 becomes "system or major subsystem" in DFARS, but both definitions restrict "weapon system" to such materials that are used directly by the Armed Forces to carry out combat missions. DFARS then continues by illustrating equipment which does and does not fit its definition, notably excluding support equipment, training devices, and ammunition (unless the weapon system could not be warranted without its inclusion).

DFARS 46.770-2 then defines DoD policy under the act. After January 1, 1985, every weapon system contract within the designated cost range must incorporate from its prime contractor three written warranties:

1. A design/manufacturing guarantee of conformance to contractual requirements.
2. A defects-in-materials/workmanship warranty, specifying freedom from such defects at the time of acceptance or delivery.
3. If in mature full-scale production, an EPR warranty that the system conforms to these specifically delineated requirements.

As in the general DoD warranty provisions presented in Chapter III, penalties for nonconformance to any of these warranties at the discretion of the contracting officer include:

1. Requiring the contractor to undertake prompt corrective action (repair, replacement, and/or redesign) at no additional cost to the government.
2. Requiring the contractor to pay the reasonable costs incurred to effect such corrections.
3. Equitable reduction in the price of the contract.

Contracting officers may obtain warranties with greater coverage than that provided by the three required or with greater penalties than those specified, as, for example, including an EPR warranty in a system not in mature full-scale production.

Section 46.700-3 expands upon the desirability of contracting officers' actions to tailor warranty conditions to the specifics of the system. Durations should be clearly

related to requirements and sufficient to determine their achievement after acceptance. Contractor liability may be limited in the light of technical or financial risk. Scope of the warranty may be narrowed if the contractor has not designed the system when the contracting officer considers this equitable. In line with general DoD policy, liability for consequential damage to third parties from breach of warranty is not imposed upon contractors in warranties.

Rather surprisingly, Section 46.770-4 concerning EPRs gives no guidance to their determination. It simply repeats the statute's requirement that SECDEF, heads of military departments, or delegees designate them. It also allows for subsequent changes when in the interest of the government.

The usual waiver of warranties by prime contractors on government-furnished property except for installation or modifications by the contractor is found in 46.770-5. Alternate-source contractors are exempted from the EPR warranty until the first 10 percent of the contracted units are manufactured (46.770-6). And, relief from the three warranties for foreign military sales is extended in 46.770-7, with some qualifications.

Section 46.770-8 gives guidance to required cost-benefit analysis and DoD policy to obtain warranties only when they are cost-effective. Costs and benefits must include quantitative and qualitative assessments. On the costs side, administrative expenses, acquisition price, life cycle costs with and without the warranty, and enforcement costs must be considered. Costs incurred during development specifically to reduce production warranty risks should be considered. Comparisons with the costs of obtaining and enforcing warranties on similar systems should be made where possible. Benefits should include the advantages in logistical and asset availability expected and the impact or contractor incentivization from the warranty.

Section 46.770-9 details waiver procedures when warranties are judged to be non-cost-effective. These are wholly concerned with conditions that must be fulfilled in the procedures and are of little interest to the study. Finally, Section 46.770-10 requires contracting officers to insert in solicitations and contracts for weapon systems a clause describing the warranties required.

In largest part, DFARS simply repeats with some refinement the provisions of Section 2403 and provides little guidance to contracting officers beyond that contained in the statutes. Notably, from the standpoint of the present study and its concern with the broader implications of warranty usage, it does not attempt to develop guidelines for the choice of EPRs or conditions that would define the appropriateness in their definition of OCs and RMACs. SECDEF and military service delegees--presumably contracting personnel in many instances--are given a free hand in negotiating EPRs with the contractor.

The DFARS also do not attempt to give any indication of a general length of time envisioned for establishment of conformance to D/M and EPR warranties, nor as to manners of demonstrating conformance to the materials/workmanship warranty. The D/M and M/W warranties are implicitly treated as applications of the standard guarantees discussed in Chapter III, without notable extensions of the post-acceptance length of applicability.

2. Army Regulation Supplementation

As an example of military service supplementation to FAR and DFARS guidance, Army Regulation 700-139, Army Warranty Program Concepts and Policies, effective April 10, 1986, is interesting. It provides more detailed rules for contracting officers to narrow some of the scope the statute and federal-DoD regulations permit.

First, the tailoring concept of warranty to system is given priority in the concerns of implementation. Two basic warranty concepts used by the Army are presented to guide the warranty design:

1. Expected Failure Concept. This concept asserts that the contractor should not be held responsible for failures that are expected on the basis of accepted design. He should, however, be held liable for failures in excess of that expectation. The cost of the warranty should be zero or very low.
2. Failure-Free Concept. A period of failure-free usage is required by this concept. All failures in this period are the responsibility of the contractor. The price of the warranty will include the expected cost of repair and replacement, and may be included in the contract price or quoted separately.

In determining the warranty duration, two periods should be computed: the first is *average elapsed time to operation*, and it includes all normal delays between delivery of the

item from the contractor and operational use, and the second is *operational use*, or the period of time in actual operation that will prove the quality of the equipment and the acceptability of its manufacture. The contribution of the operational use period to the warranty duration should be 10 to 25 percent of the expected life of the equipment and generally not less than one year of calendar time or equivalent usage. The warranty period should be the sum of the average elapsed time to operation and the operational use factor. The duration period starts on the date of acceptance. And, it should be noted that the average elapsed time to operation accommodates equipment with long dormancy periods (i.e., War Reserves or prepositioned stocks) since these periods will be reflected in the average.

Second, in an Army Materiel Command supplement to this regulation, dated April 10, 1986, the Army's interpretation of the three types of warranties required by Section 2403 is given in more detail. The three warranties are distinct and separate, and limiting either the D/M or M/W warranties to be operative *only* when they affect EPRs is not allowable tailoring.

Also, explicitly, the EPRs must be verified in the operational use phase following acceptance. And, in general, it is to be the user of the equipment who determines whether it fulfills the EPRs, so that warranties should be written to validate the EPRs using only the tools in the hands of the user for operations and maintenance. Interviews with Army contracting personnel indicate that this provision is followed religiously in defining EPRs that can be verified by field manuals and standard maintenance equipment.

3. The Scope of Flexibility

There is a discernible reduction in the flexibility given contracting officers as one goes from statute to DFARS to service guidance. DFARS is concerned primarily with sharpening definitions and eliminating ambiguities in Section 2403, whereas service regulations are concerned with integrating the new procedures into existing practice. With the emphasis given tailoring by Congressional committees, DFARS, and Service guidance, however, a hallmark of the mandated warranty policies remains the great amount of discretion which is afforded contracting officers in fulfilling their requirements.

Some of this is lost in the negotiation process. Warranty provisions are the result of bargaining between contractors' lawyers and government contracting personnel. Instances exist where firms have walked away from contracts rather than accept government warranty provisions. The degree of competition for the contract also is an important factor in the strength of DoD's hand in specifying the content and price of these guarantees. A frequent theme sounded by contracting personnel is that contractors' legal personnel are frequently more skilled and experienced than their government counterparts. Also, the government negotiator is often under pressure to get monies obligated, to keep costs down, and to prevent schedule slippages, which weakens their bargaining position. Recent reductions in funding also contribute to disincentives to seek extensive warranty protection.

Some potential obstacles to innovating new warranty policies--if that is Congressional intent--inhere in such circumstances. The purposes of the new departures are not clear in the legislation or Congressional hearings, as further revealed in the marked change in resolve between Section 794 and Section 2403 acts. Contracting personnel in several Services expressed uncertainty whether incentive contracts meet the requirements of Section 2403, for example. The new policies have been intruded into a body of existing policies, and the temptation exists to interpret them as affirmations, repetitions, or simple extensions of the old policies whose insufficiencies presumably gave rise to the legislation. The manner of determining content and locus of determination of the EPRs, whose mandated definition is one of the important features of the new procedures, is not firmly established by the body of measures. Much discretion is given negotiating personnel who are practiced in existing procedures and experience a natural inertia in searching for continuities of new with old policies. Interviewees admitted, for example, that RMACs inflict a much smaller paperwork burden than OCs, and that significant pressure from above is necessary to pull EPRs in the OC direction. And, finally, those personnel are confronted by contractors whose profit motivation leads them to resist interpretations of new policies that extend the old into unfamiliar and potentially costly terrain.

To what extent are recent contracts extending warranties into the post-acceptance phase? Are EPRs being defined in significant numbers as OCs, or are they predominantly RMACs in the old mold? Are the durations of the warranties being written significantly

different from those that predate Section 794 and Section 2403? Do the limitations on financial liability accorded contractors interfere with the motivation Congress sought to enplace in weapon system procurement? Has the legislation, with its strong emphasis on negative incentivization, discouraged the use of positive incentive RIWs? Have contracting officers attempted to use the new warranties as means of shifting risk onto contractors rather than to incentivize them?

These are some of the questions that will be addressed by the study of current practice in this chapter. A first task will be an analysis of the use of the RIW in DoD contracting activities.

B. RELIABILITY IMPROVEMENT WARRANTIES

As developed in Chapter III, the RIW program was initiated by DoD in the mid-1970s as an experiment in the use of warranties for negative and positive incentivization. Their introduction into procurement contracting marked the beginning of government concern for the functioning of military systems in the post-acceptance stage--a concern which motivated Congress in the mandated warranties legislation presented in Chapter IV. The intention was to lower the support costs of equipment and increase its availability on the line by providing contractors with incentives in the design and manufacturing phases to produce a system with improved RMACs.

The typical RIW contract provided that the contractor guaranteed to repair or replace units of equipment at a firm fixed price over a fixed duration of operating or calendar time. Another type combined this with penalties if equipment failed to meet a target mean time between failure (MTBF). Frequently, the contractor also agreed to service this equipment within a designated turnaround time (TAT), and failure to do so resulted in an extension of the warranty period, damage payments to the government, or the need to deliver spare parts on consignment to field units to permit repairs in the field. Also, failure to meet a target MTBF might also require the contractor to analyze the equipment for design flaws, force him to submit engineering change proposals (ECPs) to the government, and, if the ECPs were accepted, to effect such changes at his own cost.

Because the RIW was tied so closely to contractor repair of equipment at a fixed price, the predictability of failure was a most important precondition of their successful

usage. Because electronic equipment frequently reveals the "Markovian quality" of not aging--i.e., it is no more likely to break down at the end of 20 weeks than it is at the end of one week, unlike mechanical equipment which wears out--it is subject to more exact probabilistic prediction of numbers of failures over a period and therefore of mean times between failures. Hence, the RIW was most frequently applied to electronic detection, navigation, or similar equipment types.

Also, because repairs were effected by the contractor, the equipment had to be susceptible to depot repair or rapid transportation to factory facilities, or to modular substitution of parts on site with delayed repair of failed modules. These characteristics also favored the electronic rather than mechanical type of system. The Air Force, therefore, with its heavy usage of avionics, became the prime user and advocate of RIW warranties. By 1978, for example, it had 17 programs underway with RIW warranties. They are listed in Table V-1.

These early experiments with RIW have been judged generally to have been cost-effective by industry and DoD personnel. In 1975, the TACAN system warranty, for example, was modeled closely upon commercial practice, and was deemed most favorable to DoD. It had a fixed price of \$12.5 million, or about 4.34 percent of acquisition cost per year of warranty, for the repair of all nonconforming units for four years. It guaranteed a MTBF of 500 hours in the first year, 625 hours in the second year, and 800 hours in the last two years with repair or replacement of defective units by the contractor in order to achieve these targets. Moreover, in the event of their nonachievement the contractor was required to consign spares for field repair, and if the specified TAT was exceeded price adjustments to the repair cost specified in the warranty were made. In short, it would be difficult to fault these provisions from DoD's viewpoint for a high-technology military navigation system. The system actually achieved a MTBF over 1,000 hours and was an early RIW success.

The Air Force has asserted that all of these warranties have been cost-effective and that in 1984 only one RIW could be cited as not then conforming to target MTBFs. This was the Standard Inertial Navigation Unit on A-10 and F-16 fighters, listed as 1.e.7 in Table V-1. Its RIW price was 26.6 percent of unit acquisition price for a five year period,

Table V-1. AIR FORCE CONTRACTS WITH RIW WARRANTIES IN FORCE IN 1978

1. Major Applications

- a. ARN-118 TACAN. Short-range navigation system for range and bearing data for aircraft. Provided for a target MTBF and TAT with a fixed price contract for 8,500 sets and spares. Warranty price was about 4.9 percent of hardware price per year of warranty.
- b. C141/KC135 INS. Carousel inertial navigation system. Provided for a MTBF of 1,128 hours and a TAT.
- c. C141 AHRS. Altitude, heading and reference system. Provided for target MTBF and TAT.
- d. C130 Omega NAV. Navigation set. Set MTBF of 4,000 hours and provided for maximum TAT.
- e. F-16 Components.
 - (1) Flight Control Computer. Set TAT.
 - (2) Radar Antenna. Set TAT.
 - (3) Radar Low Power RF. Set TAT.
 - (4) Radar Digital Signal Processor. Set TAT.
 - (5) Radar Computer. Set TAT.
 - (6) Head Up Display. Set TAT.
 - (7) Navigation Unit. Set TAT.
 - (8) Radar Transmitter. Set MTBF and TAT.
 - (9) HUD Electronics. Set MTBF and TAT.

2. Minor Applications

- a. F-111 Displacement Gyro.
- b. AV-8 C/A Airspeed Indicator.
- c. C-130 Hydraulic Pump.
- d. Klystron Electronic Tubes.

over which the MTBF was to achieve increased values at target points. These target rates were not achieved and additional consignment spares were provided by the contractor.²

Table V-2 displays in fuller detail the actual versus targeted MTBF performance for RIW contracts. It reveals in all but one case--that of an Air Force gyroscope--that MTBF goals were exceeded, and in eight of the 13 cases by 20 percent or more. Cost-effectiveness cannot be judged on the basis of performance alone, but goals were overachieved in 12 cases.

In general, conversations with Air Force contracting personnel support the contention that RIWs were succeeding in improving RMA performance and were cost effective. Indeed, in one conversation with very influential Air Force contracting personnel it was asserted that they were the most effective type of performance warranty and should be given priority in the definition of Section 2403 EPRs. The recently published Warranty Handbook asserts that they have proved administratively workable and are one of the more important and useful forms of incentive warranty. The TACAN and F-16 avionics warranties were explicitly mentioned as successful applications, as were the guarantees on Navy F-14 hydraulic pump and Army 123 CONUS NAV radio.³ Goree, writing in 1984, asserts from his experience that the warranty on the AN/TPQ-37 Firefinder Radar led to substantial growth in its system reliability.⁴

Writing at the time of the inception of the RIW program, Gándara and Rich expressed some anticipatory skepticism on the basis of earlier reliability warranties. In 1973, the Navy issued a contract on the APN-154 Radar Transponder which contained a RIW-type warranty. First produced in 1965, its purpose was to provide a radar beacon to extend the range of surface radar and permit identification of some airborne targets. The guarantee given in 1973 was for 218 units, and Navy analysis at the end of the contract concluded that the warranty succeeded in raising the MTBF almost four times from about 500 to 2,025 hours.

² See [23], p. 66.

³ See [4], p. 3-7.

⁴ Discussed in [17].

Table V-2. MTBF EXPERIENCE IN RIW CONTRACTS

Equipment	Service	Contract Date	MTBF (Hours)		Ratio Field to Goal
			Field	Goal	
1. Gyroscope	Navy	1967	531	520	1.02
2. Gyroscope	Air Force	1969	1,000	1,300	.77
3. Pump	Navy	1973	1,100	600	1.82
4. VOR/ILS	Army	1974	800 ^a	700 ^b	1.14
5. Pump	Air Force	1975	8,500	5,000	1.69
6. TACAN	Air Force	1975	1,482	800 ^b	1.85
7. Klystron	Air Force	1975	3,780	1,000	3.85
8. INS	Air Force	1975	1,261	1,090 ^b	1.16
9. AHRS	Air Force	1975	2,943	1,285 ^b	2.27
10. Omega	Air Force	1977	769	700 ^b	1.10
11. Transmitter	Air Force	1977	310	238 ^b	1.47
12. HUD	Air Force	1977	826	325 ^b	2.56
13. LDNS	Army	1977	600	500 ^b	1.20

^a Estimated.

^b Guaranteed by contract.

Source: [4], p. 8-2.

Gándara and Rich's analysis is valuable in pointing to the need to assess causation in RMA improvement when *ex post* cost-effectiveness analysis is performed. They felt that factors other than the warranty explained the improvement. The major sources of early failures were in certain pre-solid-state devices which management had already taken steps to eliminate before the warranty was written. The introduction of solid-state devices into the assemblies when they become economically feasible also improved reliability. Much of the credit for the results of these actions, Gándara and Rich believe, accrued falsely to the warranty's presence.⁵

Another early case in which these authors believe the military analysts gave too much credit to a reliability warranty was in the case of the Navy 2171 Gyroscope, designed in the 1950s and introduced into A-4 and F-4 aircraft in the early 1960s. In 1967 the contractor proposed a warranty for 800 units after about 3,200 had been installed, with the goal of improving MTBF by 30 percent. The MTBF of the warranted gyros rose from 400 to 520 hours in three years, and for the unwarranted units, MTBF rose to 442 hours in the same period. The warranty played a role in this improvement, Gándara and Rich concede, but they believe that the contractor would have continued to perform the design and test activities begun before the warranty had it not been awarded. Also, Naval Air Systems Command found that the warranty cost was less than the probable cost of support in the absence of the warranty, but Gándara and Rich believe that cost slightly exceeded the savings, although reduced costs from spare parts consumption and greater operational readiness probably offset the deficit.⁶

The Gándara and Rich analysis is valuable in highlighting the need to judge what motivation a contractor has in the absence of an RIW to continue design and manufacturing research and improvements. Competitive pressures and the desire to maintain a reputation for quality to enhance future contract prospects may very well lead him in these directions. In Chapter VI the notion of *positive moral hazard* will be introduced and the usefulness to government contract officials of judging this propensity in contractors during negotiations will be discussed.

⁵ See [16].

⁶ *Ibid.*

It has proved difficult to obtain any closely reasoned evidence that RIWs are cost-effective. What is more accessible are general comments about "success" or "failure" of RIW warranties in fulfilling their goals. For example, Lt. General Donald M. Babers, Army Deputy Commander for Materiel Readiness testified that performance and reliability characteristics of the following systems were improved by RIWs: the Blackhawk T700 helicopter engine; the lightweight Doppler navigation system; the navigational receiving set; the target acquisition designation sight; the pilot night vision sensor; and nap-of-the-earth high frequency radio. He asserts that on the basis of experience with the RIW the Army will continue to use it.⁷

RMA types of provisions, which under Section 2403 are capable of definition as EPRs, tend now to be found in many weapon system contracts of the 1980s, as will be seen in Sections C, D, and E. Examples include the SINGARS airborne radio; the F-100 engine for F-15 and F-16 aircraft; NAVSTAR and other avionics equipment; the MX reentry and launch control system and support equipment; C-17 aircraft; T-46 trainer aircraft; the C-5B aircraft; and the air launched cruise missile. Among the services, they continue to be most favored by the Air Force in large part because of their aforementioned appropriateness to electronic applications.

Positive incentive clauses permitting payments for exceeding RMA targets do not seem to be common features of these contracts. They do exist in the DSCS II satellite program, which provides positive payments for more than two years of performance in orbit; the air launched cruise missile program; and the AN/AJQ25NAV contract (which will be discussed more fully below). But only one positive incentive RIW is to be found in the sample of weapon system contracts employed in this study. The seeming reluctance of the Services to avail themselves of this flexibility in incentive contracting is somewhat puzzling, but perhaps reflects a sentiment of inability in the general case to design an incentive fee schedule that tracks costs in the absence of an extensive data bank. Also, as noted above, the status of such warranty provisions in fulfilling Section 2403 requirements is not clear.

⁷ See [23], p. 57.

From the available evidence--much of it fragmentary or informal--the use of negative incentive RIW-type guarantees should be judged a success in achieving RMA goals, although cost-effectiveness can be established only with further analysis. This type of incentive contract has only been in use for about ten years and has been concentrated in the avionics and electronics areas, so that extensive data are not yet available to permit definitive judgments about its general applicability. However, from the beginning of DoD's encouragement of its usage, the conditions compatible with RIW applications have been well understood, and the concerns of the services and contractors quickly addressed.

The initiating DoD memorandum to the military departments⁸ enunciated a set of guidelines for the services to use to assess the appropriateness of RIWs to the contract:

1. Maintainability is a design feature of the system.
2. The price of the warranty is commensurate with its benefits.
3. Moderate to high support costs are characteristics of the system.
4. Equipment is readily transportable to permit return to the contractor or he can provide field service.
5. Equipment is self-contained, immune from failure produced from external sources, and has readily identifiable failure characteristics.
6. Expected operating times and use environments are known.
7. Equipment is susceptible to fixed-price contracting.
8. The contract can provide a warranty duration of several (at least three) years to permit the contractor time to identify failures and make improvements.
9. Potential contractors are cooperative.
10. Sufficient quantities are to be purchased to make the RIW cost-effective.
11. Equipment has potential for reliability growth and reduction in repair cost.
12. Equipment configuration discourages unauthorized field repair, and preferably is sealed and capable of containing an elapsed time indicator.
13. A reasonable assurance of a high rate of utilization for the equipment exists.
14. The equipment permits the usage of no-cost ECPs after government approval.
15. Failure data and other relevant data can be furnished to the contractor.

⁸ See [33].

None of these guidelines was ill-conceived in retrospect. Moreover, the goals of the program were clearly delineated: to incentivize contractors to design and produce equipment with low failure rates and repair costs in the post-acceptance period. It was a device to make contractors responsible for field reliability of equipment and to encourage initial design features and subsequent modifications via line-item fixed-price warranties to cover their costs. A cost-effectiveness study was required, and the separately-priced warranty was designed to permit subsequent comparisons with in-house government costs for equivalent functions. Finally, the services' fears that warranty costs would be deducted from acquisition budgets were stilled by indicating that funding would come from O and M or RDT and E appropriations.

These guidelines were expanded in a subsequent memorandum in 1975⁹ in the light of early experience. Interestingly, the major concern of the memorandum was contractor protest that military department contracting personnel were using the RIW as a means of insuring DoD rather than as an incentivizing instrument. It was emphasized that the price of the warranty was to reflect a reasonable sharing of the risks of high support costs. Therefore, the field reliability, support costs, and potential for reliability growth should be capable of reasonable prediction before the RIW is used. To protect DoD it is desirable to elicit a price quote for the RIW during the competitive phase, but that opens the possibility that the firm may have to bid before completion of development testing. The general practice should be to delay the price quote as long as possible and to tailor terms of the warranty to meet the uncertainties of the specific contractor. The concern of the memorandum is that contracting personnel view the RIW as an incentivization, not an insurance, instrument for DoD.

The documents cited reveal that the RIW program was well planned from its inception, with clear goals, insightful guidelines for compatible applications, and rapid response to contractor concerns. Those contractor misgivings, as collated by the Council of Defense and Space Industries Association were well anticipated by this planning and centered around risk factors. The major risk factors to which contractors felt the RIW exposed them were the following:

⁹ See [34].

1. Inability to forecast the frequency of failure or repair costs.
2. Possibility equipment would be subjected to unforeseen operational stresses and suffer increased failures.
3. Military personnel might mishandle or tamper with the equipment and cause failures beyond contractor control.
4. Greater-than-planned utilization rates might increase failure rate above the designed reliability rates.
5. Slow government processing of ECPs by DoD might hamper improvements.
6. Competitive pressures, optimistic support cost estimates, or misinterpretation of provisions might lead the contractor to underprice the warranty.
7. Inflation rates could exceed estimates.¹⁰

In general, these risk factors have proved manageable and both sides have tailored terms in such manners as to make the RIW an acceptable feature in weapon system contracts. As noted, it is judged to be successful overall in achieving incentivization to improve RMACs, although data does not yet exist to judge cost effectiveness. As will be shown below, RMACs are the most widely used manner of defining EPRs under Section 2403, which raises questions concerning the possibility of employment when OC definitions may be more appropriate and in greater conformance to Congressional intent. Finally, as incentive instruments, these warranties are designed to accomplish a function that the economic analysis of Chapter VI will assert is capable of achieving greater efficiency in DoD procurement.

It was pointed out above that the extension of the *negative* incentive features of the standard RIW or, more broadly, the RMA-type warranty, into *positive* reward schemes seems to be lagging, and may be penalizing DoD in denying it even greater improvements in RMA. As an example of the tool, the AN/AJQ25 NAV attack system may be cited. It provides for a fixed price repair warranty for three years on a fixed quantity of units. Baseline repair cost ceilings are set for each year on the basis of aircraft flying hours, with adjustments when those hours exceed ± 10 percent of target values.

¹⁰ See [3].

Interestingly, MTBF guarantees established target MTBFs for the three years on the basis of cumulative actual hours flown with the system. A Duane model learning curve MTBF improvement function was established to defined expected progress in reliability:

$$\text{Target Cumulative MTBF} = 32.801t^{-2},$$

where t is actual hours flown and

$$\text{Actual Cumulative MTBF} = \frac{\text{Total Flying Hours}}{\text{Number of Failures During Period}}.$$

For example, when $t = 50,000$ hours, the target cumulative MTBF is 286 hours. Target MTBFs are established each year on the basis of this model and actual flying hours. When MTBF is within ± 10 percent of target, repair costs are fixed at baseline values. Where MTBF exceeds target by more than ten percent, costs increase linearly up to a ceiling of 150 percent of baseline at 150 percent of target MTBF. If actual cumulative MTBF falls below target value by more than ten percent, repair cost falls linearly to a floor of 50 percent of baseline value at 50 percent of target MTBF. During the last three months of the contract, actual cumulative MTBF must be at least 120 percent of target or the field manager is to remain on station at no cost to DoD until it is attained.¹¹

Imaginative and flexible extensions of incentivization, tailored to meet the uncertainties of equipment usage and uncertain reliability by sharing risk, and using rewards as well as sanctions to motivate improved RMA, do not seem to be used much in present weapon system contracting. Their usefulness to DoD declines, of course, as production experience with a system increases, and thus the mature phases of most currently produced systems may explain the sparse usage.

C. CONCLUSIONS

From the sample of 13 weapon system contracts analyzed in detail in the Annex to this chapter, the literature concerning a large number of other contracts, and interviews with contracting personnel the following conclusions emerge. In reviewing the contracts, one must be aware of the heterogeneity of the warranties that results from the differences in the natures of the systems, the procedures of the services, and the strengths of the bargaining

¹¹ See the discussion in [38].

agents. Generalizations are difficult across such differences in so many dimensions. Nonetheless, certain consistencies do emerge from the record.

1. The Dominance of the Assurance-Validation Function

The preeminent function of the warranties currently being written is that of assurance-validation that the systems are conformant to specifications and performance requirements. This is reassuring in that this is the most fundamental purpose of such guarantees and its dominance indicates no major perversion of purpose is occurring.

2. The Nonevidence of the Insurance Function

One of the fears expressed by contractors and the drafters of RIW guidelines--that contracting officers would use RIWs or mandated warranties to shift risk onto contractors--is not justified by the evidence examined. Liability limits are frequent when warranty periods are long and seem so low as to be ineffective in shifting risk or in incentivization. From the viewpoint emerging from this study's analysis this refusal to use warranties as DoD insuring instruments is a healthy awareness of proper function, as will be developed more fully in Chapter VI.

One departure from this general conclusion is the Army's intention to employ systemic defect warranties in the future with periods of up to one-half service life. Such an extension of the post-acceptance period makes the dominant function of the warranty that of insurance. The potential cost-effectiveness of such warranties will be examined in Chapter VI.

3. The Limited Presence of the Incentivization Function

Given the general belief that RIWs have been extremely useful in improving RMA quality and lowering DoD support costs, both in their negative and positive incentive roles, a surprising finding is the scarcity of use of such incentives in the 13 contracts sampled. Only one such system revealed an RIW and that was in a FY1979 contract for the Army's Blackhawk engine. It was not present in the FY1985 contract for the engine, but even when in force at a maximum incentive payment of \$3,353 per engine it could not have been

much of a spur to achievement. And it has already been noted that the frequency of low liability ceilings in the warranties dampens negative incentive considerably.

Several reasons for the decline in usage of incentive warranties were cited in interviews with contracting personnel. Their high cost, especially in recent periods of funding restrictions and encouragement of fee reductions, is one major reason. The extent of the effort and data needed to design incentive schemes is another. Some question as to whether they conform to Section 2403 mandates exists in the legal departments of the services. Finally, the maturity of most weapon systems at the present time means that "steady state" production is occurring with little need for incentives.

But has the new mandated warranty legislation played a part in suppressing the use of incentive warranties that was a marked characteristic of the procurement in the late 1970s and early 1980s? Does the emphasis given assurance-validation by the need for D/M, M/W, and EPR warranties submerge the desirability for incentivization? If so, the legislation has had an effect counter to Congressional intention, for the use of rewards and (especially) penalties to effect the purposes of the legislation was certainly foreseen by advocates of the acts. In Chapter VI the economic analysis will highlight the use of positive incentives to affect the marginal actions of contractors to improve design and performance.

One meliorative factor may be that other forms of incentive contracting have been used instead of the RIW or similar guarantee. Several contracts do reveal fixed price incentive provisions. Nonetheless, the new contracts mute the potential of the incentivization function rather noticeably.

4. Impacts Upon the Post-Acceptance Warranty Period

There is little evidence that recent legislation is increasing post-acceptance warranty periods; indeed, in the case of the Army's T700 Blackhawk engine there has been a reduction. Army personnel did assert, however, that an effort is being made to extend post-acceptance warranty periods. Service reluctance to extend these periods greatly is motivated in part by the desire to protect in-house capability to repair such systems

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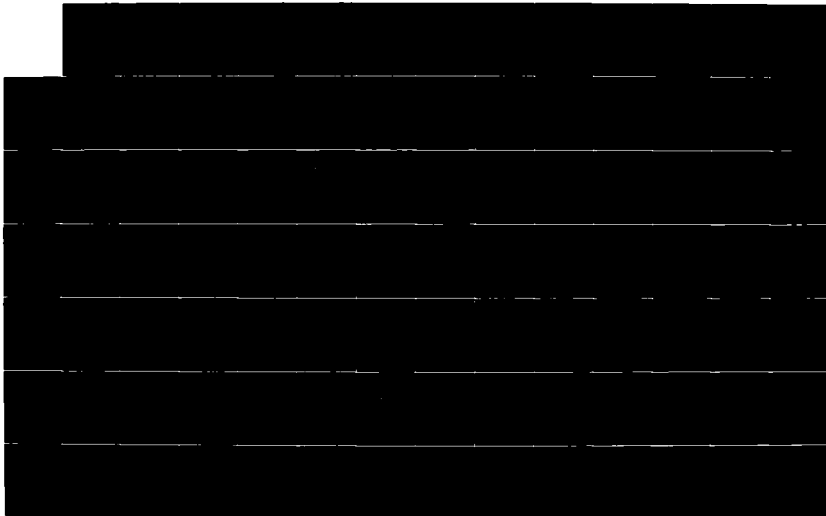
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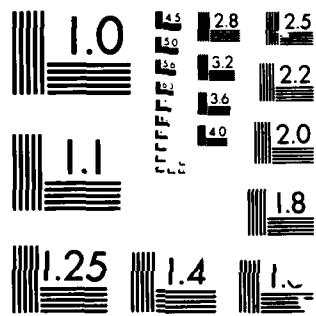
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5. Impacts Upon Essential Performance Requirements

The evidence that the new legislation has impacted performance requirement warranties is mixed. In many cases, the formal need to include an EPR warranty has merely resulted in defining them as all performance requirements in previous contracts with no discrimination, or in defining them as D/M configuration specifications. On the other hand, the new requirements have had some strong effects in this area, as Air Force F100 Turbofan Engine, Army 5-Ton Cargo Truck, Stinger Missile, Ground Laser Locator, and T700 Engine, and the Navy CG47 Major Subsystems contracts will attest. Conformance in principle is greatest in Army contracts where a significant rewriting of such requirements is most apparent.

The structure of the EPRs in terms of OCs and RMACs is difficult to judge because in many contracts the performance requirements are many, complex, and/or classified. In the case of the Air Force and Navy one has the feeling that except for engines, most of the emphasis remains on RMACs: that is, that former practices continue. In the Army, similar tendencies prevail with the notable exceptions of the 5-Ton Cargo Truck, Ground Laser Locator, and T700 Engine contracts. Overall, the dominant concern is with equipment failures in the sense of breakdowns rather than with capabilities when functioning on line.

6. Failure to Specify Warranty Prices

One noticeable feature of the contracts is the reluctance to specify a warranty price or if a portion of the contract price represents a payment for warranties. This interferes seriously with useful analysis. This study argues that a pure assurance/validation warranty should not be purchased but should be implicit in the cost of the equipment. Inability to discern whether a warranty price has been paid hinders analytical judgment. Further, cost-effectiveness studies are difficult to conduct if warranty price is not explicit. One means of judging such effectiveness is to determine life cycle cost with and without warranties for a comparison with warranty price. This is impossible in the absence of that price.

Section 2403 essentially relieves contracting officers from the need to specify such prices unless a waiver is requested. Because of the time and cost involved in determining such a price in the absence of firm data, contracting officers rely upon "should cost"

estimator models to give guidance to negotiators and roll the warranty cost into the contract price. Price-of-warranty data are difficult to obtain, therefore.

The Warranty Handbook [4] provides some useful data in these respects for past warranties. For RIWs applied to avionic equipment, it estimates that warranty prices ranged from 2 to 7 percent of hardware price per year of warranty, if no MTBF guarantee was included. If that reliability feature was included, the price mounted by 10 to 25 percent for the RIW price *sans* MTBF guarantee.

For non-incentive warranties signed after Section 794 the Handbook estimates the following distribution for prices:

Warranty Price as a Percent Per Year of Hardware Price:	Percentage of Analyzed Contracts:
0 - 1 percent	24 percent
1 - 2 percent	34 percent
2 - 3 percent	20 percent
3 - 5 percent	12 percent
Over 5 percent	<u>10 percent</u>
	100 percent

This provides an estimated weighted average of about 2.1 percent of hardware price per year. This percentage applied to a \$100 billion hardware budget each year is significant, and warrants a breakout of warranty prices.

In summary, the post-1984 legislation does not seem to have effected major changes in the manner in which the services are writing warranties. EPRs have been specified but not in manners that differ significantly from those used formerly in less explicit statements. Post-acceptance warranty periods have not significantly increased. OCs may have gained somewhat in their representation in performance requirements at the expense of RMACs but not strikingly. The ability to specify liability ceilings seems to have been used to reduce negative incentivization on the part of the contractor, and positive

incentivization does not seem to be as frequently used as in the pre-1984 period. On the other hand, assurance-validation remains the fundamental function and insurance a minor one, which displays a healthy sense of purpose on the part of contracting officers.

ANNEX A

In order to study the types of warranty provisions being written currently by the Services, and to compare departures in those provisions from the contracts of the recent past, a sample of 13 important weapon system contracts was obtained and analyzed. This exercise was supplemented by interviews with contracting officials who were involved in the contracting process for the specific contracts, as well as officials at higher levels of decision-making. The results of these efforts are presented in this Annex.

A. A SAMPLE OF RECENT AIR FORCE CONTRACTS

The Air Force has been a leader among the military services in experimentation with warranties, or, more broadly, "product performance agreements," and with the analysis of their effectiveness in contracting. Since 1980, when it published the first edition of its Product Performance Agreement Guide, summarizing the features of warranties, through its revision in 1985, this service has actively promoted the use of such guarantees in its contracting. In 1982 it established the Product Performance Agreement Center (PPAC) at Wright-Patterson Air Base to collect data on warranties, to model impacts of warranties on system costs, and to analyze the quality improvements deriving from their usage. A good deal of the Air Force's extensive experience in obtaining warranties is in the areas of aircraft engines, where it had the advantage of the availability of a history of commercial warranty usage, and of electronic gear, where failure analysis is amenable to known techniques of projection.

1. The F110-100 Engine (Alternate Fighter Engine)

This contract was negotiated in the period before Congress enacted Section 794 and was signed in December 1984; therefore, it provides an example of one of the more sophisticated warranties that was being signed in the era that pre-dated mandated written warranties.

a. Design/Manufacture Defects. The engine was warranted to be free from any condition that would render it unusable and/or unserviceable or cause it to operate other than in accordance with specified technical order limits. The warranty was to be in force at acceptance and for three years thereafter or for 1,000 flight hours, whichever came first. It extended to the modules, components, and serialized parts of the engine, and included support equipment as well.

b. Materials/Workmanship Defects. This M/W warranty parallels the D/W defects warranty in guaranteeing freedom from defects arising from these causes.

c. Performance Requirements. The contractor guaranteed:

- (1) For a period of 3,000 total accumulated tactical cycles, the engine's intermediate thrust was not less than 98 percent of the requirement in specifications.
- (2) For a period of 3,000 total accumulated tactical cycles, the engine's fuel consumption would not exceed 105 percent of the intermediate specific fuel consumption required in specifications.
- (3) For a period of 3,000 total accumulated tactical cycles or eight years, whichever came first, the "hot section"--combustor and high pressure turbine--would meet contract specifications.
- (4) Over a specified period, fleet-wide scheduled and unscheduled engine replacement would be at or below a designated engine removal rate.

A tactical cycle measures engine throttle movements from zero to intermediate or maximum power plus a percentage of throttle movements between idle and maximum positions. A fighter aircraft records on a typical mission about two tactical cycles. In FY1983 Congress mandated warranties on 3,000 tactical cycles for engines, thus the warranty was written with some legislative motivation. The Pratt and Whitney F-100 engine in use at the time had a warranty for only 1,350 cycles, so the legislation more than doubled that requirement.

d. Remedies Available to Government. The contractor is obligated to repair or replace defective parts, or reimburse government for the cost of repair and parts via equitable adjustment of the contract price. Delay in repair permits government to exact a penalty. In the event of loss of an aircraft because of engine failure, the contractor is obligated to provide a new engine.

e. Warranty Price and Liability Limit. The price of the warranty was \$27,075,510. Contractor liability was limited.

The Alternate Fighter Engine Warranty is often cited as an ideal type of warranty, containing both OC and RMA performance requirements over extended periods of time in the post-acceptance phase. In addition, it incorporated the essentials of D/M and M/W warranties with standard government remedies. Also, because it was obtained in an extremely competitive procurement, its price was most reasonable.

It is in many respects an exemplary warranty from DoD's viewpoint. However, it cannot be viewed as typical of DoD warranties in the period before Congressional mandates. The heightened cycle requirements were a direct result of a Congressional action. The contract took many months to negotiate by personnel who had years of experience in negotiating all Air Force engine contracts (the Aeronautical Systems Division). Years of commercial warranty provision provided some guidance and facilitated acceptance of warranty liabilities by the contractor. Experience with similar engines had accumulated at the time of the contracting. And competition for the procurement was fierce.

It is, indeed, nonexemplary of warranties in general use by DoD in this period in that 1) performance requirements included OCs as well as RMACs, and 2) guarantees were extended so far into the post-acceptance phase. Therefore, while it is a warranty the Air Force had every right to feel proud for having negotiated, it should not be held up as a model of standard practice, especially outside the area of aircraft engines, in the 1975-1984 period.

2. The F-15 Fighter Aircraft Airframe

This last point can be illustrated by a study of the warranty provisions for the F-15 aircraft in contracts that held in FY1972-83, FY1984, and FY1985. The last two contracts permit an analysis of meaningful changes instituted to conform to the new legislation.

FY1979-83

a. Design/Manufacture Defects. The contract incorporated a standard clause concerning conformance to specifically designated performance specifications for 12 months after acceptance.

b. Materials/Workmanship Defects. The contractor warranted the equipment to be free of such defects for 12 months after acceptance.

c. Performance Requirements. No specific performance requirements were specified other than conformance to "fabrication" specifications in the D/M guarantee.

d. Remedies Available to Government. In the event of a warranty breach, the contracting officer might:

- (1) Require repair or replacement of defective or nonconforming supplies at no increase in contract price.
- (2) Require the contractor to furnish necessary supplies to repair or correct defects, along with necessary data and reports to permit such corrective action at no increase in contract price.
- (3) Elect not to repair or replace and reduce the price of the contract equitably in compensation.

These are the standard remedies currently used in federal warranty FARs as discussed in Chapter III. They include the standard clauses with respect to the time of response of the contractor to a notice of breach and the contractor's obligation to pay transportation cost on the defective supplies.

e. Warranty Price and Liability Limit. None listed.

FY1984

This contract for the F-15 is the first written explicitly to conform to the provisions of Section 2403. Its differences from the prior contracts are therefore of some interest.

a. Design/Manufacture Defects. This warranty is listed under the heading "performance guarantee," in conformance with the statute's requirement of three distinct warranties. The wording of the warranty follows Section 794 defense guidance by using the term "specified performance requirements:"

The supplies furnished under this contract are designed and manufactured to conform to the specified performance requirements of this contract. For purposes of this Performance Guarantee, the 'specified performance requirements' are those delineated in the Statement of Work as relating to the Part I specifications.

This wording differs significantly from prior year warranties in specifying Part I specifications rather than Part II fabrication specifications. This separation of specifications may mean that a new set of performance requirements of the OC or RMAC type is written into the contract. The present study has been unable to have access to these requirements.

This D/M warranty obligates the contractor to undertake corrective action only for defects discovered within six months of acceptance--a rather short period of time given the longevity of the aircraft. This period of time is more relevant to latent defects provisions than OC or RMAC performance requirements. However, the contractor was obligated to perform an ECP for the defect and to retrofit any defective items delivered within the six months prior to notification as well as any subsequently delivered items.

b. Materials/Workmanship Defects. This guarantee essentially repeats the prior year counterpart, referring to fabrication specifications (in Part II of the contract) and obligating the contractor for remediation up to 12 months after acceptance.

c. Performance Requirements. As noted above, performance requirements are interpreted as D/M requirements. They obligate the contractor in either case only for six months after acceptance.

d. Remedies Available to the Government. A new clause obligates the contractor if he becomes aware of a defect before acceptance to correct it or notify the contracting officer of its existence. The contracting officer is required to notify the contractor of a defect discovered in the relevant warranty period within 90 days. The contractor must submit written recommendations to the contracting officer within 90 days, and the latter issue direction to correct, partially correct or not correct the defect:

- (1) If the contracting officer elects to correct or partially correct a defect, it will be done promptly at no increase in cost to the government.
- (2) If the decision is to partially correct or not correct the defect, negotiation of an equitable adjustment in the price of the contract will occur.

These provisions conform in important essentials to those specified in FAR 52.246-18 for complex systems, as presented in Chapter III. Also, they do not contain any substantial changes from the FY1979-83 contracts.

e. Warranty Price and Liability Limits. The price of the warranty is not listed separately as a line item but was estimated by the contractor to be .5 percent of the total airframe price. The sum of (1) the costs of correcting deficiencies under the performance warranty, (2) the price reductions occurring because the contracting officer elected to partially repair or not repair deficiencies under the performance warranty, and (3) the costs charged by government to the contractor for corrections related to the performance guarantee not done by the contractor will not exceed \$3,930,516 for the FY1984 increment of 36 aircraft. That averages to a ceiling of \$109,181 per aircraft. Further, when the costs detailed above plus withholdings for design deficiencies exceed the specified ceiling, no further withholdings for such deficiencies will be made.

However, M/W warranty claims are not included in the liability cap and have unlimited dollar coverage for the 12 month period.

The two innovations of significance brought about by the new legislation are the requirements of design and manufacture to conform to a set of specified performance requirements for six months after acceptance and a limitation of contractor liability for nonconformance to those specified performance requirements. In the absence of knowledge concerning the nature of those requirements, the extent to which they depart from prior fabrication specifications, and the additional burden they place upon the contractor, it is difficult to judge the advantage gained by government. This is compounded by the failure to price the warranties as a line item. However, to judge by the limitation on contingent liability by a contractor for defects resulting from these novel requirements, and the short period for which they bind, it is not difficult to imagine conditions that would lead to the contractor producing a mature weapon system actually benefiting from the new provisions at the expense of government. It would be difficult in any event to conclude that the provisions provided important incentives to improve the aircraft and certainly they do not provide government worthwhile insurance protection against large remediation costs.

FY1985

There are only two substantive changes in this contract from the prior contract. In the new contract, contractor obligations, reference is made "to the Performance Guarantee and those Design and Manufacturing Guarantees related to the Part I specifications." Previously, the same clause referred only to the Performance Guarantee. The seeming distinction makes the envisioned role of performance warranties even more confusing. The reference to *specified* performance requirements rather than *essential* performance requirements as required by statute, continues. However, the Warranty Handbook notes that the performance requirements are classified but include such OCs as speed, take-off roll, landing distance, and excess power.¹

The other departure is simply the size of the contingent liability ceiling under the performance warranty. It is raised to \$5,043,864 for the FY1985 increment of 42 aircraft, or \$120,092 per aircraft.

The following concluding observations are made concerning the warranty provisions on F-15 aircraft:

- (1) They differ markedly in nature from the Alternate Fighter Engine warranties in the length of performance warranty periods. Because the nature of the performance specifications that are warranted in the later F-15 contracts are not known, the degree of protection afforded government is difficult to judge.

¹ See [4], p. 8-7.

- (2) The wording of the pre-1984 and post-1984 contracts was not changed much with respect to M/W and government remedies. The D/M warranty was changed in uncertain ways to conform to the need to incorporate performance warranties, but the six month period of coverage was not changed.
- (3) The inclusion of contractor liability ceilings on performance warranty clauses did occur in the later contracts at dollar levels which could not provide incentives for product improvement. This ceiling was determined by the contractor's determination of an acceptable earning level, and accepted by government negotiators.
- (4) The warranty price was not listed separately in any year, which makes judgment about cost-effectiveness difficult. However, the contractor did reveal the approximate cost.

Some of the difficulties of administering weapon system warranties are illustrated by the experience with this contract. It has a Reliability Maintainability Incentive clause pertaining to a mean-time-between-maintenance target. But this target requirement is not included in the list of F-15 specifications which the D/M warranty guarantees. Hence, it is difficult to segregate warranty effort from the independent incentive program efforts. The two programs lack coordination.

The practical difficulties of administering a warranty program are highlighted by several aspects of this procurement. Only about 50 serialized items of the hundreds covered by the M/W warranty can be identified by the contractor or Air Force once they are removed from an aircraft. The Air Force, therefore, has no system to identify such components and present claims. The contractor requires an exhibit of every alleged warranty defect, however. The result is that the M/W defect claims have been all but nonexistent.

The contractor's accounting system does not track warranties. Therefore, the defect correction costs under the D/M warranty which count toward the liability cap are estimates only. Moreover, it is difficult to discern how much of those costs are truly borne by the contractor and how much are rolled forward as "sustaining engineering" charges for ECPs entailed by design defects but paid by DoD. The sustaining engineering account does not contain a breakout of warranty costs and hence is difficult to audit.

Finally, the shortcomings of the formal warranty provisions and administration, which place DoD in the position of a supplicant, do not present an adequate picture of the contractor's willingness to support his system. Informal agreements to guarantee the quality of the product given and observed by the contractor over the years go far in the minds of government contracting officials to overcome the apparent unilateralism of the formal contract provisions. It is difficult to factor these important considerations into judgments about the sufficiency of operationally effective guarantees.

3. The F-16 Fighter Aircraft Airframe

The first contract for the F-16 fighter to be considered covered the period FY1982-85 and the second FY1986-89. The first of these was a fixed-price incentive contract and the second a fixed-price contract. Their kinships with the F-15 contracts and the differences between the two periods in terms of Section 2403-inspired clauses will be addressed below.

FY1982-85

These contracts contained the minimal standard provisions for warranties prior to the recent legislation.

a. Design/Manufacture Defects. These are not specified by name, nor are M/W defects so specified. Rather both are lumped implicitly under "deficiencies," which is simply defined as any condition or characteristic not in compliance with the requirements of the contract. The obligation of the contractor to correct applies only to deficiencies discovered within six months after acceptance.

b. Materials/ Workmanship Defects. See the discussion of Design/Manufacture Defects.

c. Performance Requirements. None listed.

d. Remedies Available to Government. These are the standard obligations imposed upon contractors and options available to government:

- (1) Contracting officer notifies contractor of deficiency within 30 days.
- (2) Contractor responds "promptly" with recommendation for remediation.
- (3) Contracting officer responds within 90 days with directions to correct, partially correct, or not correct.
- (4) If the decision is to partially correct or not correct, an equitable adjustment in price will be negotiated.

e. Warranty Price and Liability Limits. No warranty price is broken out and no liability limits are set. The standard clauses for a fixed price incentive contract are included: the time necessary to correct deficiencies cannot be used to excuse delays in scheduled delivery, and no change in the final contract price can result from the costs incurred in repairing deficiencies.

Considering the complexity and expense of the weapon system the protections afforded government seem deficient. They may be compensated for by the incentive provisions of the contract which were not reviewed by this study.

FY1986-89

The contracts negotiated under Section 2403 requirements do contain important departures, but have certain characteristics that retain the nonrigorous flavor of their older counterparts. Unlike the later F-15 contract it does incorporate the three required warranties and specifies essential performance requirements as a separate warranty and by that name. But it limits the periods of the warranties to six months, which, in the light of the operational life of the aircraft, is short.

a. Design/Manufacture Defects. The system must conform to all design and manufacturing specifications not specifically labelled "goal" or "objective" for six months after acceptance.

b. Materials/Workmanship Defects. The aircraft must be free of such defects for six months after acceptance.

c. Performance Warranty. Essential performance requirements are defined as all those performance requirements delineated in the contract and any amendments which do not contain the word "goal" or "objective." The contractor is obligated, however, only for six months after acceptance.

d. Remedies Available to Government. These are essentially unchanged from the previous contracts except for specifying that the response time of contractor to contracting officer after receipt of a notice of defect will be 90 days. Clauses also are added requiring contractor payment of transportation costs and for contractor payment for the disassembly and reassembly labor cost to repair defects under warranty. These are standard and alternate clauses respectively of the FAR 52.246-18 Warranty of Supplies of a Complex Nature.

e. Warranty Price and Liability Limits. No warranty price is stated. The only limit on contractor liability is that his payments for disassembly and reassembly costs will not exceed \$14.4 million.

The F-16 contracting after enactment of Section 2403 conforms formally to the statutory requirements in specifying the three types of warranties required. But the substantive requirements show little change from warranty obligations on the contractor that were minimal. The 180 day limit after acceptance upon all three types of warranties make them effectively latent defect warranties. Moreover, the EPRs seem to include all requirements related to performance scattered throughout the contract, without selectivity, and to what extent this performance warranty differs from the rather vague warranties of the earlier contracts is not clear. There is, to say the least, a good deal of continuity in the provisions of the contracts of both periods.

4. The F100 Turbofan Engine

The warranties provided the government by Pratt and Whitney in calendar years 1983, 1984, and 1985 are, being aircraft engine guarantees, most complicated. In this respect they are distinctly different from the F-15 and F-16 warranties discussed above. Contracts for calendar years 1983, 1984, and 1985 show virtually no changes. EPRs are not specifically mentioned in the last contract and no significant changes chargeable to the legislation can be discerned.

a. Design/Manufacture Defects. The engine and its parts are warranted to be free of such defects in conformance to purchase descriptions and all other requirements for 240 days after installation for engines and modules provided such installation occurs within one year of delivery. This, of course, protects the contractor from claims for engines or modules that are permitted to be dormant in stock for long periods. For all other parts the warranty is for 240 days after delivery.

b. Materials/Workmanship Defects. These are merged with the D/M warranty discussed above.

c. Performance Requirements. In an expanded warranty for engine, modules, and certain parts, and in separate warranties for the high pressure turbine and for fan disks, additional warranties are exacted.

The engine, modules, and specified parts are warranted in the 1983 contract to be "serviceable" with respect to specified criteria in the work package technical orders for two years from original delivery or 200 hours of total engine operating time (TOT), whichever occurs sooner. The TOT is the amount of operating

time with the fan turbine inlet temperature above 260°C, which is measured by an events history recorder time clock. In 1984 and 1985, for certain parts these requirements were raised to four years or 400 hours TOT.

The high pressure turbine warranty guarantees serviceability under specified criteria for five years or 1,350 tactical cycles, whichever is earlier, for all turbines with eight specified parts that conform to certain engineering changes (ECs). If any one or more of these parts does not so conform, the warranty period falls to 42 months or 900 cycles.

Finally, for fan disks, the engine is guaranteed against damage induced by flawed disks for 3,000 tactical cycles or ten years after delivery, whichever event occurs earlier.

d. Remedies Available to the Government. The remedies include two of the standard three: repair/replace at no increase in contract price, or, if the contracting officer elects not to repair, equitable adjustment in price. However, the contractor is liable only for repair or replacement, and under no conditions is redesign required. This is an interesting limitation on contractor liability. The repair TAT for engines is 120 days from receipt if replacement parts are in stock, otherwise within 120 days of receipt of such parts; for parts from the prime contractor's factory ten days; and for parts that must be ordered from subcontractors 30 days from receipt of damaged parts. If these TATs are not met, the government may exact specified daily damages up to specified ceilings.

e. Warranty Price and Liability Limits. In all three years the contracts specify no warranty prices and no liability limits on the *general* warranty. In the expanded warranty on engines, modules, and specified parts the liability is limited to \$9,200,000 in 1983, \$12,450,000 in 1984, and \$3,830,000 in 1985. In the last year, the liability is split into two parts, one for repair/replace expenses and the other for secondary damage to the aircraft caused by engine failure. No liability ceilings are specified for the turbine or fan disk warranties.

The interesting departure of the F110-100 engine warranty from this one is the presence of operating characteristics (thrust and fuel consumption) in the former and the seeming absence of these in the latter. It is not possible to be certain of this in the absence of the criteria defining serviceability. However, it will be recalled, these OC warranty clauses were not the result of Section 793 or Section 2403.

The warranties are complicated and extensive, and in these respects unique among those sampled in this study. A defense against the charge that Section 2403 effected no change in existing practices is their

pre-existing thoroughness in providing DoD the protection of guarantees. It is difficult to assess the importance of the incentive impacts of the warranties without the means of assessing the costs of the general warranty and those on turbines and fan disks on repair/replacement account. The engine, module, and selected parts liability ceilings seem to nullify negative incentivization, however. Finally, the failure to break out warranty prices as line items is a barrier to judging cost-effectiveness.

B. A SAMPLE OF RECENT ARMY CONTRACTS

Of the three services, to judge from the admittedly small samples of contracts analyzed in this study and from interviews, the Army has been the readiest to conform to the formal requirements of Section 2403. This applies to the use of terminology, contract structure, and tightening of warranty provisions in DoD's favor. This may merely indicate that the nature of its equipment did not make warranties as necessary or their terms as needfully stringent as the Air Force or Navy systems. Whatever the cause, there seems to emerge a general exaction of more favorable terms from contractors in the post-mandate period.

In this section, five Army weapon systems' warranty histories will be analyzed to detect such trends and to discern patterns of warranty types favored by this service. Also, one of the contracts--that for the T-700 helicopter turbo shaft engine--provides the only example of a RIW positive incentive contract found in the contracts observed by this study.

1. Five-Ton Cargo Truck

The progression in warranty stringency is readily observable in contracts and contract modifications in the period FY1980-85 for the Army's Five-Ton Cargo Truck, all of which were signed with AM General Corporation as contractor.

FY1980

The contract signed in FY1980 contained no warranty on the vehicle, and provided merely that any warranties obtained by the contractor from his suppliers on components would be passed-through or conveyanced to the government.

In 1984, however, under Section 794 provisions and in anticipation of Section 2403, a contract modification was negotiated which provided for an "essential performance warranty" to be satisfied by an "essential performance warranty test" (EPWT). This test was to be conducted at the contractor's expense,

was applicable to all vehicles already delivered or to be delivered under the contract, and was to be furnished within four months after award of the modification.

Randomly selected trucks were subjected in the EPWT to a 10,000 mile durability test over various types of terrain, and with 90 percent of the mileage performed with a 5-ton payload, the remaining ten percent without payload. Performance criteria were the following:

a. Durability. The trucks were to demonstrate a .6 probability of completing the test without replacement or overhaul of the engine, transmission, transfer case, or differential. Also, failure was deemed to have occurred for breakdowns requiring major repair or corrective actions.

b. Performance Parameters. Fully loaded, the truck was to meet the following standards:

- (1) Loading. During the test the vehicle was to carry 5 tons or tow 7.5 tons.
- (2) All Terrain Operation. These loads were to be carried or towed over highway, unimproved roads, trails, open fields, hills, and rough cross-country terrain.
- (3) High Speed/Low Speed Operation. The vehicle was to demonstrate a sustained high speed of at least 50 miles per hour, and a sustained low speed of 2.5 miles per hour or less without damage.
- (4) Fording Operation. The vehicle had to ford a hard-bottomed body of fresh or salt water at least 30 inches deep for a 15 minute period without requiring special equipment or adjustments.
- (5) Grade Ability. The vehicle was to demonstrate ability to meet longitudinal grade and side slope requirements and the engine was to pass specified test criteria.
- (6) Braking Ability. Service and parking brakes were required to meet specified requirements.
- (7) Cramping Angle. Turning radius requirements were to be met.
- (8) Cruising Range. Without refueling, the loaded vehicle had to operate for at least 300 miles at an average speed of 30 miles per hour on hard surfaced roads over rolling terrain without refueling.

The contractor was to correct deficiencies revealed on vehicles already delivered to the Army and to remedy revealed defects before delivery on those trucks produced in the future. Presumably, the price of the contract was modified to include the warranty price, but no indication of this was present in the material available. Also, presumably some or all of the performance requirements in the warranty were written into the specifications of the contract, and some tests specified to qualify the trucks for acceptance. It is unclear, therefore, the extent to which the EPWT was a genuine innovation or simply a restatement of existing requirements to attain formal compliance with the new legislation.

It is clear, however, that the warranty functions wholly as an assurance/validation guarantee. No post-acceptance warranty period is specified over which the essential performance requirements must be maintained, and, indeed, no D/M or M/W warranties are included as such. Rather, the nature of the EPWT indicates that they are subsumed in the qualifying tests.

FY1981

The contract modification negotiated in this agreement is a more complex one and reflects conformance to Section 2403. It can be analyzed within the standard format used to structure the study of Air Force contracts.

a. Design/Manufacture Defects. The truck components are divided into two types: depot/GS (general service) parts, or the larger assemblies, and non-depot/GS parts, or all other components. Both types are warranted to be free of design and manufacture defects for 18 months after acceptance. If such a defect could endanger personnel, the warranty period is extended by the amount of time necessary to make corrections for the defective items.

b. Materials/Workmanship Defects. This warranty is identical to the D/M warranty for this category of defect.

c. Performance Requirements. The essential performance warranty is identical to that in the modification to the FY1980 contract, involving passing the EPWT.

d. Remedies Available to the Government. The government reserves the right to correct a defect at one of its depots or to direct the contractor to do so. If it elects the former option, it may use spare parts obtained through its own channels and charge their cost to the contractor, and will bill the contractor at a rate of \$17 per hour for necessary labor. If the contractor is directed to take corrective steps, such actions will be performed at no cost to the government. The government will not submit bills to the contractor for repairs to depot/GS parts whose materials and labor costs are less than \$50.

The contractor is protected against claims when DoD personnel have taken certain improper actions, the vehicle is used in unusual environments or in combat, or the failure is due to reasonable wear and tear. He is also entitled to receive any defective parts he wishes to examine.

e. Warranty Price and Liability Limits. No warranty price or liability limit is specified.

The notable changes in this warranty over the prior are the inclusion of specific D/M and W/M guarantees and the extension of their time periods to 18 months after acceptance. The desire of the Army to maintain in-house repair capability on warranty defects is also a feature worth noting. It would have been unallowable without a waiver under Section 794, which required contractor repair.

FY1985

The warranty written into this contract conforms rather closely to the requirements of Section 2403 and FAR 52.246-19 (Warranty of Systems and Equipment Under Performance Specifications or Design Criteria) as presented in Chapter III. Some tailoring to the nature of the equipment and its long-standing production experience has been incorporated.

a. Design/Manufacture Defects. No D/M warranty as such is specified. However, the extensive performance warranties on the system and its components effectively incorporate one.

b. Materials/Workmanship Defects. This warranty holds for defects discovered within 15 months of acceptance of the vehicle or 12,000 miles of operation, whichever is earlier. Also, any warranty received by the contractor from his suppliers is conveyed to DoD.

c. Performance Requirements. The performance warranty is somewhat altered from the contract modification clauses in FY1981. The EPWT is replaced by an Initial Production Test (IPT), which is performed on eight trucks (presumably from the contract lot size) to check 12 large assemblies. Two of these eight are subjected to vehicle performance testing which essentially duplicates the EPWT with some added requirements for the engine and an additional radio interference suppression requirement on component equipment. However, the warranties apply only to defects discovered during the IPT.

Finally, for the first time, and following the guidelines of FAR 52.246-19, there is a warranty on data. These include documents, drawings, photographs, computer software, and so forth. It must conform to contract requirements and is warranted for three years after delivery of the data.

d. Remedies Available to the Government. The remedies are the standard ones outlined in the FARs. In the event of an M/W defect, the contracting officer must notify the contractor with 45 days, the contractor must respond with a recommendation within 30 days, and the contracting officer must decide within 15 days to direct correction, partial correction, or noncorrection. In the first case, the contractor must bear the cost at no increase in contract price. In the latter two cases, the government will receive an equitable price adjustment. Some of the alternate clauses of the FAR are included: contractor liability for costs of disassembly/assembly and transportation, as well as non-extension of schedules because of defects.

The vehicle performance warranty requires the contractor to perform all required engineering and manufacturing work (essentially a D/M warranty) to permit the sample vehicles to pass the IPT. Any such defect is presumed to exist in all IPT and production vehicles, and must be corrected in all vehicles unless the contracting officer excuses this requirement. The same types of procedures and remedies as exist for M/W defects, with some changes in time periods, are specified for performance warranties.

Finally, for breach of warranty on data, the contracting officer can direct correction or noncorrection. If the contractor does not correct promptly when so ordered, the contracting officer can contract the task to other parties at the contractor's expense. In the event of noncorrection an adjustment in contract price will be negotiated.

e. Warranty Price and Liability Limits. No warranty price or liability limits are specified.

The history of contracts for this weapon system reveals a clear-cut case where recent Congressional legislation effected sharp changes in warranty procedures. From an initial position where no warranties were exacted from the firm, the guarantee clauses evolved to extensive protection for DoD. The primary function they serve is assurance-validation, being oriented primarily toward being satisfied through passage of an acceptance test. However, the latent defect period in the latest contract was extended to 18 months or 10,000 miles. The performance warranty, is quite extensive, covering both OCs and RMACs, and is in conformance with this study's interpretation of Congressional intent.

2. **Bradley Fighting Vehicle and Multiple Launch Rocket System Carrier**

The warranty provisions for the Bradley Fighting Vehicle (BFV) and the Multiple Launch Rocket System carrier (MLRSC) were negotiated in one package. These guarantees follow a progression to

conformance to Section 2403 requirements and reveal interesting new departures such as the threshold assurance warranty which is based on the Army's expected failure concept. Army contracting officials in discussions said that they felt it was a valuable warranty form in incentivizing the contractor, spreading risk equitably, and reducing support costs. Finally, the contract series reveals, to the objective analyst, a pro-contractor leaning, in that contractor responsibilities and liabilities are more restricted than in most other Army contracts in recent years. It is believed that competitive pressures were less strong in the contract award than in other cases, and that the contractor has a reputation among contracting personnel as a tough negotiator.

FY1984

In a FY1984 contract modification the basic warranties on the equipment were established in the light of Section 794.

a. Design/Manufacture Defects. The equipment is warranted to be free of D/M defects that would interfere with meeting the performance requirements for 1) 365 days after acceptance, 2) 1,000 miles, or 3) 200 hours of operation after arrival at the first active or inactive (i.e., POMCUS or War Reserve stocks) use destination, whichever occurs first. The duration will be extended up to 90 days if the vehicle is in transit or storage before its first use. Repaired or replaced parts receive the same warranty but the period cannot exceed 21 months beyond the date of vehicle acceptance, unless a supplier warranty greater than that is passed through to DoD.

The maximum duration of the vehicle guarantee, therefore, is 455 days. For any BFV which enters inactive status and remains so for more than 455 days, DoD was to receive a price reduction of \$2,731, and for an MLRSC \$2,083.

b. Materials/Workmanship Defects. This warranty is coextensive with the D/M warranty.

c. Performance Requirements. The vehicles must conform to specified performance requirements over the periods designated in the discussion of D/M defects above. They are deemed to have conformed to those requirements if they do not require repairs or parts replacements for D/M and M/W defects. Hence, the performance requirements are RMACs and are straightforward extensions of these two

types of warranties. The length of the post-acceptance warranty period is at the lower end of the range specified by AR 700-139 discussed in Section A.2 above.

d. Remedies Available to the Government. In the event of a warranty breach, the contractor is obligated to repair or replace (at his option) necessary parts, and if such repairs are at his facilities to bear transportation costs from and to points of breakdown in CONUS or Western Europe. Most significantly, however, "the Contractor shall not be responsible for redesigning any part in order to achieve compliance with the performance requirements." This is a significant relief from contingent liability, and may reflect contractor insistence on the strict interpretation of Section 794, discussed in Chapter IV, whose provisions could be interpreted as requiring only repair or replacement.

Army insistence on capability to make repairs in the warranty period--which was formalized later in AR 700-139--is manifest in a clause which permits it to do so and charge the contractor at \$15.88 per hour for labor as well as to receive parts to replace its depleted stocks.

The government is required to report defects within 45 days and the contractor is required to remedy the defect "promptly." The contractor is protected against claims arising from the usual sources: unauthorized spare parts, reasonable wear and tear, acts of God, combat, mishandling, and so forth.

e. Warranty Price and Liability Limits. No warranty price is listed, but the refunds afforded DoD for equipment that is inactive beyond the warranty period--\$2,731 for a BFV and \$2,083 for a MLRSC--may be taken as estimates of the implicit prices of the warranties per vehicle. No monetary liability limits are present in the warranty clauses.

FY1985

In the FY1985 contract the warranty portion refers explicitly to the requirements of Section 2403. Its terms became more complicated.

a. Design/Manufacture Defects. The distinction between depot/GS and non-depot/GS parts, found in the Five-Ton Cargo Truck warranties for the FY1981 modification, is repeated here. For the latter type of part, a "lot defect" is defined as one in which the part is not in conformance with the D/M and M/W guarantees and which necessitates DoD action to correct previously accepted vehicles from the same lot.

For depot/GS parts the D/M warranty requires all parts to conform to contractual requirements for 12 months after acceptance of the last vehicle delivered under the contract. For non-depot/GS parts only lot defects are warranted for the 12-month period, and that coverage begins only after failures exceed 150 percent of the predicted failure rates of these parts. For depot/GS defects, the contractor is liable for parts, labor, and transportation costs, but for non-depot/GS parts he is responsible for the costs of the parts only. In no case is the contractor responsible for redesign necessary to achieve compliance with any warranty. This type of waiver was specifically authorized by DFARS 46.770-3, as noted in Section A.1, so that it receives a sanction it did not have explicitly in the FY1984 modification.

b. Materials/Workmanship Defects. This warranty parallels the D/M warranty for defects resulting from faulty materials and workmanship.

c. Performance Requirements. Essential performance requirements are explicitly listed for both vehicles, but *only* depot/GS parts are warranted for the 12-month period. In the absence of the listings of the EPRs, the study cannot characterize them as to type of characteristics warranted. However, because the vehicles themselves are not guaranteed, and only one category of parts is, it is reasonably clear that the EPRs are dominantly RMACs.

d. Remedies Available to the Government. When depot/GS parts are defective and subject to any of the three warranties, DoD will make the repairs from its stocks of spares and bill the contractor for labor at the rate of \$18 per hour. DoD may then require the contractor to correct or partially correct the defective components, may elect to do so itself at contractor expense, or elect not to correct the defect and reduce contract price equitably. The notice of a defect must be given by DoD within 45 days of discovery and the contractor must comply with DoD directions within 30 days.

However, these remedies for depot/GS parts are available to DoD *only after a cumulative total of 2,756 valid warranted defects are registered.* This is an instance of a threshold assurance warranty, that threshold determined by the expected failures of such parts over the period.

For D/M and M/W defects under warranty in the case of non-depot/GS supplies, the contractor is free to choose repair or replacement in the case of lot defects. That is, the contractor is not responsible for failures that are not classified as lot defects, is not responsible for EPR breaches of warranty when induced

by lot defects, and is then responsible only for repair or replacement of parts. All other costs of the lot defect correction are to be borne by DoD.

Beyond these protections to the contractor for both types of parts defects, a financial liability ceiling on his warranty obligations has been established, to be noted below. The contractor is protected by the standard disclaimer clauses discussed in prior contracts. He will be responsible for maintaining delivery schedules in the contract despite any warranted defects discovered. Finally, no warranty claims whose costs are \$50 or less will be submitted by DoD.

e. Warranty Price and Liability Limits. The contract refers to "prices for warranty administration." They are based on the assumption that the contractor will receive subsequent annual contracts for BFVs and that those contracts will include warranties against which those administrative costs can be charged. In the event those contracts do not get awarded, or they are awarded but do not contain warranties, the contract price will be adjusted upward to absorb unallocated warranty administrative costs up to a maximum DoD obligation of \$445,435. Except for administrative costs, DoD paid nothing for the threshold warranty.

Finally, the contractor's contingent liability for the correction of all types of warranted defects will not exceed \$6.5 million.

On the whole, one must judge that the added flexibility given contracting officers by Section 2403 redounded substantially to the benefit of the contractor. It is true that the warranty period was extended from a maximum of 455 days to the period between the acceptance of the first vehicle and 12 months after the acceptance of the last vehicle delivered under the contract. But in other respects the contractor's burdens were substantially reduced: warranty coverage, financial liability limits, and government responsibilities record notable gains for the firm. Cost pressures upon government negotiators were cited as major reasons for this relaxation of contractor responsibility in interviews.

Also, the dominant function provided DoD by the warranty is that of assurance/validation of RMACs in a post-acceptance phase. Incentivization is negative and not overly strong, and insurance plays no role at all.

FY1986

The one notable innovation in this contract, when compared with that for FY1985, is the definition of a *systemic defect*. This occurs when a depot/GS or a non-depot/GS part is in compliance with D/M and M/W warranties but causes noncompliance with the EPR warranty and therefore requires redesign and refitting on vehicles already produced and those to be produced in the future. Finally, the parts afflicted with systemic defects must show a failure/defect rate in excess of 150 percent of predicted failure rates. Correction of such a defect requires redesign.

The inclusion of this warranty provision is significant. With the establishment of proof of design and mature production experience for current Army weapon systems, contracting personnel indicated that the Army will orient its warranty policy increasingly to obtain systemic defect guarantees for (ideally) half the service life of systems. This is a substantial reorientation of perceived warranty function from assurance/validation to insurance and the wisdom of the move will be addressed in Chapter VI.

The changes in the warranty provisions from the FY1985 contract are listed below.

- a. Design/Manufacture Defects. No changes.
- b. Materials/Workmanship Defects. No changes.
- c. Performance Requirements. The EPR warranty is extended to cover systemic defects, which implies that non-depot/GS parts are warranted only to the extent they reveal such failures.

The threshold level of depot/GS part defects is set at 1,570.

The contractor is now made liable for the cost of correction of systemic defects after DoD has expended a threshold level of \$1,923,833 in redesign, test and evaluation, manufacturing, transportation, and installation costs. Moreover, systemic defects in depot/GS parts will be included in the cumulative total of defects that determine proximity to the threshold. If DoD opts to correct the defect before reaching the threshold cost value, the contractor is relieved of his liability. If the systemic defect threshold is breached, a contingent liability ceiling is set for the contractor equal to that threshold. Hence, the maximum percentage of costs of systemic defects correction that can be borne by the contractor is 50 percent.

When redesign is required, the contractor must submit a redesign plan within 45 days or some other period mutually agreed upon, and it must be accepted or rejected by the contracting officer within 30

days. If accepted, the contractor will proceed with the plan. If rejected, he must submit a revised plan within 30 days. If deemed adequate, but DoD elects to use its own design instead, the contractor is entitled to an equitable adjustment for the difference in costs between his and DoD's designs. Moreover, the contractor will not be responsible for defects in the DoD design.

d. Remedies Available to the Government. No changes except those indicated in the discussion of systemic defects.

e. Warranty Price and Liability Limits. Except for administrative costs, the warranty for systemic defects was purportedly costless. The government's maximum liability for unallocated administrative costs is \$387,507. The contractor's liability for depot/GS and non-systemic lot defects is limited to \$3,847,765. As noted above, his liability ceiling for systemic defects is \$1,923,883.

The inclusion of the systemic defects clause is a step in the direction of increasing DoD's protection. It recognizes the partial responsibility of the contractor for the design of the system and provides a means of sharing the risk of redesign costs that is capped at 50 percent for the contractor. This obviously provides a negative incentive to the contractor in his design activities.

This inclusion is a significant move in the employment of warranties for the purposes Congress intended in the new legislation. Nonetheless, with the rather small liability ceilings and the dominant assurance/validation function of the warranties for RMACs, the judgment must be that it is distinctly liberal in its treatment of the contractor.

3. The Stinger Missile

The Stinger missile is an air defense weapon which uses an infrared sensor to home in on fixed- or variable-wing aircraft. It is shoulder-fired, is stored in a sealed tube and requires no maintenance in the field. It replaced the Redeye system, and was initially deployed in 1981. The Stinger-POST, for which the following two sets of warranties were written, has a follow-on seeker of advanced design and entered production in FY 1983. The prime contractor is General Dynamics Corporation.

FY1983

The Stinger-POST missile rounds were produced under a fixed-price incentive contract and its common hardware was manufactured under a firm fixed-price contract. The warranty provisions were straightforward assurance-validation clauses and are contained in a September 1984 modification.

a. Design/Manufacture Defects. Rounds and hardware are warranted in design and manufacture to conform to specified performance requirements for 36 months after acceptance. They are deemed initially to have conformed upon passage of all required tests.

b. Materials/Workmanship Defects. Rounds and hardware are also guaranteed to be free of M/W defects for 36 months after acceptance.

c. Performance Requirements. These are merged into the D/M and M/W warranties. It is stated that performance requirements will not include any such that are stated in terms of goals or objectives.

d. Remedies Available to the Government. The contractor is obligated to repair or replace items necessary to achieve the specified performance requirements. The contractor will not receive an increase in the ceiling price to recompense costs in the fixed-price incentive contract nor in the contract price for the firm fixed-price contract for the hardware. If prompt repair or replacement of items is not made by the contractor, DoD has the right to procure items from its sources and charge the contractor for them.

If the technical data package has to be corrected, the contractor must submit an ECP for approval, and DoD is charged to review it promptly. The contractor may incorporate the change before approval, and DoD has no ability to interfere with the incorporation. But if the government challenges the change and is upheld, the contractor must retrofit all affected units at its expense. DoD also has the right to direct the contractor to use an alternative solution.

DoD must notify the contractor of a breach of warranty within 60 days. Failures must be verified where feasible. Launched missiles are excluded from the repair and replacement clauses of the warranty. Time necessary for warranty corrections cannot be used to excuse schedule slippages. The contractor is protected from test failures due to personnel error or equipment deficiencies or from exposure to environments beyond specifications.

e. Warranty Price and Liability Limits. No warranty price is listed. The contractor's liability for transport costs on failed items to and from the Red River Army Depot in Texas is limited to \$75,000 for the contract.

FY1985

In accordance with Section 2403, the warranties in this contract were rewritten to conform formally with the act. Few actual changes were made, however, with the exception of defining *modal failure* as a repetitive failure with the same root cause. This is unlike a systemic failure because it may occur due to failure to conform to warranty requirements. A *warranted item lot* is defined as two consecutive one-month production quantities which have been produced under the same conditions utilizing the same processes.

a. Design/Manufacture Defects. This warranty is essentially the same as the prior year's, but is related to the design and manufacturing requirements of the contract, not to performance requirements.

b. Materials/Workmanship Defects. This provision is identical with that in the prior contract.

c. Performance Requirements. The items are warranted to conform to the EPRs and product specifications of the contract.

d. Remedies Available to the Government. In the 36 month warranty period, DoD may direct the contractor to conduct an analysis *at DoD expense* of failed items. If the analysis reveals a modal failure due to nonconformance to one or more of the three warranties, such that weapon performance reliability falls below the minimum level of .864 with 75 percent confidence, the contractor must take corrective action. No change in target cost or price, ceiling price, or share ratio of the incentive portion, and no change in the firm fixed-price portion of the contract will be made in the way of adjustment. Compliance with the reliability minimum will be determined lot-by-lot, and the failure rate projected on the basis of the quantity of missiles in the lot.

The contracting officer must notify the contractor of the need for corrective action promptly, and the contractor must respond within 30 days with recommended corrective action. Within the next 30 days

the contracting officer must notify the contractor of his desire to correct, partially correct, or not correct the defect. Noncorrection or partial correction requires the contractor to submit within 90 days a proposal for a contract price reduction.

The contractor is relieved of the burden of transportation costs to and from Red River. No schedule stretching will result from correction of warranty deficiencies. If the contractor does not conform to the above procedures promptly, DoD may correct the deficiencies and charge the contractor. The contractor is protected from the need to correct deficiencies under the conditions listed in the prior contract analysis.

e. Warranty Price and Liability Limits. No warranty price or liability limits are listed.

The new legislation seems to have inspired somewhat tighter reliability requirements than existed in the previous agreement. Given the nature of the equipment, the EPRs must be defined predominantly as RMACs, and the provision for the possibility of modal failure and lot analysis indicates a tightening of standards. The warranty period of 36 months has not been changed and does not seem excessively long, given the dormant nature of the missiles. Indeed, retesting on a sample basis after this period, as is required on the Navy MK48 ADCAP to be analyzed below, might be expected. DoD bearing of the cost of analysis is nonstandard. In sum, the new legislation seems to have impacted the contract primarily by sharpening the definition of the EPRs, not by changing their nature. No changes in the post-acceptance warranty period or in other important characteristics of the warranties were made.

4. The Ground Laser Locator Designator

The Ground Laser Locator Designator (GLLD) is a precision instrument to support ground fire by determining range, azimuth, and elevation of enemy targets, thereby reducing the time necessary to put artillery fire-for-effect on target. After this locating function is fulfilled the GLLD can also put an invisible laser spot on the target if desired for a laser homing munition. It was originally fielded at the end of 1982, and is now in mature, full-scale production by the Hughes Aircraft Company.

FY1982

The warranties in this contract are assurance/validation warranties, with conformance at delivery or acceptance. It contains a standard application of early 1980's equipment warranties, modified to quiet DoD concerns about time to repair.

a. Design/Manufacture Defects. This warranty (termed a drawing/manufacturing conformance warranty) warrants the equipment to conform for 12 months after acceptance or delivery (whichever is earlier) to all drawing and manufacturing requirements.

b. Materials/Workmanship Defects. This warranty guarantees the equipment to be free of M/W defects for 12 months after acceptance or delivery.

c. Performance Requirements. No separate warranty is incorporated for performance, but it is implicitly subsumed by the D/M warranty, and performance requirements for DoD acceptance are deemed to be met when the product passes a procurement quality assurance test and a checkout procedure at the contractor's facility.

d. Remedies Available to the Government. Upon detection of a defect within the warranty period, the contracting officer must notify the contractor promptly, and the latter must correct it at no increase in contract price. The repaired or replaced parts are warranted for the remainder of the 12-month period. No schedule extensions are permitted for time needed to correct defects. Except for one procedure which can be performed without breaking a seal, the warranties are invalidated for any repair or adjustment by DoD personnel. Transportation costs on repaired or replaced units are to be borne by the contractor.

Since all spare parts must be produced by the prime contractor and all corrections performed by him, elaborate procedures for provision of parts from government stocks and their replacement are included. A 90-day repair TAT is required if necessary parts and facilities are available. Priorities are established for repair/replacement relative to current production. The TAT may be extended to 180 days if repair parts must be procured from supplier sources.

The contractor is protected by the standard clause concerning combat and consequential damage to third parties.

e. Warranty Price and Liability Limits. Because of the strict assurance/validation nature of the warranty, it would not be expected that a warranty price was charged, and no mention of such a charge is present. Also, no liability limit is specified for contractor responsibility. However, because the contract is a fixed-price incentive agreement, there is a clause asserting that costs to effect the warranties can be considered in establishing the final price.

In brief, the warranties on the GLLD, which was just beginning to enter full production, were standard assurance/validation guarantees, requiring passage of acceptance tests and a one-year latent defect period. They are, therefore, unexceptionable in their representative content, and furnish a good base from which to judge departures instituted by the recent legislation.

FY1984

The warranty provisions of this contract are duplicates of those in the FY1982 contract except for one feature. A total liability ceiling on repair, transportation, field engineering and administration costs borne by the contractor to execute the warranties is set at \$360,000. This is in lieu of the earlier contract's provision for consideration of such costs in the final price of the contract. This is a change necessitated by going to a firm fixed-price contract. The contingent liability ceiling for units of equipment that are being produced at the rate of at least 360 units per year certainly prevents strong negative incentive effects.

FY1985

The warranty provisions of this contract were written explicitly to meet the requirements of Section 2403. They are more extensive and written within the format of the statute.

- a. Design/Manufacture Defects. This warranty is now termed a design/ manufacturing warranty, but provides, as in prior contracts, for a 12-month warranty period following acceptance or delivery.
- b. Materials/Workmanship Defects. This duplicates prior M/W warranties.
- c. Performance Requirements. For the 12-month period specified above, the equipment is guaranteed to meet EPRs which are specific to 11 characteristics of the system, all of which specify OCs.
- d. Remedies Available to the Government. These contain no significant departures from the two prior contracts.
- e. Warranty Price and Liability Limits. The contract is most interesting because it lists the portions of the contract price attributable to the warranties. The equipment is composed of two

components: the Laser Designator Rangefinder (LDR) hardware and the LDR unit. The first has a warranty price of \$863 per unit and the second \$925 per unit. These are subject to adjustment, along with contract price, if amendments or changes to the contract affect warranty compliance.

The total liability ceilings on the hardware, including repair and transportation costs only, is \$604,100, or \$2,237 per unit. For the LDR unit it is \$2,312.50 per unit, with the quantity to be produced between 180 and 240 units at DoD option.

The most notable changes effected by the recent legislation are the negotiation of liability limits for the contractor on generous terms. Warranty periods were not extended. It is true that EPRs of the OC type were explicitly specified, but the degree to which the prior test requirement incorporated them is not clear. The new legislation cannot be said to have had major effects upon assurance/validation, insurance, and incentive characteristics of the contract. One positive contribution from the viewpoint of judging the cost effectiveness of the warranty is the breakout of warranty price. The payment of premiums of 39 to 40 percent of potential reimbursements for defects does not seem to be effective insurance. The incentivization function is the one, therefore, that must justify cost-effectiveness, and the low limits on contingent liability raise questions of the warranties' potentials in this dimension.

5. The T700-GE Turboshaft Engines

As a last Army weapon system contract, that for the T700-GE-700 and T700-GE-701 engines for helicopters will be analyzed with respect to warranties in the FY1979 and FY1985 versions. This is the General Electric turboshaft engine used in the UH-60A Blackhawk utility helicopter produced by Sikorsky.

FY1979

This is an RIW and, as an aircraft engine warranty, complex. It covers the T700-GE-700 engine, and the contract in which it is embedded provides for the delivery of 170 engines.

a. Design/Manufacture Defects. No D/M warranty as such is provided in the contract. The concept of defect is wholly defined in terms of engine failure, and that in turn is defined as the breakage or malfunction or a part or injury to a part rendering it unserviceable. Hence, design is not involved in the warranty. The control of the configuration of the engine insofar as changes are required to eliminate present or future failures is reserved by the contractor, although DoD must approve any changes that affect engine

performance or weight, part or modular interchangeability, maintainability, or installation in the Blackhawk aircraft.

b. Materials/Workmanship Defects. Each of the engines is warranted to be free of M/W defects at the time of delivery and for three years from the date of acceptance of the first engine or after 500 total engine hours on each engine delivered, whichever occurs first.

c. Performance Requirements. No specific performance warranty is contained in the contract, but the limitations on the contractor's ability to effect engineering changes indicates that conformance to such requirements is necessary for acceptance.

d. Remedies Available to the Government. If a part has been found to be defective, a contractor and a DoD representative will determine jointly if warranty liability exists. If engine teardown is necessary to establish this, DoD will bear the expenses. The government must maintain records on the engine and permit the contractor to inspect them. If both representatives agree that any one of a variety of improper procedures by DoD personnel has been followed or the engine was operated in combat, the warranty is voided. This also holds true if spare parts other than the contractor's are used in repairs. The information concerning a possible warranted defect will be conveyed by the contracting officer to the contractor within 60 days of discovery.

If an engine failure occurs within the first 250 hours of operating time, the contractor must give DoD 100 percent allowance for all parts involved in the failure. If the engine requires removal to depot for repair, the contractor must repair the engine at no charge.

If the engine fails after 250 hours but before the end of the warranty period, the contractor is liable for a pro rata share of the sum of the parts prices (P) determined by

$$\text{Allowance to DoD} = (P) \frac{(500 - T)}{250},$$

where T is the hour of failure. The allowance due the government for repair of the engine is the same proportion of the repair price. Transportation, assembly, and disassembly costs are borne by DoD.

The RIW provides that DoD will pay a reliability incentive (RI) for each hour that an engine (and some other components) operates in excess of the warranted 500 hours up to 750 hours during the three years following the first engine delivery. The amount of the RI is either:

- (1) Five percent of the target price of the engine times the fraction $(T-500)/250$, or
- (2) Seven percent of a part's price multiplied by the same fraction,

where T is the time of failure. The maximum total RI is \$570,000, or \$3,353 per engine.

e. Warranty Price and Liability Limits. No warranty price is listed in the contract. The contractor's total liability under the warranty is limited to \$4,085,000 or about \$24,000 per engine.

The warranty is an extensive one in terms of protection of the government against parts failure. It does not provide for redesign in the event performance characteristics do not persist after acceptance. The limit on contractor liability continues to surprise in terms of its tempering of negative incentives or insurance to DoD. And it is difficult to believe that a maximum reliability incentive of less than \$3,500 per aircraft engine could independently inspire much extra effort on the contractor's part.

FY1985

The warranty provisions in FY1985 include both the T700-GE-700 and T700-GE-701 engines and are written to conform to Section 2403. They are, therefore, considerably more complex than the earlier warranties, but do not contain a RIW.

a. Design/Manufacture Defects. The aircraft engine and its primary components (hydromechanical control unit and electrical control unit) are warranted to be conformant to design and manufacturing requirements for 240 flight hours or 24 months after acceptance, whichever is earlier. This is a reduction from the 500 hour/36 month warranty in the FY1979 contract. Parts other than primary and secondary components, which are repairable only at depot level, are warranted only on a lot defect basis. When correction of such parts must be done on a campaign basis, meaning retrofit of fielded units, DoD bears all costs of repair except for parts.

b. Materials/Workmanship Defects. In the same period and under the same limitations as in the D/M warranty, the equipment is guaranteed to be free of defects in materials or workmanship that would cause it to fail to meet the performance requirements specified in the next warranty.

c. Performance Requirements. The equipment is warranted over the period and within the conditions of the D/M warranty to meet performance requirements specified as engine operating and

maintenance limits of serviceability, shaft horsepower, and specific fuel consumption requirements listed in certain technical manuals. Changes in these requirements will be made by mutual agreement with equitable adjustments in price.

d. Remedies Available to the Government. Repairs to primary and secondary depot reparable components will be performed at a depot repair point either at a contractor facility or, at the option of DoD, at a government facility. In the event, Corpus Christi Army Depot was chosen. This provision is in line with Army policy to provide organic depot maintenance for its equipment. On a case-by-case basis these component repairs may be diverted to the contractor's facility if the contractor assumes the costs and risk of loss involved in transport, DoD undergoes no additional expense, no increase in TAT is exacted, and the contractor agrees that all repairs are warranted before shipment.

Items returned to the depot for repair will be examined by a contractor and DoD representative to determine if the items are warranted. If a teardown is required, DoD will bear the cost. In the event of disagreement, the dispute will be resolved in accordance with the disputes clause of the contract. Upon preliminary determination of warranty coverage, the representatives will estimate the extent of needed repairs, and their costs to the government will be reimbursed by the contractor, with labor priced at \$48 per hour. However, the contractor has no obligation to conduct failure investigations or redesign efforts under the warranty.

The government must notify the contractor of a warranted failure within 90 days of its discovery, and deliver the failed item to the depot within 180 days of failure. Within 15 days of receipt the contractor must be notified, and he must arrange for the joint investigation with 30 days of that notice. DoD will bear the costs of shipment.

At lower-than-depot levels, Army personnel will conduct maintenance, and their use of non-contractor provided parts will not void the warranties unless those parts caused failure.

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e. Warranty Price and Liability Limits. No warranty price is specified, nor are incentive clauses included in the warranties. The maximum liability of the contractor for all costs of all warranties is \$19.7 million.

This recent warranty is more thorough in its provisions and incorporates all three mandated types explicitly. Performance requirements are explicitly stated and encompass OCs. Defects are no longer defined in terms of breakage or malfunction of parts, but include failures to attain such OCs as shaft horsepower and engine fuel consumption. However, the period of warranty was reduced from the FY1979 contract, and the contractor remains free of any redesign commitment.

The Army reasserts control over the repair procedure under the contract in line with Army policy. Finally, the RIW feature is eliminated along with its positive incentive effects.

C. A SAMPLE OF RECENT NAVY CONTRACTS

The Navy has had a long history of requiring warranties (the service's term is "guaranties") on its vessels and equipment, and hence revealed some uncertainty about the implications of the new legislation in the light of its existing procedures. Its initial reaction to the Section 794 legislation was that it would interpret the statute as simply a mandated requirement to continue to use its inspection of supplies and correction of defects clauses.² The Navy felt that Congressional intent was simply to mandate warranties for weapon systems which it had long required, and it was the least concerned of the services in its ability to conform to the new requirements.

The sample of Navy weapon system warranties analyzed below tends to support the view that adaptation to the new legislative procedures was relatively smooth in several respects. Past warranties had stressed the demonstration of performance capabilities in extended acceptance tests and post-acceptance periods. Although Navy practice had stressed the assurance/validation function of guaranties, and therefore a reluctance to pay for such warranties, it was also experienced in incentivizing contractors. Hence, the flexibility in contracting urged by Congress and incorporated in Section 2403 and DFARS was incorporated rather easily in the Navy's recent contracting.

1. The CG-47 Aegis Guided Missile Cruiser

This FY1985 incentive price contract for a major weapon system is a good example of the format and content of ship contracts executed by Naval Sea System Command (NAVSEA) prior to Section 2403.

² See, for example, the testimony of Admiral Steven A. White, Chief of Naval Materiel, in [22], pp. 36-40.

Its guaranty provisions do not fit neatly within the classifications used in prior warranty analyses, and they will be dispensed with for this contract.

The warranty provisions are written in terms of a series of trials of the completed vessels. Builder dock and sea trials are conducted with Navy cooperation and observation, and deficiencies with respect to contract specifications and performance are corrected. When that is done to the satisfaction of the contracting officer, the contractor and the Navy perform acceptance trials. Upon their completion, at least 30 days must be provided by the contractor to correct all contractor-responsible deficiencies which could have an adverse effect on operational capability. The vessel is then delivered to the Navy for preliminary acceptance.

A nine-month guaranty period commences with preliminary acceptance, during which the ship is fully equipped and armed and in all respects complete and ready for service. It is given final trials under conditions prescribed by and at the expense of the Navy, with a contractor engineer on board with contracting officer approval. The guaranty period is extended by any time periods during which the ship is not operational because of a contractor-responsible defect. At the end of the guaranty period the vessel receives final acceptance, at which point the contractor's guaranty obligations cease except for defects caused by fraud or gross mistakes amounting to fraud.

During the entire period from the start of construction to final acceptance the Navy has the right to inspect and test, where practicable, all supplies--raw materials, components, intermediate assemblies, and end products. All defects during this period will be corrected by the contractor, subject to contractor inspection where feasible, with disputes being settled within provisions of the contract, or, at Navy discretion, corrected by its personnel or by contract.

If the contractor does not promptly effect corrections within required time periods, the Navy may make the repairs by other means and reduce the target or final price, or may cancel the contract for default. Contractor repairs will be made at no expense to the government.

The expected costs of supporting the warranties will be included in the final negotiated cost of the incentive price finally agreed on, and it will not be increased subsequently because of repair costs. However, the liability of the contractor for the correction of all defects discovered after preliminary acceptance, except for fraud and effective fraud, is limited to \$1 million per vessel.

2. Major Subsystems - CG47 Guided Missile Cruiser

In FY1984 the Navy decided to obtain separate warranties on three major Aegis subsystems: two transmitter groups and the fire control system, produced by RCA. The warranties were repeated in the FY1985 contract. The two contracts are interesting in their essentially identical contents, illustrating the continuity of the Navy's movement from nonmandated to mandated warranties. Both contracts will be discussed simultaneously to emphasize their similarity.

a. Design/Manufacture Defects. Both contracts specify the requirement that the components are designed and manufactured in conformity with *minimum specified performance requirements* referred to in specified technical manuals. These requirements are deemed to be met upon passage of the System Performance Test. The warranty period is for two years after acceptance.

b. Materials/Workmanship Defects. Both contracts guarantee that the equipment will be free of M/W defects at the time of acceptance that would cause it to fail to conform to the minimum specified performance requirements. These are met upon passage of the System Performance Test. The warranty period is two years after acceptance.

c. Performance Requirements. The FY1984 contract contains no performance warranty. The FY1985 contract contains a third warranty which guarantees conformance to the "performance requirements" of the contract for two years after acceptance. This is somewhat compromised as a separate warranty by the clause that refers to such nonconformance "due to material or workmanship," which rules out nonconformity because of design failures. It would seem, therefore, to be largely a repetition of the M/W defects guarantee. Another confusion is that the M/W warranty refers to minimum performance requirements as stated explicitly in an exhibit, whereas "performance requirements" are not explicitly referenced.

d. Remedies Available to the Government. These are almost identical in both contracts. The contracting officer must notify the contractor of a defect within 45 days, and where practicable the contractor will participate in the investigation of any special or unusual circumstances connected with the failure if they exist. The contractor must repair or replace the parts at his option promptly at no increase in cost to DoD, or the contracting officer can have the work done at contractor expense. The contractor is obligated to pay transport costs and to furnish data to DoD on the causes of the

failure and steps taken to correct it. The contracts contain the standard clause giving the contracting office the right to an equitable adjustment in price if he does not elect a full correction of the defect. The contractor is not obligated to repair combat damage or ordinary wear and tear under the warranties nor is he responsible for consequential damages from failure of the equipment. He is also protected from the obligation to repair when failures result from inadequate support facilities or mishandling, misuse, or incorrect installation by DoD personnel.

e. Warranty Price and Liability Limits. The FY1984 contract states that the contract price of \$102.5 million does not contain an allowance for the price of the warranty which, in negotiations, is not to exceed \$3,763,000, which is 3.67 percent of contract price or 1.84 percent per warranty year. The FY1985 warranty price is not to exceed \$5,525,600, and no contract price is listed. Neither contract contains liability limits.

Both contracts are essentially identical, with the formal difference of an addition of a performance requirements warranty to conform to the requirements of Section 2403. However, its terms are ambiguous and seem to add no substantive protection for DoD to prior conditions. In brief, the new legislation impacted the warranty provisions negligibly, in largest part because existing warranty protection conformed closely to Section 2403 requirements.

In addition to the CG-47 major subsystems warranties, the guarantee provisions for close-in weapon systems and for machinery were examined for FY1985 contracts. They reveal standard clauses which do not warrant extensive analysis since they simply duplicate the analysis above. The close-in weapon systems warranty period is for two years after acceptance and performance requirements include an MTBF specification of 1,168 hours. The machinery warranty period begins with conditional acceptance of the equipment and ends 12 months after successful passage of combined sea trials. Given the long warranty periods for both systems, the Navy retains the right to remedy defects with its own personnel and charge the contractor for such corrections.

3. The MK48 Advanced Capability (ADCAP) Torpedo

The FY1985 contract for the MK48 ADCAP torpedo with Hughes Aircraft does not permit a comparison with earlier contracts to denote procedural changes, but does have other contributory potentials for the study. First, it contains warranties on an item which is a dormant system not subject to continuous performance checks, but whose performance when required must be as near-perfect as precautions and

guarantees can assure. Second, as a consequence, the warranties and testing procedures are complex and exemplify Navy procedures for such systems that predate current warranty legislation. Third, the contract has a rationale appendix explaining the reasons for the warranty provisions.

The life-cycle testing program for the MK48 is highly structured. After manufacture the torpedoes are tested by the contractor for subassembly and complete system validation. This is supplemented by a contractor-conducted periodic/environmental test in which one of each twelve torpedoes is tested to destruction. If a sample fails its test, deficiencies in the lot from which it was drawn must be corrected and a sample must pass the test. Both of these tests are supplemented by rigorous quality control in accordance with military specifications.

With the passage of these in-plant tests, the torpedoes are delivered to the Navy for conditional acceptance. Every torpedo is then subject to in-water proofing at a Navy installation in Keyport, Washington. This test validates conformance to design/manufacture, materials/workmanship and performance requirements. The contractor retains total system responsibility in this period which averages six months per torpedo. He retains responsibility for failure analysis and correction of defects under the warranties. Final acceptance by the Navy follows this in-water and post-range testing.

After final acceptance the torpedo enters the Navy's maintenance program. It has a shelf life of three years and a service life of 25 years. Because at the end of a shelf life certain components will have deteriorated and need replacement, these routine functions are accomplished and in-water testing is performed on each torpedo before it is certified to begin another shelf life. If any age-related, non-routine deficiencies are uncovered, a failure analysis is conducted and ECPs initiated if necessary. Over the 25-year service life of the individual torpedo, it is assumed that it will undergo 30 in-water exercise runs.

With this background, the seemingly lenient terms of the warranties are better understood.

a. Design/Manufacture Defects. For a warranty period of 30 days after final acceptance, the contractor warrants the torpedoes will conform to product specifications as confirmed by specified finished product tests discussed above.

b. Materials/Workmanship Defects. In similar fashion, the torpedoes are warranted for the same period to be free from M/W defects.

c. Performance Requirements. The torpedoes are guaranteed for the 30-day warranty period to be in conformance to the performance requirements of the contract. This conformance will be determined by the torpedoes passing successfully a comprehensive system test on specified test equipment. Contractual performance requirements described as goals or objectives are excluded from the warranty.

d. Remedies Available to the Government. The remedies available to DoD are stated in standard form. The contracting officer must notify the contractor of a breach of warranty within 30 days of discovery. The contractor is obligated to take full or partial correction steps promptly as directed at no additional cost to the government. At his discretion, the contracting officer may correct the defects using Navy or other facilities and bill the contractor. And, if no correction is deemed to be in the government's interest, an adjustment in contract cost and fee will be made. The contractor is responsible for transportation costs and risk of loss on torpedoes shipped to his facilities for corrections, and is obligated to furnish data on the corrections he undertakes. The contractor is protected from the need to honor the warranties in the standard cases of combat damage or improper Navy personnel procedures, and is relieved of responsibility for consequential damages.

e. Warranty Price and Liability Limits. No price is specified for the warranty, although a payment is provided for. Interestingly, the partial funding clauses indicate that the fixed fee is 7.19 percent of the contract cost. The total liability ceiling on the warranty is limited to three percent of the target cost in effect at the time of acceptance of the last deliverable torpedo produced under the contract.

In reviewing the warranty provisions in the light of Section 2403 (and possibly to head off criticism of the short warranty period) Navy contracting personnel in the rationale noted one of the problems in extending the warranty period into the current shelf life of the torpedoes. Because it is necessary to maintain the extensive maintenance facilities and personnel assignments for life cycle testing, extending the warranty period would lead to duplication of functions by contractor and Navy at an increase in the cost of the warranty. Also, during shelf life, torpedoes are subject to rough handling probably beyond the legal standard of "normal use," so that disputes over liability would have to be anticipated were an extended warranty initiated. Finally, the extended contractor testing after conditional acceptance is effectively a warranty period, since the contractor accepts total responsibility. Hence, the six month period of guarantee is effectively one year.

In the light of these considerations, the contracting personnel recommend extending the warranty period in future contracts by adding 30 days of warranty coverage during the final check-out period just before the ready-for-fleet issue status.

Navy contracting personnel considered the warranty provisions stated above in the contract to be in conformance to the requirements of Section 2403, even in the absence of specifications of EPRs. Given the extensive testing procedures and the nature of "acceptable performance," it is difficult to disagree with this conclusion. The application of performance warranties to dormant systems generates problems, which were frequently alluded to in the Section 794 hearings, and the greater flexibility of the newer legislation provides for these problems to be confronted without the need for seeking waivers.

The other common problem with warranties stressed by the services is also highlighted with this system. This is their desire to develop and maintain in-house maintenance and repair capabilities for the post-warranty or wartime phases of support. The tension between this desire and warranties' provision for contractor correction was most intense under Section 794, which required all such warranted defects to be remedied by the contractor. The newer legislation eliminates this, and, as shown above, the services tend to write in clauses permitting in-house remediation with compensation. Indeed, as noted above, the Army's regulations concerning Section 2403 implementation require such a clause in warranty contracts. But the duplication of costs remains a problem for long warranty periods.

4. Guidance Control Sections of the AIM-9M (Sidewinder) Missile

A last analysis concerns the Guidance Control Sections (GCSs) of the Sidewinder missiles produced for the Navy and Air Force by Raytheon. The contract, issued in May 1985, is almost identical to a FY1984 contract, so that Section 2403 led to no significant changes. The warranty clauses are standard, but interest focuses upon the test procedures to assure conformance to performance requirements and the length of the warranty period.

a. Design/Manufacture Defects. The contract warrants that for 36 months after acceptance the GCSs will conform to design and manufacturing requirements.

b. Materials/Workmanship. A similar warranty is exacted for M/W defects.

c. **Performance Requirements.** Each GCS is warranted to conform to performance requirements specifically delineated in two publications and any revisions or exceptions to them. This conformity is to be demonstrated by *product verification testing (PVT)* and *incoming inspection*.

Each lot of GCSs will undergo PVT at the Pacific Missile Test Center using its test equipment to verify an MTBF no less than 450 hours. The PVT will be performed within 12 months of delivery of the lot. If a lot should fail, the contractor is obligated to repair or replace the failed units, analyze the reason for the failure and recommend correction action.

After passage of the PVT, the units will be subject to inspection when delivered to designated naval weapon stations to assure their conformance to performance requirements. Those GCSs that fail will be returned to the contractor for repair or replacement. The Navy will employ best effort to inspect units upon receipt, but when this is not practicable has the right to perform inspection up to 24 months after acceptance.

d. **Remedies Available to the Government.** In the event of a breach of warranty the contracting officer will return the defective units at contractor expense to the contractor if DoD desires corrective action. The contractor will analyze the failure and report the results to the contracting officer as soon as possible. The contracting officer will make the final determination subject to disputes procedures as to whether breach of warranty has occurred. If the government does not require remediation of the defects, an equitable reduction in price will be negotiated.

The repair TAT will be no longer than 180 days under normal circumstances and in no event more than 12 months. "Normal circumstances" are defined as GCS returns of no more than 25 units per month. If these TATs are not observed, DoD has the option to procure supplies from other sources and accomplish the remediation at contractor expense. All relevant data concerning diagnosis and repair of failures must be furnished to the contracting officer.

The contractor is protected by the standard clauses and is excused from warranty provisions if the failure is due to design or specification deficiencies furnished by the government.

e. **Warranty Price and Liability Limits.** The firm fixed price of the contract includes the firm fixed price of the warranty and is not broken out. No contract or liability limits are specified.

The featured warranty function is assurance-validation, and that is performed by tests that focus on MTBF. The contractor is explicitly excused from warranting design defects other than conformance to specifications. Under such conditions the D/M and M/W warranties become latent defect warranties and the performance requirements simply conformance-to-configuration acceptance norms. The set of warranties, therefore, is a standard set characteristic of the pre-1984 period.

It would, therefore, be interesting to observe if a warranty price actually was included explicitly in the contract price during negotiations. The warranty provisions, being exclusively assurance-validation warranties, provide guarantees that are automatically assumed with the signing of an agreement to provide such supplies, and are therefore part of normal costs. DoD should not be required to pay again for them, and to the extent the new legislation encourages "automatic" consideration of warranty prices without respect to the function they serve it could be detrimental to government interest.

VI. A THEORETICAL ANALYSIS OF WARRANTY USAGE IN DEPARTMENT OF DEFENSE PROCUREMENT

The issues that divide proponents and opponents of mandatory written warranties in DoD procurement of weapons systems--and, more specifically, EPR warranties for extended periods of time--have been presented in some detail in Chapter IV. Because experience with such warranties is too recent to yield much data, assessment of the validity of the arguments on both sides must rely to an extent, which is admittedly not ideal, upon formal and informal analyses. By formal analysis is meant the specification of rigorous frameworks incorporating explicit assumptions involving relevant variables whose relationships are deduced by mathematical techniques. Informal analysis, on the other hand, as undertaken in Chapter V, is less rigorous and more dependent for its insights upon intuition and frank conjecture.

This chapter presents a formal analysis of warranty issues. Because the ability to manipulate such models in order to derive the relationships among variables is dependent upon their retaining a relatively simple structure, and because such a structure is obtained importantly by abstracting from detail, the goals of these exercises are restrained. They are to suggest hypotheses about the more complex relationships among variables in realistic procurement practices; to raise questions that can challenge the assertions in the more informal analyses of the issues; and to guide empirical research and data collection into useful areas. Therefore, it is recognized that the modeling to be presented in this chapter can seldom, if ever, be definitive in yielding answers to the issues arising in the use of warranties. Nonetheless, the insights into core relationships that it provides can provide important guidance for the informal analysis that so frequently steers policy.

Because of the technical nature of the theoretical analysis of this chapter it has been placed in an Annex. The conclusions from the exercise are summarized in Section B. Section A contains a more intensive consideration of the three economic functions of warranties that were introduced briefly in Chapter II.

A. THE ECONOMIC CHARACTERISTICS OF WARRANTIES

In Chapter II three basic functions of warranties from DoD's standpoint were introduced with brief indications of their natures that sufficed in that and subsequent

chapters for the uses to which they were put. For purposes of a theoretical treatment, however, these functions must be defined more exactly and with the purposes of their usefulness in the analysis to follow clearly in mind. To that preliminary task this section now turns, after a brief review of the historical material in Chapters III and IV.

1. The Assurance-Validation Function

As this study has shown in previous chapters, pre-1984 DoD usage of the warranty was a means of assuring that the contractor delivered a product which met design, manufacture, materials, and workmanship standards at the time of acceptance. Contractual specifications were treated as exact or minimum requirements, depending upon their nature, and firms were held fully responsible for correcting deficiencies in these regards. This assurance extended into the post-acceptance phase for any deficiencies present but not detectable at the time of inspection and acceptance. However, major contractor responsibility ended with government acceptance.

This type of assurance-validation warranty was viewed by DoD, courts, and claim commissions as a means of guaranteeing government that it received that for which it contracted. Essentially it was meant to protect DoD against the potential penalties of information asymmetry. The contractor might take advantage of DoD's inevitable inability to assess fully the quality of a delivered product, given the many opportunities the firm had to cheat on specifications or to be careless in its execution of the contract. Such lapses might escape detection by a government inspector, given his limited information concerning the procedures used in design and manufacture. The warranty was designed to reduce such temptations and increase the probability of DoD receipt of the product desired.

Beginning about 1976, DoD began to concern itself more with the RMA characteristics of weapon systems in the post-acceptance phases of the life cycle. When contracts specified some MTBF, mean time between repair (MTBR), or other such down-time index as a minimum acceptable standard, and forced the contractor to take steps at his expense to correct deficiencies, this constituted an extension of the assurance-validation contract into the post-acceptance period.

Finally, in Section 2403 the potential was established for extending the assurance-validation warranty in this post-acceptance phase to the OCs of the weapon system (speed, range, fuel consumption, thrust, etc.) as well as RMACs. In the legislation, EPRs may be

stated in the contract either as restrictions on OCs or RMACs. Where such restrictions are written as minimum standards for acceptability and lapses from such standards are correctible at contractor expense, they fulfill the requirements of this definition of assurance-validation warranties.

Because such warranties are simply to assure that the product delivered is what has been contracted--and paid--for, analysis and practice in general prescribes that the cost of such guarantees be considered in the negotiation of the price of the contract. No explicit line-item pricing of such a warranty provision is appropriate.

There is an implicit assumption in an assurance-validation warranty that the contractor is capable of exercising full control over the quality of the product within the limits of the contract by the exercise of ordinary management prudence. The differing "states of nature" that may emerge in the execution of the contract are viewed as having nonsignificant implications for the firm's tasks. And, finally, there is no desire on the part of DoD to pay for a product which exceeds the specified characteristics of the contract: assurance of explicit minima suffices.

This study will have little more to say about the pure assurance-validation function in warranties. Defined as above, such warranties fulfill an important but straightforward function *in contracts containing product specifications*. They have an extensive legal history, are well-recognized in contracting circles, and their usage in DoD practice is in harmony with their economic analytic properties. Their practical impact should be and, in fact, is found in the negotiated price of producing and delivering the product.

In Section 2403 the first two of the three types of warranties mandated--protection against defects in design and manufacture and in materials and workmanship--are essentially assurance-validation warranties. They encode standard DoD practice that is relevant to the inspection/acceptance phase, and do not raise any new, challenging issues. But the attempt to mandate performance warranties in the Section 794 legislation and the less rigorous EPRs in Section 2403 is not so easily handled.

To the extent that an EPR warranty--whether an RMAC or OC type--extends minimum standards into the post-acceptance stage, it possesses the flavor of a standard inspection/acceptance warranty. But there is a marked qualitative difference in at least two dimensions that may force it to be treated as having functions that dominate that of

assurance-validation. The first difference is that because the period of warranty is some distance in the future and may have a much longer duration, the states of nature that may emerge to have a significant impact on product conformance may not be foreseeable, and if foreseeable may not be easily measured in probability terms. The control of the contractor over product quality may be perceived as markedly less than in an acceptance phase counterpart. The second difference is that the size of contingent liabilities in the event of nonconformance may be much larger than those involved in the acceptance phase assurance-validation warranty.

When these differences are substantial, the *insurance function* of a warranty--the definition of risk-sharing between contractor and DoD--will dominate the assurance-validation function. Separate pricing of the warranty as one of the aspects of such risk-sharing, as well as possible limitations on contingent liability, become appropriate. The analysis of warranty usage for this purpose raises different sorts of questions in terms of cost-effectiveness, and such EPR warranties are best considered as of an insurance-dominant form.

Finally, when DoD is willing to pay for overachievement of minimum EPR standards, and/or is unwilling to accept their underachievement, and when the attained EPR levels are capable of being affected by contractor actions subject to random states of nature, warranties can serve a third function: *incentivization*. The analysis of such a usage of warranties by DoD in a cost-effective context calls for another set of techniques. The incentivization function may dominate both the assurance-validation and the insurance function in a given contract, and if so will be classified for analysis by this dominant function.

Hence, it is the third type of mandated written warranty in Section 2403--the EPR warranty--which raises the more important and complicating issues to be confronted in this chapter, and the analysis will be phrased in its terms. This is not to deny that every DoD warranty contains elements of all three functions, nor that no simple classification of warranties is possible. It is simply to assert that this three-function categorization has proved useful for the purposes of the present study and that simple dominant-function classifications of contracts have served well in presenting the important economic implications of each function. It is necessary, therefore, to define these additional functions more carefully before proceeding to their analysis.

2. The Insurance Function

The distinctive functions of a warranty in weapon systems procurement make it a more complicated instrument than its counterpart in the commercial economy, and the use of analogies between them can be misleading. In the latter type of usage it serves as a marketing tool for its issuer and as a "costless" insurance policy for the customer. As such it protects the buyer of the product against a contingent liability for all or a specified portion of losses that may arise from design, manufacturing, materials, or workmanship deficiencies for an explicit time period. In general, the buyer has had no voice in determining the specifications of the product, so assurance-validation is limited to a common law implicit merchantability guarantee. Moreover, the ability of the buyer of a standardized commodity to incentivize its producer is minimal. Therefore, the insurance feature is dominant, and the analysis of economic function can focus closely upon it.

Insurance is the provision of risk-bearing services that permit the insured to shift the losses incurred when certain known contingent-states of nature occur in a random manner. For a specified premium payment (perhaps hidden in the price of the purchased good) the insurer guarantees the insured complete or partial reimbursement of losses incurred when unfavorable states of nature are realized. The insured does not escape the cost of losses due to random events: by paying their average value in the large he escapes their disturbing variance in the small.

An important aspect of the insurance function to the insurer is the degree to which the probabilities of the occurrence of the contingent states can be affected by the insured. In a negative sense, if the insured is fully protected against the malfunctioning of a warranted product, he may not take the prudent precautions in use of the product that the insurer has a right to expect. Under certain circumstances, the insured may find it worthwhile to take positive steps to damage the product to claim reimbursement.

This danger to the insurer of the failure of the insured to devote sufficient resources to the protection of the insured object--all of which actions exploit the insured's power to affect the probability function over the states of nature--is called *moral hazard*. The insurer attempts to protect himself against it by specifying prudent usage constraints in warranty provisions, and by underinsuring contingent losses. Most frequently, underinsurance is accomplished by provisions which require the insured to absorb a fixed amount (a

deductible provision) or percentage (a *coinsurance* provision) of the realized loss as a means of risk-sharing designed to counter moral hazard.

The availability of such insurance services and a demand for them are based upon differential attitudes to risk-bearing by insurer and insured. A stricter definition of preferences under risk and of differences in risk-aversion among economic agents is presented in Section A of the Annex to this chapter. In general, however, an economic agent will be more willing to bear risk 1) the greater the size of his resources relative to the extent of the potential losses, 2) the more plentiful and reliable is his information concerning the likelihoods of the occurrence of relevant states of nature, and 3) the greater is his ability to pool risks among other agents. In the case of commercial warranties the seller of the product is generally stronger financially than the buyer, more knowledgeable about the quality and failure characteristics of the product than the consumer, and capable of spreading the risks of failure over the whole body of his customers and so able to exploit the law of large numbers. Frequently, he may shift the risk by reinsuring with an insurance company which specializes in the risk-bearing function.

In the defense sector, warranties on weapon systems do provide an insurance function to the government against all or a portion of the costs of uncertain breakdowns and uncertain costs of repairs. But, as is shown in Section A of the Annex, there is a certain perversity in the strict insurance feature that militates against its dominance as a motivation: the warranty establishes the contractor as an insurer and the government as the insured. The contractor, however, must be expected to be much more risk-averse than the government: his resources are much more limited, as is his ability to pool risks among other projects. His presumed advantage in knowledge of the system's failure profile cannot be expected to outweigh his disadvantages in the other two respects.

The immediate implication of this asymmetry is that the "premium" that the government must pay for such warranties in the form of a fixed price to overcome the risk aversion of the contractor must be expected to be quite large, and in general larger than the protection is worth to it. It possesses resources of such great extent and is able to diversify such risks over so many weapon system contracts that it must be expected to have minimal risk aversion.¹ As is shown in Section A of the Annex, this implies that the "risk

¹ Indeed, Arrow and Lind argue that the government should be assumed to be "risk-neutral," or indifferent to such uncertainty. [2], pp. 364-378.

premium" it will pay to avoid uncertainty should be small, and that self-insurance is a much more likely prospect for cost-effectiveness than prospective payments to a risk-averse contractor.

3. Incentivization Function

The government's primary motivation for weapon system EPR warranties beyond assurance-validation, therefore, must have different sources, and their cost-effectiveness must be judged by other criteria. That purpose takes its roots in the ability of the contractor to control the realized performance characteristics of the system. This converts the nature of the dominant relationship of the government and contractor from that of insured and insurer to a principal-agent affiliation.² Correlatively, the pre-eminent attraction of an EPR warranty (beyond assurance-validation) to the government lies in its function as an *incentivization instrument* rather than as an insurance instrument.

A principal-agent relationship arises when one party (the principal) delegates the authority to make decisions concerning a designated set of acts to a second party (the agent). The relationship may be defined formally with a set of components:

1. An *action set*, A , from which the agent chooses an *act*, a . The act may be illustrated by the level of effort the contractor expends in the design and manufacturing process to assure the attainment of essential performance requirements of the weapon system when fielded.
2. The *states of nature*, θ , whose realizations will, in conjunction with the chosen act a , determine the *payoff* x , or the value of the agent's product. Hence,

$$x = X(a, \theta), X'_a > 0 \text{ for all } a, \theta.$$

The states of nature may be thought of as the alternative levels of technological proficiency that may emerge during the design and production phases of the contract.

3. The state probabilities, π , over the states of nature. These may be subjective probabilities held by the parties as informed guesses of the likelihoods the relevant states will emerge. There will be both a random component to the emergence of such states and a functional dependence on the act of the agent.

Thus,

$$\pi_\theta = f(\theta/a),$$

² Good treatments of principal-agent relations may be found in Milton Harris and Arthur Raviv, [18], pp. 20-30; and Stephen A. Ross, [37], pp. 134-139.

a probability function conditional upon the agent's selection of an act. As illustration, the probability that technological state θ will rule in the design and production phases is conditional upon the contractor's level of effort, measured perhaps by the costs he devotes to research, development, and quality control.

4. The contract, $[S(z), z]$ where z is the body of variables that are agreed to by principal and agent to be measures of conformance to requirements and $S(z)$ is the share of the payoff x that accrues to the agent. The variable z must be observable to both parties and measurable. For example, z might constitute the set of EPRs, measurable as MTBF and fuel consumption. The payoff, x , may be the monetized net benefit of EPR levels to the government, and $[S(z), x - S(z)]$ the contractor-government shares of such payoffs.

The following list of components clarifies the features of a procurement that make it incentive-compatible:

- 1) The outcomes of the relevant states that determine the nature of the product must be dependent upon the actions of the contractor.
- 2) The choice of acts by the contractor that impact those payoffs must be capable of effective response to reasonable contractual incentives offered by the government.
- 3) The states of nature or their surrogates in the form of the results of those states must be measurable and observable by both parties to the contract.

The first of these features is a precondition for the existence of moral hazard in its negative and positive forms. In the former sense, its existence implies that the contractor may be tempted to deliver a product whose performance characteristics are less than alternative feasible acts on his part would permit. More positively, it opens the possibility of inducing him to produce a better product. *It follows, therefore, that in the negotiation of the terms of the warranty the government should devote some effort to gauging the extent of susceptibility to moral hazard of the contractor in both senses.*

The second condition assures the possibility of cost-effective incentives by the government, and its fulfillment depends largely upon the degree of risk aversion of the contractor. Inducing the contractor to choose acts that may improve the product's quality generally requires the assumption of greater risk. An extremely risk averse contractor may require incentive payments that are non-cost-effective to the government. A contractor with low risk aversion may require little incentivization. *Some dedication of effort to estimating the risk aversion exhibited by a contractor is, therefore, prudent in government pre-negotiation and negotiation strategy formulation.*

The third condition is an obvious constraint upon the applicability of incentives. It indicates two potentially available indices of contract performance: 1) direct observation of the emergent state of nature, e.g., the availability of sub-micron technology permitting the manufacture of integrated circuits with certain characteristics, or 2) the observation of "result-states,"³ which measure the outcomes of one or more states of nature, e.g., a measure of the speed with which employed integrated circuits transmit signals. The states of nature may be regarded as the "causes" of the ultimate outcomes (given contractor effort) and are in general difficult to observe. On the other hand, the result-states are the effects of those causes and have several practical advantages over the states. They are more susceptible to observation and measurement; permit the consideration of fewer alternatives, as a result-state may be the outcome of more than one state; and are likely to be less dependent upon technical expertise for interpretation and definition.

In the general case, therefore, DoD warranties will be expected to specify result-states as EPRs. In further references in this chapter, therefore, the term "states" will refer to such result-states unless specifically noted otherwise.

4. An Analytical Categorization of Warranties

An analytical categorization of warranties was introduced in Section B.2 of Chapter II, and Figure II-1, which presents the categorization schematically, is reproduced as Figure VI-1 for convenience. Assurance-validation types of warranties include the first two types required under Section 2403--materials/workmanship and design/manufacture guarantees. Insurance-dominant warranties are exemplified by maximum part cost guarantees and logistics support cost guarantees, which are strongly motivated by the desire to insure against uncertain cost levels in the operation and maintenance phases of life cycle costs. Assurance-validation types contain incentive features, most importantly the design/manufacture guarantee, and they do serve as means of shifting to the contractor the cost of patent and latent defect repairs in the earliest phases of equipment fielding. Their dominant function remains one of assuring receipt of the product as specified in the contract.

³ The term is John H. Marshall's in [31], pp. 880-890.

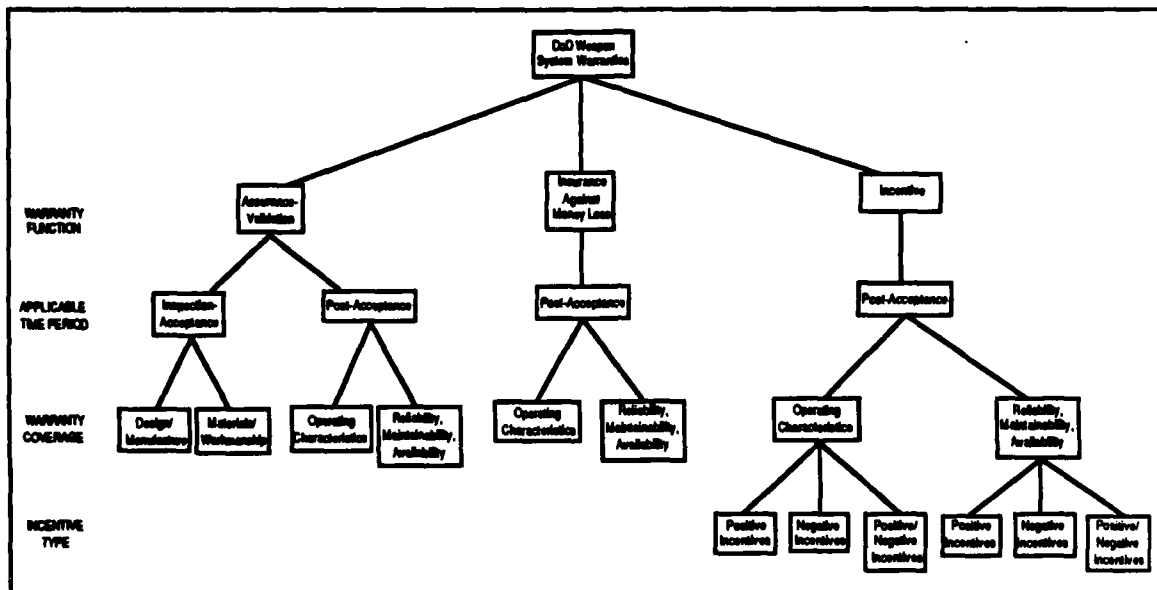


Figure VI-1. A CATEGORIZATION OF DOD WEAPON SYSTEM WARRANTIES BY DOMINANT FUNCTION

Penalty-types of incentive-dominant guarantees which concern operating capabilities are illustrated by provisions in aircraft engine contracts, which set thresholds for fuel consumption or thrust. Much more frequent is the reliability, maintenance, and availability type of penalty warranty, setting threshold levels for MTBF, MTTR, mean logistic down time (MLDT), TAT, operational availability, and so forth. The early RIWs frequently had negative incentivizing provisions of the MTBF, TAT, or MTBF/TAT form, requiring minimum standards to avoid penalties.

Reward-and-penalty types of incentive warranties take the same forms as their counterparts of the penalty type but provide positive incentives for performance beyond target levels. As discussed in Chapter V, the AN/AJQ25 NAV attack system, for example, provided that when actual MTBF was within ± 10 percent of target MTBF, repair costs were performed by the contractor at an agreed base price. When MTBF exceeded the target value by more than 10 percent the repair price rose up to 150 percent of base price, that upper bound being reached at an MTBF value of 150 percent of target. When MTBF fell short of target MTBF by more than 10 percent, the price paid for repairs decreased linearly with the percentage shortfall to a lower bound of 50 percent at 50 percent of target MTBF. A negative incentive provision was also included to require the actual MTBF to equal or exceed target MTBF by 20 percent in the last 3 months of the warranty period or the contractor's field manager would be required to remain on station at no cost to the government until that goal was attained.⁴

5. Economic Characteristics and the Goals of Formal Analysis

The relevance of the distinctions discussed above to the goals of formal analysis can now be presented. Ideally:

- a. The analysis of the insurance-dominant warranty provides answers to the following questions:
 - 1) What is the optimal distribution of the risk of contingent costs between government and contractor?
 - 2) What is the optimal form for that risk-sharing to take--full insurance, deductible, or coinsurance?

⁴ Discussed in [38], pp. 221-224.

b. The analysis of the incentive-dominant warranty provides answers to the following question:

- 1) What is the optimal fee schedule for the government to use to incentivize the contractor to choose desired acts, where the fee schedule is a function of the result-states?

These statements of aims beg the question of a definition of optimality, which must be a prior goal of the analysis.

When incentive warranties are restricted to the penalty type, a constraint is placed upon the derivation of the optimal fee schedule which is not active if the reward-and-penalty type is permitted. In this manner this aspect of the classification dimension intrudes itself into the analysis.

The uncertainties concerning the occurrence and size of contingent liabilities for breach of OC warranties appear to be considerably greater than for RMAC warranties. The two types will impact risk-averse parties in different manners, therefore, especially with respect to choices involving the level of technological aspiration for the prospective system. These influences upon the optimal strategies of contractor and government must be examined analytically.

There exists, therefore, a bias on the part of the contractor to obtain EPRs defined as RMACs. That preference is rooted in the larger expected costs he expects to undergo if OCs are stipulated, and that differential desirability will be enhanced by his risk averseness. On the other hand, DoD on the basis of the same cost considerations, will favor OCs, but that preference will not be reinforced by strong risk aversion. Consequently, in negotiations, OCs may be expected to be priced by contractors at levels that overcome the advantages that DoD contracting officers believe they afford government, with the result that RMACs dominate the EPRs.

B. CONCLUSIONS

The contribution of formal analysis to the understanding of the role of warranties in DoD procurement is best viewed as the derivation of hypotheses and conjectures with which to confront empirical data and field studies. Beyond this, it permits insights into the nonobservable that can be judged in terms of intuitive plausibility. The analysis of this

chapter, as detailed in the Annex, has sought to provide guidance in both of these directions, and its major propositions will be summarized in this section.

1. The Functions of Warranties in DoD Weapon System Contracting and a Categorization

In general, warranties provide DoD with three rather distinct if not completely separable services:

a. **Assurance-Validation.** This feature of a warranty is designed to assure DoD that the system is in conformance with two clearly specified sets of requirements:

- *At the time of inspection and acceptance*, the design, manufacture, materials, and workmanship conform to contract specifications. This includes protection against latent defects in the above dimensions that may appear in the early part of the post-acceptance period.
- In the post-acceptance period, for a stated duration or set of durations, the EPRs will be met or exceeded.

Implied in the definition of this function is the assumption that conformance to both types of specifications can be achieved by the contractor's exercise of ordinary prudence in the production of the weapon system.

b. **Insurance Against Monetary Loss.** A weapon system warranty provides DoD with protection against the occurrence of large money expenses caused by redesign, retrofit, repair, or remanufacture due to states of nature whose emergence is not controllable by contractor or DoD. In this study the function has been closely linked to EPR assurance-validation in the post-acceptance phase because of the uncertainty and size of contingent liabilities.

c. **Incentivization.** In circumstances when payoffs to DoD beyond contractual threshold levels are capable of attainment by acts of the contractor, a weapon system contract may provide *positive* incentives to the contractor to expend such effort. Where threshold levels are not stated as specifications whose attainment is warranted by the assurance-validation function but as targets, *negative* incentive provisions in the form of penalties for shortfalls may be included in the contract.

Of course, these functions merge into one another at the margins and no clear-cut classification of realistic warranty provisions into one or the other of these three headings is always possible. However, for analytical purposes they do summarize the purposes of warranties acceptably and yield a convenient classificatory framework.

This categorization of warranties is simply based on which of the three functions is perceived as dominant in a particular contract. Further subdivision of assurance-validation post-acceptance warranties and incentive warranties are performed on the basis of whether EPRs are stated as RMACs or OCs. Finally, in incentive contracts, subcategories of positive and/or negative forms are employed. This schema is presented graphically in Figure VI-1.

2. Assurance-Validation Warranties

Assurance-validation warranties of the inspection/acceptance type are appropriate to all weapon systems in mature production where it is correct to assume that the relevant specifications may be attained through the exercise of ordinary prudence. The costs of so doing are properly incorporated in the price of the contract and no separate line item warranty price is appropriate. This conclusion supports DoD practice and the rulings of many claims commissions and courts in the litigation of disputes concerning government contracting as discussed in Chapter III.

Assurance-validation warranties of the EPR type are mandated by current legislation and raise a variety of issues discussed at some length in Chapter IV. In their pure form--in which case they are included in this category--they require the contractor to meet or exceed EPR standards explicitly stated over some definite time period in the post-acceptance phase. In this pure form they are simply projections of the first type of assurance-validation warranty and their expected cost should be included in the fixed price of the contract. No separate line-item price is appropriate.

Seldom, however, are conditions consistent with this pure form of the EPR warranty. Realistically, conformity with EPR requirements--especially of the OC type--may be highly dependent on states of nature in the future that are difficult to catalog and therefore impossible to attach to probabilities of occurrence. Moreover, the size of contingent liabilities created by such warranties may be huge relative to the financial resources of the firm. The risk-averse firm may insist on explicit risk-sharing by DoD in

the form of a separately-priced warranty with explicit conditions and possibly a financial liability ceiling. From DoD's viewpoint it is frequently desirable to "split" the warranty into a strict assurance-validation type for the achievement of readily attainable threshold values, but then incentivize the contractor to achieve higher values through a fee schedule.

Given the presence of one or more of these characteristics in most EPR warranty provisions in realistic situations, they are best analyzed as forms of insurance or incentive contracts, and were considered in the analysis of this chapter. However, when threshold values are stated as minima, their cost of achievement should be included in the contract price, and negative or positive incentive fees subtracted from or added to that contract price according to an explicit fee schedule.

3. Insurance-Against-Money-Loss Warranties

DoD usage of weapon system warranties primarily as a means of protecting itself against money losses rather than provision for availability of military assets of high quality in the interests of readiness is suspect in terms of cost-effectiveness. A strong presumption exists for the desirability of self-insurance by DoD against money loss. Considerations that lead to this conclusion are the following:

- a. There is a perversity in forcing a contractor into the role of insurer to the government. Government resource availability and its greater ability to spread risks over projects when compared with like qualities for the contractor create a *prima facie* question of appropriateness.
- b. Government must be expected to be risk-neutral or mildly risk-averse. Under such conditions, even if the contractor offered insurance at its fair or actuarial value, government would better its position only slightly or not at all by purchasing such a warranty.
- c. The contractor will not offer such a warranty at its fair value, but will "load" the price to reflect his risk-averseness and his administrative expenses. Under such conditions DoD will actually worsen its position by taking insurance.
- d. Not only will the contractor load the insurance premium but that loading will rise faster than linearly with the amount of insurance purchased through warranty by DoD. The contractor will insist upon large and rising coinsurance via risk-sharing.

4. Incentive Warranties

Positive or negative incentivization through warranties becomes feasible when a contractor can alter the quality of a weapon system through actions; those actions can be induced by practicable monetary rewards or sanctions; quality levels that surpass or underachieve threshold minima have meaningful impacts on the utility of the system; and when achieved quality can be measured and monitored readily by both contractor and DoD.

Incentive payments--negative and positive--are a feasible way of coping with *moral hazard* on the part of the contractor. Their cost-effectiveness in this function must be judged by the likelihood that a contractor will devote too few resources to achieving quality in the absence of penalties or can be induced to increase that expenditure of effort by positive payments.

Government contract officers should attempt to derive an operational optimal incentivization function with which to induce desired quality levels. In all likelihood that will have to be done by piecewise-linear estimates of the monetary costs of achieving EPRs and using linear fee schedules parametrically. In the Annex a practical method of designing such a fee schedule is presented. To the extent a contractor is judged (1) to be risk-averse and (2) to value quality independent of its contribution to profit, that estimated schedule will be biased upward from DoD's viewpoint, and lower fees can be set to achieve the same quality levels.

5. Biases in the Preferences for EPR Types

In the formulation of strategies in the prenegotiation phase of the contract, self-interest will lead the contractor and DoD to strive for different structures for the EPRs. The negotiation phase, therefore, should be characterized by wide differences in aims in writing the EPRs.

In the definition of EPRs in negotiation, the contractors will be biased for profit reasons to their specification in RMA terms, and DoD is expected to be biased toward OC definition. To the extent these predilections are not manifest in the bargaining, analysis should be used to seek an explanation. Because correction of these preferences through cost-sharing and alteration of warranty duration in negotiation may be difficult, DoD should investigate the use of incentive warranties designed to induce the contractor to accept EPR

definitions in OC terms rather than as RMACs when it has strong preferences for the former type of capability.

In practice, one of the strongest forces acting to compromise these differences in favor of contractor interests is the large costs of OC types of warranties. Although both OC and RMA types of EPRs imply a strong role for the insurance function, the definition of states of nature and the estimation of probabilities of their occurrence are more difficult for OC types, and lead the contractor to heavy loadings of insurance premia.

ANNEX A

The formal analysis of the economic functions of weapon system warranties designed to obtain insights into the questions posed in Section A.5 is presented in some detail in this annex. Section A lays the foundation for theoretical treatment of the insurance and incentivization functions by presenting the basic contents of the economics of uncertainty. Section B uses these principles to analyze the insurance function and Section C exploits them to probe into the incentivization function. Finally, Section D employs the framework to study the strategies formulated by contractor and DoD in prenegotiation phases of the contract process with a view to discerning the role of OCs and RMACs in those strategies.

A. THE ECONOMICS OF UNCERTAINTY

1. Choice Under Risk

The beginning of analysis of decisionmaking in conditions of uncertainty is the specification of the preferences of an economic agent for income under conditions of risk, where risk is related to the *variance* of outcomes or the degree of variations in actual realizations. The von Neumann-Morgenstern utility index that measures these preferences is the only instance in which economists have been successful in mapping utilities with a degree of uniqueness that surpasses a mere ranking of alternatives.¹ It also permits them to be multiplied by scalars and added or subtracted, which allows the calculation of "expected values"--an operation which will be explained below.²

¹ That is, the von Neumann-Morgenstern index is unique up to a linear (affine) transformation. If their technique of derivation is followed, any utility index obtained will be capable of derivation from any other index so obtained by a linear relation. If U and U^* are two such indexes, then $U = a + bU^*$, where a and b are arbitrary constants. This implies that the increments on any such scale are meaningful, and hence the slopes of such utility functions can be compared. However, ratios of such utility values are not meaningful.

An illustration in more familiar terms may be helpful. Temperature measurements are unique up to a linear transformation. If F° is an index of Fahrenheit measure, and C° is an index of centigrade measure, the two may be related linearly: $F^\circ = 32^\circ + 1.8C^\circ$. These are the "same" measurements except for an arbitrary choice of origin (32°) and degree size (1.8). If two Fahrenheit readings are considered--say, 35° and 70° --it is allowable to say that the second is $35^\circ F$ above the first. It is not permissible to say that the second is twice as large as the first. The illegitimacy of this can be seen by translating these Fahrenheit measures to Centigrade-- $1.67^\circ C$ and $21.11^\circ C$ respectively--whose ratio is not the same as the ratio of the Fahrenheit measures. However, a 35° increment on the Fahrenheit scale will always be equal to a 19.44° increment on the Centigrade scale.

² A good recent survey of the economics of uncertainty may be found in [26], pp. 1375-1421.

To extract an agent's preferences under risk the following experiment is performed. Suppose a contractor's fee on a risky government contract could attain a maximum of \$1 million at the most optimistic and \$0 at the most pessimistic. A *lottery option* or *reference gamble* is constructed with a specific prize greater than or equal to \$1 million which would be awarded if he won the lottery, but a prize with specific value of \$0 or less which would be awarded if he lost. As an example, set the winning prize (Heaven) equal to \$1 million and the losing prize (Hell) equal to \$0.

The contractor is then offered a succession of choices involving two options:

1. The lottery option
 - a. L (\$1 million, \$0; π_1)
 or the probability π_1 of winning Heaven and therefore the probability $\pi_2 (= 1 - \pi_1)$ of winning Hell. That is, he would be facing the uncertain prospect of contingency - state of nature θ_1 (win) emerging with probability π_1 or contingency - state θ_2 (lose) with probability π_2 . The corresponding result-states are \$1 million won and \$0 won respectively.
2. A *certainty option* or the certain receipt of \$X.
 - b. C(\$X), $0 \leq X \leq \$1$ million.

A specific value for X is chosen (say \$500,000). The contractor is then asked what value of π_1 in the lottery option would make him feel indifferent between the two options. The values [π_1 (500,000), \$500,000] are recorded, and a different certain value is chosen and the *indifference* π_1 - value noted. When a large number of such probability/certainty value pairs have been observed, they may be graphed with certainty values on the horizontal axis and π_1 - values on the vertical axis. On Figure VI-2 the pattern of responses has been graphed for three alternative patterns of revealed attitudes to risk.

The pattern the contractor would reveal if he were risk-averse is revealed in Panel a. The dashed line reveals the expected value of the lottery option at any π_1 on the vertical axis. For example, for $\pi_1 = .5$, the expected value (actuarial value, mathematical expectation) is simply the value of Heaven if won times the probability of winning plus the value of Hell if won times the probability of losing:

$$(3) \quad E\{L(\$1 \text{ million}, \$0; \pi_1 = .5)\} = \pi_1 (\$1 \text{ million}) + \pi_2 (\$0) = .5(\$1 \text{ million}) + .5(\$0) = \$500,000.$$

This is the value of a fair gamble, for if the organizer of such a lottery were to charge \$500,000 for one play of the game, and were to award \$1 million or \$0 on the flip of a fair coin, in the long run he would just break even. The unattractive quality of the lottery option to the contractor, of course, is the *variance* of the payoff. It is *either Heaven or Hell*, and that uncertainty on a play of the game has a disutility to him.

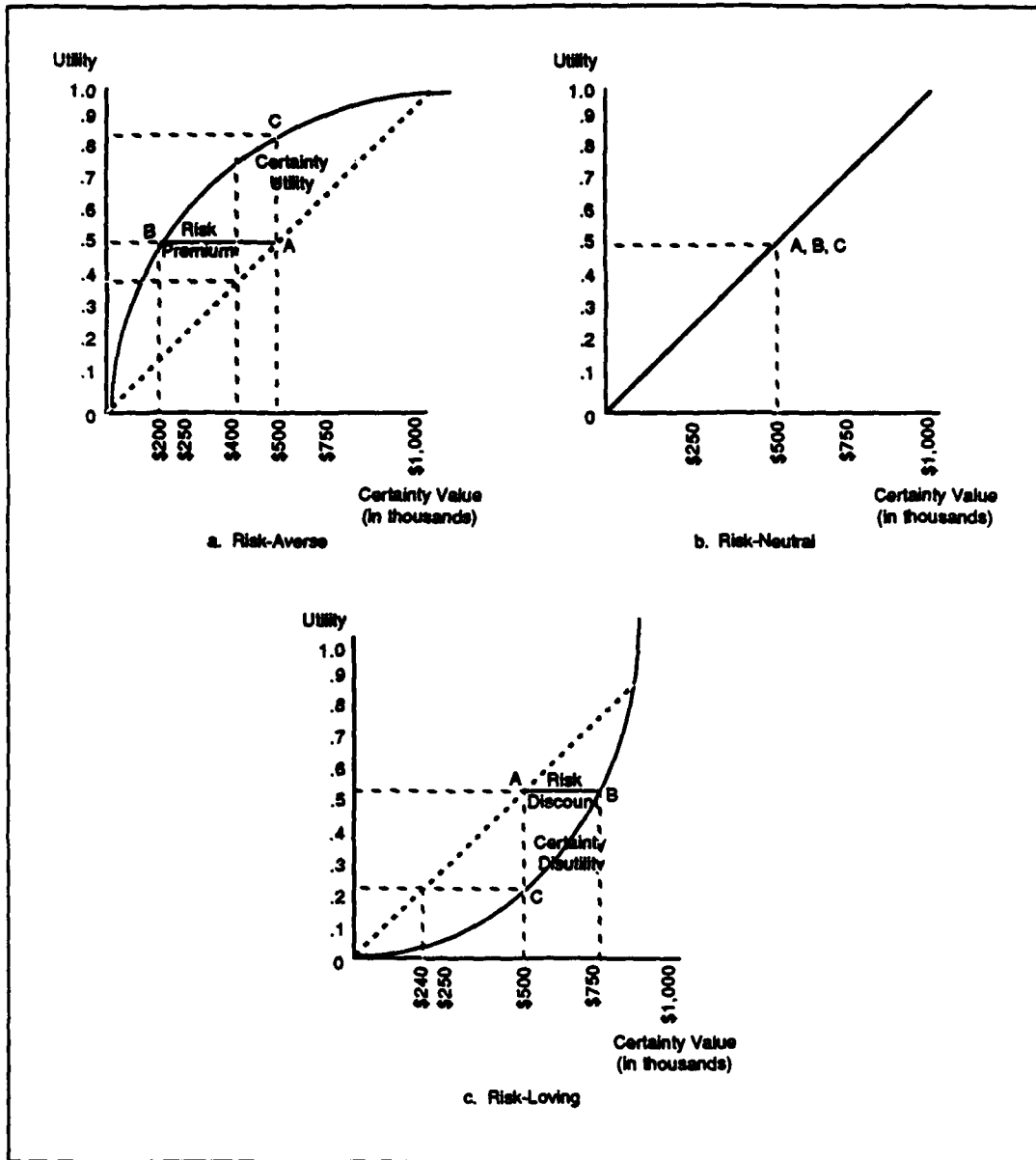


Figure VI-A-1. ALTERNATIVE PREFERENCE PATTERNS UNDER RISK

In general, if a finite number n of contingent states θ_i , $i = 1, 2, \dots, n$, can be realized with probabilities π_i , and if $V(\theta_i)$ is the payoff if state θ_i is realized, the expected value of the uncertain outcome is:

$$(4) \quad E(V) = \sum_i \pi_i \cdot V(\theta_i).$$

If the number of contingent states θ is infinite, so that $V(\theta)$ is a continuous value that can range between $-\infty$ and $+\infty$, and if $p(\theta)$ is the probability density function over θ , then:

$$(5) \quad E(V) = \int_{-\infty}^{+\infty} p(\theta) \cdot V(\theta) dV.$$

Return now to Panel a and the expected value in (3). At $\pi_1 = .5$ on the vertical axis, a line is drawn to A which is directly over \$500,000--the expected value of the lottery--on the horizontal axis. However, the contractor has revealed in his prior choices between the lottery option and the certainty option that when $\pi_1 = .5$ he would feel indifferent with a certainty value of \$200,000. This point [$\pi_1 = .5$, \$200,000] is found on the solid curve, as are all of his choices in the experiment.

The value AB is the *risk premium*, or the maximum amount the contractor would be willing to pay in expected value if he could escape the uncertainty of the gamble between contingency states θ_1 (Heaven) and θ_2 (Hell). In the present case he would be willing to accept a certain payment of \$200,000 even though the fair value of the uncertain opportunity is \$500,000. He is, therefore, *risk-averse*, and the larger AB is the more risk averse he is. Geometrically, the more *concave* the solid curve is, the greater his dislike of risk.

Another way of stating this is by considering the value AC. This says that if he were given a certain payment of \$500,000 instead of an expected value of \$500,000, he would value this the same as the lottery option with $\pi_1 = .85$ instead of .50, i.e., a much more favorable bet. That is, we can consider $\pi_1 = .85$ in a lottery the equivalent of \$500,000 certainty value (and $\pi_1 = .50$ the equivalent of \$200,000 certainty value). Therefore, the π values can be treated as *utility index values* for the receipt of profits in conditions of uncertainty. Hence, the vertical axis has been labeled "utility."

It was von Neumann's and Morgenstern's contribution to show that if the contractor's attitudes toward risk conformed to five plausible (but not incontestable) assumptions that these utility values could be substituted for their respective payoff values in (3), (4), and (5) to obtain the *expected utility* of these uncertain outcomes. By computing the expected utilities of various outcomes, they showed that the choices of the contractor could be predicted by *maximizing the expected utility values*. This capability depends upon the degree of uniqueness of this measurement procedure that was discussed earlier.

It follows, then, that the contractor would value--in utility terms--a substitution of \$500,000 in certain income for \$500,000 in expected value of income at the utility increment AC , or .15 in the present instance. That utility increment falls to zero if he were to obtain \$200,000 in certain income in lieu of the \$500,000 expected value. He would, therefore, be willing to accept a certain income between \$200,000 and \$500,000 if he could thereby escape the gamble. This is equivalent to accepting an unfair gamble. For example, if he were forced to take \$400,000 in certain value this is equivalent to a lottery option with $\pi_1 = .4$ instead of $\pi_1 = .5$.

Panel b in Figure VI-2 depicts the risk attitudes of a risk-neutral economic agent. That decision maker has neutral attitudes to risk: the variance of the return from a fair gamble is neither to be avoided nor sought. Expected value is regarded equally with a certain value of the same amount. He will sacrifice no expected value, therefore, to obtain certain income as the risk-averse agent will do. Neither will he be willing to pay for the thrill of gambling by accepting unfair gambles, i.e., those whose payoffs are less than their expected value. It follows, therefore, that the risk-neutral decision maker's preference function will coincide with the dashed line of expected value.

Panel c depicts the preferences of the risk-loving decision maker whose desire to experience the thrill of gambling leads him to value a fair gamble at more than its expected value. For example, were he offered the lottery option of the diagram with $\pi_1 = .5$, or a gamble whose actuarial value is \$500,000, the agent would be willing to pay \$760,000 in certain income for it. The variance of the income received gives him pleasure which he is willing to pay for in the form of a risk discount, AB . The utility of the gamble with expected value of \$500,000 gives him AC more utility than would the receipt of \$500,000 with certainty. He would be willing to pay \$500,000 for a bet with $\pi_1 = .24$ and an expected value of \$240,000 if necessary. He is the professional gambler's prey of choice.

Only the first two patterns of preference under risk are relevant to the warranty problem: the risk-lover is rarely encountered in business and then only in bankruptcy court. On the other hand, several studies have indicated that the typical defense contractor, especially when dealing with potential earnings and losses the size of those associated with major weapons systems, is a risk-averter, ready and willing to shift the risk of earnings variance to the shoulders of others.³

It is arguable whether government decision makers display or should display risk neutrality in their procurement practices. In the abstract, the national government's financial resources are so huge relative

³ For empirical studies of these attitudes see [13] and [14].

even to large system costs that substantial contingent costs should not be worrisome⁴ Government is in this sense a natural self-insurer. On the other hand, in reality, "government" does not negotiate contracts as a grand collectivity whose risk attitudes are shaped by total receipts. Procurement is executed by contracting teams who are indoctrinated by superiors with the need to restrain costs, to remain within budget limits, and to avoid Congressional attention to cost overruns. Such concerns could justify the view that in negotiating major weapon systems contracts government procurement officers must be and should be risk averse.

With these basic tools of risk analysis, it is now possible to move to the study of the role of the insurance function of warranties in the management of risk in defense major weapon systems procurement.

B. THE INSURANCE FUNCTION OF WARRANTIES

1. The Contractor as Risk-Averse

Consider the plight of the risk-averse contractor depicted in Panel a of Figure VI-2. Suppose he has signed a contract with an EPR warranty clause to cover potential remediation costs when the system is fielded. For simplicity suppose the expected value of his profits on the contract is dependent on only two result-states. If θ_1 occurs only normal maintenance costs will occur for which he is not responsible, and he will pocket \$1 million. However, if θ_2 is realized, the system will undergo extensive repair, redesign, and retrofit costs for which he is responsible, and his profit, P , will be only \$70,000. From (4), then, the expected value of his profit on the contract will be

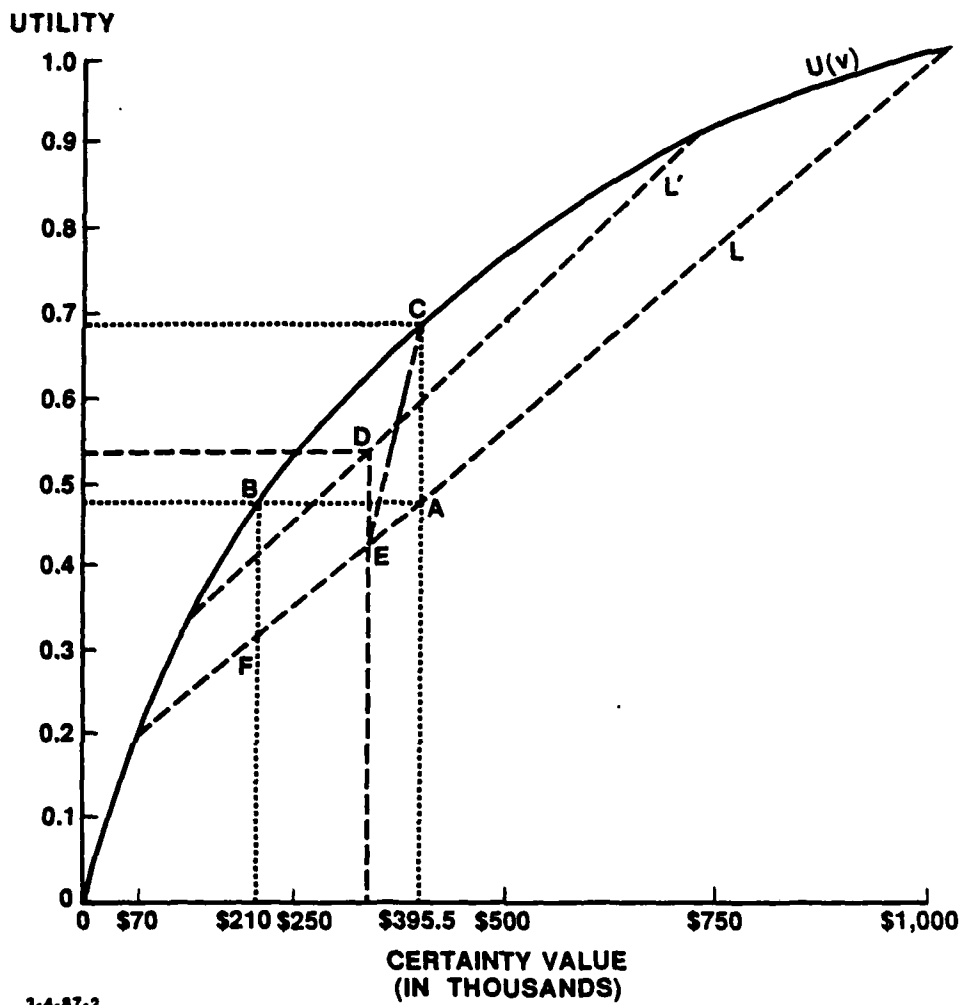
$$(6) \quad E\{P\} = \pi_1 \cdot V(\theta_1) + \pi_2 \cdot V(\theta_2)$$

where, of course $\pi_2 = 1 - \pi_1$.

Suppose the contractor, on the basis of experience with similar weapon systems and perhaps intuition believes the probabilities of θ_1 and θ_2 are $[\pi_1, \pi_2]$, and fixes them in (6) at those values. Figure VI-3 then employs the mapping of his preferences in Figure VI-2, Panel a, to depict his present situation.

As drawn in Figure VI-3, $\bar{\pi}_1 = .35$, $\bar{\pi}_2 = .65$, and the contract has an expected value of \$395,500, which the contractor values at a utility value of .48. This is the equivalent: in certain income of \$210,000. Therefore, the risk premium AB equals \$185,500, which is the maximum amount an insurer could extract

⁴ Cf. the Arrow-Lind argument in the article cited in footnote 1.



3-4-87-2

Figure VI-A-2. THE WARRANTY CONTRACT LOTTERY AND THE RISK-AVERSE CONTRACTOR

from him to escape the risk. On the other hand, if the contractor had the opportunity of receiving \$395,500 in either θ_1 or θ_2 (i.e., with certainty), he would value this outcome over the fair gamble by AC in utility terms, or by .20. That is, if he could buy insurance on fair terms, he would be willing to pay a premium of \$604,500 in θ_1 - profit for a compensatory payment of \$325,500 if θ_2 - profit of \$70,000 should be realized.

Let q_1 be the price of \$1 of profit in θ_1 and q_2 the price of \$1 of profit in θ_2 . Then

$$(7) \quad \frac{q_1}{q_2} = \frac{\$325,500}{\$604,500} = .538 = \frac{\pi_1}{\pi_2}$$

Fair insurance is that insurance which prices dollars of state-profit proportionately to the probabilities of the states' occurrence, for at those prices the insurer will just break even in the long run. At *unfair insurance* rates the contractor would be willing to purchase insurance to an extent that reflects the poorer terms on which he can hedge risks. In the elucidation of these points Figure VI-3 has limitations which can be avoided by a more flexible approach whose graphic display is Figure VI-4.

Consider the expected profit function of (6) where π_1 and π_2 are fixed at values $\bar{\pi}_1$ (= .35 in the example) and $\bar{\pi}_2$ (= .65):

$$(8) \quad E\{P\} = \bar{\pi}_1 \cdot P(\theta_1) + \bar{\pi}_2 \cdot P(\theta_2)$$

The *expected utility* function is then

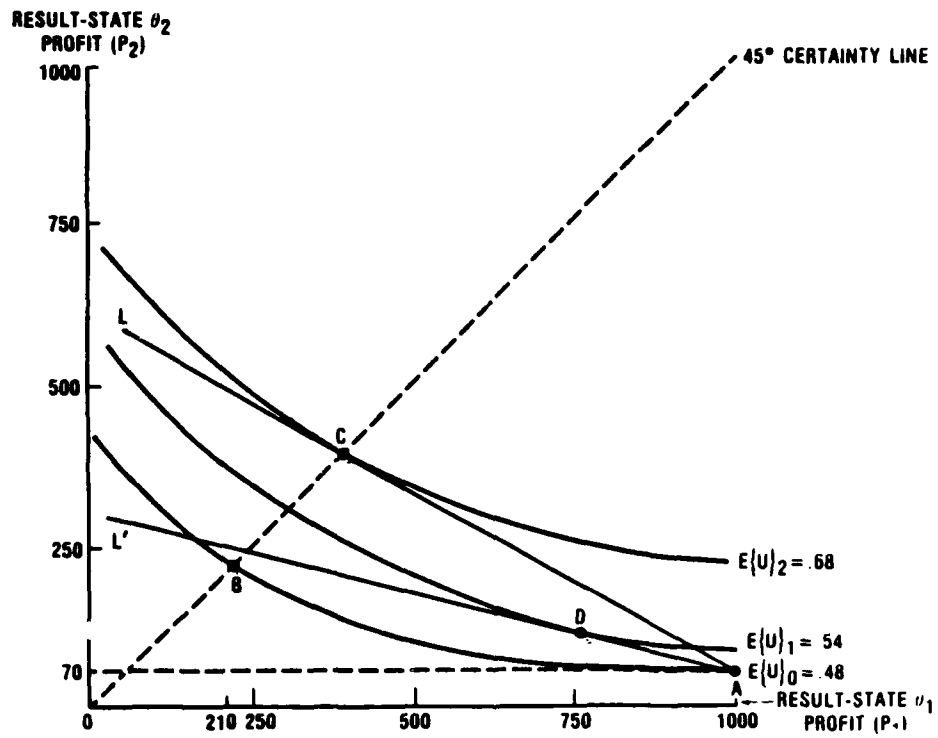
$$(9) \quad E\{U\} = \pi_1 \cdot U(P_1) + \pi_2 \cdot U(P_2)$$

where $P_i = P(\theta_i)$. Suppose, now, P_1 and P_2 are permitted to take any pair of values in the nonnegative quadrant (this quadrant restriction being adopted wholly for convenience).

Then $E\{U\}$ may be envisioned as a hill rising in three dimensions over the $P_1 - P_2$ plane, becoming indefinitely higher as one gets further from the origin. If the "contour lines" of this expected utility hill are projected down upon the $P_1 - P_2$ plane, they will have the convex forms illustrated on Figure VI-4 by $E\{U\}_0$, $E\{U\}_1$, and $E\{U\}_2$ for the *risk-averse* contractor.

All points on any such contour line are combinations of P_1 and P_2 which yield a fixed amount of expected value $E\{U\}$. Consider, for example, $E\{U\}_0$. At the point A the contractor's initial profit position is depicted: in the example he will receive \$1 million if θ_1 occurs and \$70,000 if θ_2 is realized. From point A on Figure VI-3 and equation (9),

$$(10) \quad E\{U\}_0 = .35(1) + .65(.2) = .48,$$



12-10-88-6

Figure VI-A-3. THE CONTRACTOR'S INSURANCE PURCHASES

as shown on Figure VI-3. However, Figure VI-4 extends the analysis by permitting the display of *all* combinations of P_1 and P_2 which will yield .48 in expected utility on the "indifference curve" $E\{U\}_0$.

Consider the 45° dashed "certainty" line drawn from the origin on Figure VI-4. It represents the "perfect insurance" situation where the contractor would receive the same profit no matter which result-state occurred (i.e., $P_1 = P_2$). The contractor would have eliminated all risk at any point on this certainty line. For example, at point *B* the contractor has attained a certainty profit of \$210,000 in either result-state, and it yields him the same utility as he receives at *A* (i.e., .48). Hence, this is also point *B* on Figure VI-3, whose utility equivalence to the expected value of the uncertain event at *A* is quite clear.

Suppose, now, an insurer exists who agrees to trade θ_1 profit for θ_2 profit in the ratio of q_1/q_2 , where q_1 is the price of a dollar of θ_1 profit and q_2 the price of a dollar of θ_2 profit. The contractor now has an opportunity to trade θ_2 profit for θ_1 profit and thereby shift risk of some or all of the variance in earnings to the willing risk-bearer. How much "insurance" will the contractor buy in an optimum solution?

Suppose the insurer offers P_2 and P_1 at the trade-off given by the line L' . The slope of that line as drawn is .22, so if $q_1 = 1$, it follows that $q_2 = \$4.55$. That is, one dollar of profit in θ_2 is valued at 4.55 times one dollar in θ_1 . Knowing this slope and the fact that L' passes through [1,000, 70] permits the derivation of the "insurance trade-off function":

$$(11) \quad P_2 = 290 - .22 P_1$$

or, in general

$$(12) \quad q_1 P_1 + q_2 P_2 = K$$

where q_1 , q_2 , and K are given parameters.

The firm's optimal decision is derived by maximizing expected utility given (12)

$$(13) \quad \begin{array}{l} \text{Max } E\{U\} = \bar{\pi}_1 U(P_1) + \bar{\pi}_2 U(P_2) \\ P_1, P_2 \end{array}$$

$$\begin{array}{l} \text{subject to:} \\ q_1 P_1 + q_2 P_2 = K. \end{array}$$

The first-order necessary condition for this constrained maximum is

$$(14) \quad \frac{\bar{\pi}_1 U'_1}{\bar{\pi}_2 U'_2} = \frac{q_1}{q_2}$$

where U'_1 is dU/dP_1 evaluated at P_1 . Since $U(P)$ is a concave function for the risk-averse contractor (i.e., $U'' < 0$ everywhere) and the insurance trade-off constraint function is linear, the second order sufficient conditions will be met and guarantee that the optimum determined by (14) is a global maximum.

Condition (14) says that the optimum will be located where the expected marginal utility of P_1 per dollar of cost equals the expected marginal utility of P_2 per dollar of cost. Alternatively, the left-hand side of (14) is the marginal rate of substitution of profits in the two result-states and the right-hand side is the insurance rate of substitution for the two state profits. The left-hand side is simply the slope of an indifference curve and the right-hand side is the slope of L' . The equality requires, therefore, a tangency between an indifference curve and L' , which in Figure VI-4 occurs at D . The contractor has been enabled to rise to a higher level of expected value by moving from A to D , and at D has attained the highest indifference he can achieve with the proffered insurance opportunity. He will pay a premium of \$250,000 for the opportunity of receiving \$55,000 in coverage if θ_2 occurs, to bring his profit up to \$125,000 in that event. Hence, his expected profit is $(.35) 750,000 + (.65) 125,000 = \$343,750$. From Figure VI-3 this yields a new "lottery," L' , which has less variance than the original "lottery," L . At D on L' , $\pi_1 = .35$, and $E\{P\} = \$343,750$, with $E\{U\} = .54$. This new lottery is equivalent to moving to E on L , the old lottery, with $\pi_1 = .29$ instead of $.35$ --an unfair bet. This exceeds the expected utility value at A and is preferred to A . On Figure VI-4 this means D lies on a higher indifference curve, and it is now known that $E\{U\}_1 = .54$.

To translate this into DoD contracting contexts, suppose in negotiations the government were willing to absorb some of the risks of a failure of the system to conform to EPRs (θ_2). It therefore offers the contractor his choice of two options:

1. To receive a fee of \$1 million if the EPRs are achieved (i.e., state θ_1 is realized) or \$70,000 if θ_2 occurs.
2. To increase the fee received in θ_2 by \$.22 for every \$1 reduction in θ_1 that the firm accepted, so that P_2 and P_1 are determined by the contractor by equation (11).

If the contractor does select option 2 at the values $[P_1, P_2] = [750,000, 125,000]$ DoD is lifting six percent of the potential loss from the contractor. That is, if θ_2 emerges the firm suffers a loss of \$930,000 and receives compensation of \$55,000 reducing that loss by six percent or \$35,750 in expected value. For this the firm pays \$87,500 in expected value, or \$2.45 for each dollar of expected compensation. The contractor is paying an unfair price, but his risk-averseness yields a net gain in expected utility.

In terms of an EPR warranty setting, these propositions imply that if DoD wishes to assume all risk of failure to conform to EPR specifications *due to the emergence of nature states over which the firm*

has no control it should include a warranty that holds the firm responsible for remediation in the event of θ_2 but pay for that warranty at the expected value of the loss, or, in the present case,

$$.35 \times \$0 + .65 \times \$930,000 = \$604,500.$$

The terms on which the contractor is offered insurance along L' are extremely "unfair." The probabilities of result-states θ_1 and θ_2 are [.35, .65]. A fair bet, then, between insurer and contractor, which results in no net gain to either party, would occur when

$$(15) \quad q_1 \Delta P_1 + q_2 \Delta P_2 = \bar{\pi}_1 \Delta P_1 + \bar{\pi}_2 \Delta P_2 = 0,$$

where ΔP_1 is the insurance premium paid when θ_1 is realized and ΔP_2 is the loss compensation paid when θ_2 occurs. Hence, from (15)

$$(16) \quad \frac{q_1}{q_2} = \frac{\Delta P_2}{\Delta P_1} = \frac{\bar{\pi}_1}{\bar{\pi}_2}$$

or fair insurance requires that the ratio of prices the insurer places upon profits in result-states be equal to the ratio of the probabilities of those result-states.

The insurance trade-off line L is drawn to conform to this fair-insurance requirement. Hence, its slope is $q_1/q_2 = \bar{\pi}_1/\bar{\pi}_2 = .54$, compared with that of L' which in (11) was seen to be .22 (where both slopes are, of course, negative). Along L' the price of a dollar of profit in θ_2 is too high relative to the probability of that state's emergence, but this is corrected on L .

Proposition 1. A risk-averse party when offered insurance at prices proportionate to the probabilities of the result-states will reach an expected-value optimum where he eliminates all variance in the outcomes. That is, he will choose a certainty option and shift the burden of risk-bearing completely to the insurer.

Proposition 2. The optimal type of insurance for a risk-averse party when offered insurance at prices proportionate to the probabilities of the result-states is to pay a fixed premium in return for 100 percent reimbursement for all losses.⁵ Graphically, in Figure VI-4, the motivation is clear.

Proposition 3. A risk-averse party when offered insurance at unfair prices will purchase some insurance, thereby shifting some of the risk, providing the ratio of prices placed by the insurer on profits in the result-states is no less than the unfair bet that lies below the risk-premium certainty value on the original lottery (point F on Figure VI-3).

⁵ A similar proposition is proved by Kenneth Arrow in "Uncertainty and the Welfare Economics of Medical Care," *American Economic Review*, 53(1963), Appendix, Theorem 1. In the present case θ_2 implies a loss of \$930,000. The contractor can be viewed as buying insurance which covers 100 percent of his losses for a premium of \$604,500.

Consider, once more, the certainty point C on Figure VI-4. This corresponds to point C on $U(V)$ in Figure VI-3 which is indeed a certain-income utility function. When the insurance is priced fairly, at the optimum point C in Figure VI-4, from (14) and (15),

$$(17) \quad \frac{\bar{x}_1 U'_1}{\bar{x}_2 U'_2} = \frac{q_1}{q_2} = \frac{\bar{x}_1}{\bar{x}_2}$$

$$\frac{U'_1}{U'_2} = 1$$

$$U'_1 = U'_2$$

That is, along the 45° certainty line the marginal utility of profits is equal. Of course, it must be because profit in both states is equal. This illustrates a classic proposition in insurance theory that is a corollary of Proposition 1: a risk-averse insurer, offered fair insurance, will equate the marginal utility of income in all result-states. It follows that the slopes of the indifference curves on the 45° line will all equal the ratio of the fixed probabilities.

It is necessary to translate these theoretical considerations into the specifics of DoD weapon system warranties, for several novel features arise in the use of these instruments in the insurance function within this context.

An obvious but frequently ignored aspect of most insurance transactions is that the insured does not escape the social costs of nature's potential reduction of his welfare. Insurance permits a shifting of risk, not the avoidance of the cost implicit in situations of risk. The consumer who receives a warranty on his new automobile pays the expected cost of remediation in the way of a premium although it is hidden in the price of the car. Or he may be offered a warranty on his new microwave oven at an additional cost which incorporates the expected cost of repairs over the period of the warranty. The homeowner who buys insurance for his home pays a premium that is based upon the expected cost of replacing or repairing it in the event of fire. The basic economic principle that buyers should face the full marginal social cost of their purchases encompasses the expected cost arising from uncertain events.

What buyers are purchasing in their payments for insurance is the reduction in the variance of such costs--to zero in the case of full insurance. For the certain loss of a fixed amount of money, when fully insured the buyer's income or wealth is guaranteed to remain unaffected by nature's choice of states over a fixed period insofar as the insured object or process is concerned.

In DoD contracting, however, the contractor is not in the position of purchasing an object for his usage or of protecting personal property. It is DoD which is the purchaser using the contractor as an agent

and, therefore, it should pay the expected cost of uncertainty inflicted by the pure randomness of events on which neither party has an influence. Hence, the contractor should receive reimbursement in the form of expected costs of the EPR provisions from this source.

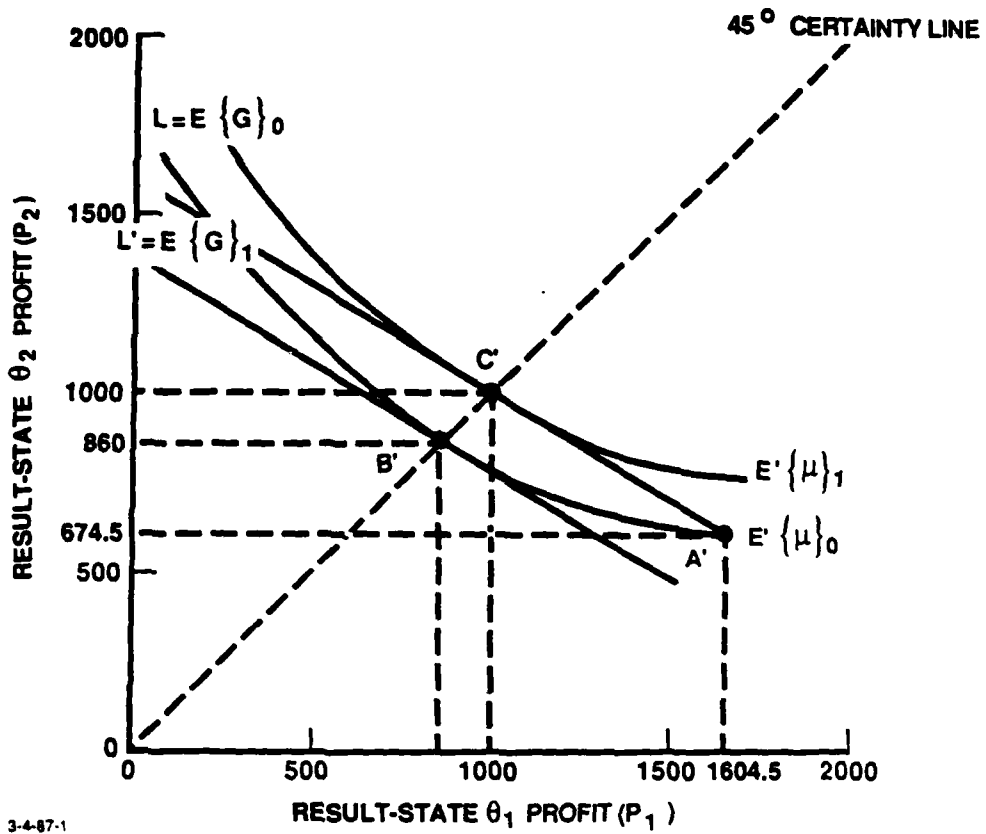
One means of effecting this payment would be to include the expected costs in the price of the contract as a non-line item covering assurance-validation expenditures. Because such costs are likely to be large, uncertain in their computation, and an important part of the negotiation, it has been argued in Section A.1 that these costs should be isolated and incorporated in the price of the EPR warranty. Indeed, FARs with DAR supplements require that the costs of contingencies must be separately justified, so that the need for isolation is reinforced by contracting regulations.

Consider the illustrative case. The expected cost of the EPR provisions was determined to be \$604,500, or $.65 \times \$930,000$. Suppose, now, that in facing up to the need to recompense the contractor, DoD agrees to a warranty with a price of \$604,500 paid to the contractor. This is an alternative to the two offers previously made, and obviously is preferred by the contractor to those.

If the contractor accepted the warranty, his original position changes to that depicted in Figure VI-5 at A' . With the payment for the warranty his profit pair for states of nature is $[1,604.5, 674.5]$ with an expected value of 1,000 (all in thousands of dollars). At expected utility level $E\{U\}_0$ he is much happier than at point A on Figure VI-4 now that his expected costs are covered.

But note an important feature of point A' : all of the risk has been placed upon the contractor. If θ_1 occurs he receives profits of \$1,604,500, but if θ_2 is realized he obtains only \$674,500 after remediation expenses of \$930,000. Given his risk aversion he would be equally happy at B' with certain profit receipts of \$860,000 in both states, paying a risk premium of \$140,000. Were he able to buy insurance at a fair price along L he would be most happy to pay a \$604,500 premium to obtain a \$325,500 compensation if θ_2 occurs, thereby attaining a certainty income of \$1 million at C' .

At A' , however, DoD is fully insured, paying \$674,500 regardless of state for the costs of the warranty. The price insurance function of the warranty has now been isolated. DoD is paying no premium for escaping the risks of EPR costs and shifting all of that risk on to the contractor. Would the contractor permit this, given his risk averseness? By bearing some or all of the risk might DoD actually better its position? To these questions the analysis must now turn. In order to lay the groundwork for answers, it will be necessary to return to abstract theory once more.



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Figure VI-A-4. THE CONTRACTOR'S INSURANCE PURCHASES

2. DoD As Risk-Neutral

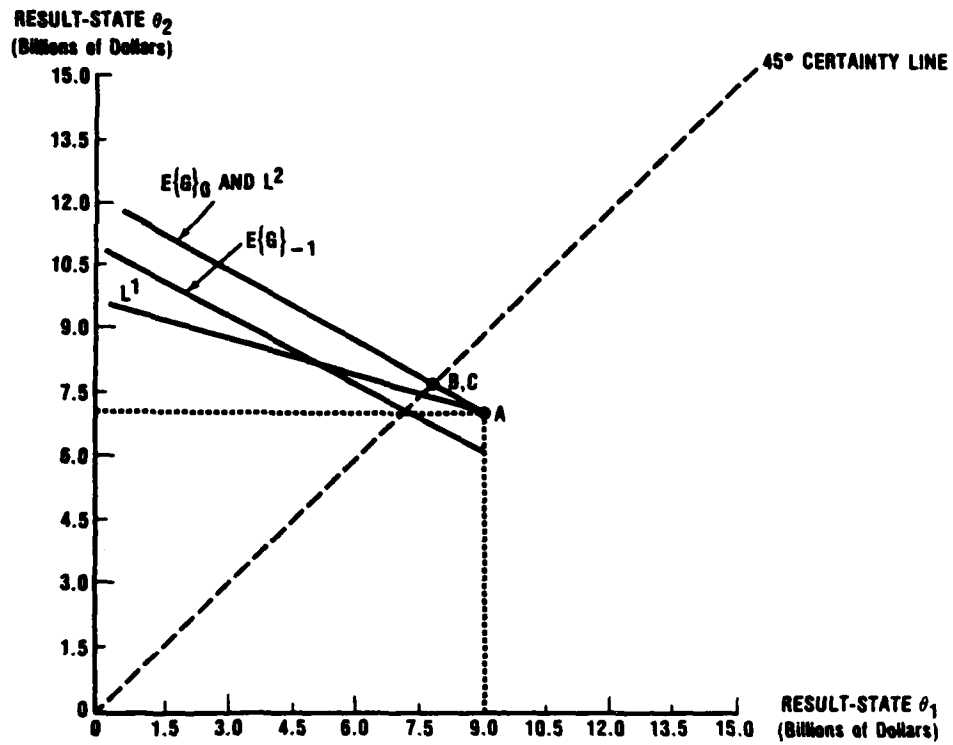
To this point the analysis has depicted the insurance choices of a risk-averse insured and a risk-neutral insurer offering insurance at prices proportionate to result-state probabilities. However, *the insurance function of DoD weapon system warranties is to provide insurance against losses on maintenance and support to government from a presumably much more risk averse contractor.*

On Figure VI-6 the preference mapping and insurance choices of a risk-neutral party are depicted. Suppose DoD's attitudes toward risk for relevant amounts of potential losses are approximated by risk-neutrality. Because the choices concern the extent of prospective costs rather than profits, and in order to depict the situation in the nonnegative quadrant, the following interpretation is given. Assume that DoD has an appropriation of \$9 billion for support costs of major weapon systems for a relevant time period. For a new weapon system whose contract is being negotiated, two result-states are possible. If θ_1 is realized, support costs will be minimal at \$1 million, so that the support cost fund will be \$8,999 million at the end of the period. On the other hand, if θ_2 occurs, major repairs and retrofitting will result in an estimated \$2 billion in costs, and the support cost fund will be debited and reduced to \$7,000 million. These are the result-state outcomes depicted by point A on Figure VI-6.

Assume that $\pi_1 = .35$ and $\pi_2 = .65$. Then if government is risk-neutral its expected utility contours will be straight lines with slope $.35/.65 = .538$, as drawn on the figure. The expected value of the support fund at the end of the period is \$7.7 billion, as shown at point B, and this is the certainty value that would make the government feel as well off as it does at A with the gamble. If an insurer were to offer it insurance at the "fair price" of \$.54 of loss restitution for each \$1 in premiums, the government could move along L_2 and fully insure itself at C. But L_2 coincides with $E\{G\}_0$ and C coincides with B: the government is not better off at C than it is at A, given its assumed attitudes toward risk. It neither gains nor loses utility.

It is now possible to apply this to the DoD warranty example of Section 1 as depicted in Figure VI-5. Assume that the point C (and B) on Figure VI-6, where DoD is completely insured by the contractor against risk is the point A' in Figure VI-5. The line L on the latter figure is the line of fair insurance but it is also an expected government utility contour line such as $E\{G\}_0$ on Figure VI-6, where DoD's utility function is $G(z)$, z being expenditure on the contract.

If DoD moved to A on Figure VI-6 this is equivalent to a move to C' on the contractor's expected utility function on Figure VI-5 where he is now bearing no risk and DoD is bearing all of the risk. Being risk-neutral, DoD is just as well off at C' as at A' but the contractor has improved his utility from $E\{U_0\}$



12-10-66-7

Figure VI-A-5. GOVERNMENT AS A RISK-NEUTRAL DECISION MAKER

to $E\{U_1\}$. To the economist, C' is socially superior to A' since DoD is no worse off at C' and the contractor is better off.⁶

DoD could achieve C' simply by self-insuring. Instead of offering a fixed price of \$604,500 for the EPR warranty it would simply pay no extra dollars (above \$1 million contracted for in the price of the contract) if θ_1 occurred and \$930,000 to compensate the contractor if θ_2 occurred. This has the same expected cost as the former warranty, but DoD bears all the risk at no disutility to itself.

At C' on Figure VI-5 the contractor obtains all of the benefits of DoD's assumed risk-neutrality and DoD gets none. Compare the point B' with A' to understand the opposite case, where the contractor once more is fully insured but DoD receives all of the increased utility. At B' the contractor is no better nor worse off than he was at A' but the government is on expected utility contour $L' = E\{G\}_1$. The lower contour, which is simply a straight line parallel to L , represents smaller government expenditures and hence greater DoD utility. Thus, DoD is better off at B' than at A' and the contractor is just as well off. At points of tangency between $B'C'$ on the 45° line (the indifference curves have not been drawn) the benefits of DoD assuming all of the risk are shared between the parties.

Thus, DoD could reduce its contract costs at B' compared with C' by offering to pay the contractor only \$860,000 in profits if state θ_1 occurred and \$1,790,000 if state θ_2 materialized, for an expected value of \$860,000 rather than \$1,000,000.

However, the insurance warranty finally agreed to in this contract is the product of joint negotiation. The contractor will desire to be at C' in Figure VI-5, which is similar to point A in Figure VI-6, where the contractor is perfectly insured and at the best terms possible. His bargaining over the price of the warranty is effectively offering insurance to DoD at a price, and this process must now be analyzed.

But the insurer is a contractor who must be assumed to be risk-averse. It is simple to show that the risk-averse firm will not offer insurance at a price proportionate to the result-state probabilities, but will always offer it on "unfair" terms, as, for example, along L^1 in Figure VI-6, where the government is offered a compensation of \$.30 per dollar of loss for each \$1 in insurance premiums. On Figure VI-2, Panel a, assume the firm is at certainty income level B . To induce it to take the fair gamble at A as an insurer would require the insured to pay the risk premium AB . This is equivalent to moving the insured from the fair bet at A to an unfair bet.

⁶ This is, of course, the concept of Pareto optimality or superiority.

But if the contractor offered insurance at the unfair prices of L^1 the government should not buy any, because all of the indifference contours of its utility function in Figure VI-6 that are intersected by L^1 are lower than $E\{G\}_0$ (except at A), as illustrated by $E\{G\}_{-1}$.

Hence, it can be asserted:

Proposition 4. *If the government can be assumed to be risk-neutral in its preferences over money resources under uncertainty it cannot benefit by purchasing a warranty to insure against losses even if the warranty is offered at a fair price. If the firm negotiating the warranty is risk-averse the price will reflect unfair odds, and the degree of departure of that unfair price from the fair price will rise with the degree of risk-averseness of the contractor. In this case the government cannot benefit from insurance. Therefore, if the government is risk-neutral, it should never use warranties wholly to insure against money losses.*

Risk-neutrality is likely to be a good approximation to DoD preferences when the potential losses are small relative to the cost of the weapon system. And, finally, to the expectation of the risk premium that warranty issuing contractors will incorporate into the price must be added the costs of administering the insurance. Hence, the final price must be expected to depart even more from the ratio of the probabilities of the result-states: that is, the premium charged will be "loaded" with a risk premium and administrative expenses including profit.

3. DoD As Risk-Averse

Suppose, however, DoD is considered to be risk-averse, and considers purchasing insurance against repair and support costs from a risk-averse contractor via warranty. DoD may then find it advantageous to purchase a warranty at a negotiated price that will be less than fair. It has been shown on Figure VI-4 that it will benefit a risk-averse party to purchase some insurance against losses at unfair prices although not to the point of full coverage of losses (i.e., at L^1 on the figure, an unfair price, he will move to D from A, but not to the 45° full coverage line). However, as can be seen from Figures VI-4 and VI-6, as the insured becomes less risk-averse (the expected utility contours approach closer to the linear) and the insurer becomes more risk-averse (the insurance price lines L^1 approach the horizontal) the benefit of insurance to the insured becomes smaller and his purchases correspondingly less.

To formalize this the following proposition will be demonstrated:

Proposition 5. *If both DoD and the contractor are risk-averse, if negotiations between them result in an efficient price, and if administrative costs of the insurance are neglected, the warranty will*

provide for a sharing of the risk between the parties. That is, the optimal insurance warranty will provide for partial insurance.⁷

Assume that the firm's utility function over money, y , is $U(y)$, and that DoD's utility function is $G(y)$, and that both are risk-averse. From Figure VI-2, risk-averseness means that the functions are strictly concave, or that $U''(y)$ and $G''(y)$ are strictly negative. Of course, both marginal utilities, $U'(y)$ and $G'(y)$ are positive.

Define:

1. W_G . The initial wealth of DoD that is relevant to the contract to be negotiated.
2. W_C . The initial wealth of the contractor.
3. X . The loss if result-state θ_2 occurs.
4. $I(X)$. The net compensation paid by insurer if loss X is suffered, or gross payment less price of warranty.
5. P . Price paid for warranty.
6. K . Price paid for contract.

The final money positions of DoD and the contractor are

$$(18) \quad \begin{aligned} 1. \quad Y(X) &= W_G - X + I(X) - K \\ 2. \quad Z(X) &= W_C - I(X) + K. \end{aligned}$$

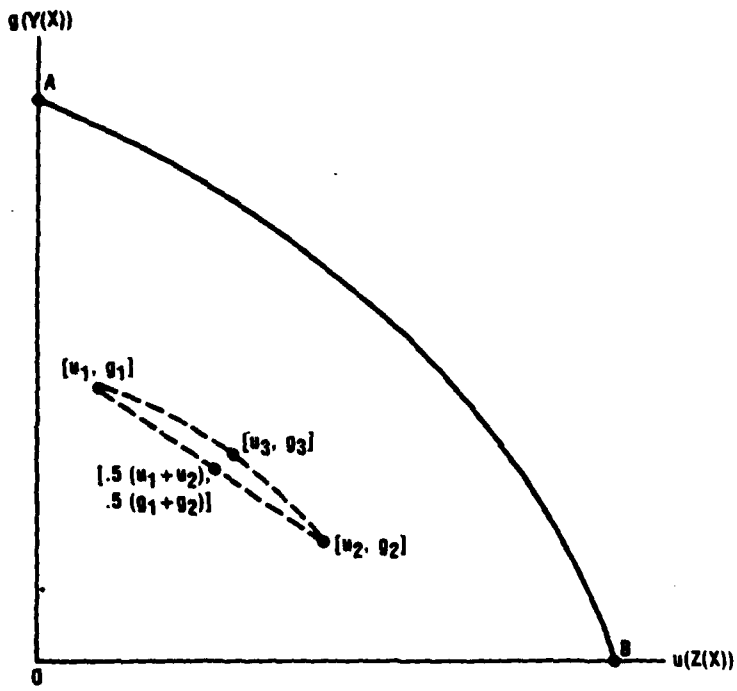
The expected utilities of these money positions are defined as:

$$(19) \quad \begin{aligned} u &= E\{U[Z(X)]\} \\ g &= E\{G[Y(X)]\} \end{aligned}$$

The first task is to define and illustrate the concept of efficiency employed in this context. A warranty is efficient when it is not possible to alter its terms in any way that would benefit one of the parties without reducing the utility of the other.⁸ Consider all possible warranties, $I(X)$, and the resultant $[Y(X), Z(X)]$ positions resulting from them. Then, under the assumption that both parties agree upon the result-state probabilities, π_θ , it is possible to graph the expected utilities for each such policy on Figure VI-7.

⁷ The theorem was first proved by Karl Borch in [8], pp. 163-184. The proof to be used in this paper is due to Kenneth Arrow, *op. cit.*

⁸ This is another instance of the economic concept of *Pareto optimality or superiority*, defined in footnote 10.



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Figure VI-A-6. THE EFFICIENCY SET OF WARRANTIES

Now, choose any two possible policies, $I_1(X)$ and $I_2(X)$, and their respective expected utilities $[u_1, g_1]$ and $[u_2, g_2]$, as shown on Figure VI-7. Define a third policy as the mean of the two:

$$I_3(X) = .5I_1(X) + .5I_2(X).$$

It follows that

$$Y_3(X) = .5Y_1(X) + .5Y_2(X)$$

$$Z_3(X) = .5Z_1(X) + .5Z_2(X).$$

But the expected utilities of $I_3(X)$ will in general be greater than the mean of the expected utilities of the component warranties:

$$u_3[Z_3(X)] \geq .5u_1[Z_1(X)] + .5u_2[Z_2(X)]$$

$$g_3[Y_3(X)] \geq .5g_1[Y_1(X)] + .5g_2[Y_2(X)].$$

This result holds because both parties experience diminishing marginal utilities to money, and the consequent concavity of the utility functions.

This is illustrated in Figure VI-8 for the contractor. The line segment connecting U_1 and U_2 is the convex combination $\lambda U_1 + (1 - \lambda)U_2$, $\lambda \in [0, 1]$, and the point where $\lambda = .5$ is the mean of U_1 and U_2 . U_3 , however, lies above that mean value, as does every point on $U(Z)$ between U_1 and U_2 except the end points. This is a definition of the (strict) concavity of the function. Another definition of concavity is that a tangent to $U(Z)$ at any point will lie on or above $U(Z)$ everywhere in the domain of the function. The tangent at U_3 , for example, has the form

$$U = U_3 + U'_3(Z - Z_3),$$

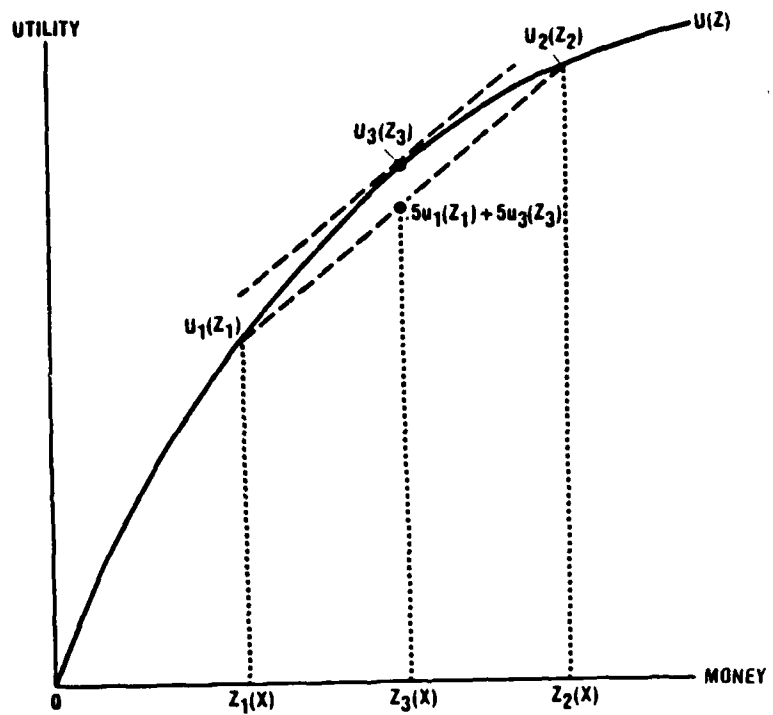
where U'_3 is the slope of U at U_3 and Z is any value of $Z(X)$. On the other hand, $U(Z)$ can be approximated by a Taylor's series expansion around U_3 as

$$U(Z) = U_3 + U'_3(Z - Z_3) + .5U''_3(Z - Z_3)^2,$$

where $(Z - Z_3)$ is a small distance from Z_3 . Then the difference between the value of the tangent, U , and the value of $U(Z)$ directly beneath it is

$$U - U(Z) = U_3 + U'_3(Z - Z_3) - U_3 - U'_3(Z - Z_3) - .5U''_3(Z - Z_3)^2 = \\ - .5U''_3(Z - Z_3)^2 > 0.$$

Since $U''_3 < 0$, U lies above $U(Z)$, and the role of diminishing marginal utility in causing this is clear.



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Figure VI-A-7. IMPLICATIONS OF THE CONCAVITY OF THE FUNCTIONS

Since this holds for $G(Y)$ as well, and because it readily extends to expected utility, the point $[u_3, g_3]$ can be located on the chord connecting $[u_1, g_1]$ and $[u_2, g_2]$ in Figure VI-7. Because the relation is true for any two points in the set, it is true for the boundary. Hence, that boundary-- AB in Figure VI-7--is concave as drawn.

The boundary AB contains all efficient warranties, because at any point on it the contractor can gain utility only if the government loses, and vice versa. At warranties in the interior of the set it is possible to find at least one point on the boundary which benefits one party without hurting the other, or which benefits both parties. The hypothesis in Proposition 5 is that negotiations will result in an efficient warranty somewhere on AB .

Any point on AB can be obtained by maximizing a weighted sum of the parties' expected utilities, $w_1u + w_2g$,

where w_1 and w_2 are nonnegative (with at least one positive) and suitably chosen, and where the maximization is taken over the whole set of possible warranties. That is

$$\text{Max}_{I(X)} w_1 E\{U[Z(X)]\} + w_2 E\{G[Y(X)]\},$$

or

$$(20) \quad \text{Max}_{I(X)} E\{w_1 U[Z(X)]\} + E\{w_2 G[Y(X)]\}$$

To maximize these expected values it suffices to maximize the certainty expressions within the curly brackets. From (18)

$$\frac{dY(X)}{dI(X)} = 1, \quad \frac{dZ(X)}{dI(X)} = -1.$$

Then, performing the maximization of (20),

$$(21) \quad w_1 U' \frac{dZ}{dI} + w_2 G' \frac{dY}{dI} = 0$$

$$-w_1 U' + w_2 G' = 0.$$

Hence, the efficient warranty relevant to $[w_1, w_2]$ is obtained when

$$(22) \quad \frac{G'}{U'} = \frac{w_1}{w_2}$$

or when marginal utilities of money are proportionate to the weight parameters. By permitting w_1 and w_2 to take nonnegative values, the whole boundary AB on Figure VI-7 can be traced out. Solution of (22) permits the relevant optimal warranty, $I^*(X)$, to be obtained, where $I^*(X)$ is the optimal net compensation to be paid by the firm if the government suffers loss X .

Now, if either w_1 or w_2 equals zero one party gives all of its wealth to the other, which is not feasible. Therefore, it is assumed $w_1 > 0$ and $w_2 > 0$. It is then of interest to ask: how does an efficient policy anywhere on boundary AB treat a rise in X ? If loss increases by ΔX , does the optimal policy fully compensate the government? In negotiations on insurance warranties between government and contractor, when efficient, how do the parties share the risk?

To obtain the answer (21) is differentiated with respect to loss X :

$$(23) \quad -w_1 U'' Z'_x + w_2 G'' Y'_x = 0.$$

From (18)

$$(24) \quad Z'_x = -I'_x$$

$$Y'_x = -1 + I'_x$$

Substituting into (23)

$$(25) \quad w_1 U'' I'_x - w_2 G'' + w_2 G'' I'_x = 0,$$

which yields

$$(26) \quad I'_x = \frac{w_2 G''}{w_1 U'' + w_2 G''}$$

This is a fundamental result. When insurance is sold at actuarial value or at a premium above such value that is independent of the size of loss:

1. If both government and contractor are risk-averse ($G'' < 0$, $U'' < 0$), $I'_x < 1$. Therefore, the firm will insist that the government share the risk of all repair and support losses. That is, the optimal contract will require partial insurance. The degree of risk-sharing rises as the relative risk-averseness of the firm rises.
2. If the government is risk-neutral ($G'' = 0$) and the firm is risk-averse ($U'' < 0$), the government will self-insure.
3. If the government is risk-averse ($G'' < 0$) and the firm is risk-neutral ($U'' = 0$), the firm will fully insure the government against all losses.

Results 2 and 3 have formalized the graphic analyses given above. Result 1 is a new deduction for the case when both parties are risk averse. Note that these results include the pricing of insurance to include administrative costs or unfair terms. The price of the warranty, P , has been deducted from gross compensation to obtain $I(X)$, but this deduction, being independent of X , does not affect I'_x .

From (26), in general, as losses X rise, money resources of both government--which is only partially compensated--and the contractor will fall. The absolute values of G'' and U'' should rise. If the contractor is more risk-averse than government, I'_x will fall as X rises, so that the contractor will require larger risk-sharing as the size of potential loss rises relative to his money resources. This is illustrated in Figure VI-9. The risk preferences of government are drawn weakly risk-averse, and the insurance offer curve of the contractor is the concave function L^1 . Were actuarially fair insurance offered along L^2 , government would choose the certainty outcome at C , paying BJ as the price of the warranty for a compensation of FH should θ_2 emerge. But L^1 represents the "loaded" offer of a risk-averse insurer whose terms become more severe as loss-compensation rises. Under these conditions, government chooses to buy only FG in loss compensation for a price EB which lifts its utility to $E\{G\}_1$, only slightly above that obtained at initial position A (where $E\{G\}_0$ through A is not drawn).

4. The DoD Warranty in a Pure Insurance Context

The analysis of Section C suggests that the warranty as an instrument of price insurance against potential money losses when outcomes cannot be affected by contractor actions is suspect in terms of cost-effectiveness. The reasons may be summarized as follows:

1. Government must be expected to be risk-neutral or mildly risk-averse, and certainly less risk-averse than a contractor. Therefore, even if insurance were offered at its fair, actuarial value, permitting DoD to move to a certainty position, it would not benefit much if at all (Figures VI-6 and VI-9).
2. But a risk-averse contractor will not offer such a warranty at its actuarial value, but must include a loading in its price to cover administrative expenses and to incorporate coinsurance. Moreover, the degree of loading will rise more than linearly with the size of potential loss and with the degree of its risk-averseness relative to that of DoD. This reduces the value of the insurance to DoD below that which it would have were the price a fair one (Figure VI-9).

The hypothesis: When the sole consideration in a weapon system contract is a concern that large money losses may occur if certain randomly determined result-states occur, the cost-effective route for DoD is self-insurance.

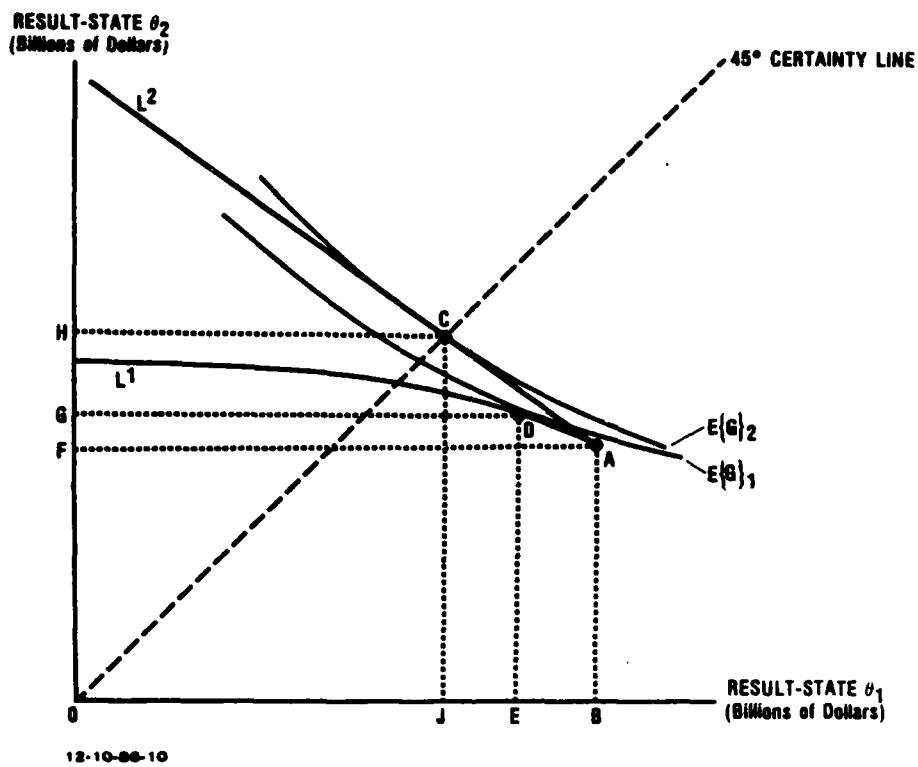


Figure VI-A-8. THE INSURANCE WARRANTY CHOICE OF A SLIGHTLY RISK-AVERSE GOVERNMENT AND A RISK-AVERSE CONTRACTOR

In Chapter V in the consideration of the sample of Army contracts it was noted that the Service intended in the future to move its warranty policy to negotiation of systemic defect protection for up to one half of systems' service life. On the basis of the analysis just completed it is predicted that such a policy will prove too costly to be cost-effective.

C. THE INCENTIVIZATION FUNCTION OF WARRANTIES

1. Contractor Impact Upon Result-States

In Section A.3 it was indicated that the incentivization potential for warranties hinged upon three characteristics of the production process of a weapon system: 1) state-probabilities that could be affected by contractor acts; 2) the capability of motivating such acts by cost-effective rewards and sanctions in DoD contracts; and 3) the capability of both sides to monitor the realized states.

Consider now the production of a weapon system under an incentive warranty. Define:

1. $q = q(f, \theta_i)$: q is a measure of the essential performance requirement variable *in excess of a specified minimum level* q necessary to conform to an assurance warranty. The variable f is total fees paid by DoD.
2. C_q : expenditures by the contractor with the goal of raising q above q .
3. θ_i : states of nature, $i = 1, 2, \dots, n$, interpreted as degrees of success in developing technologies that permit q to be increased. There is a finite number of such potential technologies, and they are known by both contractor and government. Alternatively, θ_i may be envisioned as a simple random event realization that affects the ability of an expenditure C_q to obtain desired q outcomes.
4. π_i : probabilities of states θ_i , held in common by the contractor and DoD.
5. $f = f(q, \theta_i)$: a fee schedule payable by DoD for achievements of $q > q$, where $f(q) = 0$, $f' > 0$, $f'' \leq 0$. This is to be derived by the analysis
6. $C_q = C(q, \theta_i)$: $C' > 0$, $C'' > 0$.
7. K : cost of producing the weapon system buy with standard q .
8. $P = aK + f - C_q$: contractor's profit, where a is a fee parameter applied to cost.
9. $U = U(P, q)$: contractor's utility function, where $U'_p > 0$, $U''_p < 0$, so contractor is risk-averse, and $U'_q > 0$, $U''_q < 0$, so contractor gets diminishing marginal utility from increases in product quality.
10. $G = G(q, z)$: government's utility function, where $z = B - (1 + a)K - f$, where B is a maximum sum available to DoD for the total cost of the weapon system. It is assumed that $G'_q > 0$, $G''_q < 0$, so that DoD obtains diminishing marginal returns from quality, and $G'_z > 0$, $G''_z \leq 0$, or DoD is either risk-averse or risk-neutral with respect to budget funds.

In terms of the elements of principal-agent relations outlined in section A.2, the *action set* A available to the contractor is the expenditure of C_q . The *states of nature* are θ_i , and their *probabilities* π_i . Result-states can be interpreted as the *payoffs* q , and the *warranty contract* as the fee schedule, f . Because the acts are expenditures of money, it is assumed that both parties can monitor them. It is also assumed that *ex post facto* θ_i is capable of being observed by both parties, and that the manner in which θ_i affects q and the quantities π_i are agreed to by both parties. Finally, payoffs q are observable to both parties *ex post facto*.

Consider, now the principal's (DoD's) problem. It must first derive, at least on an approximate basis, the function $q = q(f, \theta_i)$. For each state, θ_i , it is reasonable to assume that $C(q|\theta_i)$ --the conditional cost curve for quality--can be estimated by DoD. Then, because $f(q) = 0$ for $q = 0$, suppose this function has the form $f(q) = bq$. On the assumption that the contractor's utility function is dominated by its profit argument, DoD determines the maximum profit q for the specified fee slope parameter \bar{b} :

$$(27) \quad \underset{q}{\text{Max}} P_\theta = aK + f(q) - C(q|\theta_i)$$

whose first order necessary conditions are

$$(28) \quad \bar{b} - C'_\theta = 0,$$

and whose solution yields $q^*(b|\theta_i)$.

By permitting b to take a range of values, values of q^* may be obtained and plotted against f to obtain an approximation to $q = q(f|\theta_i)$. This procedure has been illustrated on Figure VI-10. For every b_i ray from the origin, q_i is determined at the point on C_q whose slope equals b_i . Then the pair $[f, q_i]$, where $f = b_i q_i$, is plotted in the third quadrant to obtain $q = q(f|\theta_i)$. The expected response-to-incentive curve over all states of nature can then be derived:

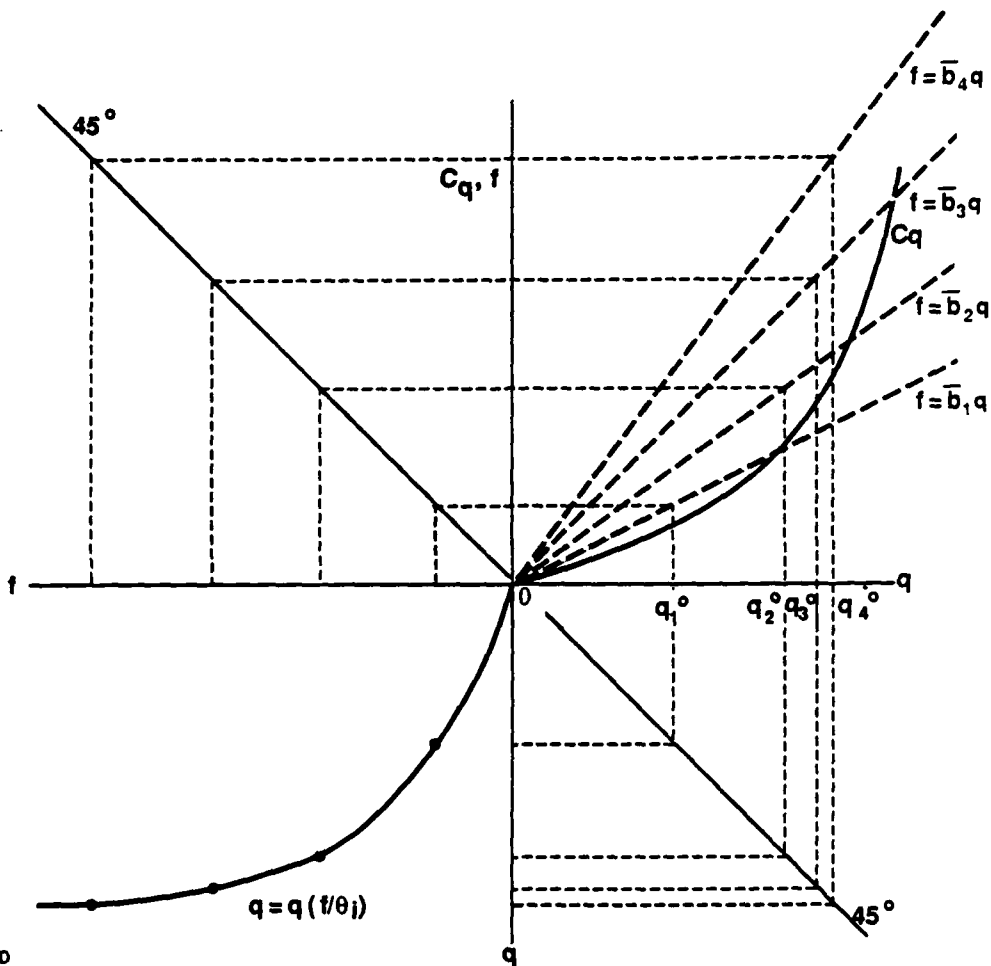
$$(29) \quad E(q) = \sum_i \pi_i q(f|\theta_i).$$

It is plotted on Figure VI-11.

DoD's decision concerning optimal quality and fee levels is made by maximizing its utility subject to (29):

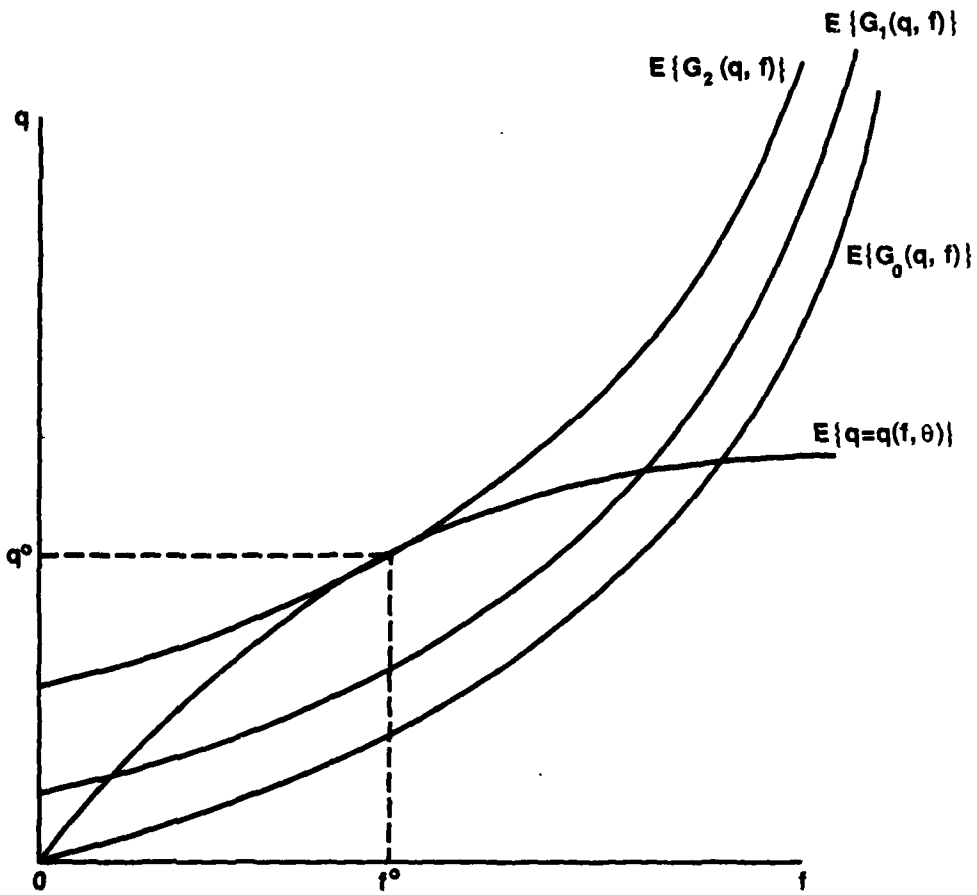
$$(30) \quad \underset{q, f}{\text{Max}} E\{G(q, z)\} - \lambda E\{q(f, \theta) - q\}$$

which yields as a first-order condition:



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Figure VI-A-9. DERIVATION OF APPROXIMATION TO CONTRACTOR'S RESPONSE-TO-INCENTIVE FUNCTION FOR A GIVEN STATE OF NATURE



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Figure VI-A-10. DOD'S OPTIMAL CHOICE $[q^0, f^0]$ WITH GIVEN CONTRACT RESPONSE-TO-INCENTIVE FUNCTION.

$$(31) \quad -\frac{E(G'_q)}{E(G'_q)} = E\{q'\beta\}$$

Some of the expected utility indifference curves are drawn in Figure VI-11. Note that because $G(q, f)$ falls as f rises the indifference curves are positively sloped. Expected government utility, balancing the utility of quality improvement with the utility of funds, is maximized at $[q^0, f^0]$, when DoD is (1) risk averse with respect to funds and (2) expecting diminishing marginal returns to quality improvement. Were DoD risk-neutral the indifference curves of Figure VI-11 would be flatter and attain an optimum with a larger expenditure on fees with greater expected quality return.

Several points should be made. First, Figure VI-11 overstates the amount of fees necessary to induce a given q because the response-to-incentive function does not incorporate the firm's utility return. The fee schedule, therefore, is upward biased in terms of incentives needed to induce any quality level q . Second, f^0 should constitute an upper bound upon fee payments in the fee schedule chosen by DoD. Third, because suboptimal quality achievements do place DoD above $E\{G_0(q, f)\}$ or the expected utility level from achievement of the assurance--validation warranty value of q , the fee schedule should encourage as much improvement as possible up to f^0 given the uncertainty of the states of nature.

The (approximately)⁹ optimal fee schedule for DoD is the inverse of $E\{q(f, \theta)\}$, or

$$(32) \quad E\{q^{-1}(q, \theta)\}$$

for the domain $q \in [0, q^*]$. It is depicted in Figure VI-12 as $E\{f=h(q)\}$.

Because the fee schedule $f = h(q)$ may be too complicated to use for computing fees in the contract, piecewise linear approximations may be more practical. One manner would be to form a mesh of two or three points and draw linear segments as illustrated with S_{11} and S_{12} . These would *overestimate* the required fees (except at the segment endpoints) and would enhance incentives at higher than indicated necessary costs to DoD. Because $h(q)$ is upward biased to start with, it may be a smaller departure from actual optimality to *underestimate* $h(q)$ by a piecewise linear approximation illustrated by segments S_{21} .

⁹ To summarize, $E\{q(f)\}$ is approximated in two senses: (1) it fails to consider the utility the contractor gets from quality directly as opposed to that he gets indirectly. This would lead him to provide a larger q for a given f than $E\{q(f)\}$ predicts; (2) the function maximizes profits, P , rather than $E\{U(P)\}$, which is equivalent to assuming that the contractor is risk-neutral in the domain of income relevant to fee receipts. If $U(C_q)$ had been used in Figure VI-10 instead of C_q , the curve in quadrant I would have risen more steeply because any fee would be more highly valued. Hence, any given quality q could be evoked with a smaller fee. This simplification, therefore, enhances the upward bias in the fee schedule depicted in Figure VI-12.

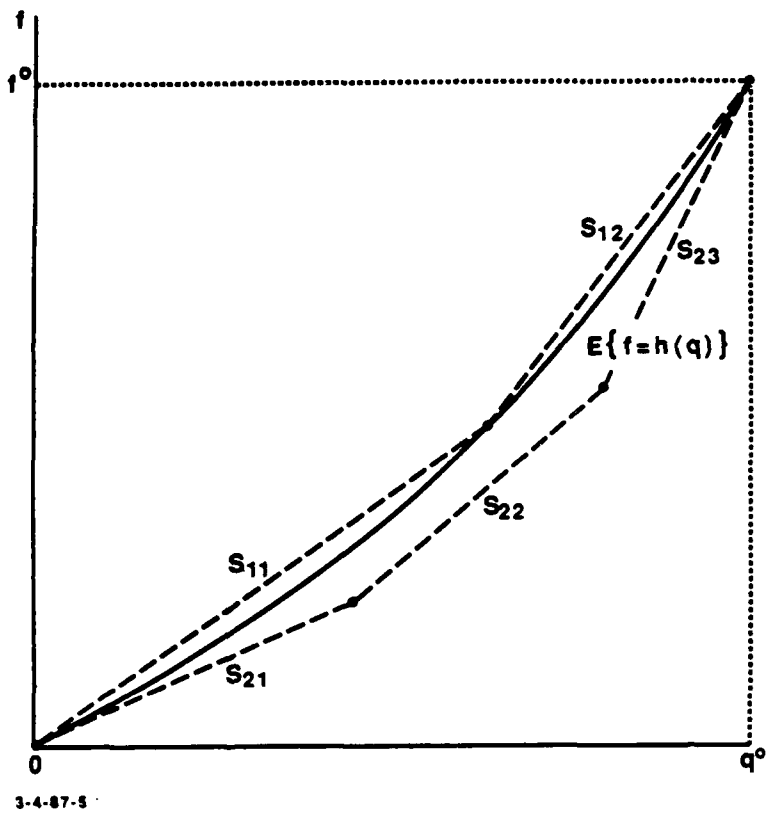


Figure VI-A-11. DOD'S OPTIMAL INCENTIVE FEE FUNCTION AND OPERATIONAL PIECEWISE-LINEAR APPROXIMATIONS

S₂₂, and S₂₃. One disadvantage of the underestimation alternative is that because of the convex nature of the curve the approximations will tend to depart farther from $h(q)$ for any given size of mesh.

Given increasing marginal costs of achieving quality improvements the incentive schedule will feature fees rising faster than a linear fee schedule ($h'' > 0$).

2. Some Unexplored Problems

The analysis in Section 1 has not examined some interesting problems which are suggested as topics for future research.

A first is the derivation of an optimal fee schedule which includes the contractor's utility function. One manner of proceeding is to apply calculus of variations to a Hamiltonian functional. To do so, it must be assumed that the states of nature, θ , are continuous. The following procedure suggests itself.

Assume DoD agrees to derive a family of Pareto-efficient fee schedules by maximizing a weighted sum of utilities:

$$(33) \quad \underset{f}{\text{Max}} E\{G(q, z) + wU(P, q)\}, w \in [0, 1].$$

where w is a relative weighting factor. By the Borch theorem the maximum of (33) can be obtained by ignoring the expectation operator:

$$(34) \quad G'_q \cdot q'_f + G'_z \cdot z'_f = -w(U'_p \cdot P'_f + U'_q \cdot q'_f).$$

Solution of (34) defines the fee schedule family:

$$(35) \quad f_q = f_q(q, \theta_i/w).$$

Given a fee schedule, the contractor chooses C_q so as to maximize utility, which yields

$$(36) \quad E\{U'_p \cdot P'_f \cdot f'_q \cdot q'_c + U'_q \cdot q'_c\} = 0.$$

Then, DoD can form a Hamiltonian functional to maximize over the function f using (36) as a constraint:

$$(37) \quad \underset{f}{\text{Max}} E\{H\} = \underset{f}{\text{Max}} E\{G(q, f) + \varphi(U'_p \cdot P'_f \cdot f'_q \cdot C'_q + U'_q \cdot C'_q)\}.$$

The Euler-Lagrange condition is

$$(38) \quad \frac{G'_q \cdot q'_f + G'_z \cdot z'_f}{U'_p \cdot P'_f + U'_q \cdot q'_f} = \lambda \cdot \varphi \left(\frac{d \left[\frac{q'_c}{q'_f} \right]}{d} \right).$$

and the optimal C_q is chosen by the contractor by differentiating (37) with respect to C_q .¹⁰

Time was not available to investigate this path, especially given its questionable contribution to an operational approach. However, it may have some theoretical payoff in terms of deriving Pareto-efficient fee schedules, which the method in section 1 does not yield.

A second problem is that raised by a contractor's potential ability to alter the probability function over the states of nature. The manner in which this would complicate DoD's problem of obtaining an optimal fee schedule is not clear, and time was not available to investigate it further.

D. NEGOTIATION OF THE ESSENTIAL PERFORMANCE REQUIREMENTS

In section D the important function of warranties in incentivizing the contractor to extend the quality of product beyond the contractually defined essential performance requirements for the system was discussed. These requirements extend contractor liability into the post-acceptance phase. As such, the costs of the contingent liabilities they impose must enter into the negotiated price of the contract, in the form of heightened contract costs of the system, preferably as a line item warranty price.

As has been discussed in Chapters IV and V, a major innovation of Section 2403 legislation was the mandating of EPR warranties. These can be defined as OCs or RMACs or both, and some evidence has been evinced in Congressional hearings that Congressional intent was to foster increased usage of OC warranties. This has not happened to any noticeable extent to date. The typical EPR is an RMAC guarantee.

The question arises of why this bias in the contract negotiation phase exists. Do both sides favor the RMAC for reasons of self-interest, so that they enter the negotiations with pre-negotiation strategies that seek their inclusion as EPRs? Or do the sides have opposing interests in these regards, so that the contract reflects the bargaining strengths of the parties? Or might other considerations lead the party favoring OC definition to acquiesce in RMACs? The theoretical analysis attempts to discover whether both parties are inclined egoistically to favor one form of the EPR or the other.

This section deals with the EPR portion of the warranty, on the assumption that defects in design and manufacture and in materials and workmanship in the acceptance phase are covered by the assurance-validation warranty and are properly costed in the contract price. This paper has taken the position that such stipulations are not properly priced in the form of a warranty. The EPR provisions impose costs that are

¹⁰ This approach is illustrated in work of Stephen A. Ross, [37], pp. 134-139.

properly chargeable to DoD, but because default of contract is discoverable only in a post-acceptance period through complaint channels that are far less formal than the inspection-acceptance process, an important element of moral hazard may intrude. Full assumption by DoD of the expected costs of contract compliance may tempt the contractor to underperformance standards, and separate pricing of the EPR warranty, therefore, can be used as negative incentivization. By forcing some proportion of the expected costs of EPR provision default upon the contractor, DoD incentivizes the firm to reduce the probability of that default with the lessened readiness it implies.

One manner in which the contractor can seek to escape a portion of the risk is by trying to have the EPRs defined as RMACs instead of OCs. It will be argued below that RMA standards are more familiar to contractors and incidence of noncompliance more readily predictable than operating characteristics and are likely to inflict lower costs for remediation. On the other hand, DoD may frequently have a greater interest in operating characteristics than in RMA, especially in the light of the recent Congressional legislation discussed in Chapter IV. Therefore, in the negotiation phase the contractor may have a marked preference for RMACs to be adopted as EPRs and DoD for OCs.

This section will investigate the source and implications of these conflicting aims in the design of prenegotiation strategies by both parties.

1. Government Prenegotiation Strategy

Suppose DoD has decided to produce a weapon system under a firm fixed price contract negotiated with a selected contractor. In this section the analysis seeks insights into the design of a set of DoD goals for the negotiation process, with emphasis upon the role of warranties in such a phase. In Section 2 the analogous strategy for the contractor will be examined. Of course, both parties realize that their goals will have to be compromised in the negotiation, but useful hypotheses about the nature of EPR warranties can be obtained by these one-sided strategy formulations.

Four variables are defined which are significantly related to EPR warranties and whose values, once determined, constitute the government's prenegotiation strategy. They will be defined and discussed in turn.

1. q This variable is now defined more narrowly to be an accurate measure of the operating characteristics of the system defined as "essential performance requirements" that must be attained and retained over some period of time to comply with the contract. The technological ambition and complexity of the system is assumed to rise as q rises, and the probability that it can be attained is assumed to fall as q increases. Although realistically q may be capable of taking on only a finite set of values for any system, it will be treated as a continuous variable over some domain for purposes of the analysis.

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WARRANTIES IN WEAPON SYSTEM PROCUREMENT: AN ANALYSIS OF

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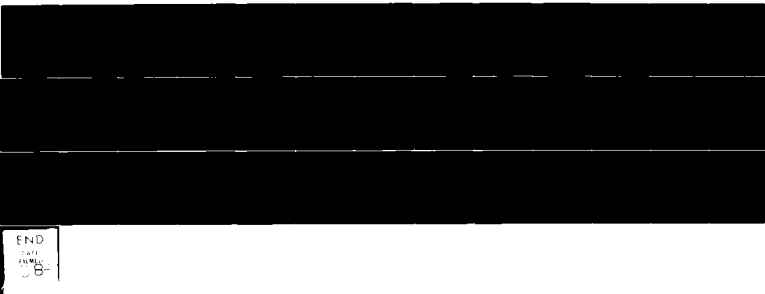
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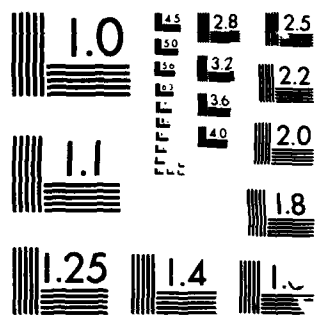
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2. m . The surrogate variable to measure other EPRs defined in terms of the designed reliability, maintainability, and availability of the system, once produced, is so denoted. It may be envisioned as MTBF, and is a characteristic concern of the reliability improvement warranty. Dependability rises as m rises, and the difficulty of attaining a given value for m is viewed as rising as q rises.
3. t . The period of time for which the essential performance requirements warranty is to be effective is designated t .
4. x . To achieve its primary goal of inducing a contractor to produce a system with sustainable performance level q or m the contractor must bear a significant contingent financial liability in the event of nonconformity. The costs of redesign, retrofit, retesting, and remanufacture of system units in order to meet the performance warranty must be incorporated in the cost of the system, and be borne singly or jointly by DoD or the contractor. Of course, in the pre-negotiation and negotiation phases the costs are only speculation, and will be viewed as determined by a family of probability density functions whose expected values and variances rise with q . It will be assumed that government and contractor envision the same family of density functions and use the expected values of such functions as measures of prospective costs for the performance warranty. Then, $0 \leq x \leq 1$ is the fraction of the expected value of performance warranty costs that will be borne by the firm in the contract. That fraction of costs, burdened by a profit margin, will constitute the price of the EPR warranty in the analyses to follow.

Three total cost functions are defined for the analysis:

1. $C(q, m, x, t)$. This function yields the total cost of executing the contract through the acceptance phase. It is a rising function of q and m , reflecting the higher costs of designing and manufacturing more technologically advanced and reliable hardware. It is assumed also to rise as x and t rise, incorporating the expectation that the firm will inflate production costs to include contingent liabilities as the fraction of potential EPR nonconformity costs borne by the firm rises.

For any given set of values for the arguments of this function - $[q, m, x, t]$ - it is assumed that government and contractor have the same probability density function over the values $C(q, m, x, t)$ that may emerge in the execution of the contract. In the prenegotiation and negotiation phases, therefore, both parties plan with the expected value of $C(q, m, x, t)$,

$$E\{C(q, m, x, t)\} = \int_0^{\infty} C \cdot f_C(C | q, m, x, t) dC$$

where $f_C(C)$ is the probability density function over C .

2. $W_d(q, m)$. This cost is the expense to the firm of correcting deficiencies in materials, workmanship, or design necessary to pass the inspection and acceptance testing by government officials. It is taken to be a rising function of technological sophistication and reliability standards of the product. For any given $[q, m]$, W_d is defined probabilistically with the density function $f_d(W_d)$, and the expected value of W_d is

$$E\{W_d(q, m)\} = \int W_d f_d(W_d | q, m) dW_d$$

3. $W_e(q, m, t)$. The expenses of maintaining conformance to performance warranties over the period of the warranty, t , are assumed to be a function of q and m . They are assumed to rise with technological complexity ($\partial W_e / \partial q > 0$), to fall as reliability of design rises ($\partial W_e / \partial m < 0$), and to rise with time duration ($\partial W_e / \partial t > 0$). They can only be forecast by government and contractor, and it will be assumed that both envision the same density functions over the costs:

$$E\{W_e(q, m, t)\} = \int_0^{\infty} W_e \cdot f_e(W_e | \bar{q}, \bar{m}, \bar{t}) dW_e$$

DoD's utility function is now defined as

$$G(q, m, z, t),$$

where

$$(39) \quad z = \bar{B} - C(q, m, x, t) - (1-x) W_e(q, m, t) (1+a),$$

with B once more defined as a budgetary ceiling on the system. It is assumed that $G(\cdot)$ is strictly concave.¹¹

It is assumed that an effective ceiling, t , is set upon the duration of the EPR warranty. DoD's optimal strategy is the solution to:

$$(40) \quad \text{Max } E\{G(q, m, z, t)\}$$

q, m, x, t

subject to:

1. $t - \bar{t} \leq 0$
2. $x - 1 \leq 0$
3. $q, m, x, t \geq 0$.

Since the objective function $G(\cdot)$ is assumed to be jointly concave in its arguments and all constraints are linear and hence convex, this is a convex nonlinear programming problem and any local maximum will also be a global.

¹¹ That is, $d^2G < 0$. A sufficient condition for strict concavity is that the Hessian of the function be negative definite. Letting $G''_{qm} = \partial^2 G / \partial q \partial m$, etc., the Hessian is

$$\begin{bmatrix} G''_{qq} & G''_{qm} & G''_{qx} & G''_{qt} \\ G''_{qm} & G''_{mm} & G''_{mz} & G''_{mt} \\ G''_{qx} & G''_{mz} & G''_{zz} & G''_{zt} \\ G''_{qt} & G''_{mt} & G''_{zt} & G''_{tt} \end{bmatrix}.$$

It will be negative definite if and only if the nested principal minors alternate in sign negative, positive.

The Lagrangean form for this constrained maximum is:

$$(41) \quad L = E\{G(q, m, z, t) - \lambda_1 (t - \bar{t}) - \lambda_2 (x - 1)\}$$

and the necessary and sufficient conditions for a maximum are:

$$(42) \quad \begin{aligned} 1. \quad & \frac{\partial L}{\partial q} = E\{G'_q + G'_z [-C'_q - (1-x) W'_{e,q} (1+a)]\} \leq 0 \\ & qE\{G'_q + G'_z [-C'_q - (1-x) W'_{e,q} (1+a)]\} = 0 \\ 2. \quad & \frac{\partial L}{\partial m} = E\{G'_m + G'_z [-C'_m - (1-x) W'_{e,m} (1+a)]\} \leq 0 \\ & mE\{G'_m + G'_z [-C'_m - (1-x) W'_{e,m} (1+a)]\} = 0 \\ 3. \quad & \frac{\partial L}{\partial x} = E\{G'_z [-C'_x + W_e(q, m, t) (1+a)] - \lambda_2\} \leq 0 \\ & xE\{G'_z [-C'_x + W_e(q, m, t) (1+a)] - \lambda_2\} \leq 0 = 0 \\ 4. \quad & \frac{\partial L}{\partial t} = E\{G'_t + G'_z [-C'_t - (1-x) W'_{e,t} (1+a)] - \lambda_1\} \leq 0 \\ & tE\{G'_t + G'_z [-C'_t - (1-x) W'_{e,t} (1+a)] - \lambda_1\} = 0 \\ 5. \quad & \frac{\partial L}{\partial \lambda_1} = t - \bar{t} \leq 0 \\ & \lambda_1 (t - \bar{t}) = 0 \\ 6. \quad & \frac{\partial L}{\partial \lambda_2} = x - 1 \leq 0 \\ & \lambda_2 (x - 1) = 0 \\ 7. \quad & q, m, x, t, \lambda_1, \lambda_2 \geq 0 \end{aligned}$$

where $G'_q = \partial G / \partial q$, etc.

Consider, now, the constraint pair in 3. above. The terms in square brackets yield the marginal gain or loss in dollars of a slight increase in x . The multiplier G'_z converts these marginal dollars to marginal DoD utility. If $dx > 0$ yields a marginal loss to DoD, $x = 0$, so DoD bears 100 percent of the expected cost of EPR warranties. By 5. and 7., λ_2 must then be zero.

Suppose that a marginal gain occurs, the saving of $W_e(q, m, t) (1+a) dx$ outweighing the rise in price of the system, $C'_x dx$. Then λ_2 must be positive, which, from 6., implies that $x = 1$.

If the bracketed term is zero, then the alternatives are:

1. $\lambda_2 > 0$ which implies $x = 0$. But this contradicts 6. which requires $\lambda_2 = 0$ when $x = 0$.
2. $\lambda_2 = 0$ which implies x can be positive.

To summarize, the possibilities permitted by the first order necessary conditions are:

<u>If net marginal gain to x is:</u>	λ_2 is:	x is:
< 0	0	0
= 0	0	$0 < x \leq 1$
> 0	> 0	1

It is the last of these relations that must be expected. Even though DoD expects the firm to inflate cost as x rises, it would not expect its gain from the shift in liability to be offset or more than offset by the cost rise. It follows, except in cases where a contractor is a notorious cost inflator in these warranty respects that the optimal prenegotiation goal for DoD is to shift the burden wholly on the firm. Hence, $x^\circ = 1$, where ($^\circ$) symbolizes the optimal value.

With $x^\circ = 1$ and $\lambda_2^\circ > 0$, condition 4. relations simplify to

$$(43) \quad 4! \quad E\{G'_t - G'_z C'_t - \lambda_1\} \leq 0$$

$$tE\{G'_t - G'_z C'_t - \lambda_1\} = 0$$

Since $t^\circ > 0$ if the EPR warranty is to exist, the expectation in curly brackets must hold as an equality. However, the marginal cost of time duration could very well equal or exceed its utility to DoD, so t° could fall short of t . If it does, $\lambda_1 = 0$ from condition 5. It will be assumed that $0 < t^\circ < \bar{t}$ and $\lambda_1 = 0$.

Conditions 1. and 2. then are simplified to:

$$(44) \quad 1. \quad E\{G'_q - G'_z C'_q\} \leq 0$$

$$qE\{G'_q - G'_z C'_q\} = 0$$

$$2. \quad E\{G'_m - G'_z C'_m\} \leq 0$$

$$mE\{G'_m - G'_z C'_m\} = 0.$$

Since q° and m° must surely exceed zero, in the DoD prenegotiation optimum

$$(45) \quad \frac{E\{G'_m\}}{E\{G'_q\}} = \frac{E\{G'_z C'_m\}}{E\{G'_z C'_q\}}$$

That is, net expected marginal effectiveness utility of OCs and RMACs must be equated.

2. Contractor Prenegotiation Strategy

It is assumed that in the prenegotiation period the firm will have been informed of the government's cost constraint, B, the effective limit in time duration, t, and its profit margin, a. Also, it is

assumed that both contractor and DoD have the same subjective probability density functions over the states of nature and the same cost functions for those states.

In the prenegotiation stage of strategy planning the firm is assumed to maximize its utility function subject to four relevant constraints:

1. A minimum profit constraint, where profits are defined as

$$P = a[C(q, m, x, t) + xW_e(q, m, t)] - W_d(q, m) - xW_e(q, m, t).$$
2. A maximum cost constraint, where

$$C(q, m, x, t) + (1 - x)W_e(q, m, t)(1 + a) - \bar{B} \leq 0.$$
3. A maximum EPR warranty duration constraint.
4. A constraint keeping x within the unit interval.

Formally, the problem is:

$$(46) \quad \text{Max } E\{U(P, q, m)\}$$

$$q, m, x, t$$

subject to:

1. $\bar{P} - E\{P\} \leq 0$
2. $E\{C(q, m, x, t) + (1 - x)W_e(q, m, t)(1 + a)\} - \bar{B} \leq 0$
3. $t - \bar{t} \leq 0$
4. $x - 1 \leq 0$
5. $x, t, q, m \geq 0.$

If $U(\cdot)$ is strictly concave in its arguments and $C(\cdot)$ and $W_e(\cdot)$ are convex in theirs (so that rising marginal costs are present in both functions for all arguments), then the Kuhn-Tucker conditions are both necessary and sufficient for a global maximum:

$$(47) \quad 1. \quad E\{U'_p [aC'_q - (1 - a)xW'_{e,q} - W'_{d,q}] + U'_q\}$$

$$+ \lambda_1 E\{aC'_q - (1 - a)xW'_{e,q} - W'_{d,q}\}$$

$$- \lambda_2 E\{C'_q + (1 - x)W'_{e,q}(1 + a)\} = C_1 \leq 0$$

$$q(C_1) = 0$$

$$2. \quad E\{U'_p [aC'_m - (1 - a)xW'_{e,m} - W'_{d,m}] + U'_m\}$$

$$+ \lambda_1 E\{aC'_m - (1 - a)xW'_{e,m} - W'_{d,m}\}$$

$$- \lambda_2 E\{C'_m + (1 - x)W'_{e,m}(1 + a)\} = C_2 \leq 0$$

$$m(C_2) = 0$$

3. $E\{U'_p [aC'_x - (1-a)W_e(q, m, t)]\}$
 $+ \lambda_1 E\{aC'_x - (1-a)W_e(q, m, t)\}$
 $- \lambda_2 E\{C'_x - W_e(q, m, t)(1+a)\}$
 $-\lambda_4 = C_3 \leq 0$
 $x(C_3) = 0$
4. $E\{U'_p [aC'_t - (1-a)xW'_{e,t}]\}$
 $+ \lambda_1 E\{aC'_t - (1-a)xW'_{e,t}\}$
 $- \lambda_2 E\{C'_t + (1-x)W'_{e,t}(1+a)\}$
 $-\lambda_3 = C_4 \leq 0$
 $t(C_4) = 0$
5. $P - E\{P\} = C_5 \leq 0$
 $\lambda_1(C_5) = 0$
6. $E\{C(q, m, t) + (1-x)W_e(q, m, t)(1+a)\} - \bar{B} = C_6 \leq 0$
 $\lambda_2(C_6) = 0$
7. $t - \bar{T} \leq 0$
 $\lambda_3(t - \bar{T}) = 0$
8. $x - 1 \leq 0$
 $\lambda_4(x - 1) = 0$
9. $q, m, x, t, \lambda_1, \lambda_2, \lambda_3, \lambda_4 \geq 0.$

To evaluate these expressions, consider the impact of $dx > 0$ and $dt > 0$ upon expected utility.

From (46):

$$(48) \quad \begin{aligned} 1. \quad dE\{U\} &= E\{U'_p [aC'_x - (1-a)W_e(q, m, t)]\} dx \\ 2. \quad dE\{U\} &= E\{aC'_t - (1-a)xW'_{e,t}\} dt \end{aligned}$$

The expression in (48.1) must be expected to be strongly negative for any value of x , since C'_x could not be expected to exceed $W_e(q, m, t)$. Hence, the firm's x^0 must be zero and $\lambda_4^0 = 0$ (from 47.8).

Consider (48.2). For $x > [a/(1-a)] (C'_t/W'_{e,t})$ it will be negative as the increased contingent liability borne by the contractor outweighs the fee received on the warranty. Since a can be expected to be in the neighborhood of 1 to 3 percent, the critical value for x is quite small. When $x^0 = 0$, however, $t^0 = t$ and $\lambda_3^0 > 0$. Nonetheless, this is a knife-edge solution for use when x reaches a small value $t^0 = 0$.

Finally, assume $P^* > \bar{P}$ and that the DoD budget B^* is completely spent, so that $\lambda_1 = 0$ and $\lambda_2 > 0$. Then, conditions C_1 and C_2 become (when $q, m > 0$):

$$(47) \quad \begin{aligned} 1. \quad & E\{U'_p [aC'_q - W'_{d,q}] + U'_q\} - \lambda_2 E\{C'_q + (1+a)W'_{e,q}\} = 0 \\ 2. \quad & E\{U'_p [aC'_m - W'_{d,m}] + U'_m\} - \lambda_2 E\{C'_m + (1+a)W'_{e,m}\} = 0. \end{aligned}$$

Hence,

$$(49) \quad \frac{E\{U'_p [aC'_m - W'_{d,m}] + U'_m\}}{E\{U'_p [aC'_q - W'_{d,q}] + U'_q\}} = \frac{E\{C'_m + (1+a)W'_{e,m}\}}{E\{C'_q + (1+a)W'_{e,q}\}}$$

3. A Comparison of the Prenegotiation Strategies

Consider equations (45) and (49) in order to compare the goals of DoD and the contractor under conditions that are maximal for each taken separately. Assume that DoD is risk-neutral or only slightly risk-averse, so that (45) may be written

$$(50) \quad \frac{E\{G'_m\}}{E\{G'_q\}} = \frac{G'_z E\{C'_m\}}{G'_z E\{C'_q\}} = \frac{E\{C'_m\}}{E\{C'_q\}},$$

because G'_z will be a constant (or approximately so with slight risk-averseness).

When compared with the contractor's optimal adjustment of his marginal utilities for q and m to their marginal costs in (49), it is noteworthy that DoD is adjusting to different marginal costs. The contractor's costs include the marginal expenditures on EPR warranties and DoD's do not. Suppose the contractor tends to increase the costs of the contract by some fixed fraction, k , of marginal EPR warranty costs. Then, (49) may be written

$$(51) \quad \frac{E\{U'_p [aC'_m - W'_{d,m}] + U'_m\}}{E\{U'_p [aC'_q - W'_{d,q}] + U'_q\}} = \frac{E\{(1+a+k)W'_{e,m}\}}{E\{(1+a+k)W'_{e,q}\}} = \frac{E\{W'_{e,m}\}}{E\{W'_{e,q}\}}.$$

If DoD perceives C'_m and C'_q to be proportionate to $W'_{e,m}$ and $W'_{e,q}$, then it and the contractor will be adjusting the marginal rates of substitution of q and m to the same marginal costs. However, because it is expected that $C'_q > C'_m$ and that $W'_{d,m} < 0$ while $W'_{d,q} > 0$, a rise in m should contribute *positively* to marginal profit but a rise in q would contribute *negatively* or *weakly positively* to marginal profit. Therefore, the marginal rate of substitution of m for q on the left-hand side of (51) should be small: a reduction in q can be compensated by a small rise in m .

On the other hand, since it is expected that DoD's preference for OCs over RMACs will lead to marginal utilities for the former declining more slowly than for the latter, the marginal rate of substitution on the left-hand side of (50) should be large.

The resulting preferred mixes of q and m by contractor and DoD are shown in Figure VI-13. The concave function is the feasible set of $[q, m]$ mixes available for the budget \bar{B} . The bias of the contractor toward m , or RMA definitions of EPRs is evident in $[q^{\circ}, m^{\circ}]$, and the bias of DoD toward q is displayed in $[q^{\circ}_g, m^{\circ}_g]$.

4. The Negotiation Phase

If both parties accept that x and t will take intermediate values in the negotiation period, the optimal conditions of (49) and (50) become

$$(52) \quad 1. \frac{E\{U'_p[aC'_m - W'_{d,m} - (1-a)xW'_{e,m}] + U'_m\}}{E\{U'_p[aC'_q - W'_{d,q} - (1-a)xW'_{e,q}] + U'_q\}} = \frac{E\{C'_m + (1-x)(1+a)W'_{e,m}\}}{E\{C'_q + (1-x)(1+a)W'_{e,q}\}}$$

$$2. \frac{E\{G'_m\}}{E\{G'_q\}} = \frac{E\{C'_m + (1-x)(1+a)W'_{e,m}\}}{E\{C'_q + (1-x)(1+a)W'_{e,q}\}}$$

But under the assumption employed above that firms adjust the costs of the contract proportionately to changes in the cost of the EPR warranty, in a negotiated Pareto optimal bargain (52) reduces to

$$(53) \quad \frac{E\{U'_p[aC'_m - W'_{d,m} - (1-a)xW'_{e,m}] + U'_m\}}{E\{U'_p[aC'_q - W'_{d,q} - (1-a)xW'_{e,q}] + U'_q\}} = \frac{E\{W'_{e,m}\}}{E\{W'_{e,q}\}} = \frac{E\{G'_m\}}{E\{G'_q\}}$$

If a Pareto optimum can be reached, it is attained by changes in the shapes of the parties' indifference curves as x and t , and therefore, P and z change. However, as x rises from a prenegotiation value of zero for the contractor his bias toward m should be reinforced, not reduced. And as x falls from an assumed value of 1 for DoD the preference for q should be enhanced. To attain a compromise may, therefore, be extremely difficult, and a positive incentive warranty to overcome the firm's predilection toward defining EPRs as RMA provisions may be most cost-effective.

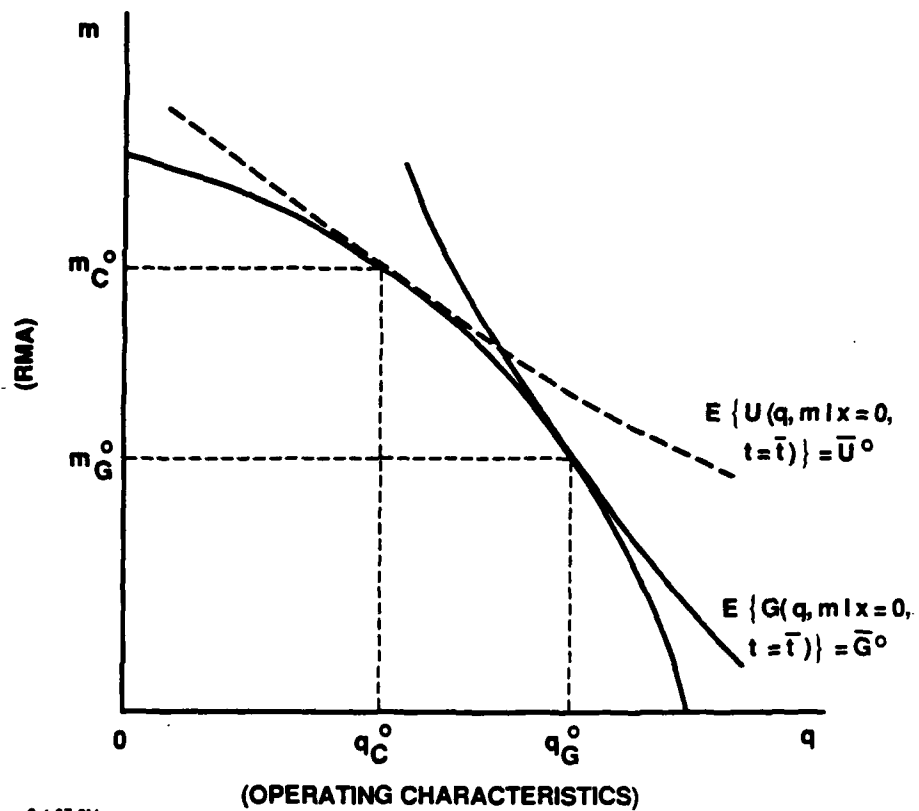


Figure VI-A-12. OPTIMAL MIXES OF OPERATING CHARACTERISTICS AND RELIABILITY-MAINTAINABILITY-AVAILABILITY CHARACTERISTICS FOR CONTRACTOR AND GOVERNMENT, PRENEGOTIATION PHASE

VII. SUMMARY AND CONCLUSIONS

In this study the review of warranty usage in DoD weapon system procurement has been organized within the following framework:

- A. Description of Present Policy and Implementation
 - 1. Legal and Policy Bases for Warranty Usage
 - 2. Current Field Practice in Warranty Usage
- B. Analysis of Warranty Instruments' Functions
 - 1. Roles in Integrating the Procurement Process
 - 2. The Economic Functions of Warranties
- C. Policy/Practice and Analysis/Policy Conformance
 - 1. Conformance of Current Field Practice to Legal and Policy Bases
 - 2. Conformance of Present Policy to Analytical Propositions

This chapter will adopt this organizational scaffolding to review the results of the study. In sections A and B the conclusions drawn in previous chapters concerning topics A and B respectively will be summarized. Section C will present the major normative conclusions that derive from a comparison of topics A and B under the two headings contained in topic C. It contains judgments concerning the extent to which current major weapon system contracting is following Congressional and DoD guidelines, and the extent to which those guidelines are in accordance with what is judged to be optimal or efficient usage of warranties.

A. DESCRIPTION OF PRESENT POLICY AND IMPLEMENTATION

1. Legal and Policy Basis for Warranty Usage

In the postwar period DoD procurement policy has relied heavily upon long-standing inspection and acceptance clauses in its contracts to assure that its purchased supplies conform to contract requirements. A lengthy record of court decisions and claims commission rulings support the government's right to insist that the goods it purchases meet exact contracting requirements and pass contractually-specified tests if the requirements are clearly stated and the tests are reasonable. When supplies are commercial, DoD receives from the Unified Commercial Code merchantability and fitness-for-a-special purpose implied warranties and when supplies are tailored to its specifications it receives in

addition protection in the post-acceptance period against latent defects, fraud, and mistakes whose egregiousness amounts to fraud.

DoD policy until the mid-1960s was to rely almost wholly upon these standard express and implied guarantees. Explicit warranties were not regularly used, since it was believed that assurance/validation of conformity to contract configuration was protected and that self-insurance against post-acceptance failures was in the government's best interests.

In the McNamara era, as weapons systems became more complex, expensive, and risky in terms of acquisition and support costs or performance, greater interest began to be taken by DoD in more explicit warranty protection. An effort to unify the Services' employment of warranties was initiated in the period 1964-1967. A decade later a more focused approach to warranty usage resulted in extensive--and largely successful--experimentation with the reliability improvement warranty, especially in the area of electronic equipment. This shifted the function of warranty clauses from an exclusive concern with assurance-validation of contractual requirements to a form of incentive contracting, providing negative sanctions and positive rewards for under- or overperformance of reliability, maintenance, or availability targets.

Of greater significance, however, was a Congressional drive to mandate written warranties in weapon system contracts. Exasperated by highly publicized accounts of DoD procurement deficiencies, Congress in 1983 enacted Section 794 of the Defense Appropriations Act of 1984. Its wording seemed to be altering standard DoD warranty policy for weapons systems from that of assurance that the equipment meet contract specifications and be free from defects at the time of acceptance to guarantees by prime and subcontractors that the system would meet the performance requirements specified anywhere in the contract for an indefinite period after the equipment was fielded. Moreover, in the hearings that followed passage of the legislation, Congressional interpretation of "performance" seemed to emphasize the operating characteristics of the equipment when on line rather than the RMA characteristics and their implications for downtime.

Objections by DoD and the defense industrial community to the inflexibility of the provisions and their insistence on altering assurance-validation from that of conformance to specifications at acceptance to conformance to performance parameters in an extended post-acceptance period led to enactment of a new statute. In the Defense Procurement Reform

Act of 1984, provisions were included which became Section 2403 of Title 10 of the U.S. Code (Section 2403).

This new law was a substantial retreat by Congress from the Section 794 provisions. It limits the mandatory warranties to expensive weapons systems and, in the use of the performance warranty, to those systems in mature full-scale production; binds only prime contractors; and gives contracting officers a great deal of flexibility in the design of the warranty provisions. However, it requires these separate and distinct written warranties on weapons systems: a design/manufacture guarantee that the system conforms to contract specifications, a materials/workmanship warranty that no defects exist from these sources of the time of delivery, and an essential performance requirements warranty for expensive systems in mature full-scale production that all specifically designated EPRs will be conformed to for some negotiable time duration. The EPRs may be OCs or RMACs designated to be necessary for the system to fulfill its military requirement.

The legislation, therefore, permits the interpretation of D/M and M/W warranties to revert to their pre-Section 794 interpretation as conformance-to-specifications and absence of patent and latent defects at acceptance, narrows performance requirements to a subset of EPRs, and permits these to be OCs or RMACs. Further, the EPRs will bind only when substantial production experience has been acquired.

The legislation was supplemented by DoD guidance in the form of Defense Federal Acquisition Regulation Supplements and individual service regulations. It went into effect for all weapon system contracts signed after January 1, 1985. The Federal Acquisition Regulations, which evolved from the Armed Services Procurement Regulations and Defense Acquisition Regulations, govern warranty usage in all federal government contracts. The FARs contain five models for such warranty clauses depending upon the nature of the supplies purchased, and in practice, DoD weapon system warranties tend to follow the model for supplies designed to specific specifications, suitably modified to meet Section 2403 requirements.

Because of the relatively short period of mandated warranty usage and the lack of an adequate data base, it is difficult to make judgments concerning the cost-effectiveness of such warranties. The theoretical and empirical analysis of them to follow, therefore, concerns the formal functions provided DoD by warranties, principles affecting their efficient usage, the extent to which recent weapon systems contracts conform to those

principles and, lastly, the extent to which the mandated warranties in those contracts meet Section 2403 requirements and, more ambiguously, conform to Congressional intent.

2. Current Field Practice in Warranty Usage

This study has analyzed the warranty provisions of 13 major weapon systems contracts in detail, numerous other contracts less formally from secondary literature, and interviewed procurement officials in the military departments. The 13 contracts were studied, where possible, over the pre- and post-legislation periods to denote breaks in practice. They include weapon systems for all three of the services, and, although a small sample, are deemed to be reasonably exemplary of current practices.

The following are the major relevant conclusions concerning the current practices in weapon system warranty inclusion reached by the present study:

- a. Warranties are being written in formal compliance with Section 2403. Occasionally essential performance requirements are not so designated, but substitute terms clearly cover the EPR substance. The contracts contain D/M, M/W, and EPR warranties written in conformance to the statutes, with D/M guarantees concerned with the equipment being true to drawings, tolerances, and other technical specifications of the contract and M/W warranties the absence of patent and latent defects. The EPR requirements are usually stated by reference to explicit requirements in a specific set of clauses in the contract.
- b. The dominant tendency is to make the warranty period durations coterminous. Since the M/W warranty duration is meant to protect against latent defects discovered rather soon after delivery, the impact of this practice is to make the EPR warranty period shorter than might be expected given the life expectancy of the systems.
- c. A notable lack of positive incentivization features and a seeming reluctance to impose negative incentives upon the contractors exist in the sample. Only one contract revealed positive incentives, and a sizeable number restricted contractor liabilities to very low ceilings. The stress on assurance/validation and deemphasis of incentivization may be grounded in the bias in that direction that exists in Section 2403 and in the models in the FARS. From the sample analyzed, therefore the new legislation seems to have checked the prior impetus given incentivization by the RIW and similar provisions.
- d. A difficulty exists in judging the nature of the EPRs in terms of their structuring between OCs and RMACs. They are frequently classified and/or stated in extremely complicated form. From the evidence available in the 13 contracts studied and from secondary sources, the EPRs are being written predominantly in terms of RMACs rather than OCs. Few instances are encountered that guarantee that equipment *x* will equal or exceed parameter *y* after *z* years in the field.

If this conclusion is true it may have several causes. RMACs may be more readily measured and RMA failures may generate fewer disputes. The failure concept is also the traditional one that is central to commercial warranties, to which military warranties owe much of their form and development. If a complicated system fails to attain an OC--a ship, for example, does not achieve its design speed of 40 knots--there may be little that can be done to remedy the problem short of redesign, and a contractor may not be capable of sustaining such financial liabilities. Indeed, stating EPRs in terms of OCs orients the function of the warranty more strongly in the direction of insurance than does the typical EPR stated in RMAC terms with obligations of repair and replacement of defective parts.

- e. The last point leads into a more general conclusion; warranties are not being used to shift the risk of large contingency costs on to contractors. Assurance/validation and incentive warranties, of course, imply a measured assumption of risk by the contractor. But the limitation of EPR warranties to systems in mature full-scale production, the reluctance to state EPRs in OC terms or extend warranties far into the post-acceptance period, and the frequent establishment of modest liability ceilings for contractors evidence the reluctance of DoD to establish an independent insurance function for these guarantees. Cost is a major barrier to exploit the insurance function of warranties intensely.
- f. There exists a notable reluctance to break out the price of a warranty as a line item--a practice which is explicitly allowable in the DFARs. This makes it difficult to compare the cost of the warranties with financial liability ceilings or more importantly to judge the cost-effectiveness of the instruments.
- g. Overall, the degree of assurance/validation given DoD that weapon systems meet design and manufacture configurations and are free of patent and latent defects upon acceptance or delivery seems very high. Protection against EPR defects in the post-acceptance phase--the true innovation of Section 2403--has certainly been instituted. The warranty periods for these EPR defects do seem relatively short given the lifetime of the equipment. And, the EPR stated as an OC rather than a RMAC is rarer than an analyst might expect, given the presumed importance of on-line performance of such systems.

B. ANALYSIS OF WARRANTY INSTRUMENTS' FUNCTIONS

To help in judging the desirability of existing legislation, regulation, and practices in weapon system warranty usage, it is essential to place these instruments functionally within the whole procurement process, and to analyze the economic appropriateness of those functions within that process.

1. Roles in Integrating the Procurement Process

A weapon system progresses from concept through design, manufacture, testing, fielding and support phases with anticipatory interdependence of earlier with later stages in an integrated process. Design must anticipate manufacturing capability, test technology, performance requisites and support costs, and experts in all phases must have input into design. Manufacture, similarly, must be concerned with the phases that will succeed it, and tailor its concerns and processes with them in mind. Modern computer capability is increasingly enabling such complicated forward planning and anticipatory feedbacks to bind together the sequential stages of a procurement into an instantaneous unity of interdependent concerns.

The institution of enhanced integration in the procurement process has the goals of improving equipment performance and economizing economic resources in so doing. Warranties are one tool available to help to achieve these goals via their performance of a group of functions within the process. As legally binding guarantees of certain characteristics of the weapon system, with contingent liabilities for non-conformance and possible rewards for surpassing targets, warranties can reinforce the concerns of the manufacturer with design of the product, its testing, its performance when fielded, and its support costs. It has the potential, therefore, of being an important tool of integration.

What are the functions it provides that give it this potential? In response, consider first the economic characteristics of the DoD weapon system procurement environment. It features limited competition in supply because of the sophisticated technology involved; a great deal of uncertainty in terms of cost and ultimate performance of the equipment; information asymmetry between contractor and DoD to the potential detriment of the latter; and potential conflict between the profit motive and the dominant interest of DoD in product quality, or *moral hazard*.

Warranties provide DoD with some protection from the implications of these characteristics by serving three functions:

- a. **Assurance/Validation.** The D/M, M/W, and EPR warranties substitute to some extent for competition in assuring quality, compensate somewhat for government's disadvantage in information concerning design and/or manufacture of the equipment, and protect DoD against moral hazard.
- b. **Insurance.** The assurance-validation type of warranty shifts onto the contractor a burden of risk which it is assumed can be escaped by ordinary management prudence. Warranties, however, can serve a more ambitious

goal of protecting DoD against the uncertainty of success in performing military requirements or of undergoing large monetary losses for unforeseen support costs. The insurance function of warranties, therefore, is performed when they are used to shift the more burdensome and unpredictable uncertainty of new technology onto the contractor, wholly or partially.

- c. **Incentivization.** To the extent assurance/validation and insurance warranties affect contractor behavior, they incentivize. But by an incentivization function is meant an effort to provide explicit positive and/or negative financial motivation to the contractor beyond that implied in warranties emphasizing the other two functions. Profit reduction for failure to achieve certain targets deemed especially important or enhancements for surpassing such targets are the tools employed. Their use is to add to the assurance-validation warranty in compensating for the lack of competition to guarantee quality, to intensify protection against moral hazard, and to enhance product quality by eliminating its conflict with profit maximization.

By linking quality specifications and improvements to contingent monetary liabilities and rewards, warranties provide a means of linking the phases of weapon systems procurement in an effective and rational way. Profit incentives to insure that design will accord with warranty obligations, or that manufacturing facilities will be able to meet design requirements, are exploited. Rational decisions are facilitated in that trade-off curves between the costs of enhancements in design and reductions in future remediation costs can be computed, or the costs of redesign to correct a defect can be compared with the costs of repair of units in the warranty period. In these types of roles warranties serve as one means of furthering the integration of the procurement process along with their primary function of improving product quality.

The second goal of warranties, listed above, is the improvement of resource usage: that is, obtaining a given performance more cheaply or an improved performance from the same expenditure of resources. The second type of economy is the more likely result of warranty usage, since warranties do not really provide much scope for reducing the real cost of technological uncertainty. Cost-effective incentivization however, can improve product quality to extents that benefit-cost trade-offs dictate net gain.

2. The Economic Functions of Warranties

To what extent can the use of warranties as cost-effective methods of enhancing the national interest in improved quality of weapon systems and better usage of national resources be supported by formal analysis? Which of the three functions listed above are economically justified on the basis of prospective benefits and costs? If their usage is

reasonable in the above senses, what are operational manners of designing warranties in efficient or optimal ways? How can economic theory provide guidelines in answering these important policy questions?

The results of the formal economic analysis may be summarized as follows:

- a. A warranty which is limited to the assurance-validation function for a supply which has been produced to design specifications is simply a guarantee that the goods supplied are the goods for which the contractor received payment and which he is legally bound to deliver. Hence, no separate warranty price is justified. All costs of delivering the product, including those for rectifying defects that result despite prudent management should be included in the negotiated or bid price of the contract. It follows that, ideally, that portion of a warranty which fulfills the assurance-validation function should be excluded from the price of warranties serving the other functions.

The D/M and M/W warranties are pure assurance-validation warranties, in that an implicit assumption underlies their usage that they may be conformed to by the ordinary exercise of prudent management. When that management is in full control of the design and/or manufacture process, it should pay the costs of defects originating from lapses.

The dominant function of an EPR warranty depends upon its specific provisions and the technological conditions and complexity of the weapon system. At one extreme, if the EPR warranty has the same time duration as the D/M and M/W warranties, if the weapons system is relatively simple in structure and draws upon well-known technology and if a good deal of experience has been accumulated in its production, the EPR warranty is a straightforward assurance/validation warranty and its cost should be included in the price of the contract.

At the other extreme, if the EPR warranty extends far into the post-acceptance phase, if the technology of the system is new and the states of nature that might emerge with its usage are highly unpredictable, if production and field experience are not extensive, and if the costs of remediation of a nonconformity are potentially large, the EPR warranty is one with the insurance function dominant. A separate price of the warranty should be negotiated apart from the price of the contract.

For EPR warranties whose provisions and technological circumstances fall between these extremes, subjective judgments must be made concerning the distribution between the two functions. The price of the warranty should rise, of course, as its insurance content rises.

- b. There is a presumption that warranties whose dominant purpose is to insure DoD against the occurrence and size of large costs of remediation of defects will not be cost-effective. Hence, unless special circumstances can be shown, the warranty whose dominant function is that of insurance of DoD against monetary loss is not justifiable theoretically.

As noted above, this type of warranty will bear a price. That price will be determined in large part by the risk-averseness of the contractor, whom the warranty forces into the role of an insurer. Risk-averseness is determined to a great degree by the ability of a firm to undergo large monetary losses without threatening its viability and the degree of predictability of having to bear such losses. The larger the contingent liabilities, the more uncertain the probabilities that the states of nature which inflict them will emerge and the fewer the contracts over which he can disperse such risk, the greater the insurance premium (the price of the warranty) exacted by the contractor will be. Moreover, that premium can be shown to rise more than linearly with the size of potential losses.

On the other hand, DoD, with the large financial resources over which it disposes, the large number of contracts over which it could disperse risks, and in the absence of threats to its survivability, should be considered to be risk-neutral, or at least only mildly risk-averse. That is, it should be most unwilling to pay much more than the actuarial value of a risk (i.e., the probability of loss times the amount of loss if it occurs) to escape it.

There is, therefore, a perverseness in placing a risk-averse contractor in the position of insuring a nearly risk-neutral DoD at a high premium to provide a protection against variance in support costs that DoD does not much fear.

A point to be emphasized is that an insured party does not escape the average costs inherent in an uncertain situation. They must be paid--in this case in the form of a premium (loaded above that average cost with a risk premium and administrative costs). What insurance does is to protect against the *variance* of such losses, and it is the variance that a risk-neutral party does not find it worthwhile to escape.

Economic theory asserts, therefore, that the pure insurance function of warranties is not one that DoD should normally employ.

- c. When a contractor can exert efforts at a cost to affect the quality of a weapon system, when the increase in quality so obtained is desirable, and when the variation in quality can be measured by both contractor and DoD, the government and contractor are placed in a principal-agent relationship. By negative or positive incentives, government as principal can seek through the profit motive to alter the contractor's actions to improve quality.

The negative aspect of a need to incentivize a contractor to fulfill some target objective is deemed *moral hazard*. If past experience with the contractor indicates he is susceptible to devoting fewer resources to quality improvement than would be possible in order to increase profit from the contract, DoD can shift a portion of the risk of underachieving a specified target by reducing the fee paid through an incentive warranty. The negative fee schedule should be such as to provide marginal inducements to achieve the target as determined by the degree of moral hazard in potential contractor performance and the valuations placed upon the increments below target by DoD.

In positive terms, moral hazard becomes the degree of alacrity with which a contractor responds to marginal increases in contract profits for overachieving targets. An optimal fee schedule would provide marginal fees just sufficient to induce desired increases in quality, presumably rising with the marginal costs of obtaining them, up to the maximum quality level DoD is willing to pay to obtain. Such schedules can be approximated by using estimated cost functions and contractor response-to-fee estimates, and these approximations may be made operational by piecewise-linear schedules for use in incentive warranties.

Incentive warranties may incorporate both negative and positive schedules. In all cases they are a form of incentive contracting, and, when their provisions are designed with the responsiveness of the contractor to marginal profit inducements and the benefits from improved quality in mind, economic theory supports their usage. Limitations of incentive contracts to negative forms restrict the potential gains from using positive forms as well.

- d. In the definition of EPRs, theoretical analysis supports a hypothesis that contractors would prefer to have them specified as RMACs and government should be biased toward OC definitions. The reasons inhere in complicated relationships between costs, fees, and expected warranty prices. Because of the difficulty of achieving an efficient negotiating outcome between these predelictions, a positive incentive warranty to achieve DoD's OC objectives may be a preferable route to obtain desired EPR definitions.
- e. Prices are an indispensable instrument in judging the economic efficiency of procurement transactions. If warranties are to be judged in terms of cost-effectiveness, it is essential that the prices of warranties (other than assurance-validation types) be broken out as line items.

C. POLICY/PRACTICE AND ANALYSIS/POLICY CONFORMANCE

Does current weapon system contracting conform in its warranty provisions to the legal and policy guidelines established to govern it? Beyond the letter of these established constraints, does practice conform to the intentions of Congress in writing the legislation?

Finally, how well does the policy that follows the legal-regulatory doctrines harmonize with the propositions emerging from the economic analysis of warranties? To these questions the study now turns.

1. Conformance of Current Field Practice to Legal and Policy Bases

Major conclusions from the close study of 13 weapon system contracts and of numerous other contracts in secondary studies are the following:

- a. The sample of contracts reveals that all three services are conforming to the letter of Section 2403, the DFARs, and the service regulations this study has been able to access. The required D/M, M/W, and EPR warranties are being written with only minor deviations (e.g., failure to term performance requirements in the contract *essential* performance requirements).
- b. Beyond this literal compliance, the warranties place meaningful standards upon contractors and exact proper correction of defects at no cost to the government.
- c. Congressional intent in the passage of Section 794 and Section 2403 is not easy to discern from the hearings concerned with the legislation. There is some evidence, however, that the stress placed upon performance warranties in both legislative acts was meant to assure and enhance OCs as well as RMACs. With the notable exception of aircraft engines and 5-ton trucks, the warranty provisions do not seem to place great stress on OCs. Most of the EPRs are defined in terms of failures. This conclusion must be qualified, however, because of the difficulties mentioned above in accessing performance requirements in the contracts.
- d. One express concern of Congress was an alleged failure of contracting officers to tailor warranties to the specifics of a weapon system. There is a marked tendency of the warranties to follow the FAR model warranty for supplies designed to specifications rather slavishly.
- e. Congressional intent in creating the flexibility for contracting officers in negotiating warranties was to enhance penalties for nonconformity as their importance justified as well as to protect contractors from inequities that inflexibility would inflict. The evidence, however, is that the flexibility is being used to lessen contractor burdens. Warranty periods for EPRs tend to be short. EPRs tend to be defined as RMACs rather than OCs, and liability ceilings are frequent and eliminate significant negative incentives.
- f. There is also evidence in the hearings that Congress desired to protect the public against financial losses from failed or underperforming weapon systems. There is no evidence of a serious use of the insurance function in any of the contracts studied.

2. Conformance of Present Policy to Analytical Results

The congruence of present warranty practice with the major propositions derived from the economic analysis, as gleaned from the contract sample, may be summarized as follows:

- a. The evidence is that assurance/validation warranties are not being provided at an extra charge to the Government over the contract price. This accords with the analytical results.
- b. Warranties are not being used as insurance vehicles. This may be to some extent a violation of Congressional intent, but it conforms to good economic reasoning.
- c. Incentive warranties are much less used than their theoretical justification would indicate they should be used. It is recognized that this may be because of the time and expense needed to negotiate them, and the lack of cost data bases necessary to calculate fee schedules. Positive incentivization warranties seem to be notably rare, especially given the promising start that RIWs provided.
- d. The seeming predominance of EPRs defined as RMACs suggests that contractors' interests are winning over DoD's legitimate concerns. This may reflect the greater ease of definition of RMACs, the longer history of their usage, and their ability to be measured more accurately. The state of maturity of most current weapon systems may also explain this de-emphasis.
- e. One notable lapse from theory is the failure, with few exceptions, to break out the price of warranties in the contracts.

In the comparison of current practice to economic analysis certain insights have been derived or questions raised having implications that are less sweeping than the five propositions summarized above. They deserve mention and consideration and are listed below:

- a. Warranty administration by contractor and DoD is costly and requires a major devotion of resources to be effective. In general, systems to administer warranties are not in place at contractors or in the services. Accounting systems of contractors are not designed to accommodate warranty data and Service personnel are not adequately attuned to the existence of guarantees. Widespread skepticism about the cost-effectiveness of post-acceptance warranties exists among the services' contracting personnel.
- b. One concern raised by theoretical analysis was a conjecture that EPRs would lead DoD and contractors to opt for more conservative designs rather than seek to innovate. No evidence emerged in the interviews that this is a problem in the field.
- c. In one important respect a theoretical conclusion has been confirmed extensively in practice. This is the expectation that warranties with accents

upon the insurance function are extremely expensive. Their cost is a major explanation for the relatively short post-acceptance duration periods for EPRs observed in the contracting, for example.

- d. The length of an EPR warranty is important in fulfilling its purpose of improving weapon system quality. If it is too short, a contractor will not find it economical to institute engineering change proposals when such design changes may be in DoD's interests. He will elect to repair defects until the warranty period expires. The period should be long enough to encourage design changes, the necessity of which generally is discovered within the first year of their being fielded. Periods of at least two years, therefore, are advisable. However, as indicated above, warranty price mounts rapidly as durations of this length are sought.
- e. Theory suggests that cost-feasible warranties are more easily obtained for electronic equipment than for mechanical equipment. Field practice bears this out. Failure rates for electronic gear follow known probability density functions more predictably than mechanical equipment, and they are more stable over system lifetimes. The duration of the warranty period can be much shorter for electronic gear, therefore, which contributes with more predictable nonconformance rates to lessen costs.
- f. In many major weapon systems (e.g., Bradley Fighting Vehicles, M-1 tanks, aircraft) the prime contractor's role is largely that of an assembler of components, many of which are government-furnished. Warranties on the *system*, therefore, as opposed to the components, may be difficult to enforce, especially if its design was not wholly the contractor's responsibility. EPR warranties on the system, therefore, may be inappropriate.
- g. One potential result of positive incentive warranties in theory is that they may lessen competition. When successful, they strengthen the competitive position of a sole-source contractor in subsequent contract bidding, and may make second-sourcing more difficult. Higher long-run equipment prices may be the result.

Appendix A

**SECTION 794, DEPARTMENT OF DEFENSE APPROPRIATIONS ACT OF
1984**

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SECTION 794, DEPARTMENT OF DEFENSE APPROPRIATIONS
ACT OF 1984

SEC. 794. 1. Except as otherwise provided in this section, none of the funds appropriated by this or any other Act may be obligated or expended for the procurement of a weapon system unless the prime contractor or other contractors for such system provides the United States with written guarantees:

- a. 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, or
 - in any other agreement relating to the production of such system entered into by the United States and *the contractor*;
 - b. 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 as specifically delineated
 - in the production contract, or
 - in any other agreement relating to the production of such system entered into by the United States and *the contractor*; and
 - c. That, in the event of a failure of the weapon system or a component to meet the conditions specified in clauses a. and b.:
 - *the contractor* will bear the cost of all work promptly to repair or replace such parts as are necessary to achieve the required performance requirements; or
 - if *the contractor* fails to repair or replace such parts promptly, as determined by the Secretary of Defense, the contractor will pay the costs incurred by the United States in procuring such parts from another source.
2. A written guarantee provided pursuant to subsection 1. shall not apply in the case of any weapon system or component thereof which has been furnished by the Government to *a contractor*.
3. The Secretary of Defense may waive the requirements of subsection 1. in the case of a weapon system if the Secretary:
- a. determines that the waiver is necessary in the interest of the national defense or would not be cost-effective; and
 - b. notifies the Committees on Armed Services and Appropriations of the Senate and the House of Representatives in writing of his intention to waive such requirements with

respect to such weapon system and includes in the notice an explanation of the reasons for the waiver.

4. The requirements for written guarantees provided in subsection 1. hereof shall apply only to contracts which are awarded after the date of enactment of this Act and shall not cover combat damage.

Appendix B

SECTION 794, DEFENSE GUIDANCE AND MODEL GUARANTEE

Appendix B

SECTION 794, DEFENSE GUIDANCE AND MODEL GUARANTEE

A. POLICY GUIDANCE

Section 794 of the Department of Defense Appropriations Act, 1984 requires that written guarantees be obtained in connection with the procurement of weapon systems. This guidance is issued to provide for implementation of section 794. It sets forth the policy and procedures for requiring and obtaining such guarantees at the weapons system and/or component level. To the extent this guidance may be inconsistent with the provisions of DAR 1-324, this regulation shall control.

1. Definitions:

For purposes of this guidance:

- a. "Weapon System" is equipment which, without substantial modification, is or can be used directly by Armed Forces to carry out combat missions. By way of illustration, the term includes bombers, fighter aircraft, attack helicopters, combat naval vessels, strategic and tactical missiles, tanks, combat vehicles, small arms, torpedoes, bombs, and artillery. The term includes software, ordnances, related support equipment such as ground handling equipment, training devices, test equipment and accessories thereto.
- b. A "component" is an assembly or any combination of parts, subassemblies, and assemblies mounted together in manufacture, assembly, maintenance, or rebuild. Spare parts, per se, are not deemed components unless otherwise fitting this definition.
- c. A "procurement" is a direct contract between the government and a contractor for the production of a weapon system and/or components thereof, irrespective of contract type.
- d. A "specified performance requirement" is any specifically delineated mandatory performance requirement set forth anywhere in a government production contract for a weapon system or in any other agreement relating to the production of such system incorporated or referenced in such contract.
- e. "Conform" means designed and manufactured so as to meet or achieve, or both, the government's specified performance requirement.
- f. "Bear the cost of" means at no increase in contract price irrespective of contract type. The written guarantees set forth in a contract award for the production of a weapon system shall be a separately priced firm fixed price line item.
- g. "At no cost to the government" means that the cost will not be reimbursed the contractor directly or indirectly under the production contract for the weapon system or an other government contract (except for the firm fixed price guarantee line item).

2. This guidance applies only to contract awards made subsequent to March 14, 1984.

For purposes of this guidance:

- a. A modification to a contract to add additional quantities constitutes a contract award.

- b. The exercise of a priced production option even where no further definition or negotiation of terms is required constitutes a contract award.
 - c. The notice to proceed with quantities after the first year quantity in a multi-year procurement does not constitute a contract award.
 - d. The placement of an order under a basic agreement or basic ordering agreement constitutes a contract award.
 - e. The definitization of an existing redeterminable contract does not constitute a new award.
 - f. The definitization of a letter contract constitutes a contract award.
3. Except to the extent otherwise provided herein, all government contracts for the production of a weapon system or components thereof shall contain a clause:
- a. Guaranteeing that the weapon system and each component thereof were designed and manufactured so as to conform to the government's specified performance requirements and that, at the time of delivery to the government, the weapon system and each component thereof are free from such defects in materials and workmanship as would cause the system to fail to conform to the government's specified performance requirements delineated in the contract.
 - b. Guaranteeing that the contractor will bear the cost of all work promptly to repair or replace such parts as are necessary to achieve the required performance requirements and providing that if the contractor fails to repair or replace parts promptly as required by the contract, the contractor will reimburse the government for any cost incurred by the government in procuring such parts from another source.
4. A model clause that may be used for this purpose in contracts for less complex weapons systems is attached. For complex systems, where different types of requirements (see paragraph 5) are present, special guarantee clauses may be written.
5. The written guarantees called for herein pertaining to design and manufacture so as to conform to the government's specified performance requirements will generally be of either or both of two types:
- a. Where the specified performance requirement(s) is a test or demonstration and the requirement(s) is deemed to be satisfied upon the satisfactory completion of the specified test or demonstration, e.g., of a first prototype or production unit, the guarantee shall provide that, in the event of a failure of a weapon system or component to complete satisfactorily the specified test or demonstration, the contractor shall promptly perform all design and manufacture work as necessary to conform to the government's specified performance requirements at no increase in contract price and at no cost to the government and to complete satisfactorily the specified test or demonstration at no increase in contract price.
 - b. Where the specified performance requirement(s) consists of the operation of the system without designated failures for a specified period or interval, the guarantee shall, at a minimum, provide that, in the event of a failure of a weapon system or component thereof within the stipulated period to meet the designated performance requirement(s), the contractor shall promptly, at no increase in contract price and at no cost to the

government, perform all work to (1) design and manufacture the system and each component thereof so to conform to the government's specified performance requirements as specifically delineated and/or (2) repair and/or replace such parts as necessary, to meet the designated performance requirement at no increase in contract price and at no cost to the government.

6. In contracts for weapon systems, however, there are two types of guarantees: One for performance to insure conformity of design and manufacture to specifically delineated performance requirements (as set forth above); and, one for freedom from all defects in materials and workmanship which would cause the system not to achieve the specified performance requirements. The latter is a separate and distinct guarantee provision which would attach to all delivered end items under the weapons system contract for a specified period of time. These guarantees are not mutually exclusive and both will be contained within a single contract for a weapon system or components thereof.
7. Consistent with the policy stated in DAR 1-324, the contract may provide such additional warranty protection and remedies thereof as may be deemed appropriate by the government in the circumstances.
8. The duration of the written guarantee shall be tailored, as appropriate, to the specific contract award. The duration of the written guarantee(s) within any given contract award need not be the same for all specified performance requirements.
9. Payment for the written guarantee shall be made on a pro-rata basis at time of delivery of the contract end items covered by the guarantee.
10. During negotiation of a proposed contract, care must be taken to identify firm and/or prescribed performance requirements that have been included in the specifications and other relevant documents in order to avoid subsequent dispute. These performance requirements should be reviewed to assure that they are realistic and achievable and that the performance requirements specified in the contract accurately reflect the needs for the weapon system. Unless otherwise indicated by the government, all specified performance requirements fall under the performance guarantee(s). In the event it should be determined that a written guarantee at the weapons system level is not cost-effective or otherwise not in the interest of the national defense, the identification and examination of appropriate components of the weapon system for applicability of a written guarantee(s) is also required. This examination should include a review of individual performance parameters (such as durability) for application of a written guarantee if comprehensive coverage is determined to be infeasible.
11. During negotiation of the contract, each circumstance(s) that could have the effect of voiding the guarantee should be identified and specifically delineated in the contract. For example, if the guarantee would be voided, in whole or in part, by the subsequent incorporation of spare parts that were not predetermined to be a duplicate of the replaced part, this should be the subject of negotiation. Contracting officers should not agree that any circumstance(s) will void the guarantee unless the relationship between the circumstance(s) and the performance requirements is direct and the circumstance(s) identified as voiding the warranty is beyond the control of and not attributable to any fault of the contractor.
12. The firm fixed price of the guarantee(s) should be separately identified. In order to facilitate the identification of the cost of the guarantee, it shall be set forth in the contract as a separate line item.

- a. In determining whether use of a guarantee is cost effective to the government, the benefits to be derived from the guarantee must be related to the costs of the guarantee to the government. Guarantee costs arise from the contractor's charge for accepting the deferred liability created by the guarantee and from the government's administration and enforcement of the guarantee. In most cases, contractors will quote a higher price to provide the guarantee. Competition will be a major factor in the price quoted by the contractor to the government for the guarantee. In addition, the experience of the contractor in producing the item is another major factor in the cost of the guarantee since it may rely on an actuarial basis to assess financial risk. As a further consideration, the estimated cost to the government for correction or replacement by the contractor, by another source, or by the government, in the absence of a guarantee, should be compared to the guarantee costs considered above.
- b. There are other factors which must be considered in determining whether the guarantee is cost effective such as any indirect costs to the Government necessary to maintain the guarantee in effect. For example, if certain spare parts must be purchased only from designated suppliers in order to keep the guarantee in effect, the estimate of the loss to the government attributable to this limitation on competition should be estimated. By way of a second example, the effect on breakout and competitive procurement of weapon system components should be considered.

13. The waiver authority granted in Subsection 794(3) is hereby delegated to the Secretaries of the Army, Navy, and Air Force and to the Directors of Defense agencies with authority to redelegate not below the level of the Vice or Assistant Commander of a Major Command or the Assistant Director of a Defense Agency. Class waivers for specific programs may be granted, where justified. Class waivers may not be approved below the level of the Assistant Secretary of the Military Department or the Director of a Defense Agency. A written record will be kept of each waiver granted, together with supporting documentation, to meet the reporting requirements to the Congress. A waiver of the guarantee requirements in whole or in part set forth above must be:

- a. Supported by a written determination that the waiver is necessary in the interest of the national defense or would not be cost-effective.
- b. An intention to waive such requirements must be forwarded to the committees on Armed Services and Appropriations of the Senate and the House of Representatives in writing, including in the notice an explanation of the reasons for the waiver(s).
- c. Notification of all class waivers will be sent to the DoD Acquisition Executive.

14. This guidance is effective immediately.

Attachment.

MODEL GUARANTEE

- a. Notwithstanding inspection and acceptance by the government of supplies furnished under this contract or any provision of this contract concerning the conclusiveness thereof, the contractor guarantees:

1. That line item --- and each component thereof are designed and manufactured so as to conform to the performance requirements of this contract and all other supplementary agreements relating to the production under this contract of line item --- entered into by the United States and the contractor, and
 2. That line item --- and each component thereof, at the time of delivery, are free from all defects in materials and workmanship which would cause the line item to fail to conform to the performance requirements of this contract and all other supplementary agreements relating to the production under this contract of line item --- entered into by the United States and the contractor; provided, however, that with respect to government-furnished property the contractor's guarantee shall extend only to its proper installation so as not to degrade its performance and/or reliability, unless the contractor performs some modification or other work on such property, in which case the contractor's warranty shall extend to such modification or other work.
- b. In the event of a failure of line item --- to meet the conditions specified in subparagraphs a.1. or a.2. above:
1. The contractor will promptly repair or replace such parts as are necessary to achieve the required performance requirements and the contractor shall bear all costs in connection therewith, or
 2. If the contractor fails to repair or replace such parts promptly, as determined by the contracting officer, the contractor will pay the costs incurred by the government in procuring such parts from another source and in accomplishing the repair.
- c. The contractor will also prepare and furnish to the government data and reports applicable to any correction required under this clause (including revision and updating of all affected data called for under this contract) at no increase in contract price or cost to the government.
- d. When items covered under the guarantee are returned to the contractor, in pursuance to this clause, the contractor will bear the transportation costs from the place of delivery specified in the contract (irrespective of the f.o.b. point or point of acceptance) to the contractor's plant and return.
- e. If the government determines that it does not require repair or replacement of defective or nonconforming supplies, the government shall be entitled to an equitable adjustment in the price of such supplies.
- f. The contractor shall be notified in writing of any failure of line item --- or any component thereof subject to the guarantee set forth in paragraph a. above within ---days after discovery of the failure. Upon election by the government of a remedy in accordance with paragraph b. or c. above, the contractor will, notwithstanding any disagreement regarding the guarantee, comply with such direction. In the event it is later determined that the failure was not subject to the guarantee set forth in paragraph a. above, the contractor price will be equitably adjusted.
- g. The guarantee provisions of this clause do not apply to combat damage.

- h. For purposes of this clause, the term "performance requirements" means only those performance characteristics that are mandatory. The term "performance requirements" does not include performance characteristics that are described as goals or objectives.
- i. The rights and remedies of the Government provided in this clause are in addition to, and do not limit, any rights the government may have under any other clause of the contract. Dispute arising under this clause will be resolved in accordance with the clause of this contract entitled Disputes.

Appendix C

TITLE 10, UNITED STATES CODE, SECTION 2403

Appendix C

TITLE 10, UNITED STATES CODE, SECTION 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 139a 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.
- (e)(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)(1) 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.
- (h)(2) This section does not apply to the Coast Guard or to the National Aeronautics and Space Administration."

Appendix D

BIBLIOGRAPHY

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BIBLIOGRAPHY

1. Arrow, Kenneth, "Uncertainty and the Welfare Economics of Medical Care," American Economic Review, 53 (1963), pp. 941-973.
2. Arrow, Kenneth and Robert C. Lind, "Uncertainty and the Evolution of Public Investment," American Economic Review, 60 (1970), pp. 364-378.
3. Balaban, Harold S. and Martin A. Meth, "Contractor Risk Associated with Reliability Improvement Warranty," Proceedings of the Annual Reliability and Maintenance Symposium, 1978, pp. 123-129.
4. Balaban, Harold S., Kenneth B. Tom, and George T. Harrison, Jr., Warranty Handbook: Final Report, ARINC Research Corporation, Annapolis, MD, June 1986.
5. Bayer, H. and R. N. Speir, "Long Term Commercial Warranty," Proceedings of the Annual Reliability and Maintenance Symposium, 1978, pp. 50-54.
6. Blischke, W. R. and E. M. Scheuer, "Calculation of the Cost of Warranty Policies as a Function of Estimated Life Distribution," Naval Logistics Research Quarterly, 22 (1975), pp. 681-696.
7. Blischke, W. R. and E. M. Scheuer, "Applications of Renewal Theory in Analysis of the Free-Replacement Warranty," Naval Logistics Research Quarterly, 28 (1981), pp. 193-204.
8. Borch, Karl, "The Safety Loading of Reinsurance Premiums," Skandinavisk Aktuarietidskrift, 1960, pp. 163-184.
9. Borch, Karl, "Equilibrium in a Reinsurance Market," Econometrica, 30 (1972), pp. 424-444.
10. Chelson, Paul O., "Can We Expect ECPs Under RIW," Proceedings of the Annual Reliability and Maintenance Symposium, 1978, pp. 204-209.
11. Cummins, J. M., "Incentive Contracting for National Defense: A Problem of Optimal Risk Sharing," Bell Journal of Economics, 8 (1977), pp. 168-185.
12. DAR Warranties Subcommittee, "Policy Comments to Defense Acquisition Circular (DAC) 84-9, Warranties," Action Memorandum, undated.
13. Edwards, F. R. and A. A. Heggstad, "Uncertainty, Market Structure, and Performance: The Galbraith-Caves Hypothesis and Managerial Motives in Banking," Quarterly Journal of Economics, 77 (1973), pp. 455-473.
14. Fisher, I. N. and G. R. Hall, Risk and the Aerospace Rate of Return, RM-5440-PR, The Rand Corporation, 1967.
15. Gándara, Arturo and Michael D. Rich, Reliability Improvement Warranties for Military Procurement, Report R-2264-AF, The Rand Corporation, December 1977.
16. Gándara, Arturo and Michael D. Rich, A New Look at Warranties in Defense Contracts, Rand Paper P-6100, April 1978.
17. Goree, Paul F., "DoD Industry-R&M Case Study Analysis," Proceedings of the Annual Reliability and Maintenance Symposium, 1984, pp. 91-98.

18. Harris, Milton and Arthur Raviv, "Some Results on Incentive Contracts with Applications to Education and Employment, Health Insurance, and Law Enforcement," American Economic Review, 68 (1978), pp. 20-30.
19. Hauter, Andrew J. and Clair W. Stempke, "TACAN RIW Program," Proceedings of the Annual Reliability and Maintenance Symposium, 1978, pp. 62-64.
20. Headquarters, U. S. Army, Procurement Law, Department of the Army Pamphlet 27-153, March 15, 1983.
21. Headquarters, U. S. Army, Army Regulation 700-139, March 10, 1986.
22. Hearings, U. S. Senate Armed Services Committee, Warranties on Weapons Systems, February 28, 1984, Washington, D.C., 1984.
23. Hearings, U. S. House of Representatives Armed Services Committee, Warranties, April 25, 1984, Washington, D.C., 1985.
24. Hearings, U. S. Senate Armed Services Committee, Task Force on Selected Defense Procurement Matters, Quality Control, October 18, 1984, Washington, D.C., 1985.
25. Hearings, U. S. Senate Armed Services Committee, Implementation of the 1984 Defense Procurement Legislation, October 17, 29, November 7, 13, 1985, Washington, D.C., 1986.
26. Hirshleifer, J. and John G. Riley, "The Analytics of Uncertainty and Information-An Expository Survey," Journal of Economic Literature, 17 (1979), pp. 1375-1421.
27. Marshall, Clifford W., Incentivizing Availability Warranties, Polytechnic Institute of New York, Research Report Poly EE 80-002, March 1980.
28. Marshall, Clifford W., "Incentivizing RIWs," Proceedings of the Ninth Annual DoD/FAI Acquisition Research Symposium, June 1980.
29. Marshall, Clifford W., "Design Tradeoffs in Availability Warranties," Proceedings of the Annual Reliability and Maintenance Symposium, 1981, pp. 38-45.
30. Marshall, Clifford W., "Warranty Definition for Bulk Availability," Proceedings of the Annual Reliability and Maintenance Symposium, 1983, pp. 225-230.
31. Marshall, John M., "Moral Hazard," American Economic Review, 66 (1976), pp. 880-890.
32. Memorandum, Brigadier General Gerald J. Post, USAF, "Use of Commercial Support/Warranty Concepts for Selected F-15 Subsystems," August 15, 1973.
33. Memorandum, Assistant Secretary of Defense/Installations and Logistics, "Trial Use of Warranties," August 17, 1973.
34. Memorandum, Assistant Secretary of Defense/Installations and Logistics, "RIW Guidelines," September 16, 1975.
35. Meth, Martin M. and Kurt Greene, "The Operational Readiness: The Reliability and Maintainability Connection," Proceedings of the Annual Reliability and Maintenance Symposium, 1984, pp. 83-85.
36. Newman, David G. and Lance D. Nesbit, "USAF Experience with RIW," Proceedings of the Annual Reliability and Maintenance Symposium, 1978, pp. 55-59.
37. Ross, Stephen A., "The Economic Theory of Agency: The Principal's Problem," American Economic Review, 63 (1973), pp. 134-139.

38. Rypka, Edward A. and George F. Kujawski, "Repair/Reliability Guarantee Programs Can Work," Proceedings of the Annual Reliability and Maintenance Symposium, 1983, pp. 221-224.
39. U. S. Congress, Committee of Conference Report, Department of Defense Authorization Act of 1985, September 26, 1984.

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