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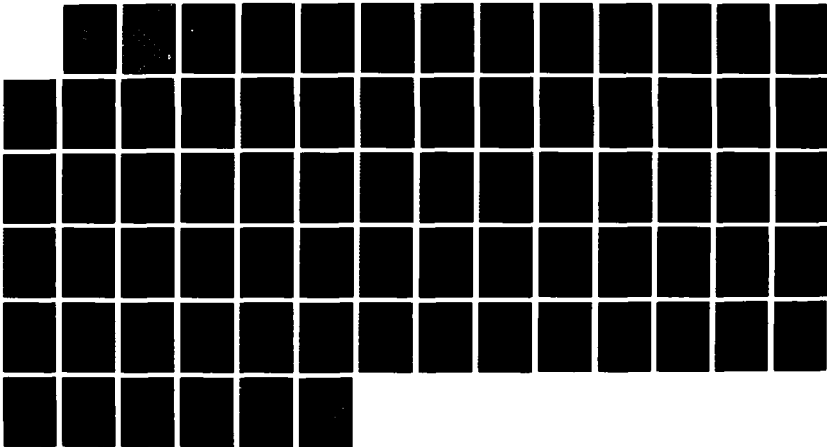
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WARRANTY CLAUSE..(U) CARNEGIE-MELLON UNIV PITTSBURGH PA
SOFTWARE ENGINEERING INST. L DRUFFEL ET AL. JUN 87
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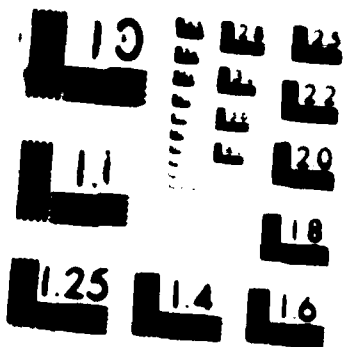
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Technical Report

CMU/SEI-87-TR-4
ESD-TR-88-104



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Software Engineering Institute

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Software and System Warranty Issues and Generic Warranty Clause

Larry Druffel

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June 1987

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Software Warranty Project

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This technical report was prepared for the

SEI Joint Program Office
ESD/XRS
Hanscom AFB, MA 01731

The ideas and findings in this report should not be construed as an official DoD position. It is published in the interest of scientific and technical information exchange.

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This report has been reviewed and is approved for publication.

FOR THE COMMANDER


Karl H. Shingler
SEI Joint Program Office

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Software and System Warranty Issues and Generic Warranty Clause

Abstract: This report describes how to effectively include software issues into a system warranty. The report includes a generic system warranty clause, with a description of the rationale for each paragraph in the clause. The clause will have to be tailored to the circumstances of the system, and some tailoring considerations are described. There is also a description of the important legal, technical, and administrative concerns which are directly related to the warranty issues. The report describes the need for such a systems warranty, and includes firm recommendations on how to use such a warranty to improve the quality of the delivered system. ←

1. Executive Summary

Task Description

The Software Engineering Institute was asked by the Department of Defense to recommend a "clear, enforceable software warranty clause(s) that can be integrated into . . . system warranties." The clause was to be "concise (one to two pages) and understandable." In response to that request, we have drafted a straight-forward two-page generic system warranty clause that covers software, not in isolation, but as part of a warranted system.

At first, our task appeared to be strictly a legal exercise. On investigating the motivation for the task, however, it became clear that a software warranty clause alone would not solve the basic problems that led to the task in the first place. The Software Engineering Institute (SEI) discovered that the enforcement problem was not so much associated with the legal framework of various warranty clauses, but with the lack of meaningful specifications and tests designed to demonstrate system defects that trigger warranty coverage of the system as a whole. The scope of the task was therefore broadened to address technical and administrative issues associated with the system warranty process.

Those issues are fundamental to the generic clause we have developed. Chapters 3 through 9 of this report, therefore, outline the legal, technical, and administrative issues associated with the application and enforcement of an inclusive system warranty. The clause, and a paragraph by paragraph explanation of its provisions, are found in Chapters 10 and 11 of this report.

Approach

Our understanding is that recent experiences with deployed systems have revealed problems, and existing warranties have not been an effective remedy to those problems.

The crux of the matter is twofold:

1. The deployed systems do not meet user requirements and have unacceptable failure rates.
2. Often the failures appear to be associated with software, but existing warranties have not generally provided an adequate remedy for such failures.

We believe these warranty-related problems have two causes:

1. The burden of proving not only the existence of a defect, but also the contractor's responsibility for that defect, ordinarily falls on the government.
2. Existing warranties frequently have not defined defects in terms of adequately verifiable specifications and tests that would permit the government to demonstrate a breach of warranty in satisfaction of its burden of proof.

Although there are several possible remedies to problems of system failure, in conformity with the SEI's assigned task, this report describes one approach to relieving these problems: write a more enforceable system warranty clause, and address the legal, technical, and administrative issues that support warranty enforcement. The goal is to ease the government's burden of proving the existence of a defect for which the warranty clause provides a remedy. The key to satisfying that goal is to develop technical tests and specifications that provide objective and demonstrable standards against which a claim for breach of warranty can be measured.

Recommendations

The following recommendations are derived from the report:

1. To ease the burden the government bears to prove a breach of warranty, the generic warranty should cover the failure of a delivered system as a whole, including, but not limited to, its software, to satisfy clear and measurable essential performance requirements for the system. Essential performance requirements must be based on a clear distinction between the warranted product and other components in the environment.
2. Conditions for establishing breach of warranty should be described in terms of analysis of recorded symptoms and diagnostic results. The test methods to determine breach should be described in the specifications.
3. Through careful drafting and aggressive litigation techniques, the government has a good chance of changing the currently accepted legal standard, and of shifting to the contractor the burden of proving that system defects are attributable to government-furnished equipment. Even if the burden cannot be shifted, however, the government's burden of proof can

be minimized by developing tests and procedures that will isolate defects in government-furnished equipment.

4. To provide maximum applicability and enforceability, the generic clause should be modeled after the Weapon Systems Warranty Act, and must be carefully tailored on a case by case basis.
5. Government procurement practices contribute substantially toward existing problems. If it is to reap the benefit of improved legal and technical warranty considerations, the government must improve such practices.
6. The quality of the product is heavily dependent on the specifications describing the product and the clear description of the critical functions to be performed. The success of a product and the applicability of a warranty depend on a well crafted specification.
7. Warranties are not costless, and contractors can be expected to price warranties even higher as their exposure to warranty liability increases through increased warranty scope, remedies, and enforceability. There are remedies other than warranties which also would improve the deployed products, so, in each individual case, the costs and benefits of the warranty must be balanced against the costs and benefits of other applicable remedies.

2. Introduction

Deployed military systems involve a mixture of computer software, hardware, and associated other equipment, operating in unison with operational personnel, to provide functions vital to national security. Recent experiences with deployed systems have revealed problems, and existing warranties have not been an effective remedy to those problems. The crux of the matter is twofold:

1. The deployed systems do not meet user requirements and have unacceptable failure rates.
2. Often the failures appear to be associated with software, but existing warranties have not generally provided an adequate remedy for such failures.

We believe these warranty-related problems have two causes:

1. The burden of proving not only the existence of a defect, but also the contractor's responsibility for that defect, ordinarily falls on the government.
2. Existing warranties frequently have not defined defects in terms of adequately verifiable specifications and tests that would permit the government to demonstrate a breach of warranty in satisfaction of its burden of proof.

In response to these problems, the SEI was asked to write a concise (no more than two-page) and enforceable software warranty clause. We note here, however, that there are other possible remedies to current system acquisition problems that should also be considered in each individual case — contractors can be expected to include their anticipated costs of providing warranty protection in the acquisition costs, and those additional costs may at some point outweigh the incremental benefits the warranty provides. This report describes one approach to relieving system performance problems in future acquisitions: Write a more enforceable warranty, and address the legal, technical, and administrative issues that support warranty enforcement. The goal is to ease the government's burden of proving the existence of a defect for which the warranty clause provides a remedy.

At first this task appeared to be strictly a legal exercise, but, on investigating the motivation for the task, it became clear that a software warranty clause alone would not solve the basic problems. The scope of the task was therefore broadened to address technical and administrative issues associated with the system warranty process. After meeting with Department of Defense (DoD) personnel, we decided to look more closely into the problems associated with a specific system illustrating the problem. We chose to concentrate on the FPS-117 Seek Igloo radar, since it is deployed and applicable failure data are available. We had hoped that an analysis of the failure conditions and

corrections would provide information which we could then extract and apply directly toward the warranty specifications. Unfortunately, the failure reports on this project were not sufficiently detailed to support a meaningful analysis. Nevertheless, evaluation of the FPS-117 radar specification and summary failure data provided valuable insight.

This report outlines the issues associated with the application of a product warranty. In Chapters 3 through 9, we describe the context in which the problem arises, and then we describe legal, technical, and administrative issues involved in developing a system warranty. Chapter 10 contains the two-page generic system warranty clause that was originally requested. The warranty clause is based on the issues and considerations outlined in the earlier chapters of this report. A paragraph by paragraph explanation of the clause appears in Chapter 11.

3. Context

Any discussion of warranty needs to consider the question, "To what does the warranty apply?" In the context of systems acquisition, the simplest answer is: The warranty applies to a product produced by a contractor. Practically speaking, a contractor can warrant nothing else. A warranty is a statement made by a contractor about the nature, usefulness, or condition of a product, and the contractor's intention to stand behind those statements under stated terms and conditions. See FAR (Federal Acquisition Regulations) Section 46.701.

Where systems employ computers, a product is often considered to be composed of hardware or software, or some combination of both. But thinking of a product in terms of its components often causes confusion and detracts from the main intent of a warranty: to encourage the contractor to produce and be accountable for a finished product that meets the needs of the intended mission. To satisfy that intent, a warranty should be neither a hardware nor a software warranty. Rather, a warranty should be a product warranty and should cover what the contractor produces, regardless of the particular elements making up the product. This approach also best addresses the legal issues respecting burden of proof, issues to which we now turn.

A product consists of various types of deliverables besides the hardware and executing code. Included within the scope of the product are source code, test harnesses, executable code, persistent data objects, and documentation. The warranty issues described throughout this document relate mostly to the hardware and executable code in the operational environment, rather than to issues concerned with descriptive documentation.

4. Legal Issues

Three fundamental legal issues shaped the development of our proposed generic system warranty clause:

1. the government's burden of proof respecting breach of warranty claims,
2. the applicability of the Weapon Systems Warranty Act, and
3. the need for careful, case by case tailoring of the generic clause.

4.1. Burden of Proof

As stated by FAR Section 46.703(c), "[t]he Government's ability to enforce the warranty is essential to the effectiveness of any warranty." Fundamental to this essential issue of enforceability is the two-part burden of proof that is imposed on the government with respect to warranty claims under prevailing federal procurement law. First, the government must prove by a preponderance of the evidence the existence of a defect — that is, that during the warranty period, conditions have developed or been discovered in the warranted product that are inconsistent with the conditions specified in the warranty. *E.g.*, *M-Pax, Inc.*, HUD BCA No. 80-529-C11, 81-2 BCA Paragraph 15410 (1980); *Genco Co.*, DOT CAB No. 75-22, 76-1 BCA Paragraph 11823 (1976). Second, even after proving the existence of a defect, the government must ordinarily prove by a preponderance of the evidence that the probable cause of the defect is attributable to contractor fault under the warranty. *Id.* It appears that the government has not generally been able to meet this two-part burden with respect to software. The generic system warranty clause should be drafted to ease, so far as possible, the government's burden of proving breach of warranty.

4.1.1. Burden of Proving a Defect.

First, the government must prove the existence of a defect in the warranted system. In considering this aspect of the burden of proof problem in connection with a generic warranty clause, we rejected an approach to software warranty clauses that limited the warranty to software exclusively, and instead used a system approach that warranted software as part of a generally warranted system. The government's burden of proving a defect may be unnecessarily complicated if it has to identify the defect with a particular hardware or software warranty. Where a contractor is responsible for delivering an operational system, the government should not have to bear the burden of isolating and proving a defect in the system's software, computer hardware, or any other particular component of the system. It should be enough that the delivered system is demonstrably defective; it is then up to the contractor to find and fix the defect(s). This system approach is consistent with our observation (see Chapter 3) that the contractor's product

under a system acquisition contract is an operational *system*, and that the system is therefore the appropriate subject of the warranty.

Further, defects for purposes of system warranty coverage should be defined in terms of system performance requirements. The coverage for system performance requirements is not necessarily instead of, but it is in addition to, more traditional warranties against defects in workmanship and materials or against failure to conform to design specifications. If the warranty is drafted in terms of the system's contractually established operating, reliability, and maintainability standards — which is what we mean by a system's performance requirements — a demonstrable failure of the system to meet those standards should be sufficient to satisfy the government's burden of proof, without a need to isolate the cause of the system failure in particular hardware or software defects.

Critical to the success of this approach to warranting software through system performance requirements is the development of (1) performance standards that are clear and complete, and (2) procedures and tests that can measure compliance with those standards in such a way that the government will be able to demonstrate system noncompliance with as much ease as possible. Thus, FAR Section 46.703(c) provides that enforceability depends on the existence of a defect reporting system that is adequate in terms of, among other things, the difficulty in establishing the existence of, and the responsibility for, defects. As we understand it in light of discussions with DoD personnel, existing warranties have frequently been inadequate because they have not been tied to carefully defined and measurable performance requirements. Nor have they incorporated objective and mutually agreed upon tests for measuring and verifying compliance with the performance requirements that have been stated. As a result, the government has not been able to carry its burden of proof because its contracts have not contained sufficiently objective and demonstrable standards against which a claim for breach could be measured.

Under the system performance approach to software warranties such as we propose, the critical matter of enforceability is ultimately tied less to generic legal drafting issues than to specific technical ones; the warranty is only as good as the technical articulation of system performance requirements. Moreover, the applicable performance requirements for any given procurement must be developed in the context of that particular procurement and cannot themselves be included in a generic model clause itself. Chapter 5, *Product Specification*, addresses issues relevant to the development of such performance requirements and verification procedures.

4.1.2. Government-Furnished Equipment and the Burden of Proof.

Assuming proof of the existence of a "defect" as defined in the warranty, the second part of the government's burden is to prove that the defect is the responsibility of the contractor under the warranty, not the government. The effect of this burden is that the government must generally prove that the defect was not attributable to any cause for which the government was responsible. See, e.g., *Lucerne Construction Corp.*, VACAB No. 1494, 82-2 BCA Paragraph 16,101 (1982); *R.H. Fulton, Contractor*, IBCA No. 769-3-69, 71-1 BCA Paragraph 8674 (1971); *Araco Co.*, VACAB No. 532, 67-2 BCA Paragraph 6440 (1967); *S&E Contractors, Inc.*, ASBCA No. 11044, 67-1 BCA Paragraph 6175 (1967); *Jefferson Construction Co.*, ASBCA No. 7008, 1962 BCA Paragraph 3409 (1967).¹

This burden of proof can adversely affect warranty enforceability where some defects in system performance are excluded from system warranty coverage. Defects attributable to government-furnished equipment (GFE), for example, are generally excluded from warranty coverage, and must be so excluded under the Weapon Systems Warranty Act. See Section 4.2 on page 12.

We think the better rule of law, applicable outside the narrow context of federal procurement law, is that, where a party seeks to bring itself within an exception to a contractual provision — such as an exclusion of GFE from warranty coverage — that party bears the burden of proving the facts necessary to bring itself within that exclusion. E.g., *New Britain Machine Co. v. Yeo*, 358 F.2d 297 (6th Cir. 1966); *Davies Flying Service v. United States*, 216 F.2d 104 (6th Cir. 1954); *Reece Construction Co. v. State Highway Comm'n*, 627 P.2d 361 (Kan. Ct. App. 1981); *Lang v. F.G. Arwood & Co., Inc.*, 65 A.2d 194 (D.C. Mun. App. 1949). This is especially so where the exclusion is set forth in a separate clause, rather than just as a proviso to, or part of, a single general clause. See generally 29 Am. Jur. 2d, Evidence, Section 144. Under this rule, to avoid its warranty obligations, the contractor would bear the burden of proving that defective system performance was caused by GFE, rather than the government's having to isolate the cause and prove that the defect was not attributable to GFE.

Were the government aggressively to pursue the matter in litigation or otherwise, it might successfully clarify federal procurement law consistently with the more favorable civil rule. Careful drafting would substantially assist in this effort. Thus, any GFE exclusion should be drafted as a separate provision, and should not be included within the contractor warranty provision itself.

4.1.2.1. Contractually Shifting the Burden.

It may further be helpful to include in a system warranty a provision that explicitly provides that the contractor bear the burden of proving government fault for a defect, whether attributable to GFE or otherwise. There is a split in authority respecting the validity of such contractual provisions, with perhaps the weight of authority holding that parties may not contractually change what are normally considered to be rules of evidence. See generally, 29 Am. Jr. 2d, Evidence, Section 13; 1 *Wigmore on Evidence* Section 7a (Tillers Rev.). Until the issue is finally decided, however, there would appear to be no good reason not to include such a provision for whatever additional protection it may provide.

Moreover, the clause should be drafted to define any GFE exception in terms of contractor proof of GFE fault. By making the burden of proof an element of the exception itself, rather than only a rule of evidence for proving the exception, the government may be able to increase further the likelihood that a court or board of contract appeals would put the burden of proving the exception on the contractor.

4.1.2.2. Tests and Procedures for Determining GFE Defects.

In the final analysis the best method for easing the adverse effects of the government's burden of proving contractor responsibility for defective performance is to develop technically sound criteria and procedures for verifiably isolating system failures that are due to GFE from failures that are due to causes within the contractor's area of responsibility under the warranty.² The generic clause should incorporate such tests by reference and make them the standard for applying the exception. Like the performance requirements and verification procedures described above in connection with proving a defect, such criteria and procedures can only be developed on a case by case basis depending, for example, on the system involved, what GFE is used and how it is incorporated into the system. But in the absence of technically verifiable tests and procedures for determining whether or not performance defects are caused by GFE, the government will have little chance of proving that the contractor is responsible for system failure under the warranty. Chapter 7, *Problem Detection and Isolation*, addresses issues relevant to the development of such verification tests and procedures.

4.2. Applicability of the Weapon Systems Warranty Act

The generic clause, of course, should be drafted to conform to the fundamental requirements of FAR Sections 46.702-46.710, which govern warranties in government contracts generally, and DFAR (defense federal acquisition regulation supplements) Sections 246.701-246.708, which are warranty regulations specifically promulgated by the Department of Defense. The clause should also conform, we believe, to the Weapon Systems

Warranty Act of 1984 (WSWA), 10 U.S.C. Section 2403, and to the DFAR provisions implementing WSWA, DFAR Sections 246.770-246.770-10.

WSWA, which mandates certain warranty requirements for government acquisition of "weapon systems," is relevant to the generic system warranty clause for two reasons. First, although we understand that to this point DoD procurements have not generally been warranted under WSWA, it is our view that the intended scope of the Act is very broad in the context of defense procurements, and that its applicability should be carefully considered in connection with future DoD procurements.³ To assure the broadest possible applicability for the model clause, therefore, it is useful to develop a clause that will satisfy the specific requirements of WSWA, as well as the more generally applicable FAR and DFAR warranty clause requirements.

The second reason WSWA is relevant to the generic clause is that, whether or not WSWA is strictly applicable to a particular DoD procurement, WSWA applies to "systems" and establishes warranties of essential performance requirements for those systems. Thus, WSWA provides a congressionally approved model for a system warranty incorporating essential performance requirements — the approach we have taken for warranting software. As such, the WSWA warranty requirements provide useful guidance and precedent for warranty provisions that could be at issue in later litigation.⁴

Where Congress has specifically addressed performance warranties and legislated an approach to such warranties, enforceability of a warranty clause will be improved if the clause conforms to Congress' approach. DFAR Section 246.703 indeed encourages application of WSWA warranties, even where not strictly required, if warranties are otherwise to be obtained. ("Acquisition of warranties in the procurement of supplies that do not meet the definition of a weapon system . . . is governed by FAR 46.7. However, should the Government elect to obtain a warranty for such supplies, contracting officers should negotiate warranties that meet or exceed the requirements of 246.770 [governing WSWA warranties] where such warranties are advantageous and in accordance with Department policy.")

4.3. Tailoring

A further warranty fact of life relevant to developing a generic or model clause is that a model clause is just that — a model. Such a generic model should not purport to resolve the myriad of procurement-specific issues that will arise in connection with particular procurements. The clause we have developed is, therefore, not intended as a form clause to be simply inserted into systems acquisition contracts. As earlier noted, the heart of the clause is in paragraphs that reference performance requirements, and in

tests and procedures that establish and verify compliance with, or deviation from, those performance requirements; the clause similarly references tests and procedures for distinguishing defects for which the contractor is responsible from defects in GFE, for which the contractor is not responsible. We have already observed that such requirements, tests, and procedures can be developed only in the context of specific procurements, not generically. Issues specific to particular procurements — and negotiations with individual contractors — will likely also require carefully tailored provisions relating to procedures for notification, investigation, and resolution of claims of breach, as well as to remedies, exclusions, limitations, and warranty periods. In promulgating model clauses for general acquisition purposes, FAR Section 76.710 recognizes that "because of the many situations that may influence the warranty terms and conditions appropriate to a particular acquisition, the contracting officer may vary the terms and conditions of the clauses to the extent necessary." More compellingly, to the extent that WSWA applies to a given system acquisition, a nongeneric, case by case approach was plainly intended by Congress⁵ and is specifically required by the governing DFAR provisions.⁶

In short, the model system warranty clause can be designed to address generic requirements and problems, but it must be specifically and carefully tailored for each application.

4.4. Summary

To summarize our observations on some of the legal issues underlying a generic system warranty clause, a generic clause should take account of the requirements of WSWA and should provide for substantial tailoring on a case by case basis. Most importantly, the system warranty clause should be based on carefully developed performance specifications and on testing and measuring procedures that can verify system compliance with the contractual requirements and help determine responsibility for system defects. In the following chapters, we discuss approaches and methods for developing such system specifications and verification procedures.

5. Product Specification

A key aspect to consider when dealing with a system warranty as we have described it above is the product's essential performance requirements. These can be defined, and have been under WSWA, as "the operating capabilities and maintenance and reliability characteristics of a system necessary for it to fulfill the military requirement for which the system is designed" (DFAR Section 246.770-1). In this chapter, we address issues relevant to developing such essential performance requirements.

Specifying a product's essential performance requirements is a critical component of the specification activity. Specifications are commonly used to describe a product and to act as a basis for product testing and acceptance. Requirements specifications should also be viewed as a tool for acquiring and enforcing a product warranty. To be an effective warranty tool, the specifications must be developed in a way that simplifies the task of warranty enforcement. They must be clear, concise, consistent, correct, and complete. Creating specifications with these characteristics, however, is an extremely difficult and error-prone task. To aid in warranty enforcement, special and careful attention must be paid to the creation of the specifications (see FAR Sections 46.703(c)(5)&(6)).

Electronic systems products incorporating computers, which are the subject of this report, are often large, technically complicated, and especially difficult to specify. The collection of all product specifications in such complex systems, even after considerable review, may not completely identify all aspects of the product, may lack clarity in some areas, and may contain inconsistencies. A wholesale or mechanical application of warranty clauses to a complete set of product specifications, therefore, may easily lead to problems of enforcement. Thus, as a practical as well as a legal matter under FAR Section 246.706-1, it is necessary to determine and spell out exactly what, of all the things that make up the product, is to be warranted. Such essential requirements should stand separately and be clearly identified. The separation should allow critical review and analysis of the essential requirements, and should be less difficult than critical review of the entire specification.

There are three basic product-related areas that must be considered when defining a product's essential performance requirements:

1. where and how the product will be used [environment],
2. what the product does [functionality], and
3. how well the product does it over time [quality].

These areas are discussed separately below, but it is important to consider them together to determine the essential performance requirements and what is to be warranted for a particular system. Review of several DoD system specifications indicates that design constraints should be separated out in existing specifications. While constraints may not apply directly to the specification of critical requirements, they may well play a role in warranty enforcement.

5.1. Operational Environment

A product must be considered in relation to the environment in which it operates. The term environment is often used to describe physical conditions such as temperature, humidity, power, and vibration. Environment, as used here, includes these physical conditions. It also includes other equipment with which the product must interact, such as communications networks and other government-furnished equipment. Special attention must also be paid to software packages, such as operating systems, that are provided by the government. A product is useful only if it operates successfully in its intended setting. As a practical matter, it is usually neither possible nor economically practical to engineer a product for all possible environments. It is mandatory to clearly distinguish and define the boundaries between a product and its environment. Those points where a product interacts with, or is affected by, its environment deserve special attention. These interface points, and the conditions and interactions that occur at these points, form part of a product's essential performance requirements. It is impossible to create a description of a product without a precise definition of its boundary. The product includes everything inside the boundary. The product's environment includes everything outside the boundary. Without a clear boundary, it is impossible to define what the product is supposed to do.

As a very simple example, consider requirements specifications for two alphanumeric video display terminals: the first, with a boundary drawn between the keyboard and the terminal operator; the second, with a boundary drawn between the terminal and the keyboard.

- **In the first case**, the keyboard is part of the product and the operator is part of the environment. In this case, the specifications must deal with issues such as keyboard layout, keycap legends, keyboard physical dimensions, pressure required to activate a key, and tactile feel to the operator.
- **In the second case**, the interface is part of the product and the keyboard is part of the environment. In this case, the specifications will deal with very different issues. These include physical connection between terminal and keyboard, electrical interface between terminal and keyboard, content and format of data messages passed, rate of data messages, control of message flow, and detection and handling of transmission errors.

A small change in the boundary brings about the need for very different specifications of requirements. It also presents a very different picture and statement of what is to be warranted.

This separation of product from environment is crucial at an early stage of specification development. It allows the specification to be developed in a coherent, meaningful way, and aids other warranty-related activities, listed below.

1. **Separation helps identify the points at which the product interfaces with the environment.** For each interface point, it is necessary to describe in detail how the product deals with the interface. For example, what conditions, data, and signals does the environment present? If the interface is provided by software, what is the interface mechanism, what data flow across the interface, what checking for proper interfaces occurs, and what errors are reported? What functions are to be performed by the product in each case? How are problems in the interface to be recognized, and what is to be done in each problem situation?
2. **Definition and specification of interface points aid in the process of test specification and development.** Tests are known to be useful during the development and acceptance of products. Tests are also important in the area of warranty enforcement. A predefined set of well defined interface tests greatly aids defect detection and isolation necessary to support warranty enforcement.
3. **A clear separation between product and environment aids in determining the instrumentation required to support warranty enforcement.** Any question of warranty will bring questions from the contractor about the conditions of the environment at the time of a failure. Predefined instrumentation that monitors the condition of the environment should aid defect detection and isolation.

Environment specification also deals with defining general physical conditions of the operating environment rather than interface points. These physical conditions, e.g., heat, relative humidity, shock, and vibration, seem well understood. They are not dealt with here other than to say that instrumentation and recording of the physical conditions may be an aid to warranty enforcement.

5.2. Functionality

A product is useful and valuable only if it does what it is purported to do. What a product does can be described by the functions it performs. In many real-time systems, each function description must contain a specification of the time period in which the function must occur. From a warranty standpoint, the important functions are those that occur at the boundaries of a product — that is, those that a product provides to its environment. Internal functions are necessary to support the operation of external functions, but in the area of product warranty, they are represented by their observability at the product

boundary. Functions provided to the environment form part of a product's essential performance requirements.

The portion of the specification covering functionality should answer the questions, "What is the system supposed to do?" and, "What functions will it perform under what conditions within what time periods?" The specification of functionality must relate to the specification of the operational environment and must pay careful attention to the points where the product interfaces with the environment. In many cases, it may be necessary to separate functions that occur in the normal operating environment from those that occur when the product is stressed by abnormal conditions in the environment, e.g., unusually high burst data rate, loss of processing power due to hardware malfunction, and loss of communications paths due to defects in system components outside the product. The key point here is that specifying what to do under the normal system environment is not enough. The specification should also define what must be done during times of abnormal conditions in the environment, e.g., abnormal load.

Separating functions into levels allows the specification of different reliability and availability measures. There are cases in which all functions provided by a product are critical to accomplish the mission of the system, but in practice this is not always the case. Separating functions into critical, noncritical, and possibly other levels is a product-specific activity that depends on the needs a product must satisfy. Specifying levels of functionality, which must all exhibit ultra-high reliability and availability, may well lead to products that are "gold plated" — extremely expensive to produce and maintain.

5.3. Quality

The third product area that must form part of the essential performance requirements is the quality of a product. It is important to define quality measures for each product. Quality deals with how well the product performs its functions in the operating environment over time. Quality is one of the most difficult areas of product specification. Although quality is often easy to recognize, it is difficult to discuss and describe in measurable, quantitative ways. A product exhibits quality only if it provides the required set of functions to the outside environment when they are required. Quality characteristics of individual components of a product are secondary to the quality characteristics of the external functions.

From a warranty standpoint, two key specification issues must be dealt with:

1. **The specification must be unambiguous.** Required quality characteristics must be measurable in a quantitative way. The measures and the methods of measurement should both be defined. In general, the following five areas must be defined in the quality specification:
 - a. **What is product failure?** A product failure definition can usually be tied to the product's functional specification. A product failure occurs when the product does not do what the functional specification says it is supposed to do.
 - b. **What is reliability?** Reliability is a measurement of the number of failures over time. Mean Time Between Failures is often used to specify required reliability characteristics. MTBF should be specified for each level of functionality defined for the product.
 - c. **What is recovery and repair?** Recovery from failure should specify what actions are acceptable to restore a system to operation following a failure, and the maximum length of time allowed to perform those functions. Recovery is not the same as repair. In some cases — for example, intermittent failures — a system may be restored to operation without repairing the cause of the failure. Recovery from failure, even if rapid, should not relieve the contractor from the responsibility of repairing the defect that caused the failure.
 - d. **What is availability?** Product availability can be defined as the fraction of time during which a system functions without failure. It deals with both reliability and recovery.
 - e. **What is maintainability?** Maintainability deals with the ease with which a product can be kept in an operational state and possibly be extended over time. While maintainability is an important quality characteristic, it is difficult to specify in a quantitative way. Care must be taken to specify maintainability characteristics in a way that can be measured.
2. **The specification must define quality required in the operational product.** It should not confuse delivered quality with predicted quality, or with the methods to be used by the contractor to obtain quality. Quality assurance methods are extremely important and are discussed separately in Section 8.4, page 28. Existing product specifications deal with quality in several ways: what quality is required in the delivered product, what methods are to be used to produce a quality product, and what role do reliability models play in product development. The methods and quality predictions, however, are not the subject of a performance warranty. From the warranty standpoint, the specification should clearly separate the definition of required quality from other quality considerations. The warranty must cover the end result of the engineering process: the quality of the delivered product. Methods to achieve quality cannot be warranted and should be discussed separately to avoid confusion and promote warranty enforcement.

5.4. Constraints

Existing specifications deal with an area separate from functionality, environment, and quality. This area — constraints — covers restrictions placed on the contractor's development process and defines characteristics of individual product components. Sections covered include standards to be followed, methods to be used, attributes of product components, and restrictions on component interfaces. Other areas specific to the individual product are also included.

These constraints are important and should remain in the specification. Many describe process and component characteristics that have proven useful in delivering quality products. The constraints, however, may make obtaining and/or enforcing a performance warranty more difficult. Although they should continue to be included in the specifications, they should be clearly separated from the essential performance requirements. They should also be analyzed carefully to insure they do not contradict the product's essential performance requirements.

6. Product Problems

This chapter describes the problems that occur in a developing operational system. It describes the types of failures that arise, the reasons for these failures, and then proceeds to give an overview the failures most relevant to the warranty conditions. The chapter then discusses the remedies that apply, and clearly distinguishes between fixing problems and restoring the system to operational status.

A defect for warranty purposes is a deviation from warranted specifications, including essential performance requirements as fixed by the contract.

A failure occurs when the system has been working, ceases to work, and some operational loss of availability occurs. Failures may be caused by defects in the system, or a pattern of failures may constitute a performance defect. Failures can be classified by their consequences as those that:

1. cause degraded operation of the system,
2. cause the system to be unavailable for some time,
3. cause hazardous situations to occur.

Obviously, all failures should be avoided, but those that may lead to hazardous situations must definitely be eliminated in the design process.

6.1. Reasons for Failure

There are four basic reasons for failure:

- birth defects, which occur when a component is new, and fails shortly after installation
- wear out, which occurs when a component has been in use for some time, and a part is out of tolerance due to wear and tear
- infrequent occurrence of operating conditions exposing a defect
- incorrect maintenance actions

The effects of failures on the operation of the system can also be lumped into two types:

- persistent failures, which occur each time a condition arises, and
- intermittent failures, which seem to occur randomly, though in practice may reoccur each time an infrequent combination of internal states and input sequences is encountered.

Most failures are detected during the building, testing and installation of a system. Once the system is in operation, the failures that occur can be categorized as described below:

1. Hardware wear out (causing persistent or intermittent failures), which can be remedied by replacing a bad part with a good part. This type of failure is the one that is best understood, and conventional reliability theory models such failures well. The reliability and availability of a system can be predicted from the expected failure rates of components, and the redundancy and fault tolerance can be designed into the system.
2. Hardware or software failures due to design defects. These can be difficult failures to resolve, since performance failures due to system defects are often not easily reproducible, and they can occur infrequently. These are basically design flaws, and are not well modeled by conventional reliability theory.
3. Failures due to changes in the environment. These can range from changes in the physical environment surrounding the hardware, to failures encountered after software upgrades are made to the system, for example, replacing the operating system.

6.2. Remedies

The basic remedies that apply to the failure conditions are listed below.

1. For a persistent hardware failure, replace the bad component.
2. When the software fails to perform a function persistently, redesign and reinstall the software causing the failure.
3. Intermittent failures can be due to hardware failure, hardware defects, or software defects. For a defect, isolate and fix the defect, then reinstall the updated hardware and/or software in the system. Often installation of new modules has to be done carefully, with special software being introduced and executed to transform any populated data structures from the "old" structure to the modified structure. The system can often be restored to operational status without isolating and fixing the defects by one of the methods outlined below.
 - A warm restart, in which the system is restored to operation in the same state as when it failed.
 - A cold restart, in which the system is reinitialized to some previous state, but usually with a loss of some information at the time of failure. This also takes considerably longer than a warm restart.

6.3. Warranty Issues

The intent of a warranty is to have the contractor fix all defects within the scope of the warranty. However, fixing a software defect can often lead to the introduction of a further defect, so defect fixing should not be routinely postponed, but should be performed in a timely manner. For warranty purposes, it is important to distinguish between fixing the defects and recovering operational capability, which is merely fixing the symptoms.

This is not intended to downplay the recovery issues — failures will occur, and a good recovery procedure will reduce the effect of those failures on the availability of the system.

Problems involving the effects of software testing, instrumentation, and other issues on the warranty are presented in Chapter 7.

7. Problem Detection and Isolation

Chapter 6, *Product Problems*, outlined the types of failures that occur in a deployed system, and how they can be categorized and remedied. Unfortunately, detecting and isolating defects is a difficult, time-consuming, labor-intensive effort. In current practice, it is further exacerbated by the lack of instrumentation to record secondary symptoms, and the lack of tools to analyze the data that get recorded.

7.1. Boundaries with the Environment

In deployed mission critical computer resource (MCCR) systems, it is often more difficult to isolate a defect than to fix it. In view of the government's burden of proof, enforceability of any warranty, therefore, is critically related to the definition of demonstrable defects. One of the difficulties in satisfying the burden of proof is in determining the boundaries of the product under warranty. The basic question is, "Does the defect reside within the product, or within the environment of which the product is a part?" A reasonable way to resolve this problem is outlined below.

1. In the specification, the government should state that boundary problems will be resolved by the execution of tests on the system or on the recorded symptoms. The government must describe the extent of the tests at this time.
2. During the design process, these tests will be described in detail and approved by the government as part of the quality assurance program. The tests should be automated as much as possible.
3. When a deviation from the system's essential performance requirements occurs, the appropriate agreed-upon tests will be conducted to determine responsibility for the defect.

7.2. Instrumentation and Analysis

Until the problem of isolating and fixing the defects is alleviated, the contractor will always be tempted to justify the failures, rather than fix the defects. Hence, one way of enhancing warranty enforcement is to improve the process of isolating and fixing the defects. This section describes these issues in more detail.

In general, the most difficult types of failures to isolate are infrequent, intermittent ones that "crash" the system and require a recovery mechanism to restart it. If these failures do not cause a hazardous condition, or a specified function to work incorrectly, they can only be resolved by invoking the reliability clauses. If the failure rates are within the specified range, then the users of the system will probably be able to live with them. If the failure rates are outside the specified range, then the system is defective and must be fixed. In many installations, there are so few symptoms describing the failure that isolating the cause of the defect is very difficult. Some options for making the isolation less difficult are given below.

1. Require that the hardware components have Built In Tests, which will help isolate hardware defects from software defects.
2. Build in instrumentation to measure and record in a timely manner state variables, significant state transitions, exceptional conditions, and environmental conditions. This is necessary to provide secondary symptoms of the failure condition. The instrumentation should be able to be turned on and off, and the level of detail recorded should be selectable. The recorded data should be transportable to another environment for analysis. Tactical requirements must have precedence over data extraction.
3. Provide interfaces to external data collection and recording devices.
4. Build tools to filter and analyze the recorded data to help determine the cause of the failure and isolate the defect.
5. Monitor the appropriate environmental conditions, such as temperature, humidity, and power.

7.3. Repair of Defects

Once a software defect has been isolated, it has to be fixed. This requires changing one or more software components in the deployed system, and should be done under a strict configuration management policy. However, before the updated software is installed, it should undergo extensive testing to make sure it performs all of the functions of the older version, and does not contain any discernible defects. When the update has been made, sufficient on-site testing should occur to ensure that the new product meets the essential performance requirements of the contract.

8. Administrative Issues

The warranty of a system involves not just legal and technical issues, but many administrative issues as well. Since these issues are vital to resolving the warranty problem, they have been gathered together in this chapter.

8.1. Maintenance

The government often performs the maintenance on a deployed system with government personnel, or hires an outside contractor (not necessarily the systems development contractor) to perform the maintenance. This creates problems since failures can be blamed on badly performed maintenance, and the burden of proof then rests on the government to prove that the most likely cause of the failure was a defect existing in the delivered product. The government should consider these warranty issues when making the choice between having the maintenance done organically, by the original contractor, or by another contractor.

A second warranty problem will arise if the development contractor is not performing maintenance. It may be difficult to obtain contractor responsibility for the availability and Mean Time To Repair (MTTR) criteria defined for the product in the essential performance requirements. These characteristics are obtained by a combination of the quality of the product and the quality of the maintenance activities. Holding the contractor responsible for the actions of others will complicate warranty enforcement problems.

8.2. Specification

Specifications were discussed in detail previously. The specifications must be well written if a warranty is to be enforceable. It is the responsibility of the Systems Program Office (SPO) to have clear, unambiguous, complete, and testable specifications. "Developing Reliable Space Flight Software," by Lt. Col. Ed Koss, details methods leading to the acquisition of quality products.⁷ Specification techniques are included in those methods and receive heavy emphasis. The paper provides lists of things to do and things to avoid in writing specifications. The specifications should clearly describe not only functionality and performance, but also degraded operation, failure conditions, overload conditions, recovery considerations, and safety issues.

8.3. Process

The process of developing the system must be such that a high quality product that meets all the functional, performance, and reliability requirements in the specifications can be produced. Military standard 2167 describes in detail the government's approach to this problem, and, although this document is far from perfect, it does emphasize that a well defined process should be followed to produce a high quality product. This requires a commitment on the part of the SPO to follow the design details technically and to ensure that the details are given on schedule and within budget.

8.4. Quality Assurance (QA)

The enforcement of quality assurance practices should ensure delivery of a satisfactory product. However, it must always be stressed that quality is designed into a system, and defects are tested out of a system. Quality assurance is only effective if it is combined with good design practices and a well crafted warranty to cover the remaining defects. Some further comments are given below.

1. Military standard 2168 describes QA procedures.
2. Prototyping should be done where appropriate to reduce risks of conceptual errors.
3. Factory acceptance tests should test functionality, performance, and reliability in a simulated environment before shipment. Detecting and fixing defects is easy and inexpensive in this environment. Acceptance of delivery will make it more difficult to isolate and fix defects.
4. Field acceptance tests should be run after the system is installed and working in the final environment, and before acceptance of the system by the government. During installation, there are usually knowledgeable contractor people on-site; this is the time to correct as many remaining defects as possible. In some sense this is also a critical time in the decision-making process, especially if the installed system works well with "only a few flaws," and the operational command "needs" the system to perform its function.

8.5. Cost Considerations

The cost of a warranty must always be weighed against the benefits the warranty provides beyond those available through other maintenance, specification, and quality assurance methods. A contract with an enforceable warranty will cost more up front than a contract with no warranty or with a relatively unenforceable warranty. If the clause is perceived to provide the government with substantial and enforceable warranty protection, contractors will want to be paid for giving that protection. Moreover, the expected cost of providing warranty protection on systems developed for a particular acquisition

will not be spread over multiple purchasers as in the ordinary commercial setting, but will be borne wholly by a single purchaser — the government. Warranty cost problems may be further exacerbated by pricing difficulties where, for example, acquisitions are of state of the art, unproven systems with no performance or maintenance history, or where contractors are providing performance warranties on systems they did not design.

All this said, if a contract is properly administered, contracting for an enforceable warranty for particular systems may be cost effective in the long run, since the government's burden of proving breach of warranty will be eased, and the government will not have to pay the costs to "fix" the system to perform as it should have. The cost effectiveness of a rigorous system warranty should be carefully evaluated on a case by case basis in light of other available quality assurance mechanisms.

8.6. Government-Furnished Equipment

If the system specified by the government contains a substantial array of both GFE and contractor-supplied equipment, then the warranty will be difficult to enforce, since the boundaries of responsibility will be unclear. Before deciding to use GFE procurement, the government agency should consider the viability of receiving an enforceable warranty for the portion of the system not covered under the GFE, and the cost of realizing the warranty. The effort of defining a set of tests to isolate GFE defects from defects in contractor-supplied equipment should be estimated, as well as the effort of maintaining and executing these tests. A cost/benefit analysis should then be conducted, comparing GFE savings, warranty cost, and maintenance costs.

8.7. System Enhancements During Development

The contracted systems tend to be large, complex, and on the leading edge of technology. In addition, there is usually an extended time period between the award of the contract and the deployment of the system, during which enhancements to the system are defined. The mechanisms for including the enhancements vary from agency to agency, but in many cases, the enhancements do not cause changes to the specifications, but are agreed to on a piecemeal basis. This causes problems with the product warranty. Since there is no single document describing the system specification, ambiguous interpretations of the effects of the enhancements can be made. The warranty issues must be resolved with each enhancement, and the government must protect itself at initial contract time against purchasing a warranty that cannot be updated in a cost-effective manner to include enhancements.

8.8. System Enhancements After Deployment

The system is initially installed with a "baseline" product, and, as defects are found and fixed, the system may be changed to include the remedies to these defects. In addition, the system may be changed to increase its functionality, or improve its performance, in "block releases." After so many block releases, a new baseline may be created for the system. If the system baseline is still under warranty, and enhancements are introduced as a block release, how does this affect the original warranty if the system now exhibits rates inconsistent with essential performance requirements failures? This can be resolved in a manner similar to that described in Section 7.1 (page 25) for distinguishing between product errors and environmental errors by devising test procedures to establish the source of failures. The crucial problem occurs if there is a defect that is benign in the baseline, but causes a failure of essential performance in the block release. This type of defect cannot be found by merely "restoring to baseline" and waiting for the failure to occur.

8.9. Failure Reporting

A meaningful failure reporting scheme must be devised and implemented if warranty enforcement is to be realized. The failure report and its supporting documentation should contain at least the information detailed below.

1. Downtime and recovery time, in order to generate the reliability, availability, and maintainability metrics.
2. Results of diagnostic tests.
3. Details of both primary and secondary error and failure symptoms for analysis and evaluation.

In addition, each failure should be tracked from its occurrence to its resolution, and operational personnel should receive sufficient training to perform these tasks.

8.10. Acceptance Testing

System acceptance, which ordinarily starts the warranty period, is usually done based on a Factory Acceptance Test (FAT) and a Field Acceptance Test (FIAT). Some comments on both sets of tests are given below.

8.10.1. Factory Acceptance Tests.

By the very nature of the factory environment, factory acceptance tests can only demonstrate system conformance capabilities, since the field environment can rarely be completely simulated for the test. However, there are many things that can be done to increase confidence in the product, some of which are enumerated below.

1. Most of the functionality of the specification can be tested by well designed test procedures, and designing the software to be testable substantially improves this capability.
2. Overload conditions cannot be simulated in detail in the factory environment. For example, it is rarely possible to fly hordes of airplanes, flocks of birds, cruise missiles, and other objects around the radar installations in a factory environment. It is possible, however, to isolate the parts of the system that must operate under these conditions, and emulate the conditions in a test setting to validate that the software performs as specified when overload conditions arise.
3. Often the product must conform to certain spare capacity requirements, but the FAT cannot create an environment emulating the fully loaded operating conditions. In this case, the government and the contractor should agree on some formula for extrapolation to the final environment, and the FAT should demonstrate that the extrapolation is reasonable, and the spare capacity and system performance can be satisfied.
4. Failure conditions, graceful degradation, and recovery should all be thoroughly tested.

The main emphasis in this area is on error classification. The system should not pass FAT with unresolved high risk items outstanding, such as unexplained crashes. If time criticality is predicted to force acceptance and continued removal of known defects during installation, the warranty should be extended to provide a full warranty period following removal of those defects.

8.10.2. Field Acceptance Tests.

Acceptance should also be contingent on the acceptable operation of the system in the field. In field acceptance tests, normal operating conditions are in effect, and the system can be verified to meet these conditions, including reliability, availability, and maintainability. However, the system has often been specified to meet certain overload conditions, stressful operating conditions, and environmental conditions, some of which may not occur naturally before acceptance or even during the warranty period. The government should be confident that the correct actions will be taken should these conditions arise. Hence, there is a need for special field acceptance tests emulating each such condition.

9. FPS-117 Study

We decided early in this project that a warranty is a real-world legal instrument used to solve real-world problems, and that our study should focus on actual problems rather than hypothetical, abstract issues. We thought that an understanding of an existing product and its history would focus our thinking and drive us to treat issues that are relevant to those actually involved in the process of system acquisition, development, deployment, and maintenance.

Discussions with DoD personnel indicated that the FPS-117 Seek Igloo radar system would be a good candidate for study. It is a deployed system and is being maintained. Deployment, operation, and maintenance activities have uncovered problems in the system, and problem resolution has been difficult and lengthy. A warranty should address the problems in the FPS-117 product and program.

Our study of the FPS-117 was valuable. We had access to requirements documentation, summary error data, and project personnel. Choosing an existing system gave us the advantage of hindsight — both ours and the hindsight of those who have been involved in the FPS-117 project.

The balance of this chapter discusses the FPS-117. The discussion is divided into four sections: requirements specification, quality assurance, system acceptance and deployment, and operation and maintenance. This chapter is intended to help the reader gain a better understanding of what we are saying in the report by relating our points to an existing system. We are not knowledgeable in the complex area of radars, and this missing skill, along with time constraints, may have caused us to overlook areas or misinterpret what we read or heard. The discussion is not a criticism of what has been done in the past. We recognize, for example, that the FPS-117 specification was written seven years ago and that more recently developed specifications already incorporate much of what we are saying.

9.1. Requirements Specification

Our analysis is based on the specification titled "System Specification For Seek Igloo Minimally Attended Radar (MAR) Radar System AN/FPS-117 (V)." In reviewing the specification, we attempted to isolate the system's essential performance requirements to answer the following questions:

1. What is the system supposed to do?
2. For each failure reported on the FPS-117, which requirement was not met?

Answering these questions proved to be a difficult task. The requirements section of the specification (3.0) deals with a variety of issues including functionality, quality, environment, and design constraints. These issues are not easily separated, making it difficult to determine answers to our simple questions.

Section 3.0 begins with a general description of the system and the mission the system is to accomplish. This is followed by a set of functional area schematic diagrams of the system. To aid the following discussion, a slightly embellished version of one of these diagrams is included in Figure 9-1.

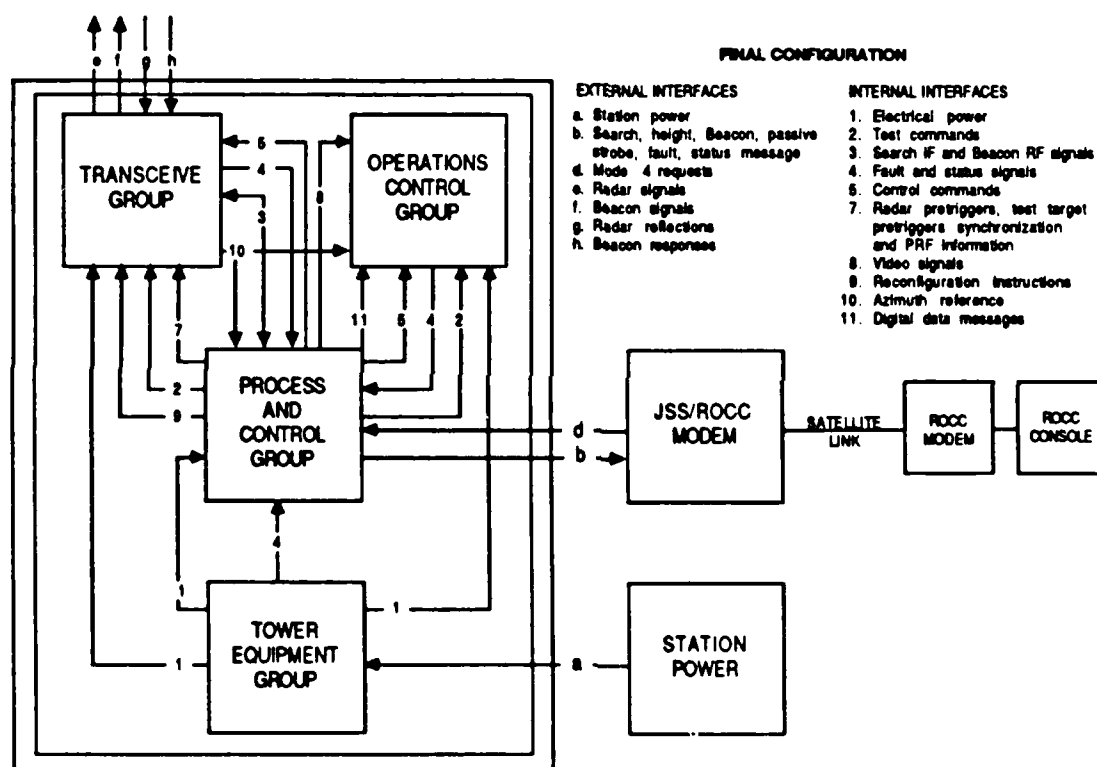


Figure 9-1: Final Configuration

The diagram clearly distinguishes between the product and its environment. Everything inside the double-lined rectangle is part of the product; everything outside the double-lined rectangle is part of the environment. The points at which the product interfaces to its environment are indicated by lines that pass through the walls of the double-lined rectangle. This simple diagram could have been used to aid the following activities.

1. **Definition of functions and characteristics included in the product's essential performance requirements.** The product's essential performance requirements must include a definition of the functions and characteristics of the product at the external interface points. These are clearly marked in the diagram as lines a,b,d,e,f,g, and h. For each interface, it is necessary to describe the functions performed there and other interface characteristics.
2. **Definition of tests and procedures to aid warranty enforcement.** Enforcement of the warranty of a product's essential performance characteristics requires careful attention to the external interfaces. For example, the functions provided by interface b include sending messages to the JSS/ROCC Modem (which in turn relays the messages over satellite link to the ROCC). One of the predominant failures found in the problem reports we reviewed is reported as "no data to ROCC." To determine if the problem is caused by the product, it will be necessary to develop procedures and tests similar to the following:
 - Insure power (interface a) arrives at system properly. Power monitoring equipment could provide a history of power status over a period of time.
 - Test to insure proper operation of ROCC Console.
 - Test to insure proper operation of communications path between ROCC Console and JSS/ROCC Modem.
 - Test to insure proper operation of communications path between JSS/ROCC Modem and Process and Control Group (interface b). Part of this test must be provided by the contractor, since it must execute on the contractor's equipment.
 - External interfaces (e,f,g, and h) should not need to be tested. In this case, however, the specification is inadequate, since it does not specify how the system handles situations of data overload or invalid beacon response messages. Nothing in this area should cause the symptom "no data to ROCC."

Several other points regarding the requirements section of the specification are worth mention.

1. Requirements are not confined to Section 3.0. Requirements are also stated in Sections 10.0 and 30.0. Scattering requirements complicates the task of insuring consistency across requirements.
2. The requirements section (3.0) places heavy emphasis on design constraints, i.e., what is to occur inside the double-lined rectangle, how the product components are to be interfaced, and how the components are to be fabricated. Approximately 45% of the paragraphs in this section describe constraints. This places the government in the business of system design as well as specification, a position of sharing responsibility for the product's design that could complicate warranty enforcement.
3. The maintainability section (3.2.4) provides a definition of Mean Time To Repair (MTTR) requirements. There is a special definition for software

MTTR: "MTTR for software shall include the time required to determine that a fault was caused by software and to return the system to operation." This definition defines recovery, not repair, and is consistent with the definition in Section 30.0. If that is all a warranty covers, it may give the contractor the opportunity to walk away from software defects by simply providing recovery. The remainder of Section 3.2.4 details hardware maintenance procedurally, but says nothing about software maintenance.

4. The reliability/availability/maintainability section (3.7.2.11) for the Process and Control Group, specifies that software will fail only 10 times per million operating hours (about once every 10 years). This is an unattainable goal with today's technology, and is impossible to verify within a warranty period acceptable to contractors. There is no referenced section in the Quality Verification Matrix to indicate how to validate this requirement.
5. The clutter model is specified to the contractor in Section 30.0 of the specifications. This leaves the government completely at risk if the model has errors. Perhaps such models should be given as an example of the clutter model, with the contractor taking the responsibility of ensuring that the model works, or deriving a better model. This will cost more at contract time, but should produce a better final product and place more of the risk on the contractor's shoulders.
6. The specification should also explain what to do if there are more than the maximum number of targets, for example:
 - choose the first hundred
 - choose the hundred most likely to be good targets
 - choose the hundred within a specified and restrictive detection envelope
 - choose a different hundred from the previous scan

9.2. Quality Assurance

The quality assurance program for the FPS-117 system is outlined in Section 4.0 of the FPS-117 specification. The goal of the quality assurance program, as stated in the specification, is to provide a high degree of confidence that the Minimally Attended Radar (MAR) system meets all the requirements of Section 3.0 in its intended operational setting (paraphrased from Paragraph 4.1). The specific quality assurance activities to be performed are outlined in Table III of Section 4.0 of the FPS-117 specification. That table indicates that the activities of inspection, analysis, demonstration, and test will be carried out in three phases:

- **Phase A - Development Test and Evaluation** conducted at a test facility.
- **Phase B - Development Test and Evaluation** conducted at a test range.
- **Phase C - Development Test and Evaluation** conducted at the King Salmon operational site.

Table III identifies specific activities that are to be conducted during each phase. Review of this table indicates the following two key points:

1. **Quality assurance activities are emphasized early in the project.** This is the proper emphasis and is supported by the widely known fact that the sooner problems are detected, the easier and less expensive they are to correct.
2. **Test activity decreases in the final (operational site) phase of the quality assurance program.** Since the goal of the quality assurance program is to provide a high degree of confidence that the system meets its needs in the operational setting, it seems contradictory to limit testing at the operational site. Early testing should not eliminate the need for testing at the later stages of the program. Early testing is aimed at reducing risk and decreasing cost. It should not be used as a replacement for thorough quality assurance activities at the operational site. Errors can be introduced into a product at any stage of development, and there must be a final check on the product.

9.3. System Acceptance and Deployment

As stated in Section 8.10 (page 30) of this report, the warranty period ordinarily should not start until acceptance following the completion of field acceptance tests. Discussions with DoD personnel indicate that a production decision for the SEEK IGLOO FPS-117 units was based on DT&E and IOT&E tests of the first unit at the King Salmon site which has a benign clutter environment. With systems like the FPS-117, we believe decisions based on the operation of one unit at one site is not adequate, and leaves the government in a vulnerable position. Our reasons are listed below.

1. **Radar systems are especially sensitive to the physical environment.** The initially deployed system operated well because of its physical location. Other sites with different terrain and other clutter characteristics uncovered a severe problem in the system's ability to handle clutter.
2. **Large scale systems often have early production problems.** System manufacturing generally involves two of a contractor's organizations: engineering and manufacturing. The first units installed usually receive special attention from the engineering organization. These early units, while not really prototypes, are often tuned and very carefully crafted by design engineers. Later units are produced by the manufacturing organization with decreasing support from engineering. The manufacture of a new product is subject to the same learning curve as other new activities, and there are bound to be problems in units produced while the manufacturing organization is on the early part of the learning curve.

3. **Field tests of each unit allow an extended test period.** Unless all units are installed simultaneously, field tests of each unit provide an extended test period. Quality assurance programs, no matter how well designed, do not find all problems in the product. Problems found in later field acceptance tests must be resolved by the contractor, and the corrections to the problems must be installed in the unit being tested. These same corrections can often be retrofitted into earlier accepted units by means of a warranty clause applicable to the earlier units.

Each SEEK IGLOO FPS-117 production radar was accepted based on in-plant and on-site (i.e., Installation and Checkout) acceptance tests. These acceptance tests included a subset of the DT&E tests. During Installation and Checkout testing of the production radars, excessive false report rates were noted at several sites, and, on some occasions, "not data to ROCC" failures were observed. These performance deficiencies were documented and cited as residual tasks at the time the radars were turned over to Alaskan Air Command. Subsequently, ESD directed the contractor to correct these deficiencies at no cost to the government. A two-facet correction program was initiated by the contractor in the Fall of 1986. The correction program is still in process. Initial results are very good. Availability of a system warranty would have expedited correction of the SEEK IGLOO deficiencies.

9.4. Operation and Maintenance

Operation and maintenance activities play an important role in warranty enforcement. To enforce the warranty, the government may have to demonstrate that the most probable cause of a defect or deficiency is the contractor's failure to meet warranty obligations. This implies that the government must provide evidence that the actions of operations and maintenance personnel most likely did not cause the problem. Our understanding of how the FPS-117 units are operated and maintained suggests the following actions may aid warranty enforcement.

1. **Physical access to the system units should be restricted.** Logs of who had access to the system at what times and what activities were performed should be maintained.
2. **Operational personnel should have limited access to functions and adjustments that affect system performance.** Internal instrumentation and activity logs could help demonstrate what adjustments, if any, were made.
3. **Operational personnel should receive training on how to operate the system.** The training should be conducted or approved by the contractor.
4. **Maintenance of the system should be provided by the contractor if possible.** Maintenance is especially troublesome, and the best way to solve the warranty enforcement problem caused by organic or alternate contractor maintenance is to avoid it, i.e., have the contractor provide the maintenance. If this is not possible, the second best solution is to allow the con-

tractor to provide or supervise maintenance for a period of time that helps insure design problems in the system have been resolved. This solution eases the task of problem isolation and allows government maintenance personnel to come up to speed over time.

5. Maintenance personnel should receive training from or approved by the contractor.
6. Detailed maintenance logs should be maintained.
7. Maintenance should be performed with contractor-approved (or even supplied) spare parts and maintenance procedures.

10. Generic System Warranty Clause

Based on the considerations we have addressed in the foregoing chapters of this report, we have developed the following two-page generic system warranty clause.

A. Definitions.

For purposes of this System Warranty:

1. "System" means the integrated and operational product(s) that is (are) to be delivered by the Contractor under this contract. A "system" includes all of its elements or components, including software.
2. "Defect" means any condition or characteristic of a system that does not conform with the Contractor Warranties of this System Warranty.
3. "Acceptance" means the act of an authorized representative of the Government by which the Government assumes ownership of an existing system tendered as partial or complete performance of this contract (e.g., by execution of DD Form 250 by an authorized representative of the Government).

B. Statement of the Warranties.

The Contractor warrants as follows:

1. Materials and Workmanship. Each system delivered under this contract will conform to all requirements of materials and workmanship specified in this contract.
2. Design and Manufacture. Each system delivered under this contract will conform to all design and manufacturing requirements specified in this contract. For purposes of this warranty, "design and manufacturing requirements" includes the meaning stated in DFAR Section 246.770-1, and also includes software design specifications, including software configuration.
3. Essential Performance. Regardless of Government initiation of or participation in developing system design or specifications, each system delivered under this contract will conform to the Essential Performance Requirements set forth in Paragraph ____ of this contract, as those Essential Performance Requirements measured, tested, and verified by the tests and procedures set forth in Paragraph ____ of this contract.

C. Notification Requirement.

1. Within ____ days of the date on which the Contractor first discovers that a defect(s) may exist in a system(s) delivered under this contract, the Contractor shall notify the Contracting Officer of such possible defect(s), in writing, unless the Contracting Officer has first notified the Contractor, in writing, of the same defect(s).
2. Within ____ days of the date on which the Government discovers that a defect(s) may exist in any system(s) accepted by the Government under this contract, the Contracting Officer shall notify the Contractor of such

possible defect(s), in writing, unless the Contractor has first notified the Contracting Officer, in writing, of the same defect(s).

D. Duration of the Warranty.

For each system delivered under this contract, the Contractor Warranties stated in Paragraph B. above shall extend to all defects discovered within ____ months from the date of acceptance of the system by the government.

E. Government Remedies for Breach.

1. The rights and remedies of the Government under this System Warranty (a) are in addition to any rights and remedies of the Government under any other provision of this contract, including, but not limited to, the Government's rights in relation to latent defects, fraud, or gross mistakes that amount to fraud; and (b) shall apply notwithstanding inspection, acceptance, or any other clauses or terms of this contract.
2. In the event of any defect as defined herein with respect to a system delivered under this contract, the Government in its sole discretion may, (a) require the contractor to take such action as may be necessary to eliminate the defect, at no additional cost to the Government for materials, labor, transportation, or otherwise, (b) require the contractor to supply, at no additional cost to the Government, all materials and instructions necessary for the Government to eliminate the defect and to pay any costs reasonably incurred by the Government in taking such action as may be necessary to eliminate the defect, or (c) equitably reduce the contract price.
3. The Government may elect the remedies provided in Paragraph E.2.(a) or (b) above notwithstanding any dispute respecting the existence of or responsibility for any alleged defect as defined herein with respect to any system delivered under this contract; provided that the Contractor will not be required to pay costs incurred by the Government under Paragraph E.2.(b) until final determination of the existence of the defect. In the event that the alleged defect is subsequently determined not to be a defect subject to this warranty but the Contractor has incurred costs under Paragraph E.2.(a) or (b) as required by the Government by virtue of this Paragraph E.3., the contract price under this contract shall be equitably adjusted.
4. Election by the Government of the remedy provided under Paragraph E.2.(a) or (b) above shall not preclude subsequent election of a different remedy under Paragraph E.2. If the defect is not successfully eliminated under the prior election within ____ days of notification under Paragraph C. above.

F. Limitations and Exclusions from Warranty Coverage.

1. All implied warranties of merchantability and fitness for a particular purpose are excluded from this contract.
2. This System Warranty shall not apply to alleged defects that the Contractor demonstrates to be in or otherwise attributable to Government-furnished property as determined, tested, and verified by the tests and procedures set forth in Paragraph ____ of this contract. Notwithstanding this

Paragraph F.2., a defect is not attributable to Government-furnished property if it is the result of installation or modification of Government-furnished property by the Contractor or of the integration of Government-furnished property into any system delivered under this contract if the installation, modification or integration of the Government-furnished property voids or renders unenforceable any warranties otherwise applicable to the Government-furnished property.

3. In any dispute respecting the application of Paragraph F.2. or any other claim by the Contractor that a defect existing in any system delivered under this contract is due to a cause for which the Government is responsible or which is otherwise beyond the control of the Contractor, the Contractor shall bear the burden of demonstrating that the alleged defect is not within the coverage of this system.

G. Markings.

All systems delivered under this contract will be marked with, or the operating and/or maintenance manuals or instructions accompanying such systems will prominently include, notice of the existence of this warranty, its substance, its duration, and instructions to notify the Contracting Officer promptly if the system is found to be defective.

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11. Commentary on the Generic System Warranty Clause

In this chapter, we explain the particular provisions of the generic system warranty clause we have drafted. Our procedure is to set forth the text of each paragraph of the clause, and then to follow the text with our commentary.

11.1. Definitions

A. Definitions. For purposes of this System Warranty:

- 1. "System" means the integrated and operational product(s) that is (are) to be delivered by the Contractor under this contract. A "system" includes all of its elements or components, including software.**
- 2. "Defect" means any condition or characteristic of a system that does not conform with the Contractor Warranties of this System Warranty.**
- 3. "Acceptance" means the act of an authorized representative of the Government by which the Government assumes ownership of an existing system tendered as partial or complete performance of this contract (e.g., by execution of DD Form 250 by an authorized representative of the Government).**

The definitions provisions, nearly universally included in more recent warranty clauses, and particularly those under WSWA, help identify the nature of the item or items warranted, the extent of the contractor's warranty, and the scope and duration of the warranty, all as directed by FAR Section 46.706(a).

11.1.1. System.

Most clauses identify the subject of a warranty as "supplies" (or "services" where appropriate), but we have chosen to make the subject of the warranty a "system" to clearly establish that the contractor is warranting an integrated and operational whole, not just the discrete characteristics or operations of individual pieces of the system. In individual applications it may be desirable to more specifically identify the particular system being warranted. If software coverage is intended, the clause should clearly include software as a warranted element of the system since software is often excluded from warranty coverage.

11.1.2. Defect.

A "defect" is most commonly defined in existing warranties in terms of any deviation from contractual requirements. That definition is too broad for purposes of warranty coverage under WSWA, which mandates warranties of *essential* performance requirements only, 10 U.S.C. Section 2403(b)(3), leaving outside the warranty those contractually specified "operating capabilities or maintenance and reliability characteristics of the system" that are not "necessary for the system to fulfill the military requirement for which the system is designed." *Id.* Section 2403(a)(4).⁸ It is possible, of course, that in a given procurement all performance requirements might be "essential." That is probably not the usual case, however, particularly since the cost and administrative difficulty of a warranty will likely increase in relation to the scope of warranty coverage. Thus a defect for our purposes should be defined in terms of deviations from the contractor's *warranted* undertaking, not from any and all contractual requirements. Such a definition both limits the warranty and, when essential performance requirements are warranted, makes clear that any deviation from those performance requirements comes within the definition of a "defect" for which the contractor is liable under the warranty.

The definition does not distinguish between latent defects and patent defects for the reason that there is no difference between the two for purposes of warranty protection. Latent and patent defects must be distinguished for purposes of acceptance, but not for warranty — at least where the warranty clause is properly drafted. Thus, acceptance is ordinarily conclusive as to patent defects — defects that are discoverable by ordinary or reasonable inspection or testing — and absent warranty protection the government generally has no post-acceptance remedy for such defects. See, *e.g.*, *California Power Systems, Inc.*, GSBCA No. 7462, 86-1 BCA Paragraph 18,598 (1985); *Harold Bailey Painting Co.*, ASBCA No. 28,443, 84-1 BCA Paragraph 17,043 (1983); *Solid State Electronics Corp.*, ASBCA No. 23041, 80-2 BCA Paragraph 14,702 (1980). Where, as in this generic clause, however, the warranty clause is drafted to apply notwithstanding previous inspection or acceptance, see Paragraph E.1.(b), then the warranty survives acceptance and applies even to patent defects discovered within the warranty period. See, *e.g.*, *Standard Blackboard and School Supply Co.*, GSBCA No. 7403 and 7255, 86-1 BCA Paragraph 18,712 (1985); *Z.A.N. Co.*, ASBCA No. 75488, 86-1 BCA Paragraph 18,612 (1985).⁹ In such cases, the warranty is generally the only post-acceptance remedy available for patent defects. Where, on the other hand, defects are latent — that is, not discoverable by ordinary or reasonable inspection or testing at the time of acceptance — the government can usually require repair or replacement of the defective product even after acceptance with or without a separate warranty. *Coral Petroleum, Inc.*, ASBCA No. 27,888, 86-1 BCA Paragraph 18,533 (1985); *Teller Environmental Systems, Inc.*, ASBCA No. 25,550, 85-2 BCA Paragraph 18,025 (1985); *American Trans-*

Coll Corp., ASBCA No. 27037, 85-1 BCA Paragraph 17,864 (1985). In such cases of latent defects, the warranty is simply an alternative remedy to remedies otherwise already available. See Paragraph E.1.(a).

11.1.3. Acceptance.

Acceptance is the event that in most cases will trigger the period of warranty coverage. Up to that point, the government's right to require correction of any identified deviations from contractual requirements are independent of the warranty. The definition of acceptance here expands on, but is consistent with, FAR Section 46.101.

11.2. Statement of the Warranties

B. Contractor Warranty. The Contractor warrants as follows:

- 1. Material and Workmanship.** Each system delivered under this contract will conform to all requirements of materials and workmanship specified in this contract.
- 2. Design and Manufacture.** Each system delivered under this contract will conform to all design and manufacturing requirements specified in this contract. For purposes of this warranty, "design and manufacturing requirements" includes the meaning stated in DFAR Section 246.770-1, and also includes software design specifications, including software configurations.
- 3. Essential Performance.** Regardless of Government Initiation of or participation in developing system design or specifications, each system delivered under this contract will conform to the Essential Performance Requirements set forth in Paragraph ____ of this contract, as those Essential Performance Requirements measured, tested, and verified by the tests and procedures set forth in Paragraph ____ of this contract.

11.2.1. General Background.

Paragraph B states the characteristics of the system that the contractor warrants and further defines the extent of the warranty, consistent with the instructions of FAR Section 46.706(a)(1) & (2). The three elements of the generic warranty — (1) materials and workmanship, (2) design and manufacture, and (3) essential performance, — are those generally required by WSWA. 10 U.S.C. Section 2403(b)(1)-(3). Warranties of materials and workmanship have long been included in government contracts. WSWA's warranty of conformity with design and manufacture requirements is fundamentally a traditional "build to print" warranty. DFAR Section 246.770-1, cross-referenced in Paragraph B.2. of the generic clause, defines "design and manufacturing requirements" as "structural and engineering plans and manufacturing particulars, including precise measurements, tolerances, materials and finished product tests for the weapon system being produced."

In view of the software-oriented nature of our task, we have expanded the definition of design and manufacture requirements to include software requirements, including software configuration specifications. For example, the contract might specify that each computer program must consist of less than 100 lines of source statements, excluding comments. Under the generic clause as drafted here, the contracts would warrant production conformity with that specification just as with the hardware specifications to which "design and manufacture" requirements commonly apply. This expanded warranty coverage is consistent with WSWA's directive that "[n]othing in this section prohibits the head of the agency concerned from . . . using written guarantees to a greater extent than required by this section, including guarantees that exceed those" strictly specified in the Act.

11.2.2. The Warranty of Essential Performance Requirements.

Paragraph B.3., Essential Performance, is the heart of the warranty as far as software and system performance is concerned. As noted in Chapter 5, the object here is to define essential performance requirements in terms of objective and carefully defined essential operating, maintenance, and reliability characteristics, see FAR Section 246.770-1, that can be measured and verified by means of tests and procedures to which the contractor has agreed in the contract. Under this approach, if the system fails the tests that define conformity with the contract's essential performance requirements, then the system is defective. Much of the enforcement problem in previous performance warranties has been a failure to articulate standards against which system performance can be measured, for it is nearly impossible to prove a breach of standards or requirements that are not defined or measurable. Drafting performance requirements is a technical, not a legal, exercise and can only be performed in the context of individual systems. The generic clause thus cross-references to the contract's essential performance requirements and to the means to be used in establishing conformity with those requirements.

11.2.3. The Effect of Government Participation in System Design.

In view of a general reluctance to make contractors responsible for failures due to faulty government design, *cf.*, *e.g.*, *S&E Contractors, Inc.*, ASBCA 11044, 61-1 BCA Paragraph 6175 (1967); *R.H. Fulton, Contractor*, IBCA 769-3-69, 71-1 BCA Paragraph 8674 (1971), Paragraph B.3. of the generic clause also makes explicit that the system performance warranty applies despite government initiation of or participation in system design. In the ordinary course, "[i]f the Government specifies the design of the end item . . . the contractor's obligations for correction of defects shall usually be limited to defects in material and workmanship or failure to conform to specifications." FAR Section 46.706(b)(1)(ii). The point of a performance warranty as mandated by WSWA, however,

is to force the contractor to assume responsibility for determining whether the design of the system — whether initially developed by the contractor or the government — will result in a product that can satisfy the contract's essential performance requirements. The contractor, in other words, assumes a responsibility for proposing alternate designs if the existing design will not work.

Thus, the mere fact that the government is a player in system design should not invalidate the performance warranty. Even so, WSWA's legislative history and the DFAR provisions implementing WSWA both recognize that there may come a point where the government so dictates the system design that it would be inequitable to obligate the contractor to warrant system performance, or at least to warrant those aspects of system performance directly affected by the government's design.¹⁰

Design specifications, of course, may change during the period of contract performance. Indeed, WSWA's approach to essential performance warranties encourages such changes, if necessary, in order to make the warranted system capable of achieving its essential performance requirements. Design changes that do not, or do not necessarily, adversely affect the capabilities of the system should have no effect on the essential performance warranty (although, of course, they would change the specifications to which the system must conform under the design and manufacture warranty).¹¹

11.2.4. A Possible Warranty Exception for Initial Production.

The essential performance warranty of Paragraph B.3. as drafted applies by its terms to every system delivered under the contract. WSWA, however, would routinely require an essential performance warranty only for weapons systems "in mature full scale production." 10 U.S.C. Section 2403(f). Weapons systems are "in mature full scale production" under WSWA "after the manufacture of the first one-tenth of the eventual total production or the initial production quantity of such system, whichever is less." *Id.* Section 2403(a)(6). This WSWA limitation to systems in mature full scale production was intended to provide contractors and the government with the opportunity, in light of actual experience, to make any necessary modifications to system design or other contractual requirements before the contractor's warranty obligations attached. It was hoped that by exempting initial production from warranty coverage, the warranty would be less costly and would avoid negotiated downgrades of performance requirements. See generally, S. Rep. No. 98-500, *supra*, 248-49.

We did not limit the generic clause to mature full-scale production because it seemed to us that such a limitation might be undesirable where only a few systems are being produced under a contract, as, for example, under the North Warning procurement. Indeed, because the various North Warning installations all must work as part of a larger system,

It may be that in such cases the single larger system, not each individual unit of the larger system, may be the subject of the warranty. Even if "system" were not defined so expansively, it may be that such necessary system integration itself provides a reason for warranting every unit without excluding initial production.¹²

11.3. Notification Requirement

C. Notification.

1. Within ____ days of the date on which the Contractor first discovers that a defect(s) may exist in a system(s) delivered under this contract, the Contractor shall notify the Contracting Officer of such possible defect(s), in writing, unless the Contracting Officer has first notified the Contractor, in writing, of the same defect(s).
2. Within ____ days of the date on which the Government discovers that a defect(s) may exist in any system(s) accepted by the Government under this contract, the Contracting Officer shall notify the Contractor of such possible defect(s), in writing, unless the Contractor has first notified the Contracting Officer, in writing, of the same defect(s).

11.3.1. The Purpose of Notification.

FAR Section 46.4706(b)(4) requires that a notice period be established for notification to the contractor of discovery of a defect. The notice period is to be "reasonable" considering the time necessary for the government to discover the defects, the time reasonably required for the government to take necessary administrative steps and make a timely report of discovery of the defects, and the time required to discover and report any defective replacements. Those factors will vary from system to system and so will require tailoring the clause for each procurement. The objective in any case is to make sure that the government has adequate time to give notice. Further, it seems sensible to add a reciprocal obligation of the contractor to notify the government of any defects it may discover after delivery. The contractor should not be permitted to remain silent about known defects in an attempt to avoid its warranty obligations.

11.3.2. The Need for Case by Case Tailoring.

Individual systems may make desirable further tailoring of the notification provision to provide detail respecting such matters as the content of the notification, contractor response obligations, or contractor investigation obligations. For example, in some circumstances it may be desirable, before triggering repair or replacement obligations, to provide (1) that the government will provide a description of the defect or its effects, (2) that the contractor will then investigate the defect and provide a written response to the notification proposing a course of action, and (3) that the government may then elect a remedy following the contractor's response. In some circumstances it may be desirable

also to include a second more immediate notification obligation of the contractor where the defect discovered — or perhaps even only reasonably suspected — by the contractor is such as would endanger person or property, including defects that could cause damage to the system if unremedied.

11.4. Duration of the Warranty

D. Duration.

For such system delivered under this contract, the Contractor Warranties stated in Paragraph B. above shall extend to all defects discovered within ____ months from the date of acceptance of the system by the government.

FAR Section 46.706(b)(3) requires that the duration or time period of the warranty be clearly specified in the warranty. The regulations further provide that the warranty period for patent defects should not extend beyond a reasonable time after acceptance, and that the warranty period should be set in view of such factors as the estimated useful life of the item, the nature of the item, and trade practice. These factors all require individually tailored warranty periods. Individual circumstances also may make it sensible to apply different warranty periods to each of the three different WSWA warranties, or to extend the warranty period if full field testing of the system cannot be completed before acceptance. The government might also consider in individual cases restarting, or providing for an extension of, the warranty after repair or replacement of the defective system. Such extensions of the warranty period might be especially appropriate where software repairs result in software enhancements. See Section 8.8, (page 30). In such cases a "new" system has been provided, and the considerations that led to requiring a warranty in the first place are at least in some measure reimplicated when system enhancements are added.

11.5. Government Remedies for Breach

E. Remedies.

1. The rights and remedies of the Government under this System Warranty (a) are in addition to any rights and remedies of the Government under any other provision of this contract, including, but not limited to, the Government's rights in relation to latent defects, fraud, or gross mistakes that amount to fraud; and (b) shall apply notwithstanding inspection, acceptance, or any other clauses or terms of this contract.
2. In the event of any defect as defined herein with respect to a system delivered under this contract, the Government in its sole discretion

sary to eliminate the defect, at no additional cost to the Government for materials, labor, transportation, or otherwise, (b) require the contractor to supply, at no additional cost to the Government, all materials and instructions necessary for the Government to eliminate the defect and to pay any costs reasonably incurred by the Government in taking such action as may be necessary to eliminate the defect, or (c) equitably reduce the contract price.

3. The Government may elect the remedies provided in Paragraph E.2.(a) or (b) above notwithstanding any dispute respecting the existence of or responsibility for any alleged defect as defined herein with respect to any system delivered under this contract; *provided that* the Contractor will not be required to pay costs incurred by the Government under Paragraph E.2.(b) until final determination of the existence of the defect. In the event that the alleged defect is subsequently determined not to be a defect subject to this warranty but the Contractor has incurred costs under Paragraph E.2.(a) or (b) as required by the Government by virtue of this Paragraph E.3., the contract price under this contract shall be equitably adjusted.
4. Election by the Government of the remedy provided under Paragraph E.2.(a) or (b) above shall not preclude subsequent election of a different remedy under Paragraph E.2. If the defect is not successfully eliminated under the prior election within ____ days of notification under Paragraph C. above.

11.5.1. General Regulatory Background.

FAR Section 46.706(c)(2) & (3) requires that a warranty clause state the contractor's obligations to the government for breach of warranty and the specific remedies available to the government for breach. Paragraph E of the generic system warranty is designed to conform to that requirement. Much of Paragraph E.1. and 2. is routinely grounded in existing statutory and regulatory requirements.

Paragraph E.1. complies with the requirements of FAR Section 46.705(b) & (c),¹³ which, broadly stated, are intended to assure that the government's warranty protections are in addition to, and not instead of, any other rights the government has under its contracts. Paragraph E.2. cumulates the various remedies established under FAR Section 46.706(b)(2). It is drafted to assure that the remedies provided will be without cost (additional to the cost of including the warranty in the first place) to the government. WSWA by its terms provides only for the remedies provided in E.2.(a) & (b), but the implementing regulations provide for the equitable adjustment remedy provided in E.2.(c) as well.¹⁴

11.5.2. Government Remedies In the Event of Disputed Defects.

Paragraph E.3. permits the government to require the contractor to eliminate defects in advance of final determination of contractor liability under the warranty if there is a dispute with respect to the existence of or responsibility for a defect. The government may also take action to eliminate the defects itself before final resolution of such a dispute, and, pursuant to Paragraph E.2.(b), may require the contractor to supply materials and instructions. Such protections seem appropriate in the context of critical defense systems, and are wholly consistent with ordinary disputes procedures where continued contractor performance is required notwithstanding the existence of a dispute. The contractor is entitled to an equitable adjustment if the contractor incurs costs for which it is finally determined that the contractor was not liable under the terms of the warranty.

11.5.3. Alternate Remedies In the Event of Incurable Defects.

There may be occasions when neither the contractor nor the government are able to remedy a discovered defect. Paragraph E.4. permits the government, within a period of time to be fixed in the context of particular systems and procurements, to elect a different remedy if its initial election proves unsatisfactory. This paragraph does not require the government to elect an alternate remedy upon expiration of the stated time, but allows the government to do so at its option any time thereafter.

11.6. Limitations of and Exclusions from Warranty Coverage

F. *Limitations and Exclusions.*

1. All implied warranties of merchantability and fitness for a particular purpose are excluded from this contract.
2. This System Warranty shall not apply to alleged defects that the Contractor demonstrates to be in or otherwise attributable to Government-furnished property as determined, tested, and verified by the tests and procedures set forth in Paragraph ____ of this contract. Notwithstanding this Paragraph F.2., a defect is not attributable to Government-furnished property if it is the result of installation or modification of Government-furnished property by the Contractor or of the integration of Government-furnished property into any system delivered under this contract if the installation, modification or integration of the Government-furnished property voids or renders unenforceable any warranties otherwise applicable to the Government-furnished property.
3. In any dispute respecting the application of Paragraph F.2. or any other claim by the Contractor that a defect existing in any system delivered under this contract is due to a cause for which the Government is responsible or which is otherwise beyond the control of the Contractor, the Contractor shall bear the burden of demonstrating that the alleged defect is not within the coverage of this system warranty.

11.6.1. The Purpose and Scope of Possible Limitations and Exclusions.

Paragraph F.1., which excludes implied warranties of merchantability and fitness for a particular purpose, conforms with the requirements of FAR Section 46.706(b)(1)(iii). Other limitations or exclusions might be appropriate or necessary in specific situations in order to obtain reasonably priced warranty coverage. WSWA, 10 U.S.C. Section 2403(g)(1), provides that nothing in WSWA prohibits the head of a procuring agency from "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." DFAR Section 246.770-3 amplifies this authorization by providing that "Contracting officers may exclude from the terms of the warranty certain defects for specified supplies (exclusions) and may limit the contractor's liability under the terms of the warranty (limitations), as appropriate, if necessary to derive a cost-effective warranty in light of the technical risk, contractor financial risk or other program uncertainties." Thus, in order to obtain cost effective warranties, the warranty might exclude such things as defects arising out of normal wear and tear, combat, or misuse or improper maintenance by the government.¹⁵ It also might exclude liability for consequential damages, damage to property, or loss, damage, or injury to third parties, or might limit the contractor's liability to a fixed "cap," set either in terms of an absolute dollar amount or a percentage of the contract price.

11.6.2. Exclusion of Government-Furnished Equipment.

Paragraphs F.2. and F.3. are, with the exception of Paragraph B.3. which relies for its effectiveness on carefully crafted essential performance requirements and verification procedures, probably the most problematic paragraphs of the warranty clause. WSWA directly prohibits requiring warranties 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." 10 U.S.C. Section 2403(c). This exclusion, however, is not absolute. The warranty may require 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." *Id.* Section 2403(g)(2). Moreover, DFAR Section 246.770.5 provides that contractors may be required to warrant defects in installation or any modifications made to the property by the prime contractor. Paragraph F.2. is designed to make the exclusion for government-furnished equipment (GFE) as narrow as possible consistent with these statutory and regulatory authorities.

11.6.3. The Government's Burden of Proof.

As we explained in Section 4.1.2 (page 11), the problem with even a narrow exclusion is that in most cases taken before boards of contract appeals the rule applied has been that as part of its burden of proof the government must prove, not only the existence of a defect, but also that the defect is the contractor's responsibility within the terms of the warranty — which can involve proving that the alleged defect was not attributable to any cause for which the government is responsible. Consistent with the considerations addressed in Section 4.1.2, the GFE exclusion in the generic clause has been drafted in such a way as to maximize the government's chances of shifting to the contractor the burden of proof with respect to GFE defects, and minimizing the government's burden if the burden cannot be shifted. This has been done by (1) setting the exclusion in a separate clause, and not as an exception made part of the Paragraph B.3. contractor warranty of essential performance; (2) phrasing the exception in terms of contractor demonstration of GFE fault; (4) explicitly providing that the contractor bears the burden of proof; and (5) drafting the exclusion in terms of tests and procedures that demonstrate the responsibility or nonresponsibility of GFE for the system defect.

11.7. Markings

G. *Markings.*

All systems delivered under this contract will be marked with, or the operating and/or maintenance manuals or instructions accompanying such systems will prominently include, notice of the existence of this warranty, its substance, its duration, and instructions to notify the Contracting Officer promptly if the system is found to be defective.

This paragraph is intended to conform with the requirements of FAR Section 46.706(b)(5). Where large or unattended systems are involved, a marking on the system itself may not be effective as notice to the user of the existence of the warranty and of the need to act in compliance with that warranty to protect the government's rights. Notice to the user by other means, such as through operating or maintenance manuals, may be more effective.

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12. Conclusions

Our investigation of the motivation behind the request for a software warranty clause indicated that a software warranty clause alone would not solve the basic problems that led to the task in the first place. The Software Engineering Institute discovered that the enforcement problem was not so much associated with the legal framework of the various warranty clauses, but with the lack of meaningful specifications and tests designed to demonstrate system defects that trigger warranty coverage of the system as a whole. The scope of the task was therefore broadened to address technical and administrative issues associated with the application and enforcement of an inclusive system warranty that covers software as part of the warranted system.

Our approach to relieving the problems of system failure, described in the body of this report, is to write a more enforceable warranty clause and to describe legal, technical, and administrative issues that support warranty enforcement. The objective is to ease the government's burden of proving the existence of a defect for which the warranty clause provides a remedy. The key to satisfying that objective is to develop technical tests and specifications that provide objective and demonstrable standards against which a claim for breach of warranty can be measured.

Our specific recommendations are summarized below.

1. To ease the burden the government bears to prove a breach of warranty, the generic warranty should cover the failure of a delivered system as a whole, including, but not limited to, its software, to satisfy clear and measurable essential performance requirements for the system. Essential performance requirements must be based on a clear distinction between the warranted product and other components in the environment.
2. Conditions for establishing breach of warranty should be described in terms of analysis of recorded symptoms and diagnostic results. The test methods to determine breach should be described in the specifications.
3. Through careful drafting and aggressive litigation techniques, the government has a good chance of changing the currently accepted legal standard, and of shifting to the contractor the burden of proving that system defects are attributable to government-furnished equipment. Even if the burden cannot be shifted, however, the government's burden of proof can be minimized by developing tests and procedures that will isolate defects in government-furnished equipment.
4. To provide maximum applicability and enforceability, the generic clause should be modeled after the Weapon Systems Warranty Act, and must be carefully tailored on a case by case basis.
5. Government procurement practices contribute substantially to existing problems. If it is to reap the benefit of improved legal and technical warranty considerations, the government must improve such practices.

6. The quality of the product is heavily dependent on the specifications describing the product and the clear description of the critical functions to be performed. The success of a product and the applicability of a warranty depend on a well crafted specification.
7. Warranties are not costless, and contractors can be expected to price warranties even higher as their exposure to warranty liability increases through increased warranty scope, remedies, and enforceability. There are remedies other than warranties which also would improve the deployed products, so, in each individual case, the costs and benefits of the warranty must be balanced against the costs and benefits of other applicable remedies.

Appendix I. Pertinent Abbreviations and Acronyms

AFSC	Air Force Systems Command
ASBCA	Armed Services Board of Contract Appeals
BCA	Board of Contract Appeals
DFAR	Defense Federal Acquisition Regulations Supplements
DoD	Department of Defense
DoT	Department of Transportation
ESD	Electronic Systems Division
FAR	Federal Acquisition Regulations
FAT	Factory Acceptance Test
FIAT	Field Acceptance Test
GFE	government-furnished equipment
GSBCA	Government Services Board of Contract Appeals
HUD	Office of Housing and Urban Development
IBCA	Interior Board of Contract Appeals
JSS	Joint Surveillance System
MAR	Minimally Attended Radar
MCCR	mission critical computer resource
MTBF	Mean Time Between Failures
MTTR	Mean Time To Repair
QA	Quality Assurance
ROCC	Regional Operations Control Center
SEI	Software Engineering Institute
SPO	Systems Program Office
VACAB	Veterans Administration Contract Appeals Board
WSWA	Weapon Systems Warranty Act

Appendix II. Applicability of the Weapon Systems Warranty Act

We read the Weapon Systems Warranty Act (WSWA) to have broad, though certainly not universal, application to military acquisition programs, including those of the Department of Defense. WSWA by its terms applies to all "weapon systems," which are defined broadly in the Act as "items that can be used directly by the armed forces to carry out combat missions." Radar systems for which the DoD is responsible, for example — even though such systems might not be thought of as "weapons" in common usage — would seem to fit within this definition since they are plainly intended to be used directly by the armed services in carrying out combat missions. The DFAR provisions implementing WSWA appear to take such a view: They specifically include "military surveillance, command, control, and communication systems" within the regulatory definition of "weapon systems." DFAR Section 246.770-1.

An expansive definition of "weapon systems" plainly conforms to the congressional intent. WSWA was enacted as a modification of an earlier weapon systems warranty statute, Section 794 of Public Law 98-212, which applied strictly to "weapon systems" without any explicit definition of that term. S.2723, the Senate bill that became WSWA, expanded the application of weapon systems warranties to weapon systems "and other defense equipment." The Senate Report accompanying that bill explained that this modification was "intended to enlarge the types of equipment covered by warranties as compared with Section 794." S. Rep. No. 98-500, 98th Cong., 2d Sess. 243 (1984). Although the added phrase "and other defense equipment" was eliminated from WSWA in conference, the Conference Report made clear that although "the use of the term 'other defense equipment' was deleted" from the Senate bill, "the definition of covered items was not changed." H. Conf. Rep. No. 98-1080, 98th Cong., 2d Sess. 323 (1984).

Thus, it would appear that "weapon system" should be broadly construed. Consistent with this view, AFSC FAR Supplement (C2), Paragraph 46.770-2, Policy (90), for example, seems effectively to establish a presumption of WSWA applicability by requiring formal approval of any determination that a system is not a weapon system. ("Determination of a Weapon System. The determination that an item is not a weapon system, as defined in DFARS 46.770-1, Definitions, shall be approved by the Vice Commander of the Product Division for major weapon systems and by the Director of Contracting for 'other' systems. The approved determination shall be made part of the contract file.")

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Notes

¹There are some cases that at least lean the other way, and would appear to favor putting the burden of proving an exclusion from warranty coverage on the contractor. *E.g.*, *Westinghouse Electric Corp.*, IBCA No. 182, 60-1 BCA Paragraph 2550 (1960). There are still other cases that seem unable to make up their mind, and say both (1) that the government bears the burden of proving that the most likely cause of the defects was inadequate contractor performance, and (2) that if the contractor contends that the defects are due to government fault, then the contractor bears the burden of proving that assertion. See, *e.g.*, *Great Valley Construction Co.*, ASBCA No. 24449, 81-2 BCA Paragraph 15,308 (1981); *George E. Jensen Contractor, Inc.*, ASBCA No. 23284, 81-2 BCA Paragraph 15,207 (1981). But the prevailing view plainly is that the government must prove contractor responsibility for the defect(s). See FAR Section 46.703(c).

²Effective identification of GFE as the cause of a defect, of course, would in turn also enable the government to carry its burden of proof in a separate warranty action against the supplier of the equipment to the government under that supplier's warranty, which would be independent of the system warranty.

³The basis for our broad reading of WSWA is explained in Appendix II, *Applicability of the Weapon Systems Warranty Act*.

⁴Indeed, it is apparent that Congress intended WSWA to provide warranty guidance for procurements that might be beyond the strict terms of the statute:

"The omission of certain systems from the statutory provision, or certain limitations on the warranties referred to in the statute, is in no way intended to evidence any congressional preference for the warranty described in the statute rather than a more demanding warranty. The committee believes that the statutory requirement should set forth a minimum standard." S. Rep. No. 98-500, 98th Cong., 2d Sess. 244 (1984).

⁵See H. Conf. Rep. No. 98-1080, *supra*, 323-24 (1984). Congress there condemned a mechanical approach to warranties as had been pursued under WSWA's predecessor warranty act, Section 794 of Public Law 98-212 (see Appendix II).

"Specifically, the Congress anticipated that weapon systems warranties would be negotiated on a case-by-case basis. Each warranty situation is unique. Different approaches will be required depending upon whether a system is expendable (such as a missile) or nonexpendable; what the logistical support capabilities of both the government and the contractor are; the extent to which the contractor has designed the system; and numerous other factors.

"It has come to the attention of the conferees that the general approach of the military departments with regard to Section 794 has been to specify a warranty

clause and to require that this be utilized with no adjustment in its terms. The warranty law, in the view of the conferees, was never intended to create this type of simplistic, mechanistic approach to defense contracting."

⁶DFAR Section 246.770-3:

"As the objectives and circumstances vary considerably among weapon system acquisition programs, Contracting Officers shall appropriately tailor the required warranties on a case by case basis, including remedies, exclusions, limitations and duration. . . ."

⁷Koss, E. Developing Reliable Space Flight Software. *Proceedings: Annual Reliability and Maintainability Symposium*, 1986.

⁸S. Rep. No. 98-500, 98th Sess., 2d Sess. 244 (1984) made clear that the limitation to essential performance requirements was intended "to clarify that DOD may designate certain types of performance characteristics as nonessential, or as goals or objectives, and remove such characteristics from the statutory requirements."

⁹If, however, the warranty clause fails explicitly to provide that the warranty survives acceptance, then the warranty will not apply to patent defects discovered after acceptance. See, e.g., *Bergen Expo. Systems, Inc.*, IBCA No. 1348-4-80, 82-2 BCA Paragraph 16,010 (1982); *Instruments for Industry, Inc. v. United States*, 496 F.2d 1157 (2d Cir. 1974).

¹⁰See, e.g., S. Rep. 98-500, *supra*, 242 (1984). The Conference Report states:

"[T]he conferees discussed at length the concern that under . . . the language in the Senate bill, contractors which may have had limited responsibility in the design of a weapon system would nevertheless be called upon to guarantee the performance of that system. The House conferees believed that performance guarantees are appropriate only where a contractor had substantial design responsibility. Though this change in the statute was not agreed upon, the conferees did agree that the department should have the authority in crafting specific warranties to consider the formulation of exclusions or limitations to address situations where a contractor has not designed a system. In such situations, the conferees believe that the department could, consistent with the intent of the statute, narrow the scope of the warranty if it would be inequitable to require a warranty of all essential performance requirements because of a lack of contractor design involvement." H. Conf. Rep. No. 98-1080, *supra*, 324.

DFAR Section 246.770-3 similarly provides, among other things, that contracting officers "may narrow the scope of a warranty where such is appropriate (e.g., where it would be inequitable to require a warranty of all essential performance requirements because a contractor had not designed the system)."

¹¹On the other hand, Congress plainly is of the view that the government could not properly require a design change that made compliance with essential performance requirements impossible without adjusting the warranted performance requirements. Thus, the Conference Report accompanying WSWA provides:

"[T]here is some concern about the appropriate manner of dealing with contractual changes after contract execution. It is the understanding of the conferees that if the United States takes any actions which affect the contractor's ability to comply with the terms and conditions of the contract, the contractor is entitled to an equitable adjustment of such terms and conditions to account for such act. For example, if the government would direct a change that affected the performance of a system, the conferees believe it would be necessary for the government to grant an equitable adjustment to the extent appropriate in the terms of any performance guarantee in the contract to recognize the effect of such change."

H. Conf. Rep. No. 98-1080, *supra*, at 324. The negative implication of this congressional instruction, of course, is that design changes that do not affect essential system performance do not invalidate performance warranty.

¹²The statute provides authority for warranting all systems in such circumstances. 10 U.S.C. Section 2403(f) ("nothing in this section prohibits the head of the agency concerned from negotiating a guarantee [of essential performance requirements] for a weapon system not yet in mature full-scale production").

¹³FAR Section 46.705(b) & (c) provide as follows:

"(b) Warranty clauses shall not limit the Government's rights under an inspection clause . . . in relation to latent defects, fraud, or gross mistakes that amount to fraud.

"(c) Except for warranty clauses in construction contracts, warranty clauses shall provide that the warranty applies notwithstanding inspection and acceptance or other clauses or terms of the contract."

¹⁴While some commentators apparently find the basis for the E.2.(c) remedy under WSWA to be "vague and unclear," see "Weapon Systems Warranties — Basic Principles and Guidelines," *The Government Contractor Briefing Papers*, No. 85-7 (July 1985), the additional remedy is plainly authorized under 10 U.S.C. Section 2403(g)(5), which authorizes procuring agencies to include in their contracts "guarantees that provide more comprehensive remedies than the remedies specified" in the statute.

¹⁵As a practical matter, where system performance is warranted contractors may insist on performing all maintenance on warranted systems during the life of the warranty to guard against warranty liability triggered by improper maintenance. This is especially the case where software is warranted, since "maintenance" in the context of software

means not only preservation, but enhancement or improvement. Contractors simply may be unwilling to warrant software performance in all circumstances unless they can control all software maintenance during the warranty period.

While Congress was plainly concerned about tying maintenance agreements to performance warranties under WSWA in view of the general policy favoring broad competition, see, e.g., S. Rep. No. 98-500, *supra*, 242, we do not believe that the Competition in Contracting Act, P.L. 98-367, 98 Stat. 1175, or any other provision of law precludes including in system procurements provisions for the prime contractor to perform all required maintenance during the term of the warranty, so long as the system procurement itself complied with all competitive procurement requirements. Such clauses should be carefully considered and drafted, however, because the maintenance provisions will likely increase the cost of the contract (though that cost may be offset by a decreased warranty cost). The government should make sure that it is not, in effect, paying twice for the same protection (warranty and maintenance).

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED		1b. RESTRICTIVE MARKINGS NONE	
2a. SECURITY CLASSIFICATION AUTHORITY N/A		3. DISTRIBUTION/AVAILABILITY OF REPORT	
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE N/A			
4. PERFORMING ORGANIZATION REPORT NUMBER(S) CMU/SEI-87-TR-4		5. MONITORING ORGANIZATION REPORT NUMBER(S) ESD-TR-87-104	
6a. NAME OF PERFORMING ORGANIZATION SOFTWARE ENGINEERING INST.	6b. OFFICE SYMBOL (If applicable) SEI	7a. NAME OF MONITORING ORGANIZATION SEI JOINT PROGRAM OFFICE	
6c. ADDRESS (City, State and ZIP Code) CARNEGIE-MELLON UNIVERSITY PITTSBURGH, PA 15213		7b. ADDRESS (City, State and ZIP Code) ESD/XRS1 HANS COM AIR FORCE BASE HANS COM, MA 01731	
8a. NAME OF FUNDING/SPONSORING ORGANIZATION SEI JOINT PROGRAM OFFICE	8b. OFFICE SYMBOL (If applicable) ESD/XRS1	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER F19628-85-0003	
8c. ADDRESS (City, State and ZIP Code) CARNEGIE-MELLON UNIVERSITY PITTSBURGH, PA 15213		10. SOURCE OF FUNDING NOS.	
		PROGRAM ELEMENT NO. 63752F	PROJECT NO. N/A
		TASK NO. N/A	WORK UNIT NO. N/A
11. TITLE (Include Security Classification) Software and System Warranty Issues and Generic Warranty Clause			
12. PERSONAL AUTHOR(S) Larry Druffel, I. Michael Greenberger, Timothy Shuba, William G. Wood, Richard D. Perthia			
13a. TYPE OF REPORT FINAL	13b. TIME COVERED FROM NA TO NA	14. DATE OF REPORT (Yr., Mo., Day) June 1987	15. PAGE COUNT 64
16. SUPPLEMENTARY NOTATION			
17. COSATI CODES		18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)	
FIELD	GROUP	SUB. GR.	
19. ABSTRACT (Continue on reverse if necessary and identify by block number)			
This report describes how to effectively include software issues into a system warranty. The report includes a generic system warranty clause, with a description of the rationale for each paragraph in the clause. The clause will have to be tailored to the circumstances of the system, and some tailoring considerations are described. There is also a description of the important legal, technical, and administrative concerns which are directly related to the warranty issues. The report describes the need for such a systems warranty, and includes firm recommendations on how to use such a warranty to improve the quality of the delivered system.			
20. DISTRIBUTION/AVAILABILITY OF ABSTRACT UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT ☐ DTIC USERS ☐		21. ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED, UNLIMITED DISTRIBUTION	
22a. NAME OF RESPONSIBLE INDIVIDUAL KARL M. SHINGLER		22b. TELEPHONE NUMBER (Include Area Code) 412 268-7630	22c. OFFICE SYMBOL SEI JPO

END

9-87

Dtic