ADA 025084

76-7

AD-A025 084

he Developmen ilitary Equipments: Reliability and Nuclear Survivability Considerations—by Joseph J. Halpin, Bruce E. Pritchard, Frederic W. Balicki

The Development of Military Equipments: Reliability and Nuclear Survivability Considerations

February 1976

THIS RESEARCH WAS SPONSORED BY THE DEFENSE NUCLEAR AGENCY
UNDER SUBTASK Z99QAXTD032, WORK UNIT 51, WORK UNIT TITLE "COST-EFFECTIVE TRE"
AND DARCOM (U.S. ARMY MATERIEL DEVELOPMENT AND READINESS COMMAND).

U.S. Army Materiel Command
HARRY DIAMOND LABORATORIES
Adelphi, Maryland 20783

UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE *(When Data Entered)*

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER
HDL-TM-76-7

2. GOVT ACCESSION NO.

3. RECIPIENT'S CATALOG NUMBER

4. TITLE *(and Subtitle)*
The Development of Military Equipments: Reliability and Nuclear Survivability Considerations

5. TYPE OF REPORT & PERIOD COVERED
Technical Memorandum

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s)
Joseph J. Halpin
Bruce E. Pritchard
Frederic W. Balicki

8. CONTRACT OR GRANT NUMBER(s)
DA: 1W162118AH75
Subtask: Z99QAXTD032

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Harry Diamond Laboratories
2800 Powder Mill Road
Adelphi, MD 20783

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
Program: 62704H
6.21.18A
Work Unit: 51

11. CONTROLLING OFFICE NAME AND ADDRESS
Director
Defense Nuclear Agency
Washington, DC 20305

US Army Materiel Development & Readiness Command
Alexandria, VA 22333

12. REPORT DATE
February 1976

13. NUMBER OF PAGES
35

15. SECURITY CLASS. *(of this report)*
UNCLASSIFIED

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT *(of this Report)*

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT *(of the abstract entered in Block 20, if different from Report)*

18. SUPPLEMENTARY NOTES
HDL Project: X75620, 263528, DRCMS Code: 612118.11X7500
698000.22.11334
This research was sponsored by the Defense Nuclear Agency under Subtask Z99QAXTD032, Work Unit 51, Work Unit Title "Cost-Effective TRE."

19. KEY WORDS *(Continue on reverse side if necessary and identify by block number)*

Reliabilility
Nuclear survivability
Nuclear hardening
Nuclear vulnerability
Life cycle management

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

This paper discusses the development cycle of Army equipments including the influences exerted by various concerned agencies and individuals involved in the development cycle and the ways in which these pressures affect nuclear survivability and reliability.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

The design-to-cost philosophy is described. The viewpoints of both the contractor and Project Manager are given along with the features each considers most important (profit and performance for the former, cost and schedule for the latter).

The importance of military standards and specifications and their impacts on reliability are discussed. This paper stresses the importance of considering nuclear survivability and reliability at the beginning of the development cycle plus the use of contractors with experience in nuclear survivability.

The various nuclear radiation effects (neutrons, gamma dose, gamma rate, and EMP) on electronics are discussed, and the association between reliability and nuclear survivability is explored. Usually, nuclear survivability tends to be aided by reliability considerations, but the relationship between the two is not one of dependency, because many of the controlled parameters are different for the two problems. But the fact that parameters are controlled for each constitutes a major similarity between solutions of the two problems.

CONTENTS

TABLE

1. INTRODUCTION

Recently, increasing interest has been shown for the nuclear survivability of fielded and developmental tactical Army electronic equipments. The Harry Diamond Laboratories (HDL), Army Materiel Command* lead laboratory for Nuclear Weapons Effects, is concerned about this problem, to more intelligently support the Project Manager (PM) in development programs and provide Department of the Army (DA) staff with timely information on the vulnerability of current inventory items.

Herein is addressed a specific and limited aspect of the nuclear survivability problem. This paper is in response to a request from the Army Director of Telecommunications and Command and Control through the Defense Nuclear Agency. But many people in the business of supporting the development of military hardware could benefit from an outline of the model development cycle and the real world pressures and processes. Most of the statements in this report regarding nuclear survivability and reliability apply equally to all military services.

The specific problem addressed in this paper is the association of electronic system reliability considerations during development with the equipment survivability to transient nuclear radiation effects (TRE) (i.e., neutrons, gamma dose, gamma dose rate) and electromagnetic pulse (EMP). Specifically excluded are the problems associated with nuclear blast and thermal radiation, since these effects are not dependent on electronic piece-part selection, circuit design, or circuit/subsystem interfaces. Areas covered are life cycle management, reliability requirements, military standards and specifications that apply, the considerations of semiconductor technology, and the nuclear survivability implications. How the system should work is discussed, and the practical problems are illustrated.

2. DISCUSSION

2.1 Life Cycle

To understand the framework of events related to reliability, it is best to first consider the life cycle for developmental hardware programs. In appendix A, there is a more complete discussion of the approved Life Cycle System Management Model (LCSMM), which includes the documentation and decision events. The LCSMM that applied before 1975 is not addressed here, since the differences are not critical to this paper. It suffices for our purposes to lay out the general flow of events. There are four primary phases: (1) conceptual, (2) validation, (3) full-scale development, and (4) production and deployment.

**Now the US Army Materiel Development and Readiness Command.*

In the conceptual phase, threat projections, technological forecasts, and Joint Service and Army plans are examined to determine operational capabilities and potential materiel systems that will improve Army effectiveness. During this time, the technical and economic bases for proposed systems are established by tradeoff analyses through the development and evaluation of experimental hardware (experimental prototype/breadboard). The planning and experimental work in this phase is designed to identify the critical issues and problems that must be addressed in the subsequent phases, to minimize risks and control costs. The duration of this phase is in part controlled by the resource constraints and the urgency of the operational threat. What comes out of this phase must be acceptable and credible tradeoffs among operational needs, performance requirements, cost, and schedule. Since both reliability and nuclear survivability are performance requirements, they should be considered in this first phase. The cost figures used are unit-production cost goals in fixed fiscal year dollars.

The validation phase is intended to verify the preliminary design and engineering, reevaluate the tradeoffs, and validate the hardware concept for full-scale development. In this stage, the advanced development (AD) prototype (brassboard) is made, and upon its acceptance as a viable and necessary equipment, the Required Operational Capability document is initiated. During this validation phase, the first formal Research and Development Acceptance Test (RDAT) is performed by the contractor, and the first set of Development and Operational Tests (DT/OT)-I is initiated by the Armed Services. These are system level tests, for the most part. Reliability and/or nuclear survivability subassembly and piece-part tests by the Government or the contractor in both the conceptual and validation phases should precede these scheduled, formal tests. The results of the RDAT and DT/OT are used to estimate the proposed system's military utility, cost, and performance and to refine the configuration prior to full-scale development. These advanced development prototypes are designed to closely represent the complete system to permit a thorough evaluation and tradeoff analysis. However, the quantity and level of prototype hardware and software validation is very much dependent on the nature of the program and the risks and tradeoffs involved. In fact, more than one contractor may be used to produce AD prototypes if resources permit.

In the full-scale development phase, the engineering problems are to be identified and solved so that a decision can be made as to the acceptability of the equipment. The engineering development (ED) prototypes undergo RDAT and DT/OT-II, and if the test results are favorable, the equipment is type classified, indicating that it is ready to be placed into the inventory. All the necessary support equipment and documentation must now be finalized. Even at this stage, tradeoffs among stated operational requirements, cost, schedule, and operational readiness data are conducted with the design-to-unit-production-cost (DTUPC) figure as the controlling parameter. The main reason for using cost as the controlling parameter is that cost can be quantized and measured very easily. However, it is not always possible to accurately predict cost over the lifetime of a system.

In the final phase, there are usually an initial production run and an RDAT and DT/OT-III before full-scale production. After production and deployment, maintenance and product improvements become the critical issues.

2.2 Design to Cost

Up to this point, we have glossed over the concept of Design to Cost (DTC). The DTC philosophy is to manage and control the DTUPC by adequate research and development efforts in the preproduction phases. In general, this requires more time and more dollars (15 to 20 percent more), especially in the conceptual and validation phases. The payoff is that some investments have been shown to reduce the DTUPC up to 80 percent. The reason for this potential savings is that changes brought on by identifying deficiencies, modifying performance requirements, or chasing technology late in the development program are very expensive from the engineering, tooling, and hardware aspects--that is, the nonrecurring costs. To assist in this DTUPC concept, some contracts contain incentives for the contractor to produce cost-savings ideas.

There are several problems with this concept and implementation. Instead of DTUPC, the goal should be design-to-life-cycle costs. This is recognized as a laudable goal in DA Pamphlet 11-25 (LCSMM for Army Systems, p. 45), and the reliability community feels it can be achieved,* but in practice, DTUPC dominates. Performance tradeoffs are too likely to be made under DTUPC, where unit production cost is the dominant factor. This may seriously impact the maintenance and logistics problems of fielded equipment. In the absence of design-to-life-cycle cost constraints, contractors are likely to make proposals that are optimistically priced, often based on the benefits of advanced technology or custom-built integrated circuits (IC's). But without life-cycle cost data, the costs inherent in such proposals can be much higher than those indicated by unit production costs.

**A member of the Army Electronics Command Reliability group cited these figures: a 20-percent-cost impact in development and production costs for piece part and design could save up to five times the invested dollars in lifetime maintenance costs. Joseph B. Brauer from RADC expressed it another way--in development it might cost $2 to detect and fix a defective part. In the field, the detection and fix might cost $500.*

Contractor incentives also are likely to reduce the reliability. This follows from the fact that in practice, the PM has the final say on the matters that ultimately impact system reliability and nuclear survivability. What this means is that even though the PM has an engineering staff, in many cases, reliability engineers and nuclear survivability experts are not on the PM staff. (We know of no formal requirement or guidance on the inclusion of reliability* or nuclear survivability experts on the PM staff.) This limitation often does not deter a PM from accepting contractor recommendations concerning piece-part selection and circuit design that can impact both reliability and survivability. It is very unlikely that the reviewing committee (namely, the In-Process Review, Army Systems Acquisition Review Council, or Defense Systems Acquisition Review Council) would be made aware of kinds of tradeoffs on the piece-part and circuit level that the PM has made.

The classic, yet common, example of the problem cited above is the use of contractor-specified semiconductor piece parts in place of military standard parts. Traditionally, the contractors have found it easy to obtain waivers based on the cost and availability of military standard parts. The difficulty with this approach is that although production costs may be lowered, reliability, maintenance, and logistics may bear the burden of this move. In fact, production costs usually increase when commercial devices are used throughout, because after initial production, serious problems occur requiring additional work and testing. The cost for this extra work is typically two to five times the total parts cost. As an example, the Air Force Rome Air Development Center (RADC) traced failures to several commercial IC's. The extra cost to rework the IC's was $6.74 per IC. A JAN replacement was found for only $2.47 per device.

Another not so obvious example is the following. The initial performance criteria of a circuit can be met by using a capacitor rated for 20 V in such a way that 20 V or more is applied across it. However, the lifetime of this device is seriously affected because of this underdesign. Good reliability engineering practice calls for an overdesign factor of two in capacitor voltages to insure the maximum capacitor lifetime. The point is that piece-part cost or volume could be the desired traits, while the reliability consideration may be unwittingly sacrificed.

**The suggestion is made in AR 70-17, System/Project Management (16 June 1975), para. 2-1b(9), that among authorized PM staff might be Reliability, Acceptability, Maintainability personnel.*

Yet another problem is the inadequate allowance of time and dollars in the preproduction stages to allow the DTC philosophy to work properly. There is no point in speculating why this condition can and does exist. Nevertheless, DTC can and does work when given the proper conditions and valid cost data, and DTC can add support to both reliability and nuclear survivability requirements.

2.3 The Project Manager and Contractor Viewpoints

Another barrier to logical, effective program management is the nature of the PM position within the Army. In most if not all instances, the PM is military. Even though the Army policy is that the PM position is to be considered a select career assignment, some officers feel that a PM assignment is a mixed blessing and a risky assignment for career purposes. The Army is working to counteract these attitudes. Assume that this factor by itself is not a barrier to effective management. The PM position is, like other assignments, military or civilian, in part a means of getting a promotion. The measurable "success factors" are cost and schedule goals. This position is mainly caused by management preoccupation with these factors. This position is borne out by the fact that up to this time there were no plans to determine reliability performance in the field. This fact was a problem for the logistics people or the basis for a product improvement.

On the other hand, the contractor performs an economic analysis to assess the tradeoffs that lead to maximum profit. Next to profit in importance to the contractor is performance. No known contracts have been terminated for cost or scheduling violations, but some contracts have been terminated for lack of critical performance characteristics. In all fairness, it is best to mention that fixed fees have been lost due to cost overruns. Nonetheless, the Army has established the precedent of accepting equipments that have not met the reliability requirements when the principal operational requirements are met.

2.4 Military Standards and Specifications

It is a matter of record that poor reliability is associated with many military equipments.[1] In spite of this poor record, the Army apparently has no way of accumulating data from the field to find the exact causes or trends that influence materiel reliability. Meanwhile, the reliability community has been trying to cope with this problem by emphasizing the manufacture and production of reliable semiconductor piece parts. Here is where military standards and specifications can be

---

[1] *H. P. Gates, B. S. Gourary, et al, Electronics X: A Study of Military Electronics with Particular Reference to Cost and Reliability, Vol. 2: Complete Report, DARPA R-195, Institute for Defense Advanced Research Projects Agency, AD-A001065 (January 1974).*

important. But reliable systems do not depend only on piece-part selection. It is absolutely essential that this be coupled with good circuit design practices. Little useful military documentation exists to provide guidance on circuit design, specifically in the area of piece part derating factors, which is an important facet of reliable design.

There is available to the PM a vast array of documents to help him and the contractor sort out the proper approach to reliability. Particularly in the late 1960's, military (i.e., tri-Service) standards, specifications, and handbooks relating to the reliability considerations for electronic equipment began to be recognized for their potential influence on the reliability problem. Two of these documents are particularly important to the reliability and survivability aspects of the semiconductor device technology. These are MIL-S-19500 (the specification document for discrete transistors and diodes) and MIL-M-38510 (the specification for IC's). These specifications treat the mechanical and electrical parameters of qualified parts, production assurance measures, and lot acceptance techniques that are designed to lead to producible, predictable, and uniform devices. Both of these documents are being updated to reflect the latest thinking on semiconductor reliability.

A related document, MIL-STD-701H, indicates that military equipment should be built from military-qualified parts. But an obvious evolution in thinking has taken place over the years; under the heading of MIL-S-19500E (1968), it was stated that, "This specification is *mandatory* [italics ours] for use by all Departments and Agencies of DoD." In the following supplements and amendments to MIL-S-19500 and in MIL-M-38510A (1972), the citation reads, "This specification is *approved* [italics ours] . . . ."

For putting together the contract package, at least two standards can be used to assist in the reliability engineering of a system. MIL-STD-701 lists the diodes and transistors, and MIL-STD-1562 lists the microcircuits that are approved for use. Military specifications and standards are binding only if they are cited in the procurement package. Even when these and similar documents are cited, approval of nonstandard parts is easy to obtain in actual practice, since the approving official is the PM, and he is influenced mostly by the cost and availability problems associated with military standard parts.*

The assumption in requiring the use of military standard parts is that reliability is an inherent quality of these parts. This assumption is not always correct. If the parts are made to the

---

**The requests must be formalized through MIL-STD-7498, Military Preparation and Submission of Data for Approval of Non-Standard Parts.*

specifications and the lot acceptance tests are performed according to MIL-STD-883 (IC's) or MIL-STD-750 (discretes), the assumption of reliability is good when adequate circuit design margins are used. However, there exist some data[2] within the reliability community that demonstrate that the semiconductor vendors have not been living up to their side of the bargain even though they certified their compliance to the standards and specifications. In the hopes of improving the reliability of communications electronics, the Army Electronics Command (ECOM) began requiring contractually that the prime contractor deliver to the Government traceable data that could be used to verify that the lot acceptance tests were performed. Much to their chagrin, ECOM soon found that the vendor charge for these data was inordinate. Now ECOM requires these data for "critical" piece parts only. Who defines these critical parts for each system is not known, perhaps the contractor. This is a step in the right direction, but not without problems.

2.5 Hardness Assurance Subcommittee

In the revised version of MIL-S-19500F now being circulated for coordination and approval, in addition to updating the criteria and tests in 19500E, process controls are being added. This addition means that the vendor has to make the device using certain approved techniques. Changes in these processes are made only at the discretion and approval of the Government. Process controls, if acceptable to the Government and the vendors, would be a significant step in controlling not only the reliability, but also the nuclear response of semiconductor piece parts, since the product would be more uniform. A subcommittee composed of Government and industrial experts* is working to iron out the details of qualifying, testing, and controlling the nuclear response of discrete and IC semiconductors. Their success will in large measure depend on the acceptability of the concept of process controls.

Specifically, this subcommittee is considering specifying the nuclear induced response of a limited (or preferred) list of piece parts (approximately 50 discretes and 50 to 100 IC's). The nuclear environments to be considered are neutrons, ionizing radiation, ionizing dose rate, nuclear EMP-induced voltages and currents, and thermomechanical stresses. The concept being studied now is to experimentally determine, from a statistically significant sample of device types from various manufacturers, the change in the appropriate device parameters (e.g., beta or gain for neutron effects, photocurrent

---

[2] *M. K. Church, Reliability/Field Failure Experience with Microelectronic Devices, Naval Ammunition Depot (NAD), Crane, IN, Proceedings Solid State Device Reliability Workshop, Ser 16-033 (24 July 1972), 249.*

**The Hardness Assurance, Military Parts Standardization Subcommittee on the NASA-SAMSO Space System Reliability Committee.*

for dose rate). The device response could be expressed as a damage threshold or a damage constant. This in turn can be related to changes in the appropriate device parameter over a specified linear range of the degrading environment. For example, $I_{pp} = K_p\dot{\gamma}$, where I_{pp} is the gamma-induced device photocurrent, K_p is the experimentally determined damage constant, and $\dot{\gamma}$ is the gamma radiation peak dose rate.

Over the next year, this subcommittee hopes to work out the details of (1) dosimetry and simulation facility selections, (2) simulation test methods and procedures, (3) piece-part parameter specifications, (4) production process controls, (5) lot acceptance tests, and (6) periodic requalification of the vendor process and product.

Again, good as this approach sounds, there are some basic shortcomings. In theory, reliability and nuclear survivability considerations should be applied beginning in the conceptual phase. In practice, through at least the validation prototype development, only a few military-qualified parts are now used. This is an essential part of the reliability growth concept[3] for which, in each phase of the program, the reliability is supposed to improve. Therefore, the reliability and nuclear survivability tests and predictions will not be realistic until the piece part list is firm and based on the maximum use of military standard parts. (For Army field equipment, this is never expected to be 100 percent and is currently 50 to 75 percent.)

Two drawbacks exist to the reliability-growth concept. The first is that if the decision to use military-qualified devices is put off until the validation or full-scale production phases, the PM is more likely to refuse the proposed changes, no matter how small the cost increase is. The second drawback is that if military-qualified parts are not insisted on early enough, contract renegotiations may be unavoidable.

2.6 Semiconductor Device Classes

The assumption that the expected reliability of military standard (Joint Army-Navy or JAN) parts is better than commercial parts has been borne out by the available data. But MIL-S-19500 and MIL-M-38510 provide for more than one class of device, because these general specifications satisfy the needs of a broad spectrum of users. The equivalent designations, reliability figures, and cost are listed in table I.

---

[3] *AR 702-3, Army Materiel Reliability, Availability, and Maintainability (15 May 1973).*

TABLE I. RELATIVE FAILURE RATES AND ITEM COSTS FOR VARIOUS CLASSES OF DEVICES

Device classes		Approximate relative failure rate[1]	Relative cost per gate[1]
Captive line product (nonstandard)		≤1	30 to 100
MIL-S-19500 (MIL-M-38510)			
JANA	(A)	1	5 to 15
JANTX	(B)	2 to 10	2 to 5
JAN	(C)	16	1
Commercial product (nonstandard)		30 to 150	0.2 to 0.5

[1] *Joseph B. Brauer, The Development and Status of MIL-STD-883 and MIL-M-38510, Rome Air Development Center [n.d.].*

More often, the designer and the PM are exposed to the data of the last column, i.e., the cost, without appreciating the relative reliability figures in column 3. Naturally, they would conclude that anything more than a commercial part would at least double the UPC. Information available from RADC indicates that only 5 to 10 percent of the UPC for ground equipment is in the piece parts. Therefore, the use of class B or JANTX parts compared with commercial parts would be expected to impact the UPC by 25 to 50 percent. However, in actual practice, the impact is typically closer to 10 to 20 percent. What this buys is a very significant improvement in the piece-part failure rate, a factor of 15 to 75. In addition, the cost may be completely offset by savings in rework and retest which generally range from 10 to 40 percent of the manufacturing cost.

MIL-M-38510 and MIL-S-19500 list the types of inspections and tests that must be performed on the various classes of devices (to sort out the suspect and defective parts). Both specifications list a Lot Tolerance Percent Defective (LTPD) table. Given the part reliability figure, this matrix is used for selecting the minimum number of devices that must be sampled in a given lot size and the number that must pass the specified test. In the case of devices with a desired reliability figure of 95 percent (LTPD = 5 percent) with 90 percent confidence, the minimum sample size is 45 with no rejections allowed, 77 with one rejection allowed, 105 with two rejections, and so on.

Piece-part reliability is related to system level mean time between failure (MTBF), mean time to repair, and equipment availability by a series of generally simplified assumptions and formulas. More often than not, the system level specifications are not validated either through careful monitoring of the semiconductor vendor tests on the piece parts or by tests of statistically significant numbers of equipments. In fact, the sample size of the equipments tested is an inverse function of the system cost.

No mention is made in any DoD-level document of the use of the various classes of JAN parts. In practice, informed designers prefer to use class B or JANTX parts* in the validation and full-scale development phases. These provide a good reliability figure at a modest cost. In fact, ECOM requires waivers for the contractor to use class C (JAN) or commercial devices (because of their lower reliability) or to use class A (JANA) devices (because of their higher cost).[4] However, the burn-in requirements for class B or JANTX devices can cause availability and cost problems in the production phase, and waivers at this stage often lead to commercial devices, but not to JAN or class C devices, because it appears that the design engineers are far removed from these decisions. However, the availability problem of class B or JANTX parts is more apparent than real, since the parts require only a 1-wk (168 hr) burn-in time plus time for testing. Some of these parts are available off the shelf. The cost for class B and JANTX parts would be lower if more were employed.

2.7 Reliability of the System

Through the ED prototype phase, inadequate tests and imprecise calculations tend to characterize the reliability aspects of program development. But these tests and analyses, whatever their quality and quantity, end at DT/OT-III. For the production phase of the reliability program, quality assurance techniques are assumed adequate to preserve the reliability figure, and therefore, reliability of production line equipments is tested only in the field. The quality assurance techniques are controls and inspections.

Current emphasis within the developing community is the use of commercial off-the-shelf equipments. This approach is justified by both reliability and cost. Reliable commercial systems have evolved without the need for military-specified parts, because the production has continued over many years without significant product changes, and this continuation was backed by good data from the field on failure modes. This evolution led to an optimum combination of piece parts, circuit design, derating factors, and cost. The most reliable equipments were found to be made with the equipment manufacturers' own production-line semiconductor parts, wherein they could assure the uniformity of the products. When commercial off-the-shelf items are procured, sufficient historical data should exist, i.e., get items that are field proven, not those that just recently commenced production. In addition,

---

[4] *ECOM specification MIL-P-11268, Parts, Materials, and Processes Used in Electronic Equipment.*

**These parts are burned in at high voltage and temperature stresses to weed out the weak parts.*

modifications should be avoided, since they alter the status of the equipment such that it can no longer be considered the same field-proven equipment. Also, one must be careful not to confuse off-the-shelf *designs* with hardware, because the former have no field history on reliability.

This is an opportune place to reflect on what has been said so far. First, in practice, reliability is subjugated to cost and schedule goals. Second, military hardware development programs have often chased technology and changed performance requirements throughout the development cycle. Both of these practices are contrary to good reliability practices. Third, adequate documentation (regulations, standards, and specifications) may exist, but all too often these proven procedures are not followed.

2.8 Nuclear Survivability

The discussions above have centered on the models, technology, aids, and problems of reliability requirements. The nuclear survivability criteria application to system development has an even rockier road to travel. There is little, if any, formal documentation (regulations, standards, and specifications) to lay out a road map for the system developer. The DNA Handbooks are available for the equipment designers, but they are formidable piles of paper for the designer without previous experience in nuclear survivability design. These problems are currently being addressed at HDL. But the lack of the appropriate documentation is a good reason or excuse for unhardened equipment in the inventory.

A substitute, although not a good substitute, is nuclear survivability design expertise early in the development cycle. As in the case of reliability, advice on hardening considerations often is not sought until the whistle is blown, i.e., when somebody recognizes late in the development cycle that nothing has been done about the nuclear requirement. At this time, the cost and schedule impacts can be quite serious and may result in a decision to waive the nuclear requirement or reduce it to the level at which hardware can meet the requirement without modifications.

For the most part, the nuclear survivability requirement associated with tactical equipments can be treated with a modest effort and low cost if considered from the time of the conceptual phase. The estimate for the SAM-D system was on the order of 3 percent R&D cost impact for balanced, man-limited nuclear survivability. However, the tradeoffs, design, and validation must be performed with the support of experienced Government or contractor personnel or both.

Our experience has been that when the contractor had the nuclear expertise available, his cost estimates were reasonable, and the hardness was achieved. The problem is with the unknowledgeable contractor, since estimates of the cost for nuclear hardening are quite often inordinate. This problem alone has been the overriding cause of the cancellation of nuclear survivability requirements for tactical systems with modest criteria. This response of the unknowledgeable contractor is to be expected since he is unsure of his capability to solve the problem and most likely has to include learning costs or subcontract for expertise. Here is where suitable documentation could possibly provide sufficient insight and understanding of the nuclear hardening requirements. Unfortunately, the closest approach to such documents is the DNA Handbooks. However, they are much too long. They discuss measures of hardening for all survivability levels, and they cannot keep up with the state of the art. What is required is something concise and to the point, applicable to the specific criteria of concern, and current.

2.9 Association between Nuclear Survivability and Reliability

The nuclear effects on electronic piece parts for the tactical survivability criteria are generally confined to the semiconductor parts (i.e., diodes, transistors, and IC's). It is rare that a specially hardened semiconductor device is required to produce tolerable responses in a system with these modest criteria when survivability is designed into the system from the start. However, there are many semiconductor devices whose nuclear responses are far more favorable than others for survivable designs. The key is to select these less susceptible parts and couple survivivability with the proper circuit design.

No military standard or specification can be associated with nuclear survivability. Rough calculations of the piece-part response can be made based on some device parameters (e.g., minimum gain, gain-bandwidth product f_T). When the device parameters used for nuclear response determinations are controlled parameters and are designated as such in the appropriate military specifications, then nuclear survivability begins to resemble reliability by the nature of the controls imposed. The Hardness Assurance Subcommittee is evaluating the device parameters and process controls necessary to control and predict the device response as a possible approach to nuclear survivability. However, piece-part response is not the whole story. Circuit design considerations, hardness assurance controls, and verification of survivability are also essential ingredients to a sound nuclear survivability program.

In general, reliability and nuclear survivability tend to follow the same trend because both require controls. However, these controls are not necessarily the same for both problems. An example of the differences is in the f_T requirement. Low frequency minority-carrier devices are in general more susceptible to neutron damage than high frequency ones. However, the reliability of a device is not dependent upon f_T, but rather on many other parameters controlled by the military standards and specifications.

2.10 Nuclear Radiation Effects on Electronics

The primary degrading effect of neutrons is a reduction of minority-carrier lifetime in bipolar transistors. This causes a reduction in gain, an increase in saturation voltage, and an increase in leakage current. In analog IC's, this usually results in some loss in device gain, a reduction in gain-bandwidth product, and changes to the input offset voltage. In addition, the device may no longer be able to drive a heavy load. In digital IC's, fanout is reduced, because the changes in the output transistor parameters reduce the maximum current that the device can sink. In addition, the HIGH and LOW voltages may degrade somewhat so that the protective voltage difference (guaranteed noise voltage margins) between the two levels is reduced. Thus, the circuit may be vulnerable to logical changes in state caused by smaller noise signals than before irradiation.

The piece-part reliability and neutron response require control of different parameters. However, on a circuit level, the two requirements are more closely related. For example, to insure the reliability figure, large derating factors may be used so that less power is dissipated in the transistors and larger variations in the ageing of piece parts can be tolerated.

The total ionizing dose effects on electronics at the levels of interest to field Army equipments are generally limited to IC latchup. This phenomenon, which can occur at very low doses but only for high dose rates, affects both complementary metal oxide semiconductors (CMOS) and junction-isolated bipolar IC's. The occurrence of latchup in bipolar IC's is relatively rare. On the other hand, bulk silicon CMOS devices appear to be plagued with this problem. Unfortunately, these technologies comprise the bulk of the IC's being manufactured today, and avoiding them is not a viable solution. There are special manufacturing techniques available for avoiding latchup in CMOS, even at very high dose rates.[5] Among these techniques are gold doping, dielectrically isolated substrates, mask layout design, and even neutron irradiation.

---

[5] *B. L. Gregory and B. D. Shafer, Latchup in CMOS Integrated Circuits, IEEE Transactions on Nuclear Science, NS-20, No. 6 (December 1973), 293-299.*

The goal is either to reduce the minority carrier lifetimes so that all possible gain (h_{FE}) products between parasitic NPN and PNP transistor pairs are less than unity or to isolate the layers so that no SCR-like action is possible. A possible solution for latchup in the case of the standard, unhardened CMOS is to isolate the IC from the power supply by the addition of a small series current-limiting resistor. It is unclear as to whether this is a universal solution, and if it is not, avoidance of CMOS would be advisable. Since latchup in junction-isolated bipolar IC's is infrequent, response data on the specific device type is required. Reliability considerations alone would not preclude the use of these susceptible devices. However, once these susceptible devices are identified, controls like those available to the reliability engineers are necessary to keep these susceptible devices out of survivable system designs.

The only other significant total dose effect at tactical system survivability levels is the degradation of lasers.[6] Doses of a few hundred rads(Si) have been shown to alter the threshold for lasing in some materials. This change leads to cessation of lasing action or loss of output power. This effect can be mitigated by operating the laser well above the threshold. In this case, the only effect is that the laser power is degraded. Where power consumption is critical, the system operating point is designed to be near the lasing threshold (e.g., in a man-pack laser range finder, the margin might be less than 10 percent). Our information leads us to believe that for reliability, the same philosophy would apply, since lower operating voltages on capacitors and less power dissipated in flash lamps imply longer part lifetimes. The implication is that where power consumption or reliability dominates the laser system design, the nuclear response of the system is more likely to be a problem.

The nuclear dose rate effects are transient false signals, device burnout, magnetic logic upset, and reversible and irreversible changes of state. In general, Army equipments do not have an operate-through requirement for nuclear survivability. Therefore, transient false signals and logic upsets can be compensated for (e.g., the bad data can be discarded, or a retransmission of a message can be requested, and a way to reestablish stored information can be provided). In most military equipments, logic upset is provided for, since the commonly occurring power transients and outages can produce the same effect.

---

[6] *J. J. Halpin, A Progress Report on the Transient Radiation Effects on Laser Materials FY'71, NRL Memorandum Report 2337, Naval Research Laboratory (30 June 1971).*

Semiconductor burnout in discretes and IC's is strongly associated with reliability considerations and good design practice. There are two types of burnout: metallization and thin conductor burnout and junction burnout. Both types are caused by the large currents induced in the circuit by the gamma pulse or coupled from the external or system-generated (internal) EMP. Most metallization burnouts are due to defective metallization, which can be avoided by proper reliability methods. Another major consideration is good design practice. To preclude generation of currents capable of burning out the metallization or junction, it is necessary to properly isolate the piece part from its primary source of current, i.e., its power supply. Proper isolation is normally achieved with limiting resistors. This is not found in nonnuclear survivable designs.

Many dose rate effects fall into the reversible and irreversible categories. For example, silicon controlled rectifiers (SCR's) are triggered by the transient gamma pulse and can be reset only by removing primary power to them. Power supplies designed to shut down when an overcurrent or overvoltage is sensed are reversible events if they are easily reset. Semiconductor burnout is one example of an irreversible action produced by the transient gamma pulse. Other examples are nonresettable timers that may be started by a false signal or fuses or electrically activated squibs that may be destroyed by the false signal induced by the gamma pulse. In general, there are categories of devices to be avoided and certain circuit design guidelines to be followed to prevent such events from occurring, many of which are not included in the standard practices of reliability engineering.

The EMP response of a system is a complex phenomenon involving electromagnetic coupling, cross coupling, and device burnout. Shielding of cables, cable connectors, and electronic enclosures combined with protection devices at the terminations of antennas, cables, and other critical entry ports are the commonly applied EMP hardening techniques. The intent is to reduce as much as possible the amount of EMP energy coupling into a system and then use circuit hardening and circumvention techniques as required to survive the effects of that energy that does penetrate to the circuit and device level. Electromagnetic compatibility (EMC) and lightning requirements come closest to ameliorating, but not solving, the EMP problem. Therefore, normal reliability considerations associated with EMC and lightning protection are not enough to protect a system against EMP.

In summary, reliability considerations by themselves can work contrary to nuclear survivability considerations (e.g., laser systems); they can work in consonance with nuclear survivability requirements (e.g., metallization burnout, transistor piece-part derating in circuits); and these two requirements can be unrelated (e.g., latchup, semiconductor piece-part response determinants, metallization or junction burnout current limiting requirements). A generalized statement might be that nuclear survivability tends to be aided by reliability considerations, but the relationship between the two is not one of dependency, because many of the controlled parameters are different for the two problems. However, the fact that parameters are controlled for both problems constitutes a major similarity between solutions of the two problems.

The final item for consideration is the effect on the MTBF due to the exposure of an electronic system to the nuclear TRE and EMP environments. Assuming that the system survives the single-burst, nuclear encounter, the electronic systems performance is most likely degraded somewhat if the exposure level was at or near the "typical" nuclear survivability requirements for tactical systems. The performance degradation results from piece-part degradation. The net result would be to narrow the circuit design margins, making the circuit more sensitive to device parameter changes due to normal ageing or to the increased power dissipated in the device. The conclusion is that without proper consideration to the nuclear response of the electronic system, the MTBF is expected to be degraded. The extent of this effect is dependent on the design margins in the circuits.

The effects of ageing are virtually nonexistent for good quality semiconductor devices, however. In addition, the effect on the MTBF is small even for equipment exposed to the maximum expected nuclear environment. The effects on the MTBF over the inventory of equipments is even smaller because of the small probability of exposure.

3. SUMMARY

There is an orderly process for developing reliable and nuclear survivable equipment. The reliability community has documented the procedures, controls, and management insight into military regulations, standards, and specifications. The nuclear community, however, does not have this type of supporting documentation that the users and developers find most useful. However, the methodology has been developed and used for more than 10 yr, and during this time, systems have been hardened to much higher levels than Army field equipments require. Now, HDL is supplementing the nuclear effects documentation. In spite of the existing documentation, the logic and orderliness are often perturbed by pressures and priorities that subjugate reliability and nuclear survivability to cost and schedule.

For any important performance characteristic, it is necessary to have expert advice from the conceptual phase to assist in supplying informed inputs, making the tradeoffs, and assuring that adequate time, money, and equipment are available for verification of the system performance. The plan should include the concept of performance growth because new, unproven devices and materials are often being applied, and their capabilities, response, and lifetime have to be validated. But it is important that the entire emphasis not be placed on favorable piece-part characteristics and response, since circuit design and component derating are also critical factors in both reliability and nuclear survivability.

The comparison of reliability and nuclear survivability is valid in that similarities of planning, expert assistance, and control procedures are indicated. However, the controlled parameters and the circuit design philosophies are somewhat different. A system may be very reliable and yet quite vulnerable to nuclear radiation, and vice versa.

The constraints on a design engineer are performance, cost, schedule, size, and weight. These are the immediate, measurable system features. Reliability and nuclear survivability are more distant, abstract, and often less important.

Reliability engineering and nuclear survivability design are specialties of design engineering. To assume that a competent design engineer has a working knowledge of the nuances of reliability and nuclear survivability is fallacious.

When one addresses the reliability and nuclear survivability of equipments from the concept phase following a logical and firm path, the reliability and survivability goals can be met cost effectively and timely. But all too often the near-term influences dominate the long-term payoffs.

LITERATURE CITED

(1) H. P. Gates, B. S. Gourary et al, Electronics X: A Study of Military Electronics with Particular Reference to cost and Reliability, Vol. 2: Complete Report, DARPA R-195, Institute for Defense Advanced Research Projects Agency, AD-A001065(January 1974).

(2) M. K. Church, Reliability/Field Failure Experience with Microelectronic Devices, Naval Ammunition Depot (NAD), Crane, IN, Proceedings Solid State Device Reliability Workshop, Ser 16-033 (24 July 1972), 249.

(3) AR 702-3, Army Materiel Reliability, Availability and Maintainability (15 May 1973).

(4) ECOM specification MIL-P-11268, Parts, Materials, and Processes Used in Electronic Equipment.

(5) B. L. Gregory and B. D. Shafer, Latchup in CMOS Integrated Circuits, IEEE Transactions on Nuclear Science, NS-20, No. 6 (December 1973), 293-299.

(6) J. J. Halpin, A Progress Report on the Transient Radiation Effects on Laser Materials FY'71, NRL Memorandum Report 2337, Naval Research Laboratory (30 June 1971).

ACKNOWLEDGEMENTS

The authors wish to gratefully acknowledge the assistance of Joseph Brauer, RADC, James Ramsey, NWSC, and George Messenger, consultant, for their contribution and review of this paper.

APPENDIX A.--THE LIFE CYCLE SYSTEM MANAGEMENT MODEL FOR ARMY SYSTEMS

This material is extracted from DA Pamphlet 11-25, Life Cycle System Management Model for Army Systems (23 January 1975). The model is a simplified flow chart representing the life cycle of an Army system from conception to fielding of finished equipment, personnel training, product improvement, maintenance, and phase out or disposal of unneeded equipment. In this brief description, only the major events are related. In a given system development program, certain events (or possibly entire phases) may be bypassed if the information already exists or if the required developmental work has already been performed or is otherwise unnecessary. However, if there is any controversy regarding cost, complexity, or high visibility, the event or phase may then become mandatory. There are four phases in the life cycle of any Army system: conceptual, validation, full-scale development, and production and deployment.

In the conceptual phase, the combat development agencies, usually the Army's Training and Doctrine Command (TRADOC), examine threat projections, technology available and forecasted, and Joint Services and Army plans to determine the operational capabilities and potential materiel systems that could improve the Army's effectiveness. A Letter of Agreement (LOA) is signed by the combat and materiel developers in which they outline basic agreements for further investigation of a potential materiel system. During this phase, the basic research and the applied research are performed that lead up to the breadboards or experimental prototype. They also agree in the LOA upon the nature and characteristics of the proposed system and the tests required to validate the system concept.

A Special Task Force (or Special Study Group) is then assembled by the Army Chief of Staff and is normally composed of the Charter Task Force Director, representatives of the materiel and combat developers, the trainer, the operational tester, and perhaps a Project Manager designee. This group prepares a Decision Coordinating Paper (DCP, previously called Development Concept Paper) or an Army or Defense Program Memorandum, which presents the rationale for starting, continuing, reorienting, or stopping a development program. It identifies the issues in a decision and assesses the important factors such as threat, risks, military and economic consequences, and critical problems to be resolved by test and evaluation. They also prepare a Concept Formulation Package, which includes tradeoff determination and analysis, best technical approach, and cost and operational effectiveness analysis. The tradeoff determination studies the technical and economic feasibility of each approach to a realization of a potential system including the risks involved with each. In the tradeoff determination, the Special Task Force decides which technical approaches are best. From these documents (including a final report), an Outline Development Plan (ODP) is prepared that records program decisions and analyzes technical options and plans for development of the system in the validation phase.

These documents, plus an Independent Parametric Cost Estimate (performed by the Comptroller of the Army before entry into each succeeding phase), are submitted for review and acceptance at the first meeting of the Army Systems Acquisition Review Council (ASARC-I). After favorable review, the Army accepts the DCP. Then it is submitted at the first meeting of the Defense Systems Acquisition Review Council (DSARC-I) and then to the Secretary of Defense for final acceptance. These ASARC and DSARC reviews are performed for major systems to determine whether a phase is complete and if the program is ready for the succeeding phase. The level of review (i.e., ASARC or DSARC) is determined by the importance of the dollar value of the system. For nonmajor systems, the final review could be at the Army Materiel Development and Readiness Command level and is called the In Process Review.

In the validation phase, preliminary design and engineering are verified experimentally and analytically. Tradeoff proposals are analyzed, and logistics problems are identified. A contract is awarded to develop prototypes representing complete systems (advanced development prototype). The prototypes are then submitted for the first set of Development and Operational Tests (DT/OT-I). Development testing is performed to determine that the design risks are minimized, the engineering is complete, solutions to problems are at hand, and the system meets or will meet its specifications (including nuclear, if applicable). Operational testing is conducted to determine a system's military utility with representative users in an environment as realistic as possible, its operational effectiveness, and its operational suitability, including compatibility, reliability, availability, maintainability, logistic support, tactics, and training requirements. If possible, the new equipment should be compared with existing equipment.

These test results are used in preparing the Required Operational Capability (ROC), the Development Plan, and the Provisional Qualitative and Quantitative Personnel Requirements Information. The ROC is a short document stating the essential operational, technical, logistic, and cost information required to initiate development or procurement of a system. The Development Plan contains the ROC and expands upon the ODP. The Development Plan is submitted for review and approval by ASARC-II or DSARC-II or both, as appropriate, to determine whether the program is ready for full-scale development.

During the full-scale development phase, the system, including all items necessary for its support, is fully developed and engineered, built, and tested. The resulting engineering development prototype should be a preproduction system closely approximating the final product. Also included in the output for this phase is the documentation to enter the production phase, including draft field manuals, and test results of DT/OT-II supporting entry to the production phase. Producibility Engineering and Planning (PEP) is conducted during the full-scale development phase to assure facility of volume production. These PEP activities include developing data packages, designing special production equipment or tooling, and possibly designing computer models of the production process to identify production problems. Long-lead-time requirements also must be identified. Again, the DT/OT-II results and the updated Development Plan are presented for review and approval by the appropriate-level committee to determine the system's readiness for transition to Low-Rate Initial Production (LRIP) in the production and deployment phase.

Finally, the production and deployment phase begins with a contract for LRIP. This is intended to provide an adequate number of production-line items for final DT/OT-III. The purpose is to minimize the government's exposure to large retrofitting problems and expenses if production deficiencies are discovered or modifications are proposed for product improvements. A production validation In-Process Review may be conducted if initial production items do not meet their required specifications. This is conducted by the materiel and combat developers and the Deputy Chief of Staff for Research, Development, and Acquisition. First editions of technical and field manuals are submitted for publication. The test results from DT/OT-III and the newly updated Development Plan are submitted for review and approval to enter full production and deployment.

Full-scale production is then authorized, including any necessary retrofitting. Final Qualitative and Quantitative Personnel Requirements Information is determined and is used to determine whether new Military Occupational Specialties should be created. A new Table of Organization and Equipment is drafted, reviewed, approved, and published. Personnel are trained, and an Initial Operational Capability is achieved by a troop unit using production items. After a period of time, the materiel developer accumulates maintenance data from field units for developing an Annual Maintenance Man-Hours data package. This package is provided to TRADOC for preparation of the Manpower Authorization Criteria, which is used to revise the Table of Organization and Equipment. Unneeded or obsolete equipment is scheduled for phase out or disposal. When adequate numbers of new equipment and spare parts are available, production may cease until further units are required.

APPENDIX A

Recently, according to the magazine AMC News, the Army changed its development test procedure to reduce duplicate testing. More reliance will be placed on contractor testing, and the Army's role will shift from that of independent tester to independent evaluator. The Army Materiel Systems Analysis Agency will perform the independent evaluation for the Army. The Test and Evaluation Command will become more of a service organization, providing facilities and expertise and performing test services for the government and its contractors. Contractor data from the Research and Development Acceptance Test will be validated to determine whether additional testing is necessary.

DISTRIBUTION

COMMANDER
US ARMY MATERIEL DEVELOPMENT
AND READINESS COMMAND
5001 EISENHOWER AVENUE
ALEXANDRIA, VA 22333
ATTN DRCRD, RES, DEV,
& ENGR DIRECTORATE
ATTN DRCRD-WB, JOHN F. CORRIGAN
ATTN TECHNICAL LIBRARY
ATTN DRCPM

OFC, CHIEF OF RESEARCH & DEVELOPMENT
USA RSCH & DEV GROUP (EUROPE)
BOX 15
FPR NEW YORK 09510
ATTN LTC EDWARD E. CHICK
CHIEF, MATERIALS BRANCH

COMMANDER
USA ARMAMENTS COMMAND
ROCK ISLAND, IL 61201
ATTN DRSAR-ASF, FUZE DIV
ATTN DRSAR-RDF, SYS DEV DIV - FUZES
ATTN DRSAR-RDS

COMMANDER
USA MISSILE & MUNITIONS
CENTER & SCHOOL
REDSTONE ARSENAL, AL 35809
ATTN ATSK-CTD-F
ATTN ATSK-CTD

ASSISTANT TO THE SECRETARY OF DEFENSE
ATOMIC ENERGY
WASHINGTON, DC 20301
ATTN DOCUMENT CONTROL

DIRECTOR
DEFENSE ADVANCED RSCH PROJ AGENCY
ARCHITECT BUILDING
1400 WILSON BLVD.
ARLINGTON, VA 22209
ATTN AD/E&PS GEORGE H. HALMEIER

DEFENSE COMMUNICATION ENGINEER CENTER
1860 WIEHLE AVENUE
RESTON, VA 22090
ATTN CODE R720, C. STANS8ERRY
ATTN CODE R410, JAMES W. MCLEAN
ATTN CODE R320, C. W. BERGMAN
ATTN CODE R400

DIRECTOR
DEFENSE COMMUNICATIONS AGENCY
WASHINGTON, DC 20305
ATTN CODE 540.5
ATTN CODE 430
ATTN CODE 930, MONTE I. BURGETT, FR

DEFENSE DOCUMENTATION CENTER
CAMERON STATION, BUILDING 5
ALEXANDRIA, VA 22314
ATTN TC-TCA, (12 COPIES)

COMMANDER
DEFENSE ELECTRONIC SUPPLY CENTER
1507 WILMINGTON PIKE
DAYTON, OH 45401
ATTN TECH LIB

COMMANDER
DEFENSE ELECTRONIC SUPPLY CENTER
DAYTON, OH 45444
ATTN DESC-EQE, RAYMOND GRILLMEIER

DIRECTOR
DEFENSE INTELLIGENCE AGENCY
WASHINGTON, DC 20301
ATTN OI-70, MR. EDWARD OFARRELL
ATTN TECHNICAL LIBRARY

DIRECTOR
DEFENSE NUCLEAR AGENCY
WASHINGTON, DC 20305
ATTN RATN
ATTN OOST
ATTN PETER HAAS, DEP. DIR,
SCIENTIFIC TECHNOLOGY
ATTN RAEV/MAJ W. ADAMS/
MAJ O. WILSON (2 COPIES)
ATTN STTL TECH LIBRARY
ATTN STSI ARCHIVES
ATTN STVL
ATTN RAEV/CPT R. STEAD/
CPT R. OAVIS (2 COPIES)

DIR OF DEFENSE RSCH & ENGINEERING
DEPARTMENT OF DEFENSE
WASHINGTON, DC 20301
ATTN DD/S&SS

HEADQUARTERS
EUROPEAN COMMAND
J-5
APO NEW YORK 09128
ATTN TECHNICAL LIBRARY

COMMANDER
FIELD COMMAND
DEFENSE NUCLEAR AGENCY
KIRTLAND AFB, NM 87115
ATTN FCPR
ATTN FCSM-F3 CDR SMITH

DIRECTOR
INTERSERVICE NUCLEAR WEAPONS SCHOOL
KIRTLAND AFB, NM 87115
ATTN TECH LIB
ATTN DOCUMENT CONTROL

DIRECTOR
JOINT STRATEGIC TARGET PLANNING
STAFF, JCS
OFFUTT AFB
OMAHA, NB 68113
ATTN JLTW-2
ATTN JPST
ATTN JSAS, MAJ MICHAEL F. BARAN

CHIEF
LIVERMORE DIVISION, FIELD COMMAND ONA
LAWRENCE LIVERMORE LABORATORY
P.O. BOX 808
LIVERMORE, CA 94550
ATTN FCPRL

NATIONAL COMMUNICATIONS SYSTEM
OFFICE OF THE MANAGER
WASHINGTON, DC 20305
ATTN NCS-TS, CHARLES D. BODSON

COMMANDER
NATIONAL MILITARY COMD SYS SUPPORT CTR
PENTAGON
WASHINGTON, DC 20301
ATTN PAUL COLMAN MD718

DIRECTOR
NATIONAL SECURITY AGENCY
FT. GEORGE G. MEADE, MO 20755
ATTN O. O. VAN GUNTEN-R-425
ATTN O. VINCENT
ATTN P. OeBOY
ATTN E. BUTALA
ATTN R233, LTC J. BOHREN

OJCS/J-6
THE PENTAGON
WASHINGTON, DC 20301
ATTN J-6, ESO-2
ATTN J-3 RDTA BR WWMCCS PLANS DIV

DEPT OF ARMY
DEPUTY CHIEF OF STAFF FOR
OPERATIONS & PLANS
WASHINGTON, DC 20310
ATTN DAMO-SSN, NUCLEAR PLANS
AND POLICY

DIRECTOR
TELECOMMUNICATIONS & COMD & CON SYS
WASHINGTON, DC 20301
ATTN OEP ASST SEC SYS

COMMANDER-IN-CHIEF
US EUROPEAN COMMAND, JCS
APO NEW YORK 09128
ATTN TECHNICAL LIBRARY

WEAPONS SYSTEMS EVALUATION GROUP
400 ARMY NAVY DRIVE
ARLINGTON, VA 22202
ATTN DOCUMENT CONTROL

COMMANDER
USA AVIATION SYSTEMS COMMAND
P.O. BOX 209, MAIN OFFICE
ST. LOUIS, MO 63166
ATTN AMDRV-R-RP/MR. CONROY

DIRECTOR
8MD ADVANCED TECH CTR
HUNTSVILLE OFFICE
PO BOX 1500
HUNTSVILLE, AL 35807
ATTN TECH LIB
ATTN BMDATC-O, F. HOKE
ATTN 8MDATC-M, B. KELLEY
ATTN BMDATC-M, M. WHITFIELD
ATTN BMDATC-M, R. RIVIERE

CHIEF OF RES, DEV & ACQUISITION
DEPARTMENT OF THE ARMY
WASHINGTON, DC 20310
ATTN DAMA-CSM-N, LTC G. T. OGOEN

DEPARTMENT OF THE ARMY
OFFICE CHIEF OF ENGINEERS
PUBLICATIONS DEPARTMENT
890 SOUTH PICKETT ST
ALEXANDRIA, VA 22304
ATTN OAEN-MCE-D, HAROLO H. MCCAULEY

DISTRIBUTION (CONT'D)

COMMANDER
PICATINNY ARSENAL
DOVER, NJ 07B01
ATTN SARPA-ND-D-B, EDWARD J. ARBER
ATTN SARPA-ND-C-E, AMINA NORDIO
ATTN SARPA-ND-D-C-2
ATTN SARPA-ND-W (SMUPA)
ATTN HYMAN POSTERNAK
ATTN SARPA-ND-DA-4
ATTN SARPA-TN, BURTON V. FRANKS (SMUPA)
ATTN SARPA-TS-I-E, ABRAHAM GRINOCH
ATTN SARPA-ND-N
ATTN SMUPA-ND-N-E
ATTN SARPA-AD-E-C-3/MR. SOKOL

COMMANDER
REDSTONE SCIENTIFIC INFORMATION CTR
US ARMY MISSILE COMMAND
REDSTONE ARSENAL, AL 35809
ATTN DRSMI-RBD, CLARA T. ROGERS

COMMANDER
TRASANA
WHITE SANDS MISSILE RANGE, NM 88002
ATTN ATAA-EAC, FRANCIS N. WINANS

PROJ MGR
US ARMY TACTICAL COMM SYS
FT. MONMOUTH, NJ 07703
ATTN DRCPM-ATC/COL DOBBINS

COMMANDER
US ARMY ARMOR CENTER
FORT KNOX, KY 40121
ATTN TECHNICAL LIBRARY
ATTN ATSAR-CD-MS
ATTN ATSB-CD

US ARMY AIR DEFENSE SCHOOL
FT. BLISS, TX 79916
ATTN ATSA-CTC-SC
ATTN ATSA-TE-CSM
ATTN ATSA-CD

DIRECTOR
US ARMY BALLISTIC RESEARCH LABORATORIES
ABERDEEN PROVING GROUND, MD 21005
ATTN TECH LIB, EDWARD BAICY
ATTN DRXBR-AM, W. R. VAN ANTWERP
ATTN DRXBR-VL, JOHN W. KINCH
ATTN DRXBR-VL ROBERT L. HARRISON
ATTN DRXBR-X JULIUS J. MESZAROS

US ARMY COMBINED ARMS COMBAT DEVELOPMENTS ACTIVITY
FT. LEAVENWORTH, KS 66027
ATTN ATCACF-S
ATTN ATCACA-E
ATTN ATCACS-P

COMMANDER
US ARMY COMMUNICATIONS CMD
C-E SERVICES DIVISION
WASHINGTON, DC 20310
ATTN CEEO-7, WESLEY T. HEATH JR.
ATTN CE SERVICES DIVISION

COMMANDER
US ARMY COMMUNICATIONS COMMAND
FT. HUACHUCA, AZ B5613
ATTN ACC-FD-M, LAWRENCE E. CORK
ATTN ACC-OPS-SM/COL KING

COMMANDER
US ARMY COMMUNICATIONS ELECTRONICS ENGINEERING INSTALLATION AGENCY
FT. HUACHUCA, AZ B5613
ATTN ACCC-CED-STS

COMMANDER
US ARMY COMMUNICATIONS COMMAND
COMBAT DEVELOPMENT DIVISION
FT. HUACHUCA, AZ 85613
ATTN ACCM-TD-A, LIBRARY

CHIEF
US ARMY COMMUNICATIONS SYSTEMS AGENCY
FORT MONMOUTH, NJ 07703
ATTN SCCM-AD-SV (LIBRARY)

COMMANDER
US ARMY COMPUTER SYSTEMS COMMAND
FORT BELVOIR, VA 22060
ATTN TECHNICAL LIBRARY

COMMANDER
US ARMY ELECTRONICS COMMAND
FORT MONMOUTH, NJ 07703
ATTN DRSEL-CT-HDK, ABRAHAM E. COHEN
ATTN DRSEL-CE, R. PFEIFFER
ATTN DRSEL-TL-MD, GERHART K. GAULE
ATTN DRSEL-GG-TD, W. R. WERK
ATTN DRSEL-TL-ME, M. W. POMERANTZ
ATTN DRSEL-TL-IR, ROBERT A. FREIBERG
ATTN DRSEL-TL, E. T. HUNTER
ATTN DRSEL-WL-D
ATTN DRSEL-NL-D
ATTN DRESL-TN-EN, S. KRONENBERG
ATTN DRESL-RD-O, DR. McAFEE
ATTN DRSEL-RP-P/JOHN KUHLTHAU

COMMANDING OFFICER
US ARMY ELECTRONICS COMMAND
NIGHT VISION LABORATORY
FORT BELVOIR, VA 22060
ATTN TECHNICAL LIBRARY
ATTN CPT ALLAN S. PARKER

COMMANDER
US ARMY ELECTRONICS PROVING GROUND
FORT HUACHUCA, AZ 85613
ATTN STEEP-MT-M, GERALD W. DURBIN

PROJECT ENGINEER
US ARMY ENGINEER DIST HUNTSVILLE
PO BOX 1600, WEST STATION
HUNTSVILLE, AL 35807
ATTN F. SMITH

DIVISION ENGINEER
US ARMY ENGINEER DISTRICT, MISSOURI RIVER
P.O. BOX 103 DOWNTOWN STATION
OMAHA, NB 68101
ATTN MRDED-MC, MR. FLOYD L. HAZLETT

COMMANDER-IN-CHIEF
US ARMY EUROPE AND SEVENTH ARMY
APO NEW YORK 09403
ATTN ODCSE-E AEAGE-DI
ATTN TECHNICAL LIBRARY

COMMANDANT
US ARMY FIELD ARTILLERY SCHOOL
FORT SILL, OK 73503
ATTN ATSFA-CTD-ME, HARLEY MOBERG
ATTN TECH LIBRARY
ATTN ATSF-CD

US ARMY INFANTRY SCHOOL
NBC COMMITTEE, BROD
FT. BENNING, GA 31905
ATTN ASH-B

US ARMY LOGISTICS CENTER
FT. LEE, VA 23801
ATTN ATCL-CC

COMMANDER
US ARMY MATERIALS & MECHANICS RESEARCH CENTER
WATERTOWN, MA 02172
ATTN TECHNICAL LIBRARY
ATTN DRXMR-HH, JOHN F. DIGNAM
ATTN DRXMR-HH, A. HOFFMAN

DIRECTOR
US ARMY MATERIAL SYS ANALYSIS AGCY
US ARMY ABERDEEN R&D CENTER
ABERDEEN PROVING GROUND, MD 21005
ATTN DRXSY-CC, D. R. BARTHEL
ATTN TECHNICAL LIBRARY
ATTN DRXSY-DT/MR. ZONKER

COMMANDER
US ARMY MISSILE COMMAND
REDSTONE ARSENAL
HUNTSVILLE, AL 35809
ATTN DRSMI-RGP, HUGH GREEN
ATTN DRCPM-LCEX, HOWARD H. HENRIKSEN
ATTN DRCPM-PE-EA, WALLACE O. WAGNER
ATTN TECHNICAL LIBRARY
ATTN DRSI-RGP, VICTOR W. RUWE
ATTN DRSI-RGD
ATTN DRCPM-MDTI, CPT JOE A. SIMS
ATTN DRSMI-RRR/DR. F. GIBSON
ATTN ATSK-CTD-F

COMMANDER
US ARMY MOBILITY EQUIPMENT R & D CENTER
FORT BELVOIR, VA 22060
ATTN STSFB-MW, JOHN W. BOND, JR.
ATTN TECHNICAL LIBRARY

COMMANDER
US ARMY NATICK LAB
NATICK, MA 01760
ATTN STSNL-WR/MR T. MARTIN

COMMANDER
US ARMY NUCLEAR AGENCY
FORT BLISS, TX 79916
ATTN TECH LIB
ATTN ATCN-W COL DEVERILL (2 COPIES)

DISTRIBUTION (CONT'D)

COMMANDER
ROCK ISLAND ARSENAL
ROCK ISLAND, IL 61201
ATTN SARRI-LR/MR W. McGARVEY

COMMANDER
US ARMY SATELLITE COMM AGENCY
FT. MONMOUTH, NJ 07703
ATTN DRCPM-5C-SB/MR P. KENNEDY
ATTN DRCPM-SA/MR. MARESCA
ATTN DRCPM-SA/V. CHEWEY

PROJ MGR
PERSHING SYSTEM
REDSTONE ARSENAL, AL 35809
ATTN DRCPM-PE/MR. J. PETTIT

PROJ MGR, SAM-D
REDSTONE ARSENAL, AL 35809
ATTN DRCPM-NEDI/MR. R. HASE

PROJ MGR
US ARMY TACTICAL COMM SYS
FT. MONMOUTH, NJ 07703
ATTN DRCPM-ATC/COL DOBBINS

PROJ MGR
AVIATION SYSTEMS INTEGRATION
USA AVIATION SYSTEMS COMMAND
ST. LOUIS, MO 63160

PROJ MGR
MULTI-SERVICE COMMUNICATIONS SYSTEMS
USA ELECTRONICS COMMAND
FT. MONMOUTH, NJ 07703

PROJ MGR
NAVIGATION CONTROL SYSTEMS
USA ELECTRONICS COMMAND
BLDG 2525
FT. MONMOUTH, NJ 07703

PROJ MGR
REMOTELY MONITORED BATTLEFIELD
SENSOR SYSTEMS
USA ELECTRONICS COMMAND
FT. MONMOUTH, NJ 07703

COMMANDER
US ARMY SECURITY AGENCY
ARLINGTON HALL STATION
4000 ARLINGTON BLVD
ARLINGTON, VA 22212
ATTN IARD-T, DR. R. H. BURKHARDT
ATTN TECHNICAL LIBRARY

COMMANDANT
US ARMY SOUTHEASTERN SIGNAL SCHOOL
FORT GORDON, VA 30905
ATTN ATSO-CTD-CS, CPT G. M. ALEXANDER
ATTN TECH LIBRARY
ATTN ATSN-CTG
ATTN ATSO-CTD/MR. MANNELL

PROJECT MANAGER
US ARMY TACTICAL DATA SYSTEMS
FORT MONMOUTH, NJ 07703
ATTN TECH LIBRARY
ATTN DWAINE B. HUEWE
ATTN DRCPN-TDS-SD
ATTN DRCPN-TDS/MR. S. PELOSI

COMMANDER
US ARMY TANK AUTOMOTIVE COMMAND
WARREN, MI 48089
ATTN AMSTA-RHM, ILT PETER A. HASEK
ATTN TECH LIBRARY

PROGRAM MANAGER
XM-1 TANK SYS
28150 DeQUIDRE
NATICK, MI 01760
ATTN DRCPM-GCM-SW/MR. WOOLCOT
ATTN DRCPM-GCM-SW/R. SLAUGHTER

COMMANDER
US ARMY TEST AND EVALUATION COMMAND
ABERDEEN PROVING GROUND, MD 21005
ATTN AMSTE-EL, R. I. KOLCHIN
ATTN AMSTE-NB, R. R. GALASSO
ATTN TECHNICAL LIBRARY
ATTN COL GREGORY

COMMANDER
US ARMY TRAINING AND DOCTRINE COMMAND
FORT MONROE, VA 23651
ATTN TECH LIBRARY
ATTN ATORI-OP-SD
ATTN ATCD-PM-S

COMMANDER
WHITE SANDS MISSILE RANGE
WHITE SANDS MISSILE RANGE, NM 8B002
ATTN TECHNICAL LIBRARY
ATTN STEWS-TE-NT
ATTN STEWS-TE-AN/MR. A DeLaPAZ

CRD
USA FOREIGN SCIENCE & TECHNOLOGY
CENTER, FEDERAL OFFICE BLDG
CHARLOTTESVILLE, VA 20901

CRD
USA PROCUREMENT RESEARCH OFFICE
FT. LEE, VA 23B01

DEFENSE SYSTEMS MANAGEMENT SCHOOL
FT. BELVOIR, VA 22060
ATTN MR. PURNELL

PM
MOBILE ELECTRIC POWER
7500 BACKLICK RD
SPRINGFIELD, VA 22150

PM
SANG
5001 EISENHOWER AVENUE
ALEXANDRIA, VA 22333
ATTN DRCPM-NG

PM
CANNON ARTILLERY WEAPONS SYSTEMS
US ARMY ARMAMENT COMMAND
ROCK ISLAND, IL 61201

PM
SAFEGUARD MUNITIONS
PICATINNY ARSENAL
DOVER, NJ 07801

PM
SELECTED AMMUNITION
PICATINNY ARSENAL
DOVER, NJ 07B01

PM
SINGLE CHANNEL GROUND AND
AIRBORNE RADIO SUBSYSTEM
US ARMY ELECTRONICS COMMAND
FT. MONMOUTH, NJ 07703

PM
DRAGON
US ARMY MISSILE COMMAND
REDSTONE ARSENAL, AL 35809

PM
HELLFIRE MISSILE SYSTEM
US ARMY MISSILE COMMAND
REDSTONE ARSENAL, AL 35809

PM
HIGH ENERGY LASER SYSTEM
US ARMY MISSILE COMMAND
REDSTONE ARSENAL, AL 35B09

PM
KUWAIT
US ARMY MISSILE COMMAND
REDSTONE ARSENAL, AL 35809

PM
STINGER
US ARMY MISSILE COMMAND
REDSTONE ARSENAL, AL 35809

PM
US ROLAND
US ARMY MISSILE COMMAND
REDSTONE ARSENAL, AL 35B09

PM
FAMECE
FT. BELVOIR, VA 22060

PM
ADVANCED ATTACK HELICOPTER
12TH & SPRUCE STS
ST LOUIS, MO 63160
ATTN DRCPM-AAH/MR ROMANO

US AMC INFANTRY R&D LIAISON OFFICE
DEPARTMENT OF THE ARMY
FT. BENNING, GA 31905
ATTN DRCLR (COL TULLY)

CRD
US ARMY CONCEPTS ANALYSIS AGENCY
BETHESDA, MD 20014

HQ
MASSTER
FT. HOOD, TX 76544

US ARMY AVIATION CENTER & FT. RUCKER
REDSTONE ARSENAL, AL 35809
ATTN ATZQ-D

US ARMY ORDNANCE CENTER & SCHOOL
ABERDEEN PROVING GROUND, MD 21005
ATTN ATSI-CTD

DISTRIBUTION (CONT'D)

US ARMY INTELLIGENCE CENTER & SCHOOL
FT. HUACHUCA, AZ 85613
ATTN ATSI-CTD

CRD
US ARMY TRADOC SYSTEMS
ANALYSIS ACTIVITY
FT. MONROE, VA 23605

COMDT
US ARMY ENGINEER SCHOOL
FT. BELVOIR, VA 22060
ATTN ATSE-CDT

US ARMY INFANTRY SCHOOL
FT. BENNING, GA 31905
ATTN ATSA-CD

US ARMY INSTITUTE FOR MILITARY
ASSISTANCE
FT. BRAGG, NC 28307
ATTN ATSU-CTD

CHIEF OF NAVAL OPERATIONS
NAVY DEPARTMENT
WASHINGTON, DC 20350
ATTN CODE 604C3, ROBERT PIACESI

CHIEF OF NAVAL RESEARCH
DEPARTMENT OF THE NAVY
ARLINGTON, VA 22217
ATTN TECHNICAL LIBRARY
ATTN CODE 427
ATTN CODE 464, THOMAS P. QUINN
ATTN DR. DAVID LEWIS

OFFICER-IN-CHARGE
CIVIL ENGINEERING LABORATORY
NAVAL CONSTRUCTION BATTALION CENTER
FORT HUENEME, CA 93041
ATTN CODE L31

COMMANDER
NAVAL AIR SYSTEMS COMMAND
HEADQUARTERS
WASHINGTON, DC 21360
ATTN TECH LIB
ATTN LCDR HUGO HARDT (AIR-350-F)

COMMANDING OFFICER
NAVAL AMMUNITION DEPOT
CRANE, IN 47522
ATTN TECHNICAL LIBRARY
ATTN CODE 7024, JAMES L. RAMSEY
(25 COPIES)
ATTN CODE 7024, RON PEASE

COMMANDER
NAVAL ELECTRONIC SYSTEMS COMMAND
HEADQUARTERS
WASHINGTON, DC 20360
ATTN TECH LIB
ATTN PME117-215A, GUNTER BRUNHART
ATTN PME 117-21
ATTN PME 117-T
ATTN CODE 5032 CHAS. W. NEILL
ATTN CODE 503/C FRANK BERG

COMMANDER
NAVAL ELECTRONICS LABORATORY CENTER
SAN DIEGO, CA 92152
ATTN CODE 2400, S. W. LICHTMAN
ATTN CODE 2200 1, VERNE E. HILDEBRAND
ATTN CODE 3100, E. E. MCCOWN

COMMANDING OFFICER
NAVAL INTELLIGENCE SUPPORT CENTER
4301 SUITLAND ROAD, BLDG 5
WASHINGTON, DC 20390
ATTN TECHNICAL LIBRARY

SUPERINTENDENT
NAVAL POSTGRADUATE SCHOOL
MONTEREY, CA 93940
ATTN CODE 2124, TECH RPTS LIBRARIAN

DIRECTOR
NAVAL RESEARCH LABORATORY
WASHINGTON, DC 20375
ATTN CODE 6631, JAMES C. RITTER
ATTN CODE 4004, EMANUAL L. BRANCATO
ATTN CODE 2027, TECH LIB
ATTN CODE 7701, JACK D. BROWN
ATTN CODE 7706, JAY P. BORIS
ATTN CODE 464, R. GRACEN JOINER
ATTM CODE 6600, B. FARADAY
ATTN CODE 6600, E. WOLICKI
ATTN CODE 6600, N. WILSEY
ATTN CODE 6600, V. CAROSELLA
ATTN CODE 6600, R. WENZEL

COMMANDER
NAVAL SEA SYSTEMS COMMAND
NAVY DEPARTMENT
WASHINGTON, DC 20362
ATTN SEA-9931, RILEY B. LANE
ATTN SEA-9931, SAMUEL A. BARHAM

COMMANDER
NAVAL SHIP ENGINEERING CENTER
CENTER BUILDING
HYATTSVILLE, MD 20782
ATTN CODE 6174D2, EDWARD F. DUFFY

COMMANDER
NAVAL SURFACE WEAPONS CENTER
WHITE OAK, SILVER SPRING, MD 20910
ATTN CODE 730, TECH LIB
ATTN CODE 431, EDWIN B. DEAN
ATTN CODE 1224, NAVY NUC PRGMS OFF
ATTN CODE 431, EDWIN R. RATHBURN
ATTN CODE 431, JOHN H. MALLOY
ATTN R. JENKINS
ATTN R. PARTAK
ATTN J. FRANKLIN
ATTN D. GILCREASE

COMMANDER
NAVAL SURFACE WEAPONS CENTER
DAHLGREN LABORATORY
DAHLGREN, VA 22448
ATTN CODE FUR, ROBERT A. AMADORI

COMMANDER
NAVAL TELECOMMUNICATIONS COMMAND
NAV TEL COM HEADQUARTERS
4401 MASSACHUSETTS AVE, NW
WASHINGTON, DC 20390
ATTN TECH LIB

COMMANDER
NAVAL UNDERSEA CENTER
SAN DIEGO, CA 92152
ATTN CODE 608, CLARENCE F. RANSTEDT

COMMANDER
NAVAL WEAPONS CENTER
CHINA LAKE, CA 93555
TTN CODE 533, TECHNICAL LIBRARY

COMMANDING OFFICER
NAVAL WEAPONS EVALUATION FACILITY
KIRTLAND AIR FORCE BASE
ALBUQUERQUE, NM 87117
ATTN LAWRENCE R. OLIVER
ATTN CODE ATG, MR. STANLEY

COMMANDING OFFICER
NAVY ASTRONAUTICS GROUP
POINT MUGU, CA 93042
ATTN TECH LIB

COMMANDING OFFICER
NUCLEAR WEAPONS TRAINING CENTER
PACIFIC
NAVAL AIR STATION, NORTH ISLAND
SAN DIEGO, CA 92135
ATTN CODE 50

DIRECTOR
STRATEGIC SYSTEMS PROJECT OFFICE
NAVY DEPARTMENT
WASHINGTON, DC 20376
ATTN SP2701, JOHN W. PITSENBERGER
ATTN NSP-2342, RICHARD L. COLEMAN
ATTN NSP-43, TECH LIB
ATTN NSP-230, DAVID GOLD
ATTN NSP-27331, PHIL SPECTOR

COMMANDER
US NAVAL COASTAL SYSTEMS LABORATORY
PANAMA CITY, FL 32401
ATTN TECH LIB

COMMANDER-IN-CHIEF
US PACIFIC FLEET
FPO SAN FRANCISCO 96610
ATTN DOCUMENT CONTROL

COMMANDER
ADC/DF
ENT AFB, CO 80912
ATTN DEEDS, JOSEPH C. BRANNAN

COMMANDER
ADC/XP
ENT AFB, CO 80912
ATTN XPQD, MAJ G. KUCH

COMMANDER
AERONAUTICAL SYSTEMS DIVISION, AFSC
WRIGHT-PATTERSON AFB, OH 45433
ATTN TECHNICAL LIBRARY
ATTN ASD-YH-EX

AF ARMAMENT LABORATORY, AFSC
EGLIN AFB, FL 32542
ATTN DLOSL-LIB

AF CAMBRIDGE RSCH LABS, AFSC
L. G. HANSCOM FIELD
BEDFORD, MA 01730
ATTN EMERY CORMIER
ATTN MAJ A. WILLOUGHBY
ATTN EDWARD A. BURKE

DISTRIBUTION (CONT'D)

AF WEAPONS LABORATORY, AFSC
KIRTLAND AFB, NM 87117
ATTN EL, MR. JOHN DARRAH
ATTN DYX, DONALD C. WUNSCH
ATTN SAT
ATTN ELA, LTC CUPKA
ATTN ELC, LTC DUDLEY
ATTN ELP, CHARLES E. BAUM
ATTN EL
ATTN SAS
ATTN SUL
ATTN ELA, J. P. CASTILO
ATTN EL (LIBRARY)
ATTN SAB
ATTN J. FERRY
ATTN P. VAIL
ATTN LTC WOOD
ATTN J. NICHOLS
ATTN MAJ R. COVELLO
ATTN B. WHITE
ATTN AFWL (SEEW)/J. SWEENEY
ATTN AFWL (SEEW)/E. A. CASIAS

AFTAC
PATRICK AFB, FL 32925
ATTN TECH LIB

AIR FORCE AVIONICS LABORATORY, AFSC
WRIGHT-PATTERSON AFB, OH 45433
ATTN TECH LIB
ATTN AFAL-TEA HANS J. HENNECKE
ATTN AFAL/AAA

HEADQUARTERS
AIR FORCE SYSTEMS COMMAND
ANDREWS AFB
WASHINGTON, DC 20331
ATTN TECHNICAL LIBRARY

COMMANDER
AIR UNIVERSITY
MAXWELL AFB, AL 36112
ATTN AUL/LSE-70-250

HEADQUARTERS
ELECTRONIC SYSTEMS DIVISION, (AFSC)
L. G. HANSCOM FIELD
BEDFORD, MA 01730
ATTN YWEI
ATTN YSEV, LTC DAVID C. SPARKS
ATTN DCKE LEWIS STAPLES
ATTN TECHNICAL LIBRARY
ATTN XRT, LTC JOHN M. JASINSKI

COMMANDER
FOREIGN TECHNOLOGY DIVISION, AFSC
WRIGHT-PATTERSON AFB, OH 45433
ATTN TD-BTA, LIBRARY
ATTN ETET, CAPT RICHARD C. HUSEMANN
ATTN FTD/PDJC

HQ USAF/RD
WASHINGTON, DC 20330
ATTN RDQPN

COMMANDER
OGDEN AIR LOGISTICS CENTER
HILL AFB, UT 84401
ATTN TECH LIB
ATTN MMEWM, ROBERT JOFFS

COMMANDER
ROME AIR DEVELOPMENT CENTER, AFSC
GRIFFISS AFB, NY 13441
ATTN EMTLD, DDC LIBRARY
ATTN RBAC, I. L. KRULAC
ATTN RBRM, JOSEPH B. BRAUER
(25 COPIES)
ATTN RBRM, CYLDE LANE
ATTN RADC-DDC/EARL SELOVER

COMMANDER
SACRAMENTO AIR LOGISTICS CENTER
MCCLELLAN AFB, CA 95652
ATTN TECHNICAL LIBRARY

SAMSO/DY
POST OFFICE BOX 92960
WORLDWAY POSTAL CENTER
LOS ANGELES, CA 90009
ATTN DYS, MAJ LARRY A, DARDA

SAMSO/MN
NORTON AFB, CA 92409
ATTN MNNH, CAPT B. STEWART
ATTN MNNH, CAPT MICHAEL V. BELL
ATTN MNNG, CAPT DAVID J. STROBEL

SAMSO/SK
POST OFFICE BOX 92960
WORLDWAY POSTAL CENTER
LOS ANGELES, CA 90009
ATTN SKF, PETER H. STADLER

SAMSO/YD
POST OFFICE BOX 92960
WORLDWAY POSTAL CENTER
LOS ANGELES, CA 90009
ATTN YDD, MAJ M. F. SCHNEIDER

COMMANDER IN CHIEF
STRATEGIC AIR COMMAND
OFFUTT AFB, NB 68113
ATTN NRI-STINFO LIBRARY
ATTN DEF, FRANK N. BOUSHA
ATTN XPFS, MAJ BRIAN STEPHAN
ATTN XPFS, CAPT DERAAD

544IES
OFFUTT AFB, NB 68113
ATTN RDPO, LT ALAN B. MERRILL

DIVISION OF MILITARY APPLICATION
US ENERGY RSCH & DEV ADMIN
WASHINGTON, DC 20545
ATTN TECHNICAL LIBRARY

EG&G, INC.
LOS ALAMOS DIVISION
PO BOX 809
LOS ALAMOS, NM 85544
ATTN L. DETCH

LOS ALAMOS SCIENTIFIC LABORATORY
P.O. BOX 1663
LOS ALAMOS, NM 87544
ATTN ARTHUR FREED
ATTN RICHARD L. WAKEFIELD
ATTN BRUCE W. NOEL
ATTN J. ARTHUR FREED

SANDIA LABORATORIES
LIVERMORE LABORATORY
PO BOX 969
LIVERMORE, CA 94550
ATTN TECHNICAL LIBRARY

SANDIA LABORATORIES
PO BOX 5800
ALBUQUERQUE, NM 87115
ATTN ORD 9353, R. L. PARKER
ATTN J. A. COOPER, 2126
ATTN GERALD W. BARR, 1114
ATTN ALBERT A. LEMIEUX
ATTN CHARLES N. VITTITOE
ATTN ELMER F. HARTMAN
ATTN ORG 2110, J. A. HOOD

US ENERGY RSCH & DEV ADMIN
ALBUQUERQUE OPERATIONS OFFICE
PO BOX 5400
ALBUQUERQUE, NM 87115
ATTN WSSB

UNION CARBIDE CORPORATION
HOLIFIELD NATIONAL LABORATORY
P.O. BOX X
OAK RIDGE, TN 37830
ATTN PAUL R. BARNES

UNIVERSITY OF CALIFORNIA
LAWRENCE LIVERMORE LABORATORY
PO BOX 808
LIVERMORE, CA 94550
ATTN HANS KRUGER, L-96
ATTN WILLIAM J. HOGAN, L-531
ATTN E. K. MILLER, L-156
ATTN LELAND C. LOQUIST
ATTN DONALD J. MEEKER, L-153
ATTN L-156, ROBERT A. ANDERSON
ATTN FREDERICK R. KOVAR, L-94
ATTN TERRY R. DONICH
ATTN JOSEPH E. KELLER, JR.

CENTRAL INTELLIGENCE AGENCY
ATTN: RD/SI RM 5G48, HQ BLDG
WASHINGTON, DC 20505
ATTN WILLIAM A. DECKER
ATTN TECHNICAL LIBRARY

ADMINISTRATOR
DEFENSE ELECTRIC POWER ADMINISTRATION
DEPARTMENT OF THE INTERIOR
INTERIOR SOUTH BLDG. 312
WASHINGTON, DC 20240
ATTN DOCUMENT CONTROL

DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS
WASHINGTON, DC 20234
ATTN TECHNICAL LIBRARY
ATTN M. BULLIS
ATTN J. FRENCH

COMMANDER
NAVAL ORDNANCE STA
INDIAN HEAD, MD 20910
ATTN CODE 502

DISTRIBUTION (CONT'D)

COMMANDER
NAVAL COMMAND CONTROL &
 COMMUNICATION DIVISION
3801 NEBRASKA AVE, NW
WASHINGTON, DC 20390
 ATTN BILL HUFF

COMMANDER
AIR FORCE COMMUNICATIONS SERVICE
RICHARD GEBAUR AFB, NY 13441
 ATTN EPEV/GERALD HARRIS

NASA
600 INDEPENDENCE AVENUE, SW
WASHINGTON, DC 20546
 ATTN CODE RFS GUID CEN & INFO SYS

NASA
LEWIS RESEARCH CENTER
21000 BROOKPARK ROAD
CLEVELAND, OH 44135
 ATTN LIBRARY

AEROJET ELECTRO-SYSTEMS CO. DIV.
AEROJET-GENERAL CORPORATION
P.O. BOX 296
AZUSA, CA 91702
 ATTN THOMAS D. HANSCOME, B170/D6711

AERONUTRONIC FORD CORPORATION
AEROSPACE & COMMUNICATIONS OPS
AERONUTRONIC DIVISION
FORD & JAMBOREE ROADS
NEWPORT BEACH, CA 92663
 ATTN E. R. PONCELET, JR.
 ATTN L. H. LINDER
 ATTN KEN C. ATTINGER

AERONUTRONIC FORD CORPORATION
WESTERN DEVELOPMENT LABORATORIES DIV
3939 FABIAN WAY
PALO ALTO, CA 94303
 ATTN N. T. MATTINGLEY, MS X22
 ATTN SAMUEL R. CRAWFORD, MS 531
 ATTN DONALD R. McHORROW MS G30
 ATTN EDWARD R. HAHN MS-X22

AEROSPACE CORPORATION
PO BOX 92957
LOS ANGELES, CA 90009
 ATTN C. B. PEARLSTON
 ATTN IRVING M. GARFUNKEL
 ATTN JULIAN REINHEIMER
 ATTN S. P. BOWER
 ATTN DONALD A. McPHERSON
 ATTN JOHN DITRE
 ATTN J. BENVENISTE

AVCO
GOVERNMENT PRODUCTS GROUP
201 LOWELL STREET
WILMINGTON, MA 01887
 ATTN RESEARCH LIBRARY, A830, RM 7201

BATTELLE MEMORIAL INSTITUTE
505 KING AVENUE
COLUMBUS, OH 43201
 ATTN DAVID A. DINGEE
 ATTN STOIAC

BELL AEROSPACE COMPANY
DIVISION OF TEXTRON, INC.
P.O. BOX 1
BUFFALO, NY 14240
 ATTN CARL B. SCHOCH, WEPS EFFECTS GP
 ATTN MARTIN A. HENRY

BENDIX CORPORATION, THE
RESEARCH LABORATORIES DIV
BENDIX CENTER
SOUTHFIELD, MI 48075
 ATTN MGR PROGM DEV, DONALD J. NIEHAUS

BENDIX CORPORATION, THE
GUIDANCE SYSTEMS DIVISION
TETERBORO, NJ 07608
 ATTN TECH LIB

BOEING COMPANY, THE
PO BOX 3707
SEATTLE, WA 98124
 ATTN HOWARD W. WICKLEIN, MS 17-11
 ATTN D. E. ISBELL
 ATTN DAVID DYE, MS 87-75
 ATTN DAVID KEMLE
 ATTN W. LANTZY
 ATTN ROBERT S. CALDWELL, 2R-00
 ATTN ITSU ARIMURA, MS 2R-00

BOOZ-ALLEN AND HAMILTON, INC.
106 APPLE STREET
NEW SHREWSBURY, NJ 07724
 ATTN R. J. CHRISNER

BROWN ENGINEERING COMPANY, INC.
CUMMINGS RESEARCH PARK
HUNTSVILLE, AL 35B07
 ATTN JOHN M, MCSWAIN, MS 18
 ATTN TECH LIB, MS12, P. SHELTON
 ATTN DAVID L. LAMBERT, MS 1B

BURROUGHS CORPORATION
FEDERAL AND SPECIAL SYSTEMS GROUP
CENTRAL AVE AND ROUTE 252
PO BOX 517
PAOLI, PA 29301
 ATTN ANGELO J. MAURIELLO
 ATTN S. E. GLUCK
 ATTN ROBERT L. DAVIS, RM G321

CHARLES STARK DRAPER LABORATORY INC.
68 ALBANY STREET
CAMBRIDGE, MA 02139
 ATTN KENNETH FERTIG
 ATTN PAUL R. KELLY

CINCINNATI ELECTRONICS CORPORATION
2630 GLENDALE - MILFORD ROAD
CINCINNATI, OH 45241
 ATTN C. R. STUMP

COMPUTER SCIENCES CORPORATION
P.O. BOX 530
6565 ARLINGTON BLVD
FALLS CHURCH, VA 22046
 ATTN TECH LIB

COMPUTER SCIENCES CORPORATION
201 LA VETA DRIVE, NE
ALBUQUERQUE, NM 87108
 ATTN RICHARD H. DICKHAUT

DIKEWOOD CORPORATION, THE
1009 BRADBURY DRIVE, SE
UNIVERSITY RESEARCH PARK
ALBUQUERQUE, NM B7106
 ATTN L. WAYNE DAVIS
 ATTN K. LEE

EFFECTS TECHNOLOGY, INC.
5383 HOLISTER AVENUE
SANTA BARBARA, CA 93105
 ATTN EDWARD JOHN STEELE

EG&G, INC.
ALBUQUERQUE DIVISION
PO BOX 10218
ALBUQUERQUE, NM 87114
 ATTN TECHNICAL LIBRARY

ESL, INC.
495 JAVA DRIVE
SUNNYVALE, CA 94086
 ATTN WILLIAM METZER

FAIRCHILD CAMERA AND INSTRUMENT
 CORPORATION
464 ELLIS STREET
MOUNTAIN VIEW, CA 94040
 ATTN 2-233, MR. DAVID K. MYERS

FAIRCHILD INDUSTRIES, INC.
SHERMAN FAIRCHILD TECHNOLOGY CENTER
20301 CENTURY BOULEVARD
GERMANTOWN, MD 20767
 ATTN LEONARD J. SCHREIBER
 ATTN MGR CONFIG DATA & STANDARDS

GARRETT CORPORATION
9851 SEPULVEDA BLVD.
LOS ANGELES, CA 90009
 ATTN ROBT. WEIR, DEPT. 93-9

GENERAL ELECTRIC COMPANY
SPACE DIVISION
VALLEY FORGE SPACE CENTER
P.O. BOX 8555
PHILADELPHIA, PA 19101
 ATTN JAMES P. SPRATT
 ATTN DANIEL EDELMAN
 ATTN DANTE M. TASCA
 ATTN JOHN R. GREENBAUM
 ATTN LARRY I. CHASEN
 ATTN JOSEPH C. PEDEN, CCF 8301

GENERAL ELECTRIC COMPANY
RE-ENTRY & ENVIRONMENTAL SYSTEMS DIV
PO BOX 7722
3198 CHESTNUT STREET
PHILADELPHIA, PA 19101
 ATTN JOHN W. PALCHEFSHY, JR.
 ATTN RAY E. ANDERSON

GENERAL ELECTRIC COMPANY
ORDNANCE SYSTEMS
100 PLASTICS AVENUE
PITTSFIELD, MA 01201
 ATTN JOSEPH J. REIDL

GENERAL ELECTRIC COMPANY
WASHINGTON OFFICE
777 14TH STREET NW, WYATT BUILDING
WASHINGTON, DC 20005
 ATTN DASIAC, WILLIAM ALFONTE

DISTRIBUTION (CONT'D)

GENERAL ELECTRIC COMPANY
TEMPO-CENTER FOR ADVANCED STUDIES
816 STATE STREET (PO DRAWER QQ)
SANTA BARBARA, CA 93102
ATTN DASIAC, M. ESPIG
ATTN ROYDEN R. RUTHERFORD

GENERAL ELECTRIC COMPANY
PO BOX 1122
SYRACUSE, NY 13201
ATTN CSP 6-7, RICHARD C. FRIES
ATTN CSP 0-7, L. H. DEE

GENERAL ELECTRIC COMPANY
AIRCRAFT ENGINE GROUP
EVENDALE PLANT
CINCINNATI, OH 45215
ATTN JOHN A. ELLERHORST, E2

GENERAL ELECTRIC COMPANY
AEROSPACE ELECTRONICS SYSTEMS
FRENCH ROAD
UTICA, NY 13503
ATTN CHARLES M. HEWISON, DROP 624
ATTN W. J. PATTERSON, DROP 233

GENERAL ELECTRIC COMPANY
PO BOX 5000
BINGHAMTON, NY 13302
ATTN DIVID W. PEPIN, DROP 160

GENERAL RESEARCH CORPORATION
P.O. BOX 3587
SANTA BARBARA, CA 93105
ATTN JOHN ISE, JR.
ATTN ROBERT D. HILL

GENERAL RESEARCH CORPORATION
WASHINGTON OPERATIONS
WESTGATE RESEARCH PARK
7655 OLD SPRINGHOUSE ROAD
MCLEAN, VA 22101
ATTN PAUL J. KRAMER
ATTN DAVID K. OSIAS

GRUMMAN AEROSPACE CORPORATION
SOUTH OYSTER BAY ROAD
BETHPAGE, NY 11714
ATTN JERRY ROGERS, DEPT 533

GTE SYLVANIA, INC.
ELECTRONICS SYSTEMS GRP-EASTERN DIV
77 A STREET
NEEDHAM, MA 02194
ATTN LEONARD L. BLAISDELL
ATTN JAMES A. WALDON

GTE SYLVANIA, INC.
189 B STREET
NEEDHAM HEIGHTS, MA 02194
ATTN DAVID P. FLOOD
ATTN CHARLES H. RAMSBOTTOM
ATTN A S M DEPT, S. E. PERLMAN
ATTN COMM SYST DIV, EMIL P. MOTCHOK
ATTN HERBERT A. ULLMAN
ATTN H & V GROUP, MARIO A. NUREFORA
ATTN PAUL B. FREDRICKSON

HARRIS CORPORATION
HARRIS SEMICONDUCTOR DIVISION
P.O. BOX 883
MELBOURNE, FL 32901
ATTN C. F. DAVIS, MS 17-220
ATTN WAYNE E. ABARE, MS 16-111
ATTN T. CLARK, MS 4040

HONEYWELL INCORPORATED
GOVERNMENT AND AERONAUTICAL
PRODUCTS DIVISION
2600 RIDGEWAY PARKWAY
MINNEAPOLIS, MN 55413
ATTN RONALD R. JOHNSON, A1622
ATTN R. J. KELL, MS S2572

HONEYWELL INCORPORATED
AEROSPACE DIVISION
13350 US HIGHWAY 19
ST. PETERSBURG, FL 33733
ATTN HARRISON H. NOBLE, MS 725-5A
ATTN MS 725-J, STACEY H. GRAFF

HUGHES AIRCRAFT COMPANY
CENTINELLA AVENUE & TEALE STREETS
CULVER CITY, CA 90230
ATTN M.S. D157, KEN WALKER
ATTN B. W. CAMPBELL, M.S. 6-E110
ATTN JOHN B. SINGLETARY, MS 6-D133

HUGHES AIRCRAFT COMPANY
SPACE SYSTEMS DIVISION
P.O. BOX 92919
LOS ANGELES, CA 90009
ATTN WILLIAM W. SCOTT, MS A1080
ATTN EDWARD C. SMITH, MS A620

IBM CORPORATION
ROUTE 17C
OWEGO, NY 13827
ATTN FRANK FRANKOVSKY

IIT RESEARCH INSTITUTE
ELECTROMAGNETIC COMPATABILITY
ANALYSIS CENTER
NORTH SEVERN
ANNAPOLIS, MD 21402
ATTN ACOAT

INSTITUTE FOR DEFENSE ANALYSES
400 ARMY-NAVY DRIVE
ARLINGTON, VA 22202
ATTN IO, LIBRARIAN, RUTH S. SMITH

IRT CORPORATION
7650 CONVOY COURT
SAN DIEGO, CA 92138
ATTN R. L. MERTZ
ATTN ERIC P. WENAAS
ATTN RALPH H. STAHL
ATTN J. AZAREWICZ
ATTN JAMES NABOR

INTERNATIONAL TELEPHONE AND
TELEGRAPH CORPORATION
500 WASHINGTON AVENUE
NUTLEY, NJ 07110
ATTN DEF SP GROUP, J. GULACK
ATTN ALEXANDER I. RICHARDSON

ION PHYSICS CORPORATION
SOUTH BEDFORD STREET
BURLINGTON, MA 01803
ROBERT D. EVANS

JET PROPULSION LAB
CALIFORNIA INSTITUTE OF TECHNOLOGY
4800 OAK GROVE DR
PASADENA, CA 91103
ATTN ALAN G. STANLEY

JOHNS HOPKINS UNIVERSITY
APPLIED PHYSICS LABORATORY
JOHNS HOPKINS ROAD
LAUREL, MD 20810
ATTN PETER E. PARTRIDGE

KAMAN SCIENCES CORPORATION
P.O. BOX 7463
COLORADO SPRINGS, CO 80933
ATTN DONALD H. BRYCE
ATTN W. FOSTER RICH
ATTN WALTER E. WARE

LITTON SYSTEMS, INC.
GUIDANCE & CONTROL SYSTEMS DIVISION
5500 CANOGA AVENUE
WOODLAND HILLS, CA 91364
ATTN VAL J. ASHBY, MS 67
ATTN JOHN P. RETZLER

LOCKHEED MISSILES AND SPACE COMPANY, INC.
P.O. BOX 504
SUNNYVALE, CA 94088
ATTN G. F. HEATH, D/81-14
ATTN D. M. TELLER, EPT 81-01
ATTN BENJAMIN T. KIMURA,
DEPT 81-14, BLDG 154
ATTN H. SCHNEEMANN ORG 81-64
ATTN EDWIN A. SMITH, DEPT 85-85

MARTIN MARIETTA AEROSPACE
ORLANDO DIVISION
P.O. BOX 5837
ORLANDO, FL 32805
ATTN WILLIAM W. MRAS, MP-413
ATTN JACK M. ASHFORD, MP-537
ATTN HAROLD CATES

MARTIN MARIETTA CORPORATION
DENVER DIVISION
PO BOX 179
DENVER, CO 80201
ATTN J. E. GOODWIN, MAIL 0452
ATTN PAUL G. KASE, MAIL 8203
ATTN BEN T. GRAHAM, MS PO-454

MAXWELL LABORATORIES, INC.
9244 BALBOA AVENUE
SAN DIEGO, CA 92123
ATTN VICTOR FARGO

MCDONNELL DOUGLAS CORPORATION
POST OFFICE BOX 516
ST. LOUIS, MO 63166
ATTN TOM ENDER

MCDONNELL DOUGLAS CORPORATION
5301 BOLSA AVENUE
HUNTINGTON BEACH, CA 92647
ATTN W. R. SPARK, MS 13-3
ATTN STANLEY SCHNEIDER
ATTN A. P. VENDITT, MS 11-1

MCDONNELL DOUGLAS CORPORATION
PO BOX 1850
ALBUQUERQUE, NM 87103
ATTN THOMAS J. LUNDREGAN

GEORGE C. MESSENGER
1501 SERENADE TERRACE
CORONA del MAR, CA 92625

MISSION RESEARCH CORPORATION
735 STATE STREET
SANTA BARBARA, CA 93101
ATTN CONRAD L. LONGMIRE
ATTN WILLIAM C. HART

MISSION RESEARCH CORPORATION
P.O. BOX 8693, STATION C
ALBUQUERQUE, NM 87108
ATTN LARRY D. SCOTT
ATTN DAVID E. MEREWETHER
ATTN J. ROGER HILL

MISSION RESEARCH CORPORATION
7650 CONVOY COURT
SAN DIEGO, CA 92138
ATTN V. A. J. VAN LINT
ATTN JAMES RAYMOND

MITRE CORPORATION, THE
ROUTE 62 AND MIDDLESEX TURNPIKE
P.O. BOX 208
BEDFORD, MA 01730
ATTN M. F. FITZGERALD

NATIONAL ACADEMY OF SCIENCES
2101 CONSTITUTION AVE, NW
WASHINGTON,DC 20418
ATTN DR. R. S. SHANE,
NAT MATERIALS ADVISORY BO
ATTN DR. D. MITCHELL

NORTHROP CORPORATION
ELECTRONIC DIVISION
1 RESEARCH PARK
PALOS VERDES PENINSULA, CA 92074
ATTN JOHN M. REYNOLDS
ATTN VINCENT R. DEMARTINO
ATTN BOYCE T. AHLPORT

NORTHROP CORPORATION
NORTHROP RESEARCH AND TECHNOLOGY CENTER
3401 WEST BROADWAY
HAWTHORNE, CA 92050
ATTN ORLIE L. CURTIS

NORTHROP CORPORATION
ELECTRONIC DIVISION
2301 WEST 120TH STREET
HAWTHORNE, CA 90250
ATTN JOSEPH D. RUSSO
ATTN PHILLIP EISENBERG

PHYSICS INTERNATIONAL COMPANY
2700 MERCED STREET
SAN LEANDRO, CA 94577
ATTN JOHN H. HUNTINGTON

PROCEDYNE CORPORATION
221 SOMERSET STREET
NEW BRUNSWICK, NJ 08903
ATTN PETER HOROWITZ

PULSAR ASSOCIATES, INC.
7911 HERSCHEL AVENUE
LA JOLLA, CA 92037
ATTN CARLETON JONES

R & D ASSOCIATES
PO BOX 9695
MARINA DEL REY, CA 90291
ATTN TECHNICAL LIBRARY
ATTN S. CLAY ROGERS
ATTN WILLIAM R. GRAHAM, JR.
ATTN CHARLES MO
ATTN WILLIAM J. KARZAS
ATTN RICHARD R. SCHAEFER
ATTN GERARD K. SCHLEGEL

RAND CORPORATION, THE
1700 MAIN STREET
SANTA MONICA, CA 90406
ATTN DR. CULLEN CRAIN

RAYTHEON COMPANY
HARTWELL ROAD
BEDFORD, MA 01730
ATTN GAJANAN H. JOSHI, RADAR SYS LAB

RATHEON COMPANY
528 BOSTON POST ROAD
SUDBURY, MA 01776
ATTN HAROLD L. FLESCHER
ATTN JAMES R. WECKBACK

RCA CORPORATION
GOVERNMENT & COMMERCIAL SYSTEMS
ASTRO ELECTRONICS DIVISION
PO BOX 800, LOCUST CORNER
PRINCETON, NJ 08540
ATTN GEORGE J. BRUCKER

RCA CORPORATION
GOVERNMENT & COMMERCIAL SYSTEMS
MISSILE & SURFACE RADAR DIVISION
MARNE HIGHWAY & BORTON LANDING RD
MOORESTOWN, NJ 08057
ATTN ANDREW L. WARREN

RCA CORPORATION
CAMDEN COMPLEX
FRONT & COOPER STREETS
CAMDEN, NJ 08012
ATTN E. VAN KEUREN, 13-5-2

ROCKWELL INTERNATIONAL CORPORATION
3370 MIROLOMA AVENUE
ANAHEIM, CA 92803
ATTN K. F. HULL
ATTN JAMES E. BELL, HA10
ATTN DONALD J. STEVENS, FA70

ROCKWELL INTERNATIONAL CORPORATION
5701 WEST IMPERIAL HIGHWAY
LOS ANGELES, CA 90009
ATTN T. B. YATES

SANDERS ASSOCIATES, INC.
95 CANAL STREET
NASHUA, NH 03060
ATTN M. L. AITEL NCA 1-3236

SCIENCE APPLICATIONS, INC.
PO BOX 277
BERKELEY, CA 94701
ATTN FREDERICK M. TESCHE

SCIENCE APPLICATIONS, INC.
1651 OLD MEADOW ROAD
MCLEAN, VA 22101
ATTN WILLIAM L. CHADSEY

SCIENCE APPLICATIONS, INC.
PO BOX 2351
LA JOLLA, CA 92038
ATTN LARRY SCOTT
ATTN J. ROBERT BEYSTER

SCIENCE APPLICATIONS, INC.
HUNTSVILLE DIVISION
2109 W. CLINTON AVENUE
SUITE 700
HUNTSVILLE, AL 35805
ATTN NOEL R. BYRN

SCIENCE APPLICATIONS, INC.
PO BOX 3507
ALBUQUERQUE, NM 87110
ATTN JAMES R. HILL
ATTN R. PARKINSON

SIMULATION PHYSICS, INC.
41 "B" STREET
BURLINGTON, MA 01803
ATTN JOHN R. UGLUM

SINGER COMPANY, THE
1150 MCBRIDE AVENUE
LITTLE FALLS, NJ 07424
ATTN IRWIN GOLDMAN, ENG MANAGEMENT

SPERRY RAND CORPORATION
UNIVAC DIVISION
DEFENSE SYSTEMS DIVISION
P.O. BOX 3525 MAIL STATION 1931
ST. PAUL, MN 55101
ATTN JAMES A. INDA, MS41T25

SPERRY RAND CORPORATION
MARCUS AVENUE
GREAT NECK, NY 11020
ATTN PAUL MARRAFFINO
ATTN CHARLES L. CRAIG EV

SPERRY RAND CORPORATION
SPERRY FLIGHT SYSTEMS DIVISION
P.O. BOX 21111
PHOENIX, AZ 85036
ATTN D. A. SCHOW, ROOM 104C
ATTN D. J. KEATING

DISTRIBUTION (CONT'D)

STANFORD RESEARCH INSTITUTE
333 RAVENSWOOD AVENUE
MENLOW PARK, CA 94025
ATTN WILLIAM C. TAYLOR

STANFORD RESEARCH INSTITUTE
306 WYNN DRIVE, N. W.
HUNTSVILLE, AL 35805
ATTN MACPHERSON MORGAN

SUNDSTRAND CORPORATION
4751 HARRISON AVENUE
ROCKFORD, IL 61101
ATTN DEPT 763SW, CURT WHITE

SYSTRON-DONNER CORPORATION
1090 SAN MIGUEL ROAD
CONCORD, CA 94518
ATTN GORDON B. DEAN

TEXAS INSTRUMENTS, INC.
P.O. BOX 6015
DALLAS, TX 75222
ATTN DONALD J. MANUS, MS 72

THE BDM CORPORATION
1920 ALINE AVE
VIENNA, VA 22180
ATTN TECHNICAL LIBRARY
ATTN JOSEPH BRADDOCK

THE BDM CORPORATION
PO BOX 9274
ALBUQUERQUE INTERNATIONAL
ALBUQUERQUE, NM 87119
ATTN ROBERT B. BUCHANAN
ATTN TECH LIB
ATTN WILLIAM ORUEN
ATTN T. H. NEIGHBORS
ATTN DAVID R. ALEXANDER
ATTN DAVID DURGIN

TRW SEMICONDUCTORS
DIVISION OF TRW, INC.
14520 AVIATION BLVD.
LAWNDALE, CA 90260
ATTN RONALD N. CLARKE

TRW SYSTEMS GROUP
ONE SPACE PARK
REDONDO BEACH, CA 90278
ATTN TECH INFO CENTER/S-1930
ATTN A. M. LIEBSCHUTZ R1-1162
ATTN AARON H. NAREVSKY, R1-2144
ATTN RICHARD H. KINGSLAND, R1-2154
ATTN JERRY I. LUBELL
ATTN LILLIAN D. SINGLETARY, R1/1070

SAN BERNARDINO OPERATIONS
PO BOX 1310
SAN BERNARDINO, CA 92402
ATTN JOHN E. DAHNKE

TRW SYSTEMS GROUP
PO BOX 368
CLEARFIELD, UT 84015
ATTN DONALD W. PUGSLEY

UNITED AIRCRAFT CORPORATION
HAMILTON STANDARD DIVISION
BRADLEY INTERNATIONAL AIRPORT
WINDSOR LOCKS, CT 06069
ATTN RAYMOND G. GIGUERE

VARIAN ASSOCIATES
611 HANSEN WAY
PALO ALTO, CA 94303
ATTN A-109, HOWARD R. JORY

WESTINGHOUSE ELECTRIC CORPORATION
DEFENSE AND ELECTRONIC SYSTEMS CENTER
P.O. BOX 1693
FRIENDSHIP INTERNATIONAL AIRPORT
BALTIMORE, MD 21203
ATTN HENRY P. KALAPACA, MS 3525

COMMANDER
HARRY DIAMOND LABORATORIES
2800 POWDER MILL RD
ADELPHI, MD 20783
ATTN MCGREGOR, THOMAS, COL, COMMANDING
OFFICER/FLYER, I.N./LANOIS, P.E./
SOMMER, H./CONRAD, E.E. (5 COPIES)
ATTN CARTER, W.W., DR., ACTING TECHNICAL
DIRECTOR/MARCUS, S.M. (2 COPIES)
ATTN KIMMEL, S., IO
ATTN CHIEF, 0021
ATTN CHIEF, 0022
ATTN CHIEF, LAB 100
ATTN CHIEF, LAB 200
ATTN CHIEF, LAB 300
ATTN CHIEF, LAB 400
ATTN CHIEF, LAB 500
ATTN CHIEF, LAB 600
ATTN CHIEF, DIV 700
ATTN CHIEF, DIV 800
ATTN CHIEF, LAB 900
ATTN CHIEF, LAB 1000
ATTN RECORD COPY, BR 041
ATTN HDL LIBRARY (3 COPIES)
ATTN CHAIRMAN, EDITORIAL COMMITTEE
ATTN CHIEF, 047
ATTN TECH REPORTS, 013
ATTN PATENT LAW BRANCH, 071
ATTN MCLAUGHLIN, P.W., 741
ATTN ROSADO, J. A., BR 230
ATTN BEILFUS, N. W., 240
ATTN SWETON, J. F., 1000
ATTN WONG, R., 1000
ATTN MILETTA, J. R., 1010
ATTN WIMENITZ, F. N., 0024
ATTN WYATT, W. T., JR., 1000
ATTN KLEBERS, J., 1000
ATTN GRAY, R. F., 1000
ATTN BOMBARDT, J., 1000
ATTN SPOHN, D., 1000
ATTN GAUL, JAMES, 0024
ATTN BALICKI, FREDERIC, 0024 (20 COPIES)
ATTN SWEENEY, WILLIAM, 210
ATTN RATTNER, S., 280
ATTN PRITCHARD, B., 280 (20 COPIES)
ATTN SELF, C. T., 280
ATTN KREY, K., 280
ATTN TRIMMER, P., 210
ATTN HALPIN, J., 280 (25 COPIES)

HARRY DIAMOND LABORATORIES (CONT'D)
ATTN SPICKLER, R., 280
ATTN ROTHSTEIN, M., 280
ATTN VALLIN, J., 280
ATTN WATSON, M., 280
ATTN SWIRCZYNSKI, J., 280
ATTN WICKLUND, J., 210
ATTN DANDO, J., 1010
ATTN CALDWELL, P., 290
ATTN AGEE, F. J., 1000
ATTN PFEFFER, R., 1000
ATTN GORNAK, G., 1000
ATTN PETTY, W., 1000
ATTN ZASTROW, K., 740
ATTN LIEBERMAN, S., 350
ATTN REODEN, M., 350
ATTN EISEN, H., 280