DOD-STD-1766A (USAF)
01 December 1986
SUPERSEDING DOD-STD-1766
01 March 1981

MILITARY STANDARD

NUCLEAR HARDNESS AND SURVIVABILITY PROGRAM REQUIREMENTS FOR ICBM WEAPON SYSTEMS

AMSC F3998 AREA ENVR

DISTRIBUTION STATEMENT A: Approved for Public Release. Distribution is Unlimited.

DEPARTMENT OF THE AIRFORCE
WASHINGTON, DC 20330

Nuclear Hardness and Survivability Program Requirements for ICBM Weapon Systems.

DOD-STD-1766A (USAF)

1. This Military Standard is approved for use by Headquarters Ballistic Missile Office (AFSC) Department of the Air Force, and is available for use by all Departments and Agencies of the Department of Defense.

2. Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: HQ Ballistic Missile Office/AWD, Norton AFB, CA 92409-6468, by using the self-addressed Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document, or by letter.

FOREWORD

This revision of DOD-STD-1766 constitutes a complete rewrite of the original version of 1 March 1981. Among the key features of this revision are the following:

a. The scope has been expanded to include the concept exploration, validation and demonstration, production and deployment phases in addition to the full scale development phase.

b. A new section on life cycle survivability requirements has been added to support the implementation of hardness assurance during the production and deployment phases and hardness maintenance/hardness surveillance during the operational phase.

c. A set of six new DIDs has been prepared to describe data items generated by this standard. Thses DIDs are identified in paragraph 6.2.

d. The entire text has been rewritten and reorganized to achieve greater clarity and internal coherence.

CONTENTS

1. SCOPE

1.1 Purpose. This standard defines nuclear hardness and survivability (NH&S) requirements and practices for use during the concept exploration, demonstration and validation, full scale development (FSD), production, and deployment phases of the acquisition life cycle of intercontinental ballistic missile (ICBM) weapon systems. It implements for the design, development, production, and initial deployment of ICBM weapon systems the NH&S policy established by Air Force Regulation (AFR) 80-38 (Management of the Air Force Systems Survivability Program) and Department of Defense Instruction (DoDI) 4245.4 (Acquisition of Nuclear-Survivable Systems).

1.2 Application. This standard, as tailored to the requirements of a program, is applicable to contractors engaged in the design and development, production, and deployment of aerospace vehicle equipment (AVE), operational support equipment (OSE), survivable real property installed equipment (RPIE), and facilities equipment configuration items and subsystems which have nuclear hardness requirements.

1.2.1 Tailoring. Department of Defense (DoD) policy is to selectively apply and tailor standardization documents to ensure their cost-effective use in the acquisition process. Individual requirements (sections, paragraphs or sentences) shall be evaluated to determine the extent to which they are suitable for a specific acquisition, and to identify modifications to ensure that each requirement achieves an optimal balance between need and cost. Tailoring of data requirements consists of the deletion of requirements from data item descriptions (DIDs). Each program office should carefully consider within DoD and Service guidelines the benefits and costs of imposing this standard on each specific acquisition. Contractors will be encouraged to propose specific application and tailoring of this document and related data requirements.

2. REFERENCED DOCUMENTS - Not applicable.

3. DEFINITIONS

3.1 Blast. Blast is one of the nuclear environments. It consists of a shock wave of air propagated outward from a nuclear explosion, in which the pressure increases sharply at the front and is accompanied by winds.

3.2 Circumvention and recovery. Circumvention and recovery (C&R) is an electronic mechanism which makes use of specially hardened circuitry to: (a) detect the presence of ionizing or electromagnetic radiation whose intensity exceeds an established set point; (b) protect stored data from alteration by erroneous writing; (c) provide resets for upset logic; (d) inhibit false inputs and false outputs; and (e) provide a controlled resumption of operation after the radiation has decreased below the set point and all circuits have recovered along with the reconstruction of critical parameter values which were lost during circumvention.

3.3 Debris. Debris is one of the nuclear environments. It consists of the material ejected from a crater and deposited in such a manner as to possibly preclude launch. Debris includes entrained material within the nuclear cloud (pebbles, dust, ice) which could damage or inhibit a flight system.

3.4 Electromagnetic pulse. Electromagnetic pulse (EMP) is one of the nuclear environments. It consists of transient electromagnetic energy generated by nuclear ionizing radiation interacting with the ambient environment. The electromagnetic energy produced by radiation interacting with the upper atmosphere is called high-altitude EMP, or HEMP. The electromagnetic energy produced by radiation interacting with the media surrounding or near a nuclear weapon detonation is called source-region EMP, or SREMP. The electromagnetic energy produced by radiation interacting with system hardware is called system-generated EMP, or SGEMP.

3.5 Hardening. Hardening refers to the use of design techniques that increase the ability of a system to withstand exposure to one or more effects of man-made hostile environments. In this standard, hardening always refers to nuclear hardening.

3.6 Hardness. Hardness is a measure of the ability of a system to withstand exposure to one or more effects of man-made hostile environments. In this standard, hardness always refers to nuclear hardness.

3.7 Hardness allocation. Hardness allocation is part of the initial hardness design process. It refers both to the activity and its outcome which a contractor undertakes to distribute, among the various hardware elements and levels of assembly that comprise his configuration item(s) (CI(s)), the stresses which the CI(s) will experience due to specified free-field nuclear environments.

3.8 Hardness assessment. Hardness assessment is a program of iterative and interactive hardness analyses and tests performed during the design and development activity to evaluate the hardness of the evolving design.

3.9 Hardness assurance. Hardness assurance is a program element of life cycle survivability. It refers to those activities performed to preserve system hardness during production and deployment so that the hardware produced and initially deployed will continue to satisfy the hardness requirements originally imposed on system design.

3.10 Hardness critical item. The concept of hardness critical item (HCI) has associated with it the following considerations:

a. An HCI is defined to be an item of hardware or software that satisfies one or more of the following rationales:

1. Functionally required hardware (i.e., hardware included in system design to accomplish any engineering requirement other than nuclear hardening) whose response to the specified nuclear environments would cause a degradation in system survivability unless additional provisions for hardness are included in item specification, design, manufacture, item selection process, etc.

2. Functionally required hardware or software identified or modified to also provide protection for the system or any of its elements against the specified nuclear environments.

3. Hardness dedicated hardware or software included in system design solely to help satisfy the specified hardness requirements.

4. Hardware items (at the level of application) to which a hardness critical process is applied.

5. A subassembly or higher level of assembly which contains one or more HCIs.

b. A complete HCI list for a given CI identifies the total means by which hardness has been explicitly incorporated within the design of that CI. A complete HCI list is therefore a critical ingredient in the capability to manage and preserve hardened configurations.

3.11 Hardness critical process. A hardness critical process (HCP) is any fabrication, manufacturing, assembly, installation, maintenance and repair, or other process or procedure which implements a hardness design feature.

3.12 Hardness design. Hardness design refers both to the process and end result of creating a design which satisfies specified or allocated hardness requirements. Hardness design must be accomplished without violating any other specified design requirement or constraint.

3.13 Hardness design feature. A hardness design feature is a design concept or approach which is used to accomplish hardness design, and which therefore supports the satisfaction of system hardness requirements.

3.14 Hardness design margin. Hardness design margin is a numerical measure of the hardness of a given hardware element, usually expressed as the ratio of the level of hardness attributed to the hardware element with respect to the specified hardness requirements assigned or allocated to that hardware element. The level of hardness attributed to a hardware element is usually based on specific test or analysis results or the application of relevant material/component characteristics data published in appropriate sources. The concept of hardness design margin applies to both transient upset and permanent damage responses.

3.15 Hardness fragility. Hardness fragility is a probabilistic measure of the capability of an item of hardware to withstand the nuclear-induced stresses imposed on it as a result of the detonation of a nuclear weapon. It is usually expressed as a plot of the probability, including confidence levels, that an item of hardware will fail to perform satisfactorily upon exposure to a given nuclear environment as a function of the magnitude of the applied nuclear environment or associated coupled stress. Hardness fragility is determined by analysis or test by some combination of these two activities. Hardness fragility data are used in support of system survivability evaluations.

3.16 Hardness maintenance. Hardness maintenance is a program element of life cycle survivability. It refers to those activities conducted to maintain and preserve the hardness of a deployed weapon system throughout its operational life.

3.17 Hardness qualification. Hardness qualification is the activity by which the contractor establishes to the satisfaction of the procuring agency that the production hardware that will be built to the approved hardened design will satisfy all specified hardness requirements. Hardness qualification is usually accomplished by hardness testing of first production hardware. Supporting analytic activity may also be required.

3.18 Hardness requirements. Hardness requirements refer to the specific nuclear environments and their associated magnitudes after exposure to which a given item of hardware must continue to function satisfactorily. Depending on system design, the hardware item may also be required to function during exposure to nuclear environments.

3.19 Hardness surveillance. Hardness surveillance is a program element of life cycle survivability. It consists of a program of periodic hardness tests and inspections of a deployed weapon system with the purpose of identifying in a timely manner any hardness related degradations that reduce the hardness of the fielded system. Such degradations may be due to aging, the effects of the ambient environment and continuous operation, and maintenance actions.

3.20 Hardness verification. Hardness verification is the activity by which the contractor establishes to the satisfaction of the procuring agency that the final hardened design for a given CI, as presented at the critical design review (CDR) for that CI, satisfies the specified hardness requirements. Hardness verification is accomplished by a review of existing hardness analysis and test data, and may be augmented, as required, by additional tests and analyses.

3.21 High-altitude electromagnetic pulse. High-altitude electromagnetic pulse (HEMP) is a particular type of EMP. It consists of transient electromagnetic energy generated by the interaction of nuclear ionizing radiation with the upper atmosphere and the earth's magnetic field, resulting in both an early-time freely propagating field and a late-time quasi-static field.

3.22 Intrinsic hardness. The intrinsic hardness of an item of hardware (at any assembly level up to system level) refers to the inherent capability of the hardware item to withstand exposure to a designated set of nuclear environments without the need for additional hardness design.

3.23 Life cycle survivability. Life cycle survivability (LCS) refers to that part of an overall system hardness program concerned with ensuring that a system which has been successfully designed to satisfy specified hardness requirements will continue to satisfy those requirements during system production and initial deployment and throughout its operational life. By definition, LCS has been divided into three major program elements. During system production and initial deployment, the relevant LCS activity is referred to as hardness assurance. Throughout the system's subsequent operational life, required LCS activities are subsumed under two program elements referred to as hardness maintenance and hardness surveillance.

3.24 Nuclear environments. Nuclear environments refer to the various nuclear-induced stresses imposed on a system as a result of the detonation of a nuclear weapon. These stresses, which may result directly from the weapon detonation or from subsequent interactions of weapon products with air, earth and system materials, are grouped into the following six categories: EMP, nuclear radiation, thermal radiation, blast, shock, and debris. Each of these is defined separately in this section.

3.25 Nuclear hardening. Nuclear hardening refers to the employment of design techniques that increase the ability of a system to withstand exposure to one or more of the environments and associated effects produced by the detonation of a nuclear weapon without suffering an unacceptable change in performance characteristics.

3.26 Nuclear hardness. Nuclear hardness is a measure, expressed in terms of applicable nuclear environment magnitude(s), of the ability of a system, or any subelement thereof, to withstand exposure to one or more of the environments and associated effects produced by the detonation of a nuclear weapon without suffering an unacceptable change in performance characteristics.

3.27 Nuclear radiation. Nuclear radiation is one of the nuclear environments. It consists of atomic and nuclear particles and photons emanating directly from a nuclear detonation or from subsequent interactions of this radiation with the surrounding media. The important nuclear radiations from a weapon effects standpoint include prompt x-rays, prompt gammas, secondary gammas, fast neutrons and thermal neutrons. An important nuclear radiation environment is a combined ionization pulse consisting of a prompt pulse followed immediately by a delayed pulse. Nuclear radiation produces both permanent and transient effects.

3.28 Nuclear survivability. Nuclear survivability is a probabilistic measure of the capability of a system to withstand the environments and associated effects produced by a hostile nuclear attack without suffering an abortive impairment of its ability to accomplish its designated mission. Nuclear survivability of ICBM weapon systems may be accomplished by a number of methods, including nuclear hardening, concealment, avoidance, and proliferation. This standard addresses only the nuclear hardness aspects of accomplishing nuclear survivability. Nuclear survivability is determined by the activity referred to as survivability evaluation.

3.29 Nuclear vulnerability. A nuclear vulnerability refers to some particular characteristic or aspect of design of a system which impairs or reduces its ability to withstand exposure to one or more of the environments and associated effects produced by the detonation of a nuclear weapon, and which, therefore, upon such exposure, would result in an unacceptable change in system performance capability.

3.30 Shock. Shock is one of the nuclear environments. It consists of the propagated stress wave in a structure and the surrounding medium caused by the blast overpressure environment for slap-induced shocks and by the upstream airburst and directly coupled energy for upstream-induced shocks. Shock results in transient and permanent facility stresses, translations, and rotations.

3.31 Source-region electromagnetic pulse. Source-region electromagnetic pulse (SREMP) is a particular type of EMP. It consists of electromagnetic energy generated by the interaction of nuclear ionizing radiation with the media surrounding or near a nuclear weapon detonation.

3.32 Survivability. Survivability is the capability of a system to withstand a hostile attack without suffering an abortive impairment of its ability to accomplish its designated mission. In this standard, survivability always refers to nuclear survivability.

3.33 Survivability evaluation. Survivability evaluation is the activity by which system nuclear survivability is determined. The magnitude of system survivability that is identified by this activity will be a function of the particular hostile nuclear attack scenario assumed at the outset of the survivability evaluation process. ICBM survivability evaluation will be performed by the procuring agency.

3.34 System-generated electromagnetic pulse. System-generated electromagnetic pulse (SGEMP) is a particular type of EMP. It consists of the electromagnetic energy generated by the interaction of nuclear ionizing radiation with system hardware.

3.35 Thermal radiation. Thermal radiation is one of the nuclear environments. It consists of the energy, in the form of ultraviolet, visible, and infrared radiation, emitted from the fireball (or other heated regions) as a result of its very high temperature.

3.36 Transfer function. A transfer function is a mathematical function which permits the calculation of the magnitude of nuclear environment or coupled stress at the output of some element of hardware of a system, given the magnitude of nuclear environment or associated coupled stress applied at the input of the hardware element.

3.37 Definitions of acronyms used in this standard. The following acronyms listed in this standard are defined as follows:

A&CO	-	Assembly and checkout.
A&CO TA	-	Assembly and checkout technical analysis.
AFLC	-	Air force logistics command.
AFR	-	Air force regulation.
AMSDL	-	Acquisition management systems and data requirements control list.
AVE	-	Aerospace vehicle equipment.
C&R	-	Circumvention and recovery.
CDR	-	Critical design review.
CDRL	-	Contract data requirements list.
CI	-	Configuration item.
DID	-	Data item description.
DoD	-	Department of defense.
DoDI	-	Department of defense instruction.
DSE	-	Depot support equipment.
ECP	-	Engineering change proposal.
EMP	-	Electromagnetic pulse.
EPM	-	External protection material.
ESA	-	Electrical surge arrestor.
FAR	-	Federal acquisition regulation
FMEA	-	Failure mode and effects analysis.
FSD	-	Full scale development.
FSE	-	Factory support equipment.
HCI	-	Hardness critical item.
HCP	-	Hardness critical process.
HEMP	-	High-altitude electromagnetic pulse.
ICBM	-	Intercontinental ballistic missile.
ILS	-	Integrated logistics support.
LCS	-	Life cycle survivability.
LSA	-	Logistics support analysis.
LSAR	-	Logistics support analysis record.
NH&S	-	Nuclear hardness and survivability.
NH&S DAR	-	Nuclear hardness and survivability design analysis report.
OSE	-	Operational support equipment.
PCA	-	Physical configuration audit.
PIDS	-	Prime item development specification.
PMRT	-	Program management responsibility transfer.
RPIE	-	Real property installed equipment.
SGEMP	-	System-generated electromagnetic pulse.
SMI	-	Structure-media interaction.
SRA	-	System requirements analysis.
SREMP	-	Source-region electromagnetic pulse.
TO	-	Technical order.
UGT	-	Underground test.

4. GENERAL REQUIREMENTS

4.1 NH&S program. The contractor shall establish an NH&S program (see 6.2).

5. DETAILED REQUIREMENTS

5.1 Concept exploration/demonstration and validation phases. The contractor shall perform hardness design trade studies and implement preliminary design activities in support of: (a) the definition by the procuring agency of system hardness requirements; and (b) the establishment by the contractor of cost-effective approaches to accomplishing a hardened design. Preliminary design activities may include some aspects of the hardness design analysis and hardness testing tasks described in 5.2.2 and 5.2.3, although usually on a less thorough and detailed level. Hardness testing may also be performed to acquire data on potential high pay-off hardening techniques for which data to assure a relatively risk-free FSD phase does not already exist.

5.1.1 Hardness design trade studies. The contractor shall perform trade studies to evaluate alternative solutions to satisfying hardness requirements (see 6.2). These solutions may include: (a) alternative allocations of hardness requirements among different levels of hardware assembly; and (b) alternative approaches to accomplishing a hardened design. Trade study results shall be used to select the most cost-effective life cycle hardened design, including consideration of the associated cost-effectiveness of accomplishing the verification, by analysis and test, of the adequacy of the hardened design, and the associated cost-effectiveness of implementing life cycle survivability. Other considerations involved in selecting the most cost-effective life cycle hardened design shall be the impact of the selected design on non-hardness performance and operation requirements and other defined program constraints.

5.1.1.1 Considerations for specific nuclear environments. When defining hardness design trade studies for specific nuclear environments, the following considerations shall apply.

5.1.1.1.1 EMP. The definition of EMP hardness design trade studies should include, but not necessarily be limited to, the following considerations: (a) utilization of box, structural, and cable electromagnetic shielding; (b) utilization of conductive coatings on exterior surfaces; (c) adequacy of electrical contact bonding; (d) utilization of EMP protection devices and circuitry, including electrical surge arrestors (ESAs), circuit breakers, diodes, and filtering; (e) utilization of low response cabling; and (f) utilization of low atomic number dielectric coatings.

5.1.1.1.2 Nuclear radiation. The definition of nuclear radiation hardness design trade studies should include, but not necessarily be limited to, the following considerations: (a) utilization of x-ray shielding at the local or box level; (b) utilization of a C&R mechanism; (c) utilization of special design features for electronic parts and circuits; and (d) inclusion of nuclear radiation-related design margin allowance in the design of electronic parts and circuits.

5.1.1.1.3 Thermal radiation. The definition of thermal radiation hardness design trade studies should include, but not necessarily be limited to, the following considerations: (a) dependence on ablation versus heating for the absorption of thermal energy; (b) utilization of integral external protection material (EPM) versus separate EPM attached by means of adhesive; (c) utilization of single layer versus multilayer EPM; (d) weight added due to use of EPM as a function of EPM material properties and the requirements for both thermal and pebble/dust protection; and (e) difficulty of EPM manufacture and application versus performance.

5.1.1.1.4 Blast. The definition of blast hardness design trade studies should include , but not necessarily be limited to, the following considerations: (a) missile in-flight blast hardness as a function of operational flight stresses and nuclear blast-induced stresses; (b) protective structure closure protection versus in-place missile blast hardness; (c) mobility versus blast hardness (dash and button-down mode), concealment, and spacing in the design of mobile launchers; (d) requirements on the guidance system to avoid loss of control due to blast winds; (e) rigid versus crushable or deformable components; and (f) vulnerability of subsystems and components inside the protective structure to pressure loadings arising from leakage, tunnel penetration, or other causes.

5.1.1.1.5 Shock. The definition of shock hardness design trade studies should include, but not necessarily be limited to, the following considerations: (a) the sensitivity of design parameters to all shock related parameters and to uncertainties in the ground motion and structure-media interaction (SMI) loading environments; (b) alternate basing locations to best utilize beneficial geology for shock mitigation; (c) alternative structure and shock isolation concepts with respect to such factors as rattlespace requirements, missile and equipment required capability, structure and isolation mechanical property requirements, constructibility, ease of maintenance, and resistance to environmental degradation; and (d) dual purpose (road vibration and nuclear shock) isolation systems for mobile launchers.

5.1.1.1.6 Debris. The definition of debris hardness design trade studies should include, but not necessarily be limited to, the following considerations: (a) parameters related to achieving resistance against impacting particles and the ability to operate through static and dynamic debris; (b) ability of launch egress systems to perform missile egress and launch functions through debris; (c) requirements for command, control, and communication through the debris; (d) cost of vehicle hardening versus measures (catchers) to prevent debris fall-in to a silo; (e) rigid versus deformable components; (f) utilization of a single layer versus multilayer EPM; (g) difficulty of EPM manufacture and application versus performance; and (h) weight added due to use of EPM versus debris protection required.

5.2 FSD phase. The contractor shall define, develop, verify, and qualify a design that satisfies all specified hardness requirements. The contractor shall perform planning and preparation in support of LCS requirements, and shall incorporate specified hardness requirements into all FSD activities related to or impacted by LCS requirements.

5.2.1 Hardness design. The contractor shall incorporate nuclear hardness into his design consistent with the hardness requirements specified in his prime item development specification (PIDS).

5.2.1.1 Hardness design guidelines. At each stage of the design process the contractor shall consider material, component, subsystem, and system responses to the specified nuclear environments. As part of the initial design process, the contractor shall determine the most critical nuclear effects parameters and combinations of these parameters, and shall compare them with those identified for other requirements (structural, thermal, etc.) to establish rationale for material and component selection and subsystem and system design. The design shall include consideration of LCS requirements, particularly optimization of the ease with which hardness maintenance/hardness surveillance tests and inspections can be implemented. Hardness design activities during the FSD phase may include hardness design trade studies as described in 5.1.1 (see 6.2).

5.2.1.2 Contractor hardness design guidelines. The contractor shall develop and implement hardness design guidelines for use in both the electrical/electronic and mechanical/structural design discipline areas.

5.2.1.2.1 Contractor electrical/electronic design guidelines. The electrical/electronic design guidelines shall include the following: (a) component derating factors for hardness response to be applied in design, including component derating procedures; (b) summaries of device hardness characterization data; (c) preferred devices and preferred circuit, wiring, and grounding procedures to be used in design; (d) preferred analysis procedures and techniques; and (e) design prohibitions.

5.2.1.2.2 Contractor mechanical/structural design guidelines. The mechanical/structural design guidelines shall include the following: (a) material properties information or acceptable sources and test techniques by which to obtain the required information; (b) identification of critical failure mechanisms for classes of relevant materials and components for all specified nuclear environments; (c) techniques for computing nuclear responses including normal operational stresses; and (d) preferred design and analysis procedures and techniques.

5.2.2 Hardness design analysis. The contractor shall perform hardness design analyses to support: (a) trade studies and the design and development activity; (b) verification and qualification of the hardened design; and (c) determination of the hardness levels (expressed as hardness design margins and hardness fragilities) that have actually been achieved in the hardened design.

5.2.2.1 Hardness design analysis guidelines. The design analysis performed shall include consideration of: (a) all specified nuclear environments and their combined and time-phased effects; (b) both single and multiple burst events, including cumulative, additive or synergistic effects of specified timing combinations; and (c) the combined effects of the nuclear environments in conjunction with the responses to other specified pre-flight and flight environments. Definition of the hardness design analysis activity required shall be based on the results of a hardness failure modes and effects analysis (FMEA), which shall be performed to identify for each applicable nuclear environment, all potential failure modes and effects induced by the environment in each material, component or subassembly of the CI under consideration. Selection of the hardness design analysis approach to be used shall be based on considerations of completeness and overall cost-effectiveness, the level of complexity (circuit, subassembly, assembly) of the particular CI element under analysis, the nuclear environment response mechanisms involved, and available hardness design margin data. An interactive relationship between analysis and test shall be implemented. Initial analysis results shall be used to define development test requirements.

Development test results shall then be used to validate and refine the analysis models and to improve design. The output of the hardness design analysis activity shall include hardness design margins, hardness fragilities, and relevant transfer functions.

5.2.2.2 Considerations for specific nuclear environments. When defining hardness design analyses for specific nuclear environments, the following considerations shall apply.

5.2.2.2.1 EMP. The definition of EMP hardness design analysis should include , but not necessarily be limited to, the following considerations: (a) utilization of hardness analysis approaches and techniques appropriate to the particular type of EMP environment (HEMP, SGEMP, or SREMP) of concern; (b) the need for coupling analysis to transform the environments specified in the PIDS into EMP circuit drivers appropriate for circuit response analysis; and (c) awareness that EMP coupling is system design dependent, and the associated need to have EMP circuit drivers reflect overall system response, where appropriate.

5.2.2.2.2 Nuclear radiation. The definition of nuclear radiation hardness design analysis should include, but not necessarily be limited to, the following considerations: (a) utilization of the analysis activity to support identification of piecepart acceptance test requirements, including transient response and post-radiation acceptance criteria; (b) the need to utilize parts parameter data that have been properly derated for radiation response and other relevant factors; (c) the need, for those CIs employing C&R, to consider subsystem/system errors resulting from the specified single and multiple events, for both pre-flight and flight conditions; (d) the need, for those CIs employing C&R, to determine the existence and magnitude of any vulnerability resulting from detector shadowing by other elements of the system; (e) the need to perform shielding analyses to determine the radiation levels incident on internal components and materials; (f) the need to evaluate mechanical responses to the nuclear radiation environment, including bulk heating effects, shock and small motion effects, and induced gross vehicle motion (vehicle motion refers to both the missile and reentry vehicles in endo- and exo-atmospheric flight); (g) the need to evaluate radiologic effects due to nuclear radiation-related energy deposition, particularly in explosive and propellant materials; and (h) the need for experimental activity to provide additional supporting data for the analysis activity, such as equation of state data, mechanical loading data, and component response data at specific environment levels.

5.2.2.2.3 Thermal radiation. The definition of thermal radiation hardness design analysis should include, but not necessarily be limited to, the following considerations: (a) material characteristics, such as thermal absorption and reflection, material ablation, and in-depth conduction of heat; (b) the need for temperature time-histories at various locations, including bond lines, internal components, and structural attachments; (c) the need for depth time-histories of ablation, charring, and melting; (d) the transmission of thermal energy through transparent materials; (e) the need to consider effects of aerodynamic flow, surface conditions, chemical reactions, and surface erosion on heat transfer at surfaces; (f) the need to consider contact resistance in calculating heat transfer between different materials in contact; (g) the need to consider two or three dimensional effects in complicated structures; (h) the need for thermal studies to address temperature transients due to leakage; (i) the need, when combustible materials are used as missile skin materials, to establish that sustained combustion will not occur during or after exposure to pre-flight or flight nuclear environments; and (j) the need, when analyzing mechanical response, to address combined environment effects, such as blast and dynamic or static loading either preceding or following exposure to the thermal environment.

5.2.2.2.4 Blast. The definition of blast hardness design analysis should include, but not necessarily be limited to, the following considerations: (a) blast and wind directions in combining normal operation loads with blast-induced loads; (b) both the shock diffraction and drag loading associated with the passage of clear and dusty blast waves over a structure; (c) both side-on shocks and a travelling-wave load due to glancing blast wave incidence; (d) overpressure and acoustic environments of internal components due to leaks; (e) response of a vehicle guidance system to blast-induced loads; (f) interaction of shocks due to a blast and the shock produced by supersonic motion of the missile; and (g) the need to consider combined environment effects.

5.2.2.2.5 Shock. The definition of shock hardness design analysis should include, but not necessarily be limited to, the following considerations: (a) the need, when validating analysis models and parameters with test data, to include degraded or enhanced material properties caused by aging and environmental effects; (b) the utilization, when analyzing the response of the shock isolation system, of multi-degree of freedom models which include coupling between translational and rotational modes, nonlinear constitutive relations for the isolators (including strain rate effects on isolator performance), friction, and gravity; (c) the need, when performing SMI analysis, to address nonlinear constitutive properties of the free field, back fill, structural material, and soil/structure interface behavior for representative siting geologies; and (d) the need to address material property degradation under multipath loading.

5.2.2.2.6 Debris. The definition of debris hardness design analysis should include, but is not limited to, the following considerations: (a) the need, when analyzing the effects of impacting debris, to address the material stress wave response and the overall structural response; (b) the need, when analyzing the effects of static debris, to address command, control and communication through the debris, and debris removal for missile system erection, if necessary; (c) the need to establish that the direct effects of debris on the missile have been minimized, if not eliminated; (d) the need to evaluate the effects of pebbles, dust, and ice on the in-flight system, including penetration, erosion, kinetic energy deposition, convective heating augmentation, chemical reactions of reactive surface materials, and surface roughening; (e) the need to address command, control and communication through the airborne dust cloud; and (f) the need to consider wind effects on the location of the dust cloud and its fallout.

5.2.3 Hardness testing. The contractor shall perform hardness testing to support: (a) trade studies and the design and development activity; (b) verification and qualification of the hardened design; and (c) determination of the hardness levels (expressed as hardness design margins and hardness fragilities) that have actually been achieved in the hardened design (see 6.2).

5.2.3.1 Hardness testing guidelines. During planning for hardness tests, response prediction analyses shall be performed, which shall include consideration of: (a) any significant differences between the simulated environment and the specified nuclear weapon environment; (b) any interactions between the item under test and the test instrumentation; (c) instrumentation response to the test environment; and (d) inaccuracies resulting from instrumentation limitations. Test levels shall be adjusted to compensate for uncertainties in environment measurements. When the simulation facility is incapable of producing the full range of nuclear environment variations specified, or where cost constraints dictate a limited test program, analysis shall be used to extrapolate/interpolate measured response to untested conditions. Where performance is affected by multiple events, test design shall consider the need for preconditioning the test item to simulate as closely as possible the conditions of actual multiple event occurrence. Whenever feasible, and if appropriate to the test purpose, test planning shall include consideration of combined nuclear environment testing. Simulation sources and test configurations shall be selected on the basis of their capability to: (a) reproduce predicted responses, including combined effects; (b) minimize spurious responses and effects on instrumentation; (c) provide acceptable distribution of the environment over the test article volume; and (d) provide support to the design and development analysis activities and to the hardness verification and qualification activities. When establishing requirements for testing, full use shall be made of existing relevant data from other programs and tests, and careful consideration shall be given to the use of such data in lieu of conducting additional tests.

5.2.3.2 Considerations for specific nuclear environments. When defining hardness testing for specific nuclear environments, the following considerations shall apply.

5.2.3.2.1 EMP. The definition of EMP testing should include, but not necessarily be limited to, the following considerations: (a) component failure level testing to determine the thermal and voltage breakdown characteristics of components identified in the EMP design analysis as being susceptible to EMP damage; (b) current injection testing to determine EMP upset and damage thresholds of circuit assemblies, boxes, and subsystems for specified waveforms; (c) electromagnetic shield testing to determine the shielding effectiveness and transfer impedance of grounding structures, electronic racks, boxes, cable shields and connectors; of particular importance is the transfer impedance of connector/connector backshell and backshell/cable shield joints; (d) radiation testing to characterize the SGEMP response of circuit assembles, boxes, subsystems and system; it is particularly important to characterize the SGEMP response of electrical cables and connectors by this type of testing; radiation testing may include tests at pulsed radiation facilities and underground tests (UGT); (e) free-field testing to characterize the response of circuit assemblies, boxes, subsystems, and systems to specified electromagnetic radiation; and (f) logic upset testing to determine upset modes and thresholds of software systems to EMP-induced transients.

5.2.3.2.2 Nuclear radiation. The definition of nuclear radiation testing should include, but not necessarily be limited to, the following considerations: (a) electronic parts radiation effects testing to determine the radiation response of selected pieceparts (e.g., semiconductor devices, capacitors, crystals, etc.) to selected simulations of nuclear radiation environments; testing should be conducted to obtain all relevant response characteristics; (b) circuit radiation effects testing to determine the responses of selected breadboard circuit designs to selected simulations of nuclear radiation environments; selection of circuits for testing should be based upon known or suspected criticalities, circuit analysis response predictions, and circuit complexity; (c) subsystem/CI radiation effects testing to determine the responses of selected subsystems/CIs to selected simulations of nuclear radiation environments; selection of subsystems/CIs for testing should be based on known or suspected criticalities, subsystem/CI analysis response predictions, and design complexity; and (d) mechanical radiation effects testing to provide additional supporting data for the analysis activity and to establish susceptible component response.

5.2.3.2.3 Thermal radiation. The definition of thermal radiation testing should include, but not necessarily be limited to, the following considerations: (a) the thermal test facility should incorporate all significant phenomena, such as thermal radiation flux, fluence and spectrum, and external air flow conditions; (b) care should be taken to match material properties such as density, specific heat, conductivity, emissivity, heats of phase change, and chemical reaction characteristics; and (c) instrumentation should be provided to measure all phenomena of interest, such as temperatures at various locations, depth of material ablated, charred, melted or otherwise damaged, and transmission of radiation.

5.2.3.2.4 Blast. The definition of blast testing should include, but not necessarily be limited to, the following considerations: (a) the test facility should incorporate all significant phenomena, such as the magnitude, shape, duration, and impulse of the blast wave, as well as provide proper simulation of normal operating loads; (b) care should be taken that the test configuration satisfactorily matches the actual system/subsystem configuration, and that all important material properties, such as stress-strain properties, are properly matched; and (c) instrumentation should be provided to measure all phenomena of interest, such as pressures, accelerations, stresses, and strains, and to note damage characteristics or failure levels.

5.2.3.2.5 Shock. The definition of shock testing should include, but not necessarily be limited to, the following considerations: (a) piecepart, component, subsystem, and system testing to determine shock hardness levels; (b) testing to determine (1) component and connecting structure response; (2) material stress wave propagation and failure levels; (3) component intrinsic strength; (4) electromechanical/software-hardware response; (5) reinforced concrete mechanical properties; (6) structure/soil interface friction properties; (7) umbilical cable shock loop and hydraulic surge; (8) umbilical cable failure from structure/soil relative motion; and (9) subsystem/component failure from rattlespace depletion or other shock isolation system failure.

5.2.3.2.6 Debris. The definition of debris testing should include, but not necessarily be limited to, the following considerations: (a) impacting debris tests; (b) operational tests through static debris; (c) debris, pebble, dust, and ice testing to obtain response data for material erosion rates, particle penetration depths and shock response, and ignition levels of combustible materials in erosive environments; (d) the test facility should incorporate all significant phenomena; (e) care should be taken to match important material properties; and (f) instrumentation should be provided to measure all phenomena of interest.

5.2.4 Hardness evaluation. During the FSD phase, the contractor shall conduct a program of hardness analysis and test to: (a) assess the hardness of the design as it is developed; (b) verify that the final design will satisfy specified hardness requirements; (c) qualify the hardness of production hardware; and (d) determine the hardness levels that have actually been achieved.

5.2.4.1 Hardness assessment. During the design and hardness development activity, the contractor shall conduct a program of iterative and interactive hardness analyses and tests to assess the hardness adequacy of the evolving design. In this context, hardness tests are performed to: (a) acquire input data for use in the analysis activity (tests performed for this purpose are usually referred to as characterization tests); (b) validate analytic models and codes; and (c) provide a direct measure of hardware hardness.

5.2.4.2 Hardness verification. The contractor shall accomplish hardness verification, and shall document in his NH&S design analysis report (NH&S DAR) the analysis and test results that support the assertion that hardness verification has been accomplished (see 6.2).

5.2.4.2.1 NH&S design analysis report. Through the completion of CDR, the primary focus of the contractor's NH&S DAR (see 6.2) shall be to support design reviews. After the completion of CDR, the NH&S DAR shall be revised and modified for release at the physical configuration audit (PCA) of a version which will support Air Force Logistics Command (AFLC) requirements during implementation of its hardness maintenance responsibilities throughout weapon system operational life. Subsequent to PCA and prior to program management responsibility transfer (PMRT), the NH&S DAR shall be maintained current to reflect any changes to the contractor's design which affect hardness. The funding required to update the NH&S DAR at this time will be provided via the engineering change proposal (ECP) mandating the design change.

5.2.4.3 Hardness qualification. The contractor shall accomplish hardness qualification of the production configuration.

5.2.4.4 Determination of hardness levels achieved. The contractor shall determine the hardness levels (expressed as hardness design margins and hardness fragilities) that have actually been achieved in his hardened design.

5.2.4.4.1 Hardness design margin determination. The contractor shall determine the hardness design margins of the hardware elements comprising his CI(s) as necessary to support: (a) hardness design analysis and hardness testing; (b) hardness verification and hardness qualification; and (c) selection of hardware candidates for fragility determination.

5.2.4.4.2 Hardness fragility determination. The contractor shall determine the hardness fragilities of selected items of hardware contained in his CI(s). Selection of the particular items of hardware to undergo fragility determination shall be based on: (a) review of relevant hardness design margin data; and (b) review of the results of the FMEA (see 5.2.2.1) for the CI under consideration. In general, the items of hardware selected to undergo fragility determination will be those with the lowest hardness design margins, and those which the FMEA has identified as having the controlling hardness failure mechanisms of the CI. The activity to determine hardness fragilities shall be integrated with other FSD hardness analysis and test activities to the maximum practical extent.

5.2.5 Life cycle survivability. During the FSD phase, the contractor shall implement those actions necessary to support the implementation of hardness assurance during the production phase, and hardness maintenance/hardness surveillance during the operational phase.

5.2.5.1 HCI/HCP identification. Contractor NH&S personnel shall review the contractor's design to identify the HCIs and HCPs contained therein. HCI/HCP identification shall be initiated early in the design process, and shall be maintained current throughout FSD.

5.2.5.1.1 CI master HCI list. Contractor NH&S personnel shall compile, and maintain current at all times throughout the FSD phase until the completion of the PCA, a separate master HCI list for each CI for which the contractor is responsible that identifies all HCIs contained within the contractor's current design of that CI (see 6.2). These list(s) shall be used in support of all hardness annotation tasks, including the hardness annotation of drawings, system requirements analysis (SRA) related documentation, and technical orders (TOs), as well as the preparation of the NH&S DAR. Contractor NH&S personnel shall be responsible to ensure that all such hardness annotation and documentation tasks are based on the most current master HCI list(s) available. Subsequent to PCA and prior to PMRT, the master HCI list(s) shall be maintained current to reflect any changes to the contractor's design which affect hardness. The funding required to update the applicable master HCI list at this time will be provided via the ECP mandating the design change.

5.2.5.2 Hardness annotation of drawings and associated documentation. Contractor NH&S personnel shall provide direct support to the contractor's activity to incorporate hardness requirements into engineering drawings, and shall ensure that the hardness requirements identified on engineering drawings are incorporated into other relevant production related documentation, such as quality assurance plans, etc. Contractor NH&S personnel shall be responsible to review all such hardness annotations and to ensure their completeness and correctness.

5.2.5.3 Hardness annotation of SRA documentation. Contractor NH&S personnel shall provide direct support to the contractor's activity to incorporate hardness requirements into that portion of his SRA activity devoted to support of his integrated logistics support (ILS) program and his assembly and checkout (A&CO) support activity. This effort includes hardness annotation of the logistics support analysis (LSA) and its associated documentation of logistics support analysis records (LSAR), and the assembly and checkout technical analysis (A&CO TA). Contractor NH&S personnel shall be responsible to ensure the completeness and correctness of this hardness annotation activity and shall have the lead responsibility to identify hardness-driven requirements for inclusion in the SRA.

5.2.5.4 Hardness annotation of TOs. Contractor NH&S personnel shall provide direct support to the contractor's activity to incorporate hardness requirements into TOs, and shall be responsible to ensure its completeness and correctness.

5.2.5.5 Factory support equipment (FSE)/depot support equipment (DSE) hardness requirements. The contractor-designed FSE/DSE shall have the capability, to the maximum practical extent, to test an end item for hardness. Contractor NH&S personnel shall provide direct support to this activity and shall have the lead responsibility to identify the hardness related characteristics of the contractor's design that can be evaluated by means of FSE/DSE, as well as to maximize the extent to which the contractor's design originally provides for the opportunity to verify end-item hardness by means of FSE/DSE.

5.2.5.6 Hardness assurance planning. The contractor shall plan a hardness assurance program for implementation by him during the production phase, and, as applicable, during sysetm deployment, to assure the preservation of CI/subsystem hardness throughout production, and as applicable, during system deployment (see 6.2). Planning shall include definition of all managerial, organizational, and technical elements of the program, including hardness assurance test and inspection requirements, and the identification of the procedural, documentation, and interface activities required of existing contractor control disciplines in support of hardness assurance.

5.2.5.6.1 Hardness assurance resource definition and acquisition. Prior to the start of production, the contractor shall identify and acquire all the hardware and software resources required to implement the planned hardness assurance program. In addition, all hardness assurance test procedures and equipment shall be validated prior to the start of production.

5.2.5.7 Hardness maintenance planning. The contractor shall plan for a hardness maintenance program which encompasses his hardness data activity and his activity in support of hardness logistics support definition (see 6.2). The contractor's hardness maintenance plan shall be used by the contractor as a resource and guidelines document during his implementation of the hardness annotation of drawings per 5.2.5.2 and the hardness annotation of SRA documentation per 5.2.5.3.

5.2.5.8 Hardness surveillance planning. The contractor shall plan for a hardness surveillance program which encompasses the hardness surveillance activities appropriate to the CI(s) for which he is responsible during design and development (see 6.2). The contractor's hardness surveillance plan will be used by the procuring agency in support of its activity to define a single, integrated hardness surveillance program for the entire weapon system to be implemented during the operational phase of the weapon system life cycle.

5.2.5.8.1 Hardness surveillance preparation phase support. The contractor shall support the hardness surveillance preparation phase to the extent directed by the procuring agency. Such support will consist of the identification and acquisition of the resources necessary to implement those aspects of the integrated weapon system hardness surveillance program approved by the procuring agency which involve hardware elements for which the contractor is responsible. Support, as required, to the hardness surveillance preparation phase will be the subject of additional contractual action to the existing FSD effort.

5.3 Production phase. The contractor shall implement the approved hardness assurance program.

5.4 Deployment phase. As applicable, the contractor shall implement the approved hardness assurance program.

6. NOTES

6.1 Intended use. This standard is to be used in the acquisition of ICBM weapon system hardware elements whose specifications include nuclear hardness performance requirements.

6.2 Data requirements. When this standard is used in an acquisition which incorporates a DD Form 1423, Contract Data Requirements List (CDRL), the data requirements identified below shall be developed as specified by an approved Data Item Description (DD Form 1664) and delivered in accordance with the approved CDRL incorporated into the contract. When the provisions of the DoD FAR Supplement, Part 27, Sub-part 27.410-6 are invoked and the DD Form 1423 is not used, the data specified below shall be deliverable by the contractor in accordance with the contract or purchase order requirements. Deliverable data required by this standard are cited in the following paragraphs.

Paragraph No.	Data Requirements Title	Applicable DID No.
a. 4.1 / 5.2.5.1.1	Nuclear Hardness and Survivability Program Plan	DI-ENVR-80262
b. 5.1.1 / 5.2.1.1	Nuclear Hardness and Survivability Trade Study Report	DI-ENVR-80267
c. 5.2.3	Nuclear Effects Test Plans	DI-T-5317
d. 5.2.3	Test Reports - General	DI-T-3718
e. 5.2.4.2 / 5.2.4.2.1	Nuclear Hardness and Survivability Design Analysis Report	DI-ENVR-80266
f. 5.2.5.6	Hardness Assurance Plan	DI-ENVR-80263
g. 5.2.5.7	Hardness Maintenance Plan	DI-ENVR-80264
h. 5.2.5.8	Hardness Surveillance Plan	DI-ENVR-80265

(Data item descriptions related to this standard, and identified in Section 6 will be approved and listed as such in DoD 5010.12-L, AMSDL. Copies of data item descriptions required by the contractors in connection with specific acquisition functions should be obtained from the Naval Publications and Forms Center or as directed by the contracting officer.)

6.3 Subject term (key word) listing.

Analysis
Design
Evaluation
Hardness
Hardness assurance
Hardness maintenance
Hardness surveillance
ICBM
Nuclear
Survivability
Testing

6.4 Identification of changes. Vertical lines or asterisks are not used in this revision to identify changes with respect to the previous issue due to the extensiveness of the changes.

Custodian:
Air Force - 14

Preparing Activity:
Air Force - 14
(Project number ENVR-F019)

User activities:
Navy - OS

INSTRUCTIONS: In a continuing effort to make our standardization documents better, the DoD provides this form for use in submitting comments and suggestions for improvements. All users of military standardization documents are invited to provide suggestions. This form may be detached, folded along the lines indicated, taped along the loose edge *(DO NOT STAPLE)*, and mailed. In block 5, be as specific as possible about particular problem areas such as wording which required interpretation, was too rigid, restrictive, loose, ambiguous, or was incompatible, and give proposed wording changes which would alleviate the problems. Enter in block 6 any remarks not related to a specific paragraph of the document. If block 7 is filled out, an acknowledgement will be mailed to you within 30 days to let you know that your comments were received and are being considered.

NOTE: This form may not be used to request copies of documents, nor to request waivers, deviations, or clarification of specification requirements on current contracts. Comments submitted on this form do not constitute or imply authorization to waive any portion of the referenced document(s) or to amend contractual requirements.

☆ U.S. Government Printing Office: 1982—360-679/5604

(Fold along this line)

(Fold along this line)

HQ BMO/AWD
Norton AFB CA 92409-6468

NO POSTAGE NECESSARY IF MAILED IN THE UNITED STATES

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE $300

BUSINESS REPLY MAIL
FIRST CLASS PERMIT NO. 73236 WASH DC

POSTAGE WILL BE PAID BY HQ U.S. AIR FORCE

HQ BALLISTIC MISSILE OFFICE/AWD
NORTON AFB CA 92409-6468

STANDARDIZATION DOCUMENT IMPROVEMENT PROPOSAL

(See Instructions – Reverse Side)

1. DOCUMENT NUMBER
DOD STD 1766A

2. DOCUMENT TITLE

3a. NAME OF SUBMITTING ORGANIZATION

4. TYPE OF ORGANIZATION *(Mark one)*

☐ VENDOR

☐ USER

☐ MANUFACTURER

☐ OTHER *(Specify)*: ______

b. ADDRESS *(Street, City, State, ZIP Code)*

5. PROBLEM AREAS

a. Paragraph Number and Wording:

b. Recommended Wording:

c. Reason/Rationale for Recommendation:

6. REMARKS

7a. NAME OF SUBMITTER *(Last, First, MI)* – Optional

b. WORK TELEPHONE NUMBER *(Include Area Code)* – Optional

c. MAILING ADDRESS *(Street, City, State, ZIP Code)* – Optional

8. DATE OF SUBMISSION *(YYMMDD)*

DD FORM 1426, 82 MAR

PREVIOUS EDITION IS OBSOLETE.

(TO DETACH THIS FORM, CUT ALONG THIS LINE.)