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MIL-STD-1766B (USAF)
09 SEPT 1994

Superseding
DOD-STD-1766A
01 DECEMBER 1986

MILITARY STANDARD

NUCLEAR HARDNESS AND SURVIVABILITY PROGRAM REQUIREMENTS FOR ICBM WEAPON SYSTEMS

AMSC F3998

AREA ENVR

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FOREWORD

1. This military standard is approved for use by all Departments and Agencies of the Department of Defense.

2. Beneficial comments (recommendations, additions, deletions) and any pertinent data that may be of use in improving this document should be addressed to: Space and Missile Systems Center, AFMC SMC/SDFC, 160 Skynet Street, Suite 2315, Los Angeles AFB, CA 90245-4683, by using the self-addressed Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document, or by letter.

3. This revision of MIL-STD-1766 contains a significant expansion and a complete reorganization of the 1 December 1986 version. It includes much new and revised text, as well as the incorporation of lessons learned during the application of MIL-STD-1766A to intercontinental ballistic missile (ICBM) procurements. The key features of the revision are summarized below.

4 SAMSO STD 77-6 (System Requirements Analysis Program for the MX Weapon System) is an essential companion document to MIL-STD-1766B.

5. The scope and content of the document has been expanded in the following ways:

   a. All phases of the system life cycle are included and a more complete and balanced treatment of each phase is given. In contrast, MIL-STD-1766A focused primarily on the engineering and manufacturing development (EMD) phase and did not address the operations and support phase.

   b. Nuclear hardness and survivability (NH&S) program requirements associated with the weapon system facilities, real property installed equipment (RPIE), assembly and checkout (A&CO) installation hardware, and, as applicable, maintenance support equipment (MSE) are covered. In contrast, MIL-STD-1766A addressed only aerospace vehicle equipment (AVE) and operational support equipment (OSE) configuration items (CIs).

   c. All the various categories of contractor functions required to acquire, deploy, and maintain an ICBM weapon system are covered. Moreover, the role of each type of contractor during each system life cycle phase is explicitly discussed. In contrast, MIL-STD-1766A dealt almost solely with the responsibilities of the AVE and OSE CI contractor.

   d. NH&S program requirements associated with the use of nondevelopmental hardware items (NDI), particularly commercial items, are introduced for the first time in MIL-STD-1766B. This important matter is of increasing concern for the procurement and maintenance of hardened weapon systems. In addition, NH&S program requirements associated with the use of government furnished equipment (GFE) are explicitly discussed for the first time in MIL-STD-1766B.

e. The NH&S activities of a technical nature performed by both the implementing command, through its cognizant system program office (SPO) responsible for a particular procurement, and the supporting and operating commands are identified, in addition to contractor requirements. Thus, all the technical activities that comprise a comprehensive weapon system NH&S program are covered.

f. A greatly expanded set of definitions has been provided in Appendix A that includes not only dictionary-like definitions of the terms addressed, but also additional comments that supply useful NH&S background and tutorial information. A careful reading of this appendix is required to ensure a full and complete understanding of the key concepts and tasks that form the underpinning of this standard.

g. Three appendices, in addition to Appendix A containing the definitions, have been included that provide information and guidance not generally otherwise available. The topics covered include:

(1) a comprehensive flow diagram overview of the system life cycle NH&S program process;

(2) guidance to SPO personnel on the generation of NH&S related program plans; and

(3) guidance on hardness critical item (HCI) identification and documentation.

h. The data item descriptions (DIDs) referenced in MIL-STD-1766A, except for the test plan and test report DIDs, have been revised or rewritten to reflect both lessons learned and the expanded scope and content of this revision.

6. A complete reorganization of the text has been implemented that provides greater clarity and insight into the various program elements and tasks that constitute a comprehensive NH&S program and their interrelationship. This new structure of the text is organized around the following four key themes:

a. <u>System life cycle NH&S requirements (section 5.1).</u> This section identifies the categories of contractor involved in each phase of the system life cycle and their NH&S responsibilities during each phase.

b. <u>Hardware category NH&S requirements (section 5.2).</u> This section identifies the NH&S requirements associated with each category of hardware, including commercial hardware, employed in an ICBM weapon system.

c. <u>NH&S program tasks (section 5.3).</u> This section contains a complete menu of all the NH&S program tasks associated with the system life cycle of an ICBM weapon system. The specific tasks applicable to each category of contractor during each phase and to each category of hardware used in the weapon system are identified in 6.3, tailoring guidance for contractual application.

d. Hardness trade study, analysis, and test requirements (section 5.4). This section identifies the requirements associated with the three types of support activities (hardness trade studies, hardness analysis, and hardness testing) utilized to accomplish the NH&S program tasks delineated in section 5.3.

7. Lessons learned from the application of MIL-STD-1766A to ICBM procurements have been incorporated. These address:

a. identification of hardness requirements for nondevelopmental hardware and GFE;

b. treatment of system elements in addition to CIs;

c. clarification of life cycle hardness (LCH) requirements; and

d. modification of contractor data requirements to enhance program efficiency and cost-effectiveness over the system life cycle; among these are:

(1) a new requirement for an HCI list drawing; this requirement is detailed in appendix C;

(2) a new requirement for a system hardness analysis report (SHAR) to document the results of the system level hardness evaluation activity;

(3) a new requirement for an NH&S design analysis report (NH&S DAR) devoted to facilities, RPIE and A&CO installation hardware; and

(4) the integration of the existing DIDs for the hardness assurance plan (DI-ENVR-80263), hardness maintenance plan (DI-ENVR-80264), and hardness surveillance plan (DI-ENVR-80265) with the DID for the NH&S program plan (DI-ENVR-80262); the title of the hardness maintenance plan has been changed to "hardness maintenance preparation support plan" to more precisely identify the document's program purpose.

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1. SCOPE

1.1 Purpose. This standard defines nuclear hardness and survivability (NH&S) requirements, procedures, and practices for use during the concept exploration and definition, demonstration and validation, engineering and manufacturing (EMD), production and deployment, and operations and support phases of the system life cycle of intercontinental ballistic missile (ICBM) weapon systems. It implements for the design, development, production, deployment, and operation of ICBM weapon systems the NH&S policy established by Air Force Regulations (AFR) AFPD 62-2 (Systems Survivability) and AFI 62-201 (Instruction for the Air Force Systems Survivability Program) and Department of Defense Directive (DoDD) 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), support equipment (SE), including operational support equipment (OSE), survivable real property installed equipment (RPIE), and facility weapon system elements that 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. Explicit recommendations for the tailoring of this standard for contractual application to ICBM programs are contained in 6.3.

2. APPLICABLE DOCUMENTS

2.1 Government documents.

2.1.1 Specifications, standards, and handbooks. The following specifications, standards, and handbooks form a part of this document and are referenced within the FORWARD of this document.

2.2 Order of precedence. In the event of a conflict between the text of this document and the references cited herein, the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

3. DEFINITIONS

3.1 Definitions. The definitions and acronyms that apply to this standard are contained in Appendix A.

4. GENERAL REQUIREMENTS

4.1 NH&S program. The contractor shall establish and conduct an NH&S program in accordance with this standard as tailored in the applicable SOW (see 6.2).

5. DETAILED REQUIREMENTS

5.1 System life cycle NH&S requirements. The contractor shall implement the NH&S tasks that are applicable to:

a. the program role performed by the contractor (see Appendix A, 40.21);

b. the particular system life cycle phase(s) under contract; and

c. the particular categories of hardware utilized.

Table 5-1 identifies the NH&S program tasks (see 5.3) that typically apply to each category of contractor. Tables 5-2 and 5-3 provide further insight into typical task applicability. Table 5-2 identifies the NH&S tasks applicable to the AVE/SE contractor as a function of life cycle phase and hardware category (see 5.2). Table 5-3 identifies the task applicability as a function of life cycle phase for the remaining categories of contractor. Explicit recommendations for the tailoring of this standard for contractual application to ICBM programs are contained in 6.3. Technical tasks performed by the system program office (SPO) and the supporting command are included below for information purposes to provide a complete definition of the technical content of a comprehensive NH&S program. The technical and program terms used throughout this section in the statement of NH&S requirements are defined in Appendix A, which is a mandatory part of this standard. Reference to this appendix is necessary to correctly and fully understand the intended content and purpose of each task defined.

5.1.1 Concept exploration and definition phase.

5.1.1.1 SPO. Based upon the need for specific operational capabilities, the commands involved will define and select alternative system concepts, one or more of which may result in further development. Among the factors considered during the definition and selection process are financial and technical constraints and military need. If the mission need statement (MNS) includes a nuclear threat, one of the technical factors considered must be NH&S. In this case, the implementing command will perform survivability trade studies to determine the optimum and most cost-effective system design approach. Among the alternative survivability approaches that are considered are mobility, spacing, replication, concealment, deception, and hardening. Each candidate approach is evaluated by means of iterative and parametric engagement analysis of the approach under consideration with the threat. Results and recommendations as to special nuclear hardening considerations will be documented and evaluated together with the other selection criteria in support of any decision to proceed to the subsequent demonstration and validation phase. For NH&S, approval to the implementing command to proceed will be based upon assurance that:

a. mission/performance/threat envelopes are adequately defined, technically feasible, and capable of being achieved within reasonable cost and schedule constraints;

	NH&S TASK	CONTRACTOR						
		AVE / SE	SS&I		FACILITIES A&E	FACILITIES CONSTRUCTION	A&CO	HARDNESS SURVEILLANCE SPT
			Sys. Integration Role	Facilities/RPIE Des. Criteria Role				
5.3	**NH&S PROGRAM TASKS**							
5.3.1	**NH&S program definition**							
5.3.1.1	SPO NH&S program planning							
5.3.1.2	Contractor NH&S program planning	●	●	●			●	●
5.3.1.2.1	WSE NEEHEM	●		●				
5.3.2	**WSS hardness requirements**							
5.3.2.1	SPO development of WSS hardness requirements							
5.3.2.2	Contractor support to development of WSS hardness requirements		●					
5.3.2.3	WSS hardness requirement allocations	●		●				
5.3.3	**WSE hardness requirements**							
5.3.3.1	AVE/SE hardness requirements							
5.3.3.1.1	Development of AVE/SE hardness requirements	●						
5.3.3.1.2	Hardness interface control requirements	●						
5.3.3.2	Facilities hardness requirements							
5.3.3.2.1	Development of facilities design criteria hardness requirements			●				
5.3.3.2.2	Support to development of facilities design criteria hardness requirements	●						
5.3.3.2.3	Review of facilities drawings			●				
5.3.3.3	A&CO installation hardware hardness requirements	●						

TABLE 5-1. NH&S task summary

	NH&S TASK	CONTRACTOR: AVE / SE	CONTRACTOR: SS&I Sys. Integration Role	CONTRACTOR: SS&I Facilities/RPIE Des. Criteria Role	CONTRACTOR: FACILITIES A&E	CONTRACTOR: FACILITIES CONSTRUCTION	CONTRACTOR: A&CO	CONTRACTOR: HARDNESS SURVEILLANCE SPT
5.3.4	**WSE hardness design**							
5.3.4.1	Hardness design implementation	●		●	●			
5.3.4.1.1	Concept Design	●		●	●			
5.3.4.1.2	Preliminary Design	●		●	●			
5.3.4.1.3	Detail Design	●		●	●			
5.3.4.1.4	Final Design	●		●	●			
5.3.4.2	Considerations for specific NH&S disciplines	●		●	●			
5.3.5	**WSE hardness evaluation**							
5.3.5.1	WSE hardness verification	●		●				
5.3.5.2	WSE hardness qualification	●						
5.3.6	**System level hardness evaluation**							
5.3.6.1	System level hardness testing and analysis	●	●	●				
5.3.6.2	System level hardness verification		●					
5.3.7	**System level assessment**							
5.3.7.1	SPO system level assessment							
5.3.7.2	WSE level support to system level assessment	●		●				
5.3.7.3	System level support to system level assessment		●					

TABLE 5-1. NH&S task summary (continued)

	NH&S TASK	CONTRACTOR						
			SS&I					
		AVE / SE	Sys. Integration Role	Facilities/RPIE Des. Criteria Role	FACILITIES A&E	FACILITIES CONSTRUCTION	A&CO	HARDNESS SURVEILLANCE SPT
5.3.8	**Life cycle hardness**							
5.3.8.1	HCI/HCP identification	●		●				
5.3.8.1.1	HCI list drawing	●		●				
5.3.8.2	NH&S support to drawing preparation	●			●			
5.3.8.2.1	NH&S support to MEDL preparation	●						
5.3.8.3	NH&S support to LSA preparation	●						
5.3.8.4	NH&S support to TO preparation	●						
5.3.8.5	NH&S support to A&CO TA preparation	●						
5.3.8.5.1	LCH during A&CO implementation						●	
5.3.8.6	Hardness maintenance preparation planning	●						
5.3.8.7	FSE/DSE hardness requirements	●						
5.3.8.8	Hardness assurance planning	●		●				
5.3.8.9	Hardness assurance resource definition and acquisition	●				●		
5.3.8.10	Hardness assurance implementation	●				●		
5.3.8.11	WSE hardness surveillance planning	●		●				
5.3.8.12	SPO system hardness surveillance planning							
5.3.8.13	Hardness surveillance preparation support	●		●				
5.3.8.14	Hardness surveillance implementation (supporting command)							
5.3.8.15	Hardness surveillance implementation support							●
5.3.8.16	Hardness maintenance implementation (supporting command)							

TABLE 5-1. NH&S task summary (continued)

Hardware Category \ Life Cycle Phase			Demonstration & Validation	EMD	Production and Deployment
Category Independent			5.3.1.2 5.3.2.3	5.3.1.2 5.3.1.2.1 5.3.2.3 5.3.6.1	5.3.1.2
CFE	DEVELOPMENTAL ITEMS		5.3.3.1.1 5.3.3.1.2 5.3.3.2.2 5.3.4.1 5.3.4.1.1 5.3.4.2	5.3.3.1.1 5.3.3.1.2 5.3.3.2.2 5.3.3.3 5.3.4.1 5.3.4.1.1 thru 5.3.4.1.4 5.3.4.2 5.3.5.1 5.3.5.2 5.3.7.2 5.3.8.1 5.3.8.1.1 5.3.8.2 5.3.8.2.1 5.3.8.3 5.3.8.4 5.3.8.5 5.3.8.6 5.3.8.7 5.3.8.8 5.3.8.11 5.3.8.13	5.3.8.9 5.3.8.10 All applicable EMD tasks to support design changes
CFE	NONDEVELOPMENTAL ITEMS (NDI)	Unmodified Commercial/ Military NDI	5.3.3.1.1 5.3.3.1.2 5.3.3.2.2	5.3.3.1.1 5.3.3.1.2 5.3.3.2.2 5.3.3.3 5.3.5.1 5.3.5.2 5.3.7.2 5.3.8.1 5.3.8.1.1 5.3.8.2 5.3.8.2.1 5.3.8.3 5.3.8.4 5.3.8.5 5.3.8.6 5.3.8.8 5.3.8.11 5.3.8.13	5.3.8.9 5.3.8.10
CFE	NONDEVELOPMENTAL ITEMS (NDI)	Modified Commercial/ Military NDI	5.3.3.1.1 5.3.3.1.2 5.3.3.2.2 5.3.4.1 5.3.4.1.1 5.3.4.2	5.3.3.1.1 5.3.3.1.2 5.3.3.2.2 5.3.3.3 5.3.4.1 5.3.4.1.1 thru 5.3.4.1.4 5.3.4.2 5.3.5.1 5.3.5.2 5.3.7.2 5.3.8.1 5.3.8.1.1 5.3.8.2 5.3.8.2.1 5.3.8.3 5.3.8.4 5.3.8.5 5.3.8.6 5.3.8.7 5.3.8.8 5.3.8.11 5.3.8.13	5.3.8.9 5.3.8.10 All applicable EMD tasks to support design changes
GFE			5.3.3.1.2 5.3.3.2.2	5.3.3.1.2 5.3.3.2.2 5.3.3.3 5.3.7.2 5.3.8.3 5.3.8.5 5.3.8.11 5.3.8.13	N/A

TABLE 5-2. Typical NH&S task applicability (AVE/SE contractor)

Contractor Category	Life Cycle Phase	Concept Exploration and Definition	Demonstration & Validation	EMD	Production and Deployment	Operations and Support
System Support & Integration Contractor	Systems Integration Role	5.3.1.2 5.3.2.2	5.3.1.2 5.3.2.2	5.3.1.2 5.3.6.1 5.3.7.3 5.3.6.2 5.3.2.2	5.3.1.2 5.3.6.2 5.3.7.3	N/A
	Facilities/ RPIE Design Criteria Role	N/A	5.3.1.2 5.3.2.3 5.3.3.2.1 5.3.3.2.3 5.3.4.1 5.3.4.1.1 5.3.4.1.2 5.3.4.2	5.3.1.2 5.3.4.1 5.3.6.1 5.3.1.2.1 5.3.4.1.1 5.3.7.2 thru 5.3.2.3 5.3.4.1.4 5.3.8.1 5.3.4.2 5.3.8.1.1 5.3.3.2.1 5.3.8.8 5.3.3.2.3 5.3.5.1 5.3.8.11 5.3.8.13	5.3.4.1 5.3.4.1.3 5.3.4.1.4 5.3.4.2	N/A
Facilities A&E Contractor		N/A	5.3.4.1 5.3.4.1.1 5.3.4.1.2 5.3.4.2	5.3.4.1 5.3.4.2 5.3.4.1.1 thru 5.3.8.2 5.3.4.1.4	5.3.4.1 5.3.4.2 5.3.4.1.3 5.3.4.1.4 5.3.8.2	N/A
Facilities Construction Contractor		N/A	N/A	5.3.8.9 5.3.8.10	5.3.8.9 5.3.8.10	N/A
A&CO Contractor		N/A	N/A	N/A	5.3.1.2 5.3.8.5.1	N/A
Hardness Surveillance Support Contractor		N/A	N/A	N/A	N/A	5.3.1.2 5.3.8.15

TABLE 5-3. Typical NH&S task applicability (Other contractors)

b. technical and economic objectives are sound, needed, reasonable, and well defined;

c. major uncertainties are identified for further investigation during the demonstration and validation phase; and

d. preliminary cost and schedule estimates are based upon sound analyses.

5.1.1.2 System support/integration (SS&I) contractor. The contractor shall perform the applicable 5.3 tasks necessary to support the conduct of a proof-of-concept development activity for the alternative system concept selected by the SPO as an acceptable candidate approach for satisfying a specific operational need.

5.1.2 Demonstration and validation phase.

5.1.2.1 SPO. The SPO will establish weapon system hardness requirements based upon the nuclear threat. The SPO will consider the allocation of hardness requirements in the selection of major subsystems for procurement. Specific hardness requirements will be allocated to major subsystems on the basis of operational requirements, technical complexity, and acquisition strategy. The hardness requirements for the weapon system will be documented in the weapon system specification (WSS). The SPO will conduct system level testing, via the SS&I contractor, to support development of a concept design and weapon system requirements. The SPO will identify future tests and analyses to support the hardness evaluation of the system in its integrated test plan (ITP) and integrated analysis plan (IAP). For weapon systems that do not require a formal demonstration and validation phase, the SPO will accomplish these activities both during the final part of the concept and exploration definition phase and the first part of the engineering and manufacturing phase, as appropriate.

5.1.2.2 AVE/SE contractor. The contractor shall perform the applicable 5.3 tasks necessary to:

a. evaluate the optimization, traceability, and technical risk associated with the allocation of weapon system hardness requirements to the weapon system elements (WSEs) under contract;

b. develop concept designs to the extent that configuration item (CI) selection can be evaluated in terms of hardness allocation strategies and hardness interface requirements with other AVE/SE contractors; and

c. Formally present the results of these tasks at a system design review (SDR).

5.1.2.3 SS&I contractor. The contractor shall perform the applicable 5.3 tasks necessary to support:

a. the SPO in the evaluation of alternate system designs with respect to the feasibility of proposed hardening techniques and their associated technology risk, and the impact of NH&S considerations on critical interfaces, cost, and schedule; and

b. system level test planning and conduct to support development of a concept design and weapon system requirements; and

c. the inclusion of hardness requirements in the facilities design criteria in a manner that is compatible with all other facility/hardware interfacing requirements.

5.1.2.4 Facilities architectural and engineering (A&E) contractor. The contractor shall perform the applicable 5.3 tasks necessary to prepare facilities drawings that incorporate all the hardness requirements identified in the facilities design criteria.

5.1.3 Engineering and manufacturing phase.

5.1.3.1 SPO. The SPO will develop models to support implementation of system level NH&S assessments and will initiate the assessment activity.

5.1.3.2 AVE/SE contractor. The contractor shall perform the applicable 5.3 tasks necessary to accomplish:

a. evaluate the optimization, traceability, and technical risk associated with the allocation of weapon system hardness requirements to the weapon system elements (WSEs) under contract;

b. develop concept designs to the extent that configuration item (CI) selection can be evaluated in terms of hardness allocation strategies and hardness interface requirements with other AVE/SE contractors;

c. develop the AVE/SE hardness requirements;

d. accomplish the design, evaluation, verification, and qualification of CIs that satisfy these hardness requirements;

e. accomplish the planning, preparation, and implementation of activities required in support of life cycle hardness;

f. support to the system level hardness evaluation activity; and

g. support to the SPO's system level assessment activity.

The contractor shall also support the development of facility and assembly and checkout (A&CO) installation hardware hardness requirements.

5.1.3.3 SS&I contractor. The contractor shall perform the applicable 5.3 tasks necessary to:

a. accomplish system level hardness evaluation;

b. support the SPO's system level assessment activity;

c. develop facility and RPIE hardness requirements for incorporation in the facilities design criteria; and

d. accomplish the correct incorporation of these facility and RPIE hardness requirements in the facility design drawings.

5.1.3.4 Facilities A&E contractor. The contractor shall perform the applicable 5.3 tasks necessary to develop and complete facilities drawings that incorporate all the hardness requirements identified in the facilities design criteria. The contractor shall ensure that the facility as constructed contains all required hardness design features.

5.1.3.5 Facilities construction contractor. The contractor shall perform the applicable 5.3 tasks necessary to accomplish the construction of facilities in a manner that preserves the hardness provided for in the facility design.

5.1.4 Production and deployment phase.

5.1.4.1 SPO. The SPO will complete its system level assessment and document the results.

5.1.4.2 AVE/SE contractor. The contractor shall perform the applicable 5.3 tasks necessary to accomplish the production of CIs that are as nuclear hard as the hardware design that was verified and qualified in the EMD phase. Any design changes implemented during the production and deployment phase shall undergo appropriate hardness evaluation to verify hardness adequacy. Any such changes that have an LCH impact shall be fully included in LCH activities and documentation, as appropriate.

5.1.4.3 SS&I contractor. The contractor shall perform the applicable 5.3 tasks necessary to support:

a. the accomplishment of system level hardness evaluation; and

b. the SPO's system level assessment activity.

Any design changes implemented during the production and deployment phase that may affect system level hardness shall undergo appropriate system level hardness evaluation update to verify hardness adequacy. Any system level changes that have an LCH impact shall be fully included in LCH activities and documentation, as appropriate.

5.1.4.4 Facilities A&E contractor. The contractor shall perform the applicable 5.3 tasks necessary to prepare a facilities design package that satisfies the hardness requirements contained in the facilities design criteria and supports the construction of facilities in a manner that will satisfy these hardness requirements.

5.1.4.5 Facilities construction contractor. The contractor shall perform the applicable 5.3 tasks necessary to accomplish the construction of facilities in a manner that preserves the hardness provided for in the facility design.

5.1.4.6 A&CO contractor. The contractor shall perform the applicable 5.3 tasks necessary to accomplish the deployment of the weapon system in a manner that:

a. preserves the hardness integrity of all system elements; and

b. results in a deployed weapon system that satisfies all specified hardness requirements.

5.1.6 Operation and support phase.

5.1.6.1 Supporting command. The supporting command will:

a. implement a hardness maintenance program and a periodic hardness surveillance program throughout the weapon system's operational life; and

b. perform system level assessments when requested by the operating command.

5.1.6.2 Hardness surveillance support contractor. The contractor shall perform the applicable 5.3 tasks necessary to support the hardness surveillance program implemented by the supporting command.

5.1.6.3 Operating command. The operating command will update or initiate system level assessments as required.

5.2 Hardware category NH&S requirements. The contractor shall implement applicable NH&S program tasks in accordance with the following requirements for specific categories of hardware.

5.2.1 AVE/SE equipment.

5.2.1.1 Contractor furnished equipment (CFE). The contractor shall give careful consideration to NH&S requirements and their associated system life cycle impacts when evaluating whether to utilize non developmental rather than developmental items to satisfy a CI requirement as specified in the applicable prime item development specification (PIDS). The feasibility and cost of preserving CI hardness throughout the operational life of the weapon system shall be given particular consideration. In evaluating the use of commercial non developmental items to satisfy a CI requirement, the contractor shall, to the maximum extent possible and practical, utilize design features in the host system that will protect the item from the specified hardness requirements, thereby minimizing or eliminating the hardness requirements that must be imposed on the item itself. Among the protective design features that can be considered for this purpose are shielding, shock isolation, and electrical surge protection.

5.2.1.1.1 Developmental items. The contractor shall be responsible for the full and satisfactory implementation of all applicable NH&S tasks, including those cases in which the contractor has chosen to acquire the developmental item through subcontract with another supplier, whether commercial or non commercial. In evaluating the possible use of commercial suppliers, the contractor shall give careful consideration to the feasibility and cost of preserving CI hardness throughout the operational life of the weapon system. When commercial suppliers are utilized for this purpose, the contractor shall take particular care that all LCH requirements are completely and correctly satisfied.

5.2.1.1.2 Non developmental items (NDI)/commercial. The contractor shall evaluate early in the preliminary design and hardness allocation activities whether any already existing commercial item intended for use in the design of a CI will meet all applicable hardness requirements. If some modification to meet hardness requirements is found to be necessary, the contractor shall first consider:

a. the utilization or alteration of design features of the host system to reduce commercial item hardness requirements to the extent that no modification is necessary; under these circumstances, the design elements in the host system that provide the required protection shall be identified as hardness critical items (HCIs), and the performance requirements associated with the modification shall be included in the applicable PIDS.

b. the selection of alternative commercial items that meet the allocated hardness requirements without modification; or

c. some combination of a. and b. such that the commercial item under consideration does not require modification.

If no modification is necessary, the requirements of 5.2.1.1.2.1 shall apply. If modification is necessary, the requirements of 5.2.1.1.2.2 shall apply. In all cases of the use of non developmental commercial items, whether unmodified or modified, the contractor shall be responsible for the full and satisfactory implementation of all applicable NH&S tasks.

5.2.1.1.2.1 Unmodified commercial NDI. If the commercial off-the-shelf (COTS) hardware item under consideration can be shown to satisfy all applicable hardness requirements without any modification, the contractor shall identify and document:

a. the design characteristics that provide the required allocated hardness and all associated HCIs and hardness critical processes (HCPs); and

b. appropriate, cost-effective test and inspection procedures that will ensure that future procurements of the item will exhibit at least the same level of hardness as the item evaluated.

5.2.1.1.2.2 Modified commercial NDI. If the hardware item under consideration is modified to meet its allocated hardness requirements, the contractor shall, based on the nature and extent of the modification under consideration, provide recommendations to the SPO, for SPO decision, as to whether:

a. the item should be treated fully as a developmental item, per 5.2.1.1.1; or

b. only those portions of the item's design that are planned to undergo modification should be treated under the requirements of 5.2.1.1.1, while the unmodified portions of the design are treated in accordance with the requirements of 5.2.1.1.2.1.

The recommendations concerning this matter prepared by the contractor shall take LCH considerations fully into account, in addition to other relevant program concerns.

5.2.1.1.3 NDI items/military. The contractor shall evaluate early in the preliminary design and hardness allocation activities whether any already existing military item intended for use in the design of a CI will meet all applicable hardness requirements. If some modification to meet hardness requirements is found to be necessary, the contractor shall first consider:

a. the utilization or alteration of design features of the host system to reduce military item's hardness requirements to the extent that no modification is necessary; under these circumstances, the design elements in the host system that provide the required protection shall be identified as HCIs, and the performance requirements associated with the modification shall be included in the applicable PIDS.

b. the selection of alternative non developmental military items that meet the allocated hardness requirements without modification; or

c. some combination of a. and b. such that the non developmental military item under consideration does not require modification.

If no modification is necessary, the requirements of 5.2.1.1.3.1 shall apply. If modification is necessary, even after careful consideration of the options identified above, and the proposed modification is permitted by interchangeability requirements, the requirements of 5.2.1.1.3.2 shall apply. In all cases of the use of non developmental military items, whether unmodified or modified, the contractor shall be responsible for the full and satisfactory implementation of all applicable NH&S tasks, except as noted in 5.2.1.1.3.1.

5.2.1.1.3.1 Unmodified military NDI. The contractor shall be responsible for the full and satisfactory implementation of all applicable NH&S tasks unless the following two conditions apply to the hardware item under consideration:

a. it has already been assessed and qualified on a prior program to at least the hardness requirements of the system under procurement, and existing documentation satisfactorily supports the conclusion that the equipment as built satisfies those requirements; and

b. it will be procured directly from the supplier that had originally designed it, or an approved second source, to the original specifications and drawings and the same manufacturing procedures.

5.2.1.1.3.2 Modified military NDI. If the hardware item under consideration is modified to meet its allocated hardness requirements, the contractor shall, based on the nature and extent of the modification under consideration, provide recommendations to the SPO, for SPO decision, as to whether:

a. the item should be treated fully as a developmental item, per 5.2.1.1.1; or

b. only those portions of the item's design that are planned to undergo modification should be treated under the requirements of 5.2.1.1.1, while the unmodified portions of the design are treated in accordance with the requirements of 5.2.1.1.3.1.

The recommendations concerning this matter prepared by the contractor shall take LCH considerations fully into account, in addition to other relevant program concerns.

5.2.1.2 Government furnished equipment (GFE).

5.2.1.2.1 GFE hardness requirements. The contractor shall use the hardness capability of the GFE (as previously established by requirements or test) to allocate hardness requirements to the WSE(s) under contract in the host system. If the resulting hardness allocations are impractical or the resulting hardness requirements allocated to the GFE are above the hardness capability of the GFE, the contractor shall provide recommendations to the SPO, such as:

a. alternative design approaches involving other WSE(s) in the host system to adequately protect the GFE;

b. additional NWE shielding or attenuation requirements allocated to other WSE(s) in the host system;

c. the substitution of a different item of GFE; or

d. additional testing or analysis to determine if a higher GFE hardness capability exists.

5.2.1.2.2 Hardness surveillance planning. The contractor shall include GFE in hardness surveillance planning.

5.2.2 Facilities/RPIE. The contractor shall implement all applicable hardness requirements in facilities/RPIE specification, design, documentation, construction, procurement, assembly, and installation.

5.2.3 A&CO installation hardware. The contractor shall implement all applicable hardness requirements in A&CO installation hardware specification, design, documentation, fabrication, procurement, assembly, and installation.

5.3 NH&S program tasks. The contractor shall implement the NH&S program tasks described below in accordance with the tasking defined by the applicable contract. The hardness trade studies, analyses, and tests performed in support of accomplishing these tasks shall be implemented in accordance with the requirements of 5.4. The task descriptions provided below constitute a complete menu of NH&S program tasks, and do not explicitly identify individual contractor responsibilities. The particular tasks that typically apply to a specific category of contractor are indicated by Tables 5-1, 5-2, and 5-3 in terms of the contractor's role in the program, the life cycle phase(s) under contract, and the hardware categories utilized. Explicit recommendations for the tailoring of this standard for contractual application to ICBM programs are contained in 6.3. Technical tasks performed by the SPO and the supporting command are included below for information purposes to provide a complete definition of the technical content of a comprehensive NH&S program.

5.3.1 NH&S program definition.

5.3.1.1 SPO NH&S program planning. The SPO will prepare an NH&S program plan that provides an overview of the entire NH&S program for the weapon system under consideration, including the planned system hardness test and analysis activity. This plan will identify and summarize the approach and schedule by which the SPO will implement this NH&S program, and will identify the organizational entities involved with accomplishing its implementation. The respective responsibilities of each organization and required interfaces will also be identified.

5.3.1.2 Contractor NH&S program planning. The contractor shall define an NH&S program that provides for the cost-effective and timely accomplishment of all applicable NH&S tasks (see 6.2). The contractor shall ensure that the NH&S program is accorded adequate recognition and support within the contractor's overall program, and shall provide for the management, technical, and coordination efforts necessary to achieve each applicable task.

5.3.1.2.1 WSE nuclear environment/effect hardware element matrix (NEEHEM). Contractor NH&S personnel shall compile and maintain current a WSE NEEHEM in support of the contractor's ongoing hardness design development activity. This NEEHEM shall be used to identify:

a. the particular nuclear environments and effects for which a given hardware element will undergo hardness evaluation;

b. the status of each evaluation; and

c. references to applicable documentation.

Other useful information lending itself to display in this matrix format by code reference may also be included.

5.3.2 WSS hardness requirements.

5.3.2.1 SPO development of WSS hardness requirements. The SPO will define the nuclear weapon effects/environments (NWE) and, as deemed appropriate by the SPO, selected WSE hardness performance requirements for inclusion in the WSS. Such definition will be based on current threat scenarios from the threat environment definition (TED), the system threat assessment report (STAR), or other approved threat definition documents, and the system concept design. This activity may require trade studies to assess the impact of parametric nuclear weapon environment levels on the cost, schedule, and technical risks associated with the system concept designs. The NH&S content of the WSS will be coordinated among the SPO's contractors, the supporting and operating commands, the nuclear criteria group secretariat (NCGS), the defense nuclear agency (DNA), and other government agencies, as appropriate.

5.3.2.2 Contractor support to development of WSS hardness requirements. The contractor shall support the activity to develop WSS hardness requirements by:

a. conducting system level trade studies in support of system concept design development;

b. conducting system level hardness analyses;

c. planning and conducting a system level hardness test program; and

d. incorporating and maintaining the SPO approved WSS hardness requirements within the appropriate operational requirements analysis (ORA) documentation.

5.3.2.3 WSS hardness requirement allocations. The contractor shall conduct hardness trade studies, hardness analyses, and hardness tests, as appropriate, at a level of detail consistent with the concept design (see 6.2). The objective of this activity shall be to identify any areas of the concept design that are driven by the WSS hardness requirements such that requirement compliance is not attainable. When such areas exist, the contractor shall make recommendations to the SPO regarding revisions to the WSS or revisions to the planned allocations.

5.3.3 WSE hardness requirements.

5.3.3.1 AVE/SE hardness requirements

5.3.3.1.1 Development of AVE/SE hardness requirements. The contractor shall conduct hardness trade studies, hardness analyses, and hardness tests, as appropriate, to develop and allocate hardness requirements from the WSS for the AVE/SE under contract (see 6.2). The hardness requirements shall be documented in the ORA, and allocated to each CI PIDS, as appropriate.

5.3.3.1.2 Hardness interface control requirements. The contractor shall identify hardness interface control requirements associated with the AVE/SE under contract and shall document these requirements in interface control documents (ICDs), as appropriate. The contractor shall provide NH&S support to the interface control working group (ICWG). When identifying and documenting hardness interface control requirements for specific nuclear environments, the following considerations shall apply.

5.3.3.1.2.1 Electromagnetic pulse (EMP). The identification and documentation of EMP interface control requirements shall include, as applicable, the following considerations:

a. electromagnetic field mitigation levels provided by shielded enclosures or equipment structures;

b. conducted transient mitigation provided by EMP protection devices and circuitry; and

c. EMP conducted transients in the form of a Thévenin/Norton equivalent source, complete with time wave form and source impedance.

5.3.3.1.2.2 Nuclear radiation. The identification and documentation of nuclear radiation interface control requirements shall include, as applicable, the following considerations:

a. circumvention and recovery (C&R) trigger levels and time lines;

b. C&R status signals that are generated to be sent to other hardware items and C&R status signals required from other hardware items with appropriate signal protocol; and

c. attenuation of the free field environment provided by inherent or dedicated shielding.

5.3.3.1.2.3 Mechanical (x-ray, thermal radiation, blast, shock, and debris). The identification and documentation of x-ray, thermal radiation, blast, shock, and debris interface control requirements shall include, as applicable, the following considerations:

a. transmitted shock and vibration in the form of shock response spectra or shock-induced motion time histories;

b. static and dynamic air pressure loads;

c. temperature or heat flux transients;

d. dynamic stress or load transients;

e. x-ray transmittance; and

f. sound pressure level spectra of acoustic noise generated by blast.

5.3.3.2 Facilities hardness requirements.

5.3.3.2.1 Development of facilities design criteria hardness requirements. The contractor shall conduct hardness trade studies, hardness analyses, and hardness tests, as appropriate, to develop hardness requirements from the WSS for the facilities/RPIE under-contract (see 6.2). These hardness requirements shall be documented in the facilities design criteria document such that:

a. hardness requirements are expressed in standard civil engineering terminology; and

b. all facility interfaces with other WSE that have hardness related requirements, as identified by WSE contractors through their facility criteria input reports, are identified.

5.3.3.2.2 Support to development of facilities design criteria hardness requirements. The contractor shall support the activity to develop facilities design criteria hardness requirements by:

a. identifying facility/RPIE hardness requirements and design features associated with installation of the WSEs under contract;

b. performing hardness analysis to express the applicable hardness design constraints in standard civil engineering terminology;

c. identifying the design and hardness requirements for any additional A&CO hardware between the WSE and the facility, as identified in the contractor's A&CO technical analysis (TA) activity;

d. communicating additional A&CO hardware hardness requirements to the facilities design criteria contractor via facility criteria inputs;

e. supporting facilities design criteria technical interchange meetings (TIMs); and

f. reviewing the facilities design criteria documentation.

5.3.3.2.3 Review of facilities drawings. The contractor shall review the incremental drawing submittals for the facilities in conjunction with the development of the facility criteria hardness requirements (see 5.3.3.1) to ensure that:

a. the hardness requirements in the facilities design criteria documentation have been fully developed and properly implemented;

b. the design is mature enough that all the hardness critical features are identified; and

c. the drawings have been properly hardness annotated.

5.3.3.3 A&CO installation hardware hardness requirements. The contractor shall identify all hardness requirements associated with A&CO installation hardware related to the WSEs under contract, and shall document them in the contractor's A&CO technical analysis.

5.3.4 WSE hardness design.

5.3.4.1 Hardness design development. The contractor shall incorporate nuclear hardness into the design of the WSEs under contract by implementing an iterative and interactive process of selecting and evaluating different design approaches and solutions to meet all applicable hardness requirements. The selection and evaluation process shall be accomplished through hardness trade studies, hardness analyses, and hardness tests, as appropriate (see 6.2). During the design process, the contractor shall:

a. ensure the hardened WSE design does not violate other non-NH&S requirements;

b. integrate the hardness design features of the WSE with other contractors' hardness design features, where appropriate;

c. select designs that minimize the cost and complexity of hardness verification and hardness qualification; and

d. make every effort to optimize the design with respect to cost-effective implementation of LCH, including the ease with which tests and inspections in support of hardness assurance, maintenance, and surveillance can be implemented.

5.3.4.1.1 Concept design. The contractor shall develop a concept design for the WSEs under contract that reflects hardness design concepts consistent with the draft WSS. This concept design shall be used during the SDR to verify that the WSS is complete and correct with respect to the WSEs under contract.

5.3.4.1.2 Preliminary design. The contractor shall develop a preliminary design for the WSEs under contract that incorporates hardness features in sufficient detail to support hardness allocation and to identify hardness critical interfaces.

5.3.4.1.3 Detail design. The contractor shall develop a detail design for the WSEs under contract that satisfies all applicable hardness requirements. The contractor shall use the detail design as the basis for accomplishing hardness verification.

5.3.4.1.4 Final design. The contractor shall develop a final design for the WSEs under contract that satisfies all applicable hardness requirements. For CIs, the contractor shall use the final design as the basis for hardness qualification of the WSEs under contract at the functional configuration audit (FCA).

5.3.4.2 Considerations for specific NH&S disciplines. For all NH&S disciplines, hardness design implementation shall include consideration of the feasibility, ease, and cost-effectiveness with which hardness verification of the design selected can be accomplished. When implementing hardness design for specific NH&S disciplines, the following considerations shall apply.

5.3.4.2.1 EMP. EMP hardness design shall incorporate the design features of a complete, well defined system/subsystem shielding topology. EMP hardness design implementation shall include, as applicable, the following considerations:

a. implementation of designs that are compatible with those of other contractors, including continuation of system shielding topologies;

b. proper implementation of box and structural electromagnetic shielding hardware, including conductive gaskets, cover fasteners, and compatible metal surface treatments;

c. proper implementation of cable shielding, including circumferential termination of cable shields through appropriate cable connector and backshell hardware;

d. proper implementation of electrical protection devices, including specified packaging and mounting parameters relating to protection device performance;

e. implementation of interface circuits impervious to EMP conducted transients, such as fiber optic technologies;

f. proper implementation of software communication protocols to reject EMP generated conducted transient noise on digital interfaces;

g. proper implementation of exterior conductive coatings;

h. proper implementation of electrical bonding and grounding;

i. proper implementation of low response cabling (i.e., filled cables);

j. proper implementation of low atomic number dielectric coatings on interior surfaces; and

k. proper implementation of a segregated power distribution system (i.e., mission critical loads segregated from non-mission critical loads.

5.3.4.2.2 Nuclear Radiation. Nuclear radiation design shall include, as applicable, the following considerations:

a. use of fully characterized and qualified semiconductor devices from the approved preferred parts list;

b. correct application of device derating factors in worst case circuit analyses;

c. use of preferred circuit, wiring, and grounding procedures;

d. use of nuclear event protection, including C&R, photocurrent compensation and current limiting techniques, as appropriate;

e. design prohibitions based on the known inadequacy of certain semiconductor technologies;

f. use of dedicated radiation shielding at the local, box, or subsystem level with all line of sight apertures covered (i.e., baffle shields or high atomic number loaded elastomer boots);

g. use of low atomic number dielectric coatings on AVE hardware internal surfaces to minimize x-ray induced currents; and

h. use of nitrogen filled pressurized volumes on AVE hardware to minimize x-ray induced currents.

5.3.4.2.3 Mechanical. Mechanical/structural design implementation shall include, as applicable, the following considerations:

a. appropriate use of material properties with consideration of any thermal degradation;

b. specified factors of safety;

c. appropriate techniques for environment mitigation, such as shock isolation and shielding;

d. loadings resultant from interactions of one or more NWE at a system or subsystem level; and

e. combinations of various nuclear and operational environments and loads.

5.3.5 WSE hardness evaluation.

5.3.5.1 WSE hardness verification. The contractor shall accomplish hardness verification of the detail design through an appropriate program of hardness analyses and hardness tests, and shall document the data that support the assertion that the detail design satisfies all applicable hardness requirements (see 6.2). The hardness verification activity shall include the determination of hardness design margins (HDMs).

5.3.5.2 WSE hardness qualification. The contractor shall accomplish hardness qualification of the approved final design through hardness analyses or qualification tests, and shall document the data that support the assertion that hardness qualification has been accomplished (see 6.2). For CIs, hardness qualification shall be accomplished through implementation of the quality conformance methodology identified in section 4 of the controlling PIDS.

5.3.6 System level hardness evaluation.

5.3.6.1 System level hardness testing and analysis. The contractor shall participate in the implementation of system level tests and analyses as specified in the ITP and IAP (see 6.2).

5.3.6.2 System level hardness verification. The contractor shall perform a system level hardness verification activity to establish that the integrated weapon system meets or exceeds WSS NWE requirements, and shall document the results in a system hardness analysis report (SHAR) (see 6.2). As part of this activity, the contractor shall review and evaluate relevant existing data and shall synthesize these data into a comprehensive statement of system level hardness with respect to the NWE requirements stated in the WSS. The data items to be reviewed and evaluated for this purpose shall include:

a. applicable requirement allocation documents referenced in the ORA; these data shall be reviewed and evaluated in the light of the final system configuration to identify and quantify any inconsistencies;

b. WSE hardness verification documentation, including all applicable NH&S design analysis reports (DARs); and

c. system level testing and analysis results.

5.3.7 System level assessment.

5.3.7.1 SPO system level assessment. The SPO will perform an assessment of the production configuration of the integrated system, using inputs from the WSE contractors and the SS&I contractor. This assessment will be limited in scope to the controlling failure mechanisms identified by the contractors. The analyses and their results will be documented and provided to the supporting and operating commands for use during the operations and support phase. The operating command will use this information to support single integrated operating plan (SIOP) activities. The supporting command will use the information for periodic assessments and for prioritizing potential modification, upgrade, or replacement actions.

5.3.7.2 WSE level support to system level assessment. The contractor shall provide support to the SPO's system level assessment activity (see 6.2). Such support shall include:

a. initial identification and prioritizing of the controlling hardness failure mechanisms for the WSE(s) under contract, as determined from the WSE hardness verification and qualification activities;

b. evaluation of the effects of selected nuclear environments on selected WSE constituent hardware elements at levels above and below specification levels, as well as those resulting from alternate threats or new environment prediction methodologies defined by the SPO; the selection of the specific nuclear environments and hardware elements to be included in this activity shall be based on the data provided under item a.;

c. fragility testing;

d. fragility analysis consisting of the calculation of transfer functions and fragility curves for the selected nuclear environments and hardware elements evaluated under items b. and c., including an estimate of associated random and systematic uncertainties; and

e. support to TIMs with the SPO and other contractors.

5.3.7.3 System level support to system level assessment. The contractor shall provide support to the SPO's system level assessment activity with respect to hardness failure mechanisms resulting from system level effects that involve multiple WSEs and are beyond the scope of any one WSE contractor (see 6.2). Such support shall consist of the tasks defined in 5.3.7.2, as applicable.

5.3.8 Life cycle hardness.

5.3.8.1 HCI/HCP identification. Contractor NH&S personnel shall review the design of all of the contractor's WSEs and their constituent elements to identify the HCIs and HCPs contained therein. The HCI identification activity shall apply to existing as well as to newly designed hardware, and shall include consideration of all levels of hardware down to the detailed part level. Contractor NH&S personnel shall compile a separate HCI list for each deliverable WSE containing HCIs in support of the release by the contractor of an HCI list drawing for each such WSE.

5.3.8.1.1 HCI list drawing. The contractor shall release each WSE HCI list as a controlled drawing early in the program and shall maintain it to reflect the most current status of HCI identification throughout the entire duration of the contractor's program. These HCI list drawings shall constitute the authoritative source of HCI identification for all contractor activities, and they shall be used in support of all hardness annotation tasks, including the hardness annotation of:

a. drawings,

b. master engineering document lists (MEDLs);

c. the A&CO TA;

d. the logistics support analysis (LSA); and

e. technical orders (TOs) and other applicable procedural documentation.

These drawings shall also be used to support the preparation of the HCI index contained in the NH&S DAR. The contractor shall ensure that a one-to-one correspondence exists between the content of the HCI list drawing for a given WSE and all other HCI annotations and listings associated with that WSE.

5.3.8.2 NH&S support to drawing preparation. Contractor NH&S personnel shall:

a. identify the hardness related test and inspection requirements associated with each WSE under contract for incorporation, as appropriate, in the contractor's engineering drawings;

b. provide direct support to the contractor's activity to hardness annotate these drawings;

c. review all such hardness annotations to ensure their completeness and correctness; and

d. ensure that these hardness annotations are incorporated, as appropriate, into other relevant production related documentation, such as quality assurance plans.

5.3.8.2.1 NH&S support to MEDL preparation. Contractor NH&S personnel shall provide direct support to the contractor's activity to hardness annotate the MEDLs corresponding to drawings with hardness annotations. Contractor NH&S personnel shall be responsible to review all such hardness annotations to ensure their completeness and correctness.

5.3.8.3 NH&S support to LSA preparation. Contractor NH&S personnel shall:

a. identify applicable hardness related test and inspection requirements for incorporation in the contractor's LSA;

b. provide direct support to the hardness annotation of LSA documentation; and

c. review all such hardness annotations to ensure their completeness and correctness.

5.3.8.4 NH&S support to TO preparation. Contractor NH&S personnel shall:

a. identify applicable hardness related test and inspection requirements for incorporation in the contractor's TOs;

b. provide direct support to the hardness annotation of the TOs; and

c. review all such hardness annotations to ensure their completeness and correctness.

5.3.8.5 NH&S support to A&CO TA preparation. Contractor NH&S personnel shall:

a. identify applicable hardness related test and inspection requirements for incorporation in the contractor's A&CO TA;

b. provide direct support to the hardness annotation of A&CO TA documentation; and

c. review all such hardness annotations to ensure their completeness and correctness.

5.3.8.5.1 LCH during A&CO implementation. The contractor shall:

a. incorporate the hardness content of the A&CO TA into all applicable aspects of the A&CO implementation activity;

b. identify any additional HCIs and HCPs associated with A&CO installation hardware;

c. hardness annotate A&CO implementation documentation, including drawings and procedural documentation (see 6.2);

d. define, plan, and implement a hardness assurance program (see 6.2); and

e. hardness annotate the as-built drawings that will be provided to the operating command.

5.3.8.6 Hardness maintenance preparation planning. The contractor shall plan for a hardness maintenance preparation activity that will result in the submittal to the SPO of the hardness information and documentation required by the supporting and using commands to implement a hardness maintenance program throughout the operations and support phase of the system life cycle for the WSEs for which the contractor is responsible (see 6.2). The hardness maintenance preparation support activity shall be considered to include:

a. HCI/HCP identification per 5.3.8.1;

b. the inclusion of hardness related test and inspection requirements in and the hardness annotation of drawings and the MEDL per 5.3.8.2, LSA and A&CO TA documentation per 5.3.8.3, and TOs per 5.3.8.4; and

c. the preparation of the NH&S DAR per 5.3.5.2.

The contractor's hardness maintenance preparation plan shall be used by the contractor as a resource and guidelines document during implementation of the hardness maintenance preparation activity.

5.3.8.7 Factory support equipment (FSE)/depot support equipment (DSE) hardness requirements. The contractor shall, to the maximum practical extent, incorporate in the design of DSE and FSE a capability to evaluate hardness related characteristics of the WSEs under contract. Contractor NH&S personnel shall provide direct support to this activity and shall have the lead responsibility to:

a. identify the hardness related characteristics of the contractor's design that can be evaluated by means of FSE/DSE; and

b. maximize the extent to which the contractor's design originally provides for the opportunity to verify WSE hardness by means of FSE/DSE.

5.3.8.8 Hardness assurance planning. The contractor shall plan a hardness assurance program to assure the preservation of the hardness provided for in the design of the WSEs under contract 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. Planning for hardness assurance testing shall include, to the extent feasible and cost-effective, consideration of the possibilities for the acquisition of baseline data in support of hardness surveillance.

5.3.8.9 Hardness assurance resource definition and acquisition. The contractor shall identify and acquire all the hardware and software resources required to implement the approved hardness assurance program. In addition, all hardness assurance test procedures and equipment shall be validated prior to their initial use.

5.3.8.10 Hardness assurance implementation. The contractor shall implement the approved hardness assurance plan.

5.3.8.11 WSE hardness surveillance planning. The contractor shall plan for a hardness surveillance program that encompasses the hardness surveillance activities appropriate to the WSEs for which the contractor is responsible during design and development (see 6.2). During the activity to identify potential hardness degradation modes and candidate tests and inspections to detect such degradations, the contractor shall:

a. utilize all relevant information from the failure mode analysis (FMA) performed in accordance with SAMSO STD 77-6; and

b. consider the possibilities for incorporating or coordinating candidate hardness surveillance tests and inspections with routine repair and maintenance activities and planned or existing aging and surveillance programs.

5.3.8.12 SPO system hardness surveillance preparation planning. Subsequent to the receipt of all contractor hardness surveillance plans, the SPO will review the recommendations made, and define a single, integrated hardness surveillance plan for the entire weapon system. This system level plan:

a. may or may not include specific recommendations submitted by a contractor; and

b. will be used to define system level hardness surveillance implementation activities during the operations and support phase.

5.3.8.13 Hardness surveillance preparation support. The contractor shall support the hardness surveillance preparation planning. Such support shall consist of the identification and acquisition of the resources necessary to implement those aspects of the integrated weapon system hardness surveillance program defined by the SPO that involve hardware elements for which the contractor is responsible.

5.3.8.14 Hardness surveillance implementation (supporting command). The supporting command will implement the integrated weapon system hardness surveillance program at periodic intervals throughout the operations and support phase.

5.3.8.15 Hardness surveillance implementation support. The contractor shall provide support to the implementation of the weapon system hardness surveillance program.

5.3.8.16 Hardness maintenance implementation (supporting command). The supporting command will implement a weapon system hardness maintenance program to continue throughout the remainder of the weapon system's life cycle.

5.4 Hardness trade study, analysis, and test requirements. The hardness trade studies, analyses, and tests performed in support of accomplishing the NH&S program tasks defined in 5.3 shall be implemented in accordance with the following requirements.

5.4.1 Hardness trade studies. Hardness trade studies shall include, as applicable, the following considerations:

a. alternative allocations of hardness requirements among different levels of hardware assembly;

b. the possible reduction or elimination of selected hardness requirements through modification of operational requirements and procedures;

c. utilization of hardware items and technologies that are inherently hard to the specified NWE;

d. alternative approaches to accomplishing a hardened design;

e. associated cost-effectiveness of accomplishing the verification, by analysis and test, of the adequacy of the hardened design;

f. associated cost-effectiveness of LCH implementation;

g. the impact of the selected NH&S design on performance and operational requirements and other defined program constraints unrelated to hardness requirements;

h. the impact on NH&S design of performance and operational requirements and other defined program constraints unrelated to hardness requirements; and

i. maximization of the use of common design solutions and hardware items.

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

5.4.1.1 EMP. EMP hardness trade studies shall include, as applicable, the following considerations:

a. box, rack, structural, and cable electromagnetic shielding;

b. conductive coatings on exterior surfaces;

c. electrical bonding and grounding;

d. EMP protection devices and circuitry, including electrical surge arrestors (ESAs), circuit breakers, diodes, and filtering;

e. low response cabling;

f. low atomic number dielectric coatings;

g. utilization of hardware items and technologies that are inherently hard to the specified EMP requirements;

h. segregation of mission critical and non-mission critical power distribution;

i. interface compatibility with the designs of other contractors, including continuation of system shielding topologies;

j. utilization of software communication protocols that reject EMP generated conducted transient noise on digital interface circuits.

5.4.1.2 Nuclear radiation. Nuclear radiation hardness trade studies shall include, as applicable, the following considerations:

a. use of dedicated radiation shielding at the local, box, or subsystem level with all line of sight apertures covered (i.e., baffle shields or high atomic number loaded elastomer boots);

b. C&R mechanization;

c. special design features for electronic parts and circuits;

d. inclusion of nuclear radiation-related design margin allowance in the design or specification of electronic parts and circuits;

e. use of low atomic number dielectric coatings on AVE hardware internal surfaces to minimize x-ray induced currents; and

f. use of nitrogen filled pressurized volumes on AVE hardware to minimize x-ray induced currents.

5.4.1.3 Thermal radiation. Thermal radiation hardness trade studies shall include, as applicable, the following considerations:

a. dependence on material ablation versus material heating for the absorption of thermal energy;

b. material property degradation versus heat loading;

c. environmental control system (ECS) sizing versus heat absorption requirements;

d. use of line-of-sight shielding for critical components; and

e. difficulty of external protection material (EPM) manufacture and application versus performance.

5.4.1.4 Blast. Blast hardness trade studies shall include, as applicable, the following considerations:

a. missile in-flight structural and shock loadings as a function of both local and whole missile response airblast loadings in combination with operational flight loads and consideration of thermal radiation induced heating and resultant material properties degradation and thermal stress;

b. effects of in-flight blast wave interaction on missile accuracy and controllability;

c. facility structural protection versus in-place blast and shock hardness;

d. rigid (linear) versus crushable or deformable elasto-plastic (nonlinear) components;

e. vulnerability of subsystems and components inside the protective structure to both the pressure loadings arising from leakage and the blast induced motion; and

f. effects of airblast induced acoustic noise on equipment and personnel.

5.4.1.5 Shock. Ground shock hardness trade studies shall include, as applicable, the following considerations:

a. sensitivity of design parameters to uncertainties in the ground motion and structure-media interaction (SMI) loading environments;

b. alternative basing locations to best utilize beneficial geology for shock mitigation;

c. alternative structure and shock isolation concepts with respect to such factors as rattlespace, missile equipment, structure and isolation performance requirements, constructibility, ease of maintenance, and resistance to environmental degradation;

d. dual purpose (transportation and nuclear shock) isolation systems for mobile launchers; and

e. alternative designs to accommodate relative motions between supporting elements, such as antennas and communication lines, and main structures, such as a missile silo.

5.4.1.6 Debris. Debris hardness trade studies shall include, as applicable, the following considerations:

a. design parameters related to the mitigation of effects caused by impacting particles;

b. ability to operate through the debris environments;

c. ability of launch egress systems to perform missile egress and launch functions through the debris environments;

d. requirements for operation of command, control, and communication through the debris environments;

e. cost of AVE and equipment hardening versus debris fall-in prevention measures for silos;

f. rigid (linear) versus elasto-plastic (nonlinear) deformable components;

g. utilization of a single layer versus multilayer EPM;

h. difficulty of EPM manufacture and application versus performance;

i. weight added due to use of EPM versus debris protection required; and

j. effects of dust/debris loading on environmental control systems, including radioactive effects.

5.4.2 Hardness analysis. Hardness analyses shall include, as applicable, the following considerations:

a. hardness allocation analysis shall utilize conservative NWE coupling assumptions in such a manner as to achieve a cost-effective compromise between minimizing the need for complex coupling models and precluding the circumstance that the resulting hardness requirements unreasonably drive hardware design;

b. hardness design analysis shall utilize the least complex analysis method available that accomplishes the goals of the analysis, and shall rely to the fullest extent possible on existing hardware performance data;

c. in cases where hardware performance data required in support of an analysis is not available, limited testing shall be performed to acquire the needed data;

d. implementation of system level hardness analysis may require progressively more complex analysis techniques to support the determination of fragility curves and transfer functions; and

e. during implementation of hardness analysis, consideration shall be given to the possibility of NWE synergistic effects that result in a given hardware element being more susceptible to other concurrent or subsequent NWE exposures as a consequence of some initial NWE exposure.

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

5.4.2.1 EMP. EMP hardness analysis shall include, as applicable, the following considerations:

a. detailed shielding topology definition and incorporation of actual, verified EMP hardness design features;

b. utilization of hardness analysis approaches and techniques appropriate to the particular type of EMP environment and the WSE under consideration;

c. the need for coupling analysis to transform the specified EMP environments into EMP circuit drivers appropriate for circuit response analysis; and

d. awareness that EMP coupling is system design dependent, and the associated need to have EMP circuit drivers reflect overall system response, where appropriate.

5.4.2.2 Nuclear radiation. Nuclear radiation hardness analysis shall include, as applicable, the following considerations:

a. utilization of the analysis activity to support identification of piece part acceptance test requirements, including transient response and post-radiation acceptance criteria;

b. utilization of parts parameter data that have been properly derated for radiation response and other relevant factors;

c. nuclear event protection (NEP), including C&R consistent with circuit recovery time requirements, photocurrent compensation, and current limiting;

d. the determination, for those WSEs employing C&R, of the existence and magnitude of any vulnerability resulting from detector shadowing by other elements of the system;

e. subsystem/system errors resulting from the specified single and multiple events, for both pre-flight and flight conditions;

f. shielding analyses to determine the radiation levels incident on internal components and materials;

g. evaluation of mechanical responses to the nuclear radiation environment, including bulk heating and thermomechanical effects and induced gross vehicle motion (vehicle motion refers to both the missile and reentry vehicles in endo- and exo-atmospheric flight);

h. evaluation of radiological effects due to nuclear radiation-related energy deposition, particularly in personnel and ordnance; and

i. experimental activity to provide additional supporting data for the analysis activity, such as equation of state data, mechanical loading data, and component response data.

5.4.2.3 Thermal radiation. Thermal radiation hardness analysis shall include, as applicable, the following considerations:

a. material characteristics, such as thermal absorption and reflection, material ablation, conduction of heat, and thermally induced materials properties changes;

b. temperature time-histories at various locations, including bond lines, internal components, and structural attachments;

c. material recession time-histories caused by ablation, charring, and melting;

d. transmission of thermal radiation through transparent materials;

e. effects of aerodynamic flow, surface conditions, chemical reactions, and surface erosion on heat transfer at surfaces;

f. contact resistance in calculating heat transfer between materials;

g. appropriateness of two or three dimensional effects in complicated structures;

h. thermal studies to address temperature transients due to hot gas leakage;

i. prevention of sustained combustion during or after exposure to pre-flight or flight nuclear environments when combustible materials are used as missile skin materials; and

j. combined environment effects, such as blast and dynamic or static loading either preceding, during or following exposure to the thermal environment.

5.4.2.4 Blast. Blast hardness analysis shall include, as applicable, the following considerations:

a. combining normal operation loads with blast-induced loads;

b. combining both the shock diffraction and drag loading associated with the passage of blast waves over a structure;

c. both side-on shocks and a traveling-wave loads due to blast wave interaction;

d. overpressure and acoustic environments of internal components;

e. response of a vehicle guidance system to blast-induced loads and accelerations;

f. interaction of shocks due to a blast and the shock produced by supersonic motion of the missile;

g. combined environment effects; and

h. structure-borne acoustic environments generated by flow field around structure.

5.4.2.5 Shock. Shock hardness analysis shall include, as applicable, the following considerations:

a. degraded or enhanced material properties caused by aging and environmental effects;

b. multi-degree of freedom rigid body finite element models that include coupling between translational, rotational and flexible modes, nonlinear constitutive relations for the isolators (including strain rate effects on isolator performance), isolator dead band friction, foam, liquid spring and hydropneumatic models of shock isolation systems;

c. nonlinear constitutive properties of the free-field, back-fill, structural material, and soil/structure interface behavior for representative siting geologies when performing SMI analysis;

d. material property degradation under multipath loading; and

e. propagation of high frequency vibration environment through to critical electronic components.

5.4.2.6 Debris. Debris hardness analysis shall include, as applicable, the following considerations:

a. for impacting debris, material stress wave response and the overall structural response;

b. command, control and communication through the static debris, and debris removal for missile system erection;

c. effects of pebbles, dust, and ice on the in-flight system, including penetration, erosion, gouging, spall, kinetic energy deposition, convective heating augmentation, chemical reactions of reactive surface materials, and surface roughening; and

d. command, control and communication through the airborne dust cloud.

5.4.3 Hardness testing. The purpose of hardness testing is to support requirements development, design development, hardness evaluation, and hardness assessment activities. In addition to pretest prediction analysis, planning for hardness testing shall include consideration of:

a. differences between the simulated environment and the specified nuclear environment, and, for multiple burst environments, pretest conditioning of the test article;

b. interactions between the item under test and the test fixture or test instrumentation;

c. instrumentation response to the test environment and means for eliminating spurious responses;

d. inaccuracies resulting from instrumentation limitations; and

e. combined nuclear environment testing, where feasible.

Analysis may be used to interpolate or extrapolate measured responses to compensate for lack of simulation fidelity. 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. When the modeling uncertainties associated with planned hardness analysis activities are large with respect to anticipated HDMs, hardness testing shall be considered for the purpose of either reducing the modeling uncertainties or replacing the hardness analysis activity, in whole or in part. When defining hardness testing for specific nuclear environments, the following considerations shall apply.

5.4.3.1 EMP. EMP testing shall include, as applicable, 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. EMP protection device testing to verify the adequacy of the devices selected for their intended application in the design;

c. current injection testing to determine EMP upset and damage thresholds of circuit assemblies, boxes, and subsystems for specified wave forms;

d. electromagnetic shield testing to determine the shielding effectiveness and transfer impedance of grounding structures, electronic racks, boxes, cable shields and connectors; of particular importance are the connector to connector backshell transfer impedance and the connector backshell to cable shield joints transfer impedance;

e. 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);

f. free-field testing to characterize the response of circuit assemblies, boxes, subsystems, and systems to specified electromagnetic radiation; and

g. logic upset testing to determine upset modes and thresholds of software systems to EMP-induced transients.

5.4.3.2 Nuclear radiation. Nuclear radiation testing shall include, as applicable, the following considerations:

a. selection of radiation test facilities that best simulate the specified radiation environment with respect to radiation level, spectrum, and the distribution of radiation over the test article volume;

b. electronic parts radiation effects testing to determine the radiation response of selected piece parts, such as semiconductor devices, capacitors, and crystals, to selected simulations of nuclear radiation environments; testing should be conducted to obtain all relevant response characteristics;

c. 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;

d. subsystem/WSE radiation effects testing to determine the responses of selected subsystems/ WSEs to selected simulations of nuclear radiation environments; selection of subsystems/ WSEs for testing should be based on known or suspected criticalities, subsystem/ WSE analysis response predictions, and design complexity;

e. mechanical radiation effects testing to provide additional supporting data for the analysis activity and to establish susceptible component response; and

f. radiation test levels shall be increased to compensate for uncertainties in dosimetry and parameter annealing.

The definition of nuclear radiation qualification and acceptance test frequency and sample size requirements for semiconductor devices shall include consideration of device hardness design margin (HDM). Appendix E provides guidance on this matter.

5.4.3.3 Thermal radiation. Thermal radiation testing shall include, as applicable, the following considerations:

a. incorporation of all significant phenomena, such as thermal radiation flux, fluence and spectrum, and external air flow conditions;

b. material properties such as density, specific heat, conductivity, emissivity, heats of phase change, and chemical reaction characteristics; and

c. instrumentation 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.

5.4.3.4 Blast. Blast testing shall include, as applicable, the following considerations:

a. incorporation of all significant phenomena, such as the magnitude, shape, duration, and impulse of the blast wave, as well as the capability to provide proper simulation of normal operating loads;

b. test configurations scaled to the actual system/subsystem configuration;

c. important material properties, such as stress-strain properties;

d. instrumentation to measure all phenomena of interest, such as pressures, accelerations, stresses, and strains, in addition to noting damage characteristics or failure levels; and

e. gravity enhancement mechanism in scale testing to simulate the proper inertial resistance to airblast loads.

5.4.3.5 Shock. Shock testing shall include, as applicable, the following considerations:

a. piece part, component, subsystem, and system testing to determine shock response and hardness levels;

b. component and transfer function inputs from connecting structure responses;

c. material stress wave propagation and failure levels;

d. time phasing between different components of the shock environment;

e. electromechanical/software-hardware response;

f. reinforced concrete mechanical properties;

g. structure/soil interface friction properties;

h. umbilical cable and hose shock loops and hydraulic surge effects in hoses;

i. facility penetration failures from structure/soil relative motion; and

j. subsystem/component failure from rattlespace depletion or other shock isolation system failures.

5.4.3.6 Debris. Debris testing shall include, as applicable, the following considerations:

a. impacting debris tests;

b. operational erection tests through static debris;

c. debris, pebble, dust, and ice testing to obtain response data for material erosion rates, particle penetration depths, impact response, and ignition levels of combustible materials in erosive environments;

d. matching of important material properties; and

e. provision of instrumentation to measure all phenomena of interest.

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. The following data item descriptions (DIDs) must be listed, as applicable, on the contract data requirements list (CDRL) (DD Form 1423) when this standard is applied on a contract, in order to obtain the data, except where defense federal acquisition supplement 227.405-70 data requirements exempts the requirement for a DD Form 1423.

Reference Paragraph	DID Number	DID Title	Document(s) Procured Via DID
a. 4.1/ 5.3.1.2/ 5.3.8.6/ 5.3.8.8/ 5.3.8.11	DI-ENVR-80262A	NH&S Program Plan	- NH&S Program Plan - Hardness Maintenance Preparation Support Section - Hardness Assurance Section - Hardness Surveillance Section
b. 5.3.3.1.1/ 5.3.3.2.1/ 5.3.5.1/ 5.3.5.2	DI-ENVR-80266A	NH&S Design Analysis	- NH&S DAR (both for CIs and non-CIs, such as facilities/RPIE) Report
c. 5.3.2.3 5.3.3.1.1/ 5.3.3.2.1/ 5.3.4.1 5.3.6.1/ 5.3.6.2 5.3.7.2/ 5.3.7.3	DI-MISC-80508	Technical Report Studies/ Services	- NH&S Trade Study Report - System Hardness Analysis Report (SHAR) - System Level Analysis Report (applies to both IAP analyses and assessment analyses)
d. 5.3.3.1.1*/ 5.3.3.2.1*/ 5.3.4.1*/	DI-NDTI-80808	Test Plans/ Procedures	- NH&S Test Plans

Reference Paragraph	DID Number	DID Title	Document(s) Procured Via DID
5.3.5.1/ 5.3.5.2/ 5.3.6.1 5.3.7.2/ 5.3.7.3			
e. 5.3.3.1.1*/ 5.3.3.2.1*/ 5.3.4.1*/ 5.3.5.1/ 5.3.5.2/ 5.3.6.1/ 5.3.7.2/ 5.3.7.3	DI-NDTI-80809A	Test/ Inspection Reports	- NH&S Test Reports

* See 6.3.1.5 for applicability constraints.

The above DIDs were those cleared as of the date of this standard. *The current issue of DOD* 5010.12-L, Acquisition Management Systems and Data Requirements Control List (AMSDL) must be researched to ensure that only current, cleared DIDs are cited on Form 1423.

6.3 Tailoring guidance for contractual application. Since the text of this standard provides a complete definition of the technical content of a comprehensive NH&S program for a major weapon system, the tailoring of this standard for application to a specific contract requires careful attention to the following particulars of program status and contractor involvement:

a. the program role performed by the contractor;

b. the system life cycle phase(s) under contract; and

c. the categories of hardware utilized by the contractor, as applicable.

In addition, other considerations related to specific NH&S tasks and program circumstances can affect both tailoring implementation and proposal evaluation. For these reasons, this paragraph provides guidance regarding these matters based on previous program experience. 6.3.1 addresses a variety of special circumstances that affect tailoring and proposal evaluation, while 6.3.2 contains explicit tailoring guidance with respect to the three parameters listed above. The format of 6.3.2 has been designed to facilitate insertion of applicable portions into the statement of work (SOW) under consideration.

6.3.1 Special considerations affecting tailoring and proposal evaluation.

6.3.1.1 Tailoring guidance for the System Design Review (SDR). Paragraph 5.3.2.3 is the AVE/SE contractor's task to accomplish the work needed to support SDR. For programs that conduct a formal demonstration and validation phase and thus a SDR, paragraph 5.3.2.3 is not required in the engineering and manufacturing development (EMD) phase.

6.3.1.2 Hardness capability of GFE. It is important that the SPO recognize and understand that it is obligated to provide existing hardness capability information of any GFE that it imposes on a contractor (refer to 5.2.1.2.1).

6.3.1.3 Facilities hardness design tasks. This standard tasks three categories of contractor to participate in the development of facilities hardness design:

a. the SS&I contractor (paragraphs 5.3.3.2.1 and 5.3.4.1);

b. the AVE/SE contractor (paragraph 5.3.3.2.2); and

c. the facilities A&E contractor (paragraph 5.3.4.1).

This overlap of tasks is such that tailoring/scoping of the above facilities hardness design tasks is required. The tailoring/scope of the activity assigned to each of these categories of contractor should be a function of each individual contractor's hardness engineering capability with respect to the applicable NWE.

6.3.1.4 Scope of hardness qualification analysis. The purpose of hardness qualification (see 5.3.5.3) is to establish that the actual hardware item (not just the detail design) satisfies its hardness requirements. If qualification is directed to be accomplished by means of analysis, the associated cost identified in the contractor's proposal should consist only of an addition to the cost of the existing hardness verification activity (see 5.3.5.2). Such an addition is intended to cover the cost of the hardness analysis of any design changes added to the final design subsequent to hardness verification.

6.3.1.5 Development testing data requirements. Paragraphs 5.3.3.1.1, 5.3.3.2.1, and 5.3.4.1 task the contractor to conduct hardness tests as appropriate. For these particular 5.3 paragraphs, the hardness tests performed may be at a level of detail consistent with development tests. The data requirements for development tests are dependent on the test facility used. For developmental testing that the contractor performs in-house, formal test plans/reports are not needed; relevant results of such testing will be documented in the NH&S DAR. For developmental testing that the contractor performs at government supplied facilities, test plans/reports are required. Paragraphs 6.2 (d) and 6.2 (e) shall be tailored accordingly.

6.3.1.6 Tailoring for system level testing and analysis. Paragraph 5.3.6.1 requires a contractor to either conduct or support system level testing and analysis per the IAP or ITP. The specific role of that contractor for a given test or analysis should be clearly defined in the IAP or ITP. With respect to data requirements, a contractor acting as a test conductor or analysis lead should always submit the required data items shown in 6.2 above (i.e., test plan and report/system level analysis report). A contractor acting in a support role may not need to submit such data items depending on the scope or magnitude of the support. The SPO should evaluate this and identify the data requirements to the bidding contractor.

6.3.1.7 NH&S program plan requirements. In tables 5-1 and 5-2, paragraph 5.3.1.2 (contractor NH&S program planning) is shown for the AVE/SE and SS&I contractors as applying to all the phases in which they play a role. This could be interpreted to mean that under the associated data requirement for an NH&S program plan, a new and separate plan must be generated for each phase. Such an approach, however, would not be cost-effective and is not required. It is sufficient that the first release of a given plan be updated as each new system life cycle phase is placed on contract.

6.3.1.8 Hardness surveillance planning and preparation. Paragraphs 5.3.8.11 and 5.3.8.13 address hardness surveillance planning and preparation. Paragraph 5.3.8.11 tasks all WSE contractors to perform hardness surveillance planning for the WSE(s) under contract. However, 5.3.8.13 is intended to apply only to those contractors whose WSE(s) are included in the system level hardness surveillance plan generated by the SPO under 5.3.8.12.

6.3.1.9 Tailoring guidance for the NH&S Design Analysis Report (DAR). The following tailoring guidance is recommended for the NH&S DAR:

6.3.1.9.1 Tailoring the NH&S DAR for CI WSE.

The NH&S DAR DID DI-ENVR-80266A provides the description of the data content and format appropriate for the AVE/SE contractor's NH&S DAR submitted for CDR (5.3.5.1) and FCA (5.3.5.2). The PDR version of the NH&S DAR (5.3.3.1.1) is intended as the appropriate place to document ORA allocation analysis not formaly documented by trade studies or test reports. It is understood the PDR version of the NH&S DAR consists of a preliminary report reflecting the WSE preliminary design. The particular organization of the text in the NH&S DAR may change based on the complexity of the WSE design. Text organization issues to be mutually decided between the SPO and contractor are:

a. Whether the applicable NH&S nuclear weapon effects/environments are nested within discussions dedicated to hardware elements or vice-versa;

b. Whether single or multiple documents will be provided; and

c. Making the HCI list a stand alone document or including it multiple times in multiple documents.

6.3.1.9.1 Tailoring the NH&S DAR for non-CI WSE.

Two versions of the NH&S DAR for non-CI WSE (e.g. RIPE, A&CO installation hardware) shall be prepared. These are:

a. A preliminary version to support the preliminary design for the WSE on contract. The preliminary version shall contain the same type of information as the PDR version of the CI NH&S DAR; and

b. A final version to be released after the completion of all design, acquisition, fabrication, and installation activities associated with the WSEs on contract. The final version shall contain the same type of information as the FCA version of the CI NH&S DAR.

6.3.2 Explicit tailoring guidance. Explicit tailoring guidance is provided below as a function of:

a. contractor role in the program;

b. system life cycle phase; and

c. hardware category, as applicable.

With knowledge of these three parameters as they apply to a particular SOW, the applicable paragraphs below can be readily identified. Their content can then be inserted into the SOW tailoring of this standard, subject only to the considerations discussed in 6.3.1. The information provided below is consistent with figures 5-1, 5-2, and 5-3.

6.3.2.1 AVE/SE contractor.

6.3.2.1.1 Concept exploration and definition phase. N/A

6.3.2.1.2 Demonstration and validation phase.

6.3.2.1.2.1 Contractor furnished equipment.

6.3.2.1.2.1.1 Developmental items. All paragraphs in 1766B except : 5.1.1, 5.1.2.1, 5.1.2.3, 5.1.2.4, 5.1.3 thru 5.1.6; 5.2.1.1.2, 5.2.1.1.3, 5.2.1.2, 5.2.2, 5.2.3; 5.3.1.1, 5.3.1.2.1, 5.3.2.1, 5.3.2.2, 5.3.3.2.1, 5.3.3.2.3, 5.3.3.3, 5.3.4.1.2 thru 5.3.4.1.4, 5.3.5 thru 5.3.8.

6.3.2.1.2.1.2 Non developmental items/commercial.

6.3.2.1.2.1.2.1 Unmodified commercial NDI. All paragraphs in 1766B except: 5.1.1, 5.1.2.1, 5.1.2.1, 5.1.2.3, 5.1.2.4, 5.1.3 thru 5.1.6; 5.2.1.1.1, 5.2.1.1.2.2, 5.2.1.1.3, 5.2.1.2, 5.2.2, 5.2.3; 5.3.1.1, 5.3.1.2.1, 5.3.2.1, 5.3.2.2, 5.3.3.2.1, 5.3.3.2.3, 5.3.3.3, 5.3.4 thru 5.3.8.

6.3.2.1.2.1.2.2 Modified commercial NDI. All paragraphs in 1766B except : 5.1.1, 5.1.2.1, 5.1.2.1, 5.1.2.3, 5.1.2.4, 5.1.3 thru 5.1.6; 5.2.1.1.1, 5.2.1.1.2.1, 5.2.1.1.3, 5.2.1.2, 5.2.2, 5.2.3; 5.3.1.1, 5.3.1.2.1, 5.3.2.1, 5.3.2.2, 5.3.3.2.1, 5.3.3.2.3, 5.3.3.3, 5.3.4.1.2 thru 5.3.4.1.4, 5.3.5 thru 5.3.8.

6.3.2.1.2.1.3 Non developmental items/military.

6.3.2.1.2.1.3.1 Unmodified military NDI. All paragraphs in 1766B except: 5.1.1, 5.1.2.1, 5.1.2.1, 5.1.2.3, 5.1.2.4, 5.1.3 thru 5.1.6; 5.2.1.1.1, 5.2.1.1.2, 5.2.1.1.3.2, 5.2.1.2, 5.2.2, 5.2.3; 5.3.1.1, 5.3.1.2.1, 5.3.2.1, 5.3.2.2, 5.3.3.2.1, 5.3.3.2.3, 5.3.3.3, 5.3.4 thru 5.3.8.

6.3.2.1.2.1.3.2 Modified Military NDI. All paragraphs in 1766B except : 5.1.1, 5.1.2.1, 5.1.2.1, 5.1.2.3, 5.1.2.4, 5.1.3 thru 5.1.6; 5.2.1.1.1, 5.2.1.1.2, 5.2.1.1.3.1, 5.2.1.2, 5.2.2, 5.2.3; 5.3.1.1, 5.3.1.2.1, 5.3.2.1, 5.3.2.2, 5.3.3.2.1, 5.3.3.2.3, 5.3.3.3, 5.3.4.1.2 thru 5.3.4.1.4, 5.3.5 thru 5.3.8.

6.3.2.1.2.2 Government furnished equipment. All paragraphs in 1766B except : 5.1.1, 5.1.2.1, 5.1.2.1, 5.1.2.3, 5.1.2.4, 5.1.3 thru 5.1.6; 5.2.1.1, 5.2.2, 5.2.3; 5.3.1.1, 5.3.1.2.1, 5.3.2.1, 5.3.2.2, 5.3.3.1.1, 5.3.3.2.1, 5.3.3.2.3, 5.3.3.3, 5.3.4 thru 5.3.8.

6.3.2.1.3 Engineering and manufacturing development phase.

6.3.2.1.3.1 Contractor furnished equipment.

6.3.2.1.3.1.1 Developmental items. All paragraphs in 1766B except : 5.1.1, 5.1.2, 5.1.3.1, 5.1.3.3, thru 5.1.3.5, 5.1.4 thru 5.1.6; 5.2.1.1.2, 5.2.1.1.3, 5.2.1.2, 5.2.2, 5.2.3; 5.3.1.1, 5.3.2.1, 5.3.2.2, 5.3.3.2.1, 5.3.3.2.3, 5.3.6.2, 5.3.7.1, 5.3.7.3, 5.3.8.9, 5.3.8.10, 5.3.8.12, 5.3.8.14 thru 5.3.8.16.

6.3.2.1.3.1.2 Non developmental items/commercial.

6.3.2.1.3.1.2.1 Unmodified commercial NDI. All paragraphs in 1766B except : 5.1.1, 5.1.2, 5.1.3.1, 5.1.3.3, thru 5.1.3.5, 5.1.4 thru 5.1.6; 5.2.1.1.1, 5.2.1.1.2.2, 5.2.1.1.3, 5.2.1.2, 5.2.2, 5.2.3; 5.3.1.1, 5.3.2.1, 5.3.2.2, 5.3.3.2.1, 5.3.3.2.3, 5.3.4, 5.3.6.2, 5.3.7.1, 5.3.7.3, 5.3.8.9, 5.3.8.10, 5.3.8.12, 5.3.8.14 thru 5.3.8.16.

6.3.2.1.3.1.2.2 Modified commercial NDI. All paragraphs in 1766B except : 5.1.1, 5.1.2, 5.1.3.1, 5.1.3.3, thru 5.1.3.5, 5.1.4 thru 5.1.6; 5.2.1.1.1, 5.2.1.1.2.1, 5.2.1.1.3, 5.2.1.2, 5.2.2, 5.2.3; 5.3.1.1, 5.3.2.1, 5.3.2.2, 5.3.3.2.1, 5.3.3.2.3, 5.3.6.2, 5.3.7.1, 5.3.7.3, 5.3.8.9, 5.3.8.10, 5.3.8.12, 5.3.8.14 thru 5.3.8.16.

6.3.2.1.3.1.3 Non developmental items/military.

6.3.2.1.3.1.3.1 Unmodified military NDI. All paragraphs in 1766B except : 5.1.1, 5.1.2, 5.1.3.1, 5.1.3.3, thru 5.1.3.5, 5.1.4 thru 5.1.6; 5.2.1.1.1, 5.2.1.1.2, 5.2.1.1.3.2, 5.2.1.2, 5.2.2, 5.2.3; 5.3.1.1, 5.3.2.1, 5.3.2.2, 5.3.3.2.1, 5.3.3.2.3, 5.3.4, 5.3.6.2, 5.3.7.1, 5.3.7.3, 5.3.8.9, 5.3.8.10, 5.3.8.12, 5.3.8.14 thru 5.3.8.16.

6.3.2.1.3.1.3.2 Modified military NDI. All paragraphs in 1766B except : 5.1.1, 5.1.2, 5.1.3.1, 5.1.3.3, thru 5.1.3.5, 5.1.4 thru 5.1.6; 5.2.1.1.1, 5.2.1.1.2, 5.2.1.1.3.1, 5.2.1.2, 5.2.2, 5.2.3; 5.3.1.1, 5.3.2.1, 5.3.2.2, 5.3.3.2.1, 5.3.3.2.3, 5.3.6.2, 5.3.7.1, 5.3.7.3, 5.3.8.9, 5.3.8.10, 5.3.8.12, 5.3.8.14 thru 5.3.8.16.

6.3.2.1.3.2 Government furnished equipment. All paragraphs in 1766B except : 5.1.1, 5.1.2, 5.1.3.1, 5.1.3.3, thru 5.1.3.5, 5.1.4 thru 5.1.6; 5.2.1.1, 5.2.2, 5.2.3; 5.3.1.1, 5.3.2.1, 5.3.2.2, 5.3.3.1.1, 5.3.3.2.1, 5.3.3.2.3, 5.3.4, 5.3.6.2, 5.3.7.1, 5.3.7.3, 5.3.8.1, 5.3.8.2, 5.3.8.4, 5.3.8.6 thru 5.3.8.10, 5.3.8.12, 5.3.8.14 thru 5.3.8.16.

6.3.2.1.4 Production and deployment phase.

6.3.2.1.4.1 Contractor furnished equipment.

6.3.2.1.4.1.1 Developmental items. All paragraphs in 1766B except : 5.1.1 thru 5.1.3 5.1.4.1, 5.1.4.3 thru 5.1.4.5, 5.1.5, 5.1.6; 5.2.1.1.2, 5.2.1.1.3, 5.2.1.2, 5.2.2, 5.2.3; 5.3.1.1, 5.3.1.2.1, 5.3.2 thru 5.3.7, 5.3.8.1 thru 5.3.8.8, 5.3.8.11 thru 5.3.8.16; 5.4.

6.3.2.1.4.1.2 Non developmental items/commercial.

6.3.2.1.4.1.2.1 Unmodified commercial NDI. All paragraphs in 1766B except : 5.1.1 thru 5.1.3 5.1.4.1, 5.1.4.3 thru 5.1.4.5, 5.1.5, 5.1.6; 5.2.1.1.1, 5.2.1.1.2.2, 5.2.1.1.3, 5.2.1.2, 5.2.2, 5.2.3; 5.3.1.1, 5.3.1.2.1, 5.3.2 thru 5.3.7, 5.3.8.1 thru 5.3.8.8, 5.3.8.11 thru 5.3.8.16; 5.4.

6.3.2.1.4.1.2.2 Modified commercial NDI. All paragraphs in 1766B except : 5.1.1 thru 5.1.3 5.1.4.1, 5.1.4.3 thru 5.1.4.5, 5.1.5, 5.1.6; 5.2.1.1.1, 5.2.1.1.2.1, 5.2.1.1.3, 5.2.1.2, 5.2.2, 5.2.3; 5.3.1.1, 5.3.1.2.1, 5.3.2 thru 5.3.7, 5.3.8.1 thru 5.3.8.8, 5.3.8.11 thru 5.3.8.16; 5.4.

6.3.2.1.4.1.3 Non developmental items/military.

6.3.2.1.4.1.3.1 Unmodified military NDI. All paragraphs in 1766B except : 5.1.1 thru 5.1.3 5.1.4.1, 5.1.4.3 thru 5.1.4.5, 5.1.5, 5.1.6; 5.2.1.1.1, 5.2.1.1.2, 5.2.1.1.3.2, 5.2.1.2, 5.2.2, 5.2.3; 5.3.1.1, 5.3.1.2.1, 5.3.2 thru 5.3.7, 5.3.8.1 thru 5.3.8.8, 5.3.8.11 thru 5.3.8.16; 5.4.

6.3.2.1.4.1.3.2 Modified military NDI. All paragraphs in 1766B except : 5.1.1 thru 5.1.3 5.1.4.1, 5.1.4.3 thru 5.1.4.5, 5.1.5, 5.1.6; 5.2.1.1.1, 5.2.1.1.2, 5.2.1.1.3.1, 5.2.1.2, 5.2.2, 5.2.3; 5.3.1.1, 5.3.1.2.1, 5.3.2 thru 5.3.7, 5.3.8.1 thru 5.3.8.8, 5.3.8.11 thru 5.3.8.16; 5.4.

6.3.2.1.4.2 Government furnished equipment. N/A.

6.3.2.1.5 Operations and support phase. N/A.

6.3.2.2 System support/integration contractor.

6.3.2.2.1 Concept exploration and definition phase. All paragraphs in 1766B except : 5.1.1.1, 5.1.2 thru 5.1.6; 5.2.1, 5.2.3; 5.3.1.1, 5.3.1.2.1, 5.3.2.1, 5.3.2.3, 5.3.3 thru 5.3.8.

6.3.2.2.2 Demonstration and validation phase. All paragraphs in 1766B except : 5.1.1, 5.1.2.1, 5.1.2.2, 5.1.2.4, 5.1.3 thru 5.1.6; 5.2.1, 5.2.3; 5.3.1.1, 5.3.1.2.1, 5.3.2.1, 5.3.3.1, 5.3.3.2.2, 5.3.3.3, 5.3.4.1.3, 5.3.4.1.4, 5.3.5 thru 5.3.8.

6.3.2.2.3 Engineering and manufacturing development phase. All paragraphs in 1766B except : 5.1.1, 5.1.2, 5.1.3.1, 5.1.3.2, 5.1.3.4, 5.1.3.5, 5.1.4 thru 5.1.6; 5.2.1, 5.2.3; 5.3.1.1, 5.3.2.1, 5.3.3.1, 5.3.3.2.2, 5.3.3.3, 5.3.5.2, 5.3.7.1, 5.3.8.2 thru 5.3.8.7, 5.3.8.9, 5.3.8.10, 5.3.8.12, 5.3.8.14 thru 5.3.8.16.

6.3.2.2.4 Production and deployment phase. All paragraphs in 1766B except : 5.1.1, 5.1.2, 5.1.3, 5.1.4.1, 5.1.4.2, 5.1.4.4, 5.1.4.5, 5.1.5, 5.1.6; 5.2.1, 5.2.3; 5.3.1.1, 5.3.1.2.1, 5.3.2, 5.3.3, 5.3.4.1.1, 5.3.4.1.2, 5.3.5, 5.3.6.1, 5.3.7.1, 5.3.7.2, 5.3.8.

6.3.2.2.5 Operations and support phase. N/A

6.3.2.3 Facilities A&E contractor.

6.3.2.3.1 Concept exploration and definition phase. N/A

6.3.2.3.2 Demonstration and validation phase. All paragraphs in 1766B except : 5.1.1, 5.1.2.1 thru 5.1.2.3, 5.1.3 thru 5.1.6; 5.2.1, 5.2.3; 5.3.1 thru 5.3.3, 5.3.4.1.3, 5.3.4.1.4, 5.3.5 thru 5.3.8.

6.3.2.3.3 Engineering and manufacturing development phase. All paragraphs in 1766B except : 5.1.1, 5.1.2, 5.1.3.1 thru 5.1.3.3, 5.1.3.5, 5.1.4 thru 5.1.6; 5.2.1, 5.2.3; 5.3.1 thru 5.3.3, 5.3.5 thru 5.3.7, 5.3.8.1, 5.3.8.3 thru 5.3.8.16.

6.3.2.3.4 Production and deployment phase. All paragraphs in 1766B except : 5.1.1 thru 5.1.3, 5.1.4.1 thru 5.1.4.3, 5.1.4.5, 5.1.5, 5.1.6; 5.2.1, 5.2.3; 5.3.1 thru 5.3.3, 5.3.4.1.1, 5.3.4.1.2, 5.3.5 thru 5.3.7, 5.3.8.1, 5.3.8.3 thru 5.3.8.16.

6.3.2.3.5 Operations and support phase. N/A

6.3.2.4 Facilities construction contractor.

6.3.2.4.1 Concept exploration and definition phase. N/A

6.3.2.4.2 Demonstration and validation phase. N/A

6.3.2.4.3 Engineering and manufacturing development phase. All paragraphs in 1766B except : 5.1.1, 5.1.2, 5.1.3.1 thru 5.1.3.4, 5.1.4 thru 5.1.6; 5.2.1, 5.2.3; 5.3.1 thru 5.3.7, 5.3.8.1 thru 5.3.8.8, 5.3.8.11 thru 5.3.8.16; 5.4.

6.3.2.4.4 Production and deployment phase. All paragraphs in 1766B except : 5.1.1 thru 5.1.3, 5.1.4.1 thru 5.1.4.4, 5.1.5, 5.1.6; 5.2.1, 5.2.3; 5.3.1 thru 5.3.7, 5.3.8.1 thru 5.3.8.8, 5.3.8.11 thru 5.3.8.16; 5.4.

6.3.2.4.5 Operations and support phase. N/A

6.3.2.5 A&CO contractor.

6.3.2.5.1 Concept exploration and definition phase. N/A

6.3.2.5.2 Demonstration and validation phase. N/A

6.3.2.5.3 Engineering and manufacturing development phase. N/A

6.3.2.5.4 Production and deployment phase. All paragraphs in 1766B except : 5.1.1 thru 5.1.4, 5.1.5.1, 5.1.5.3, 5.1.6; 5.2.1, 5.2.2; 5.3.1.1, 5.3.1.2.1, 5.3.2 thru 5.3.7, 5.3.8.1 thru 5.3.8.4, 5.3.8.6 thru 5.3.8.16; 5.4.

6.3.2.5.5 Operations and support phase. N/A

6.3.2.6 Hardness surveillance support contractor.

6.3.2.6.1 Concept exploration and definition phase. N/A

6.3.2.6.2 Demonstration and validation phase. N/A

6.3.2.6.3 Engineering and manufacturing development phase. N/A

6.3.2.6.4 Production and deployment phase. N/A

6.3.2.6.5 Operations and supply phase. All paragraphs in 1766B except : 5.1.1 thru 5.1.5, 5.1.6.1, 5.1.6.3; 5.2.1, 5.2.2, 5.2.3; 5.3.1.1,5.3.1.2.1, 5.3.2 thru 5.3.7, 5.3.8.1 thru 5.3.8.14, 5.3.8.16; 5.4.

6.4 Subject term (key word) listing.

Analysis
Assessment
Design
Evaluation

Hardness
Hardness assurance
Hardness maintenance
Hardness surveillance
ICBM
Nuclear
Qualification
Survivability
Testing
Verification
Weapon effects

6.5 Identification of changes. Marginal notations are not used in this revision to identify changes with respect to the previous issue due to the extensiveness of the changes.

Custodians:
Air Force - 19

Preparing Activity:
Air Force - 19
(Project ENVR - 0033)

Review Activities:
Army - TE, MI
Navy - OS

DEFINITIONS

10. SCOPE

10.1 Purpose. This appendix contains the definitions and acronyms applicable to MIL-STD-1766B. This appendix is a mandatory part of this standard. The information provided is intended for compliance.

10.2 Application. The terms and their definitions contained in this appendix shall be controlling in all applications of this standard. During the implementation of the tasks directed by this standard, they shall take precedence over similar or corresponding terms and definitions that may exist in other documentation. The intent of this direction is to establish the basis for and to facilitate clear and unambiguous communication concerning the work covered by this standard between the government and its contractors and among all contractor internal organizations and personnel whose responsibilities are impacted by this standard. A larger than usual number of terms has been included to allow this standard to be as self-contained as possible. In addition to dictionary-like definitions of the terms addressed, additional background and tutorial comments are also frequently supplied. The purpose of including such information is also to facilitate clear communication among all concerned parties and to foster more cost-effective implementation of the tasks involved.

20. APPLICABLE DOCUMENTS

This section is not applicable to this appendix.

30. INDEX OF TERMS DEFINED

Definitions of the following terms are provided in section 40 of this appendix.

40. DEFINITIONS

40.1 Acronyms used in this standard. The acronyms used in this standard are defined as follows:

A&CO	-	Assembly and checkout.
A&CO TA	-	Assembly and checkout technical analysis.
A&E	-	Architectural and engineering
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.
CFE	-	Contractor furnished equipment.
CI	-	Configuration item.
COTS	-	Commercial-off-the-shelf.
dB	-	Decibel.
DID	-	Data item description.
DNA	-	Defense nuclear agency
DoD	-	Department of defense.
DoDD	-	Department of defense directive.
DODISS	-	Department of defense index of specifications and standards
DSE	-	Depot support equipment.
ECP	-	Engineering change proposal.
ECS	-	Environmental control system.
EMD	-	Engineering and manufacturing development
EMP	-	Electromagnetic pulse.
EPM	-	External protection material.
ESA	-	Electrical surge arrestor.
FAR	-	Federal acquisition regulation.
FCA	-	Functional configuration audit.
FMA	-	Failure mode analysis
FSE	-	Factory support equipment.
GFE	-	Government furnished equipment.
HALAT	-	Hardness assurance lot acceptance testing.
HCI	-	Hardness critical item.
HCP	-	Hardness critical process/procedure.

HDM - Hardness design margin.
HEMP - High-altitude electromagnetic pulse.
IAP - Integrated analysis plan
ITP - Integrated test plan
ICBM - Intercontinental ballistic missile.
ICD - Interface control drawing.
IEMP - Internal electromagnetic pulse
ICWG - Interface control working group.
LCH - Life cycle hardness.
LSA - Logistics support analysis.
LSAR - Logistics support analysis record.
MEDL - Master engineering document list.
MNS - Mission need statement
MSE - Maintenance support equipment.
NCGS - Nuclear criteria group secretariat.
NDI - Non developmental item.
NEEHEM - Nuclear environment/effect hardness element matrix.
NEP - Nuclear environment protection.
NHA - Next Higher Assembly
NH&S - Nuclear hardness and survivability.
NH&S DAR - Nuclear hardness and survivability design analysis report.
NWE - Nuclear weapon effect/environment.
ORA - Operational requirements analysis.
OSE - Operational support equipment.
PCA - Physical configuration audit.
PDR - Preliminary design review.
PIDS - Prime item development specification.
PMRT - Program management responsibility transfer.
RPIE - Real property installed equipment.
SAMSO - Space and missile systems organization.
SDR - System design review.
SE - Support equipment.
SE/TA - System engineering and technical assistance.
SGEMP - System-generated electromagnetic pulse.
SHAR - System hardness analysis report.
SIOP - Single integrated operating plan.
SMI - Structure-media interaction.
SOW - Statement of work.
SPO - System program office.
SRA - System requirements analysis.
SREMP - Source-region electromagnetic pulse.
STAR - System threat assessment report.
STD - Standard.
TED - Threat environment definition.
TIM - Technical interchange meeting.
TO - Technical order.
WCCA - Worst case circuit analysis.
WSE - Weapon system element
WSS - Weapon system specification

40.2 Acquisition life cycle. The acquisition life cycle, also refereed to as the acquisition process, is a subset of the system life cycle (see 40.140) and consists of the program phases through which a system passes from the time it is initially conceived and developed, until the time it is deployed and enters operational use. One or more of these program phases may also apply to major upgrade or system replacement actions. The acquisition life cycle is usually considered to consist of the following phases, although the precise terminology used tends to vary over time:

a. Phase 0: Concept exploration and definition (see 40.19);

b. Phase I: Demonstration and validation (see 40.25);

c. Phase II: Engineering and manufacturing development (see 40.33);

d. Phase III: Production and deployment (see 40.122); and

e. Phase IV: Operations and support (see 40.116).

Each acquisition life cycle phase has associated with it a particular set of hardness tasks.

40.3 Aerospace vehicle equipment (AVE). AVE consists of the operational flight vehicle and all of its flight components. For purposes of configuration management, the SPO (see 40.141) procures AVE in equipment groupings that are treated as individual CIs (see 40.20), each with its own PIDS (see 40.121). See also WSE, 40.155.

40.4 Airblast. See blast, 40.14.

40.5 Allocation. See hardness allocation, 40.54.

40.6 Analysis. See hardness analysis, 40.57.

40.7 Assembly and checkout (A&CO). A&CO refers to the activity performed during the production and deployment phase (see 40.122) of the acquisition life cycle (see 40.2), during which the individual AVE (see 40.3) and SE (see 40.130) WSEs (see 40.155) are assembled together and united with the associated facilities (see 40.35) and RPIE (see 40.126) to form a complete weapon system ready for operational use. Part of the A&CO activity is the checkout of the assembled system to verify that the system as assembled satisfies all performance requirements.

40.8 Assembly and checkout (A&CO) contractor. See contractor, 40.21.

40.9 Assembly and checkout (A&CO) installation hardware. A&CO installation hardware refers to hardware items necessary to complete the installation of AVE (see 40.3) and SE (see 40.130) WSEs in the facilities (see 40.35). Such hardware may be provided by either the AVE and SE contractors or by the A&CO contractor (see 40.21). A&CO installation hardware sometimes have associated hardness requirements (see 40.78), which must be identified for inclusion in the A&CO TA (see 40.10).

40.10 <u>Assembly and checkout technical analysis (A&CO TA).</u> The A&CO TA is one of the four elements of SRA (see 40.142). Its primary objective is to perform the required detailed analyses and associated trade studies necessary to provide an approved A&CO program at lowest cost. The approved integrated A&CO TA becomes the baseline for the planning and conduct of the A&CO field effort, and is provided by the SPO (see 40.141) to the A&CO contractor (see 40.21) for implementation. The A&CO TA must be hardness annotated (see 40.58) to support the preservation of system hardness during the A&CO activity (see 40.7).

40.11 <u>Assessment.</u> In this standard, assessment refers to an analysis activity to estimate the as-built capability of a weapon system. The two categories of assessment pertinent to NH&S are hardness assessments and survivability assessments.

a. <u>Survivability assessment.</u> Survivability assessment is a type of assessment used to evaluate the nuclear survivability (see 40.111) status of a system. Results typically take the form of probability of survival with respect to one or more hostile nuclear threats and attack scenarios.

b. <u>Hardness assessment.</u> Hardness assessment is a type of assessment used to evaluate the actual nuclear hardness capability of a deployed system. The results can take various forms depending on need (e.g., vulnerability number, probability of survival with respect to range or environment level.) As part of the procurement of an ICBM weapon system, the SPO will produce a hardness assessment of the system and provide the results as input to the operating command for use in its survivability assessment modeling.

Initial assessments are usually performed by the implementing command (see 40.89), with contractor (see 40.21) support as required. Subsequent assessments are carried out by the supporting command (see 40.131), at the direction of the operating command (see 40.113). Among the factors that may cause a reassessment of the system are changes in the threat, revisions to the operational scenario, major system upgrades, and degradation of hardness features.

40.12 <u>Attenuation.</u> In this standard, attenuation is used as a technical term to denote the reduction in magnitude of one or more of the applicable NWE (see 40.112) by a hardware element. A common hardness design (see 40.66) approach is to introduce various kinds of shields and mechanical isolators into the design to accomplish such attenuation. Often, an existing system hardware element is used to provide this shielding function. The NWE attenuation requirements assigned to a hardware element become one of that item's hardness performance requirements (see 40.76). Correspondingly, the attenuated environment becomes the withstand (see 40.158) requirement or hardness design constraint (see 40.68) for the hardware element being shielded.

40.13 <u>AVE/SE contractor.</u> See contractor, 40.21.

40.14 <u>Blast.</u> Blast or airblast is one of the NWE (see 40.112). It consists of a shock wave of air propagated outward from a nuclear explosion, in which the static air pressure increases sharply at the shock front. This is accompanied by dynamic air flow or high winds behind the shock front. In addition, blast couples to the ground, contributing to the ground shock (see 40.128) environment. Blast environments can inhibit mission critical performance by causing high stress loading and damage, inducing shock responses, and adversely affecting missile flight control.

40.15 Circumvention and recovery (C&R). C&R is one kind of nuclear event protection (see 40.105) that consists of an electronic mechanism that makes use of specially hardened circuitry to:

a. detect the presence of ionizing radiation whose intensity exceeds an established set point;

b. protect stored data from alteration by erroneous writing;

c. provide resets for logic circuit upsets;

d. inhibit false inputs and outputs; and

e. provide a controlled resumption of operation after the radiation has decreased below the established set point by reconstruction of critical data and circuit logic states that were lost during circumvention.

40.16 Commercial off-the-shelf (COTS). An item of COTS is a category of commercial product (see 40.17) that is produced and placed in stock by a manufacturer, or stocked by a distributor, before receiving orders or contracts for its sale. The design and possible future changes to the design or configuration are controlled solely by the manufacturer. COTS hardware must be bought, used, and supported exactly as found in the civilian market, and allowed to flow with the changes and updates instituted for the commercial market. Although the manufacturer's drawings for the item may be supplied to the government, they are not controlled by the government. Usually, the government neither controls the design of COTS hardware items nor exercises configuration control over them. This circumstance interferes with the supporting command's (see 40.131) ability to implement hardness maintenance (see 40.75), and is a complicating factor in the use of COTS hardware in a hardened weapon system. In section 5 of this standard, COTS items are discussed under the heading: already existing commercial/unmodified items.

40.17 Commercial product. Commercial product is a generic term referring to hardware or software obtained from a commercial supplier or manufacturer; i.e., a company that in the normal course of business does not produce items or engineering data according to DoD specifications. Among the categories of commercial product are:

a. COTS items (see 40.16);

b. "commercial-type" items (commercially designed and built items modified to meet some government-peculiar requirement or otherwise identified differently from their civilian counterparts); and

c. "best commercial practice" items (government-controlled design built and documented to widely accepted industrial standards).

A critical NH&S issue in the use of commercial products in ICBM weapon systems is whether or not the government controls the configuration.

40.18 Concept design. As used in this standard, the term concept design refers to the design the WSE contractor (see 40.21) develops from the system concept design (also referred to as the baseline concept design). The AVE/SE WSE concept design will assist the contractor in identifying how the WSEs under contract will be partitioned into CIs (see 40.20). Aspects of the concept design may change through EMD (see 40.33). For the facilities (see 40.35), concept design refers to the first incremental design, which consists of site location, gross facility features, accesses, utility hook-ups, required code compliance's, and incorporation of any additional information supplied by the AVE/SE contractors through the facility design criteria (see 40.40).

40.19 Concept exploration and definition phase. The concept exploration and definition phase is Phase 0 of the acquisition life cycle (see 40.2). It extends from the determination of a needed operational capability major upgrade, or system replacement to the program decision that authorizes the implementation of the demonstration and validation phase (see 40.25). During the concept exploration and definition phase, the system concepts that warrant further development in response to the identified operational need are defined and selected.

40.20 Configuration item (CI). A CI is an organized grouping of hardware, firmware, and software, separately or in some combination, that satisfies an end use function and is designated for configuration management. CIs are those items whose performance requirements (see 40.76), design constraints (see 40.68), and physical characteristics, both hardness and non-hardness related, must be separately specified and controlled. With respect to procurement considerations, CIs may consist of both CFE (see 40.22) and GFE (see 40.50). CFE, in turn, may consist of both developmental (see 40.30) and non developmental (see 40.102) items. The latter may consist of both commercial and military items. See AVE, 40.3; OSE, 40.115; SE, 40.130; WSE, 40.155; and PIDS, 40.121.

40.21 Contractor. As used in this standard, contractor refers to one of the organizations contracted with by either the implementing (see 40.89) or supporting (40.131) command in support of the acquisition, deployment, upgrade, or replacement of a hardened ICBM weapon system. The separate categories of contractor referred to in this standard are listed below. It should be noted that the same organization may serve more than one contracting role.

a. A&CO contractor. The organization responsible to implement the A&CO activity (see 40.7).

b. AVE/SE contractor. The organization responsible to design, develop, and produce one or more of the items of AVE (see 40.3) or SE (see 40.130) utilized in an ICBM weapon system. The contractor that designs and develops a particular item of AVE or SE may not be the organization selected by the SPO (see 40.141) to produce the item during the production and deployment phase. The SPO often contracts with a number of different AVE/SE contractors in support of the acquisition of a given

ICBM weapon system.

c. Facilities architectural and engineering (A&E) contractor. The organization responsible to generate detailed plans and drawings for the construction of the facilities (see 40.35) from the facilities design criteria (see 40.40) document.

d. Facilities construction contractor. The organization responsible to construct the facilities (see 40.35) and install the RPIE (see 40.126).

e. Hardness surveillance support contractor. The organization responsible to support the supporting command (see 40.131) in its implementation of hardness surveillance (see 40.79) during the operations and support phase (see 40.116). Often more than one organization is contracted with to provide this function.

f. System engineering and technical assistance (SE/TA) contractor. The organization responsible to provide system engineering and technical assistance services to the implementing (see 40.89) and supporting (see 40.131) commands throughout the system life cycle (see 40.140). The responsibilities of the SE/TA contractor are not explicitly delineated in this standard. They generally support the commands in all of their technical activities.

g. System support/integration (SS&I) contractor. The organization responsible to: (a) coordinate all nuclear hardness system level aspects of the design, including system level analysis and testing in support of the acquisition life cycle (see 40.2); and (b) generate the design criteria (see 40.40) for the weapon system facilities (see 40.35) and RPIE (see 40.126). This contractor prepares the SHAR (see 40.137), the facilities/RPIE NH&S DAR, and nuclear hardness system test plans and reports, as required.

h. WSE contractor. WSE contractor is used in this standard, as appropriate, to denote any one of the individual contractors responsible for a particular type of WSE (see 40.155).

40.22 Contractor furnished equipment (CFE). CFE refers to equipment that is acquired, modified, or manufactured directly by a contractor (see 40.21) for use in the system under contract. These may consist of both developmental (see 40.30) and non developmental (see 40.102) items.

40.23 Critical design review (CDR). The CDR is a formal technical review that is conducted for each CI (see 40.20) when the detail design (see 40.29) has been completed. Its purpose is to ensure that the detail design satisfies the requirements of the applicable PIDS (see 40.121). Of prime importance to the NH&S program is the satisfactory completion of all hardness verification (see 40.85) analyses and tests, and the documentation on the drawings of all the hardness critical hardware and assembly processes required by the design.

40.24 Debris. Debris is one of the NWE (see 40.112). It is radioactive and consists of the material ejected from a crater or scoured from the earth's surface and deposited in such a manner as to possibly preclude launch or mobility or otherwise degrade mission capability. Debris also includes entrained material (pebbles, dust, ice, fission products) within the nuclear cloud that could damage AVE (see 40.3).

40.25 Demonstration and validation phase. The demonstration and validation phase is Phase I of the acquisition life cycle (see 40.2). During this phase, selected candidate solutions to the identified operational need derived from the concept exploration and definition phase (see 40.19) are validated and refined through extensive evaluations. The objective is to validate one or more of the selected solutions and thereby provide a basis for deciding whether to proceed into engineering and manufacturing development (see 40.33). The demonstration and validation phase culminates with the SDR (see 40.134).

40.26 Depot support equipment (DSE). DSE refers to the equipment necessary to repair, overhaul and test weapon system CIs (see 40.20) down to the lowest repairable level. It includes commercial equipment, as well as equipment specifically designed or built to fulfill a particular depot overhaul or repair function. Whenever possible and cost-effective, it is desirable to include in the design of applicable DSE the capability to test the hardness characteristics of the hardware items that will be evaluated by means of the DSE. Such a capability can contribute significantly to the cost-effective implementation of hardness maintenance (see 40.75) and hardness surveillance (see 40.79). See also support equipment, 40.130.

40.27 Design constraints. See hardness design constraints, 40.68.

40.28 Design reviews. In this standard, design reviews refer to the set of three reviews that are held to formalize system requirements, preliminary design (see 40.119), and detail design (see 40.29). The three design reviews, in the order of their occurrence, are the SDR (see 40.134), the PDR (see 40.120), and the CDR (see 40.23).

40.29 Detail design. For AVE (see 40.3) and SE (see 40.130) hardware, the term detail design refers to the design embodied in the engineering drawings and associated design documentation for the CIs (see 40.20) under contract that are reviewed by the SPO (see 40.141) at CDR (40.23). This design must satisfy all requirements of the applicable PIDS (see 40.121), including hardness requirements (see 40.78). For the facilities (see 40.35), detail design refers to the design embodied in the drawings used for the facilities construction bid package (see 40.37).

40.30 Developmental item. Developmental items are items of either hardware or software that do not currently exist in full satisfaction of DoD requirements or existing items that require more than minor modification to satisfy DoD requirements. These items require government-sponsored research and development efforts to provide for their availability in support of DoD programs.

40.31 Development tests. Development tests are a subset of hardness tests (see 40.83). They are performed during the hardness design (see 40.66) activity to generate engineering data, not readily available from other sources, on the hardness response characteristics of materials and selected items of hardware. These items are usually of a low level of hardware indenture such as piece parts, that are candidates for inclusion in the design of a

WSE (see 40.155). Among the uses made of these data are:

a. to directly support hardness allocation (see 40.54) for WSE design development;

b. as input data in support of hardness verification analysis (see 40.86); and

c. as inputs to procurement documentation for the items tested.

See also nuclear radiation characterization, 40.110.

40.32 Electromagnetic pulse (EMP). EMP is one of the NWE (see 40.112). 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 (see 40.88). The electromagnetic energy produced by radiation interacting with the media surrounding or near a nuclear weapon detonation is called source region EMP, or SREMP (see 40.129). The electromagnetic energy produced by radiation interacting with system hardware is called system generated EMP, or SGEMP (see 40.136). A subset of SGEMP is referred to as internal electromagnetic pulse, or IEMP (see 40.96).

40.33 Engineering and manufacturing development (EMD) phase. The EMD phase is Phase II of the acquisition life cycle (see 40.2). During this phase, the system is designed, fabricated, tested, and evaluated. The products of this phase are:

a. weapon system hardware to support EMD testing;

b. the documentation required to enter the production and deployment phase (see 40.122); and

c. the documented analyses and tests that support the conclusion that the design that has been developed will satisfy all weapon system requirements.

EMD may be considered to consist of two parts. During the first part, the contractor (see 40.21) allocates the hardness requirements of the WSS (see 40.157) to the CIs (see 40.20) under contract. This process concludes with a PDR (see 40.120). During the second part, CI design is finalized and verified (see 40.85). This process concludes with the FCA (see 40.48).

40.34 Evaluation tests. In this standard, evaluation tests are a subset of hardness tests (see 40.83). They are conducted on selected items of hardware to evaluate compliance with applicable hardness requirements (see 40.78). The test items are usually engineering models of hardware items that are complex enough to make the use of hardness analysis (see 40.57) to evaluate hardness requirements compliance either infeasible or impractical. Even in cases where hardness analysis can be meaningfully implemented, evaluation tests are sometimes performed to provide additional confidence in the analytic results. Evaluation tests are used to support hardness verification (see 40.85).

40.35 Facilities. As used in this standard, facilities refer to a building, structure, utility system, or other improvement to real property used in support of an ICBM weapon system.

40.36 Facilities A&E contractor. See contractor, 40.21.

40.37 Facilities construction bid package. The facilities construction bid package refers to the engineering drawings and associated design documentation used for the procurement of a facility (see 40.35). It is prepared by the facilities A&E contractor (see 40.21), and is used in support of acquiring a facilities construction contractor (see 40.21). All facilities hardness requirements must be expressed in the facilities construction bid package in terms of standard civil engineering terminology.

40.38 Facilities construction contractor. See contractor, 40.21.

40.39 Facilities criteria input. The facilities criteria input is a document generated by AVE/SE contractors (see 40.21) to identify to the facility design criteria contractor (see 40.21) technical requirements associated with their AVE/SE that must be accommodated in the facility (see 40.35) design. These requirements must be detailed enough to address all interfaces between the WSEs (see 40.155) under consideration and the facility. If a particular interface involves A&CO installation hardware (see 40.9), the facility criteria input will also address the requirements that must be imposed on facility design to enable it to accommodate this installation hardware.

40.40 Facilities design criteria. The facilities design criteria refer to the documentation prepared by the facility design criteria contractor (see 40.21) that identifies the SPO's (see 40.141) technical requirements, including hardness requirements (see 40.78), for facility (see 40.35) design. These requirements must be stated in the facility design criteria in such a way that they can be readily translated by the facilities A&E contractor (see 40.21) into the facility construction bid package (see 40.37) that will be used to acquire a facilities construction contractor (see 40.21). In most cases, the nature of the facility hardness requirements will require the facility design criteria contractor to perform some hardness trade studies (see 40.84), analysis (see 40.57), and tests (see 40.83) of facility hardware attenuation (see 40.12) and withstand (see 40.158) characteristics in order to be able to translate facility hardness requirements into standard civil engineering terminology.

40.41 Facilities design criteria contractor. See contractor, 40.21.

40.42 Factory support equipment (FSE). FSE refers to the equipment used in support of factory production operations. Whenever possible and cost-effective, it is desirable to include in the design of applicable FSE the capability to test the hardness characteristics of the CIs (see 40.20) that will be evaluated by means of the FSE. Such a capability can contribute significantly to the cost-effective implementation of hardness assurance (see 40.60). Since FSE is usually subsequently used as DSE (see 40.26), it is particularly important to incorporate hardness considerations in the design of FSE. See also support equipment, 40.130.

40.43 Final design. For AVE (see 40.3) and SE (see 40.130), the term final design refers to the design embodied in the engineering drawings for the CIs (see 40.20) under contract that are reviewed by the SPO (see 40.141) at FCA (40.48) in support of accomplishing hardness qualification (see 40.77). This design must satisfy all requirements of the applicable PIDS (see 40.121), including hardness requirements (see 40.78). With respect to the facilities (see 40.35), the term final design refers to the design embodied in the as-built drawings.

40.44 Fragility. See hardness fragility, 40.73.

40.45 Fragility analysis. Fragility analysis refers to the calculation of transfer functions (see 40.151) and fragility curves (see 40.46) for selected nuclear environments and hardware elements, including an estimate of associated random and systematic uncertainties. Fragility analysis can include evaluation of the effects of selected nuclear environments on selected WSE constituent hardware elements at levels above and below specification levels. In addition, fragility analysis may also address alternate threats or new environment prediction methodologies defined by the SPO.

40.46 Fragility curve. A fragility (see 40.73) curve relates the probability of failure of a hardware item to the magnitude of applicable NWE (40.112) to which the item is exposed. Fragility curves can be developed on the basis of fragility analysis (see 40.45), fragility testing (see 40.47), or the use of published data for the item's failure level. The presentation of these curves usually includes information on the associated random and systematic uncertainties.

40.47 Fragility tests. Fragility tests are a subset of hardness tests (see 40.83). They are conducted on selected items of hardware to determine the hardness fragility (see 40.73) of the final design (see 40.43). In general, the items of hardware selected to undergo fragility determination will be those identified as having the controlling hardness failure mechanisms. The objective of fragility tests is to generate hardware performance data resulting from NWE (see 40.112) conditions above the specified hardness design constraint (see 40.68). Fragility tests support system level assessment (see 40.11).

40.48 Functional configuration audit (FCA). The FCA is a formal audit whose purpose is to validate that the development of a CI (see 40.20) has been completed satisfactorily and that the CI has achieved the functional and performance characteristics required by the applicable specification. In addition, the completed operation and support documentation is reviewed.

40.49 Functional failure. Functional failure refers to the inability of an item of hardware or software, at any level of assembly up to and including system level, to continue to function in the manner required by its intended application in the design.

40.50 Government furnished equipment (GFE). GFE refers to items in the possession of or acquired directly by the government, and subsequently delivered or otherwise made available to a contractor (see 40.21) for integration into a system or equipment.

40.51 Ground shock. See shock, 40.128.

40.52 Hardening. Hardening refers to the use of design techniques that increase the ability of a system or any of its constituent elements to withstand exposure to one or more effects of man-made hostile environments. The degree of hardening achieved in any specific instance for a particular hostile environment is designated by the maximum magnitude of the hostile environment at which the item hardened is still able to satisfactorily fulfill its design function. In this standard, hardening always refers to nuclear hardening (see 40.106).

40.53 <u>Hardness.</u> Hardness is a measure of the ability of a system or any of its constituent elements to withstand exposure to one or more effects of man-made or natural hostile environments. In this standard, hardness always refers to nuclear hardness (see 40.107).

40.54 <u>Hardness allocation.</u> Hardness allocation refers to the process by which hardness requirements (see 40.78) are distributed:

a. from the WSS (see 40.157) to WSE (see 40.155) specification documentation;

b. among the various WSEs that comprise a system; and

c. among and within the various hardware elements and levels of assembly that comprise a WSE.

It should be noted that the hardness allocation process narrows the choices of available design solutions.

40.55 <u>Hardness allocation analysis.</u> Hardness allocation analysis is a subset of hardness analysis (see 40.57). It refers to the analytic activity performed by a WSE contractor (see 40.21) to accomplish hardness allocations (see 40.54) for the WSEs (see 40.155) under contract. The AVE/SE contractor (see 40.21) implements this activity not only for the CIs (see 40.20) under contract, but also for any associated A&CO installation hardware (see 40.9). It is important that all derived hardness requirements (see 40.78) be consistent and traceable throughout all CI PIDS (see 40.121), the ICDs (see 40.94), the facility design criteria document (see 40.40), and the A&CO TA (see 40.10).

40.56 <u>Hardness allocation trades.</u> Hardness allocation trades are a subset of hardness trade studies (see 40.84). They are performed by the WSE contractor (see 40.21) to identify the most technically desirable and cost-effective distribution of specified attenuation (see 40.12) and withstand (see 40.158) requirements among the hardware elements that comprise a given WSE. Hardness allocation trades also include consideration by the WSE contractor of the possibilities for the attenuation of the NWE (see 40.112) specified in the WSS (see 40.157) by the WSEs of other contractors. Hardness allocation trades are conducted in support of SDR (see 40.134), and support the identification of CIs (see 40.20) by the AVE/SE contractor (see 40.21).

40.57 <u>Hardness analysis.</u> Hardness analysis refers to activities performed to determine by analytical means the propagation of NWE (see 40.112) throughout a weapon system and the withstand (see 40.158) capability of hardware elements to NWE. Hardness analyses are performed for various purposes during the system life cycle (see 40.140) and may consist of varying degrees of complexity and sophistication. The categories of hardness analysis specifically addressed in this standard include:

a. system level analysis (see 40.138);

b. hardness allocation analysis (see 40.55);

c. hardness design analysis (see 40.67);

d. hardness verification analysis (see 40.86); and

e. fragility analysis (see 40.45)

40.58 Hardness annotations. Hardness annotations refer to the hardness dedicated symbols, notes, and other markings added to selected ICBM program data products to provide and highlight hardness related information. These data products consist of: (a) the engineering drawings; (b) the MEDL (see 40.101); (c) the LSAR (see 40.99) for both system level and subsystem level LSA (see 40.98); (d) the A&CO TA (see 40.10); and (e) the TOs (see 40.145). The requirements for accomplishing these hardness annotations are contained in the compliance documentation controlling the preparation of each of these data products. In addition to these hardness annotations, selected data products must also include, as appropriate, the documentation of hardness related test and inspection requirements associated with the purpose of the data product. These data products include the engineering drawings, the LSAR, the A&CO TA, and the TOs.

40.59 Hardness assessment. See assessment, 40.11.

40.60 Hardness assurance. Hardness assurance is a program element of LCH (see 40.97). As applied to a given WSE (see 40.155), it refers to those activities required to preserve the integrity of the hardness design (see 40.66) contained in the approved final design (see 40.43) throughout the production and deployment (see 40.122) phase. The definition of a comprehensive hardness assurance program includes the following:

a. hardness assurance tests (see 40.63), as required;

b. hardness assurance inspections (see 40.61), as required;

c. the imposition of hardness assurance related requirements on existing contractor (see 40.21) production control disciplines, including configuration control, parts/material control, production/manufacturing control, and quality assurance/quality control; and

d. the identification of a hardness assurance program management structure and associated procedures.

40.61 Hardness assurance inspections. Hardness assurance inspections refer to inspections (see 40.74) performed in support of accomplishing hardness assurance (see 40.60). Once a particular inspection activity is identified as required for the purposes of hardness assurance, the associated inspection requirements must be documented in the cognizant contractor's (see 40.21) quality assurance planning and implementation documentation. During the production and deployment phase (see 40.122), any hardness critical process (see 40.65) identified on an engineering drawing must undergo 100% inspection and any hardness critical procedure (see 40.65) identified in A&CO (see 40.7) drawings or other A&CO documentation must also undergo 100% inspection.

40.62 Hardness assurance lot acceptance testing (HALAT). HALAT is a subset of hardness assurance testing (see 40.63). It consists of the acceptance testing in one or more of the specified NWE (see 40.112) of statistically based samples of hardware items selected from production, delivery or other types of lots of such items procured in support of system production. The intent of this testing is to demonstrate statistically that the hardware items in the lot under evaluation are at least as hard in the environments of concern as the sample qualified prior to production, and that the item manufacturing process has not changed to the detriment of the end product. HALAT is performed most frequently to evaluate the response of semiconductor devices in nuclear radiation environments. The value of HDM (see 40.70) determined for a hardware element can affect decisions regarding the amount of HALAT required for that item.

40.63 Hardness assurance tests. Hardness assurance tests are a subset of hardness tests (see 40.83). Their primary purpose is to provide a direct measure, usually on a sample basis (see HALAT, 40.62), of the hardness adequacy of production hardware. Decisions as to the nature and quantity of the hardness assurance testing to be performed for a particular WSE (see 40.155) are based primarily on considerations of:

a. a review of the HDM (see 40.70) of all constituent HCIs (see 40.64) of the WSE for all applicable NWE (see 40.112); the lower the HDM in a particular instance, the more likely that hardness assurance testing will be indicated;

b. the need to verify the adequacy of hardness design features (see 40.69), such as C&R (see 40.15), that are transparent, in whole or in part, to routine factory testing or inspection;

c. the need to obtain baseline data in support of planned hardness surveillance testing (see 40.82); and

d. cost and schedule impacts and feasibility.

It is highly desirable to accomplish the goals of hardness assurance testing to the fullest extent possible through the inclusion in the design of FSE (see 40.42) of the capability to evaluate hardness related characteristics of production hardware.

40.64 Hardness critical item (HCI). An HCI is defined to be an item of hardware or software that satisfies one or more of the following five rationales in any one or more of the applicable nuclear environments. More than one rationale may apply to a particular item, and, in such cases, different rationales may apply in different environments. Each candidate HCI must be reviewed separately for the applicability of each rationale in each applicable environment.

HCI rationales:

1. Functionally required hardware (i.e., hardware that would continue to be included in the design even if all hardness requirements were removed) with the following

characteristics:

a. the item is vulnerable to the applicable nuclear environment under consideration; and

b. the hardness design approach chosen for dealing with that vulnerability is to include additional provisions for hardness in some aspect of the item's procurement requirements, such as the item's specification, design, manufacture, or item selection process.

2. Functionally required hardware with the following characteristics:

a. the item does not satisfy rationale 1; and

b. its presence in the design is taken advantage of to also provide protection for the system or any of its elements against one or more of the applicable nuclear environments; for the purposes of providing this hardness protection function, the item may be used as is, or it may be modified in some way to enhance its hardness protection capabilities.

3. Hardness dedicated hardware or software included in system design solely to help satisfy the specified hardness requirements. As contrasted with the non-hardness dedicated, functionally required hardware covered by rationales 1 and 2 above, hardness dedicated hardware and software would not be included in the design if hardness requirements had not been applied.

4. Hardware items to which a hardness critical process (see 40.65) is applied during system fabrication, manufacture, or assembly, as identified in the applicable engineering drawings. The items selected to be identified as HCI in these cases shall be the highest level(s) of assembly directly involved with the hardness critical process that will enable clear traceability via the HCI list to the documentation of the hardness critical process in the applicable engineering drawings and the NH&S DAR (see 40.108). The items identified as HCI to serve this traceability function may themselves have no special hardness characteristics.

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

40.65 Hardness critical process/procedure (HCP). The terms "hardness critical process" and "hardness critical procedure" refer to two related but different concepts that are both represented by the same symbol "HCP". A hardness critical process is any fabrication, manufacturing, or assembly activity identified on an engineering drawing that supports the implementation of a hardness design feature (see 40.69). Note that a hardness critical process results in the identification of additional HCIs (see 40.64). In contrast, a hardness critical procedure is a particular task or activity performed to accomplish facility (see 40.35) construction, A&CO (see 40.7), or maintenance and repair with the following characteristics :

a. it is noted in some type of procedural document, such as a TO (see 40.145) or other procedural instructions;

b. it satisfies one or more of the following three conditions:

1. Its implementation impacts the initial establishment (as in facility construction or A&CO) or the restoration (as in maintenance and repair) of the hardened configuration provided for in the design.

2. Its implementation involves working on or near a HCI in a manner that could result in unacceptable inadvertent damage to the HCI; and

3. Its purpose is to accomplish implementation of a hardness specific test or inspection;

c. it does not result in the identification of additional HCIs (see 40.64).

40.66 Hardness design. Hardness design refers both to the process and end result of creating a design which satisfies specified or allocated hardness requirements (see 40.78). Hardness design must be accomplished without violating any other specified design requirement or constraint.

40.67 Hardness design analysis. Hardness design analysis is a subset of hardness analysis (see 40.57). It refers to the hardness analysis activities performed in support of the development of the hardness design (see 40.66) of a WSE (see 40.155) from its preliminary design (see 40.119) through to its final design (see 40.43). For AVE/SE, the hardness design analysis performed in support of CDR (see 40.23) is considered to be its hardness verification (see 40.85) analysis.

40.68 Hardness design constraints. Hardness design constraints are a subset of hardness requirements (see 40.78). They are commonly referred to as withstand (see 40.158) requirements. They refer to the specific NWE (see 40.112) and their associated characteristics, such as magnitude, time duration, spectrum, and multiplicity, after, and sometimes during, exposure to which a given item of hardware must continue to function satisfactorily in such a way as to meet specified performance requirements in the applicable requirements documentation. Hardness design constraints are documented:

a. for the system, in the WSS (see 40.157);

b. for CIs (see 40.20) in the applicable PIDS (see 40.121);

c. for facilities (see 40.35) and RPIE (see 40.126) in the facility design criteria (see 40.40); and

d. for A&CO installation hardware (see 40.9) in the A&CO TA (see 40.10).

40.69 Hardness design feature. A hardness design feature is an implemented design approach that is used to accomplish hardness design (see 40.66), and that therefore supports the satisfaction of system hardness requirements (see 40.78).

40.70 Hardness design margin (HDM). The HDM is a numerical measure of the extent to which a hardware item can withstand (see 40.158) exposure to a particular NWE (see 40.112) beyond the stress level associated with the applicable hardness design constraint (see 40.68). HDMs are used to support:

a. hardness verification (see 40.85) activities;

b. initial identification and prioritizing of the controlling hardness failure mechanisms for individual WSEs and the system as a whole; and

c. identification of hardness assurance (see 40.60) and hardness surveillance (see 40.79) test requirements.

The concept of hardness design margin applies both to transient upset and permanent damage responses. When calculating values of HDM, the numerical measure utilized to reflect the ability of a hardware item to withstand a particular NWE exposure may be based on one of the following:

a. a "no fail NWE level" derived from a conservative derating of a performance characteristic based on accepted industry practice;

b. a "no fail NWE level" traceable to a military or industrial standard to which the item is to be procured;

c. a conservative estimate of a "no fail NWE level" based on published data for similar hardware, development tests (see 40.31), or hardness analysis (see 40.57), and having SPO concurrence;

d. the actual failure level NWE, reduced to allow for performance characteristic variation as determined by fragility testing (see 40.47).

The magnitude of HDM calculated, along with an estimate of the conservatism associated with the methods and assumptions used to determine it, are a primary resource in identifying the hardware items that control the fragility of the weapon system, and are, therefore, candidates for fragility determination. The following formal definitions of HDM for specific NH&S disciplines apply in this standard:

a. The HDM (expressed as a dimensionless factor) for semiconductor devices in a nuclear radiation (see 40.109) environment is defined by the following equation:

$$HDM = (X_f - 3s) / X_{spec}$$

where: X_f = Arithmetic mean of the radiation levels at which worst case functional failure (see 40.49) occurs for the devices contained in the nuclear radiation characterization test sample (see 40.110);

X_{spec} = Applicable specified or allocated radiation level;

s = Standard deviation of the distribution of worst case functional failure radiation levels; a normal distribution is assumed, but a log-normal distribution may be used when the test data cannot be fitted with a normal distribution.

When the standard deviation of the test data cannot be determined, the highest radiation test level achieved without any observed upset or failure may be used as the numerator in the equation above. In order to demonstrate satisfactory compliance with applicable hardness requirements (see 40.78), this value of HDM must be shown to be greater than or equal to +1.

b. The HDM for electronic circuits in a nuclear radiation environment is defined as the simple ratio of the radiation level at which functional failure (see 40.49) of the circuit occurs with respect to the applicable specified or allocated radiation level. The circuit functional failure level shall be determined by worst case circuit analysis (see 40.159). In order to demonstrate satisfactory compliance with applicable hardness requirements (see 40.78), this value of HDM must be shown to be greater than or equal to +1.

c. The HDM (expressed in decibels (dB)) for hardware elements in an EMP (see 40.32) environment is defined in terms of the stresses associated with the applicable EMP related hardness design constraints (see 40.68). It is expressed by the following equation:

$$HDM = C \log_{10} (X_f / X_{spec})$$

where: C = 20 when the stress associated with the EMP hardness design constraint is defined in terms of voltage, current, electric field, or magnetic field; or

= 10 when the stress associated with the EMP hardness design constraint is defined in terms of power, energy, or temperature;

X_f = Magnitude of the stress associated with the EMP hardness design constraint at which hardware failure occurs; failure is to be interpreted as the loss of ability to perform a specified mission critical function.

X_{spec} = Magnitude of the stress associated with the specification level EMP hardness design constraint.

In order to demonstrate satisfactory compliance with applicable hardness requirements (see 40.78), this value of HDM must be shown to be greater than or equal to zero.

d. The HDM for hardware elements in one of the mechanical response environments (thermal radiation (see 40.148), blast (see 40.14), shock (see 40.128), and debris (see 40.24)) is defined by the following equation:

$$HDM = (X_f / X_{spec}) - 1$$

where: X_f = Magnitude of applied environment at which either (a) hard-failure occurs, or (b) actual hardware performance is measured;

X_{spec} = Magnitude of the specified or allocated environment when X_f is the magnitude of the applied environment at which failure occurs; or

= Magnitude of the specified or allocated hardware performance requirement when X_f is the magnitude of applied environment at which actual hardware performance has been measured.

In order to demonstrate satisfactory compliance with applicable hardness requirements (see 40.78), this value of HDM must be shown to be greater than or equal to zero.

40.71 Hardness design trades. Hardness design trades are a subset of hardness trades (see 40.84). They are performed by the WSE contractor (see 40.21) to determine the most desirable design solutions for satisfying the given WSE's (see 40.155) hardness requirements (see 40.78). Hardness design trades also include consideration, as appropriate, of the other requirements, in addition to hardness, imposed on the WSE design. For the AVE/SE contractor (see 40.21), hardness design trade studies are performed in support of PDR (see 40.120) and CDR (40.23).

40.72 Hardness evaluation. Hardness evaluation refers to the activities undertaken to determine if the detail and final designs meet all applicable hardness requirements. System level hardness evaluation is usually accomplished by some combination of analysis and test, as defined in the ITP (see 40.93) and IAP (see 40.92), and as performed by the SS&I contractor (see 40.21). The hardness evaluation of individual WSEs includes the following activities:

a. hardness verification (see 40.85) in support of CDR (see 40.23); and

b. hardness qualification (see 40.77) in support of FCA (see 40.48).

Although hardness evaluation activities occur primarily during EMD (see 40.33), they may be performed at other points in the system life cycle (see 40.140), as required. The concept of hardness evaluation applies both to developmental (see 40.30) and non developmental (see 40.102) hardware. Hardness evaluation is a contractor (see 40.21) activity, as contrasted with hardness assessment (see 40.11), which is an Air Force activity supported by contractor inputs.

40.73 Hardness fragility. Hardness fragility is a measure of the capability of an item of hardware to withstand (see 40.158) the nuclear-induced stresses imposed on it as a result of the detonation of a nuclear weapon. It is expressed as the cumulative probability that an item of hardware will fail to perform satisfactorily as a function of the magnitude of the applied nuclear environment or associated coupled stress that produces failure. Hardness fragility is determined by analysis or test or by some combination of these two activities. Hardness fragility data are used in support of system level assessments (see 40.11).

40.74 Hardness inspections. Hardness inspections refer to inspections of hardness related characteristics of weapon system hardware elements at any level of assembly. Such hardness inspections may be performed in support of hardness qualification (see 40.77), hardness assurance (see 40.60), and hardness surveillance (see 40.79). In the context of the qualification of CIs, which is performed in conformance with the quality conformance methodology identified in section 4 of the applicable PIDS, the term inspection is defined in a very broad manner that includes the activities of examination, demonstration, test, and analysis. Such a broad definition does not apply to the concept of hardness inspection as it is implemented for hardness assurance and hardness surveillance. In these cases, hardness inspection is most similar to the qualification inspection activity called examination, which is defined as being nondestructive, and as including visual inspection, simple physical manipulation, gauging, and measurement.

40.75 Hardness maintenance. Hardness maintenance is a program element of LCH (see 40.97). It refers to those activities conducted by the supporting command (see 40.131) to maintain and preserve the hardness of a deployed weapon system throughout its operational life. The SPO's (see 40.141) role in hardness maintenance is to prepare a hardness maintenance capability for transfer to the supporting command. Contractors (see 40.21) support the SPO in this effort through HCI/HCP (see 40.64 and 40.65) identification and the hardness annotation (see 40.58) of selected data products, including drawings, the MEDL (see 40.101), the SRA (see 40.142), and TOs (see 40.145).

40.76 Hardness performance requirements. Hardness performance requirements are a subset of hardness requirements (see 40.78). They refer to the hardness related performance characteristics imposed on a WSE (see 40.155) design. The majority of hardness performance requirements refer to the required amount a WSE has to attenuate or limit an NWE (see 40.112). The purpose of attenuating an NWE is to protect more susceptible hardware items. The attenuated NWE becomes a hardness design constraint (see 40.68) for the protected hardware items. Another type of hardness performance requirement is C&R (see 40.15) requirements for nuclear radiation. Hardness performance requirements are documented:

a. for the system in the WSS (see 40.157);

b. for CIs (see 40.20) in the applicable PIDS (see 40.121);

c. for facilities (see 40.35) and RPIE (see 40.126) in the facility design criteria (see 40.40); and

d. for A&CO installation hardware (see 40.9) in the A&CO TA (see 40.10).

40.77 Hardness qualification. Hardness qualification is the program activity in which the WSE contractor (see 40.21) establishes that contractor hardware that is representative of the approved final design (see 40.43) satisfies all specified hardness requirements (see 40.78). For CIs, it is accomplished at FCA (see 40.48) through implementation of the quality conformance methodology identified in section 4 of the controlling PIDS (see 40.121). Hardness qualification is usually performed on prototype or preproduction hardware. However, when such hardware is not available, it is performed on a first production article.

40.78 Hardness requirements. Hardness requirements consist of the hardness design constraints (see 40.68) and hardness performance requirements (see 40.76) imposed on a system and its constituent elements by virtue of the NH&S requirements contained in the applicable WSS (see 40.157). Hardness requirements are documented:

a. for CIs (see 40.20) in the applicable PIDS (see 40.121) and ICDs (see 40.94);

b. for facility (see 40.35) hardware and RPIE (see 40.126) in the facility design criteria (see 40.40); and

c. for A&CO installation hardware (see 40.9) in the A&CO TA (see 40.10).

Quite often, the hardness performance requirement for one system element will constitute a hardness design constraint for another system element.

40.79 Hardness surveillance. Hardness surveillance is a program element of LCH (see 40.97). It consists of a program of periodic hardness tests (see 40.83) and inspections (see 40.74) of a deployed weapon system with the purpose of identifying in a timely manner any 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.

40.80 Hardness surveillance inspections. Hardness surveillance inspections refer to those hardness inspections (see 40.74) performed in support of accomplishing hardness surveillance (see 40.79). Based on the recommendations of its WSE contractors (see 40.21), as documented in their individual hardness surveillance plans submitted to the SPO (see 40.141), the SPO will include in its system level hardness surveillance plan those hardness surveillance inspections that are considered to be high priority, feasible, and cost-effective. Hardness surveillance inspections will be implemented by the supporting (see 40.131) and operating (see 40.113) commands periodically during the operations and support phase (see 40.116).

40.81 Hardness surveillance support contractor. See contractor, 40.21.

40.82 Hardness surveillance tests. Hardness surveillance tests refer to those hardness tests (see 40.83) performed in support of accomplishing hardness surveillance (see 40.79). Based on the recommendations of its WSE contractors (see 40.21), as documented in their individual hardness surveillance plans submitted to the SPO (see 40.141), the SPO will include in its system level hardness surveillance plan those hardness surveillance tests that are considered to be high priority, feasible, and (c) cost-effective. Hardness surveillance tests may be performed either at the operational facilities (see 40.35) or in a laboratory setting. The latter are often similar to or identical with prior hardness assurance tests (see 40.63). Hardness surveillance tests will be implemented by the supporting (see 40.131) command periodically during the operations and support phase (see 40.116).

40.83 Hardness tests. Hardness tests refer to tests performed to determine the response of weapon system hardware elements, at any level of assembly ranging from piece parts up through the system level, to exposure to either direct or simulated NWE (see 40.112). Hardness tests are performed for various purposes throughout the system life cycle (see 40.140). The categories of hardness testing specifically addressed in this standard include:

a. system level tests (see 40.144);

b. development tests (see 40.31);

c. evaluation tests (see 40.34);

d. qualification tests (see 40.125);

e. fragility tests (see 40.47);

f. hardness assurance tests (see 40.63), including HALAT (see 40.62); and

g. hardness surveillance tests (see 40.82).

40.84 Hardness trade studies. Hardness trade studies refer to studies, supported by hardness analysis (see 40.57) and testing (see 40.83), as required, to evaluate:

a. alternative system designs;

b. alternative allocations of hardness requirements (see 40.78) among system elements; and

c. alternative WSE (see 40.155) design approaches to satisfying these requirements.

The categories of hardness trade studies specifically addressed in this standard include:

a. system level trade studies (see 40.139);

b. hardness allocation trades (see 40.56); and

c. hardness design trades (see 40.71).

40.85 Hardness verification. Hardness verification refers to the activity during which it is established that the detail design (see 40.29) satisfies all specified hardness requirements (see 40.78). This activity is implemented on both an individual WSE (see 40.155), as well as a system level. Hardness verification is accomplished by a review of existing hardness analysis (see 40.57) and test (see 40.83) data and the engineering drawings for the hardware element or system under consideration. This activity may be augmented, as required, by additional tests and analyses. For CIs, hardness verification is accomplished at the CDR (see 40.23). Other terms that have sometimes been used to represent the hardness verification activity are "hardness demonstration" and "hardness validation". For purposes of standardization, these terms are not used in this standard.

40.86 Hardness verification analysis. See hardness design analysis, 40.67.

40.87 Hardware category. The term hardware category is used in this standard to distinguish between different kinds of hardware groupings that have some distinguishing characteristic relevant to the content of this standard. The following five types of hardware categories are referred to in this standard:

a. constituent ICBM WSEs (see 40.155), consisting of AVE (see 40.3), SE (see 40.130), facilities (see 40.35) and RPIE (see 40.126), and A&CO installation hardware (see 40.9); the latter is usually not considered to be a distinct weapon system element, but its separate identification is relevant to this standard;

b. CFE (see 40.22) versus GFE (see 40.50);

c. NDI (see 40.102) versus developmental items (see 40.30);

d. commercial versus military NDI and modified versus unmodified NDI; and

e. CIs (see 40.20) versus items that are not CIs, such as facilities and RPIE.

40.88 High altitude electromagnetic pulse (HEMP). HEMP is a particular type of EMP (see 40.32). 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 transverse electromagnetic wave and a late-time quasi-static field.

40.89 Implementing command. The implementing command is the command or agency appointed to manage an acquisition program. In this standard, implementing command and SPO (see 40.141) are used interchangeably.

40.90 Inherent hardness. The inherent hardness of an item of hardware (at any assembly level up to system level) refers to the capability of the hardware item to withstand (see 40.158) exposure to some designated set of NWE (see 40.112) without the need for additional hardness design. Inherent hardness is a relative term and must always be referred to in terms of specific magnitudes of particular nuclear environments. No item has complete inherent hardness with respect to all magnitudes of all environments.

40.91 Inspections. See hardness inspections, 40.74.

40.92 Integrated analysis plan (IAP). See integrated test plan, 40.93.

40.93 Integrated test plan (ITP). The ITP is a SPO (see 40.141) generated document that defines the system level testing and associated contractor (see 40.21) support activities required to verify that selected system functions comply with the requirements of the WSS (see 40.157). The SPO may identify system level analyses (see 40.138), in lieu of or in addition to system level tests, to verify WSS compliance, and in these instances, will document these analysis requirements either in the ITP or in a separate document referred to as the integrated analysis plan (IAP). The ITP forms the basis for the TPA (see 40.147). Certain of the system level tests and analyses can be hardness related.

40.94 Interface control drawing (ICD). An ICD depicts the physical and functional interface engineering requirements of an item that affects the design or operation of co-functioning items. These drawings are used as design control documents in order to:

a. establish and maintain compatibility between co-functioning items, including envelope and access compatibility;

b. control interface designs; and

c. communicate design decisions and changes to participating contractors (see 40.21) and concerned government agencies.

ICDs must include applicable hardness requirements and concerns.

40.95 Interface control working group (ICWG). The ICWG serves as the official communications link between program participants to resolve interface problems, document interface agreements, and coordinate on engineering change proposals (ECPs). It consists of at least one member from each of the contractor (see 40.21) and government agencies participating in system development.

40.96 Internal electromagnetic pulse (IEMP). See system generated electromagnetic pulse, 40.136.

40.97 Life cycle hardness (LCH). LCH refers to that part of an overall system hardness program concerned with ensuring that a system that has been successfully designed to satisfy specified hardness requirements (see 40.78) will continue to satisfy those requirements during the production and deployment, and operations and support phases. Thus, the key concept in LCH is the preservation throughout the remainder of the system life cycle (see 40.140) of the hardness provided for in the design. By definition, LCH has been divided into three major program elements. During system production and the A&CO (see 40.7) activity, the relevant LCH activity is referred to as hardness assurance (see 40.60). Throughout the system's subsequent operational life, required LCH activities are provided by the two program elements referred to as hardness maintenance (see 40.75) and hardness surveillance (see 40.79).

40.98 Logistic support analysis (LSA). LSA is one of the four elements of SRA (see 40.142). It is the systematic analytic methodology by which the logistics support requirements of the weapon system are identified, including hardness related logistics support requirements. The results of the LSA activity are documented on data forms referred to as LSA records (LSAR) (see 40.99).

40.99 Logistic support analysis record (LSAR). The LSAR consists of a set of seven data forms on which the results of the LSA (see 40.98) activity are documented. Three of these forms, the B, D1, and H data sheets, require hardness annotation (see 40.58).

40.100 Maintenance support equipment (MSE). MSE is that category of support equipment (see 40.130) required to restore a system or any of its constituent elements to operating condition. As contrasted with OSE (see 40.115), MSE is not an essential functional part of the system or system element being supported. The operating procedures defined for a system may sometimes cause some elements of MSE to have hardness requirements (see 40.78). See also DSE, 40.26 and FSE,40.42.

40.101 Master engineering document list (MEDL). The MEDL for an a WSE (see 40.155) is a master list of the individual engineering documents required to support the WSE. It is an important tool in support of configuration management. The format of the MEDL contains an HCI (see 40.64) column to identify for each hardware item listed whether or not it is an HCI.

40.102 Non developmental item (NDI). An NDI is an item of existing, developed, and available hardware or software that may be capable of fulfilling DoD requirements, thereby minimizing or eliminating the need for costly government-sponsored research and development programs. NDIs consist of the following categories of items:

a. any item of supply that is available in the commercial marketplace;

b. any previously developed item of supply that is in use by a department or agency of the United States, a state or local government, or a foreign government with which the United States has a mutual defense cooperation agreement; and

c. any item of supply described in (a) or (b) that requires only minor modification in order to meet the requirements of the implementing command.

40.103 Nuclear environment/effect hardness element matrix (NEEHEM). The NEEHEM is a matrix chart prepared by a contractor (see 40.21) to identify the hardness evaluation status of each constituent hardware element in the WSEs under contract impacted by the specified NWE (see 40.112). The NEEHEM is used as a hardness evaluation management and tracking tool by both the implementing command (see 40.89) and the contractor, and as an index to the hardness evaluation content of the NH&S DAR (see 40.108).

40.104 Nuclear environments. See nuclear weapon effects/environments, 40.112.

40.105 Nuclear event protection (NEP). Nuclear event protection refers to specific electronic design techniques implemented to protect mission critical hardware from nuclear radiation environments. These design techniques include circumvention and recovery (see 40.15), photo-current compensation, and current limiting.

40.106 Nuclear hardening. Nuclear hardening refers to the employment of design techniques that increase the ability of a system to withstand (see 40.158) exposure to one or more of the specified NWE (see 40.112) without suffering an unacceptable change in performance characteristics. The nuclear hardening requirements associated with a given system can sometimes be reduced through modification of operational procedures.

40.107 Nuclear hardness. Nuclear hardness is a measure, expressed in terms of applicable nuclear environment magnitude(s), of the ability of a system, or any of its constituent elements, to withstand (see 40.158) exposure to one or more NWE (see 40.112) without suffering an unacceptable change in performance characteristics.

40.108 Nuclear hardness and survivability design analysis report (NH&S DAR). The NH&S DAR is a comprehensive report in which the AVE/SE contractor (see 40.21) documents the approach, methodology, and results of the hardness design (see 40.66) and evaluation (see 40.72) activities performed for developmental items (see 40.30) and the hardness evaluation activity performed for non developmental items (see 40.102). This report is used by:

a. the implementing command (see 40.89) to evaluate the degree to which the contractor has demonstrated the satisfaction of all applicable hardness requirements (see 40.78); and

b. the supporting command (see 40.131) to aid in the evaluation of the hardness impact of redesign/modification/upgrade and other logistics support actions.

Access to information related to specific HCIs (see 40.64) is provided by a comprehensive HCI index that is included in the NH&S DAR.

40.109 Nuclear radiation. Nuclear radiation is one of the NWE (see 40.112). 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, thermal neutrons, and fallout. 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.

40.110 Nuclear radiation characterization. Nuclear radiation characterization refers to a category of development test (see 40.31) that consists of the measurement of the electrical parameters of a semiconductor device as a function of increasing magnitudes of individual radiation environments. Testing is continued and device parameters are recorded until either parameter functional failure (see 40.49) is observed or the limits of the particular simulator being used are reached. The data obtained are used:

a. as inputs to the device specification end-of-life table;

b. as input data in support of analysis activities; and

c. to determine the device's hardness design margins (see 40.70); these are subsequently utilized to determine the magnitude of HALAT (see 40.62) required to assure the hardness of higher levels of assembly using the particular part.

40.111 Nuclear survivability. Nuclear survivability is a measure of the capability of a system to withstand (see 40.158) 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 (see 40.106), concealment, avoidance, and proliferation. This standard addresses only the nuclear hardness aspects of accomplishing nuclear survivability.

40.112 Nuclear weapon effects/environments (NWE). NWE refer to the primary nuclear weapon environments and all associated hardware stresses experienced by a weapon system as a result of the detonation of a nuclear weapon. Primary nuclear environments, which may result directly from the weapon detonation or from subsequent interactions of weapon products with the air and earth, are usually grouped into the following six categories: EMP (see 40.32), nuclear radiation (see 40.109), thermal radiation (see 40.148), blast (see 40.14), shock (see 40.128), and debris (see 40.24). Hardware stresses are caused by the interaction of primary environments with a weapon system, or with other hardware connected to a weapon system. NWEs are identified as hardness design constraints (see 40.68) in the applicable requirements documentation. The functions of attenuating and shielding NWEs are identified as hardness performance requirements (see 40.76).

40.113 Operating command. The operating command is the command assigned responsibility for operating a weapon system throughout its operational life.

40.114 Operational requirements analysis (ORA). ORA is one of the four elements of SRA (see 40.142). It is the systematic analytic methodology by which the operational requirements of the weapon system, including those related to and impacted by NH&S considerations, are identified.

40.115 Operational support equipment (OSE). OSE refers to all items of support equipment (see 40.130) that are a functional part of a system and are required in order for the system and its constituent elements to be operational in their intended environment. For purposes of configuration management, the SPO (see 40.141) procures OSE in equipment groupings that are treated as individual CIs (see 40.20), each with its own PIDS (see 40.121). See also WSE, 40.155.

40.116 Operations and support phase. The operations and support phase is Phase IV of the system life cycle (see 40.140). During this phase, the system that was designed and produced in response to an identified operational need is maintained on full operational status until it is determined that the need no longer exists, and the system is deactivated and removed from the field. The key hardness tasks during this phase are implementation of hardness maintenance (see 40.75) and hardness surveillance (see 40.79).

40.117 Performance requirements. See hardness performance requirements, 40.76.

40.118 Physical configuration audit (PCA). The PCA is the formal examination of the as-built version of a CI (see 40.20) against its design documentation in order to verify that the CI as built conforms to the technical documentation that defines the CI, and to thereby establish the product baseline. The PCA includes a detailed audit of engineering drawings, including the completeness and correctness of hardness annotations (see 40.58).

40.119 Preliminary design. For AVE (see 40.3) and SE (see 40.130) hardware, the term preliminary design refers to the design used to support the development of PIDS (see 40.121) for the CIs (see 40.20) under contract. This level of design must be developed enough to support a meaningful allocation of WSS (see 40.157) requirements to CI PIDS requirements, including the allocation of hardness requirements (see 40.78). Aspects of the preliminary design may change with the design process through EMD (see 40.33). For the facilities (see 40.35), the term preliminary design refers to the design that has evolved subsequent to the concept design (see 40.18), but prior to the detail design (see 40.29) that will be used as the basis for the facilities construction bid package (see 40.37).

40.120 Preliminary design review (PDR). The PDR is a formal technical review of the CI PIDS and the adequacy of the design approach for a CI (see 40.20) as represented by the preliminary design (see 40.119). Among the items presented for review are trade study (see 40.84) results. Of prime concern to the NH&S program are:

a. the traceability of CI hardness requirements to the WSS (see 40.157) hardness requirements;

b. the compatibility of CI hardness requirements with other CI requirements;

c. the consistency of hardness requirements between CIs;

d. the identification of the verification (see 40.85) approach to be used for each CI hardness requirement; and

e. the identification of interface hardness requirements (see 40.94) with other WSEs (see 40.155).

40.121 Prime item development specification (PIDS). The PIDS establishes the performance, design, development, and test requirements for those elements of a system that the implementing command (see 40.89) decides will be procured as separate CIs (see 40.20). The hardness performance requirements (see 40.76) associated with a CI are identified in the main body of the PIDS. The details of the applicable hardness design constraints (see 40.68) are usually provided in a classified appendix.

40.122 Production and Deployment phase. The production and deployment phase is Phase III of the acquisition life cycle (see 40.2). During this phase, all elements of the system are united, culminating in the delivery of an acceptable integrated system to the operating (see 40.113) and supporting (see 40.131) commands. The phase extends from production approval until the last system is deployed.

40.123 Program management responsibility transfer (PMRT). PMRT refers to the transfer of program management responsibility for a system or equipment from the implementing command (see 40.89) to the supporting command (see 40.131). PMRT includes transfer of engineering responsibility.

40.124 Qualification. See hardness qualification, 40.77.

FIGURE B-1 CONCEPT EXPLORATION AND DEFINITION FLOW AND VALIDATION AND DEMONSTRATION FLOW

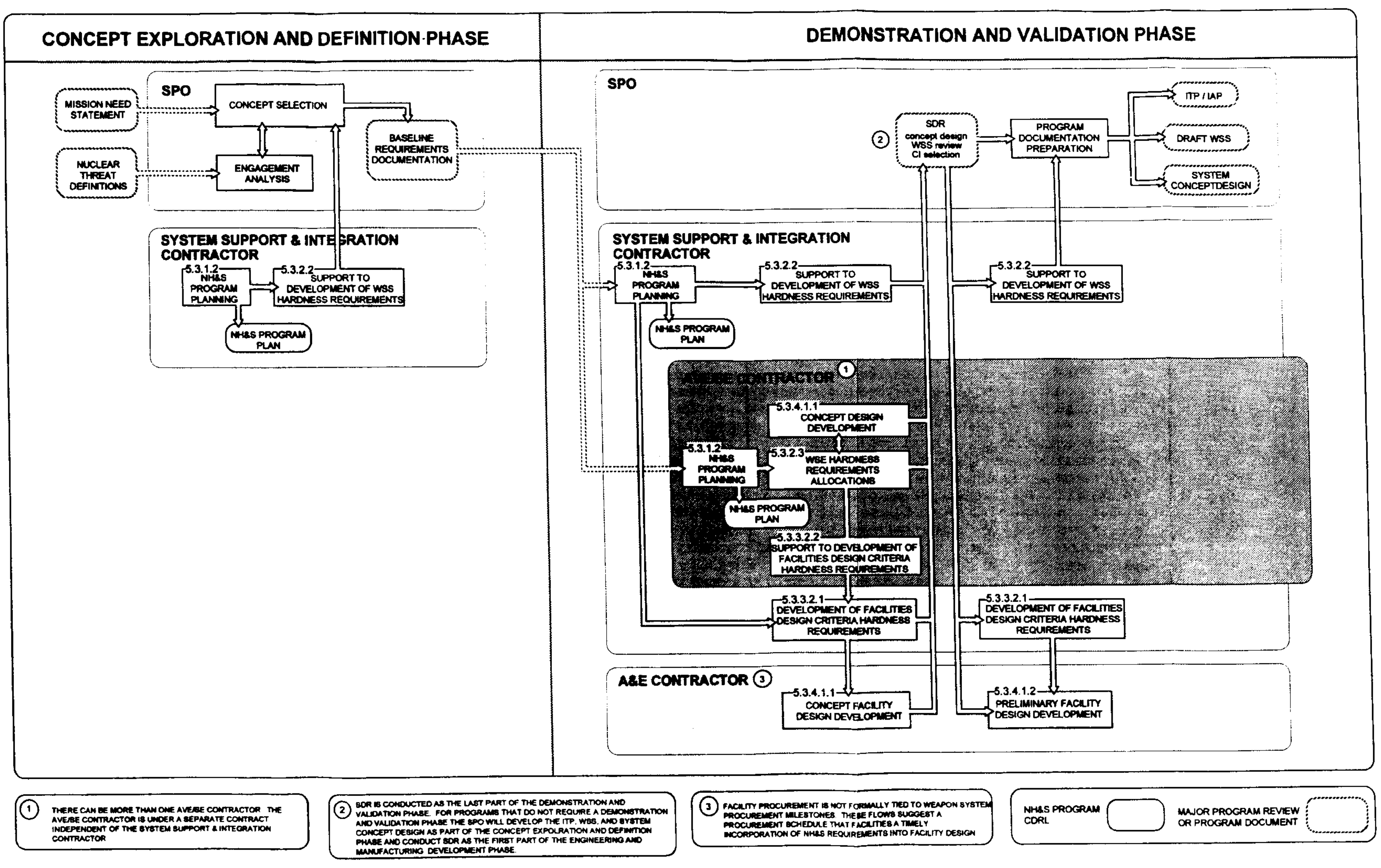
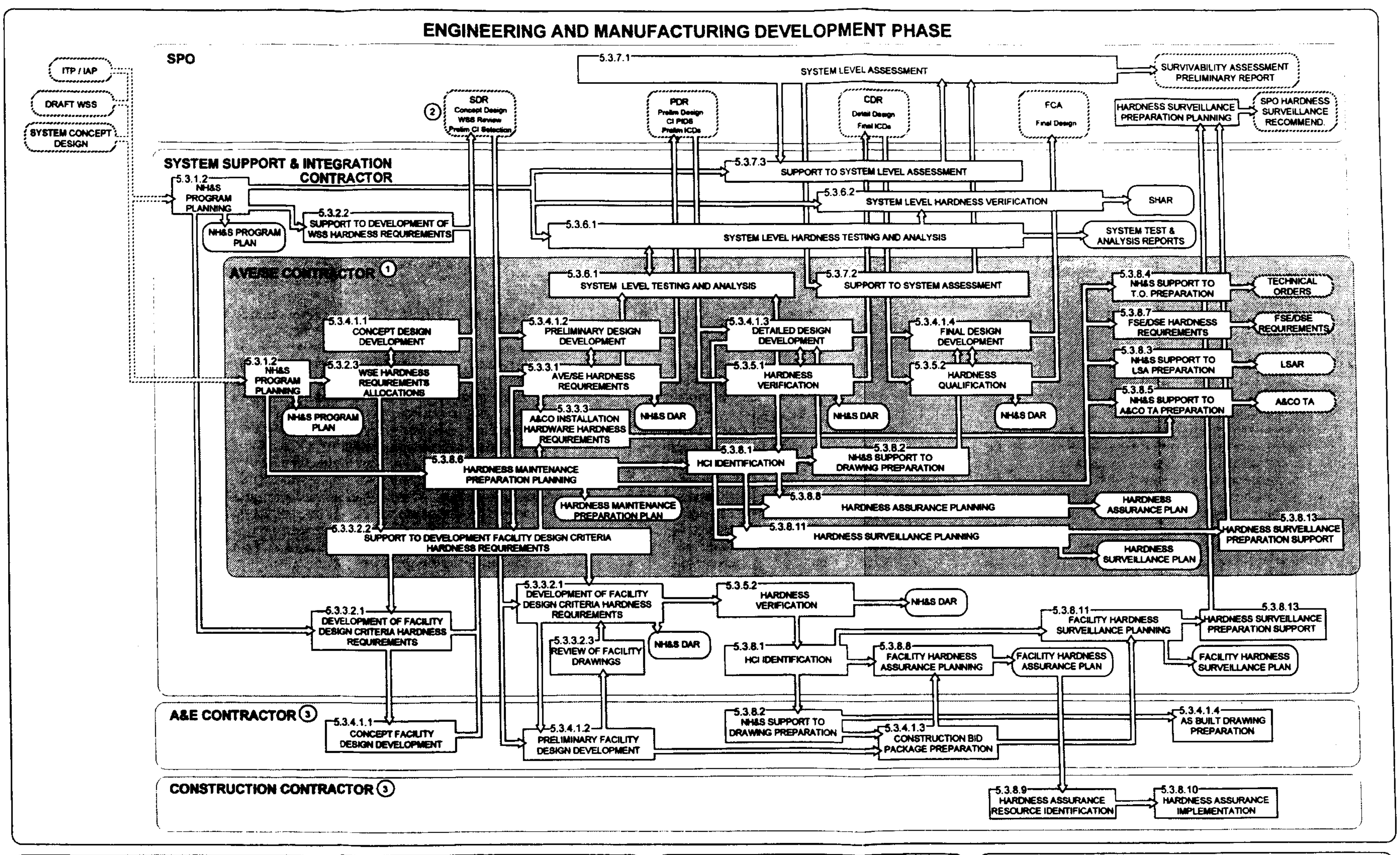


FIGURE B-2 . ENGINEERING AND MANUFACTURING DEVELOPMENT FLOW



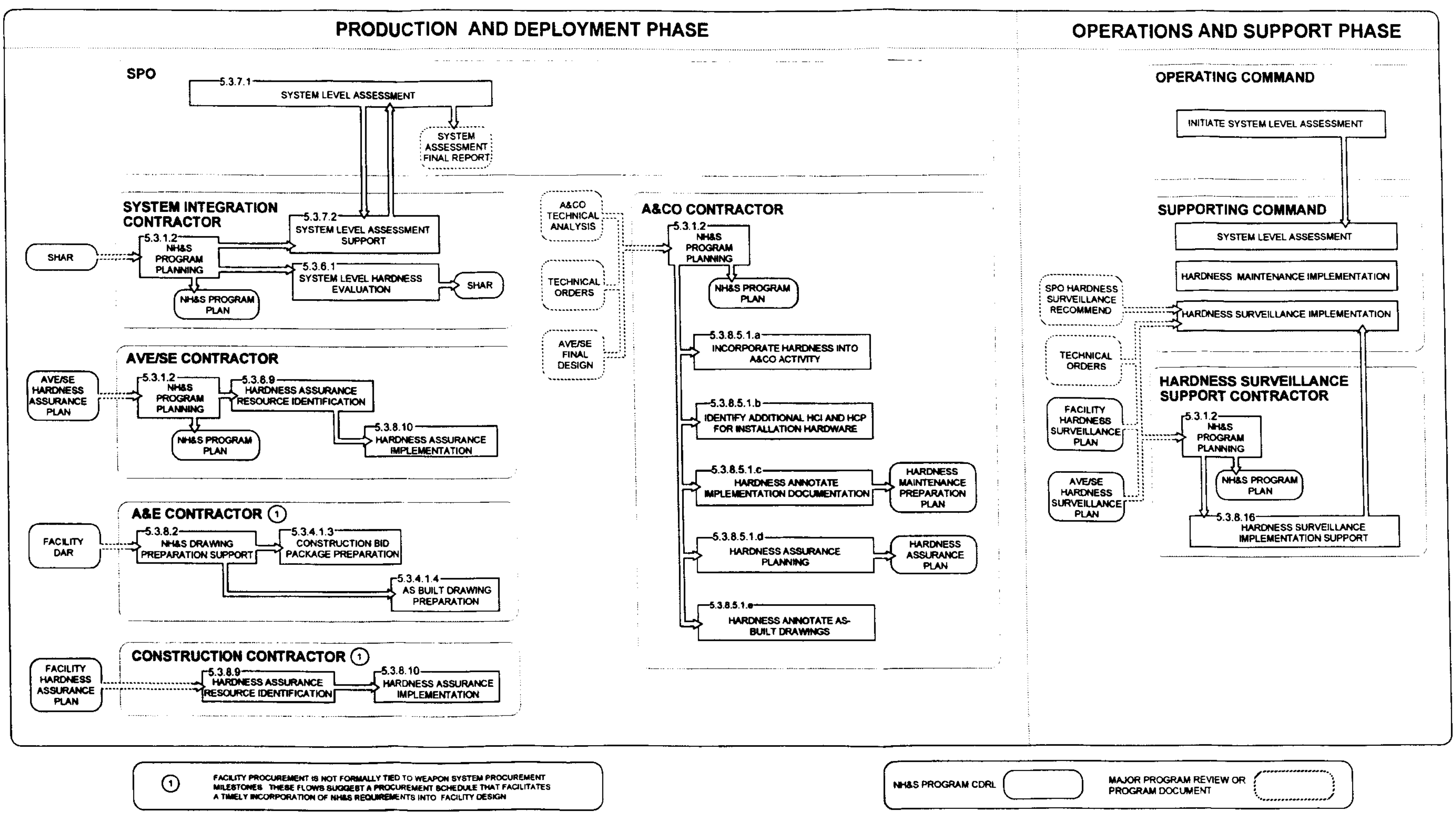
(1) THERE CAN BE MORE THAN ONE AVE/SE CONTRACTOR. THE AVE/SE CONTRACTOR IS UNDER A SEPARATE CONTRACT INDEPENDENT OF THE SYSTEM SUPPORT & INTEGRATION CONTRACTOR

(2) IF THE PROCUREMENT PROGRAM DOES NOT REQUIRE A FORMAL DEMONSTRATION AND VALIDATION PHASE, SDR IS CONDUCTED AS THE FIRST PART OF THE ENGINEERING AND MANUFACTURING DEVELOPMENT PHASE

(3) FACILITY PROCUREMENT IS NOT FORMALLY TIED TO WEAPON SYSTEM PROCUREMENT MILESTONES. THESE FLOWS SUGGEST A PROCUREMENT SCHEDULE THAT FACILITATES A TIMELY INCORPORATION OF NH&S REQUIREMENTS INTO FACILITY DESIGN

NH&S PROGRAM CDRL
MAJOR PROGRAM REVIEW OR PROGRAM DOCUMENT

FIGURE B-3. PRODUCTION AND DEPLOYMENT, AND OPERATIONS AND SUPPORT FLOWS



40.125 Qualification tests. Qualification tests are a subset of hardness tests (see 40.83). They are conducted, as required by section 4 of the applicable PIDS (see 40.121), on hardware representative of the production hardware to support WSE (see 40.155) hardness qualification (see 40.77). The objective of qualification tests is to establish by direct measurement that production configuration hardware satisfies specified hardness requirements.

40.126 Real property installed equipment (RPIE). RPIE are those items of government-owned or -leased accessory equipment, apparatus, and fixtures that aid in the function of a facility (see 40.35) and are permanently attached to, integrated into, or built in or on the facility.

40.127 Shielding topology. Shielding topology is a term used to describe the various layers of electromagnetic shielding and protection features used to attenuate and mitigate EMP (see 30.33) effects. The shielding topology is documented in a shielding topology diagram included in NH&S DAR(s) (see 40.108), as applicable. These shielding topology diagrams support:

a. the hardness allocation process (see 40.54);

b. the hardness design development process; and

c. the hardness verification (see 40.85) and qualification (see 40.77) processes.

40.128 Shock. Shock, or ground shock, is one of the NWE (see 40.112). It consists of the stress waves propagated through the earth or water medium surrounding ground zero. It results in structural or equipment shock-induced response of facilities (see 40.35), SE (see 40.130), and AVE (see 40.3). Shock can produce transient responses, which include large material deflections, relative motions, high accelerations, and resulting stresses. Additionally, permanent material deformations and displacements are possible.

40.129 Source region electromagnetic pulse (SREMP). SREMP is a particular type of EMP (see 40.32). It refers to the electromagnetic energy near a nuclear weapon detonation that is generated by the interaction of nuclear ionizing radiation with the surrounding media.

40.130 Support equipment (SE). Support equipment refers to all equipment required to make or to keep a system and all of its constituent elements operational in their intended environment. SE may be functionally sub classified as OSE (see 40.115) and MSE (see 40.100). MSE includes DSE (see 40.26) and FSE (see 40.42). SE is usually procured as CIs (see 40.20), each with its own PIDS (see 40.121).

40.131 Supporting command. The supporting command is the command assigned responsibility for providing logistics support for a system. It assumes program management responsibility from the implementing command (see 40.89) at PMRT (see 40.123). In the case of a major upgrade or a system replacement, the supporting command may also function as the implementing command.

40.132 Survivability. Survivability is the capability of a system to withstand (see

40.158) 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 (see 40.111).

40.133 Survivability assessment. See assessment, 40.11.

40.134 System design review (SDR). The SDR is a formal technical review, supported by trade studies, whose purposes are to ensure that technical program risks associated with the concept design (see 40.18) have been identified, ranked, and reduced, and that the WSS (see 40.157) is complete and consistent.

Of prime concern to the NH&S program during SDR is:

a. the allocation (see 40.54) of the WSS hardness requirements to the contractor's concept design;

b. the identification of hardness interface requirement responsibilities (see 40.94) between contractors; and

c. the ease with which it is anticipated that hardness verification (see 40.85) for a given concept design can be accomplished.

40.135 System engineering and technical assistance (SE/TA) contractor. See contractor, 40.21.

40.136 System generated electromagnetic pulse (SGEMP). SGEMP is a particular type of EMP (see 40.32). It consists of the electromagnetic energy generated by the interaction of nuclear ionizing radiation with system hardware. A subset of SGEMP is referred to as internal electromagnetic pulse (IEMP). This consists of the electromagnetic field generated inside an enclosure as a result of the interaction of ionizing radiation with the material of the enclosure.

40.137 System hardness analysis report (SHAR). The SHAR documents the results of the system level hardness verification (see 40.85) activity. It is the system level counterpart of the NH&S DAR (see 40.108).

40.138 System level analysis. As used in this standard the term system level analysis refers to the activity conducted to evaluate aspects of the system related to nuclear harness. System level analyses can be conducted by:

a. the SPO (see 40.141);

b. the contractor (see 40.21) under SPO direction through the IAP (see 40.92);

c. the operating command (see 40.113); or

d. the supporting command (see 40.131).

40.139 System level trade study. System level trade studies are conducted by the SPO (see 40.141), or by the contractor (see 40.21) under SPO direction, to support the development of a system concept design.

40.140 System life cycle. The system life cycle refers to the total set of program phases a system passes through from the time it is initially conceived and developed until the time it is deactivated and removed from operational use. Phase 0 through Phase IV of the system life cycle are referred to as the acquisition life cycle (see 40.2). One or more of the phases in the acquisition life cycle may also apply to major upgrade or system replacement actions.

40.141 System program office (SPO). The SPO is the organization consisting of technical, administrative, and management personnel assigned full time to a system program manager. It is the organization within the implementing command (see 40.89) responsible for a system during its acquisition life cycle (see 40.2). In this standard, SPO and implementing command are used interchangeably.

40.142 System requirements analysis (SRA). SRA is the systematic analytic methodology used to define and optimize the requirements associated with the acquisition and support of a weapon system. It consists of the following four major analysis activities:

a. operational requirements analysis (see 40.114);

b. test planning analysis (see 40.147);

c. logistic support analysis (see 40.98); and

d. the A&CO technical analysis (see 40.10).

Hardness inputs to the SRA are of two kinds:

a. hardness related requirements; and

b. special hardness annotations (see 40.58); these apply only to the A&CO TA (see 40.10) and the LSA (see 40.98).

40.143 System support/integration (SS&I) contractor. See contractor, 40.21.

40.144 System level tests. System level tests are conducted to support:

a. development of a system concept design during the demonstration and validation phase (see 40.25);

b. development of WSS (see 40.157) requirements; and

c. the system level hardness evaluation activity.

Participation in system level tests require coordination with system test organizations to develop and acquire hardware. The respective responsibilities of the different contractors that may be involved in a particular system test are defined in the ITP (see 40.93) for EMD (see 40.33) system level tests.

40.145 Technical order (TO). The TO is a document prepared in support of the repair and maintenance of weapon system WSEs (see 40.155). Of the various categories of TOs, the following require hardness annotation (see 40.58) in support of hardness maintenance (see 40.75) implementation:

a. organizational and intermediate level TOs;

b. depot control manuals; and

c. illustrated parts breakdowns.

40.146 Testing. See hardness testing, 40.83.

40.147 Test planning analysis (TPA). TPA is one of the four elements of SRA (see 40.142). The TPA develops detailed test objectives, success criteria, and special test equipment, instrumentation, and documentation requirements for each system test identified in the ITP (see 40.93), including system level hardness tests. Formal test planning analysis can be waived at the discretion of the SPO (see 40.141) to facilitate test planning for other than normal operational testing.

40.148 Thermal radiation. Thermal radiation is one of the NWE (see 40.112) and consists of ultraviolet, visible, and infrared radiation, emitted from the fireball (or other heated regions) as a result of its very high blackbody temperature. Thermal radiation can cause material heating and ablation, resulting in changes in material properties, including mass and surface characteristics. Thermal radiation heating can be particularly critical when combined with airblast (see 40.14) loadings.

40.149 Thermomechanical response. Thermomechanical response refers to the mechanical responses that result from the deposition of x-ray energy in materials, which produces local and gradational temperature increases. In many cases, loading is experienced both at local and global levels. Thermomechanical responses include: (a) stress resultant from bulk heating; (b) stress, stress waves, and shock resultant from surface heating induced blowoff impulse; and (c) gradational heating induced thermal line load.

40.150 Trade studies. See hardness trade studies, 40.84.

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

40.152 Validation/validate. As used in this standard, the terms "validation" and "validate" are used in their usual dictionary sense of confirming the validity or correctness of something, and do not refer to a special hardness activity or program element.

40.153 Verification. See hardness verification, 40.85.

40.154 Vulnerability. As used in this standard, a system or any of its constituent elements is said to have a vulnerability or to be vulnerable to a particular nuclear environment when one or more of its characteristics necessary for acceptable system performance are capable of being damaged or degraded upon exposure to that environment. When discussing vulnerabilities, it is important to identify the nuclear environment of concern and the magnitude above which the degradation is likely to occur.

40.155 Weapon system element (WSE). As used in this standard, WSE is a generic term that refers to any top level unit of hardware, firmware, or software below the system level. In the case of AVE (see 40.3) and SE (see 40.130), a WSE is composed of one or more configuration items (see 40.20). When dealing with facilities (see 40.35), RPIE (see 40.126), and A&CO installation hardware (see 40.9), however, the concept of configuration item does not apply. Therefore, the discussion of requirements in sections 5.3 and 5.4 of this standard for NH&S program tasks and NH&S program task support activities, respectively, is presented in terms of the general designation WSE.

40.156 Weapon system element contractor. See contractor, 40.21.

40.157 Weapon system specification (WSS). The WSS states the technical and mission requirements for a system and documents design constraints. From an NH&S perspective, it identifies the design constraints (see 40.68) and hardness performance requirements (see 40.76) imposed on the system.

40.158 Withstand. In this standard, withstand is used as a technical term to denote the inherent capability of an item of hardware, at any level of assembly, to withstand exposure to one or more NWE (see 40.112) without suffering any unacceptable degradation of performance capability of concern to the system design. Withstand requirements are included in the specification of hardness requirements (see 40.78) as hardness design constraints (see 40.68). See also inherent hardness, 40.90, and attenuation, 40.12.

40.159 Worst case circuit analysis (WCCA). Worst case circuit analysis refers to a type of circuit analysis in which the operating characteristics of circuit components, particularly semiconductor devices, are set at degraded values, usually related to their end-of-life limits, including radiation, aging, and temperature effects. Worst case circuit radiation analysis is a variant of WCCA in which current generators are added to the circuit model to simulate the magnitudes and durations of photocurrents generated by the specified prompt and secondary ionizing radiation. Worst case circuit EMP (see 40.32) analysis is a variant of WCCA in which current/voltage generators are added to the circuit model, as appropriate, to simulate the coupled EMP transients generated by the specified EMP environments. In addition, circuit component and operational power supply parameters are varied throughout their specification range in such a manner that the most severe transients are coupled into the system.

NH&S PROGRAM OVERVIEW IN FLOW DIAGRAM FORMAT

10. SCOPE

10.1 Scope. This appendix contains flow diagrams that depict the program phasing and interrelationships of the NH&S program tasks defined in 5.3 of this standard as a function of:

a. system life cycle phase;

b. contractor program role;

c. individual military command responsibilities; and

d. in the specific instance of the engineering and manufacturing development (EMD) phase, the relationship of program tasks and accomplishments to mandated design reviews and audits.

The intent of these diagrams is to provide additional insight into how all the individual tasks that comprise a comprehensive NH&S program interrelate and work together to result in the design, production, deployment, and operation of a hardened weapon system that satisfies all specified hardness requirements and preserves that hardness throughout the weapon system life cycle. These diagrams are considered to be self-explanatory, once the nature of their content and layout are understood, as explained below. They will be most useful when studied in conjunction with a careful reading of section 5 of this standard.

This appendix is not a mandatory part of this standard. The information provided is intended for guidance only.

20. APPLICABLE DOCUMENTS

20.1 Applicable documents. This section is not applicable to this appendix.

30. DEFINITIONS

30.1 Definitions. For purposes of this appendix, the definitions contained in Appendix A of this standard shall apply.

40. FLOW DIAGRAM CONTENT

40.1 Flow diagram content considerations. A separate flow diagram is presented for each of the following system life cycle phases:

a. Phase 0: Concept exploration and definition;

b. Phase I: Demonstration and validation;

c. Phase II: Engineering and manufacturing development (EMD);

d. Phase III: Production and deployment;

f. Phase IV: Operations and support.

The diagrams for the concept exploration and definition and demonstration and validation phases are contained in figure B-1. The EMD phase is delineated separately in figure B-2. The remaining phases are all depicted in figure B-3.

It should be noted that an apparent conflict exists between the diagrams for the demonstration and validation and EMD phases because both indicate the conduct of a system design review (SDR). The diagrams have been drawn in this way to allow for the possibility that a formal demonstration and validation phase may not be implemented during the course of a particular program. Such a situation sometimes arises when a procurement does not involve significant new design concepts or technologies that must be developed to mitigate procurement risks. In such instances, the system program office (SPO) will:

a. conduct the SDR as the first part of the EMD phase as depicted in figure B-2; and

b. generate the documentation needed to conduct EMD as part of the concept exploration and definition phase.

When a formal demonstration and validation phase is held, the SDR will be part of that phase, as shown in figure B-1.

It should be further noted that the procurement of weapon system facilities is:

a. implemented separately from the acquisition of other weapon system elements (WSEs); and

b. not implemented in terms of the formal phases discussed above.

For facilities that have significant NH&S requirements, the facility related flows depicted in figures B-1 through B-3 indicate a facility procurement time sequencing in relation to the procurement of other WSEs that supports timely incorporation of NH&S requirements into the facility design.

50. FLOW DIAGRAM FORMAT

50.1 Flow diagram format considerations. The following notation and layout considerations apply to figure B-1 through B-3.

50.1.1 Contractor categories. The tasks associated with each category of contractor (see Appendix A, 40.21 for a discussion of contractor categories) are identified within a separate shaded area in each of the flow diagrams. The tasks for each contractor are shown as blocks within that contractor's shaded area. It will be noted, however, that in the diagrams for the demonstration and validation and the EMD phases, the AVE/SE contractor's shaded area lies within the shaded area depicting the SS&I contractor. This overlay is not intended to imply that the AVE/SE contractor is part of or subordinate to the SS&I contractor. Each contractor has independent contractual commitments to the SPO. The overlay was introduced solely to facilitate clarity of presentation.

50.1.2 Task designation. The tasks for each contractor are depicted by rectangular blocks. Associated with each box is the corresponding 5.3 paragraph number and title. In some instances, for purposes of simplicity and clarity, only the highest indenture paragraph associated with a particular task is identified. In these cases, the corresponding lower indenture paragraphs should be understood as being included in the task.

50.1.3 Documentation categories. The items of documentation generated by each contractor are depicted by blocks with rounded corners and either a solid or dashed border. A documentation frame with a solid border indicates an NH&S dedicated CDRL. An example is the NH&S design analysis report. A documentation frame with a dashed border indicates program documentation that is not NH&S dedicated but that does contain NH&S related information. An example is the LSAR. The four EMD design review and audit milestones shown (SDR, PDR, CDR, and FCA) are depicted as dashed documentation frames because the contractor's NH&S briefing material prepared in support of these events forms a significant part of the NH&S documentation trail throughout the EMD phase. Each task shown in the flows is either directly documented or supplies inputs to another task that will eventually result in some item of documentation. Documentation that supports the performance of a task is indicated with an arrow from that item of documentation to the task that uses it as an input.

GUIDANCE FOR SPO GENERATED NH&S RELATED PROGRAM PLANS AND DATA REQUIREMENTS

10. SCOPE

10.1 Scope. This appendix contains guidance for SPO personnel regarding:

a. the preparation of SPO generated weapon system level NH&S related program plans, including an NH&S program plan, a system level hardness maintenance plan, and a system level hardness surveillance plan; and

b. the hardness tailoring of MIL-STD-100 (Engineering Drawing Practices) necessary to acquire the HCI list drawing required by 5.3.8.1.1 of MIL-STD-1766B.

This appendix is not a mandatory part of this standard. The information provided is intended for guidance only.

20. APPLICABLE DOCUMENTS

20.1 Applicable documents. This section is not applicable to this appendix.

30. DEFINITIONS

30.1 Definitions. For purposes of this appendix, the definitions contained in Appendix A of this standard shall apply.

40. SPO GENERATED NH&S RELATED PROGRAM PLANS

40.1 System level NH&S program plan. The system level NH&S program plan prepared by the cognizant SPO for a particular weapon system acquisition has a three-fold purpose:

a. to provide an overview of all aspects of the weapon system NH&S program;

b. to identify and summarize the approach and schedule by which the SPO will implement this NH&S program; and

c. to identify the organizational entities, both within and without the SPO, involved with accomplishing the implementation of this NH&S program, and their respective responsibilities and required interfaces.

The primary objective of this program plan is to provide a program tool that will aid the SPO in accomplishing NH&S program requirements in a timely and cost effective manner. The plan may also serve the subsidiary purpose of providing a comprehensive road map to the entire process by which the NH&S aspects of a major weapon system acquisition program are defined and implemented. Such a road map can be a significant aid in orienting new SPO personnel assigned to support the implementation of NH&S program requirements.

A separate NH&S program plan may be prepared for each individual phase of the acquisition life cycle, or a single comprehensive plan encompassing multiple phases may be prepared. The comprehensive approach is recommended for any system expected to proceed to engineering and manufacturing development (EMD). For system investigations during the concept exploration and definition phase, where several systems will be evaluated, a single plan is probably appropriate. This decision must be made by the cognizant SPO and project officer well prior to entry into the first phase of any program in order to support timely plan development.

40.1.1 Model outline. A model outline for the system level NH&S program plan is provided in figure C-1. The initial draft will normally not include all or even detailed aspects of the weapon system NH&S program. As system acquisition progresses, the plan should be updated to include program changes and more detailed planning. These updates should continue, at a minimum, into CDR. At this point, most planning to complete the EMD phase and the remaining acquisition phases should be included within the NH&S program plans prepared and maintained by the weapon system element (WSE) and system support and integration (SS&I) contractors.

40.2 System level hardness maintenance plan. The purpose of the SPO generated system level hardness maintenance plan is to provide the supporting and operating commands with a comprehensive overview of the hardness maintenance capability that the SPO will provide to them in support of their responsibility to preserve system hardness throughout the operations and deployment phase of the weapon system life cycle. This hardness maintenance capability will consist primarily of data products containing both hardness related information required to preserve system hardness and hardness annotations that flag the presence of such information. In addition, certain types of hardware capability that will support hardness maintenance implementation, such as the capability of particular items of depot support equipment to evaluate the adequacy of selected system hardware hardness characteristics, may also be provided. The following items of information should be included in the plan, as applicable:

a. Identify the specific items of hardness related data that will be supplied in support of the hardness maintenance responsibilities of each of the following areas of maintenance activity and maintenance support responsibility:

    (1) organizational maintenance;

1. INTRODUCTION
1.1 Purpose
1.2 Objective
1.3 Scope
1.4 Weapon system program overview
1.4.1 Weapon system description
1.4.2 System acquisition approach
1.5 Weapon system NH&S requirements
1.6 Weapon system NH&S program approach
1.6.1 Hardness design
1.6.1.1 Weapon system hard parts program
1.6.2 System level hardness evaluation
1.6.3 System level assessment
1.6.4 Life cycle hardness
1.7 NH&S authority/compliance documents

2. ORGANIZATIONAL RESPONSIBILITIES AND INTERFACES
2.1 Overview
2.2 Role of SPO and organizations under direct contract to SPO
2.2.1 SPO
2.2.2 SE/TA contractor
2.2.3 System support and integration (SS&I) contractor
2.2.4 Weapon system element (WSE) contractors
2.3 Role of Air Force/DoD organizations outside SPO

3. WSE HARDNESS EVALUATION
3.1 WSE hardness evaluation approach
3.2 Hardness development evaluation
3.3 Hardness verification
3.4 Hardness qualification

4. SYSTEM LEVEL HARDNESS EVALUATION
4.1 System level hardness evaluation approach
4.2 Hardness analysis
4.3 Hardness testing
4.3.1 Nuclear simulation testing
4.3.2 Underground nuclear testing
4.3.3 Hardness verification

5. SYSTEM LEVEL ASSESSMENT
5.1 System level assessment approach
5.2 WSE level support
5.3 System level support

FIGURE C-1. **Model format for SPO NH&S program plan.**

6. LIFE CYCLE HARDNESS
6.1 Life cycle hardness approach
6.2 HCI identification and documentation
6.3 Role and responsibilities of contractor NH&S personnel

7. NH&S PROGRAM SCHEDULE

8. DEFINITIONS AND ACRONYMS

FIGURE C-1. **Model format for SPO NH&S program plan - Continued.**

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(2) intermediate maintenance;
(3) depot maintenance;
(4) supporting command redesign activities;
(5) supporting command reprocurement activities;
(6) Defense Logistics Agency (DLA)/Defense Electronics Support Center (DESC) activities; and
(7) 20AF/MES activities.

b. For each category of maintenance activity and responsibility and each associated data item identified in paragraph a. above, identify:

(1) the nature of the hardness related information provided;
(2) the manner in which hardness related information is flagged;
(3) how the hardness related information is intended to be used; and
(4) where hardness requirements in support of competitive reprocurements are located.

c. Identify in detail any differences among the SPO's contractors in the nature and content of the hardness related data that will be supplied to the SPO for eventual transfer to the supporting and operating commands.

d. Identify the inventory of hardness related data items that will be provided to the supporting and operating commands. Identify also the manner and timing for the delivery of these items and the steps to be taken by the SPO to ensure their completeness and accuracy at the time of transfer.

e. Identify the means by which the completeness and accuracy of the hardness related information supplied by the SPO to the supporting and operating commands can be verified.

f. Identify any non-data resources or capability that the SPO will provide to the supporting and operating commands in support of hardness maintenance implementation. These may consist of test equipment, such as depot support equipment, capability to evaluate hardness related characteristics of selected items of weapon system hardware.

40.3 System level hardness surveillance plan. During the EMD phase, the SPO usually directs all end item contractors to prepare separate hardness surveillance program (HSP) plans in which they identify the prioritized hardness surveillance activities they consider to be appropriate for the particular end items under contract. On the basis of these contractor recommendations, the SPO undertakes, in consultation with the supporting and operating commands, to define the most cost-effective, single, integrated HSP plan for the entire weapon system. This activity is referred to as the HSP definition phase. Subsequent to the completion of this phase, the SPO undertakes to acquire and validate all the resources, including test plans and procedures, necessary to implement the program defined. This activity, implemented with the aid of selected contractors, is referred to as the HSP preparation phase. After this phase has been completed, the SPO is in a position to transfer essentially a turn-key HSP capability to the operating command. Given this background, the weapon system hardness surveillance plan prepared by the SPO may be said to have the following two-fold purpose:

a. to communicate to all cognizant parties the content of the weapon system HSP defined by the SPO, and the means and schedule by which the SPO will validate and transfer to the supporting command the resources required to implement the program defined; and

b. to serve as a coordination tool in support of the accomplishment of the weapon system HSP preparation phase.

A model outline for the system level HSP plan is provided in figure C-2.

1.0	INTRODUCTION
1.1	Purpose
1.2	Objectives
1.3	Scope
1.4	Ground rules and assumptions (as applicable)
2.0	DEFINITION PHASE
2.1	Definition phase approach
2.2	Definition phase outcome
3.0	PREPARATION PHASE
3.1	Definition of required resources
3.2	Acquisition of required resources
3.2.1	Resource acquisition schedule
3.3	Validation of HSP capability
3.3.1	Field validation
3.3.2	Laboratory activity validation
3.3.3	Validation schedule

FIGURE C-2. **Model outline for system level HSP plan.**

50. REQUIREMENTS FOR HCI LIST DRAWING

50.1 Description/purpose. The HCI list drawing, which is required by 5.3.8.1.1 of MIL-STD-1766B, is a critical resource for weapon system life cycle hardness. It is used by the contractor, as well as the implementing and supporting commands. It is used by the contractor as the authoritative source of HCI identification in all contract activities in which HCI identification and documentation plays a role, including the hardness annotation of engineering drawings, MEDLs, the A&CO TA, the LSA, and TOs. It is also used to support the preparation of the HCI index contained in the NH&S DAR. It is used by the implementing and supporting commands as the basis for identifying and preserving the nuclear hardness in the design of each weapon system element that has hardness requirements applied to it.

50.2 Acquisition approach. The most cost-effective approach for the acquisition of the HCI list drawing is for the SPO to procure it in-line with all other engineering drawings. This can be readily accomplished on applicable contracts by including the requirements for its preparation in the tailoring of MIL-STD-100 (Engineering Drawing Practices) applied to the contract. Detailed instructions for the preparation of the HCI list drawing are provided below.

50.3 Preparation instructions for inclusion in MIL-STD-100 tailoring.

50.3.1 Format. The format of the HCI list drawing shall be in accordance with Figure C-3.

50.3.2 Content. A separate HCI list drawing shall be prepared for each individual weapon system element under contract that contains HCIs as defined in Appendix A of MIL-STD-1766B. This drawing shall be released and maintained under configuration control. The hardware and software elements included in the initial release of the HCI list drawing shall be identical to those identified in the HCI list prepared for the weapon system element under consideration in accordance with 5.3.8.1 of MIL-STD-1766B. Each HCI list drawing shall contain the following general notes:

a. This drawing lists the hardness critical items (HCIs) contained in the designated weapon system element. All changes to or proposed substitution of HCIs must be evaluated for hardness impacts by the engineering activity responsible for survivability.

b. For additional information about the HCIs listed see (insert document number of applicable NH&S DAR or SHAR).

50.3.2.1 Entry of information. The entry of information in the various blocks and columns of Figure 1 and the use of flag notes shall be in accordance with the following.

50.3.2.1.1 Block 1, end item number. On each sheet, enter the number of the end item for which the HCI list drawing is prepared.

HARDNESS CRITICAL ITEM (HCI) LIST	1. END ITEM NO.	2. WSE DESIGNATOR			3. SHEET ___ OF ___
4. CONTRACTOR	5. CAGE CODE	6. CONTRACT NO.		7. REV. LTR.	8. REV DATE
9. PART NUMBER	10. PART NAME	11. NHA	12. CAGE CODE	13. NOTE FLAG	14. HCI RATIONALE(S)

FIGURE C-3. HCI LIST DRAWING FORMAT

50.3.2.1.2 Block 2, end item designator. On each sheet, enter the name of the end item for which the HCI list drawing is prepared.

50.3.2.1.3 Block 3, sheet number. On each sheet, enter the appropriate sheet number (i.e., 1, 2, 3, etc.). When only one sheet is required for a list, "Sheet 1 of 1" shall be entered. When two or more sheets are required for this list, the total number of sheets shall be entered on the first sheet only. When revisions are made to the list and additional sheets are required, the added sheets shall be numbered in alphanumeric sequence (i. e., 1a, 1b, 1c, etc.).

50.3.2.1.4 Block 4, contractor. On each sheet, enter the name of the contractor responsible for delivering the end item to the government.

50.3.2.1.5 Block 5, commercial and government entity (CAGE) code. On each sheet, enter the CAGE code assigned to the contractor whose name is entered in block 4.

50.3.2.1.6 Block 6, contract number. On each sheet, enter the contract number pertinent to the procurement of the end item identified by the end item number in block 1.

50.3.2.1.7 Block 7, revision letter. When the list is initially prepared, enter a hyphen (-) on each sheet of the list. Each time any sheet of the list is independently revised, enter the appropriate revision letter (alphabetical sequence) on the revised sheet.

50.3.2.1.8 Block 8, revision date. When the list is initially prepared, enter the date on each sheet of the list. Each time any sheet of the list is independently revised, enter the appropriate revision date on the revised sheet.

50.3.2.1.9 Column 9, indenture level. Enter the indenture level applicable to the item whose number is entered in column 11. The entry made in this column shall indicate the indenture level of the item with respect to the end item identified in block 1. A two digit number shall be used, beginning with "01" to indicate the indenture of the end item for which the list is prepared. Numbering shall continue in increasing number sequence to the detail part level.

50.3.2.1.10 Column 10, commercial and government entity (CAGE) code. Enter the appropriate CAGE code assigned to the contractor, subcontractor, vendor, supplier, etc., whose part number appears in column 11.

50.3.2.1.11 Column 11, part number. Enter the part number of each HCI contained in the end item identified in block 1. Part numbers for off-the-shelf items covered by commercial catalogs shall be listed by the part number followed by a space and "CAT".

50.3.2.1.12 Column 12, part name. Enter the name of the HCI identified in column 11.

50.3.2.1.13 Column 13, note flags. For each HCI listed in column 11, note flags shall be entered in this column, as appropriate, to communicate the following items of information, and corresponding flag notes shall be included in the drawing:

a. a note flag shall indicate those items for which no drawing was provided to the government.

b. a note flag shall indicate whether or not there are hardness related test and/or inspection requirements associated with the procurement and reprocurement of the item. If no such tests and/or inspections are required, the corresponding flag note shall so state. When such hardness related tests and/or inspections are required, the corresponding flag note shall identify either explicitly, or by reference to a configuration controlled document provided to the government, what these requirements consist of.

50.3.2.1.14 Column 14. HCI rationale(s). For each HCI listed in column 11, enter the identifying number of each applicable HCI rationale, in accordance with the HCI definition contained in Appendix A of MIL-STD-1766B.

GUIDE TO HCI IDENTIFICATION AND DOCUMENTATION

10. SCOPE

10.1 Scope. This appendix contains guidance for SPO and contractor personnel regarding:

a. hardness critical item (HCI) identification; and

b. the correct application of such identification to life cycle hardness documentation and implementation, particularly with respect to hardness maintenance.

This appendix is not a mandatory part of this standard. The information provided is intended for guidance only.

10.2 Purpose. The purpose of this appendix is to provide guidance intended to facilitate the correct and complete identification and documentation of the HCIs and, implicitly, the HCPs associated with the design of a hardened weapon system. Since this identification and documentation activity forms the foundation for the subsequent implementation of weapon system life cycle hardness (LCH), a proper understanding of this activity is critical to accomplishing the required preservation of weapon system hardness throughout the weapon system life cycle.

20. APPLICABLE DOCUMENTS

20.1 Applicable documents. This section is not applicable to this appendix.

30. DEFINITIONS

30.1 Definitions. For purposes of this appendix, the definitions contained in Appendix A of this standard shall apply.

40. HCI IDENTIFICATION

40.1 Clarification of the HCI identification process. The definition of hardness critical item employed for ICBM weapon systems is contained in paragraph 40.64 of Appendix A. It is reproduced in Figure D-1 for ease of reference. This definition consists of five explicit and independent rationales. Any item of hardware or software within an ICBM weapon system that satisfies one or more of these rationales is defined to be an HCI. This approach applies even in instances where the provision of such hardness was not part of the original design

An HCI is defined to be an item of hardware or software that satisfies one or more of the following five rationales in any one or more of the applicable nuclear environments. More than one rationale may apply to a particular item, and, in such cases, different rationales may apply in different environments. Each candidate HCI must be reviewed separately for the applicability of each rationale in each applicable environment.

HCI rationales:

1. Functionally required hardware (i.e., hardware that would continue to be included in the design even if all hardness requirements were removed) with the following characteristics:

   a. the item is vulnerable to the applicable nuclear environment under consideration; and

   b. the hardness design approach chosen for dealing with that vulnerability is to include additional provisions for hardness in some aspect of the item's procurement requirements, such as the item's specification, design, manufacture, or item selection process.

2. Functionally required hardware with the following characteristics:

   a. the item does not satisfy rationale 1; and

   b. its presence in the design is taken advantage of to also provide protection for the system or any of its elements against one or more of the applicable nuclear environments; for the purposes of providing this hardness protection function, the item may be used as is, or it may be modified in some way to enhance its hardness protection capabilities.

3. Hardness dedicated hardware or software included in system design solely to help satisfy the specified hardness requirements. As contrasted with the non-hardness dedicated, functionally required hardware covered by rationales 1 and 2 above, hardness dedicated hardware and software would not be included in the design if hardness requirements had not been applied.

4. Hardware items to which a hardness critical process is applied during system fabrication, manufacture, or assembly, as identified in the applicable engineering drawings. The items selected to be identified as HCI in these cases shall be the highest level(s) of assembly directly involved with the hardness critical process that will enable clear traceability via the HCI list to the documentation of the hardness critical process in the applicable engineering drawings and the NH&S DAR. The items identified as HCI to serve this traceability function may themselves have no special hardness characteristics.

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

FIGURE D-1. **ICBM weapon system definition of HCI.**

intent. With such a definition, the task of identifying the HCIs contained within a given system is reduced to a systematic and unambiguous process. One simply turns the five HCI rationales into five questions by asking, rationale by rationale, whether a given system element satisfies the conditions stated in the rationale for any of the applicable nuclear weapon environments and effects (NWE). If the answer is affirmative for one or more of the rationales, the item under evaluation is called an HCI. This questioning review process is implemented for each and every system element in those portions of the system to which NH&S requirements apply, at every level of assembly down to the piece part level. The result is a complete HCI list for the weapon system.

40.1.1 HCI identification for hardware not originally designed to be hard. The design of a weapon system with nuclear hardness requirements may include the use of hardware items that were not originally designed to satisfy the specified hardness requirements, but were evaluated to be satisfactorily hard for the intended use after the design had been completed. This circumstance may apply both to developmental and nondevelopmental hardware items. In either case, HCI identification must be fully implemented in the same manner as would be done when hardness is intentionally incorporated in the design from its inception. Such identification will be a product of the hardness evaluation activity that will be performed for all hardware elements with hardness requirements.

40.1.2 Relationship of potential vulnerabilities to HCI identification. In addition to the use of HCI identification to flag the specific hardware and software elements that contribute to the present hardness capability of a system, such identification has also sometimes been utilized to identify ways in which new vulnerabilities (see 40.151 of appendix A) could possibly be introduced into the design at some later time because of conceivable changes in the characteristics, such as material properties, of replacements for existing system elements. This concern is not included in the approach to HCI identification followed in this standard. It is considered too open-ended and impractical to identify every way in which the present hardness of a system could conceivably be compromised at a future time. Therefore, the ICBM approach to HCI identification addresses only the hardness features actually contained in the present design. To preclude the introduction of new vulnerabilities into a system, it is vital that every proposed design change or item substitution, however seemingly minor, be reviewed for hardness impact by appropriate personnel. The need for this NH&S review function applies not only to design changes or modifications that explicitly involve currently identified HCIs, but also to proposed changes that do not appear to address HCIs. Indeed, it is by means of the latter that the greatest threat exists of inadvertently introducing new vulnerabilities.

40.1.3 Responsibility for HCI identification. The activity to identify HCIs is a technical task that requires both specialized knowledge of the various NH&S disciplines and a detailed knowledge of the weapon system design undergoing an HCI evaluation. This consideration applies most strictly to rationales 1 through 4. No personnel other than experienced NH&S experts should make judgments regarding the application of these four rationales. Once the HCIs resulting from the first four rationales are identified, it is acceptable that personnel with thorough knowledge of the system design and the associated drawing trees apply rationale 5. However, it is vital that contractor NH&S personnel be recognized as the final authority regarding HCI identification and documentation. A failure to do so can result in serious technical errors and significant added program costs.

40.2 Significance of the HCI identification process. The compilation of a complete HCI list for a given hardened weapon system is critical for the implementation of a comprehensive and effective LCH program for that system. As stated in paragraph 40.97 of Appendix A, the key concern of LCH is the preservation, throughout the production and deployment, and operation and support phases, of the hardness that was verified prior to system production to be contained in the original system design. To ensure preservation of this hardness throughout the remainder of the system life cycle, we must know the specific aspects of system design that contribute to the achievement of this required level of hardness. It is this knowledge that the complete HCI list provides. It is able to do this because the HCI rationales (at least, the first four; as will be discussed subsequently, the fifth rationale serves an important configuration management purpose) were carefully chosen to encompass in broad terms every means by which hardness can be accomplished in the design. Thus, a complete HCI list tells us where the hardness in the system resides. When we know this, we are then in a position to take the actions necessary to preserve that hardness throughout the weapon system life cycle. This, in essence, is the mandate of the program activity referred to as life cycle hardness.

40.3 Clarification of HCI rationales. As noted in 40.1 and as exhibited in figure D-1, the ICBM HCI definition consists of five explicit and independent rationales. These rationales are essentially identical with those contained in prior versions of MIL-STD-1766, except that the wording has been changed in most instances with the intent of enhancing clarity and understanding. The specific changes in wording made were chosen to address particular misunderstandings regarding HCI identification that sometimes arose during the implementation of MIL-STD-1766A on prior programs. It is believed that the present text resolves all the ambiguities reported. However, in the interest of providing additional insight and background not appropriate for inclusion in the text of a definition, further comments regarding each rationale are provided below.

40.3.1 Clarification of rationales 1-3. One immediate distinction to be made between rationales 1 and 2 as contrasted with rationale 3 is that rationales 1 and 2 both concern hardware defined as being "functionally required", whereas rationale 3 deals only with "hardness dedicated " design elements. The text of rationale 1 defines "functionally required" hardware as hardware that would continue to be included in the design even if all hardness requirements were removed. It is a phrase introduced into the HCI definition to distinguish those hardware or software elements incorporated in the design solely to serve a hardness design purpose (such elements are referred to as "hardness dedicated", and are addressed in rationale 3) from those that are used to accomplish any design purpose other than NH&S.

40.3.1.1 Clarification of rationale 1. Given that rationales 1 and 2 both concern functionally required hardware, the issue now is to identify what the difference is between them. The text of these rationales, as revised for use in MIL-STD-1766B, is essentially self-explanatory in this regard. A hardware items identified as HCI by virtue of rationale 1 must satisfy the following criteria:

a. the item is vulnerable to the applicable nuclear environment under consideration; and

b. the hardness design approach chosen for dealing with that vulnerability is to include additional provisions for hardness in some aspect of the item's procurement requirements, such as the item's specification, design, manufacture, or item selection process.

Thus the two key ideas in rationale 1 are "item vulnerability" and "additional provisions for hardness". For every item identified as a rationale 1 HCI, the following two questions must be able to be answered:

a. What is the vulnerability that the item exhibits in the applicable nuclear environment under consideration?

b. What additional provisions for hardness have been included in the item's procurement requirements, such as the item's specification, design, manufacture, or item selection process, to address that vulnerability?

A simple example of a rationale 1 HCI is a transistor that has a requirement to continue to function after exposure to neutrons of sufficient magnitude to produce observable damage. The answer to the first question above in this instance is that the vulnerability involved is a decrease in device gain caused by neutron induced damage to the semiconductor material of the device. The answer to the second question for this example typically involves additional requirements on both device specification and the item selection process. The former usually consists of a requirement for a higher magnitude of initial gain to offset the decrease in gain caused by the neutron exposure, while the latter typically involves a neutron test lot sampling requirement. It is vital that the content of the answer to the second question be appropriately and thoroughly documented in both the applicable NH&S DAR and the engineering drawings that support the procurement of the item.

40.3.1.2 Clarification of rationale 2. In contrast to rationale 1, the key idea in rationale 2 is that of the utilization of an item of hardware already existing in system design to provide hardness protection to another item or items of functionally required hardware needing such protection. Thus, items identified as HCI by virtue of rationale 2 with respect to a particular nuclear environment are:

a. not vulnerable to that environment; and

b. are used to provide protection to other system elements that are vulnerable to the environment under consideration.

Functionally required hardware designated HCI under rationale 2 may be utilized to provide this hardness protection role either "as is" or after some modification to enhance its hardness protection capability. An example of the former is the use without modification of existing hardware elements to serve as x-ray shields for buried electronics. An example of the latter is the modification of existing electrical cables to include special fill material for the purpose of reducing the magnitude of x-ray induced system generated electromagnetic pulse (SGEMP) currents that may damage sensitive electronic components downstream from the cable. Thus, for every item identified as a rationale 2 HCI, the following two questions must be able to be answered:

a. What is the nature of the protection that the item is being used to provide? The answer to this question must include identification of the nuclear environment involved and the system elements being protected.

b. What are the characteristics of the item, either "as is" or modified, that allow it to provide this protection function?

In the first example given above, the answer to the first question is that the identified system elements are being shielded against x-rays. The answer to the second question will involve identification of the thickness and atomic number of the material or materials of which the item is composed. For the second example, the answer to the first question is that some sensitive identified electronics are being protected against high currents resulting from SGEMP induced current flow in the cables. The answer to the second question is that the addition of special fill material within the body of the cable reduces air voids and thereby reduces the SGEMP induced space charge effects that cause additional unwanted currents to flow. It is vital that the content of the answer to the second question be thoroughly documented in the applicable NH&S DAR.

40.3.1.3 Clarification of rationale 3. Rationale 3 is probably the easiest of the first three rationales to understand and to apply. This rationale concerns the fact that sometimes special hardware or software elements are introduced into the design of a weapon system solely for the purpose of increasing the nuclear hardness of the design. They serve no other design purpose, and if the hardness requirements associated with the weapon system were to be deleted or voided for some reason, such hardware and software could be removed form the design without affecting any other performance characteristic or capability. Such items are referred to as "hardness dedicated", and are to be identified as HCI by virtue of rationale 3. Examples of hardness dedicated hardware are electrical surge arrestors (ESAs), shielded enclosures to protect against either x-rays or electromagnetic fields, and shock isolators. It should be noted that some of the items that are typically used for hardness dedicated protection purposes are also used to protect against other environmental concerns, such as electromagnetic interference (EMI) or lightning. In those cases where a given hardware element serves multiple purposes or concerns, including NH&S, that item shall not be identified as a rationale 3 HCI, but rather as a rationale 2 HCI.

40.3.2 Clarification of rationale 4. Rationale 4 differs from the first three rationales in that it is concerned with fabrication, manufacturing or assembly processes that contribute to achieving hardness in the design, rather than with the contribution of hardware elements per se. Such processes are referred to as "hardness critical processes (HCPs)". The concept of HCP is included within the definition of HCI to provide a means to identify, track, and preserve those aspect of the hardened design whose implementation involve hardness related processes. This approach is necessary because once an ICBM weapon system is fielded, the hardened configuration is tracked and maintained only in terms of constituent hardware elements. This activity is based on the HCI list. Therefore, the only way to ensure the preservation of the integrity of hardness critical processes throughout the system life cycle is to include them in the HCI list. The means by which this is accomplished is identified in the text of rationale 4 contained in figure D-1. Once a particular process contained in a design is identified as being hardness critical (i.e., it serves to implement a hardness design feature), the approach taken is to identify as HCI those hardware items to which the HCP is applied. As noted in the text of rationale 4, the items selected to be identified as HCI in these cases are to be the highest level(s) of assembly directly involved with the hardness critical process that will enable clear traceability via the HCI list to the documentation of the hardness critical process in the applicable engineering drawings and the NH&S DAR (see 40.108). In other words, the goal here is to "tag" the HCP for inclusion in the HCI list by identifying some associated item or items of hardware as HCI. It is because the only intent here is to tag the HCP that the text of the rationale states that "the items selected to be identified as HCI in these cases are to be the highest level(s) of assembly directly involved with the hardness critical process that will enable clear traceability via the HCI list to the documentation of the hardness critical process in the applicable engineering drawings and the NH&S DAR". To avoid unnecessarily increasing the size of the HCI list, only the "highest level(s) of assembly directly involved with the hardness critical process" need be labeled as HCI. It is important to note that the item(s) identified as HCI to serve this traceability function may themselves have no special hardness characteristics. On the one hand, they may also be HCI by virtue of one of the other rationales. On the other hand, they may never have been identified as HCI if not for their association with an HCP. Processes that often are identified as being hardness critical are surface preparation requirements, bonding and welding requirements, torquing requirements, and the application of suppression coatings.

40.3.2.1 Relationship to HCI identification of distinction between hardness critical process and hardness critical procedure. In applying rationale 4 during the HCI identification activity, it is important to be aware of the distinction made in 40.65 of appendix A between the terms "hardness critical process" and "hardness critical procedure". These are two related but different concepts that are both represented by the symbol HCP. The following quote from 40.65 of appendix A explains the difference: "A hardness critical process is any fabrication, manufacturing, or assembly activity identified on an engineering drawing that supports the implementation of a hardness design feature (see 40.69). If not performed correctly, the hardness design feature will be compromised. A hardness critical procedure is any facility (see 40.35) construction, A&CO (see 40.7), or maintenance and repair task which, if not performed correctly, will have an adverse effect on system hardness. In any specific instance, the meaning of the symbol "HCP" (whether "hardness critical process" or "hardness critical procedure") is determined from the type of documentation in which it appears." Rationale 4 is intended to apply only to the concept of "hardness critical process". Even though a hardness critical procedure, as defined above, is also represented by the symbol "HCP", hardware elements involved with such a procedure must not be identified as HCI by virtue of rationale 4. The reason for this is that whatever hardness concern may be associated with the hardness critical procedure, no new information regarding the implementation of a hardness design feature will be involved that is not already identified on an engineering drawing. Therefore, no new information about how hardness is provided for in the design will be supplied. Unnecessary HCI identification is very expensive for the DoD. Therefore, care must be taken not to unnecessarily identify items as being HCI when such actions do not serve the purposes for which such identification is performed in the first place.

40.3.3 Clarification of rationale 5. Rationale 5 differs from the first four rationales in that it is intended to serve the purposes of configuration management rather than the identification of how hardness is provided for in the design. The inclusion of rationale 5 in the HCI definition allows the tracking of system hardness from the "top down" as well as from the "bottom up"; i.e., one is then able to readily identify all locations within the weapon system where a particular part, component, or assembly that is HCI is utilized. This capability is of great value in supporting cost-effective system hardness management throughout the operations and support phase. The implementation of rationale 5 does not involve any technical challenge or uncertainty. One simply applies the direction that any assembly or subassembly that contains an HCI will also be identified as an HCI. It should be noted however, that as a result of applying this rationale many assemblies may be identified as HCI, not necessarily because there is an inherent "hardness story" associated with those particular assemblies per se, but only because somewhere within these assemblies there is an item that satisfies one or more of rationales 1 through 4.

50. HCI DOCUMENTATION AND APPLICATION

50.1 HCI list drawing. Paragraph 5.3.8.1.1 of MIL-STD-1766B requires that "the contractor shall release each WSE HCI list as a controlled drawing early in the program and shall maintain it to reflect the most current status of HCI identification throughout the entire duration of the contractor's program". Full and complete implementation of this requirement is critical to accomplishing cost-effective LCH implementation. It is vital that all the various data products associated with a weapon system in which HCIs are identified exhibit a one-to-one correspondence with respect to HCI identification. Experience indicates that the best way to accomplish this requirement is the preparation and conscientious utilization of a single authoritative source of HCI identification to support all HCI annotation and documentation activities. Although on past programs, the HCI index contained in the NH&S DAR was often used for this purpose, a careful reevaluation of the actual experience to date regarding this matter indicates that the most effective vehicle to serve as this authoritative source is, in fact, the HCI list drawing that is released and maintained as a controlled drawing.

50.1.1 Requirements for the HCI list drawing. A separate DID and CDRL will not be prepared for the HCI list drawing. Since this drawing is intended to be released and controlled in the same manner as any other engineering drawing, it is most cost-effective to procure the HCI list drawing as part of the CDRL that procures all engineering drawings. The requirements for the content and format of the HCI list drawing will be included in the tailoring of MIL-STD-100 (Engineering Drawing Practices) that is placed under contract. Section 50 of appendix C contains recommended content for that tailoring.

50.2 HCI listings and annotations. Once an HCI list drawing for a given WSE is available, the information contained in it is used to support the preparation and implementation of various HCI listings and annotations. One significant listing is the HCI index required to be included in the NH&S DAR. Explicit direction for the content and format of this listing is contained in DID DI-ENVR-80266A. Contractor NH&S personnel have the lead responsibility for the preparation of this listing. Other program documentation must also be annotated with respect to HCI identification. These include:

a. drawings;

b. master engineering document lists (MEDLs);

c. the assembly and checkout technical analysis (A&CO TA);

d. the logistics support analysis (LSA); and

e. technical orders (TOs) and other applicable procedural documentation.

Such annotations must be accomplished in accordance with the direction contained in the applicable contract compliance documentation that controls the preparation of each of these data products. Lead responsibility for accomplishing these HCI annotations rests with the separate organizations within the contractor that prepare these data products, but contractor NH&S personnel have significant support and review responsibilities, as identified in paragraphs 5.3.8.2 through 5.3.8.5 of this standard. All parties involved have the overriding responsibility to utilize the applicable HCI list drawing as the only authoritative source of information for accomplishing these annotations.

50.3 Other HCI related documentation. In addition to HCI listings and annotations (which consist primarily of the inclusion of HCI flags and other symbolic notations in different types of documentation, as required), various other kinds of substantive HCI documentation must also be implemented. These range from the detailed technical discussion of HCIs that must be included in NH&S DARs to the identification for each HCI included in a HCI list drawing of hardness related test and inspection requirements. The rationale for each of these kinds of HCI documentation can best be both understood and implemented from an understanding of the hardness purpose of each type of documentation. Once a system has been deployed, there are three main categories of activity that can impact system hardness. These are:

a. reprocurement;

b. repair and maintenance; and

c. redesign.

The identification of hardness related test and inspection requirements in engineering drawings and the associated HCI list drawing clearly supports reprocurement. If system hardness is to be preserved throughout operational life, any HCIs that are reprocured must exhibit the same or better hardness capability as the original items. This can be ensured only if the documentation used in support of reprocurement identifies required hardness related characteristics and any associated tests and inspections necessary to determine that those characteristics are, in fact, present in the items reprocured. Likewise, the inclusion of hardness related cautions and hardness related test and inspection requirements in TOs provides the means to ensure that the hardness properties of HCIs will not be compromised during repair and maintenance activities. Finally, the detailed technical discussion required to be included in the NH&S DARs provides cognizant NH&S personnel the insight necessary to support redesign or modification activities and to provide a necessary review and consultation capability with respect to reprocurement and repair and maintenance actions. Thus, it is seen that every aspect of HCI identification and documentation requirements supports in some way the preservation of system hardness throughout weapon system operational life. Each aspect is necessary, and each must be accomplished carefully, thoroughly, and in full accordance with contractual requirements.

50.3.1 Utilization of HCI documentation. It is clear from the above discussion that HCI identification and documentation serve many diverse program needs and that many communities (e.g., reprocurement, repair, TO preparation), in addition to NH&S, make use of this information, each for its own purposes. Because each such community is focused primarily on the HCI needs of its own specific area of concern, awareness of the totality of NH&S technical concerns and the ways in which other communities utilize HCI identification and documentation is sometimes lost sight of. This circumstance has occasionally resulted in attempts by members of non-NH&S communities to make independent judgments about matters relating to HCIs not fully consistent with the body of data established, reviewed, and approved by cognizant NH&S personnel. This situation must be avoided. Although each separate program community is, of course, the established authority for the responsibilities assigned to that community, the NH&S community is the only entity with the depth of understanding of hardness matters and the overview of the program wide utilization of hardness information to make appropriate judgments about the correctness and completeness of all issues related to HCIs.

BMO 90-24 Rev. A
November 1992
Supersedes BMO 90-24
August 1990

SEMICONDUCTOR PARTS
RADIATION TEST MANAGEMENT PLAN

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1.0 Introduction

1.1 Purpose

The Semiconductor Parts Radiation Test Management Plan provides an integrated reference of the radiation testing requirements for semiconductors. Government Contractors, Project Officers, Project Engineers, and Item Managers shall use this plan to avoid ambiguity regarding radiation testing required of semiconductors during Engineering & Manufacturing Development (EMD), Production, and reprocurement.

1.2 Scope

This plan discusses the radiation characterization testing, qualification testing (QUAL), and hardness assurance/lot acceptance testing (HALAT) for semiconductor parts in all phases of the life cycle for ICBM Weapon System from Demonstration & Validation, EMD, Production, and Deployment. The goal of this plan is to reduce semiconductor testing as much as possible while continuing to meet all radiation requirements. Ultimately, the goal is to make the procurement of radiation hard parts for the program as cost effective as possible.

A major building block of this plan is to allow the use of previous test data to establish the Hardness Design Margin (HDM). This practice is only acceptable under the specific terms outlined in this plan. Contractors and SPO's shall avoid using data that is unreliable or not of sufficient technical integrity to assure that adequate margins are established. Therefore, users of this document must be attentive to limits placed on the use of old data

2.0 Parts Control for Weapon System Equipment

2.1 Background

Formerly, most semiconductors parts used on ICBM weapon systems have been specially designed for that application. All semiconductors used in the missile systems (AVE & OSE) are fully characterized and qualified in specified nuclear radiation environments with a complete Hardness Assurance / Lot Acceptance Test (HALAT) program.

AVE parts have small HDMs resulting from the extreme nuclear radiation environments experienced during flight. OSE parts typically have large HDMs resulting from the low radiation level encountered launch facilities and launch control facilities. The small HDM of AVE parts require tightly controlled manufacturing processes to ensure that design hardness is properly implemented during EMD, production and reprocurement. Therefore, QUAL and HALAT requirements based on margin will inherently lead to tighter controls for AVE parts.

2.2 Equipment Categories

All equipment is either contractor furnished equipment (CFE) or government furnished equipment (GFE). CFE is either developmental or nondevelopmental. Developmental and nondevelopmental categories may be designated as commercial (COMM) or military (MIL) and as modified (M) or unmodified (U) (i.e. there are four combinations, COMM-M, COMM-U, MIL-M, and MIL-U).

2.2.1 Contractor Furnished Equipment (CFE)

This is equipment that has been specifically designed or chosen by the contractor for use on the program. Developmental items are newly designed or extensively modified to meet ICBM requirements (CFE-DI). Nondevelopmental items (CFE-NDI) may or may not meet applicable ICBM nuclear radiation requirements.

For CFE equipment, the contractor is responsible for the semiconductor parts characterization testing, QUAL testing, and HALAT. CFE used for AVE, typically used tightly controlled MIL-I-38535, Class V and S parts for reliability. The strict reliability controls helps minimize the variation in radiation induced parameter shifts. The class of parts used for OSE (mostly MIL-I-38535, Class Q or B) can exhibited wide vendor-to-vendor and lot-to-lot variations, limited process controls, and a requirement only to report process changes to the Defense Electronics Supply Center (DESC) annually. HALAT for Class Q or B parts can be more significant than Class V or S parts.

DESC has been trying to include limited radiation hardness screening in Standard Military Drawing (SMD's). The use of DESC screened parts have the potential of significant cost savings. ICBM contractors and SPOs must work with DESC to include their programs nuclear radiation requirements in DESC SMD's. When the DESC SMD nuclear environments do not completely cover the program requirements, additional nuclear hardness test requirements are documented using a Selected Item Drawing (SID).

2.2.2 Government Furnished Equipment (GFE)

This is equipment which is supplied by the government directly to the contractor. It is equipment developed for other government programs. The problems encountered with the use of non-hardened GFE is more complicated than the use of COMM because the government directs the use this hardware. Usually, this equipment is used "just as it is" i.e., unmodified (GFE-U). However, it may be necessary to implement modifications for radiation hardness reasons. When GFE is modified, this equipment must be re-identified with a new part number and may not be freely interchangeable among programs.

If the equipment was hardened to radiation requirements different than the current program, a review of its NH&S Design Analysis Report (DAR) is performed to determine whether the equipment meets the nuclear radiation requirements of the current program. This is accomplished by reviewing the NH&S DAR data to determine semiconductor parts HDMs and verifying that the parts control and testing specified in this plan have been implemented. If the GFE-U does not meet the current nuclear radiation requirements, even after use of system shielding, the contractor shall notify the SPO and recommend alternate design solutions. The SPO will decide whether to modify the GFE, substitute other GFE, or implement an alternate design solution. If the original hardening effort did not implement the proper HALAT controls, the contractor must augment the existing hardness assurance program to comply with current program requirements.

2.2.3 Commercial Equipment (COMM or COTS)

This is equipment that may be procured commercially for use in the weapon system. Parts in COMM equipment require characterization by the ASCON because there was no need to consider radiation environments when the equipment was originally designed for commercial use. The class of parts used for commercial applications have exhibited wider vendor-to-vendor and lot-to-lot variations than MIL-I-38535 Class Q or B parts resulting from nonexistent process controls and no requirement to report process changes. The choice of COMM is attractive only if the radiation levels are low enough to ensure a large HDM .

2.2.4 Military Equipment (MIL)

MIL equipment usually has an existing hardness baseline of testing and controls. MIL equipment typically requires the least effort to demonstrate hardness. If the equipment was hardened to radiation requirements different than the current program, a review of its NH&S Design Analysis Report (DAR) is performed to determine whether the equipment meets the nuclear radiation requirements of the current program. This is accomplished by reviewing the NH&S DAR to determine semiconductor parts HDM and verifying that the parts control and testing specified in this plan have been implemented. If the MIL-U does not meet the current radiation requirements, even after use of system shielding, the contractor must modify the equipment. If the original hardening effort did not implement the proper HALAT controls, the contractor must augment the existing hardness assurance program to comply with current requirements.

3.0 Radiation Test Program Structure

The test program for semiconductors is comprised of three activities. These are Characterization testing, Qualification testing (QUAL), and Hardness Assurance/Lot Acceptance Testing (HALAT). The radiation environments of interest to ICBMs are gamma dose rate [short & long pulse], total ionizing dose, and neutron fluence [1 MeV D.E.S]. Single Event Upset (SEU) phenomena may be important for some part process and design technologies.

Characterization testing provides data needed to decide if a part can meet specified nuclear radiation requirements. Because it is the basis for the scope of the whole nuclear radiation test program, it must happen early in the program. Characterization testing is almost exclusively conducted during the early part of EMD. On occasion, when a qualified supplier is no longer available, such testing is performed during reprocurement.

Qualification testing is an EMD activity conducted before production and proves that the parts used in the design are ready for production. Qualification testing may be required during reprocurement for the same reasons as noted on characterization testing above.

HALAT is performed during production and on any reprocurement.

3.1 Radiation Characterization Testing

The goal of radiation characterization testing is to determine the behavior of all critical parameters when exposed to increasing levels of simulated nuclear radiation. The less variation observed, the less required testing during production. Sample size for radiation characterization testing is usually 15. Typically, 5 samples are tested in each of three environments (dose rate, total dose, and neutron). The sample tested must represent the part used in production (i.e., same process, same configuration, etc.).

Characterization testing measures the semiconductor's electrical parameters or functional performance as they vary with radiation to determine its behavior in each of the applicable environments. Parts are exposed to increasing radiation levels until parametric or functional failure or to the limits of the simulation facility. It is essential that the radiation simulator be capable of reaching or exceeding the specified radiation levels. However, the testing does not need to continue to facility maximum if the level achieved is high enough to show that large margins exist.

It is important to distinguish between parametric and functional failures. As the radiation levels are increased, the electrical parameters for a device will begin to change. Eventually, the parameters fall outside the specified limits for that part. Each parameter will seldom change at the same rate. Therefore, a single parameter may be first to fail. Such an out-of-tolerance condition is a parametric failure. The parameter which fails may be different for different radiation environ

ments. Despite the number of out-of-tolerance parameters, the first such event is a failure.

Even when a parameter failure has occurred, the part may continue to function, it will continue to respond to changes in input conditions. As the radiation level increases higher than the parametric failure level, the device will fail to respond. This is a functional failure.

During characterization, many electrical parameters must be measured (not just a chosen few). Parameters to be monitored are a function of:

a) the complexity of the device;
b) previous radiation test data on the device; and
c) the criticality of the part application to weapon system performance.

As a minimum, devices must be monitored for input and output voltages and currents. New devices may require tens of parametric tests at many radiation levels while a diode or transistor may only need limited testing or analysis using, existing data.

Because many semiconductor parts have large lead times for procurement, it is often necessary to perform characterization using "generic" type devices. These devices must be from the same vendor(s) used in production. Such parts are usually a commercial version of the actual part or a version of the actual part which has received electrical screening tests (days of testing) but has not been subjected to all reliability testing (weeks of testing) required for the production parts. These characterization samples are adequate for characterization but do not prove that actual devices will meet the design requirements developed in the SMD/SID.

Characterization test data serves two purposes. First, the data will determine which parameters will be monitored for qualification and HALAT and establish design limits for each of those parameters which will eventually be incorporated into the End of Life (EOL) Table in the SMD or SID. Second, the data will establish the HDM. This HDM will determine the complexity of the qualification testing and HALAT required (See Tables 1 & 2). The EOL limits set the capability of the part for use by circuit designers.

Before characterization testing begins, an approved test plan is required. The test plan shall include test configurations which represent the worst case expected usage for each part. A test report is required upon completion of the characterization test. The test reports includes the reduced data (with raw data appended), and includes conclusions, recommendations, and discussions of anomalous behavior and plans for action to resolve problems.

3.2 Radiation Qualification Testing

Radiation Qualification (QUAL) testing proves the semiconductor part meets radiation requirements during and after exposure to the specified nuclear radiation environments. The complexity of the test is determined by the HDM identified during characterization.

QUAL is the final opportunity before production to prove that the actual parts used in production meet the requirements of the design. These requirements shall be documented in the SMD/SID and other associated documents. QUAL determines whether the production hardware will have a high probability of meeting the nuclear radiation requirements.

It is possible to combine characterization and QUAL testing into a single test. If the characterization test parts are from the same vendor, have large HDMs, and are the actual device types used for production, then characterization test data may serve as qualification for the part.

The sample size for QUAL is usually 22 parts with all devices being exposed to all the radiation environments in the order of dose rate, total dose, and neutron.

In contrast to characterization QUAL usually includes testing at specific radiation levels (usually two or three levels for photocurrent burnout, latch up, and surge current testing). Characterization provides information needed to decide which parameters are measured during QUAL. These will usually be a small subset of those tested in characterization and represent those parameters which vary most severely with radiation.

3.3 Hardness Assurance/Lot Acceptance Testing (HALAT)

HALAT of semiconductor parts in the specified radiation environments shows statistically that the parts bought for production meet radiation requirements. Tables 1 & 2 show that this testing may be on every lot, every other lot, or on one lot per year depending on HDM. When the HDM is very large, HALAT is eliminated.

As with QUAL, HALAT is usually comprised of testing at specific radiation levels (usually three levels for photocurrent burnout, latch up, and surge current testing). HALAT can monitor a smaller subset of parameters than was tested at QUAL. HALAT provides assurance that production parts continue to meet requirements and that design requirements are being maintained.

The sample size for HALAT is based on Lot Tolerance Percent Defective (LTPD) sampling. Requirements for QUAL are based on 90% probability with 90% confidence (22 samples with no failures) and HALAT are based on 85%probability with 90% confidence (15 samples with no failures). Although LTPD sampling usually allows larger sample sizes when failures occur, such sampling must be avoided in ICBM hardware. The reason for this is that even when parts are tested at 90/90 or 85/90 probability and confidence, such testing does not necessarily guarantee a high probability and confidence of hardness at the system level. The combination of high HDM and HALAT testing with high probability and high confidence provides assurance that system requirements are met. A single HALAT failure can lower system hardness if the parts are used in the weapon system.

It is possible initial HALAT can be accomplished during characterization testing and QUAL. If the characterization test parts are from the same vendor and are the actual device types used for production, then characterization and the determination of HDMs and EOL limits will provide enough confidence in the first production buy of the particular semiconductor part in question.

3.4 Semiconductor parts radiation testing Tradeoffs

The contractor must evaluate the semiconductor parts radiation testing to be conducted in each of the program phases described above. It may be more cost effective to have minimal parts control combined with a large amount of HALAT testing. In such a case, characterization is minimized or eliminated using previous test data. In another case, the least costly approach may be to do extensive characterization testing during EMD to show that large HDMs exist and implement a production phase which has little or no HALAT. The most likely program is somewhere between these two extremes using QUAL and HALAT requirements based on HDM.

4.0 Radiation Testing Based on Hardness Design Margin (HDM)

The concept of radiation HDM is of fundamental importance in this plan. Generally, radiation HDMs of semiconductor parts are measured by characterization testing of a sample of each part type, from each vendor, in each specified nuclear environment.

The Radiation HDM is the arithmetic mean minus three sigma of the parametric or functional failure level of the test sample divided by the specification environment (free-field or local as specified). It is the ratio of two radiation levels. The numerator is the radiation level at which failure oc

curs and the denominator is the requirement level. Unless test data shows a more appropriate distribution, a normal distribution is assumed when calculating the three sigma deviation from the mean.

$$HDM = \frac{\text{Mean Radiation Failure Level} - 3\cdot\text{sigma}}{\text{Specified Radiation Level}}$$

The correct definition of a failure level is essential to the determination of HDM. The parametric failure level is the lowest radiation level at which any parameter specified for the Device Under Test (DUT) is out-of-tolerance and a functional failure level is the lowest radiation level at which the device does not respond correctly at its outputs based on known inputs. Because there are several radiation environments (dose rate [prompt and delayed], total dose, and neutron), several parameters affected by radiation, and several failure modes (parametric, burnout, latchup, excessive photocurrent, upset, and other incorrect functions), each device may have several HDMs. The lowest HDM for each environment, is the one that determines testing required for that environment.

Table 1 provides the HALAT and QUAL test requirements as a function of HDM for commercial parts without process baseline controls . Table 2 provides the reduced HALAT and QUAL test requirements as a function of HDM for MIL-STD parts with process baseline controls.

Contractors shall consider the following as they develop hardness assurance plans based on the QUAL and HALAT requirements in Tables 1 & 2:

1. The statistical variation within a given lot,

2. The variation of radiation response over the period procurement,

3. The variation of the radiation response between vendors and lots are no wider than the HDM windows,

4. Use of worst case source and load conditions during active total dose and dose rate testing, and

5. Over testing by a factor of 3X during passive neutron tests to account for parameter annealing. Passive neutron testing is performed with out bias voltage and the post radiation parameters are measured several days after the radiation exposure

4.1 Guidelines for HALAT

Once margins are measured using radiation characterization data, required HALAT for each part can be determined using the matrices in Tables 1 & 2.

Generally, for any device which is permitted to upset and for which recovery time is not an issue, dose rate HALAT is not required to address upset or recovery time. However, dose rate HALAT should address burnout and latchup. Unless these failure modes have adequate HDM, HALAT is required by Tables 1 & 2.

As stated in note 3 of Table 1, if delivery schedules or cost is a controlling factor, qualification testing may be performed as part of HALAT on the first production lot. This option should be used with extreme caution because it increases the risk of program delays and costs incurred

TABLE 1. Radiation Test and Parts Control Requirements vs. Design Margin FOR COMMERCIAL PARTS

Design Margin Break Points	Characterization Testing 1/	Qualification Testing 2/	Hardness Assurance/Lot Acceptance Testing (HALAT) 3/
HDM≤10	• Testing or analysis to: 1) Failure ≤ 10X 2) Facility Maximum ≤ 10X 3) 10X requirement	• Qualification by test required	• Testing required for all lots 4/
10<HDM≤50	• Testing or analysis to: 1) 10X<Failure≤50X 2) 10X<Facility Maximum ≤50X 3) 50X requirement	• Qualification by test required.	• Test first production lot, then every other lot
50<HDM≤100 (Total Dose & Neutron) 50<HDM≤200 (Dose Rate)	• Testing or analysis to: 1) BPL<Failure≤BPH 2) BPL<Facility Maximum≤BPH 5/ 3) = BPH times requirement	• Qualification by test or if characterization was by test, then qualification by may be by analysis 6/	• Test first production lot, then one lot per year. 7/
100<HDM≤200 (Total Dose & Neutron) 200<HDM≤500 (Dose Rate)	• Testing or analysis to: 5/ 1) BPL<Failure≤BPH 2) BPL<Facility Maximum≤BPH 3) = BPH times requirement	• Qualification by analysis 8/	• No testing required
200<HDM≤500 (Total Dose & Neutron) 500<HDM≤1000 (Dose Rate)	• Testing or analysis to: 5/ 9/ 1) BPL<Failure≤BPH 2) BPL<Facility Maximum≤BPH 3) = BPH times requirement	• No testing required	• No testing required
HDM>500 (Total Dose & Neutron) HDM>1000 (Dose Rate)	• Testing or analysis to: 5/ 9/ 1) Failure > BPH 2) Facility Maximum > BPH 3) > BPH times requirement	NO TESTING REQUIRED	

1/ Characterization by analysis means the demonstration of radiation capability by using previous test data for the same or similar part. Use of data for similar part is subject to government approval. Data used for characterization must be for all vendors being considered for use.
2/ Requalification required after major changes affecting hardness (see MIL-STD-1546).
3/ Qualification testing on the first production lot buy can serve as the first hardness assurance lot acceptance test (HALAT).
4/ If lot-to-lot or vendor-to-vendor variability (3s) is larger than 10X or if DM ≤2X, then testing and traceability shall be at the wafer level rather than at the lot level (i.e., test samples from each wafer).
5/ BPH=The Higher Break Point and BPL= the Lower Break Point.
6/ Qualification by analysis consists of verifying that no major changes in processing or design have occurred since characterization was completed.
7/ The time between tests shall not exceed more than one year unless no lots have been purchased during that time. If date codes for any lot are separated by more than one year, then test a sample from each date code which is so separated.
8/ Qualification must be by test if characterization is by analysis.
9/ If characterization is by analysis, data must be no more than three years old.

Table 2. Reduced Radiation Test Requirements
for MIL-I-38535 QPL Class B & S or QML Class Q & V
Process Baseline Controlled Parts

MIL-STD

Class S or B
Same Vendor
Same Part Type
Date Code Within 12 mo.
Process Baseline Control

Hardness Design Margin

* 1 10 50 100 200 ->
1 5 10 30 50 ->

Gamma Rate *	1	2	3	4	N/Q
Total Dose	1	2	N/Q	N/Q	N/Q
Neutron	1	2	3	4	N/Q

Reduced HALAT Requirements

1 All procured lots
2 Lot acceptance for first, then every other lot
3 Yearly lot acceptance test or notification of process change
4 Lot Acceptance testing is not required
N/Q No Qualification/Lot Acceptance tests are required

Notes

For digital devices that are allowed to upset and the recovery time is not critical to circuit operation; dose rate upset testing is not required.

Qualification testing on first production lot buy can serve as the first HALAT resulting from a failure during QUAL / HALAT. Production cannot proceed without qualified parts. The option to QUAL at first HALAT, should only be used when characterization has been by test or with reliable data and no manufacturing process changes have occurred between characterization and the first HALAT.

Caution shall be exercised when eliminating HALAT. It is essential that any elimination of QUAL or HALAT is justified with large HDMs and those HDMs are supported with technically sound data. The parts used to establish HDMs during characterization testing must truly represent the actual parts used for production. Further, characterization test methods must also represent the actual radiation environments.

4.2 HDM Tracking

It is essential that HDMs be established early in the program and that sufficient parts control and testing be implemented in order assure that it does not drop to unacceptable levels as the weapon system program progresses. Experience has shown that HDMs tend to decrease as a weapon system progresses through its development, deployment, and operational phases.

It is necessary to establish HDMs during characterization based on data from several different lots instead of from a single lot. Concern about "slipping" HDMs is low when the HDM is large. Therefore, the contractor must evaluate how many radiation levels and parameters to test during characterization, and how many lots over what time.

Throughout the development and production, the contractor shall implement a tracking program to monitor the HDM. Each time new test data is taken, the data shall be compared to previous data to assure that a negative trend is not developing. This type of tracking requires that parts be tested at or near their capability level (or at least to the breakpoint for a given HDM window). The start of the tracking chart is based on characterization data. At QUAL, additional data will be available and plotted. Each HALAT test will provide more points for trend tracking.

5.0 Guidelines for the use of existing test data

The use of previous data must be approached with extreme caution. Generally, the best data is from the same device, from the same manufacturer, and is not old (less than 1 year to reduce the risk of manufacturing process changes). Also, it is necessary to have details of how the part was tested to assure that proper procedures were implemented. Knowledge about dose rates, fluences, doses, dosimetry, length of test, length of time between irradiation and electrical tests, bias conditions, are each important.

5.1 Similar Data Tradeoffs

HDMs based on data which do not comply to the guidelines in the previous paragraph (I.e. the same part, same vendor, 1 year, with adequate test condition data) are not really firm HDMs but indications of what the correct HDM may be. The higher the margin, the less important it is that every rule be strictly followed.

Old data can be unreliable for three reasons:

a) Manufacturer process changes can have subtle and poorly understood effects on hardness;

b) Old data documentation does not include enough information for the data to be evaluated for applicability; and

c) Radiation test methods are constantly under review and periodically changed.

5.1.1 Time Tradeoffs

If data is older than 1 year, a quantity of data over several years can compensate for the age of the data. Specifically, if the data is from a several year period and the HDM is stable over that period, then it may be safe to assume that it will remain constant in the future. If data for several years is not available, then data from several vendors may show that the device has a stable HDM.

5.1.2 Device and Manufacturer Similarity Tradeoffs

The same device rule for data can be relaxed for discrete and less complex digital devices. The same device rule is more important for dose rate and much less so for neutron and total dose. The reason for this is that neutron and total dose performance is more a function of manufacturing process and device technology while dose rate response is still very much circuit design dependent. In a case where data for the same device is not available and the part is a discrete semiconductor or a simple digital device, then data for a similar device may be substituted.

The term similar, in the context of this plan, means that the data is for a device from the same process technology at the same vendor but with a slightly different electrical function or set of parameters. Such data is sometimes also called generic data or family data. These terms are identical in this plan and are interchangeable.

Another way to compensate for similar data, but different vendor, is to get data from several vendors. If large HDMs exist between several vendors, then there is enough confidence that no matter who makes the part, it will meet the nuclear radiation requirements.

5.2 Qualification of Advanced Technology Parts

Advanced technology parts include hybrids, multi-chip modules, gate arrays, and ASIC technologies. The high cost of these advanced technology parts requires consideration of qualification using reduced sample size or by similarity due to the high cost per part and the desire to limit destructive radiation testing on these expensive parts. Qualification by similarity is allowed by MIL-STD-1766B with the approval of the contracting activity. Therefore, the following requirements are provided for qualification by similarity of advanced technology parts.

1. Parts shall be selected to represent all of the standard cells, logic array blocks, functional blocks, etc. The selected parts shall be subjected full hardness characterization / qualification testing at the part or sub-part level. Radiation prediction models shall be validated using the characterization test data. The radiation prediction models shall be used to analyze the performance of all other parts of similar technology. This analysis must show that all parts meet performance requirements during and after exposure to the specified nuclear radiation environments. The analysis shall be based on standard vector test patterns. The analysis shall include prediction of prompt ionization and long pulse upset, total dose & neutron degradation, transient recovery time, and propagation delay time.

2. A part may be "qualified by similarity" if it has:

   a. the same packaging and die size(s),
   b. the same electrical and layout design rules,
   c. the same standard cells, logic array blocks, etc.,
   d. the same (or lower) level of logic complexity (gate count, latches, macros, timing loops, etc.),
   e. the same processing steps,
   f. the same process monitor chip, and
   g. is manufactured by the same vendor.

as the parts that received the full radiation characterization / qualification testing. In addition, the overall manufacturing process shall be shown to be controlled by a quality manufacturing plan similar to the Qualified Manufacturers List (QML) described in MIL-I-38535.

6.0 Categories and Hardness Critical Items (HCIs)

The use of the matrices in Tables 1 & 2 do not imply different categories of HCI based on the different margins. Whenever HALAT or source control requirements are imposed the SMD's or SID's are marked HCI. The drawings will address the proper testing and control to be implemented. Once it is documented, the drawings will control the procurement of the part without additional HCI categories.

7.0 Acronym List

ASCON	Associate Contractor
ASIC	Application Specific Integrated Circuit
AVE	Aerospace Vehicle Equipment
CFE	Contractor Furnished Equipment
COMM	Commercial Equipment
COTS	Commercial Off-The-Shelf Equipment
DAR	Design Analysis Report
D.E.S.	Damage Equivalent Silicon
DESC	Defense Electronics Supply Center
DI	Developmental Item
DoD	Department of Defense
DUT	Device Under Test
EMD	Engineering & Manufacturing Development
EOL	End of Life
GFE	Government Furnished Equipment
HALAT	Hardness Assurance Lot Acceptance Test
HCI	Hardness Critical Item
LINAC	Linear Accelerator
LTPD	Lot Tolerance Percent Defective
MeV	Million Electron Volt
MIL	Military
NDI	Nondevelopmental Item
NH&S	Nuclear Hardness and Survivability
OSE	Operational Support Equipment
QUAL	Qualification
QML	Qualified Manufacturers List
SID	Selected Item Drawing
SPO	System Program Office
SMD	Standard Military Drawing

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