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MILITARY HANDBOOK

AIRCRAFT SURVIVABILITY

This handbook is for guidance only. Do not cite this document as a requirement.

AMSC N/A

FSC 15GP

FOREWORD

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

2. This handbook is for guidance only. This handbook cannot be cited as a requirement. If it is, the contractor does not have to comply.

3. Aircraft systems operating in nonnuclear and nuclear threat environments need realistic, well-defined and logistically supportable survivability characteristics in order to achieve their operational potential. Therefore, survivability characteristics need to be treated with the same importance as aircraft speed, payload, range and other design considerations. The cost of modern aircraft systems and the potential combat loss of operational capability through aircraft and personnel attrition mandate that survivability technologies and enhancements be incorporated at the beginning of the system program, and that the survivability design discipline be effectively implemented throughout the life cycle of the aircraft system.

This handbook provides guidance to system program offices, contracting activities and contractors for the establishment and conduct of aircraft survivability programs. It also includes guidance for the formulation and contractual specification of quantitative survivability requirements which may be tailored into statements of work, system or item specifications and contract data requirements.

The Department of Defense views this handbook as a tool requiring continual modification and improvement to increase its effectiveness and to meet changing needs. Comments and recommendations of all users are solicited to achieve this goal.

4. Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: Commander, Naval Air Warfare Center Aircraft Division, Code 414200B120-3, Highway 547, Lakehurst, NJ 08733-5100, by using the Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

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1. SCOPE

1.1 Purpose. This handbook provides guidance and criteria for establishing survivability requirements and conducting survivability plans and programs throughout the system life cycle for fixed and variable wing aircraft, helicopters and remotely-piloted vehicles. The survivability program will include a mix of threat avoidance, reconstitution and repairability, redundancy, and hardening techniques to enhance system survivability to the maximum practical extents.

1 2 Applicability. This handbook applies to combat and combat support aircraft expected to be exposed to nonnuclear (i.e., conventional, chemical, biological, and directed energy) and nuclear threat environments. It is applicable to new and existing major and supporting non-major system acquisition programs, including relevant strategic and non-strategic systems. This handbook also applies to aircraft systems designated as requiring nuclear survivability, nuclear survivability high altitude electromagnetic pulse (EMP) only, and nuclear biological chemical (NBC) contamination survivability in accordance with DoDD 4245.4, DoDD 3150.3 and DoDI 4245.13.

1.3 Application guidance. This handbook will be referenced throughout the life cycle of the applicable aircraft systems, and its application should be tailored to the specific aircraft and operational requirements. It should be used as the basis for identifying survivability program tasks and requirements to be included in statements of work, system and item specifications, and contract data requirements lists which form parts of system acquisition contracts or requests for proposal.

2. APPLICABLE DOCUMENTS

2.1 General. The documents listed below are not necessarily all of the documents referenced herein, but are the ones that are needed in order to fully understand the information provided by this handbook.

2.2 Government documents.

2.2.1 Specifications, standards, and handbooks. The following specifications, standards and handbooks form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those listed in the issue of the Department of Defense Index of Specifications and Standards (DoDISS) and supplement thereto.

SPECIFICATIONS

DEPARTMENT OF DEFENSE

MIL-H-8501	-	Helicopter Flying and Ground Handling Qualities, General Specification For
MIL-F-8785	-	Flying Qualities of Piloted Airplanes
MIL-F-83300	-	Flying Qualities of Piloted V/STOL Aircraft

STANDARDS

DEPARTMENT OF DEFENSE

MIL-STD-470	-	Maintainability Program Requirements (For Systems and Equipment)
MIL-STD-471	-	Maintainability/Verification/Demonstration/Evaluation
MIL-STD-785	-	Reliability Program for Systems and Equipment Development and Production
MIL-STD-1629	-	Procedures for Performing a Failure Mode, Effects and Criticality Analysis
MIL-STD-2089	-	Aircraft Survivability Terms

HANDBOOKS

DEPARTMENT OF DEFENSE

MIL-HDBK-268	-	Survivability Enhancement, Aircraft Conventional Weapon Threats, Design and Evaluation Guidelines
MIL-HDBK-273	-	Survivability Enhancement, Aircraft, Nuclear Weapon Threat, Design and Evaluation Guidelines
MIL-HDBK-336-1	-	Survivability, Aircraft, Nonnuclear, General Criteria - Volume 1

(Unless otherwise indicated copies of the above specifications, standards and handbooks are available from the Standardization Document Order Desk, 700 Robbins Ave., Bldg. 4D, Philadelphia, PA 19111-5094.)

2.2.2 Other Government documents, drawings and publications. The following other Government documents, drawing, and publications form a part of this document to the extent specified herein.

Directives, Instructions, and laws

DODD 4245.4	-	Acquisition of Nuclear-Survivable Systems
National Defense Authorization Act for FY 1987, Section 910	-	Testing of Certain Weapon Systems and Munitions

(Copies of DOD Directive and Instruction are available from the Standardization Document Order Desk, 700 Robbins Ave., Bldg. 4D, Philadelphia, PA 19111-5094.)

2.3 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 shall take precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

3. DEFINITIONS

3.1 Terms. A selected set of terms is set forth below for use with this standard. Other applicable definitions are listed in MIL-HDBK-2089.

3.1.1 Survivability. The capability of a system, including its crew, to avoid or withstand a hostile environment without suffering an abortive impairment of its ability to accomplish its designated mission. Survivability is achieved by reducing susceptibility and vulnerability to acceptable levels through a combination of hardness, threat avoidance, redundancy and reconstitution.

3.1.2 Susceptibility. The degree to which a system is open to effective attack due to one or more inherent weaknesses.

3.1.3 Vulnerability. The characteristics of a system which cause it to suffer a definite degradation in its capability of performing the designated mission as a result of having been subjected to a certain level of effects in a man-made threat environment.

3.1.4 Hardness. The physical capability of the system to withstand the threat environment.

3.1.5 Threat avoidance. Those measures taken so as not to encounter or experience the threat environment.

3.1.6 Redundancy. The use of multiple systems or subsystems to reduce or eliminate the probability of loss of mission critical functions as a result of anticipated or actual threat weapons effects.

3.1.7 Reconstitution. The repair, resupply, remanning or recovery of damaged or undamaged systems in time to effectively complete the mission.

4. GENERAL REQUIREMENTS

4.1 Survivability program. An effective survivability program should be established and maintained throughout the system life cycle. The program should be structured to meet system effectiveness objectives identified in documents such as the Mission-Need Statement (MNS), the System Coordinating Paper (SCP), the Decision Coordinating Paper (DCP), the Program Management Directive (PMD), the Test and Evaluation Master Plan (TEMP), the Cost and Operational Effectiveness Analysis (COEA) report and the Program Baseline. The survivability program will be planned, integrated and implemented in coordination with other system design, development, test, production, support and operational aspects of the life cycle to minimize its impact on overall program cost and schedule and to accomplish specified survivability program tasks and requirements in a cost-effective and timely manner. The contracting activity will provide threat data to the contractor in sufficient depth to allow prompt initiation of survivability program efforts. The suitability and level of detail of the survivability program will be tailored to be responsive to the system phase and schedule. Figure 1 shows major activities of the survivability program by overall program phase.

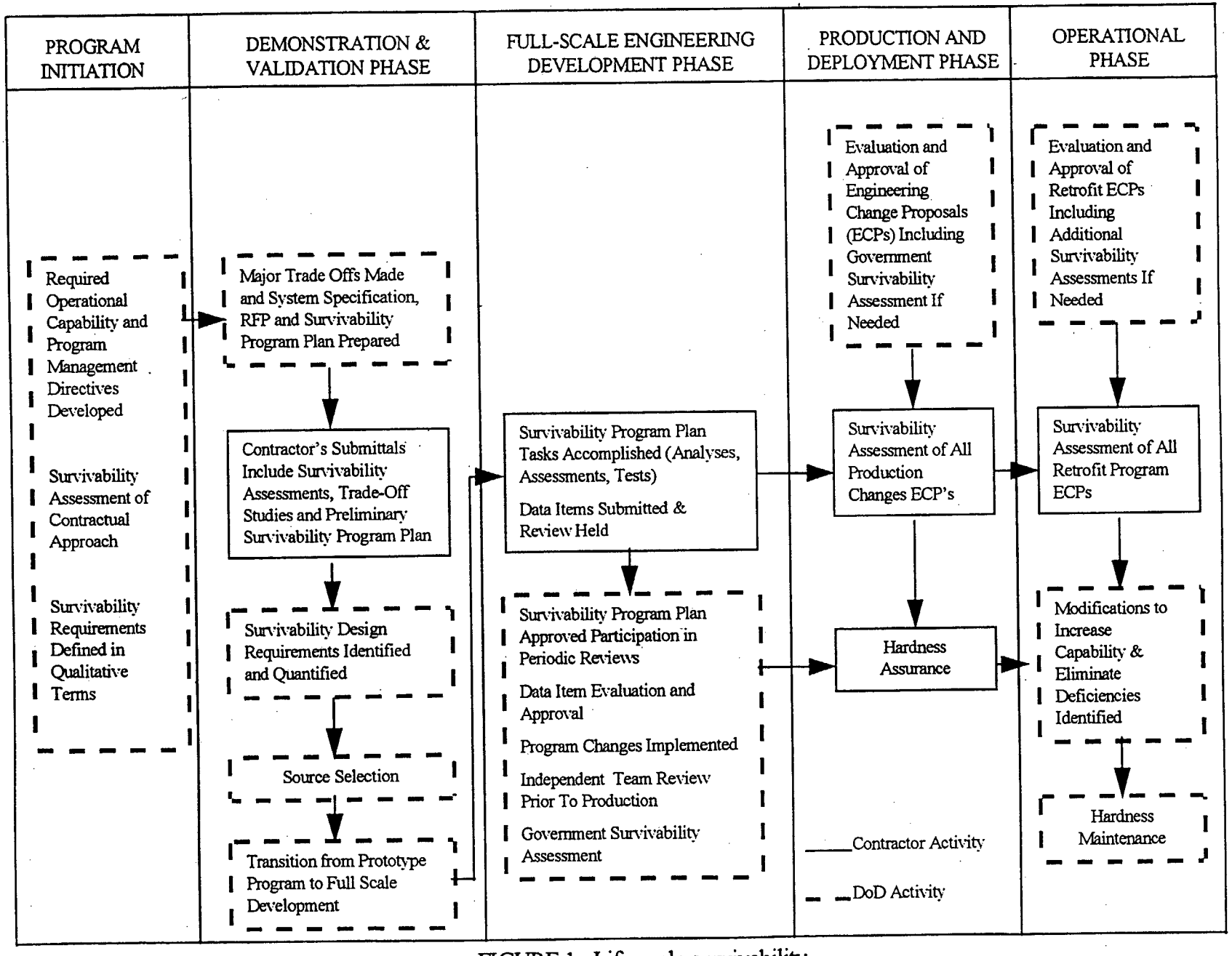

FIGURE 1. Life cycle survivability.

4.1.1 Quantitative survivability requirements. Quantitative survivability requirements for the system, major subsystem and applicable equipment should be included in the system and item specifications. System susceptibility and vulnerability requirements will be specified contractually and should be verifiable throughout the life cycle. If an aircraft system has both nonnuclear and nuclear survivability requirements, care must be taken to insure that the survivability program optimizes overall system survivability. Nonnuclear and nuclear requirements will be treated jointly in the program where possible, and separately when necessary. For the special case of nuclear hardening requirements, nuclear hardness levels will be quantified using performance and design specifications and nuclear environment criteria that are relatively insensitive to changes in operations or the nuclear threat in accordance with DoDD 4245.4. Nuclear hardness criteria will be established by the U.S. Army Nuclear and Chemical Agency (USANCA) or the Air Force Nuclear Criteria Group (NCG).

4.1.2 Requirements verification. Specifications for susceptibility and vulnerability requirements should include the method used to verify that the requirements have been satisfied. An optimum mix of analysis, simulation and testing will be a major issue in the planning and implementation of the survivability program. A clear audit trail of survivability design information and verification methods and results should be documented throughout the system life cycle to fulfill requirements for verification of survivability maintenance and surveillance capability.

4.2 Survivability program organization. The contracting activity will specify that contractor management, staffing, and organizational requirements necessary to implement and conduct the survivability program are clearly defined. The survivability organization should be integrated with all relevant design, support, production and program management activities to insure that system survivability requirements are effectively incorporated into the aircraft design.

4.3 Survivability program procedures. The contracting activity will contractually specify the establishment of procedures necessary to conduct the survivability program. These procedures will include provisions for the conduct of program tasks, incorporation of the design requirements, conduct of demonstrations and test for which the contractor is responsible, imposition and allocation of applicable survivability program requirements on subcontractors, and planning and scheduling of program reviews.

4.3.1 Program reviews. Program reviews should be planned and scheduled as specified in contractual documents and the survivability program plan to permit the contractor, subcontractor(s) and government representatives to periodically examine the status of the survivability program. There are, in general, two types of reviews: formal and informal. Formal survivability program reviews should be coordinated with and conducted at scheduled major technical design review, such as the systems requirements review, preliminary design reviews and critical design review, all of which can involve survivability issues. Less formal reviews should be conducted from time to time and can include meetings of the various working groups (e.g., threat working group, survivability working group). Which are held separately from major system reviews. The results of any informal reviews should be integrated with the formal review process. The contracting activity will contractually specify procedures for review scheduling and documentation and the distribution of review results. Survivability program review topics should include but not be limited to:

a. Schedule, status and results of analyses and trade studies.

b. Currency of threat data and encounter conditions.

c. Proposed survivability enhancement features.

d. Developmental, operational and verification test schedules and results.

e. Survivability assurance, survivability maintenance/surveillance (M/S) and design documentation programs, including hardness assurance and hardness maintenance/hardness surveillance (HM/HS).

f. Status of program funds, expenditures, allocations and contractually deliverable data.

g. Identification of action items, problem areas requiring resolution, proposed corrective actions, and responsible parties.

5. DETAILED REQUIREMENTS

5.1 Aircraft survivability, general. The survivability of an aircraft system is defined in terms of its susceptibility and vulnerability to nuclear and nonnuclear threat environments. Acceptable requirements for susceptibility and vulnerability must be achieved in the aircraft design and maintained throughout the system life cycle with the objective of enhancing system survivability to the maximum extent practical. MIL-HDBK-268 (conventional weapons), MIL-HDBK-273 (nuclear weapons) and MIL-HDBK-336 (nonnuclear weapons) contain design and evaluation guidance for aircraft survivability enhancements based on the specified threat types. Care should be taken to avoid enhancing the system's survivability characteristics in response to a given type of threat at the expense of a reduction in survivability with respect to other threat types. For the special case of nuclear vulnerability reduction, balanced hardening is desired. No critical subsystem should be more vulnerable to one nuclear weapon effect than to any other effect for the specified set of encounter conditions. For example, it is desirable to harden applicable aircraft systems such that when critical subsystems survive nuclear EMP, thermal, and ionizing radiation effects, these systems will also survive the associated blast effects.

5.2. Survivability program tasks. The survivability program should include the tasks in sections 5.2.1 through 5.2.14. These tasks are applicable to any phase of system acquisition where requirements for survivability specified, and should be tailored to the specific aircraft system and associated operational requirements. Additional details of each task regarding purpose, application guidance, tasking requirements and support information will be included in the appropriate Data Item Description (DID). The contracting activity will require full documentation to be provided and government approval to be obtained for all methodologies proposed to accomplish the following tasks.

5.2.1 Survivability program plan (Task 1). An overall system survivability program plan should be prepared and kept current to permit accomplishment of all program tasks and requirements for which the contractor is responsible. The plan will reflect a coordinated effort between the prim contractor, subcontractor(s), and involved government activities. The contracting activity will identify the DID for contractual specification of the details regarding the purpose, application guidance, tasking requirements and support information to be included in the plan. Approval of the plan by the contracting activity will be required prior to its implementation.

5.2.2 Survivability assurance program plan (Task 2). A survivability assurance program plan will be prepared and kept up to date to insure that required survivability design characteristics are preserved and maintained throughout the production, assembly, and checkout

phases. It is intended that survivability assurance program activities interface with and operate as part of the contractor's existing quality assurance program. The contracting activity will identify

the DID for contractual specification of the details regarding the purpose, application guidance, tasking requirements, and support information to be included in the plan. Approval of the plan by the contracting activity will be required prior to implementation.

5.2.3 Survivability maintenance/surveillance (M/S plan (Task 3). A survivability M/S plan should be developed to define operational and logistical support actions required to monitor, maintain, and preserve the survivability characteristics of a deployed system throughout its operational life. Survivability M/S programs are implemented during the system's operational phase by the using command and the logistic support activity. In order to have all necessary elements of the survivability M/S program in place at the start of the operational phase, these elements should be planned and documented during full-scale development and then completed during the production phase. Survivability M/S is an extension of, but not limited to, the hardness maintenance/hardness surveillance (HM/HS). M/S concepts and methods are applicable to nuclear, conventional, directed energy, and chemical and biological survivability. Pertinent survivability M/S procedures, controls, inspections, tests and relevant data will be integrated into the maintenance technical orders and referenced as appropriate in the Integrated Logistics Support (ILS) Plan. The contracting activity will identify the DID for contractual specification of the details regarding the purpose, application guidance, tasking requirements and support information to be included in the survivability M/S plan. Approval of the plan by the contracting activity will be required prior to its implementation.

5.2.4 Mission-threat encounter analysis (Task 4). An analysis should be performed to determine the nonnuclear and nuclear threats encountered during each mission and mission phase and the frequencies and geometrics of such encounters. The missions, flight profiles and threat environments will be specified by the contracting activity. An analysis of threats resulting from enemy action should be conducted for each applicable mission and/or mission phase. The analysis should be conducted as early as possible, preferably during the concept exploration and definition phase, and updated as future threat environments are identified and as more comprehensive mission and threat definitions are developed. If applicable, coordination with the appropriate agency responsible for establishing nuclear hardness criteria is essential. Results of the analysis should identify the susceptibility features of the system that determine its probability of exposure or hit by threat weapon effects. These results form the basis for required survivability assessments, tradeoff studies and design efforts. The contracting activity will identify the DID for contractual specification of the details to be included in the analysis.

5.2.5 Flight and mission critical functions analysis (FMCFA) (Task 5) A FMCFA should be conducted to determine all critical functions and related subsystems required to maintain controlled flight and to accomplish the specified mission(s). This analysis is the initial step in identifying all critical system components that, if degraded or destroyed, would result in some defined kill category of the aircraft or mission. Its objective is to identify each critical function for subsequent use in establishing priorities of protection against threat effects. Redundancies or alternate capabilities should also be identified, including degraded modes of operation which may affect safe flight, recovery or mission accomplishment. This analysis supports the failure modes, effects and criticality analysis (FMECA), and like the FMECA, is accomplished independently of threat type and effects. It should be updated as required, but cannot be iterated over too long a time before results have to become reasonable fixed in order to support subsequent analyses. The contracting activity will identify the DID for contractual specification of the details to be included in the analysis. This functional analysis is normally included as an appendix to the vulnerability analysis report.

5.2.6 Failure modes, effects and criticality analysis (FMECA) (Task 6). The FMECA is a multi-discipline (reliability, maintainability, safety, survivability, etc.) design evaluation procedure. Its purpose is to determine all possible failures of critical components or subsystems, the likely ways (modes) in which each failure can occur, the cause of each failure mode, and the effect of each failure on aircraft flight and mission capabilities. Using a systems approach, the analysis should also identify the effects of each failure on other subsystems. These secondary effects might not be evident if each critical component is considered independently. For example, if one or more engines on a multi-engine aircraft fails, maximum speed and altitude capabilities will be affected. In addition , flight control and handling characteristics may be degraded due to asymmetric thrust. However, loss of an engine or engines can also affect electrical and hydraulic subsystems that may be critical to safe flight or mission accomplishment. The criticality of each possible failure will be ranked according to hazard levels ranging from no significant loss of capability to failures that result in imminent loss of the aircraft. The FMECA is performed independently of threat type and weapon effects, but forms the primary basis for the Damage Modes and Effects Analysis, which is threat-dependent. The FMECA process, procedures, requirements and format are defined in MIL-STD-1629 and MIL-STD-785. The contracting activity will identify the DID for contractual specification of the details to be included in the analysis. The FMECA may be included as an appendix to the vulnerability analysis report, or may be a separate submittal, as required by the contracting activity.

5.2.7 Damage modes and effects analysis (DMEA) (Task 7). The DMEA. Including crew essential functions, is threat-dependent. It associates the failures identified in the FMECA with the ability of primary and secondary threat weapon effects to cause such failures. The DMEA quantifies the response of each critical component to the threat weapon effects and determines what impact, if any, this response has on other subsystems or components. It also determines if a hazardous environment can be created when a noncritical component is subjected to the type and level of damage specified. The DMEA is a prerequisite for a vulnerability analysis and a separate DMEA will be performed for each specified threat category. Weapon effects to which a component may be exposed can typically be categorized under one or more of the following:

a. Conventional weapons — penetration, kinetic energy (impact), ignition, blast.

b. Nuclear weapons — blast (overpressure and gust), thermal radiation, initial and residual ionizing radiation, electromagnetic pulse, dust and debris.

c. Directed energy weapons — burnthrough, rapid heating, ignition, thermal shock, stress, electronics overload and E-O sensor disabling.

d. Chemical and biological weapons — toxicity, infection, material deterioration and latent desorption.

The contracting activity will identify: (1) the threat categories to be used in the analysis, (2) the results of previous analyses (e.g., mission-threat encounter analysis, FMCFA, FMECA) to be used as source data for the DMEA, and (3) the DID for contractual specification of the details to be included in the analysis. The DMEA will normally be included as an appendix to the vulnerability analysis report.

5.2.7.1 Conditional probability of kill (P_K) functions. The DMEA develops data which relate vulnerability to the threat weapon effects. It provides these data in a format required for calculation of vulnerability indices, which are measures of the system's response to the threat that are quantified as part of the vulnerability analysis. A key step in the DMEA process required for

the subsequent calculation of some vulnerability indices is the generation of conditional P_K functions for the system's components. (Conditional P_K functions are also used to calculate the system's probability of survival, P_S, as part of the survivability analysis.) These functions quantify the degradation of component functional capability and are defined in relation to the specified threat weapon effect; e.g., probability of kill given a hit ($P_{K/H}$) to blast (conventional or nuclear), thermal, ionizing or electromagnetic radiation, or chemical and biological contamination. Some conditional P_K functions are based on impact energy and are relatively simple. Others, based on the exposure to nuclear, chemical or biological weapons effects, or secondary fuel fires from either nonnuclear or nuclear weapons, are more complex. For example, $P_{K/H}$ may be graphically represented as a simple function of projectile mass and impact velocity when the treat mechanism is an anti-aircraft artillery round. However, if the threat is a nuclear weapon, $P_{K/E}$ may be a more complex function of weapon yield, overpressure, dynamic pressure, and positive phase duration. Therefore, close coordination with the contracting activity and its supporting survivability organization should be maintained when developing conditional P_K functions. The contracting activity will require the contractor to provide full documentation of the source of the derived functions. Any functions developed during the DMEA that differ from those specified and provided by the government will require contracting activity approval.

5.2.8 Computerized target description (Task 8). A computerized target description of the aircraft should be developed, documented and approved for use as an input to nonnuclear and nuclear vulnerability analysis models. The target description model allows rapid computations to be made which identify the ability of each threat weapon effect to affect each critical component. This digitized geometric model will include the dimensions, shapes, thickness and material compositions of internal and external critical components to be used in the calculation of vulnerability indices. The required level of complexity and sophistication of the target description model will be determined by the contracting activity based on the availability of system design details for the acquisition phase of interest. The target description model used should be compatible with the specified type of computer. Current examples of existing target description models appropriate for use are listed in appendix A. The contracting activity will identify the DID for contractual specification of the details regarding the computerized target description.

5.2.9 Aircraft vulnerability analysis (Task 9). A vulnerability analysis should be performed and documented for each applicable aircraft configuration and threat type. The analysis should be updated during design, development and production and will ultimately include the operational configurations of the aircraft. The methodology used must be such that updated vulnerability analyses required by changes in mission, tactics, threat and aircraft configuration can be conducted throughout the operational life of the aircraft. A sample of computer models for potential use in the analysis is listed in appendix A. The objective of the vulnerability analysis is to identify weaknesses or deficiencies of the aircraft system when exposed to threat weapon effects and to provide quantified measures of vulnerability (Vulnerability indices) for specified threats. Results of this analysis are used in trade studies and design analyses to evaluate the effectiveness of potential hardening techniques, and are also used as an input to survivability analyses. The contracting activity will identify the DID for contractual specification of the details to be included in the vulnerability analysis. In addition to the threat effects, FMCFA, FMECA, DMEA, and target description, the vulnerability analysis includes a calculation of vulnerability indices which is discussed in the following subsections.

5.2.9.1 Nonnuclear vulnerability analyses. Commonly used nonnuclear vulnerability indices include vulnerable area and blast kill envelopes. Vulnerable area (A_V) is a measure of the ballistic vulnerability of a target or target element to impact, penetration or perforation by projectiles or fragments. It is expressed in square feet or square meters and is defined as the

product of the effective presented area (A_{PE}) of a component, as projected in a plane normal to the trajectory of the weapon, and the average probability of kill given a hit ($P_{K/H}$) on this presented area. That is, $A_V = A_{PE} \times P_{K/H}$ of the component or system. Vulnerable area may be an appropriate vulnerability index for directed energy and chemical or biological weapons, or other measures may be used, subject to approval of the contracting activity. For projectile warheads detonating external to a target, blast kill envelopes are applicable vulnerability indices. The kill criterion is based on a threshold level above which lethal blast damage is assumed, and the envelope depicts the burst distance from the target for which this threshold value applies. The shapes of the envelopes are based on the warhead charge weight and the encounter altitude for various target orientations.

5.2.9.2 Nuclear vulnerability analyses. Envelopes (contours) are the most commonly used nuclear vulnerability index. These envelopes are normally provided for: appropriate values of weapon yield; burst and target altitudes; aircraft speed, orientation, and configuration; and atmospheric conditions. Envelopes are generated for each weapon effect of concern (e.g., blast, ionizing radiation, thermal radiation, EMP) and each specified kill level (e.g., sure-safe, mission abort, sure-kill). The envelopes can be centered on the burst or on the target, but target centered envelopes are used most frequently. Such envelopes depict the target burst point separation distance at the time of detonation which would produce the specified level of aircraft damage.

5.2.10 Susceptibility analysis (Task 10). A susceptibility analysis should be performed and documented for each applicable aircraft configuration and threat type. Based on the results of Task 4, Mission-threat encounter analysis, applicable threats and associated characteristics will be defined, and aircraft susceptibility parameters will be analyzed for input to subsequent survivability analyses. The analysis will be updated during design, development, and production and will ultimately include the operational configurations of the aircraft. The methodology used should be such that updated susceptibility analyses required by changes in mission, tactics, threat, and aircraft configuration can be conducted throughout the operational life of the aircraft. The parameters analyzed should include consideration for all postulated threat characteristics for acquisition, identification, lock-on, track, launch, guidance, and fusing (of detonating warheads). These parameters should be analyzed for applicable aircraft flight profile conditions of altitude, speed, power setting, external stores carriage, and unique weapon delivery maneuvering and should include detectables (as applicable) enumerated in paragraph 5.3.1.1, and threat avoidance/suppression capabilities (as applicable) enumerated in paragraph 5.3.1.2. A sample of computer models for potential use in the analysis is listed in the appendix A. Results of this analysis are used in trade studies and design analyses to evaluate the effectiveness of potential susceptibility control techniques and as input to survivability analyses. The contracting activity will identify the DID for contractual specification of the details to be included in the susceptibility analysis.

5.2.11 Survivability analysis (Task 11). A survivability analysis should be performed to estimate the probability of survival (P_S) of the system for the specified mission-threat encounter conditions. It should be periodically updated over the system's life cycle as the mission, tactics, threat, scenarios and aircraft configuration change. In its most basic form, the aircraft's probability of survival is equal to one minus the probability of kill $P_s = (1-P_K)$. P_K is based on probability of detection (P_D), probability of hit or exposure to a specified weapons effect if detected ($P_{H/D}$ or $P_{E/D}$), and probability of kill if hit or exposed ($P_{K/H}$ or $P_{K/E}$); that is $P_s = 1 - (P_D \times P_{H/D} \times P_{K/H})$ for nonnuclear weapons such as anti-aircraft rounds, and $P_s = 1 - (P_D \times P_{E/D} \times P_{K/E})$ for nuclear weapon effects such as blast. P_D. and $P_{h/D}$ or $P_{E/D}$, are the susceptibility characteristics of the system. $P_{K/H}$ or $P_{K/E}$ is the aircraft's vulnerability characteristic. Probability of survival is maximized by minimizing the product of the susceptibility and vulnerability terms. An iterative survivability analysis provides a means of

defining an optimum mix of design characteristics to achieve low susceptibility and low vulnerability. The contracting activity will specify the level of analysis to be performed (e.g., one-on-one, few-on-few, campaign, base escape, etc.), and the associated threats, targets, aircraft flight conditions, weapon carried, tactics, support system (e.g., AWACS, Wild Weasel) and delivery profiles. The survivability analysis should be based on the results of the mission-threat encounter and vulnerability analyses. The contracting activity will also identify the DID for contractual specification of the details to be included in the survivability analysis, and approve the computer models and methodology to be used. A sample of computer models for potential use in the analysis is listed in appendix A.

5.2.12 Survivability enhancement trade studies (Task 12). Trade studies should be performed to evaluate alternative survivability enhancement techniques useful at the system or subsystem level. Based on analytical methods, computer models and measures of effectiveness approved by the contracting activity, study results will be used to select the most effective techniques to achieve the specified levels of susceptibility and vulnerability. One or more factors or parameters (e.g., threat, mission, tactics, performance, threat avoidance, hardness, etc.) will be varied to identify the effects on system survivability and combat effectiveness. The study should be based on some previous baseline analysis in order to establish the survivability payoffs or penalties associated with each factor or parameter variation under consideration. The trade study should analyze the impacts of these variations on aircraft weight, performance, cost, schedule, safety, reliability, maintainability, etc. It should be supported by appropriate life cycle cost analyses. These and other analyses supporting the results (decision rationale) should be included, as appropriate, in the COEA report. The timing of trade studies is critical and they should be conducted such that their results can be used to help establish design requirements. If testing is necessary to verify survivability enhancements, it should be included as part of the trade study. The contracting activity will identify the DID for contractual specification of the details to be included in the trade studies.

5.2.13 Combat damage repair analysis (Task 13). An analysis should be performed to develop and evaluate concepts, criteria, procedures and time estimates for rapid repair of nonlethal combat damage caused by nonnuclear and nuclear threats, including NBC contamination. The analytical emphasis will be on simple and rapid repair of system components under combat conditions, especially at forward operating locations. The analysis should determine:

a. Acceptable levels of degraded system and subsystem performance applicable to unrestricted, limited life and one-time flight repairs.

b. Ground rules for component repair (e.g., remove and replace, repair deferment, type of damage repairable at various maintenance levels, etc.).

c. If system redesign, or changes in personnel or support equipment, would allow field repairs of subsystems.

d. Repair time estimates and procedures under all specified conditions (including NBC contamination) for inclusion in applicable maintenance and repair technical orders.

e. Spares, long lead time items and material storage requirements.

f. Support facility and equipment requirements, including special tools, clothing and other resources for War Readiness Spares Kits.

g. Personnel and training requirements for combat damage repair operations.

The contracting activity will specify the extent to which the maintainability program requirements in MIL-STD-470 and MIL-STD-471 apply, and will identify the DID for contractual specification of the details to be included in the analysis.

5.2.14 Survivability design documentation (Task 14). All survivability design features, including associated analyses, trade studies, methodologies, test results and data bases, should be fully documented. The documentation should start in the development phase and should be updated as necessary to provide a clear audit trail throughout the system's life cycle. Survivability design documentation (SDD) is an extension of hardness assurance design documentation (HADD), which is a documentation method used for systems having nuclear hardness requirements. SDD is intended to provide documentation for all areas of survivability and is not limited to nuclear survivability documentation. The SDD, like the HADD, serves as a primary data base for development of survivability assurance, maintenance and surveillance programs, for the preparation of operational and maintenance technical orders, and for follow-on support of other activities involving system survivability. Once all revisions and updates have been completed, the SDD represents a final report of the total system survivability program effort. The contracting activity will identify the DID for contractual specification of the details to be included in the survivability design documentation.

5.3 System survivability requirements. This section identifies and describes basic survivability requirements for inclusion in system and end item specification, requests for proposal (RFP), statements of work (SOW), contract data requirements lists (CDRL) and other contractual documents. The formulation of these requirements is dependent on the system program phase and on the availability of analytical results upon which to base requirements. For the concept exploration/definition or other pre-full-scale development phases, this paragraph and those that follow provide a basis for identifying effective solutions for system survivability in a combat environment; i.e., what quantitative susceptibility and vulnerability requirements should be generated for the system and critical subsystems. The design analyses and trade studies previously described may be used as appropriate to aid in the development of these requirements. For the full-scale development and later phases, the survivability requirements should be in the form of signature levels, countermeasures capabilities, threat effects tolerance levels and other criteria that are achievable, cost-effective and measurable. If it is necessary to enter full-scale development without sufficient information to specify quantitative requirements, design studies and trades will be contractually required to derive appropriate requirements. It is essential that requirements be realistically formulated and stated in ways that make them meaningful to the designer, permit freedom of design choices, and allow them to be contractually met and verified. The following paragraphs identify the subject areas for which specification of survivability requirements is applicable and provide guidance for the formulation of the requirements.

5.3.1 Susceptibility (Requirement 1). Based on results of mission-threat analyses, survivability trade studies and tests, the contracting activity will establish design and configuration requirements that specify acceptable levels the probabilities of aircraft detection, encounter or damage by the specified threat systems. Detection avoidance and threat avoidance/suppression specifications will be quantified and become part of the contractual requirements.

5.3.1.1 Detection avoidance. Aircraft signature levels should limit detection of the aircraft to the extent specified for each threat and signature combination, encounter condition and aircraft operational environment and configuration. Detection avoidance specifications should include the following detectables as applicable to system, subsystem and armament components:

a. Radar

b. Infrared

c. Visual

d. Aural

e. Ultraviolet

f. Electromagnetic emissions

g. Radiation emissions from nuclear ordnance

h. Laser radar

i. Laser vibration sensor

5.3.1.2 Threat avoidance and suppression. On-board threat warning and active and passive countermeasure and counter-countermeasure capabilities should negate or degrade threat system capabilities to the extent specified. Threat avoidance and suppression specifications should include the following:

a. Identification of specific equipment for on-board threat warning, detection of nuclear and laser radiation and chemical or biological contamination, and ECM/ECCM; and flares, chaff, decoys and lethal defense capabilities.

b. Identification of appropriate tactics, maneuvers, and aircraft performance parameters.

5.3.2 Vulnerability (Requirement 2). The contracting activity will establish design and configuration requirements that provide safe flight and recovery capability of the aircraft, and what maximize the probability of mission completion, after exposure to the specified encounter conditions. The aircraft's handling characteristics for safe flight after sustaining damage from nonnuclear or nuclear threats should meet the requirements in MIL-H-8501 for helicopters, or should be no less than Level Three as defined by MIL-F-8785 for fixed-wing aircraft and MIL-F-83300 for V/STOL aircraft. Secondary thermal effects caused by the threat (e.g., burning fuel, fire caused by engine damage, nuclear thermal radiation effects on crew members, etc.) should be prevented or contained in all critical subsystems of the aircraft where failure do so would cause loss of the aircraft. The contracting activity will require:

a. Arrangement of the design configuration that obtains the highest possible practical level of hardening protection with the least penalty (e.g., cost, weight, reduction in aircraft performance, etc.).

b. Inclusion of detailed requirements for specified levels of vulnerability for each critical aircraft subsystem (e.g., structure, crew station, fuel and propulsion systems, etc.) in the system and item specifications.

c. Specification of battle damage repairability requirements.

5.3.3 Verification and demonstration (Requirement 3). For each survivability-related requirement in the system or subsystem design specification, a corresponding Quality Assurance (QA) requirement should also be provided in the specification. The purpose of the QA requirements is to establish the methods and criteria (e.g., pass or fail) by which required levels of susceptibility and vulnerability and battle damage repairability can be verified or demonstrated. The contracting activity will specify the mix of analysis, test, and inspection that will be used by the contractor to satisfy verification and demonstration requirements. All methodology and results will be fully documented. A detailed test plan should be prepared for those items requiring testing for verification or demonstration of compliance with the stated requirements. The system TEMP should address nonnuclear and nuclear survivability issues as appropriate, and should reference verification and demonstration test plans as required. Systems with conventional weapon survivability requirement should comply with the 1987 National Defense Authorization Act, which states that major systems may not proceed beyond low-rate initial production until realistic survivability testing is accomplished. For systems with nuclear weapon effects survivability requirements satisfaction of nuclear survivability criteria should be determined in preparation for Milestone III in accordance with DoDD 4245.4.

6. NOTES

6.1 Intended use. This handbook provides guidance and criteria for establishing nonnuclear and nuclear survivability requirements and conducting survivability programs for aircraft systems.

6.2 Subject term (key word) listing.

Data Item Descriptions
Requirements, survivability
Survivability, aircraft
Survivability assurance
Survivability, nonnuclear
Survivability, nuclear
Survivability program
Susceptibility, aircraft
Vulnerability, aircraft

6.3 Changes from previous issue. Marginal notations are not used in this revision to identify changes with respect to the previous issue. The changes involve conversion to a Military Handbook and compliance with the Department of Defense specification and standards reform.

RELATED PUBLICATIONS AND INFORMATION

A.1 SCOPE

A.1.1 Scope. This Appendix is for information only. The documents listed herein are intended for additional guidance and may be useful in the application of this handbook.

A.2 APPLICABLE DOCUMENTS

SPECIFICATIONS

DEPARTMENT OF DEFENSE

MIL-E-6051	-	Electromagnetic Compatibility Requirements, System

STANDARDS

DEPARTMENT OF DEFENSE

DOD-STD-480	-	Configuration Control - Engineering Changes, Deviation, and Waivers
DOD-STD-1766	-	Nuclear Hardness and Survivability Program Requirements for ICBM Weapon System
DOD-STD-2169	-	High Altitude Electromagnetic Pulse (HEMP) Environment
MIL-STD-461	-	Electromagnetic Emission and Susceptibility Requirements for the Control of Electromagnetic Interference
MIL-STD-462	-	Electromagnetic Interference Characteristics, Measurement of
MIL-STD-882	-	Subsystems and Equipment; General Requirements for
MIL-STD-965	-	Nonstandard (Unauthorized) Parts, Materials, and Processes
MIL-STD-1388-1	-	Logistic Support Analysis
MIL-STD-1472	-	Human Engineering Design Criteria for Military Systems, Equipment, and Facilities
MIL-STD-1799	-	Aeronautical Systems Survivability (For Combat Mission Effectiveness (Required For Issue Other Than DoD Must Be Sent Via ASD/ENES, Wright-Patterson AFB, OH 45433-6503)

HANDBOOKS

DEPARTMENT OF DEFENSE

MIL-HDBK-221	-	Fire Protection Design Handbook for U.S. Navy Aircraft Powered by Turbine Engines

DEFENSE NUCLEAR AGENCY

DNA 1420	-	TREE (Transient Radiation Effects on Electronics) Handbook 1 & 2

DNA 2048	-	Handbook for Analysis of Nuclear Weapon Effects on Aircraft
DNA 2114	-	EMP (Electromagnetic Pulse) Handbooks (Volumes 1 through 6)
DNA 6500	-	Nuclear Warhead Modeling Handbook

Directive, Instructions, and Regulations

DODI 4245.13	-	Design and Acquisition of NBC Contamination Survivable Systems
DODD 5000.1	-	Major and Non-Major Defense Acquisition Programs
DODI 5000.2	-	Defense Acquisition Program Procedures
DODD 5000.3	-	Test and Evaluation
DODD 5000.39	-	Acquisition and Management of Integrated Logistics Support for System and Equipments
DODD 5000.43	-	Acquisition Streamlining

Air Force Regulations

AFR 65-3	-	Configuration Management
AFR 80-38	-	Management of the Air Force Systems Survivability Program
AFR 800-3	-	Engineering for Defense Systems
AFR 800-8	-	Integrated Logistics Support (ILS) Program

Army Regulations

AR 70-60	-	Nuclear Survivability of Army Material
AR 70-71	-	Nuclear, Biological, and Chemical Contamination Survivability of Army Material

Navy Directives

NAVMATINST	-	Naval Material Command Nuclear Survivability Program 3401.1
NAVMATINST	-	Combat Survivability of Naval Weapon Systems 3900.16
OPNAVINST	-	Nuclear Survivability of Navy and Marine Corps Systems 3401.3
SECNAVINST	-	Design and Acquisition of NBC Contamination Survivable 3400.2 Systems

Documents

JSC Pub. 1	-	Department of Defense Dictionary of Military and Associated Terms
DoD/DoE	-	The Effects of Nuclear Weapons
DNA EM-1	-	Capabilities of Nuclear Weapons
DNA 2028	-	TREE Preferred Procedures (Selected Electronic Parts)

DNA 6509	-	Strategic Aircraft Systems - Nuclear Hardness Maintenance /Surveillance Program Management Manual
DNA-TR-85-30	-	Proposed Nuclear Survivability Program Requirements
DASIAC-5R-219	-	Program Manager's Guide to Simulation Facilities for Nuclear Hardness Validation
HDL-TR-1882-1	-	Nuclear Weapons Effects on Army Tactical Systems, Vol. 1, Overview
AFWL-TR-86-26	-	Guidelines to Hardness Assurance for Nuclear Radiation, Blast and Thermal Effects in Systems with Moderate Requirements (replaces AFWL-TR-76-147)
NAVAIR 00-25-524		Guide to the Reduction of Aircraft Vulnerability Quadripartite Standardization Agreement 244 - Nuclear Survivability Criteria for Military Equipment

A.3 COMPUTER MODEL INFORMATION

A.3.1 Sample Computer Models, Assessment Methodologies, and Data Bases.

a. Target Description Models

Conventional Weapons Effects Analyses	SHOTGEN FASTGEN MAGIC GIFT
Nuclear Weapons Effects Analyses	NASTRAN ASTROS

b. Vulnerability Assessment Models, Methodologies

Conventional Weapons

Aircraft Vulnerable Areas	VAREA COVART QRV HEIVAM HEVART
Antiaircraft Artillery	P001 FIRE ANALYZER
Proximity-fuzzed projectiles and missiles	ATTACK REFMOD
Air Defense Effectiveness and Surface-to-Air Missiles	EVADE II E-SAMS MICE

		SAMSIM FIRE ANALYZER TAC ZINGER
Flight Path and Weapon Delivery Profiles		BLUE MAX FLYGEN
End Game Analysis	BETA	
		MECA SCAN SESTEM JSEM AMEGS WHDEVAL SHAZAM ATTACK
Battle Damage Repair		COVART REPAIR
Surface to Air Attrition		SORTIE
Nuclear Weapons		
Aircraft Response to Nuclear Overpressure		NOVA-A
Gust Effects on Aircraft		VIBRA-8
Aircraft Response to Nuclear Weapon Thermal Radiation		TRAP
Laser Weapons		
LV Methodology and Code Users Manual, BRL Report 1779		
Target Vulnerability Analysis, AFWL-TR-73-197		

c. Detection Analysis models

Radar	ALARM
Infrared	ASDIR
Countermeasures	TEM
Visual	SEARCH

d. Survivability Analysis Models

One vs. One Air-to Air Engagements	ENGAGE

Few vs. Few Engagements	
Air-to-Air	TAC BRAWLER ASSPEM PACAM MULTAC
Air-to-Surface	TAC REPELLER TAC SUPPRESSOR
Airbase Attack	AAP TSARINA TSAR
Base Escape	QUANTA
Sortie Generation	SORTY 30 TSAR
Campaign Level Engagements	
Strategic Forces	APM ACE SPEED II
Tactical Forces	TAC THUNDER TAC COMMANDER TAC WARRIOR TAC GLADIATOR TAGSEM MTOM MPIRE

e. Data Bases

	Data Base or Agency
Conventional Weapons Test and Combat Damage Data; Computer Models; Laser Test Data	SURVIAC (Wright-Patterson AFB, Ohio)
Nuclear Weapons Effects and Models	DASIAC (Kaman-Tempo, Santa Barbara, CA)
Chemical Warfare Testing and Effects	USANCA (Springfield, VA) USAF TAWC (Eglin AFB, FL)

CONCLUDING MATERIAL

Custodians:
Navy - AS
Army - AV
Air Force - 11

Preparing activity:
Navy - AS
(Project 15GP-0005)