APPENDIX O

AIRWORTHINESS
QUALIFICATION REQUIREMENTS

AIRCRAFT COMBAT
SURVIVEABILITY

DISTRIBUTION STATEMENT A. Approved for public release. Distribution is unlimited.
APPENDIX O

FOREWORD

1. This handbook is approved for use by the U.S. Army Combat Capabilities Development Command Aviation & Missile Center (CCDC AvMC) and is available for use by all Departments and Agencies of the Department of Defense (DoD).

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. This handbook provides guidance for the Army aircraft combat survivability program requirements for new rotary wing design and modernization of existing design. This revision includes update of the DoD/Army aviation survivability program policy and program requirements since the 1987 standard revision, including the need to coordinate with the congressionally mandated Live Fire Test and Evaluation (LFT&E) Program. The handbook describes the overall survivability program and presents a focus on analysis and test requirements for aircraft vulnerability hardening requirements to withstand ballistic, directed energy, nuclear, and Nuclear Biological Chemical (NBC) threats. The handbook also includes aircraft crashworthiness requirements that enable occupants to survive in the event an aircraft is forced down. This revision also includes format changes to comply with MIL-STD-967, Department of Defense Standard Practice for Defense Handbooks Format and Content.

4. Technical questions may be addressed to the following office:

U.S. Army Combat Capabilities Development Command
Aviation & Missile Center
Redstone Arsenal, AL 35898-5000
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1. SCOPE

1.1 Scope. This handbook provides guidance for Army aircraft combat survivability (hereafter “survivability”) program requirements for new rotary wing design and modernization of existing design. It describes the overall survivability program and presents a focus on analysis and test requirements for aircraft vulnerability or hardening/damage tolerance requirements to withstand ballistic, directed energy, nuclear, and Nuclear Biological Chemical (NBC) threats. The handbook also includes guidance for aircraft crashworthiness requirements that enable occupants to survive in the event an aircraft is forced down.

1.2 Applicability. This handbook provides guidance for those survivability program activities conducted during Engineering and Manufacturing Development (EMD) and product improvement which define the survivability characteristics of the air vehicle. It should be used as guidance for identifying program tasks and requirements to be included in system specifications, Request for Proposal (RFP), statements of work, and other survivability program documents. It may also be used to develop and establish the guidelines and trade-offs for design selection criteria for the optimum system. This handbook is for guidance only and cannot be cited as a requirement.

2. APPLICABLE DOCUMENTS

2.1 General. The documents listed below are not necessarily all of the documents referenced herein, but are those needed to 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.

<table>
<thead>
<tr>
<th>Document</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>JSSG-2009</td>
<td>Air Vehicle Subsystems, Joint Service Specification Guide</td>
</tr>
<tr>
<td>JSSG-2010-7</td>
<td>Crew Systems, Crash Protection Handbook</td>
</tr>
<tr>
<td>JTCG/AS-01</td>
<td>Aerospace Systems Survivability Handbook Series,</td>
</tr>
<tr>
<td></td>
<td>Volume 1: Handbook Overview</td>
</tr>
<tr>
<td></td>
<td>Volume 2: Survivability and Acquisition</td>
</tr>
<tr>
<td></td>
<td>Volume 3: The Survivability Program Plan</td>
</tr>
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<td></td>
<td>Volume 4: Survivability Engineering</td>
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<tr>
<td></td>
<td>Volume 5: Survivability Models and Simulation</td>
</tr>
<tr>
<td></td>
<td>Volume 6: Survivability Test and Evaluation</td>
</tr>
<tr>
<td></td>
<td>Volume 7: Vulnerability Analysis</td>
</tr>
<tr>
<td></td>
<td>Volume 8: Susceptibility Analysis</td>
</tr>
</tbody>
</table>
Volume 9: Lethality Evaluation
Volume 10: Survivability Assessment
Volume 11: Electronic Warfare/Electronic Combat Evaluation
Volume 12: Threat and Targets

MIL-DTL-7905 Cylinders, Steel, Compressed Gas, Non-Shatterable, Seamless, 1800 PSI and 2100 PSI
MIL-DTL-27422 Tank, Fuel, Crash Resistant, Ballistic Tolerant, Aircraft
MIL-DTL-83796 Hose Assembly, Rubber, Lightweight, Field Attachable End Fittings
MIL-R-8236 Reel, Shoulder Harness, Inertia Lock
MIL-S-85510 Seats, Helicopter Cabin, Crashworthy, General Specification For
MIL-STD-464 Electromagnetic Environmental Effects Requirements for Systems
MIL-STD-662 V50 Ballistic Test of Armor, Department of Defense Test Method Standard
MIL-STD-704 Aircraft Electric Power Characteristics, Department of Defense Interface Standard
MIL-STD-810 Environmental Engineering Considerations and Laboratory Tests
MIL-STD-1290A(AV) Light Fixed and Rotary Wing Aircraft Crash Resistance
MIL-HDBK-336/1 Survivability, Aircraft, Nonnuclear, General Criteria
MIL-HDBK-336/2 Survivability, Aircraft, Nonnuclear, Airframe
MIL-HDBK-336/3 Survivability, Aircraft, Nonnuclear, Engine
MIL-HDBK-336/4 Classified
MIL-HDBK-516 Airworthiness Certification Criteria
MIL-HDBK-783(EA) Chemical and Biological (CB) Contamination Avoidance and Decontamination
MIL-HDBK-799(AR) Fire Control Systems – General
MIL-HDBK-2069 Aircraft Survivability
MIL-HDBK-2089 Aircraft Survivability Terms

(Copies of these documents are available online at https://quicksearch.dla.mil/qsSearch.aspx.)

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

AR 10-16 United States Army Nuclear and Chemical Agency
AR 15-41 Nuclear and Chemical Survivability Committee
3. DEFINITIONS AND ACRONYMS

# APPENDIX O

## 3.2 Acronyms and abbreviations.

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>AATD</td>
<td>Aviation Applied Technology Directorate</td>
</tr>
<tr>
<td>ADS</td>
<td>Aeronautical Design Standard</td>
</tr>
<tr>
<td>AED</td>
<td>Aviation Engineering Directorate (Renamed Systems Readiness Directorate)</td>
</tr>
<tr>
<td>AEP</td>
<td>Allied Engineering Publication</td>
</tr>
<tr>
<td>AGL</td>
<td>Above Ground Level</td>
</tr>
<tr>
<td>AMCOM</td>
<td>Aviation and Missile Command</td>
</tr>
<tr>
<td>AMMTIAC</td>
<td>Advanced Materials, Manufacturing, and Testing Information Analysis Center</td>
</tr>
<tr>
<td>AMRDEC</td>
<td>Aviation and Missile Research Development Command (Renamed CCDC)</td>
</tr>
<tr>
<td>AMRDL</td>
<td>Air Mobility Research and Development Laboratory</td>
</tr>
<tr>
<td>AMSC</td>
<td>Acquisition Management Systems Control</td>
</tr>
<tr>
<td>AP</td>
<td>Armor Piercing</td>
</tr>
<tr>
<td>API</td>
<td>Armor Piercing Incendiary</td>
</tr>
<tr>
<td>AQS</td>
<td>Airworthiness Qualification Specification</td>
</tr>
<tr>
<td>ARL</td>
<td>Army Research Lab</td>
</tr>
<tr>
<td>ASSIST</td>
<td>Acquisition Streamlining and Standardization Information System</td>
</tr>
<tr>
<td>ASTM</td>
<td>American Society for Testing and Materials</td>
</tr>
<tr>
<td>AVRADCOM</td>
<td>Aviation Research and Development Command</td>
</tr>
<tr>
<td>AVSCOM</td>
<td>Aviation Systems Command</td>
</tr>
<tr>
<td>BDAR</td>
<td>Battle Damage Assessment and Repair</td>
</tr>
<tr>
<td>BRL</td>
<td>Ballistics Research Laboratory</td>
</tr>
<tr>
<td>CAD</td>
<td>Computer Aided Design</td>
</tr>
<tr>
<td>CARC</td>
<td>Chemical Agent Resistant Coating</td>
</tr>
<tr>
<td>CB</td>
<td>Chemical and Biological</td>
</tr>
<tr>
<td>CBRNIAC</td>
<td>Chemical, Biological, Radiological, and Nuclear Information Analysis Center</td>
</tr>
<tr>
<td>CFE</td>
<td>Contractor Furnished Equipment</td>
</tr>
<tr>
<td>COTS</td>
<td>Commercial-Off-The-Shelf</td>
</tr>
<tr>
<td>CW</td>
<td>Continuous Wave</td>
</tr>
<tr>
<td>DoD</td>
<td>Department of Defense</td>
</tr>
<tr>
<td>DTIC</td>
<td>Defense Technical Information Center</td>
</tr>
<tr>
<td>E3</td>
<td>Electromagnetic Environmental Effects</td>
</tr>
<tr>
<td>ECBC</td>
<td>Edgewood Chemical Biological Center</td>
</tr>
<tr>
<td>ECS</td>
<td>Environmental Control System</td>
</tr>
<tr>
<td>EMD</td>
<td>Engineering and Manufacturing Development</td>
</tr>
<tr>
<td>EMP</td>
<td>Electromagnetic Pulse</td>
</tr>
<tr>
<td>FLIR</td>
<td>Forward Looking Infrared</td>
</tr>
<tr>
<td>FMECA</td>
<td>Failures Modes Effects and Criticality Analysis</td>
</tr>
<tr>
<td>FPS</td>
<td>Feet Per Second</td>
</tr>
<tr>
<td>FSC</td>
<td>Federal Supply Code</td>
</tr>
<tr>
<td>GFE</td>
<td>Government Furnished Equipment</td>
</tr>
<tr>
<td>HCI</td>
<td>Hardness Critical Item</td>
</tr>
<tr>
<td>Acronym</td>
<td>Definition</td>
</tr>
<tr>
<td>---------</td>
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</tr>
<tr>
<td>HCPE</td>
<td>Hybrid Collective Protection Equipment</td>
</tr>
<tr>
<td>HEI</td>
<td>High Explosive Incendiary</td>
</tr>
<tr>
<td>HEL</td>
<td>Human Engineering Laboratory, High Energy LASER</td>
</tr>
<tr>
<td>HEMP</td>
<td>High Altitude Electromagnetic Pulse</td>
</tr>
<tr>
<td>HFE</td>
<td>Human Factors Engineering</td>
</tr>
<tr>
<td>HPM</td>
<td>High Power Microwave</td>
</tr>
<tr>
<td>HRED</td>
<td>Human Research and Engineering Directorate (formerly HEL)</td>
</tr>
<tr>
<td>IAW</td>
<td>In Accordance With</td>
</tr>
<tr>
<td>IGE</td>
<td>In Ground Effect</td>
</tr>
<tr>
<td>IOC</td>
<td>Initial Operational Capability</td>
</tr>
<tr>
<td>IPE</td>
<td>Individual Protective Equipment</td>
</tr>
<tr>
<td>IPT</td>
<td>Integrated Product Team</td>
</tr>
<tr>
<td>IR</td>
<td>Infrared</td>
</tr>
<tr>
<td>JASPO</td>
<td>Joint Aircraft Survivability Program Office</td>
</tr>
<tr>
<td>JSSG</td>
<td>Joint Service Specification Guide</td>
</tr>
<tr>
<td>JTCG/AS</td>
<td>Joint Technical Coordinating Group on Aircraft Survivability</td>
</tr>
<tr>
<td>JTCG/ME</td>
<td>Joint Technical Coordinating Group on Munitions Effectiveness</td>
</tr>
<tr>
<td>LASER</td>
<td>Light Amplification by Stimulated Emission of Radiation</td>
</tr>
<tr>
<td>LFT&amp;E</td>
<td>Live Fire Test and Evaluation</td>
</tr>
<tr>
<td>MM</td>
<td>Millimeters</td>
</tr>
<tr>
<td>MNS</td>
<td>Mission Need Statement</td>
</tr>
<tr>
<td>MOPP</td>
<td>Mission Oriented Protective Posture</td>
</tr>
<tr>
<td>NATO</td>
<td>North Atlantic Treaty Organization</td>
</tr>
<tr>
<td>NBC</td>
<td>Nuclear Biological Chemical</td>
</tr>
<tr>
<td>NBCCS</td>
<td>NBC Contamination Survivability</td>
</tr>
<tr>
<td>NDI</td>
<td>Non Developmental Item</td>
</tr>
<tr>
<td>NIAG</td>
<td>NATO Industrial Advisory Group</td>
</tr>
<tr>
<td>NMOS</td>
<td>N-channel Metal Oxide Semiconductors</td>
</tr>
<tr>
<td>NSRDEC</td>
<td>US Army Natick Soldier RD&amp;E Center</td>
</tr>
<tr>
<td>OBIGGS</td>
<td>On-Board Inert Gas Generating System</td>
</tr>
<tr>
<td>OGE</td>
<td>Out of Ground Effect</td>
</tr>
<tr>
<td>ORD</td>
<td>Operational Requirements Document</td>
</tr>
<tr>
<td>PAM</td>
<td>Pamphlet</td>
</tr>
<tr>
<td>PEO</td>
<td>Program Executive Office</td>
</tr>
<tr>
<td>Ph</td>
<td>Probability of Hit</td>
</tr>
<tr>
<td>Pk</td>
<td>Probability of Kill</td>
</tr>
<tr>
<td>PRF</td>
<td>Performance</td>
</tr>
<tr>
<td>QSTAG</td>
<td>Quadripartite Standardization Agreement</td>
</tr>
<tr>
<td>RDEC</td>
<td>Research, Development and Engineering Center</td>
</tr>
<tr>
<td>RDECOM</td>
<td>Research, Development and Engineering Command</td>
</tr>
<tr>
<td>RFP</td>
<td>Request For Proposal</td>
</tr>
<tr>
<td>SLAD</td>
<td>Survivability/Lethality Analysis Directorate</td>
</tr>
<tr>
<td>SOF</td>
<td>Safety-of-Flight</td>
</tr>
<tr>
<td>SOW</td>
<td>Statement of Work</td>
</tr>
<tr>
<td>Acronym</td>
<td>Definition</td>
</tr>
<tr>
<td>-----------</td>
<td>--------------------------------------------------------------</td>
</tr>
<tr>
<td>SREMP</td>
<td>Source Region EMP</td>
</tr>
<tr>
<td>STANAG</td>
<td>Standardization Agreement</td>
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<tr>
<td>SURVIAC</td>
<td>Survivability/Vulnerability Information Analysis Center</td>
</tr>
<tr>
<td>TEMP</td>
<td>Test and Evaluation Master Plan</td>
</tr>
<tr>
<td>TREE</td>
<td>Transient Radiation Effects on Electronics</td>
</tr>
<tr>
<td>US</td>
<td>United States</td>
</tr>
<tr>
<td>USA</td>
<td>United States Army</td>
</tr>
<tr>
<td>USAAVSCOM</td>
<td>United States Army Aviation Systems Command</td>
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<tr>
<td>USANCA</td>
<td>United States Army Nuclear and Chemical Agency</td>
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<tr>
<td>USAAMRDL</td>
<td>US Army Air Mobility Research and Development Laboratory</td>
</tr>
<tr>
<td>USAARL</td>
<td>US Army Aeromedical Research Laboratory</td>
</tr>
</tbody>
</table>
4. GENERAL GUIDANCE

4.1 Policy. DoD Instructions 5000.1 and 5000.2, as implemented by Army Regulations 71-9 and 70-75, require that survivability against the full spectrum of battlefield threats found in the various levels of conflict be considered, in an integrated manner, in all systems acquisition programs. Aircraft combat survivability is the capability of a system to avoid (susceptibility) or withstand (vulnerability) man-made hostile environments. The term “survivability” includes both the soldier and equipment unless otherwise specified. Survivability is achieved by reducing susceptibility and vulnerability to acceptable levels through a combination of hardness/damage tolerance, threat avoidance, redundancy and reconstitution. While both susceptibility and vulnerability aspects should be included in a Survivability Program, this handbook includes only the vulnerability portion, also referred to as “vulnerability hardening”. Guidance for susceptibility (Aircraft Survivability Equipment (ASE)) is contained in MIL-HDBK-2069 and ADS-66-HDBK. Joint service guidance on aircraft survivability can be found in the Joint Technical Coordinating Group on Aircraft Survivability (JTCG/AS) Aerospace Systems Survivability Handbook Series.

4.2 Program. The Contractor should develop and implement a survivability program using MIL-HDBK-2069 as a guide in order to assure proper emphasis on nuclear and nonnuclear survivability continuously during system design, development, and test. Emphasis is to be placed on development of optimum quantitative requirements and sound planning for incorporation of features during all phases of the system (aircraft) design and development to achieve maximum reduction of susceptibility and vulnerability to the specified threats. In addition to the JTCG survivability handbook series, non-nuclear survivability guidance is contained in MIL-HDBK-268(AS) and MIL-HDBK-336. Nuclear guidance is contained in MIL-HDBK-273(AS).

4.3 Agency responsibilities and assistance. DoD agency responsibilities related to survivability are contained in the policy documents cited in this handbook. Technical area assistance for survivability technical areas can be obtained from the US Army agencies shown in Table I:

<table>
<thead>
<tr>
<th>Technical Area</th>
<th>Agency</th>
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<tbody>
<tr>
<td>Ballistic Hardening</td>
<td>US Army Research Laboratory</td>
</tr>
<tr>
<td>Survivability/Lethality Analysis Directorate</td>
<td>ATTN: RDRL-SLB</td>
</tr>
<tr>
<td>Aberdeen Proving Ground, MD 21005-5068</td>
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<tr>
<td>Directed Energy Hardening</td>
<td>National Ground Intelligence Center</td>
</tr>
<tr>
<td>Building 4465</td>
<td>2055 Boulders Road</td>
</tr>
<tr>
<td>Charlottesville, VA 22911-8318</td>
<td></td>
</tr>
<tr>
<td>Nuclear Hardening</td>
<td>US Army Nuclear and Chemical Agency</td>
</tr>
<tr>
<td>7150 Heller Loop, Suite 101</td>
<td></td>
</tr>
</tbody>
</table>

TABLE I. US Army agency technical area assistance.
# APPENDIX O

| NBC Hardening | US Army Edgewood Chemical Biological Center  
|              | AMSRD-ECB-AP-B/Kennedy E3330  
|              | 5183 Black Hawk RD  
|              | Aberdeen Proving Ground, MD 21010-5424  
|              | [On-line: CBRN@conus.army.mil](mailto:CBRN@conus.army.mil) |
| Crashworthiness | U.S. Army CCDC Technology  
| Development Directorate ATTN: Systems Integration Division  
| Ft. Eustis, VA 23604-5577 |
| Soldier Survivability | US Army Natick Soldier RD&E Center  
| Natick, MA 01760 |
| Survivability Science and Technology | US Army Research Laboratory  
| 2800 Powder Mill Rd  
| Adelphi, MD 20783-1197 |
| Effects on aircraft crew and troops | US Army Aeromedical Research Laboratory  
| Building 6901  
| Ft. Rucker, AL 36362-0577 |

## 5. DETAIL GUIDANCE

### 5.1 Survivability Program

5.1.1 **Plan.** A Survivability Program Plan should be submitted to the Government as a Statement of Work (SOW) if required by the RFP or contract. The plan should outline the method by which the Contractor intends to implement and control the program. The plan should encompass only those survivability element requirements contained in the RFP, and to the extent that survivability enhancement is possible and practical. Utilize paragraph 5.2.1 of MIL-HDBK-2069 as a guide for the preparation of the plan. Include a continuing analytical methodology to assess system survivability element levels, to identify possible areas for emphasis, and to carry out tradeoff analyses on RFP identified (required and desired) capabilities/features as well as on items identified by this program or by the Army. The analyses should be continued throughout all phases of system design and test, as an interactive process, whereby quantitative system survivability element levels are updated and current levels are available at formal design reviews.

5.1.2 **Tradeoff studies.** Tradeoff studies and cost effectiveness analyses should be performed in accordance with paragraph 5.2.12 of MIL-HDBK-2069. Survivability analyses should use work unit codes for tracking and identification of aircraft parts.

5.1.3 **Reviews.** Program reviews should be conducted per paragraph 4.3.1 of MIL-HDBK-2069.

### 5.2 Vulnerability hardening
5.2.1 Ballistics hardening / damage tolerance. Refer to USAAMRDL TR 71-41A as a design guide for small arms protection, 7.62mm through 14.5mm. Blast and fragment characteristics should be considered in the design of aircraft systems and subsystems to minimize damage effects of larger munitions as specified by the system specification.

5.2.1.1 Ballistics technical approach. The technical approach description should include:

a. A target technical description of survivability features including 1/10 or 1/20 scale drawings of the aircraft for independently assessing ballistic vulnerability from six (6) views (front, rear, left, right, bottom, and top). These drawings should show the overall aircraft configuration vulnerability reduction features, major components, subsystems, flight controls, routing of plumbing, wire bundles, location of armor, supplemental oxygen system (see JSSG-2010-10) and detailed cross section drawings of critical areas. Critical component and subsystem drawings should be included and may be of the detail, assembly or installation type. Per MIL-HDBK-2089, a critical component is defined as, “Those aircraft components which, if damaged or destroyed, would yield a defined or definable aircraft kill level.”

b. A critical components list and for each item: identify if attrition or forced landing critical, as well as the failure mode and effect in both hover and forward flight; provide presented areas from each of the 6 views based on a bare item; substantiate why the item is invulnerable to certain threats and; analyze and tabulate vulnerable areas for threats identified in the system specification.

c. A discussion of the quantitative degree of protection provided (shielding) for the crew and troops (if specified). Include body area coverage and prevention of wounding of both pilot and copilot with one projectile. Identify armor materials and finished panel construction, areal densities and substantiate $V_{50}$ ballistic limit with test reports. The $V_{50}$ ballistic limit is dependent on mass, velocity, and material properties of both the projectile and target. See JTCG document number JTCG/ME-77-16 for procedures to predict outcomes of impacts of projectiles or fragments against aircraft components.

d. For those aircraft systems that are mandated for the Army’s Live Fire Test and Evaluation (LFT&E) program (see DA Pamphlet 73-6), the LFT&E strategy is usually stated in section 4 of the aircraft system’s Test and Evaluation Master Plan (TEMP). Contractors should provide a description of their support to the Government’s aircraft system-level LFT&E program. The LFT&E program provides the means for assessing the synergistic effects of system component integration. The program will conduct an assessment of all flight-critical/mission-critical systems and will include vulnerability analyses and live-fire ballistic tests. As prescribed by contract, contractor support may include analysis, modeling aircraft assets needed for test, and Failure Modes, Effects and Criticality Analysis (FMECA) of flight-critical and mission-critical components/ subsystems, and other technical data on aircraft subsystems and components. The FMECA
analysis report should be IAW DI-ILSS-81495. The contractor may be required to provide a 3-D solid model Computer Aided Design (CAD) Target Description Model in Ballistic Research Lab (BRL) format.

e. A description of the capability of aircraft Battle Damage Assessment and Repair (BDAR) and associated level of maintenance as required in the system specification. A combat damage repair analysis should be performed to develop and evaluate concepts, criteria, procedures and time estimates for rapid repair of non-lethal combat damage caused by nonnuclear and nuclear threats, including NBC contamination. The contractor may also be required to provide on-site aircraft BDAR support for the LFT&E program. Further guidance is provided in paragraph 5.2.13 of MIL-HDBK-2069.

f. A discussion of Fault Tolerance Performance should be conducted within the following guidelines:

1. Systems requiring fault tolerance may be required to continue functioning at full performance after the loss of any one component, (in addition to actuators, sensors, boxes and circuit cards, a component for this discussion includes a source of electrical power or a segment of wiring harness).

2. Full performance with further losses may be required and will be provisioned as practical.

3. Degraded performance may be allowed after further losses but not complete or catastrophic failure.

4. Degraded performance uses the software and hardware available to the best extent practical.

5. Degraded performance can be enhanced with real-time software models of the physical properties being sensed by lost sensors. However, this is an added cost capability in terms of development and computing which needs to be weighed against the performance gained.

6. The ultimate failure will be defined (example: failed fixed, failed off).

7. No harsh electrical transients at time of loss and switchover. Graceful transition to redundant channel/signal-routing at time of loss. MIL-STD-704 addresses standard normal and abnormal power interrupt times.

8. Failures will not propagate from one component to another in a domino effect; a failure in one box or wiring harness will not cause a hardware failure in another box.
9. Fault tolerance testing. Test failures of the wiring harness. Short to ground, short between wires, hot-shots to power if possible in a segment of wiring harness (for only a short period of time, representing the time a projectile passes through the harness), open circuit (representing broken wires), complete loss (open circuit) of wiring harness segments.

10. Redundant power sources may be required for each redundant channel or processing node. The system should operate on one of the redundant power sources when electrical power is unavailable from the other.

11. Examples of Fault Tolerance Architecture are (not mutually exclusive list):

   a) Fully redundant self-contained channels.

   b) Mechanically isolated channels.

   c) Distributed processing nodes (redundant boxes in separate locations).

   d) Redundant wiring harness paths routed in separate locations.

   e) In addition to their main function, boxes acting as bridges for critical data between wired busses.

   f) Redundant power sources for each redundant channel.

G. The Army’s lead agency that supports materiel developers in the ballistic survivability elements is the US Army Research Laboratory (ARL) Survivability/Lethality Analysis Directorate (SLAD). For example, specific threat or surrogate ammunition designated for ballistic analysis and testing should be verified by the ARL/SLAD. Ammunition with similar identification can result in substantial differences in lethality. Even ammunition alternatives of identical nomenclature can result in lethality differences based on the country of origin.

5.2.1.2 Ballistic vulnerability analyses.

a. Vulnerability analyses, including the use of modeling and simulation, should be conducted within the following guidelines:

   1. Updated vulnerability assessment methodology should be obtained from ARL/SLAD (formally BRL). Extensive ballistic shotline methodology and vulnerability modeling techniques are available. Modeling and simulation tools are also available at the Survivability/Vulnerability Information Analysis Center (SURVIAC). The SURVIAC was established by the Joint Technical Coordinating
Group on Aircraft Survivability (JTCG/AS), now the Joint Aircraft Survivability Program Office (JASPO).

2. Threats as defined by the system specification by caliber and striking velocity, and other munitions characteristics, as applicable.

3. Both hover and forward flight conditions.

4. Kill categories of attrition, forced landing and mission abort. With respect to mission abort, the Government will provide inputs to define target type (point/area) and environment (day/night) adverse weather, as well as assist in identifying mission essential equipment. Guidance on kill categories and aircraft survivability requirements is contained in JSSG-2001 for air vehicles.

5. With and without aircraft external stores.

6. See Appendix A of MIL-HDBK-2069 and ARL/SLAD for computer model information that can be used to support vulnerability analyses. See SURVIAC on-line for model updates.

b. Unless otherwise specified, all kill determinations should be based on the following:

1. Environment is 4000’ pressure altitude and 95°F.

2. Aircraft is in primary mission configuration less 1/3 fuel and 1/3 ammunition.

3. Aircraft is hit in Out of Ground Effect (OGE) hover or forward flight (speed greater than streamlining) at 100 feet altitude Above Ground Level (AGL) on a clear day.

4. The post damage flight profile should consist of a compression of the system specification fatigue flight profile, to the post damage flight duration specified in the same document. However, maximum loads should be truncated to 2g’s. Unless otherwise specified, the post damage flight profile for primary airframe structure and flight essential components should be capable of continuous safe flight for 30 minutes after sustaining damage from a single impact of specific munitions at the specified velocities. The ballistic damage criteria for primary airframe structure, flight essential components, usage spectrum, and definition of “safe continuous flight” should be stated in the system specification.

5. Aircraft lands in a confined area precluding a run-on landing.
c. The optimum practical armor configuration for each crewmember (and troops, if specified) and critical component (which is not damage tolerant) should be selected based on vulnerability analyses techniques similar to the preceding. Caution should be exercised to use sufficient attack views to yield an accurate average exposure. This armor protection study should be performed in conjunction with other considerations, such as vision and ingress-egress to reach an acceptable trade-off compromise. Personal body armor worn by the crew is defined in the system specification.

5.2.1.3 Ballistic tests. Components, subsystems and a full-up aircraft (if mandated for LFT&E) should be subjected to ballistic firing tests, controlled damage tests and a vulnerability reduction demonstration using the guidance of paragraph 5.3.3 of MIL-HDBK-2069. Whenever foreign threat projectiles are specified, readily available domestic projectiles of similar penetrating, incendiary or explosive capability may be substituted with procuring activity approval (see 5.2.1.1.g). Qualification and acceptance tests of armor materials should be against Armor Piercing (AP) threats in accordance with USA AVRADCOM 1560-MULTI-001, unless otherwise specified. For additional “ball” ammunition threats, see MIL-STD-662. The contractor should select the components, subsystems and aircraft, and specify the proposed test program in an Airworthiness Qualification Specification (AQS). The most cost effective and efficient approach to LFT&E is a “building-block” approach starting with component or subsystem testing. Therefore the Government LFT&E Integrated Product Team (IPT) should coordinate with the aircraft survivability component qualification program. When cost effective, the contractor should maximize the use of available LFT&E organizations and facilities for ballistic vulnerability analyses and tests, whether or not the aircraft program is mandated for formal LFT&E.

a. Ballistic hardness/damage tolerance test plans. The following guidance is provided for the preparation of the test plans:

1. All test specimens should be clearly identified by name, description, and part number. Drawings with the proposed shotlines should be provided as an appendix to the test plan. Where multiple shots are planned, the shot sequence should be specified. Also, substantiate suitability if configuration is other than current production version.

2. For each component, the threat projectile, impact location, obliquity, tumble, and striking velocity should be specified. Tabular and drawing presentations are preferred.

3. Structural loads at ballistic impact should be determined by considering all flight modes.

4. Test setup, including loads to be applied and fixtures to be used should be clearly described. A sketch of the test arrangement should be provided. For armor testing, the armor panels should be mounted on a test fixture with rigidity equal to or greater than the actual installation of the panel in
the aircraft. All required Government equipment and special fixtures should be identified for each test.

5. Criteria should be established and provided for the following: failure of the component at ballistic impact which will result in no further damage tolerance testing; damage on each multiple shot component which will disqualify the component for the second shot; failure during damage tolerance testing. Pass/fail judgments will be based on meeting minimum requirements as well as assessing mission completion capability.

6. All ballistically impacted components should be subjected to post damage structural and functional tests. These tests are to impose loadings in accordance with paragraph 5.2.1.2.b and to evaluate loss of function.

7. The data acquisition and reduction procedures should be given for ballistic, structural and functional tests. Photographic coverage should be included.

8. An appendix should be provided which outlines how the ballistic and post damage structural test loads and functional test parameters were determined.

9. Aircraft component qualification test programs (as opposed to full-scale LFT&E) should address the environmental requirements of the host aircraft system. All ballistic impacted components should be subjected to the following environmental conditions prior to firing tests, as applicable: high/low altitude, rain, icing/freezing rain, humidity, salt fog, solar radiation, sand and dust, fungus, high and low temperatures, temperature shock, explosive atmosphere, aircraft/gun vibration, functional/crash shock and chemicals/solvents. Testing standards should be IAW MIL-STD-810. The component may be reasonably exposed to and maintained in accordance with the applicable sections of the system specification. The component should not exhibit any failures due to any form of materials degradation, including but not limited to pitting, stress cracking, delaminating, crazing, or blistering when exposed to environmental conditions. The contractor should prepare and submit test plans including procedures and reports with the test results for each environmental condition to the Aviation Engineering Directorate (AED) for review and approval IAW DI-NDTI-80566 and DI-NDTI-80809B.

Note: No observance of corrosion, materials, or functional degradation is desired. While functional testing may prove satisfactory, the observance of corrosion or minor materials degradation after short duration test (such as 48 hour salt fog) is undesirable and indicates components will not perform satisfactorily over its expected service life. Therefore, if the article is functional and minor corrosion occurs, the contractor should
specify an inspection interval in order to detect and mitigate the problem before survivability is compromised.

b. Fuel system tests. The fuel cell installation, consisting of representative tanks, plumbing, surrounding airframe and protective features should be subjected to self-sealing and fire suppression demonstration. The following test procedures apply:

1. Self-sealing. Refer to MIL-DTL-27422.

   a) All shots should be at least 6 inches below the fluid level, and the distribution of shots in elevation should encompass the minimum to maximum head. The fluid used should be JP-8, JP-5, or ASTM D471 Ref Fuel A Test Fluid. All shots should be at service velocity IAW MIL-STD-662 Table I. The number of rounds of 0.50 caliber AP ammunition to be fired should be determined on the basis of one round for each 15 gallons of cell capacity up to a maximum of 10 rounds. At least two rounds should be fired to demonstrate, on a worst case basis, that the fuel cell is protected from surrounding structure flowering into the cell material and holding the wound open. A nonmetallic yaw plate or modified gun barrel should be used to impart tumbling of rounds when required by Table II of MIL-DTL-27422. The firing distance for tumbled rounds can be adjusted to attain the required tumble, but should not exceed 75 feet. A damp seal is required in two minutes. In addition to the 0.50 caliber gunfire, one round of 20mm AP ammunition (M55A1) or PGU-27/B projectile should be fired into the self-sealing portion of the fuel cell. A seal is required for the entrance wound only.

   b) For fuel cells that are designed to be fully or partially protected up to 14.5mm impacts, the requirements specified in MIL-DTL-27422 in regard to 0.50 caliber ballistic testing apply except that the 14.5mm rounds will be counted in the total number of rounds required. Four of the rounds should be 14.5mm of which two rounds should be 3/4 to fully tumbled and two should be unyawed, all to be fired at 0 degrees obliquity to the cell surface. In addition to the 14.5mm AP rounds, one round of 20mm AP ammunition (M55A1) or PGU-27/B projectile should be fired. A seal is required for the entrance wound only.

   c) Special tools and access procedures should be utilized to gain access to the entrance and exit wounds for visual inspection not later than 60 seconds after each shot. Normally, if a good seal is to occur for a wound, the majority of leakage ceases during the first minute. Upon impact, a gush of fuel is to be expected. If a steady
stream is coming out of the fuselage after 10 minutes, chances are the wound has not sealed. However, an impact may have opened up a wound that had previously sealed. This should be disregarded and only the wound(s) from the last shot evaluated. Means should be provided to catch and periodically measure the total leakage from the cell. The definitions in Table II should be used when evaluating leakage:

**TABLE II. Definitions used for leakage evaluation.**

<table>
<thead>
<tr>
<th>TERM</th>
<th>DEFINITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry Seal</td>
<td>No visible fluid surrounding hole.</td>
</tr>
<tr>
<td>Damp Seal</td>
<td>Evidence of fluid surrounding hole but no accumulation.</td>
</tr>
<tr>
<td>Slow Seep</td>
<td>Fluid escapes through hole at a barely discernable rate and flows in contact with fuel cell wall.</td>
</tr>
<tr>
<td>Medium Seep</td>
<td>Fluid escapes through hole at an easily discernable rate and flows in contact with fuel cell wall.</td>
</tr>
<tr>
<td>Fast Seep</td>
<td>Fluid escapes through hole at a significant rate and flows in contact with fuel cell wall.</td>
</tr>
<tr>
<td>Slow Leak</td>
<td>Fluid escapes with sufficient force to separate from fuel cell wall; stream is greater than 3.2mm (1/8”) but less than 6.4mm (1/4”) in diameter.</td>
</tr>
<tr>
<td>Fast Leak</td>
<td>Fluid escapes with sufficient force to separate from fuel cell wall; stream is greater than ¼” in diameter.</td>
</tr>
</tbody>
</table>

d) The self-sealing capability of a non-integral sump should be demonstrated by an independent test. One unyawed projectile should be fired at 45 degree obliquity to the sump. The round should be of the same type as the self-sealing requirement for the lower section of the cell. A damp seal is required in two minutes while under a Type 1 fluid head equal to 2/3 fuel cell capacity.
e) After completion of the gunfire tests, debris injected into the fuel cell should be collected and evaluated for potential impact on the fuel system.
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2. Fire suppression. The test specimen should be subjected to the system specification identified API and HEI threats. The adequacy of both internal and external fire suppression protection, such as foam/powder packs and On-Board Inert Gas Generating System (OBIGGS) should be demonstrated. The tank should be 2/3 full with fuel. Care should be taken in the placement of API impacts to insure functioning. Shot placements should avoid areas of previous fuel soaking.

c. Oxygen system or component tests. A ballistic test program for oxygen systems or components (aircraft-installed, carry-on equipment or worn by crewmembers) should be based on an aircraft vulnerability analysis. The test program should be conducted in a manner that can quantify the effects on the aircraft and human body, including explosion, fire, and shrapnel. As stated in JSSG-2001, “Testing of composite cylinders with aluminum liner shows a significant hazard that should be of concern to the military designer. A small composite cylinder of this type with 2,150 psi oxygen included, when shot with a 50-caliber incendiary bullet, releases a tremendous amount of energy. This energy could easily destroy an aircraft on which it is installed.” According to JSSG-2010-10, “Composite cylinders with aluminum liners and aluminum cylinders are banned from use on military aircraft. Composite cylinders with liners other than aluminum should be tested before using to ensure that no significant blast over pressure will result in the event of failure.” Oxygen cylinders should be limited to “non-shatterable” or “shatterproof” steel cylinders as verified by fragmentation resistance gunfire testing, such as that shown in MIL-DTL-7905. Mounting provisions for the oxygen system should also withstand all forces encountered by the gunfire test. In addition to fragmentation assessment, potential hazards due to blast overpressure and fire should be assessed.

5.2.1.4 Additional ballistic vulnerability guidance. Additional guidance intended to be used in the preparation of performance specifications is contained in JSSG-2001 for air vehicles, JSSG-2009 for air vehicle subsystems and JSSG-2010-10 for oxygen systems.

5.2.2 Directed energy hardening. In accordance with requirements outlined in DoDI 5000.2 and prescribed by AR 70-75, if an item is designated as critical, flight essential or mission essential, or is a critical component of one or more of those end items, it will be survivable in an electronic attack environment (including directed energy weapons). For purposes of this document, directed energy weapons are limited to battlefield lasers and High Power Microwave (HPM). The battlefield laser threats are described in the system specification and may include several types of weapons. Parameters which describe the threat include operating frequency(ies), type (Pulsed or Continuous Wave (CW)), power level on target (or power level vs. range), pulse rate and duration, beam size, power distribution and slew rate. The laser threat may vary from a milliwatt device capable of damaging some mission equipment and causing temporary or permanent crew blindness to large devices capable of delivering sufficient thermal energy to the crew/aircraft to cause an attrition kill.
a. The directed energy survivability criteria required for inclusion in the system specification should be developed with the assistance of the US Army National Ground Intelligence Center, Charlottesville, Virginia.

b. The organization currently responsible for issuing and maintaining standards for safe exposure of personnel to directed energy effects is the US Army Aeromedical Research Laboratory.

c. The ARL is the designated leader for the Army’s directed energy weapon Science and Technology (S&T) program. They may be able to provide assistance in design, analysis and test efforts required for directed energy hardening. Design guidance is also available in MIL-HDBK-273(AS) and USAAMRDL TR 74-48A.

5.2.2.1 Directed energy technical approach. Provide a detailed discussion of the technical approach being used to achieve the directed energy requirement of the system specification to include the design as well as supporting analyses and validation testing. Address such pertinent factors as advantages/disadvantages, materials selection, system integration, operational and human factors, risk areas, and testing philosophy. Include descriptions of external antennas and other sensors and internal cabling and cable routing. The scope of the technical approach description and directed energy vulnerability assessment should be similar to that discussed for ballistics under paragraph 5.2.1.1.

5.2.2.2 Directed energy vulnerability analysis. An analysis should be conducted to define and predict the overall vulnerability of the aircraft to the laser threat(s) stated in the system specification with and without stores. The analysis should determine the predicted response of the aircraft and its ability to complete the mission. The terminal effects of battlefield laser weapons vary depending on weapon parameters (such as energy level, Pulse/CW, frequency) and component damaged (flight critical component, crew, electro-optics, and weapon systems) so the analysis procedure and format chosen should be appropriate to the conditions involved. The laser vulnerability analysis should include an identification of the laser sensitive components and their associated failure modes (as in a FMECA) with respect to the specified threats, potential shielding by non-critical components, protective features incorporated and mission related consequences. The analysis should follow ballistic vulnerable area analysis methodology where practical. An HPM hardening analysis of the aircraft should also be conducted to determine component / subsystem vulnerabilities and evaluate hardening concepts and alternatives. Critical, flight essential and mission essential electrical/electronic items should be identified with descriptions of their locations in the aircraft. Individual parts should be analyzed on an “inside-out” basis to determine their burn-out energies. The circuit should be traced through the entire architecture noting the connector and cable attenuations until the energy coupling point is identified. Estimates should be made of the incident power density required to burn out components selected as the weak circuit element. This analysis should be updated to reflect the latest design configuration used in evaluating hardening alternatives. Based on this HPM analysis, components susceptible to HPM damage should be hardened as necessary to meet the system specification. Hardening using integral techniques (circuit configuration) should be preferred over parasitic (suppression devices). Methods should also be investigated to protect the crew from the effects of HPM. The approaches should emphasize the formation of a
“cocoon” around the crew which provides sufficient attenuation of the HPM energy to preclude crew injury or death. The use of alternative attenuation concepts for the structure, canopy, or crew garment (head or eye wear) should be investigated. On-board warning system and countermeasure requirements should be identified.

5.2.2.3 Directed energy tests. The directed energy hardness should be validated through component/subsystem tests and aircraft demonstrations as appropriate. The tests should be conducted on actual or simulated components (same material and design as the actual components) and on complete subsystems or portions thereof. The vulnerability reduction substantiation, verification and demonstration tests should be integrated and “piggy backed” on endurance, fatigue, ballistic and failure type test programs to the fullest extent possible.

a. Components and subsystems. Laser testing of flight critical components such as structure, fuel sub-systems, control sub-system, drive sub-system, rotors, and engine installation, should be tested in a manner similar to ballistic vulnerability tests. The components/subsystems should be exposed to “worst case” threat encounters under simulated flight conditions. Laser testing of the aircraft transparency should be conducted to verify compliance with the low energy laser (crew eye) protection requirements, and High Energy Laser (HEL) thermal injury/fatality protection requirements of the system specification. Radiance measurements should be made during HEL tests for prediction of the period of crew flashblindness expected after the HEL exposure on the canopy. Airflow should be provided over the specimens at a rate sufficient to clear the by-products of the laser reaction from the beam path. All mission equipment susceptible to damage or impairment from battlefield lasers, such as electro-optics, Forward Looking Infrared (FLIR) devices, weapon guidance system, seekers, sensors or displays, should be tested to determine their hardness to applicable laser threats and to verify that the required hardness levels have been achieved. Electronic equipment which is potentially vulnerable to HPM should be tested in its actual or simulated installed condition and in each operational mode of the equipment.

b. Directed energy hardness demonstrations. Laser hardness demonstrations should be conducted to assure that the design concepts, configurations, integrations, and subsystem designs meet the system specification requirements. Ground test vehicle, static test article or other aircraft sections may be used provided it is suitably fitted with critical components and subsystems capable of functioning to the extent required to verify laser hardness of flight critical components. Mission equipment chosen for testing should be fully operational. Laser threats used for this testing should be essentially identical to the laser threats in the systems specification and should not be scaled down to simulate the encounter. A fully configured aircraft should be used for the HPM demonstration and exposure should be in various operational modes of electronic equipment.

5.2.2.4 Directed energy HPM vs. E3 requirements. Other Electromagnetic Environmental Effects (E3) requirements may also apply, where the design and test approaches may be similar to those required for the HPM threat. Accordingly, these efforts should be
coordinated for a more cost-effective design, analysis and test program. The primary document defining the Army Aviation E3 requirements is ADS-37A-PRF.

5.2.2.5 Additional directed energy hardness guidance. Additional guidance intended to be used in the preparation of performance specifications is contained in JSSG-2001 for air vehicles and JSSG-2009 for air vehicle subsystems.

5.2.3 Nuclear hardening. In accordance with requirements outlined in DoDI 5000.2 and prescribed by AR 70-75, if an item is designated critical, flight essential or mission essential or is a critical component of one or more of those end items, it will be nuclear contamination survivable (see 5.2.4). If this critical/essential item or component is electronic equipment, at a minimum, it will be survivable to High-altitude Electro-Magnetic Pulse (HEMP). If this critical/essential item is a weapon system (including all critical/essential equipment/components of the weapon system), it will also survive the initial nuclear weapon effects of blast, thermal radiation, Transient Radiation Effects on Electronics (TREE), and Source Region EMP (SREMP). The use of Commercial-Off-The-Shelf/Non-Development Items (COTS/NDI) does not preclude this requirement. Waiver processes exist for nuclear survivability criteria and related systems testing procedures IAW AR 15-41; however, the waiver process does not change the need to meet the survivability requirement.

a. The nuclear survivability criteria required for inclusion in the system specification should be developed with the assistance of the US Army Nuclear and Chemical Agency (USANCA), Springfield, Virginia (see AR 10-16).

b. The ARL/SLAD may be able to provide assistance in the design, analysis and test efforts required for nuclear hardening.

c. Sufficient electronic hardness margins are required to ensure that the weapon system survives the specified nuclear weapons environments and to avoid costly hardness assurance and hardness maintenance/surveillance programs and procedures in the production and deployment phases. A hardness margin represents a multiplication factor applied to each threat effect’s magnitude at each point in time (see Table III). The use of piece parts, circuits, and designs whose hardness margins are below the lower bound of Category I are unacceptable (unless justified). If possible, the contractor should avoid using items having hardness margins in the Category I range because of possible hardness assurance/hardness maintenance impacts later in the life cycle (such as piece part screens, lot sample testing). The contractor should strive to incorporate parts with the highest design margin practical; (Category II). Items that are nuclear hardened (Hardness Critical Items (HCI)), which are especially designed and fabricated to achieve the nuclear hardness levels, should be identified as such to distinguish these “special” parts from items for which no special processes were incorporated to achieve nuclear hardness. The purpose of identifying these piece parts is to prevent the inadvertent replacement of “special” parts by parts which were not fabricated with the particular processing to achieve the required hardness. A plan should be developed for maintaining hardness of these parts...
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after fielding of the equipment. Hardness margins of HCI and their categories are to be identified in the survivability report.
TABLE III. Hardness margins.

<table>
<thead>
<tr>
<th>ENVIRONMENT</th>
<th>Hardness Margin Categories</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>I (Threshold)</td>
</tr>
<tr>
<td>TREE</td>
<td></td>
</tr>
<tr>
<td>Neutron Fluence</td>
<td>2 to 10</td>
</tr>
<tr>
<td>Total Dose</td>
<td>2 to 10</td>
</tr>
<tr>
<td>Gamma Dose Rate</td>
<td></td>
</tr>
<tr>
<td>Upset</td>
<td>2 to 5</td>
</tr>
<tr>
<td>Burnout</td>
<td>2 to 10</td>
</tr>
<tr>
<td>Latch-up</td>
<td>2 to 5</td>
</tr>
<tr>
<td>EMP</td>
<td></td>
</tr>
<tr>
<td>Voltage ratio, Current ratio</td>
<td>2 to 10</td>
</tr>
<tr>
<td>Corresponding Voltage and Current Hardness above Damage Thresholds</td>
<td>6 to 20dB</td>
</tr>
</tbody>
</table>

5.2.3.1 Nuclear hardening technical approach. Provide a detailed discussion of the technical approach being used to achieve the nuclear survivability requirement of the system specification to include such details as materials selection, piece part selection, circuit design, mechanical design, and system integration. Include a discussion of the design features to ensure nuclear survivability, description of the approach for the verification of nuclear survivability at the various stages of the design, and the proposed uses of simulation facilities for nuclear environmental tests.

5.2.3.2 Nuclear hardening analyses. A nuclear survivability analysis should be conducted throughout the development cycle to continually identify and incorporate nuclear survivability into the design, development and validation program. The analysis should include the basis for selection of materials, device technologies, and circuit and mechanical designs; the specific materials, technologies and designs rejected because of nuclear survivability considerations; the assumptions concerning the system hardness margins; and planned operational fixes, such as cycling of electrical power, and any assumptions concerning the system operations, function, deployment or configuration that has been used in the analysis. There should be emphasis on design philosophy for HCI which are critical, flight essential and mission essential. The analysis should identify projected requirements, driven by the nuclear survivability of the system, for special or custom parts, materials, or components; the basis of
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need for these parts; and the impacts of these requirements on the development program and system design, operation, function or deployment. The analysis should also identify areas of high risk including the assumptions, conclusions and reasons used in the risk analysis and the actions recommended to minimize the impact of these risk uncertainties. The analysis should support the program test activities to include identification of component, subsystem and system level tests to be performed. In order to focus tests, a description should be generated of those features that constitute and control the system’s nuclear survivability. The description should identify the parameters that are critical to operation and the limits of acceptable variation. Parameters which will require analytical or empirical evaluation to meet system nuclear survivability requirements are:

a. For TREE— critical semiconductor parameters; the selection or the exclusion of specific device technologies; specific circuit design considerations; feedback circuits; current limiting; circuit parameters; and assembly parameters.

b. For EMP— shielding effectiveness parameters; shielding design; filter and arrester designs, choice of cables, connectors; the assumptions concerning EMP coupling sources; the systems’ configurations that were considered in the analysis; and the methods used and the assumptions made in the system’s response analysis. This effort should be coordinated with the overall E3 design effort as discussed in 5.2.3.4.

c. For blast— critical structural members of designs; mechanical details of the structure that provide protection against dust, impact, shock; considerations given for the blast-thermal synergistic effects and the dynamic response of rotors.

d. For thermal radiation— the identification of critical components. The worst-case analysis of the response of these and the crew should include the operational impacts.

e. For nuclear flashblindness— the intensity of the flash, sensitivity of the eye, and visual acuity required for critical tasks and potential countermeasures.

5.2.3.3 Nuclear hardening tests. The test plan should include a listing of piece parts, materials, components, assemblies, and subsystems to be tested with detailed information concerning tests and parameters to be measured before, during and after the nuclear environment tests; monitor points and rationale for choices; instrumentation for sample response measurements to be employed; ambient conditions; modes of test sample function during the environment test with rationale; number of test samples and controls; physical orientations of the sample to the test environment; number and kinds of spare parts and data to be recorded. System level test plans should address the method of extrapolating from the test environment to the threat environment; the rationale for choice of simulators to be employed, test configurations, exposure levels and test data to be obtained.
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a. Components and subsystems. Selected critical, flight essential and mission essential items should be subjected to the following types of tests and show conformance to specification requirements during and after test:

1. EMP. The equipment should be subjected to the EMP environment specified in the systems specification. The equipment should be placed within a ground-effect electromagnetic pulse facility with the connecting cables extended parallel to the electric field and perpendicular to the magnetic field. All individual units should be in the test volume but widely separated. The equipment should be exposed at threat level in the above orientations and in each operating mode of the equipment. Where necessary, test data to satisfy the EMP requirements may be obtained by extrapolation of diagnostic test levels to threat level and injection pulsing at the calculated level.

2. Neutron fluence. In general, neutron fluence is defined as a measure of the neutron energy per unit area. The equipment should be exposed in such a manner that all optical components, electronic piece parts and circuits receive the neutron fluence specified in the systems specification. The equipment should be energized, if appropriate, to examine worst case response.

3. Total dose. The equipment should be exposed in such a manner that all optical components, electronic piece parts, and circuits receive the total dose specified in the systems specification. The equipment should be energized during the exposure and should thus perform as required. Except for fiber optics and n-channel metal oxide semiconductors (NMOS), verification of device hardness against permanent damage from gamma ray dose may be achieved by the gamma output which normally accompanies the neutron fluence. Gamma dose hardness of fiber optics and NMOS devices should be verified by Cobalt 60 irradiation in which the total dose specified is delivered in a steady-state exposure on the order of 20 seconds duration.

4. Peak Gamma dose rate. The equipment should be exposed in such a manner that all optical components, electronic piece parts, and circuits receive the peak gamma dose rate specified in the systems specification. The equipment should be energized during exposure.

5. Thermal radiation. Equipment should be exposed to thermal radiation levels as specified in the systems specification. If the utilized simulation facilities provide these thermal radiation levels only over relatively small areas, many individual exposures will be required so that each of the exposed surfaces will receive the required thermal exposure. Analysis of the equipment following exposure must show no degradation that will
affect the operation of the equipment as required. Sample sections may be used for this test.

6. Nuclear air-blast. The equipment in its intended operating configuration should be subjected to nuclear air-blast testing. If the equipment is unprotected, then it should meet the air blast environments as specified in the systems specification. If the equipment is housed within an enclosure, then the equipment should be subjected to the induced shock which will be transmitted through the enclosure when the enclosure is subjected to the air blast environments specified in the systems specification. Tests or analysis should be performed to account for synergistic effects of thermal radiation received before the nuclear air blast.

b. Nuclear hardening demonstration. The thermal and blast hardness demonstration should be conducted during the next Government conducted nuclear blast simulation. A Ground Test Vehicle, static test article or other functional buildup may be used provided it is suitably fitted with critical components and subsystems capable of functioning to the extent required for a static test. For the EMP hardness demonstration, a fully configured prototype aircraft should be exposed.

5.2.3.4 Nuclear HEMP vs. E3 requirements. Various E3 requirements documents also address HEMP design and test requirements, both at the component and at the system level. Accordingly, nuclear design and test efforts should be coordinated with those of other E3 requirements for a more cost-effective design and test program. The primary document defining the Army Aviation E3 requirement is ADS-37A-PRF. The DoD E3 requirement is defined in MIL-STD-464.

5.2.3.5 Additional nuclear hardening guidance. Additional guidance intended to be used in the preparation of performance specifications is contained in JSSG-2001 for air vehicles and JSSG-2009 for air vehicle subsystems.

5.2.4 Nuclear, Biological and Chemical (NBC) hardening. Refer to AR 70-75 for policy on Survivability of Army Personnel and Material, including NBC Contamination Survivability (NBCCS). NBCCS is defined as “the capability of a system (and its crew) to withstand a NBC-contaminated environment and relevant decontamination without losing the ability to accomplish the assigned mission. A NBC contamination-survivable system is hardened against NBC contamination and decontaminant; is decontaminable, and is compatible with individual protective equipment.” Army aircraft should be designed to minimize NBC contamination threats. They should be able to conduct operations following exposure to the material-damaging effects of NBC contaminants and decontaminants. Aircraft should be capable of being operated and maintained by crew and maintenance personnel wearing their normally required uniforms and complete flight gear, along with full NBC protective ensemble (Mission Oriented Protective Posture (MOPP) Level 4). Specific NBCCS requirements and MOPP-4 ensemble definition should be stated in the system specification.
5.2.4.1 **NBC technical approach.**

a. The NBC technical approach should include a detailed description of the approach for materials selection, circuit design, mechanical design, and system integration to develop an end item which will survive the NBC contamination environment. NBC contamination survivability includes protecting aircrew, air vehicle and contractor furnished equipment (CFE) from the effects of nuclear fallout, neutron-induced gamma radiation, chemical and biological agents, and decontamination materials and procedures so that mission-essential operation can be performed. Included also is the effectiveness and efficiency of personnel who must perform tasks while protected from the NBC hazard in all climatic conditions.

b. The approach should include the concept of design for the Hybrid Collective Protection Equipment (HCPE), Individual Protection Equipment (IPE), and their integration into the total aircraft design. The approach should provide a listing of the detailed design guidelines to insure NBCCS, a detailed description of the approach proposed for the verification of NBCCS at the various stages of system design, and the proposed test methods, procedures and equipment necessary to assess the capability for NBCCS. Also provide a detailed technical description of the complete HCPE system including its components, air supply source, overall system performance (heat load, major cycle point parameters), weight, required power, size, and aircraft performance effects. Include schematic drawings showing HCPE system installation, the location of components/subsystems, and interface. The HCPE must provide the required level of protection throughout the aircraft’s design flight envelope.

c. See MIL-HDBK-783(EA) for guidance on chemical and biological contamination avoidance and decontamination. Current Chemical and Biological (CB) decontamination procedures are very corrosive, environmentally unfriendly and/or inadequate. Potential decontamination procedures need to be identified/analyzed and submitted for approval. Chapter 7 of MIL-HDBK-799(AR) provides examples of NBCCS design techniques that can be applied to mission-essential equipment. Army Regulation 750-1, Section 8-9 requires all Army combat and combat support equipment to be painted with Chemical Agent Resistant Coating (CARC).

d. The Army’s lead agency that supports material developers in the chemical/biological (CB) survivability element is the US Army Edgewood Chemical Biological Center (ECBC). Coordination should also be conducted with the USAARL.

5.2.4.2 **NBC analyses.**
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a. An analysis should be performed to show that the design, including all mechanical configurations, optical components, electronic equipment, and piece parts will be capable of meeting system specification requirements and will withstand exposure to the NBC contamination and decontamination environment likely to be encountered. Testing shall be performed to demonstrate the decontamination process will not degrade the material. The component shall not exhibit any failures due to any form of corrosion or materials degradation, included but not limited to pitting, stress cracking, delaminating, crazing, or blistering when exposed to decontamination chemicals.

b. Vulnerability of the aircraft, support equipment, and personnel to NBC threats should be assessed. Consideration should be given to the current threats, those anticipated to be present at Initial Operational Capability (IOC), and any agents considered likely to become threats during the life cycle. Design features and techniques which minimize or negate vulnerability should be identified. The assessment should address short and long term effects on materials and personnel. On-board warning and operation procedural requirements should be identified. Vulnerability of the system, support equipment, and personnel to contaminants, decontaminants and decontaminating procedures should be determined. The effects of NBC procedural constraints on mission effectiveness should be addressed. Supportability impacts should be identified for each level of hardening studied.

c. Contractor should select a preferred Environmental Control System (ECS) design based on studies of various configurations including open loop air cycle, closed loop (air cycle and vapor cycle) and air versus liquid cooled avionics for integration with a hybrid system. The following factors should be addressed: NBC environment; NBC selection and sizing of an air purification system (filters or other decontaminating systems) that will provide clean, thermally conditioned air to the aircrew and required aircraft systems; avionics cooling; redundancy and emergency cooling provisions; cockpit sealing and pressurization; crew protection/comfort; subsystem compatibility; crew and air vehicle heat sink management; transparent area clearing provisions; air vehicle interface; aircraft performance and supportability effects. The contractor should determine the optimum breathing system required to allow the aircrew to perform within the entire operational envelope, under all normal and emergency mission environment.

5.2.4.3 NBC tests. Simulant tests should be performed to reproduce the NBC contamination environment relationship to the threat environment. Where NBC surety material (actual agent) tests are necessary, test methods should be described and their relationship to the simulant tests correlated. Any assumptions that were made in the interpretation of the NBC Survivability Criteria should be identified in the test plan along with their impact on the test design, procedures, and results. This includes, but is not limited to, assumptions concerning environmental conditions, system operational specifications, configurations, enclosures, methods of deployment, and methods of operation that are used in preparing for or reacting to an NBC
environment. In addition, the methodology uses for interpolation or extrapolation of tests results to an assessment of how the system responds to the specified environment should be provided in detail. Also, testing should be performed to demonstrate that the decontamination process will not degrade the material. The component should not exhibit any failures due to any form of corrosion or materials degradation, including but not limited to pitting, stress cracking, delaminating, cracking, or blistering when exposed to decontamination chemicals.

a. Component and subsystem tests. Live-agent testing of the NBC air purification system should be conducted to verify the system’s ability to deliver the required volume at or below the maximum permissible concentration specified. Sufficient component qualification data should be developed to assure that the HCPE system will function satisfactorily in ground run-up tests. Tests should be performed on aircraft components and materials separately and in their intended operating configuration to assure NBCCS.

b. NBC protection demonstration. Ground run-up/flight tests should be conducted to verify the overall installed HCPE system capability and performance. The following parameters, as a minimum, should be measured under flight conditions, hover and cruise: Airflow rates from ECS to cockpit and to aircrew microclimate cooling system; temperatures of ECS inlet and outlet, ram ambient, and cockpit; ECS inlet pressure; cockpit overpressure. Chemical simulant testing of the aircraft with the HCPE system should be conducted while (1) hovering over contaminated terrain and (2) flying or hovering in a simulant cloud, to assure that the infiltration concentration in the cockpit does not exceed the maximum permissible concentration specified. IPE to HCPE compatibility should be part of these tests. Tests for protection factor provided by the NBC IPE should be coordinated with and conducted by the US Army ECBC to insure required protection is provided during donning, wearing, doffing and subsystem interface.

5.2.4.4 Additional NBC survivability guidance. Additional guidance intended to be used in the preparation of performance specifications is contained in JSSG-2001 for air vehicles, JSSG-2009 for air vehicle subsystems and MIL-HDBK-516 for Airworthiness Certification Criteria. Another source of technical information is the Chemical, Biological, Radiological and Nuclear Defense Information Analysis Center (CBRNIAC), which is chartered by the DoD and managed by the DTIC.

5.3 Crashworthiness. The crashworthiness section of the survivability program should address, as a minimum, structural crashworthiness, crew and troop retention, injurious environment, post-crash fire potential, and evacuation.

5.3.1 Crashworthiness aircraft design. The aircraft system should achieve the level of crashworthiness specified in the system specification. A feature description, analysis and estimate of effectiveness should be provided for each of the applicable components and subsystems discussed in Appendix A. The overall crashworthiness of the aircraft should be verified in accordance with the analyses and tests specified in this handbook.
5.3.2 Crash avoidance and crashworthiness tests.

a. Crash avoidance. Effectiveness of the wire cutter installation should be demonstrated by swing tests whereby a representative aircraft impacts a 3/8 inch 7 strand messenger cable at 40 knots straight on and at 30° yaw equivalency for each cutter. Main and tail rotors should be subjected to dynamic impacts with tree limbs of the size and hardness they were designed to withstand.

b. Crashworthiness. Components, subsystems, and an aircraft should be subjected to crashworthiness tests per paragraph 10.0 of Appendix A, MIL-STD-1290A.

6. NOTES

6.1 Intended use. This document is intended to provide guidance on the preparation of an aircraft combat survivability program. While a survivability program should include both susceptibility and vulnerability subsets, the focus of this document is on vulnerability and its subsets including ballistic hardening/damage tolerance, directed energy hardening, nuclear hardening, and NBC hardening. The document’s stated application is rotary wing aircraft, however, the guidance could also be tailored for fixed-wing aircraft and unmanned air vehicles (UAV), including the air or ground control station.

6.2 Information documents. The documents listed in Appendix B are references, but are not specifically cited within this handbook.

6.3 International standardization agreements. Certain provisions of this document are the subjects of international standardization agreements. Examples include QSTAG 244, QSTAG 1031, STANAG 2133(SD6), and STANAG 4145 for NBC analysis and criteria. When preparing program requirements or statements of work, care should be taken to accommodate any required international standardization agreements.

6.4 Subject term (key word listing).

Aircraft survivability
Aircraft survivability equipment
ASE
Helicopter survivability
Susceptibility
Vulnerability
Vulnerability hardening
Ballistic hardening
Ballistic damage tolerance
Ballistic survivability
NBC contamination survivability
NBCCS
Directed energy hardening
Nuclear hardening
NBC hardening
Crashworthiness
Aircraft crash resistance
APPENDIX A – GUIDANCE ON AIRCRAFT CRASH SURVIVABILITY

A.1 SCOPE

A.1.1 Scope. This appendix provides guidance on aircraft crash survivability elements.

A.2 CRASH SURVIVABILITY ELEMENTS. The six main overall crashworthiness survivability elements in the design of the aircraft system and some suggested details to be considered for each element are also presented below.

A.2.1 Crew retention system.

A.2.1.1 Vertical energy absorption capacity. A seat bucket energy-absorber with a minimum 12-inch stroke should be provided unless a modernization/retrofit airframe makes this impractical. In such case, a cost/benefit analysis should be conducted for less stroke length.

A.2.1.2 Restraint webbing geometry and strength. The minimum strengths and optimum widths and thickness of the lap belt, shoulder and tiedown strap should conform to JSSG-2010-7, Table VII.

A.2.1.3 Seat strength. The seat longitudinal, lateral and vertical static strength should be in accordance with JSSG-2010-7, Table IX.

A.2.1.4 Castings. Absence of Castings in Stressed Areas.

A.2.1.5 Shoulder strap pull-off angle. The shoulder strap guide should be located at 27± .5 inches above the seat cushion and not permit more than ½ inch lateral movement.

A.2.1.6 Lap belt angle to seat cushion. The lap belt centerline should project an angle of 45-55 degrees in profile with respect to the seat cushion. The centerline should be 1.5-2.0 inches forward of the seat intersection with the seat cushion.

A.2.1.7 Lap belt tiedown strap. The lap belt should be retained in place on the pelvis by a tiedown strap. Preferably, the strap should be located on the seat pan centerline between 14 and 15 inches forward of the seat reference point.

A.2.1.8 Inertia reel type. All aircraft should utilize a reel conforming to MIL-R-8236, MA-6, except that the ultimate strength of the inertia reel assembly should be 5000 lbs. minimum while statically loading the lead-in webbing.
A.2.1.9 Depth of structure between floor and belly. Generally, a fuselage of circular cross-section, with a crushable depth of two (2) feet minimum between the floor and the belly skin is ideal.

A.2.2 Troop retention system. The crashworthy survivability design requirements are identical to that for the crew retention system with the following exceptions:

A.2.2.1 Restraint webbing geometry and strength. Same as crew retention criteria with exception that a lap belt tiedown strap is not required. Also see USAAMRDL TR 75-10.

A.2.2.2 Seat strength. Seat longitudinal and lateral strength requirements should be in accordance with MIL-S-85510.

A.2.3 Post-crash fire potential.

A.2.3.1 Spillage control.

a. Fuel containment – the location of the fuel tank and construction techniques are very important design considerations affecting tank vulnerability and aircraft survivability. Smooth contoured shapes for the tanks are preferred as well as crash resistant material per MIL-DTL-27422.

b. Oil and hydraulic fluid containment – the location of the tanks, construction, and tiedown techniques are very important design considerations affecting vulnerability and survivability. Cellular construction is preferred over bladder and sheet metal.

c. Flammable fluid lines – flexible type and MIL-H-83796 construction is preferred. The routing of fuel lines is an important consideration. Breakaway fittings or self-sealing breakaway valves should be installed at strategic locations throughout the system including each line that enters or exits the fuel tank.

d. Firewall – the firewall should function as a shield between crash induced fluid spillage and the various engine ignition sources.

e. Fuel flow interrupters – very desirable, to interrupt the flow of spilled flammable fluids.

A.2.3.2 Ignition control.

a. Induction and exhaust flame locations
b. Location of hot metals and shielding

c. Engine location and tiedown strength

d. Battery location and tiedown strength

e. Electrical wire routing

f. Boost pump location and tiedown strength

g. Inverter location and tiedown strength

h. Generator location and tiedown strength

i. Lights location and tiedown strength

j. Antenna location and tiedown strength.

A.2.4 Basic airframe crashworthiness.

A.2.4.1 Crushing of occupied areas. The aircraft should have the ability to withstand a 20 fps longitudinal impact into a rigid abutment without crushing the pilot and copilot stations to an extent that would preclude a livable volume or crew evacuation and at 40 fps without crushing the passenger/troop compartment by more than 15 percent.

A.2.4.2 Absence of “plowing” tendency. The nose and belly of the aircraft should have a smooth contour with structural members of sufficient strength underneath to prevent it from plowing a furrow in the earth subsequent to a nose down impact in soil from “run-on” approach speeds.

A.2.4.3 Resistance to longitudinal impact loads. The primary objective is to provide sufficient strength to prevent the roof of the aircraft from moving forward and downward with respect to the floor of the aircraft. Enough wall structure must be available on either side of the aircraft to prevent collapse due to inadequate shear strength. In this respect, a fuselage with many large openings is undesirable. Continuous beams running from the nose of the aircraft under the floor for the entire length of the occupied section are preferable since this type design will probably prevent the floor from buckling. Ensure that mass items are restrained to the load levels specified in MIL-STD-1290A.

A.2.4.4 Resistance to vertical impact loads.

a. The structure must not collapse due to vertical impact loads of paragraph 5.1.2.1 of MIL-STD-1290A.
b. If the engine and transmissions are located over the cabin or just aft of the cabin, the design tiedown strength should not be less than ±20G in the longitudinal and +20/-10 in the vertical direction and ±18G in the lateral direction (applied separately) to prevent cabin penetration. In addition, these mass items require a simultaneous tri-axial load evaluation in accordance with MIL-STD-1290A. Regardless of tiedown strength, the fuselage shell should contain peripheral frames at a close spacing in order that a maximum amount of energy is absorbed before a mass will penetrate the structure.

A.2.4.5 Resistance to lateral and roll-over impact loads. The probability of cabin collapse during a roll-over or lateral impact as defined in MIL-STD-1290A should be provided. A circular fuselage with few large openings will have maximum integrity during a roll-over. If the entire side of the cabin consists of a door, this structure will be very weak.

A.2.4.6 Landing gear vertical force attenuation. The landing gear should be analyzed for its energy absorbing capability in both the extended and retracted modes (as applicable).

a. At the 42 fps vertical impact condition, the extended landing gear should decelerate a fully loaded aircraft to a vertical sink speed no greater than 35 fps prior to fuselage contact, thus assuring full functioning of the landing gear prior to its collapse.

b. With gear retracted, the design should be such that the system energy absorption requirement of MIL-STD-1290A, Table I is satisfied.

c. The landing gear system should have the pitch and roll tolerance capability (both gear down and gear up) stated in MIL-STD-1290A.

d. An energy absorbing device should be provided to minimize loads transferred to the tail boom in nose-high landings.

A.2.4.7 Landing gear location. Analyze the damage which will be caused by this large mass as it is displaced during a crash. For example, if the gear is located directly under the cabin floor, the probability of its being driven upward into the occupiable area should be considered.

A.2.4.8 Effect of blade strike. Analyze whether the design precludes rotor failure and transmission displacement into occupiable space when the main rotor blades impact into a rigid object (defined in the system spec) at operational rotor speed. Analysis must show that transmitted forces from such an impact will not cause main blade separation from the rotor hub nor separation of the hub from the rotor shaft, nor separation of rotor shaft from the transmission. The analysis must also show that the blade’s plane of rotation is not displaced sufficiently to enter occupied areas of the helicopter.
A.2.4.9  **Effect of fuselage fracture/separation.** A primary consideration is the manner in which the fuselage fails due to a load perpendicular to its longitudinal axis. If it appears obvious that the break in a fuselage will occur underneath a seat row, it is an undesirable design.

A.2.5  **Evacuation.**

A.2.5.1  **Ease and reliability of exit operation.** Should be simple to operate with a "single motion" jettison feature on all doors. The possibility of jamming during a crash due to fuselage distortion should be remote and there should be equal distribution of emergency exits throughout aircraft to insure that all passengers move about the same distance from their seats to an exit.

A.2.5.2  **Ratio of usable exits to occupants.** When computing a ratio, include only those exits that are available to those occupants. For example, do not include cockpit exits in the ratio for cabin occupants. Assign a rating to this ratio which reflects an evacuation time of 30 seconds desired for all occupants. It is realized that this is a difficult requirement, but it is realistic when postcrash fire is considered.

A.2.5.3  **Identification of exits.** Internal emergency markings should conform to TM 55-1500-345-23.

A.2.5.4  **Availability of exits in rolled aircraft.** Use the above ratio considering the aircraft rolled on either side, thereby blocking a certain number of exits. Take into account the size of the available exits and the height above the opposite wall. Does the occupant have to reach too high to climb up and out of an exit?

A.2.5.5  **Emergency lighting.** Impact switch (G limit) or hand operated combination is preferred. It must have enough retention strength and an independent power supply.

A.2.6  **Injurious environment.**

A.2.6.1  **Proximity of cockpit control panels and other structure.** Cockpit occupant should not be able to contact controls and panels when restrained. If shoulder harness allows lateral movement the structure that can be contacted should be determined. Analyze these throughout the adjustment range of the seat, as well as the stroke of the seat during a crash. The cyclic stick threat should be minimized with stroking type seats.

A.2.6.2  **Retention of interior equipment.** The tiedown design strength of all mass items which would pose a hazard to personnel during a crash should conform to MIL-STD-1290A.
A.2.6.3 Anti-torque pedal area. The possibility of trapping the feet between rudder pedal and adjacent structure should be remote as well as the area that may collapse easily onto the feet during crash. The area under a stroking seat should be blocked off to preclude trapping of feet.

A.2.6.4 Absence of injurious objects in cabin. There should be no sharp corners and protrusions in the vicinity of the seated occupants and head impact protection provisions should conform to paragraph 5.2.3.1 of MIL-STD-1290A.
APPENDIX B – RELATED PUBLICATIONS AND INFORMATION

B.1 SCOPE

B.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.

B.2 APPLICABLE DOCUMENTS

SPECIFICATIONS

DEPARTMENT OF DEFENSE

MIL-A-8860  Airplane Strength and Rigidity, General Specification for
MIL-A-8866  Airplane Strength and Rigidity Reliability Requirements, Repeated Loads, Fatigue and Damage Tolerance
MIL-A-12560  Armor Plate, Steel, Wrought, Homogeneous
MIL-DTL-46100  Armor Plate, Steel, Wrought, High Hardness
MIL-PRF-46103  Armor: Lightweight, Composite
MIL-DTL-46593  Projectile, Calibers .22, .30, .50, and 20mm Fragment-Simulating
MIL-DTL-46077  Armor Plate, Titanium Alloy, Weldable
MIL-DTL-62474  Laminate: Aramid-Fabric-Reinforced, Plastic

STANDARDS

DEPARTMENT OF DEFENSE

MIL-STD-129  Military Marking for Shipment and Storage
MIL-STD-1411  Inspection and Maintenance of Compressed Gas Cylinders

HANDBOOKS

DEPARTMENT OF DEFENSE

ADS-51-HDBK  Rotorcraft and Aircraft Qualification (RAQ) Handbook
ADS-65-HDBK  Data and Test Guidance for Qualification of Sensor Systems
MIL-HDBK-17  Composite Materials Handbook, Volume 1 thru 5
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ARMY REGULATIONS

AR 73-1 Test and Evaluation Policy
AR 380-86 Classification of Chemical Warfare, Chemical and Biological Defense, and Nuclear, Biological, and Chemical Contamination Survivability Information

OTHER DEPARTMENT OF DEFENSE DOCUMENTS

DEFENSE SCIENCE BOARD


DEFENSE NUCLEAR AGENCY

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

DEFENSE TECHNICAL INFORMATION CENTER (DTIC)

DTIC Guide The DTIC Review, How To Get It (AD-M001460)
(http://stinet.dtic.mil/dticrev/v6n2ntro.html)

OTHER US ARMY DOCUMENTS

FM 3-11.14 Multiservice Tactics, Techniques, and Procedures for Nuclear, Biological, and Chemical Vulnerability Assessment

TM 43-0001-27 Army Ammunition Data Sheets, Small Caliber Ammunition FSC 1305

US ARMY AVIATION SYSTEMS COMMAND (USAAVSCOM)

TR 89-D-22A thru E Aircraft Crash Survival Design Guide, (DTIC ADA-218434/5/6/7/8)

US ARMY MEDICAL MATERIEL DEVELOPMENT ACTIVITY

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DTIC AD-A219 869 Nuclear and NBC Contamination Survivability of Medical Materiel

US ARMY RESEARCH, DEVELOPMENT AND ENGINEERING COMMAND

RDECOM TR 10-D-25 Preliminary Full Spectrum Rotary Wing Crashworthiness Criteria

US ARMY RESEARCH LABORATORY (USAARL)

ARL-CR-594 Advanced Metals and Ceramics for Armor and Anti-Armor Applications, High-Fidelity Design and Processing of Advanced Armor Ceramics
ARL-TR-1045 Vulnerability Risk Assessment

US ARMY TEST AND EVALUATION COMMAND (USATECOM)

ITOP 4-2-805 Projectile Velocity and Time of Flight Measurements
TOP 1-2-612 Nuclear Environment Survivability (AD-A278230)
TOP 2-2-710 Ballistic Tests of Armor Materials
TOP 2-2-722 Fragment Penetration Tests of Armor
TOP 8-2-510 NBC Contamination Survivability, Large Items Exteriors

INTERNATIONAL DOCUMENTS

AEP-7 Nuclear, Biological and Chemical (NBC) Defense Factors in the Design, Testing and Acceptance of Military Equipment (NATO unclassified)
NIAG SG.83 Study on Reducing Vulnerability of Helicopters to Ground Attack, Especially Rocket-Propelled Grenades (RPG)
QSTAG 244 Nuclear Hardening Criteria for Military Equipment
QSTAG 1031 Consistent Sets of Nuclear Hardening Criteria for Classes of Equipment (U)
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STANAG 2133(SD6) Vulnerability Analysis of Chemical and Biological Hazards
STANAG 4145 Nuclear Survivability Criteria for Armed Forces Material and Installations ACP-14
STANAG 4477 Specification for Paints and Paint Systems, Resistant to Chemical Agents and Decontaminations, for the Protection of Aerospace Military Equipment

OTHER DOCUMENTS


CODE OF FEDERAL REGULATIONS

DATA ITEMS

DI-NDTI-81284 Test and Evaluation Program Plan (TEPP)
DI-QCIC-80553 Acceptance Test Plan

DEPARTMENT OF TRANSPORTATION

49 CFR 173.301 General Requirements for Shipment of Compressed Gases in Cylinders and Spherical Pressure vessels

B.3 OTHER SOURCES OF INFORMATION

Additional technical information concerning aircraft combat survivability can be obtained from the following DoD Information Analysis Centers on-line at http://iac.dtic.mil:

SURVIAC Survivability/Vulnerability Information Analysis Center on-line at http://www.bahdayton.com/surviac/

CBRNIAC Chemical, Biological, Radiological, and Nuclear Information Analysis Center on-line at http://www.cbrniac.army.mil/
AMMTIAC

Advanced Materials, Manufacturing, and Testing
Information Analysis Center on-line at
http://ammtiac.ailionscience.com/
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CONCLUDING MATERIAL

Custodians: Army – AV

Preparing activity: Army – AV
(AED Task 93039)