ADS-44-HDBK
3 February 2006

SUPERSEDING
ADS-44
APRIL 1990
CAGE Code 81996

AERONAUTICAL DESIGN STANDARD

HANDBOOK

ARMAMENT AIRWORTHINESS QUALIFICATION

FOR

U.S. ARMY AIRCRAFT

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Do not cite this document as a requirement.

AMSC N/A **FSC 10GP**

DISTRIBUTION STATEMENT A. Approved for public release, distribution is unlimited.

FOREWORD

1. This handbook is approved for use by the U.S. Army Research, Development and Engineering Command and is available for use by all Departments and Agencies of the Department of Defense.

2. This handbook is for guidance only. Do not cite this document as a requirement. If it is, the contractor does not have to comply.

3. This handbook provides guidance for airworthiness qualification of armament on U.S. Army aircraft. Compared to the ADS-44 it supersedes, this handbook provides a more comprehensive discussion of the Army's armament airworthiness qualification process and the related analysis, test, and documentation requirements. It is intended as a reference guide for military and civilian personnel who are preparing program documents such as Airworthiness Qualification Plans and statements-of-work. It can be used as a tutorial for persons unfamiliar with the Army's armament airworthiness qualification process. It is not intended as a design guide. This handbook also includes format changes to comply with MIL-STD-967, Department of Defense Standard Practice for Defense Handbooks Format and Content.

4. This handbook was developed as an Army supplement to tri-service documents on armament and stores compatibility. The reader is encouraged to refer to the tri-service documents listed in the Applicable Documents paragraph, especially MIL-STD-1289, MIL-HDBK-244, MIL-HDBK-1763 and JSSG-2001B. Any contradictions of this handbook with the tri-service documents should be brought to the attention of the office identified in paragraph 6. Guidelines for the use of international standardization agreements are not provided in this handbook.

5. Comments or questions should be addressed to Commander, U. S. Army Research, Development and Engineering Command, Aviation and Missile Research, Development and Engineering Center, ATTN: AMSRD-AMR-SE-TD-ST, 5400 Fowler Road, Huntsville, AL 35898-5000 or emailed to WilliamSmith@rdec.redstone.army.mil. Since contact information can change, you may want to verify the currency of this address information using the ASSIST Online database at http://assist.daps.dla.mil/online/start/.

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

U.S. Army Aviation and Missile Research, Development and Engineering Center
Redstone Arsenal
ATTN: AMSRD-AMR-AE-S-W
Building 4488, Room C-316
Huntsville, AL 35898-5000
Telephone: Commercial (256) 313-8465

AERONAUTICAL DESIGN STANDARD HANDBOOK

ARMAMENT AIRWORTHINESS QUALIFICATION FOR U.S. ARMY AIRCRAFT

FUNCTIONAL DIVISION: ______________________
David B. Cripps
Chief, Mission Equipment Division
Aviation Engineering Directorate
Research, Development, and Engineering Command

SUBMITTED BY: ______________________
Dr. William D. Lewis
Acting Director of Aviation Engineering
Research, Development, and Engineering Command

APPROVED BY: ______________________
Tony D. Hodgens
AMCOM and PEO Aviation
Standards Executive

DATE: ______________________

Certification Record

Board date:

Document Identifier and Title: ADS-44-HDBK, Armament Airworthiness Qualification for U.S. Army Aircraft

Rationale for Certification:

Decision:

General Type	Decision (√)	Certification
Specification		Performance
		Detail
Standard		Interface Standard
		Standard Practice
		Design Standard
		Test Method Standard
		Process Standard
Handbook	√	Handbook (non-mandatory use)
Alternative Action		

	Concur	Non-Concur	Date
Division Chief, Mission Equipment Division David B. Cripps	DC		1/23/2006
AMCOM Standardization Branch Chief William J. Smith	√ WJS		1/10/2006
Acting Director, Aviation Engineering			
Dr. William D. Lewis	WDL		1/30/2006
AMCOM and PEO Aviation, Standards Executive Tony D. Hodgens	TDH		2/3/06

CONTENTS

FIGURES

TABLES

APPENDICES

ARMAMENT AIRWORTHINESS QUALIFICATION FOR U.S. ARMY AIRCRAFT

1. SCOPE

1.1. Scope. This handbook provides guidelines for requirements to qualify an armament system for use on-board a U.S. Army air vehicle. Air vehicles include rotorcraft, fixed-wing aircraft, and unmanned aerial vehicles (UAV). Air vehicle and air platform are synonymous. The terms "armament" and "weapon" are used interchangeably in this handbook. Weaponization includes the addition of armament to the air vehicle and integration of the air vehicle and armament. The armament includes, as a minimum, explosive devices, guns, guided and unguided rockets, missiles, dispensed munitions, bombs, and directed energy weapons such as anti-sensor weapons and lasers. Additionally, the entire air vehicle is considered a weapon if there exists a purpose or intent to fly or direct the air platform into a target; e.g. a UAV. An armament that is fired from an airborne vehicle is normally considered to be a subsystem of the air vehicle. This document provides the requirements to fully qualify armament on a U.S. Army aircraft. See ADS-45-HDBK for the data and tests that are needed to obtain an Airworthiness Release (AWR) or Contractor Flight Release (CFR) for the testing of armament on U.S. Army aircraft. The Army organization that assesses the airworthiness, when the weapon system is mounted or used on an Army aircraft, is the Aviation Engineering Directorate (AED) in the Aviation and Missile Research, Development and Engineering Center (AMRDEC) at Redstone Arsenal, Alabama. This is so even when another agency is the proponent or materiel developer for a weapon such as a gun or ammunition.

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. 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, cited in the solicitation.

JSSG-2001B	Air Vehicle
JSSG-2010-7	Crew Systems, Crash Protection Handbook
MIL-A-8591	Airborne Stores, Suspension Equipment and Aircraft-Store Interface (Carriage Phase); General Design Criteria

MIL-E-7016	Electrical Load and Power Source Capacity, Aircraft, Analysis of
MIL-STD-331	Environmental and Performance Tests for Fuze and Fuze Components
MIL-STD-461	Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment
MIL-STD-464	Electromagnetic Environmental Effects Requirements for Systems
MIL-STD-704	Aircraft Electric Power Characteristics
MIL-STD-810	Test Method Standard for Environmental Engineering Considerations and Laboratory Tests
MIL-STD-882	Standard Practice for System Safety
MIL-STD-1289	Airborne Stores, Ground Fit and Compatibility Requirements
MIL-STD-1316	Safety Criteria for Fuze Design
MIL-STD-1425	Safety Design Requirements for Military Lasers and Associated Support Equipment
MIL-STD-1466	Safety Criteria and Qualification Requirements for Pyrotechnic Initiated Explosive (PIE) Ammunition
MIL-STD-1472	Human Engineering
MIL-STD-7080	Electric Equipment, Aircraft, Selection and Installation
MIL-HDBK-240	Hazards to Electromagnetic Radiation Ordnance (HERO) Test Guide
MIL-HDBK-244	Guide to Aircraft/Stores Compatibility
MIL-HDBK-764	System Safety Engineering Design Guide for Army Materiel
MIL-HDBK-799	Fire Control Systems, General
MIL-HDBK-1512	Electroexplosive Subsystems, Electrically Initiated, Design Requirements and Test Methods
MIL-HDBK-1763	Aircraft/Stores Compatibility: Systems Engineering Data Requirements and Test Procedures

MIL-HDBK-2069	Aircraft Survivability

Copies of the above specifications, standards, and handbooks are available from the Standardization Document Desk, 700 Robbins Avenue, Building 4D, Philadelphia, PA 19111-5094 or online at the following web site: http://assist.daps.dla.mil/quicksearch/)

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 70-62	Airworthiness Qualification of U.S. Army Aircraft Systems
AR 385-16	System Safety Engineering and Management
AR 385-63	Range Safety
ADS-1B-PRF	Rotorcraft Propulsion System Airworthiness Qualification Requirements Ground and Flight Test Surveys and Demonstrations
ADS-20-HDBK	Armament and Fire Control System Survey for Army Aircraft
ADS-33E-PRF	Handling Qualities Requirements for Military Rotorcraft
ADS-37A-PRF	Electromagnetic Environmental Effects (E3) Performance and Verification Requirements
ADS-45-HDBK	Data and Test Requirements for Airworthiness Release for U.S. Army Helicopter Armament Testing (Guns, Missiles, Rockets)
ADS-50-PRF	Rotorcraft Propulsion Performance and Qualification Requirements and Guidelines
ADS-51-HDBK	Rotorcraft & Aircraft Qualification Handbook
ADS-62-SP	Data and Test Requirements for Airworthiness Release for Helicopter Sensor Data and Testing Requirements in Development Phase
ADS-63-SP	Radar System Airworthiness Qualification and Verification Requirements
ADS-65-HDBK	Airworthiness Release and Verification for Electro-optical and Sensor Systems

ADS-66-HDBK	Guidance for Data for Safety-of-Flight Airworthiness Release for Helicopter Aircraft Survivability Equipment (ASE)
Aviation Policy Memo 03-02	Memo, Program Executive Officer (PEO), mail symbol SFAE-AV-PI, Subject: Risk Management Process
FMASAP: 1-1	AMRDEC Software Engineering Directorate (SED), Software Engineering Evaluation System (SEES), Volume 5, Special Assessment Procedure for Software Failure modes, Effects and Criticality Analysis
FSQAP: 1-1	AMRDEC Software Engineering Directorate (SED), Software Engineering Evaluation System (SEES), Volume VI, Qualification Assessment Procedure for Flight Software Airworthiness
NAVAIRINST 13034.1B	Flight Clearance Policy for Manned Air Vehicles
Software System Safety Handbook	Joint Software System Safety Committee, Software System Safety Handbook, A Technical and Managerial Team Approach
SOP AE385-16-1	Airworthiness Impact Statement (AWIS)
TOP 7-2-513	Human Factors Engineering Testing of Aircraft Cockpit Lighting
TR-RD-TE-97-01	Electromagnetic Environmental Effects Criteria and Guidelines for EMRH, EMRO, Lightning Effects, ESD, EMP, and EMI Testing of US Army Missile Systems.

(Copies of the above specifications, standards, and handbooks are available from the U.S. Army AMRDEC's Aviation Engineering Directorate, Redstone Arsenal, Alabama 35898.)

2.3 Non-Government publications. The following documents form a part of this document to the extent specified herein.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS (ASME)

ASME Y14.100M	Engineering Drawing Practices

(Copies of the above specification may be obtained from ASME International, Three Park Avenue, New York, NY 10016-5990 or online at the following web site: http://store.asme.org)

INSTITUTE OF ELECTRICAL AND ELECTRONIC ENGINEERS (IEEE)

IEEE J-STD-016 Standard for Information Technology Software Life Cycle Processes Software Development

(Copies of the above specification may be obtained from the Institute of Electrical and Electronics Engineers Operations Center, 445 Hoes Lane, Piscataway, NJ 08854-1331 or online at the following web site: http://www.ieee.org)

SOCIETY OF AUTOMOTIVE ENGINEERS (SAE)

SAE AS50881 Wiring, Aerospace Vehicle

(Copies of the above specification may be obtained from the Society of Automotive Engineers, 400 Commonwealth Drive, Warrendale, PA 15096 or online at the following web site: http://www.sae.org)

INTERNATIONAL SOCIETY OF ALLIED WEIGHT ENGINEERS (SAWE)

SAWE RP7 Weight and Balance Control Data (for Airplanes and Helicopters) Society of Allied Weight Engineers Recommended Practice 7

(Copies of the above specification may be obtained from the Society of Allied Weight Engineers (SAWE), 5530 Aztec Drive, La Mesa, CA 91942-2110 or online at the following web site: http://www.sawe.org)

3. DEFINITIONS AND ACRONYMS

3.1. Definitions.

3.1.1. Aircraft. Any vehicle designed to be supported by air, being borne up either by the dynamic action of the air upon the surfaces of the vehicle, or by its own buoyancy. The term includes fixed and movable wing airplanes, helicopters, gliders, and airships, but excludes air-launched missiles.

3.1.2. Aircraft-store. Any device intended for internal or external carriage and mounted on aircraft suspension and release equipment, whether or not the item is intended to be separated in flight from the aircraft. Aircraft-stores are classified in two categories: expendable store and non-expendable store.

3.1.2.1. Expendable store. An aircraft store normally separated from the aircraft in flight such as a missile, rocket, bomb, nuclear weapon, mine, torpedo, pyrotechnic device, sonobuoy, signal underwater sound device, or other similar items.

3.1.2.2. Non-expendable store. An aircraft-store which is not normally separated from the aircraft in flight such as a fuel tank, electronics or gun pod, suspension rack or tow target.

3.1.3. Aircraft-stores compatibility. The ability of an aircraft, stores, stores management systems, and related suspension equipment to coexist without unacceptable effects of one of the aerodynamic, structural, electrical, or functional characteristics of the others under all flight and ground conditions expected to be experienced by the aircraft-store combination. A particular store may be compatible with an aircraft in a specific configuration, although not necessarily so with all pylons (or stations) under all conditions.

3.1.4. Airworthiness. A demonstrated capability of an aircraft or aircraft subsystem or component to function satisfactorily when used within prescribed limits.

3.1.5. Airworthiness qualification. Airworthiness qualification is defined as an analysis, design, test, and documentation process used to determine that an air vehicle system, subsystem, or component is airworthy. It is a progressive assessment process performed at the component, subsystem, and system levels to ensure that a system meets airworthiness criteria. The primary purpose of the airworthiness qualification process is to demonstrate that the air vehicle has the capability to function satisfactorily and safely when used within prescribed limits. The airworthiness qualification process will ensure that the armament is properly integrated into the air vehicle. In accordance with AR 70-62, the Commanding General, U.S. Army Aviation and Missile Command (AMCOM) is the approving authority for the airworthiness of Army aircraft for which AMCOM has engineering cognizance. The primary engineering role is delegated to the Aviation Engineering Directorate (AED) within the Aviation and Missile Research, Development and Engineering Center (AMRDEC). Collocated with AMCOM at Redstone Arsenal, Alabama, the AMRDEC is part of the U.S. Army Research, Development and Engineering Command (RDECOM).

3.1.6. Airworthiness Qualification Substantiation Report (AQSR). A document prepared at the end of an airworthiness qualification program. It is prepared by a Government organization which has engineering cognizance. Prepared IAW ADS-51-HDBK, the AQSR is a technical summary that describes the scope of the qualification and its results, including prescribed limits. It includes a compilation of each requirement indexed to its status of demonstrated compliance and references to the verifying technical substantiation (including analysis, inspections, drawings, modeling, simulations, test plans and reports, and any other relevant technical data). Its purpose is to provide a single document to trace the airworthiness qualification decision.

3.1.7. Airworthiness release (AWR). A technical document that provides operating instructions and limitations, and maintenance information necessary for safe flight operation of an air vehicle system, subsystem, and allied equipment. An AWR is required prior to operating a new air vehicle system or a fielded system that has undergone a major modification.

3.1.8. All-up-round (AUR). Any ordnance store that is completely assembled, both mechanically and electrically, and ready for installation on or in an aircraft for purposes of carriage and employment on a specific mission. An AUR has all mission-necessary sub-assemblies (such as guidance and control units, fins, fairings, and fuzes), associated hardware, and electrical cables installed and serviceable, as well as necessary pre-flight safety devices and any adaptation equipment that is normally fixed to the store. An AUR does not include items of suspension equipment (such as bomb racks or missile rails), externally mounted electrical cables which attach the store to the suspension equipment, or other items which are not separated with the store.

3.1.9. Ballistics. The science that deals with the motion, behavior, appearance, or modification of missiles, rockets, bullets, or other projectiles acted upon by propellants, wind, gravity, temperature, or any other modifying substance, condition, or force.

3.1.10. Ballistics, free-stream. A model of the weapon flight path from the time the weapon reaches steady state flight after release from the aircraft.

3.1.11. Ballistic trajectory. The trajectory traced after the propulsive force is terminated and the body is acted upon only by gravity and aerodynamic drag.

3.1.12. Carriage. The conveying of a store by an aircraft under all flight and ground conditions including taxi, take-off, and landing. The store may be located either external or internal to the aircraft. Carriage should include time in flight up to the point of complete separation of the store from the aircraft.

3.1.12.1. Carriage, asymmetrical. This term applies to the carriage of stores which can be unlike in shape, physical properties, or number with reference to the plane of symmetry.

3.1.12.2. Carriage, conformal (or tangential). The concept of packaging stores to conform as closely as practical to the external aircraft lines to reduce drag and obtain the best overall aerodynamic shape. Stores are generally carried in arrays, mounted tangentially to some portion of the aircraft, usually the bottom of the fuselage. It includes those arrangements made possible by weapon shapes configured for this purpose.

3.1.12.3. Carriage, multiple. Carriage of more than one store on any given piece of suspension equipment, such as bombs carried on a triple ejector rack (TER) or multiple ejector rack (MER).

3.1.12.4. Carriage, single. Carriage of only one store on any given station or pylon.

3.1.12.5. Carriage, symmetrical. An arrangement (loading) of identical stores on either side of a dividing line or plane (usually the longitudinal axis) as related to a given aircraft, suspension equipment, or weapons bay.

3.1.12.6. Carriage, tandem. Carriage of more than one store on any given piece of suspension equipment such that one store is behind the other.

3.1.13. Carry-on equipment. Any portable device that can be used on-board by crew or passenger for the purpose of its operation in-flight.

3.1.14. Certification agency. The service office or organization having the responsibility for issuing the technical manuals, and changes thereto, which constitute store certification (e.g., Naval Air Systems Command (NAVAIR), Air Force aircraft System Program Office (SPO), or Army Aviation and Missile Command (AMCOM). The AMCOM Commander delegates the store certification role to the AMRDEC's Aviation Engineering Directorate (AED), which is collocated with AMCOM.

3.1.15. Certification of a store. A U.S. Navy and Air force term that is equivalent to the Army's airworthiness qualification of a store.

3.1.16. Circular error probable (CEP). A measure of dispersion to describe accuracy whose value is equal to the radius of a circle centered on the target or mean point of impact and contains 50 percent of the population impact points. The CEP is usually given in meters.

3.1.17. Contractor Flight Release (CFR). A CFR is a technical document and transmittal letter, signed by the Government, which authorizes an element of industry to operate an Army air vehicle of an approved configuration within prescribed limitations by established procedures. A CFR is used when the Government holds ground and flight risk and a contractor pilot is pilot-in-command. When a CFR is issued, the air vehicle is believed to be safe, and that no undue risk is being taken on the part of the flight crew, the contractor's management, or the Government.

3.1.18. Critical conditions. A combination of pertinent operational parameters expected to be encountered by an aircraft, store, or combinations thereof; upon which the design or operational limits of the aircraft, stores, or portions thereof are based.

3.1.19. Degrade: Any decomposition to a system that prevents or causes it to not perform in its intended manner.

3.1.20. Dispense. The intentional separation from an airborne dispenser of devices, weapons, submunitions, liquids, gases, or other matter, for purposes of employment of the items being dispensed.

3.1.21. Dispersion. A scattered pattern of hits around the mean point of impact (MPI) of bombs and projectiles dropped or fired under identical conditions.

3.1.21.1. Dispersion, aircraft. Refers to the errors that contribute to the overall ballistic error budget such as sensor errors, on-board avionics errors, timing delays, rotor downwash, fire control, or variation in rack ejection forces.

3.1.21.2. Dispersion, ballistic. Weapon-to-weapon variation in the free-stream ballistic flight path which is attributed to manufacturing tolerances such as mass and physical properties, and accidental misalignments occurring during assembly and handling of the weapon.

3.1.21.3. Dispersion, system. The total dispersion due to the weapon, aircraft and weather effects such as wind.

3.1.22. Electromagnetic compatibility (EMC). The capability of electrical and electronic systems, equipment, and devices to operate in their intended electromagnetic environment within a defined margin of safety, and at design levels of performance, without suffering or causing unacceptable degradation as a result of electromagnetic interference.

3.1.23. Ejection. Separation of a store with the assistance of a force imparted from a device, either external or internal to the store.

3.1.24. Electromagnetic environment effects (E3). The impact of the electromagnetic environment upon the operational capability of military forces, equipment, systems and platforms. It encompasses all electromagnetic disciplines, including electromagnetic compatibility; electromagnetic interference; electromagnetic vulnerability; electromagnetic pulse; hazards of electromagnetic radiation to personnel, ordnance and volatile materials; and natural phenomena effects of lightning and precipitation static (p-static).

3.1.25. Electromagnetic interference (EMI). Any electromagnetic disturbance, whether intentional or not, that interrupts, obstructs, or otherwise degrades or limits the effective performance of electronic or electrical equipment.

3.1.26. Employment. The use of a store for the purpose and in the manner for which it was designed, such as releasing a bomb, launching a missile, firing a gun, or dispensing a submunition.

3.1.27. Fire. The operation of a gun, gun pod, or similar weapon, so as to cause a bullet or projectile to leave through the barrel.

3.1.28. Fire control. Fire control includes any hardware and software that is necessary to safely and effectively manage, aim, launch/fire/dispense and conduct post-launch control of munitions. Fire control usually involves the fire control computer or weapons processor, stores management system, sighting and designation subsystems, interfacing sensors, aircraft data bus, fire control data links, boresight equipment, cockpit displays, symbol generator and control panels/switches. General guidance on fire control systems can be found in MIL-HDBK-799.

3.1.29. Fire control timeline. The end-to-end fire control response time from target selection to weapon launch. The time starts when the crew selects a target being tracked to the time the munition leaves the aircraft. The timeline includes target tracking time, computation time for fire control solution generation, weapon arming, aligning the aircraft or weapon to the target, trigger pull and munition launch time.

3.1.30. Flight clearance/clearance recommendation. Typically associated with the Air Force and Navy. An authorization for flight, after appropriate engineering analysis has been made, that an aircraft-store combination would not pose an unacceptable risk for a specific, limited, purpose such as Development, Test and Evaluation (DT&E) or Initial Operational Test and Evaluation (IOT&E). The flight clearance will specify flight limits and remarks for operation for the loading configuration required on a specific aircraft, or group of aircraft, and will remain valid only for a specified finite period of time for a specific user or group of users. This term is equivalent to the Army term AWR.

3.1.31. Free flight (of a store). The movement or motion of a store, either powered or unpowered, through the air after separation from an aircraft.

3.1.32. G-jump. The change in normal load factor that results from store release, due to the combined effects of ejection force, dynamic response, and instantaneous aircraft gross weight decrease.

3.1.33. Hangfire or hung store. Any store that does not separate from the aircraft or launcher when actuated for employment or jettison.

3.1.34. Integrated Flight and Fire Control (IFFC). The coupling of the flight control system to the fire control system to improve combat effectiveness. When selected by the pilot, the IFFC aligns the aircraft and/or weapon system with the target. Once the weapon has locked onto the target, the flight control system assists the pilot in maintaining the target within the weapon system's engagement envelope. Consisting primarily of software, the IFFC relies on mission tailored control laws and cueing symbology. The IFFC reduces fire control timelines. To ensure flight safety, the IFFC must be capable of being overridden by the crew at any time.

3.1.35. Interim Statement of Airworthiness Qualification (ISAQ). A document establishing a preliminary or provisional qualification status and an airworthiness release when issued in conjunction with an AQSR. Examples of occasions when an ISAQ may be issued in lieu of an SAQ are when testing is not completed, when limited production has been started, when an item is found to be safe but with some performance shortcomings, or after qualification is essentially complete but pending final documentation approval. See Statement of Airworthiness Qualification (SAQ).

3.1.36. Interval. The elapsed time between the separation of a store and the separation of the next store. The minimum release interval is the shortest allowable or usable interval between successively released stores that will allow safe separation of the stores from the aircraft.

3.1.37. Jettison, emergency. The intentional simultaneous, or nearly simultaneous, separation of all stores or suspension equipment from the aircraft in a preset, programmed sequence.

3.1.38. Jettison, selective. The intentional separation of stores or suspension equipment, or portions thereof such as expended rocket pods that are no longer required.

3.1.39. Launch. The intentional separation of a self-propelled store such as a missile, rocket, or target- drone for purposes of employment of the store.

3.1.40. Mean point of impact (MPI). A point which has as its range/deflection coordinates the arithmetic mean of the range and deflection coordinates of the impact points.

3.1.41. Mini-weapons survey (MWS). A limited set of analyses and tests that substantiate that a modification to an existing system has not adversely affected safety, airworthiness, or the operational capability. The survey includes limited weapons firing. Primary interests are compatibility and "safe functionality". If accuracy is assessed, it is done so from a qualitative perspective rather than quantitative statistical.

3.1.42. Misfire. A failure to fire, shoot or launch a munition when the trigger or switch is activated.

3.1.43. Mixed load. The simultaneous carriage or loading of two or more unlike stores on a given aircraft.

3.1.44. Multiple. The number of stores released simultaneously from aircraft store stations.

3.1.45. Operating limitation. Carriage, employment, and jettison envelopes detailing acceptable airspeed, mach, altitude, g, roll rate, wing sweep, speed brake operation, delivery angles, release modes, and minimum release intervals as required for a specified aircraft/stores configuration.

3.1.46. Pairs. The simultaneous separation of stores from two separate stations on an aircraft.

3.1.47. Ripple (or train). The separation of two or more stores one after the other in a given sequence at a specified interval.

3.1.48. Quantity. The total number of stores selected for release by an aircraft.

3.1.49. Release. The intentional separation of a free-fall store from its suspension equipment, for purposes of employment of the store.

3.1.50. Safe arming/safe arming separation. The selection of a minimum safe arming distance or fuze arm time setting that will provide the delivery aircraft acceptable protection from weapon fragmentation if early detonation should occur.

3.1.51. Safe escape. Safe escape is the set of flight conditions (altitude, speed and engagement range) that will provide the delivery aircraft acceptable protection from munition detonation downrange.

3.1.52. Safe separation. The parting of a store from an aircraft without exceeding the design limits of the store or the aircraft or anything carried thereon, and without damage to, contact with, or unacceptable adverse effects on the aircraft, suspension equipment, or other store both released and unreleased.

3.1.53. Salvo. The simultaneous separation of stores from multiple stations on an aircraft.

3.1.54. Separation. The terminating of all physical contact between a store and an aircraft; or between a store and suspension equipment.

3.1.55. Separation effects. A model of the weapon motion from the moment it is released until oscillations caused by the aircraft flow field are dampened. They are currently modeled as a function of release variables such as velocity/Mach number, normal acceleration, angle of attack, and dynamic pressure. These coefficients may be incorporated into the ballistic tables and/or into a separation effects algorithm in the aircraft ballistic operational flight program (OFP). The coefficients used in the separation effect algorithm may result in aircraft velocity adjustments used in the air-to-surface trajectory calculations or may incorporate changes in the mode of trajectory calculation.

3.1.56. Statement of Airworthiness Qualification (SAQ). A final document establishing full qualification status and airworthiness release that is issued in conjunction with the AQSR normally completing an airworthiness qualification program. The SAQ contains a description of the configuration of the air vehicle, operating instructions and procedures, limitations and restrictions, and requirements for sustaining airworthiness. An SAQ may be issued temporarily as an interim SAQ (ISAQ). See ISAQ.

3.1.57. Store. See aircraft-store above.

3.1.58. Submunition. Any munition that, to perform its task, separates from a parent munition.

3.1.59. Suspension equipment. All aircraft devices such as racks, adapters, missile launchers, and pylons used for carriage, employment and jettison of aircraft stores.

3.1.60. Technical manuals. Manuals that contain the approved data required for the loading, carriage and employment of a store. Pertinent manual types include the following:

3.1.60.1. Army Technical Manuals (TMs).

a. TM 55-1520-XXX-XXX - Aircraft Technical Manuals
b. TM 55-1520-XXX-10 - Operators Manual
c. TM 55-1520-XXX-23 - Maintenance Manual
d. TM 55-1520-XXX-23P - Parts Manual
e. TM 9-XXXX-XXX-XX - Armament Technical Manuals

3.1.60.2. Air Force Technical Orders (TOs).

a. Aircraft - 1 TO - Flight Manual
b. Aircraft - 2 TO - Aircraft Maintenance Manual
c. Aircraft - 5 TO - Basic Weight Checklist and Loading Data
d. Aircraft - 16 TO - Nuclear Weapons Loading Procedures
e. Aircraft - 25 TO - Nuclear Bombs Delivery Manual
f. Aircraft - 30 TO - Nuclear Missile Delivery Manual
g. Aircraft - 33 TO – Non-nuclear Munitions Loading Procedures
h. Aircraft - 34 TO – Non-nuclear Munitions Delivery Manual
i. Aircraft - 35 TO – Non-munitions Stores Installation and Removal Procedures
j. Aircraft - 100 TO - Aircraft Modifications

3.1.60.3. Navy Technical Manuals.

a. NAVAIR 01-XXXXX-1 Flight Manuals
b. NAVAIR 01-XXXXX-1T Tactical Manuals

3.1.61. Warnings, Cautions, and Advisories (WCA). A term that describes the operating limitations, restrictions and advisory "Notes", "Cautions" and "Warnings" established through the System Safety Program. They are used in flight releases, technical manuals and aircraft software to warn or inform the crew.

3.1.61.1. Note. An operating procedure, practice, or condition that must be highlighted.

3.1.61.2. Caution. An operating procedure, practice, or condition which, if not strictly observed, could result in damage to or destruction of equipment, or minor injury to personnel.

3.1.61.3. Warning. An operating procedure, practice, or condition which, if not correctly followed, could result in severe injury to personnel or loss of life, or loss of a major system.

3.2 Acronyms and abbreviations.

ADS	Aeronautical Design Standard
AEC	Army Evaluation Center
AED	Aviation Engineering Directorate
AFCSS	Armament and Fire Control System Survey
AFSRB	Army Fuze Safety Review Board
AGL	Above Ground Level
AIL	Aircraft/Avionics Integration Laboratory
AMCOM	Aviation and Missile Command
AMRDEC	Aviation and Missile RDEC
AMSC	Acquisition Management Systems Control
AQP	Airworthiness Qualification Plan
AQS	Airworthiness Qualification Specification
AQSR	Airworthiness Qualification Substantiation Report
ARDEC	Armament RDEC
ASME	American Society of Mechanical Engineers
AUR	All Up Round
AWIS	Airworthiness Impact Statement
AWR	Airworthiness Release
c.g.	Center of Gravity
CDR	Critical Design Review
CDRL	Contract Data Requirements List
CE	Conducted Emissions

CEP	Circular Error Probable
CFE	Contractor Furnished Equipment
CFR	Contractor Flight Release
CPG	Copilot-Gunner
CS	Conducted Susceptibility
CSCI	Computer Software Configuration Item
CSU	Computer Software Unit
DEW	Directed Energy Weapon
DID	Data Item Descriptions
DoD	Department of Defense
DoDISS	Department of Defense Index of Specifications and Standards
E3	Electromagnetic Environmental Effects
EED	Electro-Explosive Device
EGI	Embedded Global Positioning System Inertial Navigation System
EID	Electrically Initiated Device
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
EMICP	Electromagnetic Interference Control Procedures
EMITP	Electromagnetic Interference Test Procedures
EMP	Electromagnetic Pulse
EMRH	Electromagnetic Radiation Hazard
EMRO	Electromagnetic Radiation Operational
EMV	Electromagnetic Vulnerability
ESD	Electrostatic Discharge
FCC	Fire Control Computer
FFDR	First Flight Design Review
FLIR	Forward Looking Infrared
FMASAP	Failure Modes, Effects, and Criticality Analysis Special Assessment Procedure
FMECA	Failures Modes Effects and Criticality Analysis
FOD	Foreign Object Damage
FOR	Field of Regard
FRR	Firing Readiness Review
FSQAP	Flight Software Qualification Assessment Procedure
GFE	Government Furnished Equipment
HEDP	High Explosive Dual Purpose
HERF	Hazards of Electromagnetic Radiation to Fuel
HERO	Hazards of Electromagnetic Radiation to Ordnance
HERP	Hazards of Electromagnetic Radiation to Personnel
HFE	Human Factors Engineering
IAT	Image Auto Track
IAW	In Accordance With
ICWG	Interface Control Working Group
IEEE	Institute of Electrical and Electronics Engineers
IFFC	Integrated Flight and Fire Control

IGE	In Ground Effect
IR	Infrared
ISAQ	Interim SAQ
JMEM	Joint Munitions Effectiveness Manual
JTCG/ME	Joint Technical Coordinating Group for Munitions Effectiveness
KIAS	Knots In Air Speed
LOAL	Lock On After Launch
LOBL	Lock On Before Launch
LRU	Line Replaceable Units
LSA	Logistics Support Analysis
MEP	Mission Equipment Package
MPI	Mean point of Impact
MWS	Mini-Weapons Survey
NAVAIR	Naval Air Systems Command
NDI	Non Developmental Item
OFP	Operational Flight Program
OGE	Out of Ground Effect
ORD	Operational Requirements Document
PCR	Problem Change Reports
PDR	Preliminary Design Review
P_h	Probability of Hit
P_k	Probability of Kill
PAE	Preliminary Airworthiness Evaluation
PEO	Program Executive Office
PHA	Preliminary Hazard Analysis
PIE	Pyrotechnically Initiated Explosive
PNVS	Pilot Night Vision System
PRF	Performance
RAM	Reliability, Availability, and Maintainability
RAP	Resonance Assessment Profile
RDEC	Research, Development and Engineering Center
RE	Radiated Emissions
RFP	Request For Proposal
RFQ	Request for Quotation
RS	Radiated Susceptibility
SAE	Society of Automotive Engineers
SAQ	Statement of Airworthiness Qualification
SAR	Safety Assessment Report
SAWE	Society of Allied Weight Engineers
SDD	Software Design Description
SDP	Software Development Plan
SDZ	Surface Danger Zone
SED	Software Engineering Directorate
SEES	Software Engineering Evaluation System
SHRI	Software Hazard Risk Index

SIL	Software Integration Laboratory
SOF	Safety-of-Flight
SOW	Statement of Work
SRS	Software Requirements Specification
SSHA	System Safety Hazard Analysis
SSMP	System Safety Management Plan
SSPP	System Safety Program Plan
SSRA	System Safety Risk Assessment
SSS	System/Subsystem Specification
STANAG	Standardization Agreement
STD	Software Test Description
STP	Software Test Plan
STR	Software Test Report
SVD	Software Version Description
TA/DS	Target Acquisition and Designation Subsystem
TC	Type Classified or Type Classification
TEMP	Test and Evaluation Master Plan
TEPP	Test and Evaluation Program Plan
TP	Target Practice
UAV	Unmanned Aerial Vehicle
RDECOM	Research, Development and Engineering Command
WCA	Warning, Caution, Advisory
WILI	Weapon Inhibits, Limits, and Interrupts

4. GENERAL REQUIREMENTS

4.1. Tailoring. The processes defined in this handbook should be tailored to the specific armament and aircraft configuration and installation. For new armament development programs, all components affecting airworthiness should be considered and their qualification procedures identified. For modification programs, only those subsystems added, modified, or affected by addition or modification of other components should be considered. Minor modifications may be qualified using a Mini-Weapons Survey (MWS) that demonstrates safe operation of the modified armament system.

4.2. Army airworthiness. The airworthiness qualification of U.S. Army aircraft systems is governed by AR 70-62. Airworthiness is defined as a demonstrated capability of an aircraft or aircraft subsystem or component to function satisfactorily when used within prescribed limits. An airworthy aircraft is safe to fly within prescribed limits. These limits, which have their basis in data, may not make the aircraft mission capable. As shown by Figure 1, the difference between an airworthy aircraft and a "qualified" aircraft is the degree to which the aircraft meets the specified requirements and provides the performance expected by the user. In addition to safety-related requirements, the system specification includes many other requirements such as technical performance parameters, reliability and maintainability, and operating and support costs. An Airworthiness Release (AWR) is a technical document that provides operating instructions and limitations, and maintenance information necessary for safe flight operation of an air vehicle system, subsystem, and allied equipment. An AWR is required prior to operating a new air vehicle system or a fielded system that has undergone a major modification. In addition to aircraft subsystems and components, an airworthiness assessment is required for carry-on equipment that has a mission requirement for operation in-flight.

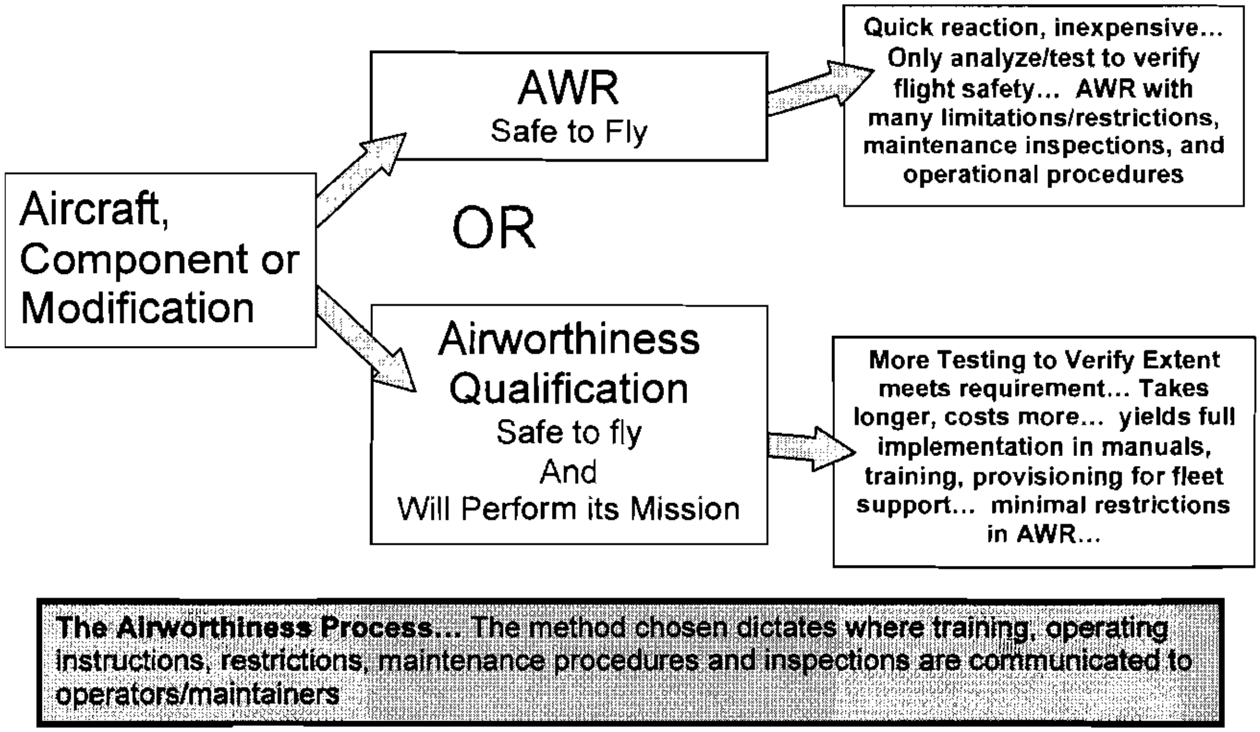


FIGURE 1. Army airworthiness

4.3. Armament airworthiness qualification process. The qualification process should consist of a structured program leading to airworthiness qualification. A progressive and incremental process is preferred that leads to establishing a basis for operating procedures, capabilities, and limitations. First, new and modified armament components undergo component qualification analyses and tests. Then subsystem-level analyses and tests are used to assure adequate safety characteristics and also to support a preflight airworthiness determination. Early identification of operational suitability and performance deficiencies allow time for the development process to correct these deficiencies. The results of the analyses and tests are used to guide the aircraft ground tests and the ground tests serve as a basis for the flight tests. Qualification tests should be performed on production or near-production hardware. Figure 2 shows the general process used to determine "when" and the "extent" to which armament airworthiness qualification is required.

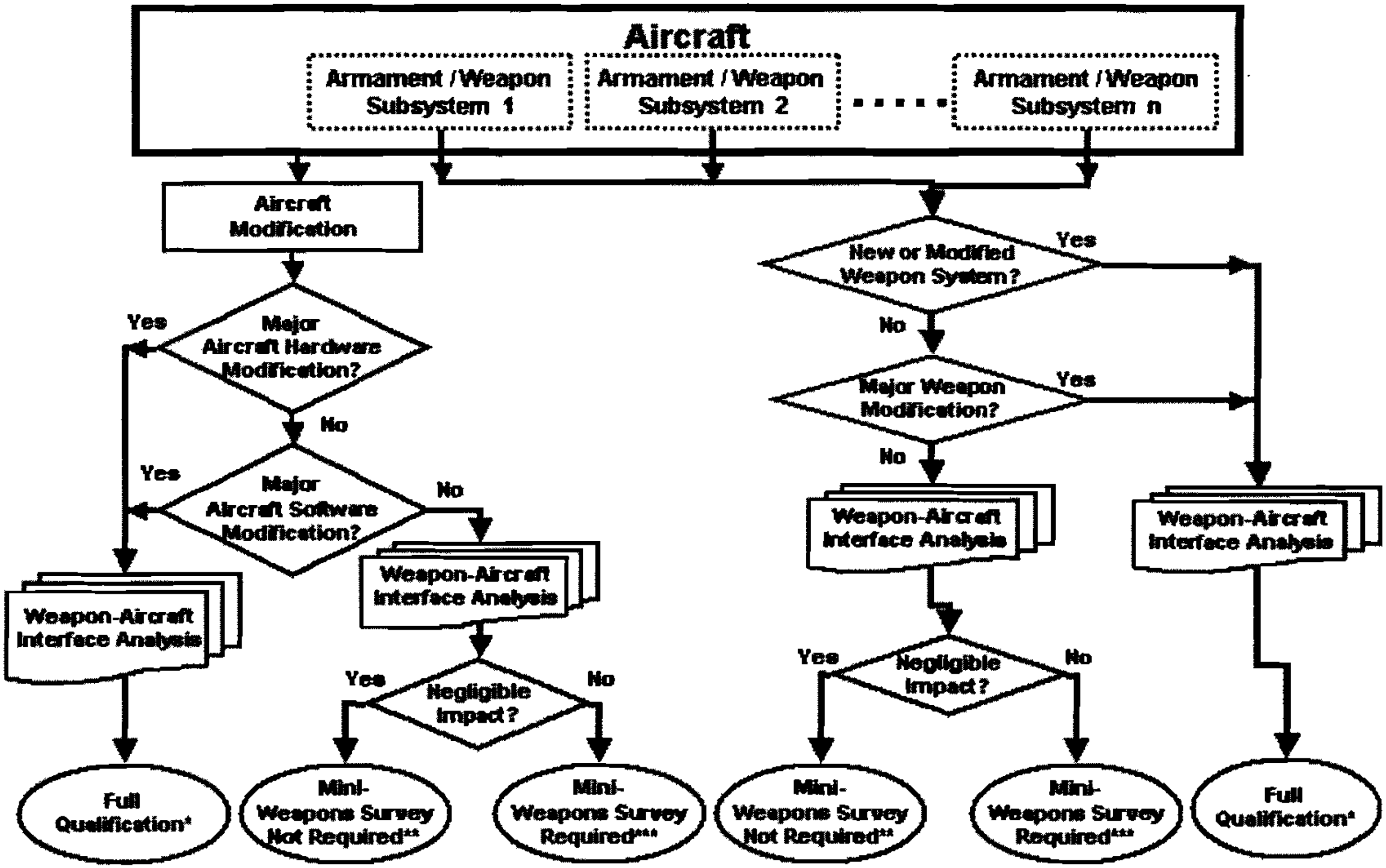
4.3.1. New aircraft or aircraft/weapon modification. A new aircraft system or a modification to either the aircraft or weapon system can trigger the weapon qualification process. Full qualification is not required for every change or modification to a weaponized aircraft. A Weapon-Aircraft Interface Analysis is used to help determine the extent of the weapon integration qualification effort. When full qualification is not imposed, a Mini-Weapons Survey (MWS) may still be required. Similar to Navy guidelines in NAVAIRINST 13034.1B, re-qualification should be addressed when the modified armament meets the following criteria:

a. Has a ± 5% weight change,
b. Causes the aircraft c.g. to change ± 0.5 inches,
c. Has a ± 10% change in inertia,
d. Has a software modification or causes aircraft software changes,
e. Has a change in the interface with the aircraft,
f. Safety is impacted.

4.3.2. New or modified weapon system. The introduction of a new weapon system for integration on an aircraft will initiate the qualification process. Additionally, modification to either an existing weapon system or to a weaponized aircraft can serve as a catalyst for the process. The qualification process should be tailored as appropriate for the configuration under review.

4.3.3. Most common qualification trigger. The majority of qualification activities will result from changes, modifications, or upgrades to existing weapon systems.

4.3.4. Other qualification triggers. The qualification process may also be initiated by the addition of an existing weapon system onto an existing aircraft when that weapon system has never been previously mounted on the aircraft. An example of this case is an attempt to mount an existing weapon system that has been in the military inventory (Army, Air Force, and Navy) onto an existing Army air platform. While the weapon itself might be acceptable, its integration on an Army aircraft would most likely require interface modifications (hardware or software), analyses and tests.



Notes:
* Tailored as appropriate.
** Other analysis and/or tests may be required based on results of Weapon-Aircraft Interface Analysis.
*** May also be required due to the accumulation of minor effects/impacts. Tailored as appropriate.

FIGURE 2. Airworthiness process for armament/weapons integration

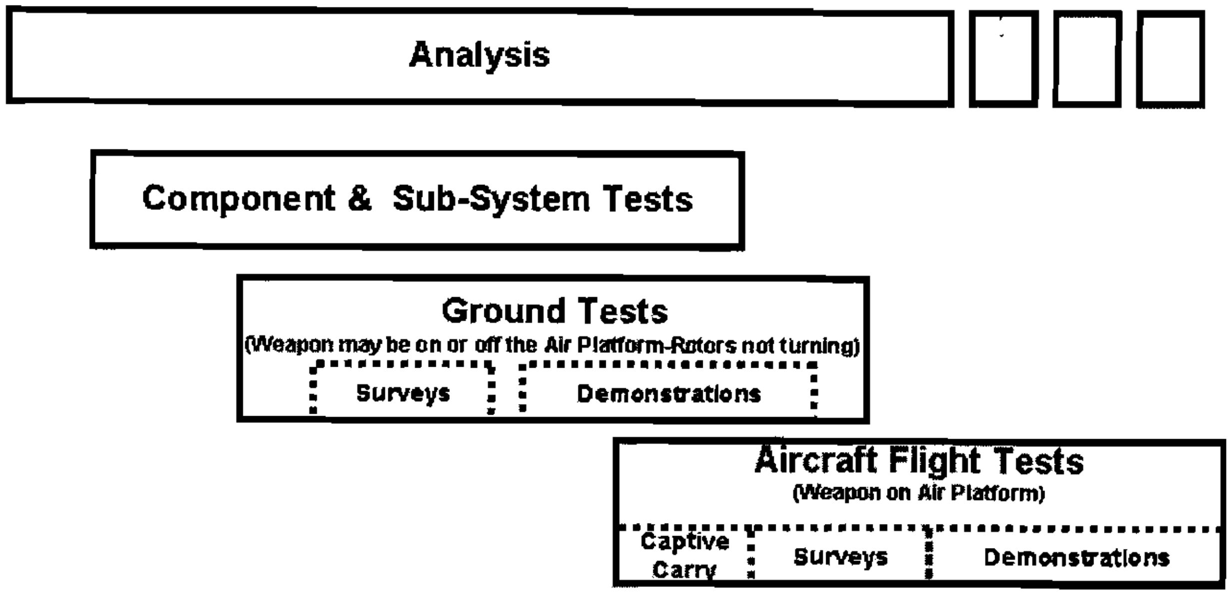
4.3.5. Weapon-aircraft interface analysis. A Weapon-Aircraft Interface Analysis is typically performed to determine the extent of the qualification activities required. This analysis will examine the changes to the weapon system, the aircraft including crew operational procedures, and the interfaces between them. A review of the paragraph 5 data and analyses will provide guidance on the types of interfaces that should be assessed. The results of the Weapon-Aircraft Interface Analysis may mandate that full qualification is required; that a MWS be performed; that no additional qualification is required; or that additional specific tests, surveys, demonstrations, inspections, and/or analysis are required. As a minimum, the following aspects will be reviewed for significance in the Weapon-Aircraft Interface Analysis:

a. Safety, such as changes to munition blast effects and exhaust products/debris
b. Effect on aircraft survivability, vulnerability and crashworthiness
c. Operational engagement techniques
d. Fire control, including ballistic coefficients
e. Software including data flow/bus traffic
f. Electrical interface
g. Mechanical interface
h. Crew, troop and maintenance personnel interface
i. Safe firing envelope
j. Surface danger zone

4.3.6. Full qualification. If full qualification is required, then the many factors described in Section 5 should be assessed first by analysis, then by ground test where feasible, and then finally by flight demonstration. The many categories of factors include aircraft compatibility, armament operation, fire control, system performance and accuracy, human factors, weapons effects on the aircraft and crew, structural integrity, electromagnetic environmental effects, environmental, shipboard compatibility, Reliability, Availability and Maintainability (RAM), Type Classification (TC) considerations and, above all, safety to the aircraft, crew and maintenance personnel.

4.3.7. Mini-weapons survey (MWS). An MWS consists of limited analyses and tests that substantiate that a modification to an existing system has not adversely affected safety, airworthiness, or the operational capability. The MWS includes limited weapons firing. Primary interests are compatibility and safe functionality. If accuracy is assessed, it is normally done so from a qualitative perspective rather than quantitative/statistical. An MWS may be required even though a current modification has only a minor impact on the overall system. The MWS may be required due to the accumulation of minor modifications that result in the overall system being near or over the acceptable performance or safety margins.

4.3.8. Airworthiness qualification schedule. Figure 3 shows a representative schedule for a new system or major modification, armament integration program. A key consideration in the development of a qualification schedule is the incremental and progressive nature of the development process. Each phase from analysis through flight testing should leverage the knowledge learned from the previous phase.



Captive Carry: Instrumented non-firing weapon. First flight requirements apply.
Surveys: Weapon fired/launched. FRR applies.
Demonstration: Weapon fired/launched. FRR applies.

FIGURE 3. Schedule for armament airworthiness qualification

In general, armament testing consists of component, subsystem, ground and flight testing. The component and subsystem testing normally coincides with laboratory testing. The ground and flight tests typically consist of user evaluations, surveys, and demonstrations.

4.3.9. Component and subsystem tests. Component and subsystem tests are conducted prior to armament and fire control aircraft-integrated ground and flight tests.

4.3.9.1. Component tests. Component qualification tests consist of functional, structural, endurance and environmental tests, including electromagnetic environment effects. These tests are normally conducted in special test facilities such as environmental chambers. Component qualification tests verify that the components comply with specified performance under operational environments.

4.3.9.2. Subsystem tests. The purpose of subsystem tests is to determine that the subsystem components perform and interface functionally as intended. They are usually performed in Software Integration Labs (SIL) and Aircraft/Avionics Labs (AIL) prior to preliminary aircraft ground and flight testing. Typical test setups and their progression at the subsystem test level are shown in Figure 4. Bare bench tests are tests in which the subsystem is assembled and interfaced functionally with its components. This setup is not necessarily representative of the positioning and environment of the actual hardware. Hot mock-ups constitute the next higher level of integration and representation of the actual subsystem configuration and actual environment. Subsystem components are positioned relative to each other, as they would be on the air vehicle. Occasionally the terminology "hot bench" and "dynamic bench" are used instead of hot mock-up. Palletized flight-testing is performed by integrating a subsystem onto a pallet for ease of installation and removal from an air vehicle and for performing flight-testing to determine subsystem performance in an actual flight environment.

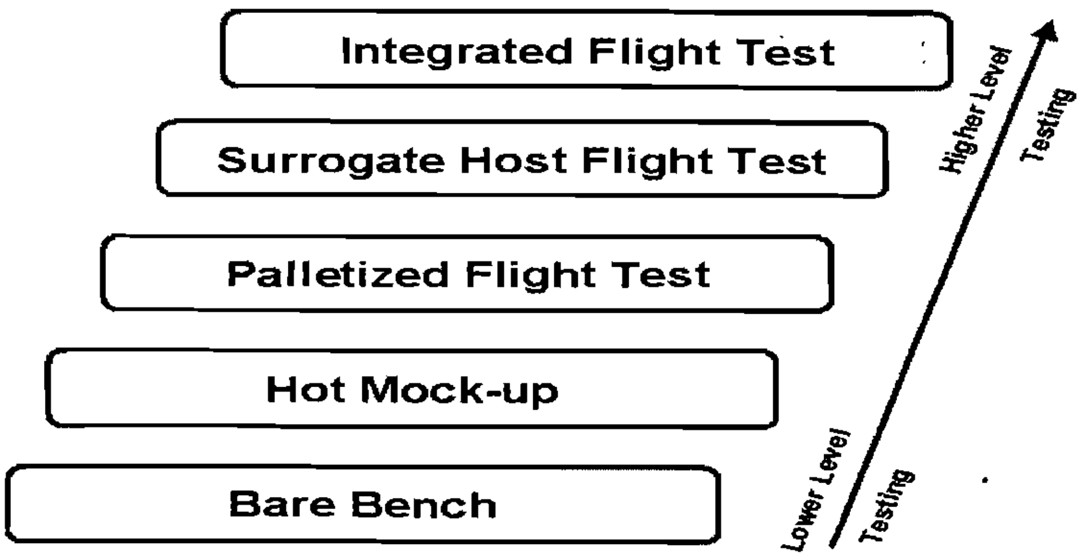


FIGURE 4. Subsystem test setups

a. Under typical conditions, SIL and AIL testing will be conducted to modify the operational software and interfaces as well as to verify that the software functionality is complete and does not degrade the aircraft system software operational performance.

b. Environmental and electromagnetic interference (EMI) qualification tests are normally performed at the component level. In some cases it might also be desirable to perform tests at the subsystem level to account for factors such as interconnecting cables and the ground plane. Electromagnetic compatibility (EMC) and electromagnetic vulnerability (EMV) tests are performed at the system level.

4.3.10. Ground and flight tests. Ground and flight tests verify the aircraft synergistic performance of the integrated armament system. The key elements of ground and flight tests are surveys and demonstrations (Figure 3). Surveys precede demonstrations in the test program schedule. Surveys are used to obtain data to establish the performance capabilities of the subsystem or system. Demonstrations are used to provide data that show a performance or contract requirement has been met. A developmental test plan should be created in such a fashion that an adequate number of survey test flights are conducted prior to the demonstration test flights. This will allow the developer to identify and fix any problems or anomalies prior to his commitment to formally demonstrate that he can meet the specified requirements.

4.3.10.1. Armament and Fire control System Survey (AFCSS). The survey that is conducted during an armament integration program is the AFCSS. The AFCSS assesses the weapon systems' performance and the effects of weapons' firing on the aircraft and its subsystems, including avionics, support structure and dynamic systems (engines, drive-train and rotors). The requirement to perform an AFCSS is a program decision that is based on the nature and complexity of the armament program and the need for risk reduction prior to commitment to the demonstration phase, The ADS-20-HDBK may be used to provide the criteria for the AFCSS.

4.3.10.2. Armament and Fire Control Demonstration. Following the AFCSS, the Armament and Fire Control Demonstration qualifies all armament subsystem installations on the aircraft. It demonstrates compliance with the system specification and contract requirements. While the requirement to conduct an AFCC is optional, a demonstration usually is mandatory.

4.3.11. Qualification completion. Successful completion of the qualification process for a weapon system results in a Statement of Airworthiness Qualification (SAQ). The SAQ is typically issued in conjunction with the Airworthiness Qualification Substantiation Report (AQSR). An interim SAQ (ISAQ) may be issued in lieu of an SAQ when testing is not completed, when limited production has been started, when an item is found to be safe but with some performance shortcomings, or when qualification is essentially complete but pending final qualification approval. The SAQ/ISAQ for a new or modified weapon system normally becomes part of or a modification to the aircraft system-level SAQ/ISAQ.

4.3.12. Weapon systems development and acquisition. The acquisition of a new or modified weapon system is normally associated with the development and publishing of an Operational Requirements Document. The systems engineering process involves the development of a Test and Evaluation Master Plan (TEMP) and the development of the Airworthiness Qualification Plan (AQP) that typically coincides with the development of the TEMP. The acquisition of new or modified weapon systems involves both the development of the weapon itself and the integration of the weapon on the aircraft. The planning for these two phases runs concurrently to ensure that the weapon system has been designed to safely and effectively operate from the aircraft. Weapons that do not meet this requirement are not permitted to be used operationally from the aircraft, or the use of the weapon system is restricted to the verified safe firing modes.

4.3.12.1. Integrated Master Schedule and Verification Matrix. An Integrated Master Schedule and a Verification Matrix are normally developed to delineate the plans to meet requirements of an AQP. The Integrated Master Schedule reflects the sequencing of ground and flight activities during qualification testing. It shows key points in the schedule when an AWR or CFR is required for flight test. A verification matrix is also normally prepared that relates the specification requirements, qualification methods, and requirements document.

4.3.12.2. Program/Project Managers (PM). The PM for the weapon system must coordinate with the aircraft PM on the integration strategy for the weapon system on-board the aircraft. There are several different methods to accomplish this goal including establishing separate weapon development and aircraft integration contracts. Often it becomes difficult for the weapon designer to accomplish the integration onto the aircraft due to aircraft software and hardware modifications that can only be accomplished by the aircraft prime contractor. Figure 5 shows one acquisition technique for the armament development and integration process. A key event in the process is the contractor's submittal of an Airworthiness Qualification Specification (AQS). The AQS defines the contractor's approach to meeting the Government's AQP.

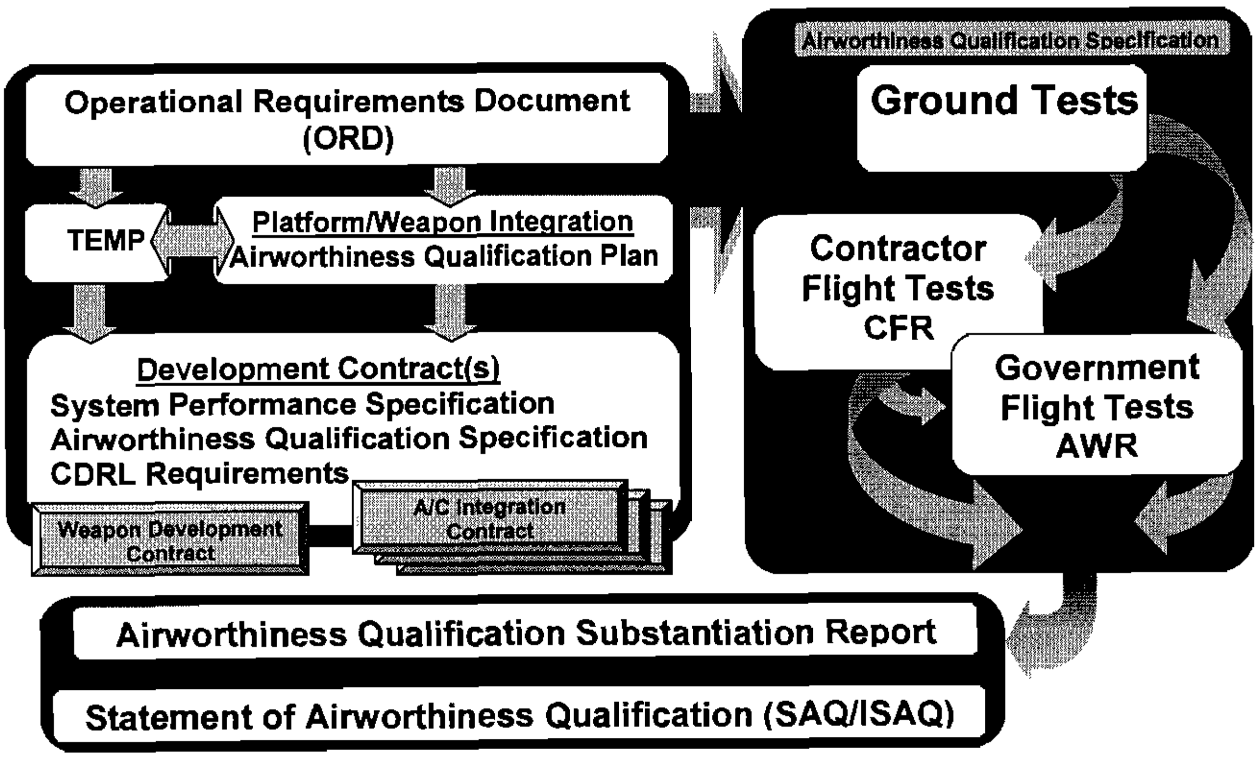


FIGURE 5. Typical development and integration process

4.3.13. Software changes. Software changes can result in a requirement to re-qualify the armament system. Normally any software change will result in a requirement to, as a minimum, perform a MWS during which all the weapons are fired to ensure that the software changes have not adversely impacted their operation. The software can be internal to the weapon system, within the launcher or interface device, or a part of the aircraft system software. Software changes may influence safety as well as the data communications bus traffic/loading, timing, throughput, and latency. The Software Engineering Directorate (SED) has overall responsibility for the software process within the AMRDEC. However, Aviation Engineering Directorate (AED) engineers have the responsibility to ensure that the software requirements correctly represent the armament, fire control, and aircraft engineering requirements. The SED utilizes the Software Engineering Evaluation System (SEES), the software industry's approach to software verification and validation. Special attention should be paid to FMASAP: 1-1 Volume 5 and FSQAP: 1-1 Volume VI, both elements of the SEES. There are several ways that software changes may be classified:

4.3.13.1. Changes that will affect safety of the armament. The difference between own-ship safety, the safety of other adjacent helicopters, and the safety of other troops on the ground must first be distinguished. Armament should not harm its own-ship, other friendly aircraft, or friendly ground troops. Primary consideration should be given to own-ship safety as well as applying a common sense approach that the crew should be able to positively identify the target they are engaging before releasing the weapon. Any software changes that may be classified as safety-related should be tested in the integration laboratory and on the aircraft.

4.3.13.2. Changes that do not affect safety but impact armament operation. Any software changes that may affect armament operation, but not safety, should be verified in the integration laboratory and also on the aircraft by conducting an armament survey. A judgment has to be made about the size and the extent of the armament survey. If the software changes are made in the component or subsystem that controls the armament, all armament configurations should be exercised. If changes are made that do not control armament functions, but control other parameter(s) that are used in the armament operation, then a MWS should be performed. The MWS should be tailored to the situation and configuration.

4.3.13.3. Changes that may affect armament accuracy. An armament accuracy demonstration should be conducted for any software change that might affect accuracy, such as changes to the ballistic equations, coefficients, and interface parameters that may affect armament accuracy. An armament accuracy demonstration may be required in cases when the software change does not directly affect the items mentioned above, but is extensive enough and performed in the same component or subsystem that handles fire control calculations. If the aircraft does not have any accuracy requirements, then an accuracy demonstration will not be needed; however a MWS may be required to verify safe functionality. The MWS should give an indication that armament accuracy has not become so degraded as to become unsafe.

4.3.14. Configuration. Armament subsystem qualification is conducted to determine the ability of the weapon subsystem to satisfy safety requirements, performance requirements of the air vehicle, and detail specifications. The armament subsystem should be configured as nearly as possible to the production installation.

The qualification process for armament involves both the weapon system and the actual aircraft type on which the weapon system will be mounted. Changes in either the weapon system or the aircraft may necessitate re-qualification. An engineering review for qualification is virtually impossible if the configuration is not known. The developer should provide a complete description of the configuration of the armament hardware/software and its installation.

4.4. Qualification methods.

4.4.1. Qualification by similarity. It is acceptable to use components or systems that have previously been qualified to the platform's environment in their off-the-shelf configuration or with some minor modification to make them compatible. Such components and systems qualify by similarity and are categorized as Category I, II, or III as defined below. The U.S. Army qualification process may be reduced based upon previous qualification by other organizations. Other recognized airworthiness qualification authorities include the Federal Aviation Administration (FAA), National Aeronautics and Space Administration (NASA), U.S. Air Force, and the U.S. Navy. Copies of the original test reports, including the original test data, are provided for review and approval for items qualified by similarity in any of the three categories below. This data then forms a part of the qualification record. When qualification by similarity is proposed, a formal qualification by similarity report is submitted for approval by the Government. Qualification by Similarity Reports should be submitted as early as possible in order to mitigate the risk of schedule impacts due to follow-on testing if the similarity is not approved. A statement of similarity without any basis for comparison is insufficient and should not be accepted. If the qualification by similarity is disapproved, the component is then qualified by test. The airworthiness points of contact within the U.S. Air Force and U.S. Navy are shown in Table I.

TABLE I. Air Force and Navy points of contact

U.S. Air Force	U.S. Navy
Air Force SEEK EAGLE Office 205 West D. Ave Eglin AFB, FL 32542-6865	NAVAIR Naval Air Warfare Center Aircraft Division (NAWC-AD) 21960 Nickles Road Patuxent River, MD 20670-5304

4.4.1.1. Category I. Category I is defined as those components used in the design, which are identical to those components qualified in previous systems and have identical operational and environmental requirements. Qualification reports for items in this category list each part by name, part number, and the other system in which the part was used. A copy of the qualification documentation listing appropriate Government, contractor, or military specifications (including revisions) must be provided.

4.4.1.2. Category II. Category II is defined as a component with minor modifications that was previously qualified for use in other systems before the component was modified. The modified component must be used in a similar operation and a similar environment as the previously qualified component. Name, part number, and a technical rationale of why the modification to the part is minor enough to waive other qualification methods are listed. All modifications should be clearly listed and described, along with the engineering rationale to substantiate the statement of similarity.

4.4.1.3. Category III. Category III is defined as those components which have been used in similar design applications by other contractors/companies and which are proposed to be qualified by similarity. Reports for items in this category list the component name, part number, specific identification numbers for the system and aircraft where the component was used, and the report substantiating initial qualification.

NOTE: For Categories II and III components, the similarity rationale and its supporting documentation should include at least two separate drawings, analyses, reports, and substantiation data that compare the two components, part to part, clearly depicting the similarities and differences between the two components.

4.4.2. Qualification by analysis. Qualification by analysis involves proving an item meets specified requirements by a technical evaluation of equations, charts, graphs, circuit diagrams, or representative data. Government review and approval is required.

4.4.3. Qualification by test. Formal qualification testing is used for components, subassemblies, and systems that do not meet qualification by similarity or analysis standards. Formal testing includes test plans, test procedures, test reports, Government witnessing (as required) and Government approval.

4.4.4. Qualification by demonstration. Qualification by demonstration is conducted to show that the capability of the system or subsystem complies with the requirements of the system performance specification.

4.4.5. Qualification by inspection. Inspections are performed to determine if the system or subsystem complies with the qualification requirements.

4.4.6. Qualification through simulation. Simulation includes verification through the use of mathematical models incorporated into a simulation which replicate the operation or performance of the equipment being evaluated, the threat and environment in which the equipment will operate; and various combinations of the equipment, threat, and environmental conditions.

4.5. Armament airworthiness qualification plan and specification.

4.5.1. Airworthiness Qualification Plan (AQP). An airworthiness qualification program normally requires the preparation of an AQP. Either an AQP or fully coordinated statement of work should be required for every acquisition involving airworthiness qualification. If an AQP is not used, then a systems integration plan should be developed and followed. The AQP converts the general requirements of the ORD and acquisition policy into performance and effectiveness criteria. Also, air vehicle design criteria, safety, performance, and limitations to be substantiated for airworthiness qualification should be defined. The AQP should define the means for determining airworthiness and the means for determining if it will satisfy user required functions and operational capabilities. The AQP should define what is required for airworthiness qualification, when required, where required, who will do it, and how it will be done. The AED aircraft system integration divisions ensure that all technical disciplines are accounted for in the AQP; e.g. aeromechanics, structures, propulsion and mission equipment package (MEP). The completed AQP can be used in a request for proposal (RFP), request for quotation (RFQ), or included as an addendum to a statement of work (SOW). The AQP is the basis for the preparation of an airworthiness qualification specification (AQS). Formats for both the AQP and AQS can be found in ADS-51-HDBK.

4.5.2. Airworthiness Qualification Specification (AQS). The AQS should be prepared in response to the requirements established by the procuring activity in the AQP and the contract data requirements list (CDRL). The procuring activity should require an AQS for each system that requires qualification or re-qualification due to major modifications. The AQS should identify the approach (reviews, analyses, tests, modeling, surveys and demonstrations), performance, and effectiveness criteria needed to validate compliance with the system specification and airworthiness qualification plan. As a minimum, the scope of the AQS should satisfy all requirements of the AQP, but should not necessarily be limited to requirements in the AQP.

4.6. Reviews. Design reviews are typically held to establish a foundation for airworthiness substantiation and assure compliance with qualification requirements. Standard reviews associated with the qualification process include:

4.6.1. Preliminary Design Review (PDR). The objectives of the PDR are to:

a. Assure that the design approach complies with design criteria, airworthiness qualification, and other contract requirements.

b. Provide an understanding of all mechanical, electrical and software interfaces. Identify any design changes that would be required to the aircraft.

c. Identify changes impacting airworthiness qualification, compliance with required specifications, or increased risk.

d. Identify changes to the test program resulting from design changes.

e. Assess the technical program and AQS progress.

f. Provide preliminary layout and preliminary detailed drawings.

4.6.2. Critical Design Review (CDR). The CDR is conducted to confirm that the detail design is complete, meets requirements and is ready to commit to major fabrication. The following items are normally provided prior to CDR:

a. Final Drawings to the extent they are completed as required by the weapon system requirements.

b. Preliminary Weight and Balance Estimates.

c. Interface control documents and resolution of all interface issues.

d. Preliminary Safety Assessment Data.

e. Structural integrity analyses.

f. Current version of software documentation.

g. Identification of all hazards and their resolution.

h. Software FMECA.

i. Tracking of compliance with RAM, testability and supportability requirements.

4.6.3. First Flight Design Review (FFDR). A FFDR for the armament is conducted at least 60 days prior to first flight for the purpose of issuing an Airworthiness Release (AWR) for the first flight. Engineering design data substantiating the preliminary airworthiness of the vehicle is provided to ensure minimum flight test risk.

4.6.4. Firing Readiness Review (FRR). A FRR is conducted prior to firing of the weapon system from an airborne aircraft. A FRR is required 30 days prior to a proposed flight test that involves firing the weapon. A Safety Assessment Report (SAR) with documentation that supports the FRR is required 30 days prior to the FRR. A SAR includes an aircraft system-level hazard analysis of the integrated armament system. The SAR substantiates it is safe to conduct flight firing tests. Attendance at the FRR normally includes representatives from AED, contractor(s), test range, and the aircraft and armament PMs.

4.6.5. Human Factors Engineering (HFE) Reviews. The HFE reviews are conducted during program reviews to ensure consistency of the system requirements with human performance requirements. These reviews ensure that user requirements are reflected in the weapon design, that any desired changes to test plan requirements can be incorporated quickly into the test plans, and that user feedback is provided in a timely manner. All activities and progress regarding the HFE analyses are described IAW with the Integrated Master Schedule.

4.6.6. Interface Control Working Group (ICWG). The ICWGs develop and maintain interface documentation between the weapon system being qualified and the airborne platform including targeting, navigation and flight controls. The ICWGs might involve future or "growth weapons" and the use of Open System Architecture. During ICWG reviews, interface analysis is performed to identify and resolve interface issues. Joint ICWGs (JICWG) are normally formed when multiple aircraft models or other military services participate in the program.

4.7. System safety. The new or modified armament system integrated on the aircraft must be safely carried, operated and maintained. Armament firing must not damage the aircraft or on-board equipment, injure the crew, or adversely affect aircraft subsystems such as the engine/transmission. For aircraft test of armament, the AED must verify whether there are any specific potential hazards in the hardware, software, procedures or environment of the test. The AED must determine whether controls for existing hazards are adequate and whether any unforeseen hazards are present. This is accomplished primarily through the Airworthiness Release process. The extent and formality of the System Safety Program depends on the magnitude, complexity and risk associated with the armament integration program. A good overall guidance document on system safety for Army materiel is MIL-HDBK-764.

4.7.1. System safety plans. When a formal System Safety Program is conducted, a Government Lead Safety Engineer is appointed by the PM as the primary safety point of contact for all aspects of the system. He or she develops a system safety management approach and documents it in the System Safety Management Plan (SSMP). The Lead System Safety Engineer also ensures that the contractor has a System Safety Program Plan (SSPP) in accordance with (IAW) AR 385-16, System Safety Engineering and Management. All tests should be planned and conducted in close coordination with the SSPP. The SSPP is a description of planned methods to be used to implement the tailored requirements of MIL-STD-882, including organizational responsibilities, resources, method of accomplishment, milestones, depth of effort, and integration with other program engineering and management activities and related systems. The SSPP ensures that the planning, implementation, and accomplishment of system safety tasks and activities are consistent with the overall program requirements. The Lead System Safety Engineer establishes a System Safety Working Group (SSWG) made up of Government and contractor representatives. The SSWG is responsible for implementing the system safety program requirements outlined in the SSMP and SSPP.

4.7.2. Safety issues. All conditions that could potentially degrade safety should be identified, characterized, and categorized IAW MIL-STD-882, Aviation Policy Memo 03-02 for Risk Management Process (Appendix C) for guidance, or applicable PM safety management process or plan. Early identification of potential risks should be accomplished to enable early solutions to be developed and implemented. Any remaining safety issues are documented and assessed in an Airworthiness Impact Statement (AWIS) IAW AED Standard Operating Procedure (SOP) Number AE385-16-

1. The primary purpose of an AWIS is to alert management of an identified post-development issue/hazard. During a weapon development/integration program, an AWIS will not normally be prepared until the hazard resolution has been terminated and needs to be elevated to management. The AWIS might involve hazards that involve the ORD. The AWIS serves as a communication tool to provide input to AED's Safety-of-Flight (SOF) message and Aviation Safety Action Message (ASAM), the PEO's System Safety Risk Assessment (SSRA) process, engineering change proposals (ECPs), Modification Work Orders (MWOs) and changes to user requirements.

4.7.3. Safety topics. Specific topics that should be addressed under system safety include (as a minimum):

a. Provisions for adequate safety devices for ground crew protection and in-flight operational safety.

b. Any adverse effects on the aircraft when launching or firing the munitions.

c. Potential for inadvertent launch.

d. Laser safety and interlocks.

e. Jettison, safe separation, safe arming, and safe escape.

f. Electromagnetic environmental effects (E3). An EMC ground test is conducted prior to first flight. The EMC test will include the air vehicle, the weapon installation, and any flight test instrumentation. The interaction matrix is limited to flight critical systems, which includes electro-explosive devices. Another E3 concern is the potential effects of high power transmitters, located in the test area, on the safe operation of the modified aircraft.

g. Gun, rocket, and missile safe firing envelopes, including gun duty cycle.

h. Adequacy of armament inhibits, limits, and interrupts.

i. Identification and development of any warnings, cautions, or advisories.

5. DETAILED REQUIREMENTS

5.1. Armament and integration configuration. The armament and its integration/interfaces with the aircraft, both hardware and software, should be clearly defined and tracked during the armament airworthiness qualification program.

5.1.1. Operational concept and procedures. An operational concept should be provided that describes the intended implementation and utilization of the armament and the weaponized platform. The operating procedures that govern the handling, loading, and operational engagement of the weapon system should be provided or updated. The focus for the procedures is typically centered on safety, efficiency and effectiveness.

5.1.2. Armament description and installation. Functional diagrams should be provided that show and describe all components of the entire armament system/subsystem. These records should identify each item of the system/subsystem and should include the functional relationship and purpose of the items. Armament geometric data, mass properties and interface documentation should be provided. The interconnections to systems, such as hydraulic, pneumatic, and electrical, should be shown. Structural attachment details must be provided and all loaded joints clearly shown. Mounting details depicting the equipment to bracket, pallet, or stores rack attachments and bracket, pallet, and stores rack attachments to the aircraft structure are needed. Description of suspension and release equipment should include impulse cartridges, ejection velocities, orifices, arming unit type and location, and inspection criteria. Electrical schematics and wire diagrams should be provided, using SAE AS50881 and MIL-STD-7080 as guides. See paragraph 5.1.4 for further electrical-related discussion.

5.1.3. Location of armament. Equipment installation and arrangement drawings should be provided that show the location of all major items of armament equipment on the aircraft. Provide three-view drawings of the armament installed, including dimensional information, which shows required clearances between stores, stores to aircraft components, and stores to ground. Provide any special installation or servicing requirements, such as boresight equipment and alignment procedures.

5.1.4. Electrical installation. Drawings, sketches and block diagrams are required that describe the location and interconnection of the armament system components and flight test instrumentation throughout the helicopter as well as the routing, support and protection of associated wires, wire harnesses and cables. Schematics and wire diagrams are also required, which should include interconnections among the new or modified equipment as well as with existing aircraft equipment including electrical power sources. Failure analyses should be provided for the interfaces with existing aircraft circuits. Detailed requirements are the identification of shielded wires, over braids, shield and over braid terminations, points of electrical bonding, wire types used, wire gauges, wire temperature ratings, details regarding harnesses and bundles of wires and cables, circuit breakers (including their ratings and locations), and power bus identification. This data will be used to evaluate E3 integrity as well as evaluate adequacy of circuit protection against electrical faults in the newly added/modified equipment.

5.1.5. Software description. Software documents or updates to the existing documents must be submitted that are necessary for the armament operation and safety, and its effective safe aircraft integration. If other aircraft subsystems are affected by the integration, the interfacing system documents should be updated. The documentation should describe the architectural design and detailed design necessary to implement the software. The Software Version Description (SVD) should identify and describe the software version for each Computer Software Configuration Item (CSCI). Problem Change Reports (PCR) should log each software, hardware, and documentation problem found during system integration testing, the proposed solution and corrective action taken. See IEEE J-STD-016 for guidance. See paragraph 5.10.14 for more guidance on software documentation.

5.1.6. Equipment furnished by contractor. Contractor-Furnished-Equipment (CFE) armament design data should be provided when CFE armament equipment or modification of Government-Furnished-Equipment (GFE) are required.

5.1.7. Equipment furnished by Government. Government furnished equipment (GFE) that is required as part of the armament subsystem design and its installation should be defined and planned/ordered in a timely manner for the program.

5.2. Analyses and simulations. Analyses and simulations are used for a variety of purposes including program reviews, AWRs, safety-of-flight, and full airworthiness qualification. The selection of analyses and simulation requirements is highly tailorable to the nature, complexity and risk of the new or modified armament.

5.2.1. Electrical loads analysis. Electrical loads analysis data should be prepared for the armament modifications using MIL-E-7016 as a guide. The purpose of the analysis is to demonstrate that adequate electrical power is available for the various modes of operation of both the armament systems and the aircraft. Results of the analysis may be presented as an update to an existing electrical load analysis that has been approved by the airworthiness authority. (Most Army aircraft have an electrical loads analysis report which has already been submitted to the airworthiness authority; and it should serve as a baseline to such an update.) In the event the contractor is not the author of the baseline report and/or the modifications are relatively minor, then the update may be submitted as a letter report with reference to the existing electrical loads analysis (a formal revision to the report may not be practical). In the event flight test instrumentation is also being installed on the test aircraft, then the update must include such equipment for as long as that equipment is installed on the aircraft. Finally, the baseline report may not be up-to-date; consequently, updates may be required to better represent the aircraft configuration that is being modified.

5.2.2. Electromagnetic environmental effects analysis (E3). See Appendix A for detailed guidance.

5.2.3. Human factors analyses. The following human factors analyses and studies are typically conducted.

5.2.3.1. Gross analysis of tasks. This analysis reviews the existing task analysis for tasks affected by the armament integration and new tasks required for the integration. The analysis is performed for all mission phases and places special emphasis where ground crew, operators' and maintainers' task loadings and coordination requirements approach saturation.

5.2.3.2. Display/control optimization study. Appropriate trade-off and simulation studies to evaluate and optimize control/display relationships are normally conducted.

5.2.3.3. Armament impact on crew vision. The impact of the armament system upon crew vision, night vision, night vision goggles and night vision sensors such as Forward-Looking Infra-Red (FLIR) needs to be analyzed.

5.2.4. Environmental analysis/tests. Environmental analyses/tests should be tailored and conducted according to MIL-STD-810 and Appendix B. Appendix B identifies "first-flight" requirements and those required for full qualification. The environmental tests that are imposed should consider the aircraft's expected operational environment in which the armament will be expected to perform.

5.2.5. Weight and balance analysis. The analysis should be conducted for the new or modified weapon system and its installation. Tables should include the weights, moments of inertia, and center of gravity (c.g.) for armament, as well as empty weights, gross weights, and c.g. for the aircraft with the armament installed. See SAWE RP7 for guidance.

5.2.6. Structural integrity analyses. For the newly designed or modified components and installation, the following analyses should be conducted.

5.2.6.1. Loads and stress analysis. This analysis is conducted on the weapons, internal and external stores, mounts/launcher, and the aircraft backup structure. It should be performed for all critical conditions throughout the aircraft/armament operational envelope, including takeoff and landing, jettison, and firing conditions. This analysis should consider the structural loading effects of the armament on the aircraft and support structure and the effects of the aircraft and support structure on the armament. The analysis should also include hangfire conditions. See MIL-A-8591 for guidance concerning aircraft stores, stores racks and interfaces.

5.2.6.2. Crashworthiness analysis. This analysis is conducted for the mounting of any equipment in the cabin, cockpit, external store stations or elsewhere on the aircraft. Each aircraft type lists its unique requirements in its Prime Item Development Specification (PIDS). Special attention should be given to any potential occupant strike hazard from sighting equipment or emergency egress blockage. Any crashworthiness degradation to the aircraft or crew/troops, due to the armament installation, must be prevented or approved by the Government. Also see JSSG-2010-7 for guidance on aircraft crash survivability.

5.2.6.3. Fatigue analysis. A fatigue substantiation report is typically provided to the Government. It defines the impact of the new or modified weapon subsystem (including installation) on component fatigue lives. The fatigue assessment must substantiate that the aircraft's existing fatigue capability has not been degraded.

5.2.7. Dynamic analysis. A dynamic analysis is performed to determine the fundamental dynamic properties of the installed armament system. These properties should include as a minimum those shown in Table II. The analysis may include a Resonance Assessment Profile (RAP) modal survey to determine if harmonic vibrations could result in mounting failure. It is conducted using an instrumented hammer to determine the natural frequencies of the object and spectral analysis of the response.

TABLE II. Dynamic analysis properties

1	The resonant frequencies, damping, and mode shapes.
2	The forced response of the installed system with the forcing frequencies of the host equal to the primary forcing frequencies of 1P, nP, 2nP, and 3nP. n = number of rotor blades P = rotor rotational frequency
3	The installed system dynamic effect on both the weapon and host system.

5.2.8. Engine ingestion analysis. An engine ingestion analysis is conducted to determine what effect the armament exhaust gases and solid debris have on engine performance throughout the flight envelope of the aircraft. The analysis should include any engine inlet temperature and pressure distortion effects and the effects of ingestion of propellant combustion products and debris generated by weapon firing. The engine and drive-train performance transients generated by the above conditions are estimated. Guidelines for rotorcraft propulsion systems qualification are in ADS-50-PRF. Guidance for propulsion surveys and tests, including armament gas ingestion, are provided in ADS-1-PRF.

5.2.9. Gas plume impingement analysis. A gas plume impingement analysis is conducted to determine the effects of the weapon subsystem exhaust gases and solid debris on the air platform.

5.2.10. Impact on sensors. Analysis of the impact of the weapons/armament systems on the air vehicle's sensor systems. Examples of concerns include sensor degradation due to blast pressure, vibration, flash smoke and debris. See ADS-65-HDBK for guidance on sensors.

5.2.11. Impact on avionics. The concerns for avionics are possible obscuration or distortion of antenna performance and their subsequent effect on communication, navigation, and other avionics performance. Analysis, modeling and simulation, and/or aircraft system level testing may be required.

5.2.12. Clearance analysis. An analysis is conducted to show that there is sufficient clearance between the propeller(s), rotors, and/or fuselage of the air vehicle and the weapons subsystem, bullet trajectory, missile trajectory, rocket trajectory, directed energy weapon beam path, store ejection clearance, and debris trajectories throughout the flight envelope of the air vehicle. Trajectory clearance between individual munitions must insure they do not collide during or after launch. For example, a munition's fins must not impact an adjacent munition which could potentially send either munition into the aircraft's rotors. Clearance must be sufficient to preclude induced damage from spent cases, links, or any loose items under a worst-case release condition. Gun safety stops should be provided that prevents the gun from traversing or elevating to an unsafe position. Clearance for rearming must be assessed for conditions expected at Forward Area Refuel and Rearm Points (FAARP) and on-board ships, as well as fixed bases. The quantitative clearance requirements are shown in Table III. Further guidance on clearance analysis can be found in MIL-STD-1289.

TABLE III. Clearance requirements

Loading clearance	Sufficient clearance is established to enable movement of the store into position when the aircraft is fully serviced and is in its normal attitude on a normal landing or servicing surface. It is desirable that sufficient clearance be provided to allow loading/unloading at maximum aircraft gross weight with tires flat and struts fully compressed.
Store to aircraft clearance	A minimum clearance of 25.4 mm (one inch) is typically provided between all required stores and aircraft with the surface deflected to the point of the closest proximity to the store.
Store to store clearance	A minimum clearance of 25.4 mm (one inch) is provided between adjacent stores noting that additional clearance may be required for fuse clearance with stores mounted on the aircraft stores suspension equipment. For stores configured in tandem, this distance is measured from the plane tangent to the rear most surface of the forward store to the closest surface of the aft store or fuse to ensure clearance during separation. The clearance should be maintained with any movable surface or component of the store that is normally free or controlled to move while the store is in its installed position, or deflected to the point of closest proximity to the adjacent store.
Store to pylon clearance	A minimum clearance of 12.7 mm (one-half inch) is established between any component along the length of the store and pylon on which it is suspended. Suspension lugs, store sensing switches, sway bracing, and bomb charging well electrical power generator components may be excepted after a review/analysis is performed to ensure sufficient clearance.
Rail launched stores clearance	A minimum of 25.4 mm (one inch) clearance is established between any movable surface or component of a rail launched store that is free or controlled to move during launch with the surface deflected to the point of closest proximity to any other store, launcher, pylon, or aircraft surface.
Store ejection clearance	A minimum of 25.4 mm (one inch) clearance is typically established for any movable surface or component of an ejected store during ejection to the point of closest proximity to any other store, launcher, pylon, or aircraft surface. This clearance is verified by actual testing or by analysis approved by the procuring organization.
Propeller and rotor disk clearance	On propeller and rotor-equipped aircraft, a minimum clearance of 152.4 mm (six inches) between the worst-case propeller/rotor disk position or any part of the aircraft and the bullet trajectory (bullet trajectory should be the worst-case position in the firing envelope and the worst-case gun dispersion) is provided. The clearance during launch for guided and unguided rockets and missiles is a five-degree half angle cone measured from the trajectory of the outermost surface of the ordnance to the worst-case rotor plane or aircraft structure. See Figure 6. The clearance should be sufficient to preclude induced damage from spent cases or any loose items under a worst-case release condition. A diagram showing the worst-case trajectory of the munition and its proximity to the rotor/propeller blades should be provided.

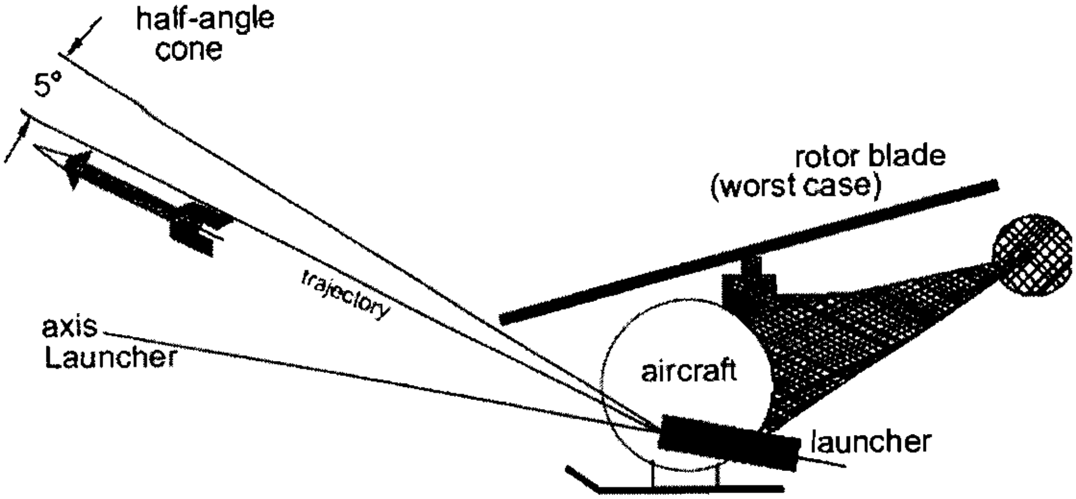


FIGURE 6. Definition of five-degree half angle clearance cone

5.2.13. Jettison analysis. Along with the launching of weapon stores, jettison is an element of "safe separation" and affects aircraft safety. The jettison analysis determines the safe jettison flight envelope for all droppable stores. Droppable stores include expendable stores such as missiles and mines, and non-expendable stores such as gun pods and fuel tanks. The analysis is conducted as a predictive tool in advance of jettison flight tests and identifies the conditions that need to be flight tested. The analysis minimizes the scope, risk, cost and schedule of the jettison flight tests. See paragraph 5.8.2.6 for minimum acceptable jettison criteria.

5.2.14. Safe arm and safe escape analysis. A safe arm and safe escape analysis should be performed to ensure that the aircraft will not be adversely affected by the debris caused by the explosive capability of the weapon. Safe arming is the selection of a minimum safe arming distance or fuze arm time setting that will provide the delivery aircraft acceptable protection from munition fragmentation if early detonation should occur. Safe escape is the set of flight conditions (altitude, speed and engagement range) that will provide the delivery aircraft acceptable protection from munition detonation downrange. The analysis should evaluate warhead debris traveling back towards the launch aircraft and calculate the probability of debris hitting the aircraft during the entire firing envelope. The probability should be less than one in a million. Firing restrictions might have to be imposed on the aircraft engagement conditions (such as altitude, airspeed, maneuver and range to target) necessary to attain safe escape criteria. Any such restrictions should be placed in the AWR, SAQ/ISAQ and in operational manuals. The safe arm and safe escape analysis for high explosive munitions is usually supported by fragmentation characteristics data gained from ground firings in a static arena test. Data on existing munitions can be found in the related Joint Munitions Effectiveness Manual (JMEM) created by the Joint Technical Coordinating Group for Munitions Effectiveness (JTCG/ME). The safe arm and safe escape analysis should consider munitions functioning within design specifications as well as potential munition failure modes.

5.2.15. Accuracy firing analysis. An accuracy firing analysis, including lethality as required, should be conducted for each new armament or armament modification that affects accuracy/lethality. The analysis is usually supported by modeling and simulation. It should analyze the weapon, its aircraft integration, error budgets and the "end-to-end" fire control from the sensors detecting the target to the munitions hitting and killing the target. The analysis should include fire control timelines. The Government usually provides operational scenario descriptions to the contractor in order to assess fire control modeling and simulation. They identify the target, target and ownship flight conditions/maneuvers to be assessed. The accuracy firing analysis is intended to supplement aircraft live fire tests in order to substantiate compliance with armament accuracy/lethality requirements. As such, the analysis and supporting simulation help reduce the scope, cost and schedule of the firing flight survey and demonstration. Even if there are no quantified accuracy requirements in the aircraft specification, the Government may require the contractor to determine the accuracy through analysis, simulation and/or test. This is so the user will be able to determine how to safely and tactically deploy the system.

NOTE: The accuracy firing analysis also supports the preparation of an accuracy/lethality report upon completion of aircraft flight firing tests. The report uses the analyses, simulations, and firing tests to substantiate that the accuracy and lethality requirements have been met.

5.2.16. Missile/rocket launch transient analysis. A launch transient analysis should assess the potential interaction of the aircraft, launcher and missile/rocket during the launch phase. The purpose of the analysis is to substantiate that there is little or no risk of an unsafe separation from the aircraft or risk of an errant missile/rocket that can exceed the test site's surface danger zone (SDZ). The analysis should include, but not be limited to, the aircraft's natural and induced environment on the munition at launch, aircraft launch constraints and data latency, store payload configurations, structural stiffness of the aircraft/store system (aircraft, weapon pylon, store rack, munition, etc.), free play between store and aircraft, and transient effects on the munition's guidance and control subsystem. In addition to aircraft safety, separation acceptance criteria also require that the transient store motions do not unacceptably degrade the weapons ability to perform its mission.

5.2.17. Combat survivability analysis. Aircraft combat survivability is the capability of an aircraft to avoid or withstand a man-made hostile environment. Susceptibility (avoid being hit) and vulnerability (withstand if hit) are subsets of aircraft combat survivability. This analysis must substantiate that the aircraft's susceptibility and vulnerability capabilities have not been degraded. See ADS-66-HDBK and MIL-HDBK-2069 for guidance.

5.2.18. Protection of classified data. An analysis is conducted that describes the methodology for preventing the loss or capture of classified data and weapons' codes due to air vehicle or weapon malfunction. Examples of protection include automatically making the data unclassified when the aircraft is powered down and destroying classified data upon crash impact or at the pilot's discretion. The weapon, its installation and operation must be in compliance with the relevant model aircraft's security classification guide.

5.2.19. Reliability, Availability, and Maintainability (RAM) analysis. A RAM analysis is conducted to assess tracking to contract RAM requirements and to determine impacts on performance, probability of failure, safety, mean down-time and overall availability. It is prepared and updated during the armament program using contractor predictions/estimates and qualification analysis/test data. In addition to the armament basic design and aircraft integration, consideration should be given to parts interchangeability, durability, boresight (alignment, retention and equipment calibration), environmental test results, lubrication, fouling, capability for sustained firing, mount compatibility, recoil effects, drop tests and transportation. Any special tools or devices required are normally identified and assessed in the RAM analysis. The RAM analysis is typically conducted in conjunction with a failure modes, effects, and criticality analysis (FMECA, see paragraph 5.10.12) and the PM's Logistics Support Analysis (LSA) process associated with the weapon system. Further guidance on RAM airworthiness considerations can be found in ADS-51-HDBK and the applicable aircraft system specification.

5.2.20. Type classification. Type classification (TC) of the weapon system and/or ammunition should be assessed during the RAM analysis. TC is the process through which the materiel developer identifies the degree of acceptability of a materiel item for Army use. TC provides a guide to authorization, procurement, logistical support, and asset and readiness reporting. TC is Army terminology that parallels the Navy's "Approved for Military Service" and the Air Force's "Program Management Directive for Production." TC is an interrelated and parallel process to airworthiness qualification. However, the responsibility for type classification rests with the material developer and is not a requirement for airworthiness qualification. Items can be certified as airworthy but be exempt from type classification. TC is important, if not critical, to the supportability of the component or system after fielding. For example, if a Government "skunk works" rapidly fabricates, tests, and fields a new door gun on a helicopter, without addressing the TC process with the Armament RDEC, the field unit might not be able to acquire ammunition for the new gun. Also, failure to obtain type classification could result in a refusal to support additional procurement of the gun through standard Army logistics channels.

5.2.21. Surface danger zone (SDZ) analysis. To help ensure range safety, the SDZ is determined for safe test and training. A SDZ includes both an armament firing footprint and a safety fan. The SDZ should be developed for the entire operational capability of the aircraft and include hover and moving aircraft both at ground level and at operational altitudes. A comprehensive SDZ is typically developed for each flight maneuver to account for variations in aircraft attitude. Project Managers are required to develop SDZs prior to Materiel Release IAW AR 385-63 for Range Safety. The SDZs will be prepared and updated IAW DA Pamphlet 385-63 for all munitions and laser systems.

5.2.22. Safe firing envelope analysis/simulation. An armed aircraft should have the capability to launch/fire its weapons throughout the operational flight envelope, up to the capability of the weapon. However, weapon safe firing envelopes must be established to restrict weapon firing to those aircraft maneuvers assessed to be safe. An example of an unsafe firing maneuver might be firing a rocket or missile while the aircraft is sustaining a negative vertical load factor. The analysis must assess whether the rocket/missile trajectory meets requirements for clearance with the aircraft's rotor blades. Safe firing envelopes for the same weapon integrated on different model aircraft will most likely be different. The weapon system safe firing envelopes are determined and verified through a combination of analysis, simulation, laboratory tests, ground tests, and flight tests. Representative safe firing envelopes (aircraft vertical load factor vs. true airspeed) are shown in Figures 7, 8, and 9 for an aircraft gun, missile and rocket system, respectively. Any other aircraft maneuver limitations for weapons engagements should be determined. The safe firing envelope analysis is conducted in conjunction with the weapon inhibits, limits and interrupts (WILI) analysis.

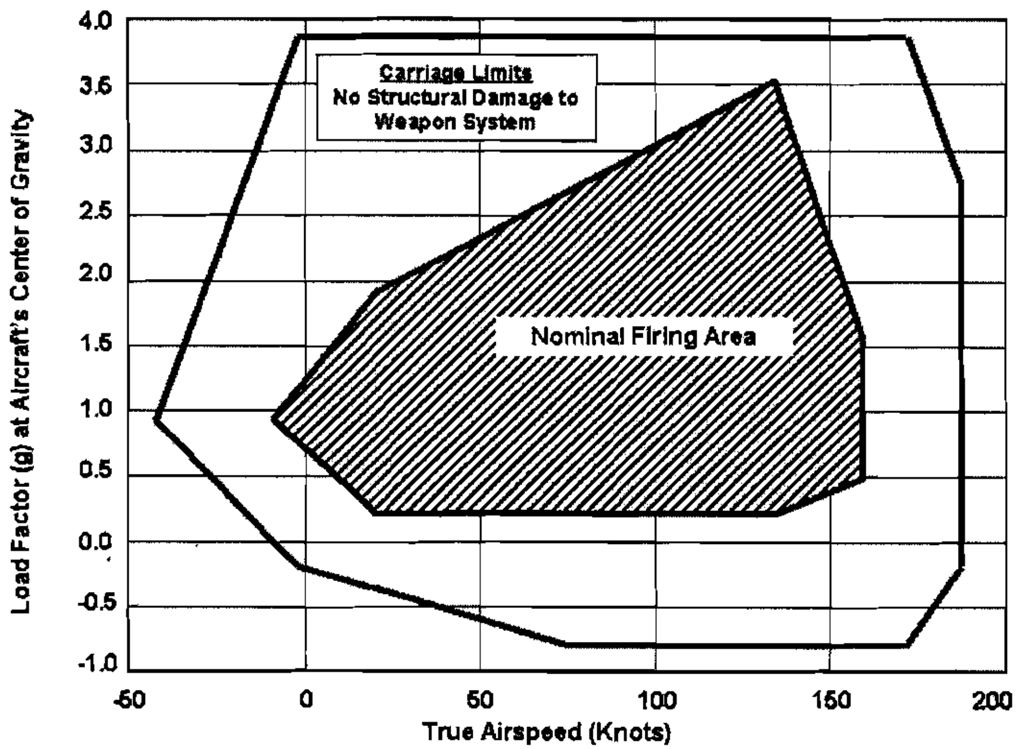


FIGURE 7. Representative safe firing envelope (gun)

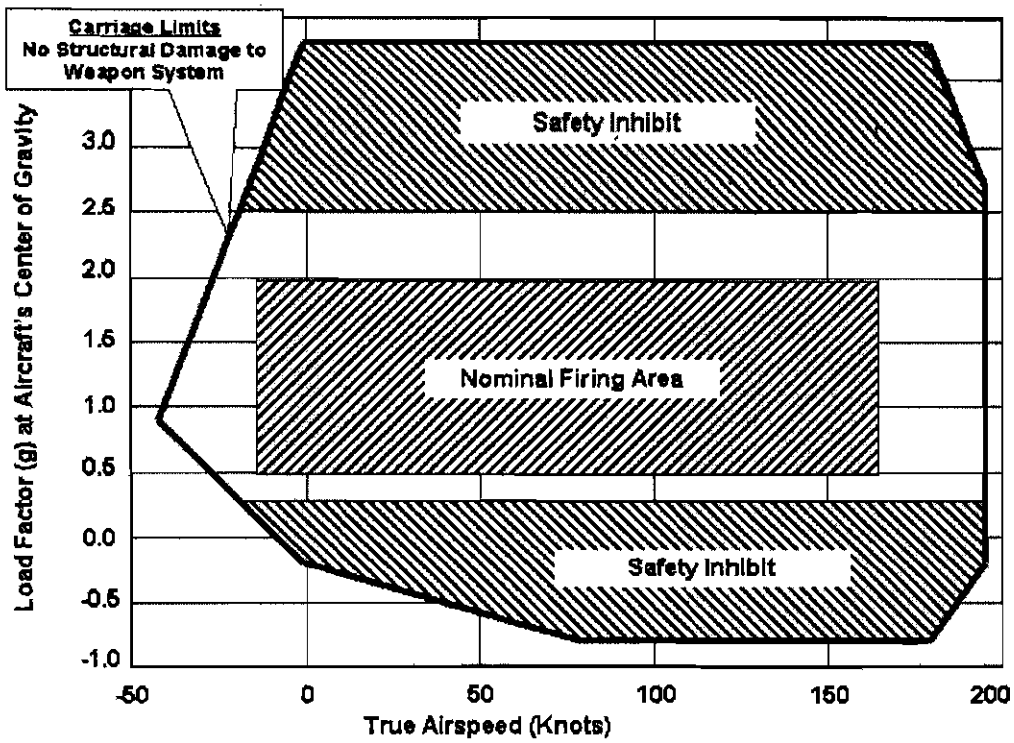


FIGURE 8. Representative safe firing envelope (missile)

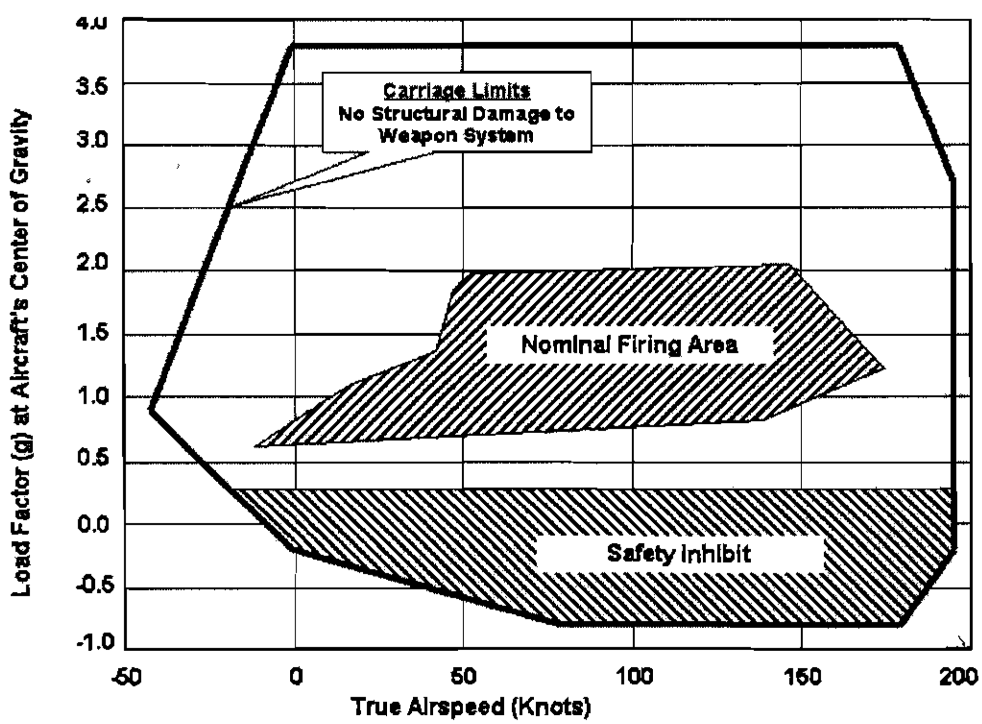


FIGURE 9. Representative safe firing envelope (rocket)

5.2.23. Weapon inhibits, limits and interrupts (WILI) analysis. An armed aircraft must have the capability to prevent the launching/firing of weapons when aircraft, sensor or weapon constraints are exceeded. To meet this requirement, a WILI analysis is conducted to identify the constraints and software necessary to limit or prevent firing. The armament WILIs are first identified through analysis and then verified by laboratory tests, ground tests and flight tests. Most of the WILI integration is conducted in a software integration laboratory (SIL) or an aircraft/avionics integration laboratory (AIL). Inhibits and limits should be categorized as "performance" or "safety". Performance WILIs are established to allow the crew to fire within performance constraints such as when the munition(s) are most likely to hit the target. Safety WILIs are designed to prevent the crew from firing under an unsafe condition. The crew should have the capability to override performance WILIs, but not safety WILIs. The operational user usually wants the capability to override performance WILIs in combat, even though they will get degraded (but safe) performance. The WILIs must be determined for each model aircraft, sight and weapon combination. The following definitions serve as a guide for identifying WILIs. The parameters shown are listed as examples.

5.2.23.1. Safety constraints (limits). Up to the limits, weapon firings are safe to both aircraft and weapons. Safety constraints can't be overridden. Parameters that define safety constraints include the following:

a. Aircraft attitude, rates, accelerations, and airspeed
b. Missile seeker parameters (angles)
c. Sight parameters (sight selection)
d. Laser backscatter
e. Other weapon launch in progress, time between weapon firing
f. In-flight/on-ground
g. In-flight boresight
h. Weapon time-of-flight
i. Range and altitude limits
j. Gun out-of-coincidence, pointing limits
k. Gun duty cycle
l. Pylon limits
m. Pylon servo error: pylon position, coincidence error

5.2.23.2. Safety inhibits. Mechanical, electronic, or software prohibition (stop) of weapon firing due to exceeding safety limits. Safety inhibits cannot be overridden.

5.2.23.3. Performance constraints (limits). Up to the limits, the weapon can function properly. They can be overridden up to safety limits. Parameters that define safety constraints include the following:

a. Aircraft attitude, rates, and accelerations
b. Aircraft airspeed
c. Pylon position

d. Missile seeker parameters (cage/uncage)
e. Sight parameters
f. Scattering laser

5.2.23.4. Performance inhibits. Mechanical, electronic, or software prohibition (stop) of weapon firing due to exceeding the performance limits. The crew can override performance inhibits and fire the weapon. Although the weapon will not perform as well as it does when it is within the performance limits, it will still perform safely.

5.2.23.5. Interrupts. Mechanical, electrical, or software logical capability or procedure to stop ongoing weapon firing when the weapon reaches both safety and performance constraints.

5.2.24. UAV integration analysis. This analysis applies if a UAV is integrated on the aircraft as a store or if the aircraft teams with or operates an armed UAV. The analysis should include those aspects similar to other armament stores and those that might be peculiar the UAV. See JSSG-2001B for guidance on air vehicles/UAVs. The factors to be analyzed should include but not be limited to the following:

5.2.24.1. Status, launch and control. The analysis should assess the ability of the airborne and/or ground-based system operators to status, launch and control the UAV and its armament while onboard the aircraft and during UAV flight. The analysis should include other functions normally performed by manned-aircraft stores management systems.

5.2.24.2. UAV safety. System safety should be assessed and implemented for the integration of armed UAVs in a manner similar to non-UAV aircraft armament programs. The analysis should include all aspects of handling, operating and supporting the UAV and its armament. The analysis should include the safety procedures to be followed when loading/unloading and when recovering an armed UAV. A misfire or hangfire, could create a potentially unsafe condition where a round is in the gun chamber or a missile/rocket/bomb is still on-board the UAV. The analysis should include the safety procedures to be followed if positive control of a UAV or its armament system is lost.

5.2.25. Laser systems. Laser systems should be designed to meet the U.S. Army Laser Safety Office criteria as well as the safety requirements specified in MIL-STD-1425 and MIL-STD-1472. A safety analysis is performed to include, but not be limited to the following criteria:

5.2.25.1. Laser beam divergence and power for all modes. An Eye Safe Mode must be verified by a safety analysis.

5.2.25.2. Safety interlocks will be incorporated for the high voltage laser electronics unit. A weight on wheels/gear/skids switch will be incorporated into the design for disabling the capability of the laser to fire or emit.

5.2.25.3. Software and/or hardware inhibits control the laser field of regard (FOR) to prevent the laser beam from hitting any part of the aircraft or aircraft systems. Laser energy must not be reflected back into the pilots' eyes.

5.2.25.4. The laser must not be susceptible to EMI resulting in inadvertent emission of laser energy.

5.2.26. New ammunition. The development of new ammunition is the responsibility of the Program Executive Officer (PEO) for Ammunition and the U.S. Army Armament Research, Development, and Engineering Center (ARDEC), Picatinny Arsenal, New Jersey. Typically, new or modified ammunition will be certified as safe by the ARDEC with a safety confirmation issued by the Developmental Test Command, Aberdeen Proving Ground. The Army Fuze Safety Review Board (AFSRB) will also review the safety features of the ammunition. They test the ammunition according to MIL-STD-1316, Safety Criteria for Fuze Design; MIL-HDBK-1512, Design Requirements and Test Methods for Electroexplosive Subsystems, Electrically Initiated; MIL-STD-1466, Safety Criteria and Qualification Requirements for Pyrotechnic Initiated Explosive (PIE) Ammunition; and MIL-STD-331, Environmental and Performance Tests for Fuze and Fuze Components. After these reviews and certifications, the ammunition is qualified for use from an airborne platform. The qualification procedure involves an electrical/HERO analysis, noise analysis, gas emission analysis for toxicity, blast effects, recoil loads, effects upon night vision goggles or devices, impact upon platform sensors, ability to feed properly, pre-detonation, clearance, and performance. Other areas should be assessed as appropriate as determined by the ammunition and weapon system configuration.

5.2.27. Shipboard compatibility analysis. This analysis is conducted if a weapon is intended for use on an aircraft which can be operated from or in proximity to a ship. The shipboard compatibility analysis should be performed to verify the capability of the armament and fire control subsystems to operate safely and effectively on and in proximity to the ships. Factors to assess include HERO requirements, aircraft takeoffs and landings, ordnance uploading/downloading, boresighting, ship/aircraft tie-down compatibility, and safeing of the weapon systems (power down).

5.3. Component qualification. Component qualification ensures, within reason, that the components meet or exceed the specified performance. Qualification tests should be performed on production or near production hardware. Performing qualification at the component level may be the only practical level at which a certain performance characteristic can be demonstrated. This is particularly true for tests requiring the use of laboratory equipment that could not practically accommodate a subsystem or system. Component qualification requirements are based on the criticality of their application in a specific air vehicle design and on the anticipated environmental conditions to which the component will be subjected.

5.3.1. Categories. Component qualification tests are categorized as functional tests, structural tests, endurance tests, and environmental tests.

5.3.1.1. Functional tests. Functional tests involve the demonstration of specified performance requirements and operational characteristics. Form, fit, and function should be validated.

5.3.1.2. Structural tests. Structural tests demonstrate the structural integrity of a component prior to its installation in the air vehicle. For critical dynamic components, determination of the service life based on fatigue loads is the basis for qualification.

5.3.1.3. Endurance tests. Endurance tests show the life adequacy of components subject to wear and/or deterioration with use.

5.3.1.4. Environmental tests. Environmental tests demonstrate that the equipment can be properly stored, operated, and maintained in the anticipated environmental conditions. See Appendix B.

5.3.1.5. Electromagnetic environmental effects (E3) tests. See Appendix A.

5.3.2. Qualification reports. Qualification reports are submitted IAW the requirements of a CDRL. They describe the procedures used to conduct component qualification and the conclusions of the component qualification. The reports are prepared for both qualification tests and qualification analyses. They describe the component and its application, its performance requirements, and the basis for the determination that the component has been successfully qualified. Qualification report formats are generally specified in a data item description (DID).

5.4. Subsystem integration test. Prior to the start of aircraft ground and flight tests, the armament and fire control subsystems must go through laboratory and hot bench tests to validate critical component and software parameters, as well as subsystem hardware and software integration. The purpose of this testing is to determine if all system level requirements have been satisfied and to uncover problems which cannot be evaluated by testing up through the Computer Software Configuration Item (CSCI) or Hardware Configuration Item (HWCI) levels. There might be an overlap between what is considered "subsystem integration test" and "system integration test". System integration test is the final level of integration that supports the aircraft ground and flight test.

5.4.1. Evaluation of interfaces. Integration involves evaluation of interfaces within the armament and fire control, with other MEP, and with other aircraft subsystems. All anomalies are tracked until they are resolved and closed. Integration involves many types of interfaces including:

a. software to software

b. hardware to hardware

c. hardware to software

5.4.2. Integration facilities. Many facilities exist for different levels of integration at armament and software suppliers, aircraft manufacturers and Government facilities.

a. Armament and software suppliers integrate components into subsystems in AILs and SILs prior to delivery to aircraft manufacturers. The objective is to ensure physical and functional compliance prior to subsystem installation. The AILs and SILs consist of a set of racks of armament and interfacing components or emulators, related architecture, instrumentation, processors and control stations. System integration tests may be conducted in the AIL/SIL when required to support flight test software.

b. The aircraft contractor conducts the aircraft system-level integration in their AIL, mission equipment development lab or hot bench to ensure safe and effective integration. The aircraft contractor integrates the armament and fire control software with other MEP software and the aircraft OFP. It is also important for them to substantiate that there is no degradation to other aircraft subsystems.

c. The Government facilities, SILs and other labs test the development of GFE armament and GFE armament integration.

5.5. Ground tests. Ground tests, also referred to as ramp tests, encompass all items requiring verification prior to the flight tests. In general, "form, fit and function" tests are conducted on the installed armament system, including fire control. The ground tests help to minimize flight test risk and increase the likelihood of good performance during flight test. The ground tests will also serve to verify the analyses conducted in paragraph 5.2. Ground testing occurs either on or off the rotorcraft. Off-aircraft testing might be conducted in simulators, hot benches or mock-ups. If ground testing is on the aircraft and the rotors are not turning, an AWR is not required. If EMC testing or other testing includes turning the rotors, an AWR will be required. Ground tests should include, but not be limited to those shown in Table IV.

TABLE IV. Armament ground test requirements

TESTS		SUBSYSTEMS				
		GUN & TURRET	ROCKETS & MISSILES	DROPPABLE STORES	CHEMICALS & PYROTECHNICS	ARMAMENT CONTROL
Ground	Fire Control Integration	X	X	X	X	X
	Cockpit Procedures	X	X	X	X	X
	Armament Controls	X	X	X	X	X
	Timelines	X	X	X	X	X
	Boresight	X	X	X	X	X
	Loading Procedures	X	X	X	X	
	Clearance	X	X	X	X	
	Firing Test	X	X	X	X	
	Armament Functionality	X	X	X	X	X
	Gas and Noise	X	X		X	
	Blast Effects	X	X		X	
	Engine Compatibility	X	X			
	Software	X	X	X	X	X
	Accuracy	X	X			
	Electrical	X	X	X	X	X
	Vibration/RAP	X	X	X	X	
	E3	X	X	X	X	X
	Environmental	X	X	X	X	X

5.5.1. Fire control integration. Evaluate and validate the joint functioning of the armament and installed subsystems such as fire control computer or weapons processor, stores management system, displays and symbology, armament control panels/switches, air data sensors, sights, target acquisition/designation subsystem (TA/DS), and navigational inputs.

a. The qualification test objectives for fire control subsystems include a determination that the fire control subsystem provides the functions required for safe and effective operation of the armament subsystems.

b. Ensure that the architecture is installed and wired correctly. Validate the correct functioning of the system hardware and software. Wiring or software installation errors can cause inadvertent launch or firing of munitions.

c. Safety interlocks are incorporated to prevent inadvertent firing of weapons. The proper functioning of the interlocks will be analyzed and tested. The armament WILIs that were identified in the analysis will be verified through a combination of ground tests and flight tests. If the system includes an Integrated Flight and Fire Control (IFFC) capability, the ability of the crew to override the IFFC at any time must be verified.

d. Sneak Circuit Analysis may be used as a tool to identify latent paths (hardware and software) which could cause unwanted operations, such as inadvertent launch or jettison. Latent paths that could inhibit desired functions might also be identified. Use of this tool earlier in the design stage would be prudent to eliminate costly redesign and schedule delays due to problems found during airworthiness qualification tests.

e. Engineering tools (such as Hellfire "house mouse"), captive flight trainers and training missiles should be used to support fire control integration. Where possible, armament and fire control timelines should be assessed. See paragraph 5.9.3.2.

f. Measurements for fire control subsystems include overall weapon firing accuracies in comparison to specified requirements. Of special significance is the latency due to data transmission during the targeting and firing sequence. The accuracy measurements should include the data required to demonstrate the end-to-end compatibility of the weapons, sights, and targeting algorithms. While degraded accuracy is normally allowed in firing from the aircraft on the ground, most specification accuracy requirements are verified in follow-on flight testing.

g. ADS-20-HDBK describes the many factors that should be assessed in armament and fire control integration. General guidance on fire control can be found in MIL-HDBK-799.

h. Guidance on fire control interface with sensors can be found in ADS-63-SP and ADS-65-HDBK.

5.5.2. Armament/fire control operations. Verify procedures utilizing the installed armament/fire control system. The armament/fire control/aircraft control logic interface is checked. Functional checkout of TA/DS modes (including symbology) is conducted.

5.5.3. Armament/fire control boresight. Verify operation, timelines and accuracy of the boresight subsystem, both static and dynamic, if applicable. Boresight procedures and boresight retention are checked. Boresighting should be re-checked periodically throughout the firing tests to determine the degree of boresight retention. Particular attention should be paid to the elements of the armament subsystem, the TA/DS, and interfacing subsystems, such as air data subsystem, that provide critical data to the fire control ballistic solutions and other operations. Verify each component/subsystem's alignment, tolerances and method of entering boresight corrector data into the fire control subsystem.

5.5.4. Loading procedures. Support equipment, procedures and timelines for the loading and unloading of ammunition and stores, as well as the safety procedures to be followed during the process, are developed and verified.

5.5.5. Clearance. Static clearances should be verified for all armament equipment installed on the aircraft. If practical, a verification of the clearance analysis should be performed to ensure that there is sufficient clearance between the munition trajectory and the aircraft. There may be situations where this testing cannot be feasibly or safely conducted from an aircraft that is not in flight. In such cases, trajectory clearances should be statically measured with the aircraft on the ground. See paragraph 5.9.3.1 for techniques to measure clearance. If safety is questionable, ground firing may also be conducted with the aircraft mounted on a test stand, but without an onboard crew. Firing can be triggered remotely.

5.5.6. Armament functionality.

a. Proper component and subsystem installation and interfaces with other subsystems. Correct functionality of armament subsystems and interfaces.

b. Armament subsystem architecture and data bus communications with other subsystems.

c. Turreted gun system slew rates, acceleration, and position accuracy.

d. Gun firing rates, burst size, duty cycles and ammunition belt loads (if linked). Compatibility with the type of rounds expected to be fired from the gun will be verified. Safe firing clearance of projectiles, cases and links should be verified.

e. External stores travel, slew rates, acceleration, synchronization, and position accuracy with typical loads.

f. Armament firing/launch modes.

g. Other functionality as required in the system specification.

5.5.7. Firing effects. Ground tests are conducted to verify/determine the following effects on the aircraft and crew.

a. Armament installation is structurally assessed. See paragraph 5.9.3.3.

b. Blast effects should be assessed. See paragraph 5.9.3.5.

c. Gas and noise from armament firing should be assessed. See paragraph 5.9.3.6.

d. Missile/rocket launch transient tests should be conducted depending on the results of the related analysis. See paragraph 5.9.3.10.

e. Effects of gun firing and missile launch on the TA/DS (including tracking) should be evaluated. Special attention should be paid to flash intensity. See ADS-65-HDBK for guidance on sensors requirements.

5.5.8. Engine compatibility. Tests may be conducted on ground test stands prior to flight testing. See paragraph 5.9.3.9.

5.5.9. Accuracy. Armament component/subsystem accuracy and dispersion are first verified in design verification tests on test fixtures separate from the aircraft. The capability to fire weapons from an aircraft on the ground is dependent on the ORD and aircraft specification requirements. Door or window-mounted guns are always capable of being fired from the ground. Accuracy of missile and rockets when launched from the ground is usually limited to "accuracy safety" in that it will not be so inaccurate as to be unsafe to the aircraft, crew or other friendly personnel on the ground.

5.5.10. Electromagnetic environmental effects (E3). See Appendix A.

5.5.11. Environmental. See Appendix B.

5.6. Prerequisites for first flight test (non-firing). Sample prerequisites for first flight test are listed in Table V. These prerequisites apply to carrying, but not firing, a weapon system onboard an in-flight aircraft which is commonly called a "captive carriage test". These prerequisites are combined with those in Table VI if the first flight involves firing of the armament system. The FFDR supports the issuance of an AWR for the first flight test. These flight test prerequisites should be tailored as appropriate.

TABLE V. Sample first flight test prerequisites (non-firing)

Requirement	Sub-Category	Paragraph
Ground Tests		5.5.
First Flight Design Review		5.6.1.
Armament/Integration Configuration		5.1.
Safety Statement		5.6.2.
Safety Assessment		5.6.3.
Weight and Balance Analysis		5.2.5.
Electrical Loads Analysis		5.2.1.
Human Factors Analysis		5.2.3.
Software Description		5.1.5.
Software Verification		5.6.5.
Safety-of-Flight	NVG Test	5.6.4.
	Structural Integrity Analyses	5.2.6.
	E3	Appendix A
	Dynamic Analysis/RAP	5.2.7.
	Jettison Analysis	5.2.13.
	Laser Safety	5.2.25.
	Environmental	Appendix B

5.6.1. First Flight Design Review (FFDR). A FFDR for the armament is conducted at least 60 days prior to first flight for the purpose of issuing an Airworthiness Release (AWR) for the first flight. Engineering design data substantiating the preliminary airworthiness of the vehicle is provided to ensure minimum flight risk. Emphasis is placed on the following:

a. Detailed configuration definition.

b. Evaluation of component and subsystem program tests, test failures, and corrective action to ensure no impact on system integration.

c. Structural integrity to ensure new or modified structural members has been analyzed and exhibit prescribed safety margins, and that the structural integrity and fatigue strength of the existing structure are not compromised.

d. All safety-related PCRs have been resolved.

e. Management procedures for conduct of flight operations, including envelope expansion.

f. Ensuring that the operation of all emergency systems, including emergency exits for crew and troops, has been checked. Crashworthiness analysis of the new and modified equipment has been approved.

g. Establishment of flight abort criteria.

h. Assurance that the prerequisites for first-flight data and tests have been accomplished.

5.6.2. Safety statement. Typically the contractor, who is conducting the test, will provide a safety statement that verifies that system safety has been assessed, and has included safety measures to the greatest extent possible. The safety statement summarizes the overall safety of the system.

5.6.3. Safety assessment. The safety assessment should include a failure modes, effects, and criticality analysis (FMECA). The Preliminary Hazard Analysis (PHA) for the integrated armament operation should be updated. If a PHA does not exist, a PHA should be developed for the weapon system integration. A Software FMECA is required only if the integration of the armament system involves software changes to the aircraft, changes to an existing software interface, or establishes a new software interface to the aircraft. See FMASAP: 1-1, Volume 5 for guidance.

5.6.4. Night vision goggle (NVG) test. A NVG compatibility test will be conducted according to TOP 7-2-513, if the test program will involve night flights or flights during reduced visibility.

5.6.5. Software verification. Software development and verification documents, including software verification and integration testing, must be approved by the Government. The software verification and validation testing should be conducted prior to first flight to ensure that the performance, interface, and safety requirements are met. The software test plan and results from successful software full qualification testing, or other requirements specified by the AMRDEC's Software Engineering Directorate (SED), may be required prior to authorization for first flight. The SED has a safety-critical software checklist that is included in the SED Aviation Division Guidebook for Evaluating Safety-Critical Software. If it is determined through this checklist that the software is safety-critical, then additional software requirements will be imposed.

5.6.6. Safety-of-flight (SOF) analysis and tests. All nonstandard equipment components used on an Army helicopter require an AWR to ensure operational compatibility with the host aircraft. See ADS-45-HDBK for the data and test requirements that must be met to obtain an AWR for armament testing on Army helicopters. Before an AWR can be issued for the initial first article test installation/user evaluation on a single aircraft, there are basic SOF criteria that must be met. The criteria should be tailored as appropriate for the aircraft and weapon configuration being considered. See Appendices A and B for E3 and environmental SOF criteria, respectively.

5.7. Prerequisites for first flight (firing). Sample prerequisites for the first aircraft flight test, during which armament is fired, is shown in Table VI. If the first flight firing test is also the first non-firing flight test, the prerequisites of Table V should also be met. The FRR supports the issuance of an AWR for the first armament firing flight test. As always, the prerequisites should be tailored.

TABLE VI. Sample first flight test prerequisites (firing)

Requirement	Paragraph
Grounds Tests	5.5
FRR	5.7.1.
SAR	5.7.2.
Engine Ingestion Analysis	5.2.8.
Gas Plume Impingement Analysis	5.2.9.
Impact on Sensors	5.2.10.
Impact on Avionics	5.2.11.
Clearance Analysis	5.2.12.
Jettison Test	5.8.2.6.
Safe Arm and Safe Escape	5.2.14.
Accuracy Firing Analysis	5.2.15.
Launch Transient Analysis	5.2.16.
SDZ Analysis	5.2.21.
Safe Firing Envelope Analysis	5.2.22.
WILIs	5.2.23.

5.7.1. Firing Readiness Review (FRR). Prior to airborne firing of the weapon system, the safe firing from the aircraft on the ground is normally demonstrated if feasible and safe. A FRR is required 30 days prior to a proposed flight test that involves firing the weapon. A Safety Assessment Report (SAR) with documentation that supports the FRR is required 30 days prior to the FRR. The FRR normally involves representatives from AED, contractor(s), test range, and the aircraft and armament PMs. The formality and scope of the FRR depends on the nature, complexity and risk associated with the armament modification. The FRR for test of minor modifications can be conducted by teleconference or waived by the AED Weapons and Sensors Integration Branch. If a formal SAR is required, it should be cited as a requirement in the contract.

5.7.2. Safety Assessment Report (SAR). A SAR, which is a safety statement that includes a hazard analysis, is required to show that there is no residual hazard and that the aircraft and integrated weapon system are certified as safe to flight test. The aircraft safety criteria of ADS-51-HDBK should be used for guidance. All known hazards and their ratings should be identified IAW MIL-STD-882 and Aviation Policy Memo 03-02 (Risk Management Process). Appendix C shows the PEO Aviation System Safety Management Decision Authority Matrix used to manage risk and determine the level of authority for risk acceptance. Safety precautions and hazard mitigation techniques should be determined. Any firing restrictions and warnings, cautions and advisories (WCA) should be defined and placed in the AWR. The hazard analysis should assess, but not be limited to, the following potential hazards:

a. All possible causes of premature or inadvertent firing.

b. Hangfire, misfire, and stoppage of guns, rockets, and missiles.

c. Potential effects on the crew from munition exhaust gas and noise levels.

d. Engine inlet temperature and pressure distortion effects.

e. Aircraft effects of ingestion of propellant combustion products, blast effects and debris generated by weapon firing. The engine and drive system performance transients generated by the above conditions should be estimated.

f. Jettison of rocket pods, missiles, launchers, and their release systems.

g. Armament firing footprint and safety fan for firing from a hovering and moving helicopter. This supports development of the SDZ.

h. Aircraft safe firing envelope considering all aircraft flight maneuvers/launch conditions. Any firing restrictions, misfire situations, duty cycles, and WCAs should be defined.

i. Loading and unloading of ordnance.

j. Potential for aircraft self-damage due to the down-range detonation of munitions launched by the test aircraft which is referred to as safe escape.

k. The veracity and reliability of safe arming/safe arming separation, which is the selection of a minimum safe arming distance or fuze arm time setting that will provide the delivery aircraft acceptable protection from weapon fragmentation if early detonation should occur.

l. Armament static and dynamic clearances from worse case rotor blade position, aircraft surface and aircraft components. See MIL-STD-1289 for guidance.

m. Any crashworthiness degradation to the aircraft and crew/troops due to the armament installation. Special attention should be given to any potential occupant strike hazard from sighting equipment or egress blockage. See JSSG-2010-7 for guidance.

n. Any degradation to the aircraft sensor system, including crew vision, night vision or night vision goggles and other devices. See ADS-62-SP for guidance.

o. E3 hazards to personnel, munitions and other safety-critical subsystems on the aircraft.

p. Potential hazards due to safety-critical hardware/software interfaces.

5.8. Flight tests. Flight testing should be IAW a test plan approved by the Government and should follow the guidelines of an AWR or CFR issued by the Government. Flight tests are conducted within the design operational flight envelope. Sufficient tests, analyses, and armament demonstrations are conducted to substantiate safe and satisfactory armament subsystem operation over the range of flight and environmental conditions, and to verify the analytical and ground test results. Test aircraft are instrumented to collect data for safe conduct of the tests, troubleshooting problems during the tests, and post test evaluation of safety and performance.

5.8.1. Flight test phases. Aircraft flight tests should consist of non-firing tests followed by firing tests. The non-firing flight tests consist of captive-carriage tests with captive flight trainers, training missiles and dummy ordnance *in lieu* of live ordnance. The correct functioning of armament and fire control WILIs, which were determined by analysis and tested in ground test, should be rechecked during flight. The non-firing tests must confirm safe functionality before the start of firing flight tests. Flight tests are typically designed to verify four primary areas. These areas are Safe Separation, Safe Firing Envelope (also known as Envelope Expansion), Compatibility Verification, and Accuracy Verification. The program context of the flight tests and its four phases is shown in Figure 10, which represents a typical flight test schedule. These flight test phases lie within the framework of captive carry, surveys, and demonstrations that were discussed in paragraph 4.3.10.

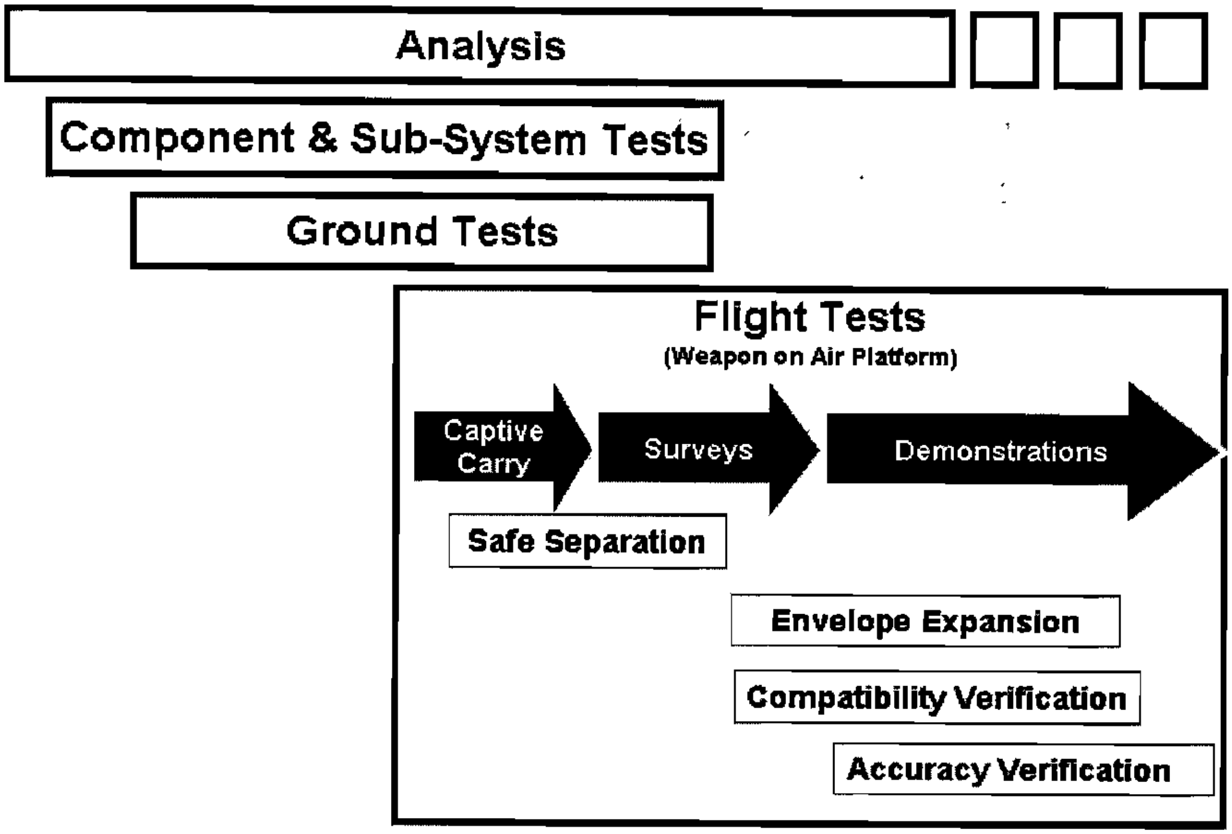


FIGURE 10. Flight test schedule

5.8.1.1. Safe separation. The safe separation phase for rotorcraft primarily involves jettison analysis/testing and clearance analysis/testing. For missiles and rockets, the clearance is typically verified by firing 6-9 missiles/rockets under initially benign aircraft maneuvering conditions such as hover and straight and level forward flight. The aircraft maneuvers progressively become more stressing but stay within the previously defined safe firing envelope to provide a level of confidence that the weapon will safely function as expected. Rockets and missiles used to verify clearance will not contain an explosive warhead, but will have the same weight, mass, and c.g. properties as the AUR. These test assets are typically called Eject Test Vehicles (ETV). Flight tests are preceded by analysis in order to maximize safety and to minimize the required number of test assets and associated cost and schedule.

5.8.1.2. Envelope expansion. The envelope expansion phase involves the firing of the weapon system at the most stressing points in the aircraft maneuver envelope as defined in the safe firing envelope. In essence, the weapon is fired at the “corners” of the safe firing envelope. The flight firing test maneuvers of the envelope expansion phase must not exceed the aircraft system approved flight maneuver envelope.

5.8.1.3. Compatibility verification. Compatibility is the ability of an aircraft, armament, stores, armament/stores management systems, and related suspension equipment to coexist without unacceptable effects of one of the aerodynamic, structural, electrical, or functional characteristics of the others under all flight and ground conditions expected to be experienced by the aircraft-store/armament combination. Compatibility testing is a part of all armament integration airworthiness programs. Compatibility testing is a focal point when only a minor change has occurred. This limited/tailored type of testing is accomplished during a MWS (paragraph 4.3.7). Compatibility testing ensures that the modifications (hardware and software) have not degraded the capability of the existing weapon, the aircraft, and other aircraft subsystems. Appendix D shows an example of a MWS conducted on a helicopter in which a second fire control computer had been added to provide redundancy and associated vulnerability reduction.

5.8.1.4. Accuracy verification. In this phase the accuracy and other performance requirements that require flight test verification are accomplished. The accuracy firing analysis (paragraph 5.2.15) supports this flight test phase and is, in part, validated by the flight firing test. In addition to customary instrumentation, the aircraft should be instrumented to support post test assessment of accuracy error budgets. Accuracy requirements are typically specified in the ORD or aircraft system specification. Even if there is no quantified "specification accuracy" to be verified, the accuracy should not be so poor as to cause a safety hazard to the firing aircraft or friendly troops. This is usually the case for unguided weapons such as rockets or guns when they are fired with no sight or a helmet-mounted sight that has a reduced accuracy. It is important to measure and characterize the accuracy during flight firing tests so that the field knows the limitations of the weapon and can better determine how to use it safely and tactically. Normally the AED Weapons and Sensors Integration Branch is the performance/accuracy evaluator of armament integration programs along with its "airworthiness" role. However some major or special situation programs have an Independent Evaluator assigned, such as the U.S. Army Evaluation Center (AEC). In those cases, the AED engineers work closely with AEC representatives and others to prepare a coordinated test program. The extent of testing depends on many factors including the following:

a. Scope of the accuracy and other performance requirements.
b. Allowance of supplemental modeling and simulation.
c. Statistical considerations such as confidence level.
d. Number of modes of armament system and munition operation.
e. Day/night operation and environmental verification requirements.
f. Number and variety of flight engagement maneuvers.
g. Available resources and test assets.
h. Affordability.

5.8.2. Flight test requirements. Key tests that should be considered are shown in Table VII.

TABLE VII. Armament flight test requirements

TESTS		SUBSYSTEMS: GUN & TURRET	ROCKETS & MISSILES	DROPPABLE STORES	CHEMICALS & PYROTECHNICS	ARMAMENT CONTROL
Flight (Non-Firing)	Aircraft Flight Performance	X	X	X	X	
	Fire Control	X	X	X	X	X
	TA/DS					X
	Armament Functionality	X	X	X	X	X
	WILIs	X	X	X	X	X
	Jettison			X		X
	Loads and Vibration	X	X	X	X	
	E3	X	X	X	X	X
Flight (Firing)	Aircraft Flight Performance	X	X	X	X	
	Fire Control Integration	X	X	X	X	X
	Noise Level Determination	X	X		X	
	Gas Accumulation Measurement	X	X		X	
	Debris	X	X	X	X	
	Loads & Vibration	X	X	X	X	
	Gas Ingestion/ Engine Operation	X	X		X	
	Armament Operation and Performance	X	X	X	X	X
	System Accuracy	X	X	X	X	X
	Firing Envelope	X	X	X	X	
	Temperature Profile Determination	X	X		X	
	Clearance Verification	X	X	X	X	X
	Loads and Vibration	X	X	X	X	
	Boresight/Retention	X	X	X	X	X
	Human Factors	X	X	X	X	X
	E3	X	X	X	X	X

5.8.2.1. Aircraft flight performance. Determine the effects of the weapon subsystem installation on air vehicle performance, stability and control throughout the flight envelope of the aircraft. Tests will include take-off and landing, climb, level flight, maneuvering flight, firing, and jettisoning. Aircraft handling qualities will be assessed. Depending on the magnitude and risk of the armament integration, a Preliminary Airworthiness Evaluation (PAE) may be required. Guidance on conducting a PAE is contained in ADS-51-HDBK.

5.8.2.2. Target acquisition/designation subsystem (TA/DS) pointing. Verify TA/DS day/night pointing. This test should include boresight retention.

5.8.2.3. Target acquisition/designation subsystem handover. Verify TA/DS handover between the sensor(s) and the weapon systems.

5.8.2.4. Target acquisition/designation subsystem/weapon firings. Establish effects of weapons firing on the TA/DS performance (vibration, flash, smoke, debris). Particular attention should be given to day/night automatic tracking.

5.8.2.5. Fire control. Test measurements should include recording of air vehicle state; weapons pointing data, such as azimuth, elevation, and range to target; and impact missed distances. Verify fire control integration and interface. Determine any considerations due to latency and stabilization. Assess fire control timelines. Verify armament/sensors cueing and slaving to optimize weapon aiming and to shorten engagement timelines. If an IFFC capability exists, assess the operation of the IFFC and the effects of the flight control and fire control subsystems on each other. When engaged, verify that the IFFC can be safely overridden by the crew at any time. Verify all targeting information and control data-links, both pre- and post-launch, including those from sources external to the launch platform.

5.8.2.6. Jettison. Jettison tests are conducted to verify safe store jettisoning from all stores stations. The external stores separation test uses actual stores or dummy stores with correct weight, center-of-gravity, shape, and moments of inertia. Jettison tests demonstrate the separation characteristics of all droppable external stores. Droppable stores include expendable stores such as missiles and mines and non-expendable stores such as gun pods and fuel tanks. When there are several different configurations of external stores, then all feasible combinations should be assessed. Stores loading and aircraft flight conditions for test are determined by analysis and simulation. Minimum satisfactory jettison criteria are shown in Table VIII.

TABLE VIII. Minimum jettison criteria

1	Immediate operation of the jettison device or operation within an allowable time period.
2	No damage to the air vehicle during or following actuation of the jettison device.
3	Jettison trajectory is clear of the air vehicle and other stores.
4	No inherent instability of the jettisoned store while in proximity to the air vehicle.
5	No adverse or uncontrollable air vehicle reaction at the time of jettison.
6	Stability and control characteristics after jettison are consistent with the those outlined in ADS-33E.
7	There is no unusual degradation of aircraft performance characteristics after jettison.

a. Droppable external stores are any items that are not an essential part of the basic air vehicle and are affixed to the airframe with provisions for quick release. Droppable external stores may include but are not limited to fuel tanks, weapons pods, rocket launchers, missile launchers or rails, bombs, mine dispensers, torpedoes, or pyrotechnic devices.

b. Jettison of all external stores should be demonstrated for sufficient combinations of flight conditions to establish and verify a jettison envelope for each type of external store configuration. Selective jettison of stores should be demonstrated for those conditions that may result in adverse operational characteristics of the air vehicle and the remaining external stores. Typically, safe jettison is almost always demonstrated by limited jettison tests in conjunction with extensive jettison analysis.

c. All jettisons should use the release method provided or specified for the store. However, each secondary or redundant release system should also be used once during the demonstrations. Typically, lower weight causes a worst case jettison condition. All system failures should be shown to not adversely affect the air vehicle characteristics or the jettison capability of the remaining stores.

d. Flight conditions for jettison demonstrations should be planned and documented. All demonstrations should be conducted at the extreme or critical combinations of weight and both longitudinal and lateral c.g. locations within the air vehicle maneuver spectrum. When external stores have expendables, such as rockets and flares, separation is demonstrated with full, intermediate, and empty weights for the stores.

e. Jettison demonstrations should be performed at sufficient airspeeds to establish the airspeed restrictions for satisfactory separation characteristics and demonstrated at the power required for level flight and during autorotative flight or unpowered glide. The maximum and minimum airspeed limits for safe operations should be established.

f. Separation characteristics of each jettison should be recorded. Additionally, still photography should be used to document the location, shape, and method of attachment of external stores and the damage to the air vehicle caused by jettison. See paragraph 5.9.3.8 for additional guidance on data and instrumentation.

g. Demonstrations should be conducted at altitudes and attitudes consistent with the normal operation of the air vehicle. If the attitudes of external stores with respect to the air vehicle are varied, the most critical attitude consistent with operational usage should be demonstrated. The sideslip envelope as a function of airspeed should be determined.

5.8.2.7. <u>Gun operation and accuracy</u>. Verify the capability to carry, control and fire the gun system. Verify gun operation, duty cycle, range, accuracy and fire control timelines. The dispersion and mean point of impact (MPI) of the rounds will be measured. If the gun is turreted, the capability to slave to sights, slew rate, acceleration, and position accuracy will be measured. Compatibility with designated ammunition type(s) will be verified. If a statistical confidence level is required, it will be a major factor in determining the number of rounds to be fired.

a. The process for developing a gun firing matrix for accuracy must ensure that the gun and aircraft are tested as a complete system. Aircraft operation may induce unexpected errors into the gun's accuracy. Additionally, the test firing matrix should be tailored to the known or expected operational conditions that will be encountered by the aircraft system. The aircraft ORD and aircraft system specification will typically specify a probability of hit (P_h) for the gun system's accuracy standard. Normally, firing from a hovering rotorcraft is required in addition to forward flight including maneuvers such as diving attacks or turns. Typically a minimum of 10 iterations will be fired at each test point. A test point consists of a specified aircraft altitude, maneuver, airspeed, range, site system, target conditions, burst size, and number of iterations for each test point. An example of a gun accuracy firing matrix for a turreted gun system and a procedure for calculation of system accuracy from test data are shown in Appendix E. A similar matrix for a non-turreted or fixed-gun system would not contain the aircraft banking/veer maneuver test points.

b. Although most gunfire tests are conducted with target practice (TP) or training rounds, compatibility testing is also conducted to ensure that the gun can safely fire specific types of rounds such as High Explosive Dual Purpose (HEDP). This testing requires that rounds be fired from the gun system to show that safety is not degraded through excessive barrel erosion, premature detonation, or other malfunction. These tests may be conducted on the ground, but should also be conducted during actual flight, which introduces more dynamic effects on the ammunition handling system. A compatibility firing matrix is typically constructed with specifications for rounds, firing modes, gun vibration, gas in cockpit/troop area, noise/acoustic impact, light/flash intensity and debris.

5.8.2.8. Rocket operation and accuracy. Verify the capability to carry, control and launch unguided rockets. Verify rocket selection functions, capability to inventory, capability to set fuzes from the cockpit, firing modes/rates, range, accuracy, and fire control timelines. Special attention should be placed on ensuring that the fire control is capable of recognizing and firing the specific type of rocket. This may entail a requirement to qualify the rockets according to each zone in the fire control/launcher. Rocket system accuracy is usually specified in terms of the cross-range and down-range errors measured in milliradians. Full accuracy qualification testing typically requires that a minimum of 10 rocket pairs be fired at each test point. This requirement has roots in the basic operational engagement procedure for most rotorcraft that specifies that rockets will normally be fired in pairs. Test points should include the number of pair iterations, rocket motor type, warhead type, fuse, range to target, and aircraft speed and maneuver. The mean point of impact for each pair is used in the accuracy determination. The test points should conform to the expected operational engagement technique for the aircraft. An example of a rocket firing matrix and a procedure to calculate accuracy from test data are shown in Appendix E.

5.8.2.9. Missile operation and accuracy. Verify the capability to carry, control and launch missiles. All modes of fire should be exercised to the maximum extent feasible.

A circular error probable (CEP), or a probability of hit (P_h), is demonstrated for the total weapon system, which includes the missile and in-flight aircraft. The flight regime and environment should be tailored to be representative of the standard engagement scenario. A captive flight trainer or training missile should be used to verify the missile and fire control functionality, including safety inhibits, as well as to ensure that the missile design does not adversely affect the in-flight capabilities of the aircraft. Missile costs, resource availability, and/or other constraints may limit the number of AUR missiles that can be fired for accuracy demonstration. Modeling and simulation may be used to augment the accuracy determination, using validated, verified, and accredited software. Methodology to calculate missile system accuracy from test data is shown in Appendix E.

5.8.2.10. Armament safety.

a. Verify safe operation, safety interlocks and armament duty cycles.

b. Where feasible, armament WILIs are verified.

c. The safe release and delivery of on-board ordnance including bombs and/or dispensed munitions are verified.

d. Verify the minimum munition delivery range and maximum aircraft flight conditions that allow for safe escape.

e. Verify that the minimum safe arming distance and fuze arm time settings are sufficient to prevent damage to the ownship if munition pre-detonation should occur.

f. Verify missile/rocket clearance cones and gun projectile trajectory clearance.

g. Safe firing envelopes that were developed by analysis are verified.

h. Verify noise levels in the cockpit and crew compartment. Determine the impact of the weapon firing noise on on-board sensors.

i. Verify gas accumulation in the cockpit and troop compartment.

j. The airframe and avionics response to blast pressure, including acoustic pressure, should be assessed.

5.8.2.11. Loads and vibration. Structural installation, recoil loads, and airframe response to weapons' rates of fire are evaluated throughout the safe firing envelopes.

5.8.2.12. Engine operation. Verify the effect of firing missiles/rockets/guns on engine operation. The worst-case ripple and salvo of armament firing should be used for the verification. Any effects on the engine(s), such as over-torqueing, detrimental increases in engine inlet temperatures, and overstressing of the drive system, are recorded and reported. See paragraph 5.9.3.9.

5.8.2.13. E3. See Appendix A.

5.9. Test instrumentation. Instrumentation consists of sensors and data transmitting, receiving, displaying and recording equipment. The test instrumentation should be sufficient to record appropriate armament, fire control, and aircraft data to establish qualification test compliance. The instrumentation and data analysis methods should be defined in the test plan.

5.9.1. Airworthiness considerations. Safety is paramount in the testing of weapon systems. Safety to the aircraft, crew, maintainers, test personnel and observers must be maximized. The installation of instrumentation on a test aircraft has the potential to introduce safety hazards. Examples include introduction of new failure modes to existing equipment, unsafe mounting and structural degradation due to mounting, E3, potential crash hazards and obstruction to emergency egress of the crew. All potential hazards must be identified and eliminated or mitigated to a risk level normally associated with test aircraft operation. As part of the AWR process, the AED divisions assess the airworthiness of the installed instrumentation, as well as the new systems or modifications to be evaluated. To this end, SOF EMI and environmental data may also be required for selected flight test instrumentation, depending on past history with usage of that instrumentation on helicopter platforms. In any event, flight test instrumentation will be included in the SOF EMC test of paragraph A.2.4.1.

5.9.2. Typical aircraft instrumentation. During armament testing on aircraft, it is important to monitor the state of the aircraft, such as velocity, accelerations, rates, attitudes, temperatures, pressures and human factors related parameters. Typical instrumentation sensors include accelerometers, strain gages, temperature and pressure sensors, flow sensors, position sensors, vibrations sensors, and audio and video-sensing devices. For onboard digital communication buses, bus monitoring devices monitor and record bus traffic. Data can be collected "real time" or non-real time and can be recorded onboard the aircraft or be sent by telemetry to a ground station. It is important that the instrumentation system be able to provide time-tagged information relative to aircraft state and armament events such as jettison and firing. Instrumentation guidance for each aircraft subsystem is contained in ADS-51-HDBK and, in some cases, the ADS associated with each subsystem.

5.9.3. Special armament instrumentation. Extensive guidance on aircraft testing of armament, including instrumentation and data parameter requirements, is provided in the tri-service MIL-HDBK-1763 and to a lesser degree in MIL-HDBK-244. Special instrumentation exists for component qualification of armament, such as environmental testing and performance testing in development facilities. Guidance provided herein is intended as examples of instrumentation for aircraft testing. Aircraft ground tests with installed armament are conducted, both non-firing and firing, to verify safety, compatibility and performance prior to flight test. Examples of instrumentation and parametric data to be collected include the following:

5.9.3.1. Clearance. Armament stores static clearance is measured with standard measuring devices. Bullet trajectory clearance with rotors and other aircraft parts can be statically determined by placing a long rigid rod in the gun barrel and measuring the clearance as the rod passes the aircraft part. Clearances can also be determined using sighting devices or eye-safe laser lights projected along the munition's trajectory to a target board next to each aircraft part in question. The dynamic clearances can be measured during and after firing/launch through the use of high-speed video equipment.

5.9.3.2. Timelines. Arm and rearm times are measured along with other human factor aspects. Armament start-up time to fire, fire control timelines and crew workload can be measured on the ground and in flight using timing devices. On the ground, engineering test tools such as the Hellfire "house mouse" can be used to conduct a functional check. During flight test, training missiles or captive flight trainers can be used for functional check, engagement modes and timelines, and verification of firing/launch inhibits.

5.9.3.3. Structural integrity. Structural integrity of the armament and its aircraft supporting structure, both non-firing and firing, can be assessed through the use of load cells or load transducers, strain gauges and deflection gauges. Structural tests should be accomplished on an aircraft ground test stand prior to flight test. In-flight loads are measured throughout the captive carriage and firing maneuver envelope. External stores racks and pylons should be instrumented for carriage loads, reaction loads and vibration. Gun systems are instrumented to measure recoil loads and gun mechanism displacement. Gun cradles, turrets and aircraft interfaces are instrumented to measure reaction loads and vibration. White reference dots should be painted on the cradle, turret, and aircraft to provide visual reference for video coverage and analysis of displacements.

5.9.3.4. Aeroelastic and aeroacoustic effects. See MIL-HDBK-1763. These tests are first conducted in wind tunnels using instrumentation such as structural and vibration sensors, and microphones and sound pressure sensors. Although applicable to all armament, it is especially important for weapon stores in aircraft internal weapon bays.

5.9.3.5. Blast overpressure, thermal, flash and debris. These weapon effects should be first measured and assessed on ground test fixtures prior to aircraft flight firings. The tests can be conducted with AURs or motor-only firings. Representative aircraft structure or flight safety parts such as main rotor, tail rotor, and horizontal/vertical stabilators may be used. A whole aircraft structure should be used if available. If witness panels are used, they should be placed in the actual proximity of the firings as the parts would be on the aircraft. The witness elements should be instrumented for the relevant effects. Examples of instrumentation include flow field, force, pressure, temperature, vibration and acoustic transducers, time monitors, high-speed cameras, and optical and infrared spectrometers with suitable recording devices. Blast debris must be characterized and patterns must be measured and located with respect to the aircraft. Debris content, fragment size, mass, hardness, velocity profile and impact energy profile should be measured. Do not place a backboard in the thrust path because it can substantially reduce the velocity of the debris.

5.9.3.6. Gas and noise. Gas and acoustic noise measurements resulting from armament firing, both internal and external to the aircraft must be measured. They must be assessed from a health hazards aspect, crew performance viewpoint, and potential damage to the aircraft and its equipment. These tests and their instrumentation should be coordinated with the U.S Army Health Hazard Assessment Office that is within the Center for Health Promotion and Preventative Medicine (CHPPM). Noise instrumentation consists of strategically placed microphones, sound level meters and recording equipment. CHPPM also provides gas monitoring equipment and assessment.

5.9.3.7. Firing/launch signal. Prior to the test, the launching/firing system should be connected and checked for circuit continuity and spurious electrical impulses. The signal received from the aircraft should be measured at the launcher, gun or other armament interface. The signal strength level, waveform, time delay and command content should be measured. The test instrumentation data collected should be examined for evidence of voltage spikes, cross talk and other undesirable phenomena. All mechanical and electrical safety interlocks should be checked for fit and function with the armament in place and the armament pointing downrange. Instrumentation before and during the flight test includes voltage, current and time monitors.

5.9.3.8. Jettison. Aircraft jettison tests must provide data that documents the stores separation characteristics. The data must be quantitative and must allow comparison of flight release motion and aircraft clearance (or impact) with that predicted in simulations. This data is usually provided by onboard and chase aircraft high speed video cameras with a minimum frame rate of 200 frames per second. A combination of views is needed to adequately record separation characteristics including store oscillations, functioning, store-to-store collisions and store passage through aircraft shock and flow fields. Stores racks can be instrumented to measure reaction loads, hook opening, or to provide a “stores away” signal. The aircraft should be instrumented to determine the aircraft conditions at time of stores jettison (speed, attitude, accelerations). Test aircraft configuration, including ejector rack information and jettison sequence/interval, should be recorded. Store mass, physical, and operational characteristics should be measured and documented.

5.9.3.9. Engine compatibility. Exhaust ingestion surveys are conducted to determine the effects of hot munition exhaust gas ingestion into the helicopter's engines. Engine performance is monitored and recorded during firing events. The helicopter’s drive train is also monitored for torque oscillations. Instrumentation should measure the pressure and temperature distortion at the engine inlet due to ingestion of munition exhaust gas. Typical instrumentation includes high speed probes and thermocouples. Also, flight infrared photography may be used to determine the signature of the ordnance hot gas plume. All specified firing modes and rates should be assessed, including rapid, ripple and salvo. The data collected will support a safe firing envelope for the armament system. While Army helicopter experience has shown this survey is important for rocket systems, it should also be considered for missile and gun systems. Propulsion system guidelines for armament gas ingestion survey and test are provided in ADS-1B-PRF. Concurrent with the ingestion surveys, noise and gas levels within the cockpit should also be monitored.

5.9.3.10. Launch transients. Prior to aircraft launches, new or major modified missile/rockets should be instrumented and launched from an instrumented ground test fixture that simulates the aircraft structural installation. Mounted on the fixture should be the aircraft wing, pylon, stores ejector rack and launcher. The munition can be modified to include a lanyard and/or telemetry (TM) package to obtain missile data, including internal guidance mechanism, during launch and flight. Pitch, yaw and roll data are obtained on the munition and are also independently taken from the guidance mechanism. High-speed video is also used to capture the launch and early flight sequence. The munition should be painted with a 30-degree roll pattern on the side facing the cameras to provide visual contrast and to support analysis. Typical instrumentation for the fixture and installed test articles include strain gages, accelerometers and rate sensors. The objective is to measure the dynamic motion of the aircraft, aircraft interface, launcher and launcher component (such as rail) during the missile/rocket launch. Following ground fixture launches, munition launches should be conducted from the aircraft on the ground, then in flight. The same launcher used in ground shots and the same instrumentation configuration should be maintained. The lanyard instrumentation can be used for aircraft ground shots, but only TM modified munitions can be launched during flight launches. The aircraft should also be instrumented to obtain its state information during launch.

5.9.3.11. Data bus monitor. Portable lightweight (under 10 pounds) bus monitors serve as a useful instrumentation tool in avionic subsystem development and testing. They can monitor bus message traffic, including content, frequency and timing. Experience has shown that even the timing of bus messages, can affect armament functionality. Bus monitors can be used to monitor 100 per cent of bus traffic or a programmed subset of traffic. They can be used in SIL tests or in flight testing of armament to assess integrated software compatibility or to trouble shoot anomalies. When an aircraft subsystem hardware or software that interfaces with armament is modified, a MWS of the already qualified armament is normally required. However, if agreed to by the AED Weapons and Sensors Integration Branch, bus monitoring can be used in lieu of a MWS. An analysis/test of the modification would have to substantiate that it has no effect on the armament. Some of the primary concerns are that WILIs, safety interlocks, line of sight or range information to the armament might have been degraded. On the surface, the bus monitoring alternative might seem to be a tempting alternative. However the amount of time and effort it takes to prove that everything is "just the same" for armament, could be extensive. Therefore it might be easier and faster just to shoot the armament as is done in a MWS.

5.10. Documentation. The following airworthiness related documentation should be tailored, prepared, reviewed, approved, and utilized as appropriate for the configuration.

5.10.1. Data Item Descriptions (DID). The following DIDs are applicable and should be tailored and cited as appropriate for the specific configuration:

a. DI-NDTI-80566 Test Plan

b. DI-NDTI-80603 Test Procedure

c. DI-NDTI-80809B Test/Inspection Report

d. DI-EMCS-80200B Electromagnetic Interference Test Report

e. DI-SAFT-81626 System Safety Program Plan (SSPP)

f. DI-SAFT-80103B Engineering Change Proposal System Safety Report (ECPSSR)

g. DI-DRPR-81000C Product Drawings/Models and Associated Lists

h. DI-GDRQ-80198A Internal Loads and Static Strength Analysis Report

i. DI-MGMT-81501 Weight and Balance Report for Aircraft

j. DI-EMCS-80199B Electromagnetic Interference Control Procedures (EMICP)

k. DI-SAFT-80101B System Safety Hazard Analysis (SSHA) Report

l. DI-SAFT-80102B Safety Assessment Report (SAR)

m. DI-ILSS-81495 Failure Mode Effects and Criticality Analysis (FMECA) Report

n. DI-EMCS-80201B Electromagnetic Interference Test Procedures (EMITP)

o. DI-MISC-80711A Scientific and Technical Reports

p. DI-SESS-81002D Development Design Drawings/Models and Associated Parts Lists

q. DI-NDTI-81284 Test and Evaluation Program Plan (TEPP)

r.	DI-CMAN-81314	System/Segment Interface Control Specification
s.	DI-CMAN-81022C	Configuration Audit Summary Report
t.	DI-IPSC-81430A	Operational Concept Description (OCD)
u.	DI-IPSC-81431A	System/Subsystem Specification (SSS)
v.	DI-EMCS-81540A	Electromagnetic Environmental Effects (E3) Integration and Analysis Report (E3IAR)
w.	DI-EMCS-81541A	Electromagnetic Environmental Effects (E3) Verification Procedures (E3VP)
x.	DI-EMCS-81542A	Electromagnetic Environmental Effects (E3) Verification Report (E3VR)
y.	DI-MGMT-81502	Sample Chart A and Chart E Report for Aircraft
z.	DI-MGMT-81503	Post-Design Weight Analysis Report

5.10.2. Airworthiness Qualification Specification (AQS). The AQS is normally prepared by the contractor and submitted for approval by the program manager and AED. The AQS defines the contractor's approach for conducting specific analyses, reviews, tests, demonstrations, and surveys to satisfy the requirements of an AQP. The AQS should be a complete integrated test plan for the new system or modification describing the set of minimum analysis and testing requirements that satisfy all contractual provisions. A Master Schedule and Verification Matrix are included in the AQS. Formats for an AQP and AQS are provided in ADS-51-HDBK.

5.10.3. Verification matrix. The verification matrix documents all verification testing of the system against qualification requirements. An indication of the qualification method is found at the matrix intersection between each system requirement and system.

5.10.4. Test plans and procedures. Qualification test plans and procedures, except EMI/E3, are normally prepared IAW DI-NDTI-80566 and DI-NDTI-80603 for all tests and demonstrations. EMI and E3 test plans and procedures are prepared IAW DI-EMCS-80201 and DI-EMCS-81541, respectively. EMI control procedures are submitted IAW DI-EMCS-80199. Test plans and procedures are submitted for approval no later than 60 days prior to the start of test, survey, or demonstration. Government approved test plans are used to conduct all tests.

5.10.5. Test reports. The results of tests, demonstrations, and analyses required for qualification are submitted for acceptance to verify compliance with the design and test plan requirements. Test reports will include the aircraft configuration used, any deviations from the test plan, the test results, and a comparison of the test results with the test plan requirements. Test results, except EMI/E3, are prepared IAW DI-NDTI-80809. Results of EMI and E3 test and E3 analysis are prepared IAW DI-EMCS-80200, DI-EMCS-81542 and DI-EMCS-81540, respectively. Reports are submitted for distribution within 60 days of test completion. Reports developed from tests conducted at Government facilities, where the Government is the responsible data collector, are distributed within 60 days following receipt of the test data from Government facilities.

5.10.6. System Safety Management Plan (SSMP). Tests are planned and conducted IAW the SSMP. Hazard analyses and safety statements should be developed, presented, and approved by the Government prior to testing. System safety reviews are conducted as a part of the program design reviews. The analyses and reviews are IAW MIL-STD-882, Aviation Policy Memo 03-02 (Appendix C) or applicable PM safety management process or plan.

5.10.7. System Safety Program Plan (SSPP). The SSPP details the task and activities of system safety management and system safety engineering required to identify, evaluate, and eliminate or control hazards throughout the changes from the baseline configuration. The System Safety Program Plan describes fully the planned safety tasks and activities required to meet the System Safety Program requirements. The SSPP is prepared IAW DI-SAFT-81626.

5.10.8. Preliminary Hazard Analysis (PHA). The PHA is the first of a series of hazard analyses conducted in an acquisition development program. The PHA documents which hazards (hardware, software and human interface causal factors) are associated with armament integration into the platform design and weapon integration into the platform operational concept. This provides the initial framework for a listing of hazards and associated risks that require tracking and resolution during program design and development. The PHA can be used to identify potential safety-critical hardware/software interfaces that will require the application of a Failure Modes Effects and Criticality Analysis (FMECA) during design. The results of the PHA must be available prior to the PDR for integration into the design documents.

5.10.9. Subsystem Hazard Analysis (SSHA) Report. The SSHA follows the PHA as the design matures. The SSHA is performed to verify previously unidentified hazards associated with the design of the subsystems including component failure modes, critical human error inputs, and hazards resulting from functional relationships between system components and equipment comprising each subsystem. In addition to a FMECA, a useful tool to uncover hazards, such as potential for inadvertent launch, is a sneak circuit analysis. The SSHA Report is usually prepared IAW DI-SAFT-80101B.

5.10.10. System Hazard Analysis (SHA). The SHA defines the safety interfaces between subsystems and identifies safety hazards in the overall system. Typically, it will determine whether system hazards can be eliminated or controlled with safeguards.

The SHA is usually initiated during the early stages of development and updated as the system matures. It begins as soon as functional allocation of requirements occurs and continues through the completion of system design. The SHA analyzes the operation of the aircraft-integrated armament system as a whole and considers human interfaces and operational scenarios. Its value lies in its identification of interface problems, dependent failure problems, synergistic hazards and additive hazards.

5.10.11. Safety Assessment Report (SAR). The SAR is a system hazard analysis report. It identifies and evaluates safety provisions, hazards, hazard control measures, and residual risk associated with the integration of armament and the aircraft. The aircraft system-level SAR assesses both hardware and software integration. Safety hazards are assessed using MIL-STD-882, Aviation Policy Memo 03-02 or applicable PM safety management process or plan as guides. The SAR documents safety risks associated with test operations of the weapon system. The report formally identifies all safety requirements that were not implemented or partially implemented. It identifies hazards that were risk minimized. The report documents the ramifications of not proceeding further with risk mitigation techniques or "designing out" the residual hazardous conditions of the weapon system. See paragraph 5.7.2 for typical potential hazards to be assessed. The SAR is usually prepared IAW DI-SAFT-80102B. The results of the flight test program might necessitate that the SAR be updated prior to approval of a fielding AWR. Depending on the scope and integration risk of the armament airworthiness qualification program, the SAR may be preceded by a PHA, SSHA and SHA in the development cycle of new armament. The SAR for an aircraft armament modification program is typically an update to the existing aircraft SAR.

5.10.12. Failure Modes Effects and Criticality Analysis (FMECA). The FMECA is a procedure to determine the operational impacts that hardware and hardware/software interface failures will have on the system. The FMECA is intended to promote design corrective actions early in a development program by identifying potential failure modes and risks. The FMECA Report is usually prepared IAW DI-ILSS-81495. The FMECA may be combined with the software FMECA provided it includes hardware/firmware failure modes.

5.10.13. Drawings. The drawing list and set of drawings are normally provided IAW with ASME Y14.100M, Engineering Drawing Practices, which is the preferred requirements document for engineering drawing practices.

5.10.14. Software documentation.

5.10.14.1. Software Development Plan (SDP). The SDP describes the developer's plans for conducting a software development effort. The Software Development Plan provides insight to monitor the processes and approaches for each software development under contract. The SDP includes project schedule, organization, and approach used for each activity and resources.

5.10.14.2. Module Safety-Criticality Analysis. This analysis determines which Computer Software Configuration Items (CSCI) or Computer Software Units (CSU) are safety-critical and assists the safety engineer in prioritizing the level of analysis to be performed on each. The analysis develops a Safety-critical Function Matrix to illustrate the relationship each CSCI or CSU has with the safety-critical functions. Examples of safety-critical functions are to ensure all safety interlocks are satisfied prior to issuing the "ARM command and "FIRE" command. Reference the Joint Services Software Safety Committee, Software System Safety Handbook, December 1999, sections 4.2.1.5.3 and 4.3.5.1.

5.10.14.3. Software Design Description (SDD). The SDD describes the design of the software. It also describes software design decisions, the architectural design and detailed design needed to implement the software. The SDD includes a matrix that shows where the requirements from the SRS are designed into the software.

5.10.14.4. Software Requirements Specification (SRS). The SRS specifies the requirements and methods to be used to ensure that each requirement has been met. Requirements are listed for each CSCI. Each safety related requirement is individually flagged. An existing SRS is normally updated to include the added software requirements for the armament integration into the platform. The SRS includes a matrix that shows requirements traceability between the SRS and the SSS.

5.10.14.5. Software Interface Requirements Specification (IRS). The Software IRS specifies the requirements imposed on the hardware/software interface, and the interfaces between software. An existing IRS is updated to include the added interface requirements for the weapon integration into the platform.

5.10.14.6. System/Subsystem Specification (SSS). The SSS specifies the requirements for the weapon integration into the platform and the methods used to assure that each requirement has been met. The SSS includes a matrix that shows where requirements are designed into the software code.

5.10.14.7. Software Test Plan (STP). The STP describes plans for qualification testing of the software (CSCI items) associated with the weapon integration into the platform. It also describes the software test environment to be used for the testing, identifies the test to be performed, and provides schedules for test activities. The STP addresses the method that will be used to perform software regression testing, if required, for the safety requirements identified in the SRS.

5.10.14.8. Software Test Description (STD). The STD includes the test preparations, test cases, and test procedures to be used to perform qualification testing of the CSCIs used in the weapon system.

5.10.14.9. Software Test Report (STR). The STR is the record of the software qualification testing performed on each CSCI/ CSU. The STR will include system level and system integration tests if they are not covered by stand-alone documents. The

STR includes the result of each test, the procedures used for the test, and who witnessed the test.

5.10.14.10. Software Failure Modes, Effects and Criticality Analysis (FMECA). The software FMECA is the procedure to determine the operational impacts hardware and hardware/software interface failures will have on the software and the software response to the failure.

5.10.14.11. Software Safety Program Plan (SSPP). The SSPP includes software safety assurance procedures based on the Software Hazard Risk Index (SHRI) of the software components. Emphasis is placed on those software components with a SHRI of 1, 2, 3, or 4. A hazard requirements flow down matrix, which maps system/safety functions to safety requirements and hazard controls for software modules and components, is normally developed. Identification of the hardware or software items that receive, transmit, or process critical (potentially safety related) signals or commands is required. The software functions or objects that receive, transmit, or process critical signals or hazardous commands should be identified. Reference the Joint Services Software Safety Committee, Software System Safety Handbook, December 1999, Appendix C.1.19.

5.10.14.12. Software Version Description (SVD). The SVD describes a software version for each Computer Software Configuration Items (CSCI). It is used to release, track and control software. The SVD contains a list of all changes incorporated into the software version since the previous version. The SVD identifies the problem reports, change proposals and change notices associated with each change and the effects of each change on the system operation and on interfaces with other hardware and software.

5.10.14.13. Problem Change Reports (PCR). The PCRs log each software, hardware, or documentation problem found during system integration testing, the proposed solution, and the corrective action taken.

6. NOTES

6.1. Intended use. This document is intended to provide guidance on the airworthiness qualification process, analysis and test requirements for new or modified armament on Army aircraft. While the focus is on guns, missiles and rockets, the document provides limited information on UAV and directed energy weapons. As these armament technologies become more mature, there will have to be new special requirements to assure safety and effective performance on Army aircraft. However, the airworthiness qualification process is likely to be quite similar.

6.2. Information documents. The following documents are listed as references, but not specifically cited within the handbook.

AR 70-38	Research, Development, Test and Evaluation of Materiel for Extreme Climatic Conditions
AR 95-20	Contractor's Flight and Ground Operations
MIL-DTL-31000	Technical Data Packages
MIL-HDBK-310	Global Climatic Data for Developing Military Products
MIL-HDBK-5400	Electronic Equipment, Airborne General Guidelines for
STANAG 3899	Ground Fit and Compatibility Criteria for Aircraft Stores
AIR STD 20/21	Ground Fit and Compatibility Criteria for Aircraft Stores

6.3. International standardization agreements. Certain provisions of this document are the subjects of international standardization agreements. Examples of international standardization documents are NATO STANAG 3899 and Air Standardization Coordinating Committee AIR STD 20/21, each for Airborne Stores Ground Fit and Compatibility 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).

Army airworthiness qualification

Airworthiness qualification

Armament qualification

Weapon qualification

Helicopter armament

Helicopter weapons

APPENDIX A

GUIDANCE ON ELECTROMAGNETIC ENVIRONMENTAL EFFECTS (E3)

A.1 SCOPE

A.1.1 Scope. This appendix provides guidance on E3 requirements for analysis and test of new or modified armament integrated on Amy aircraft.

A.2 E3 REQUIREMENTS

A.2.1 Overarching E3 requirement. It should be demonstrated that the armament modifications are electromagnetically compatible with other onboard aircraft systems as well as with the aircraft's external operating environment IAW ADS-37A-PRF.

A.2.2 E3 analysis. For any major design work or modification and only if required by the procuring activity, the contractor should conduct an E3 analysis IAW paragraph 4.1 of ADS-37A-PRF. This analysis should clearly establish the contractor's approach for achieving compliance with the requirements of ADS-37A-PRF. The E3 analysis should be conducted prior to finalization of any major design work or modification to the aircraft. Results of this analysis should be documented in a report prepared IAW Appendix A of ADS-37A-PRF. The report should depict the design techniques employed and provide assurance through analysis, preliminary test data, and planned testing that the delivered system will comply with the E3 requirements. This report should be submitted to the airworthiness authority for approval.

A.2.2.1 First-flight requirement. Analysis will address potential interference effects of the new or modified armament system on critical aircraft systems. The effects might be influenced by the duration and timing of armament system operations and the recovery times of aircraft equipment that could be upset by such EMI. Aircraft system operations should also be analyzed with respect to safety-critical effects on the armament system. Analysis should also substantiate that the armament is compatible with aircraft power furnished IAW MIL-STD-704. (The specific version of MIL-STD-704 that applies is dependent on which aircraft model is being used.) Analyses should pay particular attention to electrical transients caused by armament system operations. Results of these analyses should be considered during the planning of the EMC test of paragraph A.2.4.1; e.g., it might be appropriate for the electrical power buses to be monitored for the presence of interfering and, possibly, damaging transient effects. The analytical report will summarize how the results of the analysis have influenced the installation design and subsequent E3 testing.

A.2.3 Subsystem/component electromagnetic interference (EMI) tests. EMI tests IAW MIL-STD-461 should be conducted on all armament and related subsystems IAW paragraph 4.2 of ADS-37A-PRF. Injection tests for cables and/or pins should be included for mission- and safety-critical subsystems to address susceptibility due to lightning-induced pulse interference. EMI qualification tests should use cables similar to the actual aircraft interconnecting cables in type, size, and installation.

A.2.3.1 First-flight requirement. In accordance with paragraphs 3.2 and 4.2 of ADS-37A-PRF, the minimum Safety-of-flight (SOF) EMI data required is conducted and radiated emission data (i.e., CE101, CE102 and RE102 of MIL-STD-461). For flight and safety-critical equipment, conducted and radiated susceptibility data (i.e., CS101, CS114, CS115 and RS103 of MIL-STD-461) are also required. These data are required to support planning of EMC testing of the armament system on the helicopter platform as well as enable evaluation of the susceptibility of the installed armament system in the electromagnetic environment of the flight test area. These data are required since the more detailed E3 testing will not have occurred prior to first flight. The concern is that (1) the armament system does not cause unacceptable interference to other aircraft systems, and (2) the armament system does not fall into an unsafe condition due to other sources of interference, whether onboard the helicopter platform or external to the helicopter platform. Conducted and radiated emission data may also be required for selected flight test instrumentation, depending on past history with usage of that instrumentation on the helicopter platforms. Tailoring of these requirements may be justified to take into consideration how the armament is electrically connected to the aircraft and the timing of its operations relative to aircraft operations, which could mitigate the effects of EMI.

A.2.4 Electromagnetic compatibility (EMC) test. An EMC qualification test must be conducted IAW paragraph 4.3.2 of ADS-37A-PRF on a complete aircraft system with emphasis on the newly added armament and related subsystems. The EMC test is conducted to demonstrate that the operation of one or more onboard subsystems does not result in degraded performance, unacceptable response, or malfunction of any onboard subsystem. Testing should include the demonstration of safety margins for Electrically Initiated Devices (EIDs) IAW with paragraph 3.1 of ADS-37A-PRF. If there are any significant radiated emission over-specification conditions noted during the EMI tests, then radio receiver noise floor tests may also be required to determine if radio distance performance is degraded. Testing should also include the demonstration of EMC with ground servicing equipment and ground support equipment. All mission equipment, including provision items and ordnance, should be installed when these tests are conducted.

A.2.4.1 First-flight requirement. A SOF EMC test must be conducted IAW paragraph 4.3.1 of ADS-37A-PRF prior to first flight. It is conducted to demonstrate qualitatively that the operation of the armament and related subsystems (including flight test instrumentation), as well as operation of existing aircraft subsystems, does not result in an unacceptable response or malfunction that may jeopardize aircraft safety, the safety of ground systems and personnel, or adversely affect the flight test program.

A.2.4.2 Electrical bonding. Bonding measurements must be performed IAW paragraph 4.10 of ADS-37A-PRF for all newly installed and re-installed equipment prior to any aircraft-level E3 test.

A.2.4.3 Electrical power quality tests. If there are any significant conducted emission over-specification conditions noted during the EMI tests, then electrical power quality tests may be required IAW paragraph 4.9 of ADS-37A-PRF to evaluate the effects of armament subsystem operations on the aircraft electrical power quality. In that case, ripple voltage, transients, harmonics, and power usage (steady-state and surge) should be measured on the affected busses and compared to the requirements of the version of MIL-STD-704 that applies to the aircraft being modified. Test requirement is limited to the aircraft power bus corresponding to the electrical power lead of the unit under test that failed the conducted emission test. A baseline measurement should be conducted to facilitate distinguishing between anomalies caused by the unit under test versus pre-existing anomalies, which are not the subject of this requirement. This test may be included as a part of the EMC test. Depending on the length of the test program and the level of exceedance, this may become a first-flight requirement due to concern with cumulative effects and resulting potential damage to aircraft equipment.

A.2.5 Electromagnetic Vulnerability (EMV)/Hazards of Electromagnetic Radiation to Ordnance (HERO) tests. The Government will conduct EMV and HERO tests to determine the overall capability of the modified aircraft to perform its mission in its expected external operating environment. These tests will be conducted IAW paragraphs 4.4 and 4.6.1 of ADS-37A-PRF (except that HERO test levels will be IAW Table IA of MIL-STD-464) on a complete aircraft (to include all provision items) to determine the vulnerability of onboard aircraft electrical and electronic subsystems/components (including EIDs) to external emitters. The Government will conduct these tests at Government facilities. The contractor will be required to assist the Government in the preparation of test plans, procedures, and reports, provide appropriate engineering consultation to the Government to resolve anomalies observed during testing, and maintain the aircraft while it is at the test facility. Detailed HERO test guidance is provided in MIL-HDBK-240.

A.2.5.1 First-flight requirement. The flight test area must be surveyed for electromagnetic emitters with respect to helicopter operations, the results of which will be analyzed in the context of armament system EMI susceptibility data and/or existing helicopter platform Electromagnetic Vulnerability (EMV) and Hazards of Electromagnetic Radiation to Ordnance (HERO) data. The intent is to minimize the risk of an unacceptable response or malfunction of either the armament or an aircraft system that may jeopardize aircraft safety, the safety of ground systems and personnel, or adversely affect the flight test program. Full use will be made of susceptibility test data obtained previously on the armament system or helicopter platform; e.g., EMV and HERO data at the aircraft level (reference paragraphs 4.4 and 4.6.1 of ADS-37A-PRF) and RS103 data at the component level (reference paragraph 4.2 of ADS-37A-PRF). Where such data is not available, the use of Electromagnetic Radiation Ordnance (EMRO) and Electromagnetic Radiation Hazard (EMRH) data for the armament system should be considered (reference TR-RD-TE-97-01).

A.2.6 Static electricity tests. Static electricity tests should be conducted to demonstrate that electro-static discharges, associated with handling and helicopter operations, do not cause unsafe conditions with, or adversely affect the reliability of, armament subsystems. Testing should generally be IAW paragraph 4.7.2.1 of ADS-37A-PRF. Alternatively, verification may be accomplished by a combination of qualification tests, development tests, analyses, and previously verified designs. If tests are conducted by the Government, the contractor will be required to assist the Government in the preparation of test plans, procedures, and reports, provide appropriate engineering consultation to the Government to resolve anomalies observed during the testing, and maintain the equipment while at the test facility.

A.2.6.1 First-flight requirement. Electrostatic Discharge (ESD) hazards (reference paragraph 3.7 of ADS-37A-PRF) must be analyzed with respect to inadvertent ignition of safety-critical ordnance. Weapon round test data may be available for mature weapon systems; which would be pertinent to such an analysis. These hazards are generally addressed through design and operational constraints prior to initiation of the above qualification testing.

A.2.7 Hazards of Electromagnetic Radiation to Personnel (HERP). HERP analyses and/or tests (when appropriate) should be performed to demonstrate that the levels of electromagnetic radiation, associated with newly added radio frequency transmitters (e.g., fire control radars), are not hazardous to personnel in areas of the aircraft which are accessible during flight and external areas in which personnel are present during on-ground system operation. The requirements of paragraph 3.6.3 of ADS-37A-PRF should apply. This is a first-flight requirement.

A.2.8 Lightning protection tests. It must be demonstrated that a 200,000-ampere lightning strike to the aircraft and/or armament store does not cause unsafe conditions with and adversely affect the reliability of the armament subsystem. Verification may be accomplished by a combination of qualification tests, development tests, analyses, and previously verified designs. Testing must generally be IAW paragraph 4.8.2 of ADS-37A-PRF. If conducted by the Government, the contractor will be required to assist the Government in the preparation of test plans, procedures and reports, provide appropriate engineering consultation to the Government to resolve anomalies observed during the testing, and maintain the equipment while at the test facility.

A.2.8.1 Lightning protection analysis. A lightning protection analysis must be conducted IAW paragraph 4.8.1 of ADS-37A-PRF. If the analysis shows the potential for a problem, or if the analysis cannot be completed with sufficient accuracy, then testing should be performed. This analysis may be included as a part of the E3 analysis of paragraph A.2.2.

A.2.8.2 First-flight requirement. Lightning hazards (reference paragraph 3.8 of ADS-37A-PRF) must be analyzed with respect to inadvertent ignition of safety-critical ordnance. Weapon round test data may be available for mature weapon systems;

which would be pertinent to such an analysis. These hazards are generally addressed through design and operational constraints prior to initiation of the qualification testing.

APPENDIX B

GUIDANCE ON ENVIRONMENTAL REQUIREMENTS

B.1 SCOPE

B.1.1 Scope. This appendix provides guidance on environmental requirements for analysis and test of new or modified armament integrated on Amy aircraft.

B.2 ENVIRONMENTAL REQUIREMENTS

B.2.1 Overarching environmental requirement. Unless otherwise specified by the Government, the overarching requirement should be to verify operability of the armament modifications for the range of environmental conditions specified in the associated aircraft system specification.

B.2.2 Environmental tests. Environmental tests should be conducted on all newly added and modified subsystems IAW MIL-STD-810 and Table B-I.

B.2.3 First-flight environmental requirements. The minimum first-flight requirements are High and Low Temperature (operational), Vibration, Shock – Crash Hazard (breakaway or breakup hazard to aircraft or crew), Altitude (may be combined with Temperature) and Explosive Atmosphere.

TABLE B-I. Environmental test matrix

Test	Method	Procedure [0]
Altitude (Low Pressure)	500	I-Storage and II-Operational. [1]
High Temperature [11]	501	I-Storage [10] and II-Operational [1]
Low Temperature [11]	502	I-Storage and II-Operational [1]
Temperature Shock [11]	503	I-Steady State or II-Cyclic as appropriate
Solar Radiation (Sunshine) [2]	505	I-Cycling (Thermal) or II-Steady State (Actinic) as appropriate
Rain	506	I-Rain/Blowing Rain or II-Watertightness or III-Drip as appropriate
Humidity[7]	507	
Fungus	508	Test is preferred. Analysis is optional.[3]
Salt Fog	509	
Sand and Dust	510	I-Blowing Dust and II-Blowing Sand and/or III-Settling Dust (as appropriate)
Explosive Atmosphere [11]	511	Test is preferred. Analysis is optional. [4]
Leakage (Immersion)	512	I-Immersion

Acceleration	513	I-Structural [5] and/or II-Operational [5]
Vibration [11]	514	I-General Vibration (Category 14)
Acoustic Noise [9]	515	
Shock [11]	516	I–Functional and V-Crash Hazard [6] and VI–Bench Handling
Gunfire Vibration	519	
Combined Temperature/ Altitude/Humidity/Vibration	520	III-Qualification [7]
Icing/Freezing Rain [8]	521	

Note 0 – These are the typical procedures that are appropriate for most equipment. Some tailoring of procedures may be required and/or additional procedures may be appropriate depending upon the type and location of the equipment and the operational mission of that equipment.
Note 1 –Temperature and altitude operational requirements (usually not including storage) can also be satisfied by the using the combined test method 520 (see Note 7).
Note 2 – Solar Radiation testing is conducted for externally-mounted equipment directly exposed to sunlight or for sunlight sensitive internal equipment (e.g., multi-function displays in which the optical elements may be vulnerable to ultraviolet radiation fading the color filters of the commercial liquid crystal displays) and which may be exposed to sunlight for indefinite time periods.
Note 3 - Fungus testing is preferred due to the uncertainty and proven unreliability of conducting a fungus analysis (also documented per MIL-STD-810); however an analysis may be sufficient if it includes a listing of all parts and chemical-based substances (including glues, sealants, etc.) employed in the design of the component along with contractor certification.
Note 4 – Explosive Atmosphere (EA) requirements may be satisfied by Analysis through submittal of a complete thermal analysis along with any other pertinent explanatory data for evaluation. EA may also be approved by analysis, if the component designs and system controls can be shown to avoid sparks or arcing, or high temps and hotspots are less than 200ºC.
Note 5 – Acceleration testing, unless specifically required by an aircraft's contractual requirements document should be determined on a case-by-case basis. Examples are equipment and systems that measure acceleration (e.g., EGI, TA/DS and PNVS), equipment which have a large moment arm away from the center of gravity of the aircraft, and equipment that has or depends on accelerometers.
Note 6 – Crash Hazard testing should be conducted on a case-by-case basis. Examples are components with displays or LEDs that may break into pieces, components located in a place such as the cockpit or cabin where parts could become projectiles and could cause injury to the crew, and components located in a place where parts could become projectiles and reduce the airworthiness of the aircraft (e.g., in an area where it could enter an engine or fuel tank or damage fluid lines).
Note 7 – This test method is optional and is specifically designed to be a combined synergistic test, and (if selected), without extensive tailoring, only satisfies the operational temperature, altitude, humidity and vibration qualification test requirements. This test method is sometimes tailored to conduct a limited operational

temperature/altitude test (mainly due to contractor test chamber limitations). The High Temperature, Low Temperature, and Humidity non-operating (storage) requirements are not satisfied by this test method unless the full test ranges of each of their individual test methods is tailored into the Method 520 test profile. For High Temperature Storage testing, the 168-hour diurnal cycle option referenced in test Method 501 is always required versus the 2-hour constant temperature option (newly added to MIL-STD-810), which would preclude tailoring of Method 520. Likewise, test Method 507 for humidity is a ground/storage test, and due to its extensive cyclical test durations is also not a good candidate for tailoring into Method 520; hence, it is always conducted as a separate individual test. In addition, MIL-STD-810 specifically prohibits tailoring of Method 520 to include Altitude Storage (Transportation) testing. If test method 520 is not selected, the individual test Methods 500 (Altitude), 501 (High Temperature), and 502 (Low Temperature) will satisfy both operational and non-operational (storage) requirements.

Note 8 – Icing/Freezing Rain. This test method is a requirement when there is a requirement to evaluate the effect of icing on the operational capability of equipment. It can also be used to evaluate the effectiveness of de-icing equipment and techniques, including prescribed means to be used in the field.

Note 9 – Acoustic Noise testing is required on a case-by-case basis and is not typically found in existing contractual documents. It should be conducted when specifically requested by an approved requirements document or when it has been determined to be a materiel testing requirement due to a particular mission profile.

Note 10 – For High Temperature Storage, the Army requires the more rigorous diurnal (minimum seven cycles of 24 hours cyclic storage (total 168 hours)) test, in lieu of the recently added constant temperature procedure (minimum two hours following test item temperature stabilization).

Note 11 – It is strongly recommended that the temperature, vibration, and shock testing be done on the same unit, and then that same unit undergo the explosive atmosphere test. This provides a more conservative explosive atmosphere test due to the stresses applied to the unit during the previous tests. However, if conducting all of the above tests on the same unit is not practical (usually due to scheduling conflicts or lack of availability of the units) the testing on the separate units is allowed. If the testing is conducted on the separate units as requested in this case, it is preferable that the explosive atmosphere test be conducted on the unit that underwent the vibration and shock tests.

APPENDIX C

AVIATION POLICY MEMORANDUM NUMBER 03-02 RISK MANAGEMENT PROCESS

DEPARTMENT OF THE ARMY
OFFICE OF THE PROGRAM EXECUTIVE OFFICER, AVIATION
REDSTONE ARSENAL, AL 35898-5000

REPLY TO
ATTENTION OF

SFAE-AV-PI

3 0 APR 2003

MEMORANDUM FOR SEE DISTRIBUTION

SUBJECT: Program Executive Officer (PEO), Aviation Policy Memorandum Number 03-02, Risk Management Process

1. References:

a. Army Regulation 385-16, System Safety Engineering and Management, 2 Nov 01.

b. Program Executive Officer (PEO), Aviation Policy Memorandum Number 03-03, Processing of Hazard Executive Summaries, 29 Apr 03.

c. Program Executive Officer (PEO), Aviation Policy Memorandum Number 03-04, Processing of System Safety Risk Assessments, 29 Apr 03.

2. Purpose: This memorandum provides current policy for System Safety Risk Management within PEO Aviation.

3. Scope: This policy letter applies to all Aviation Project Managers under the PEO, Aviation and all agencies providing risk documentation support.

4. Responsibilities:

a. PEO, Aviation has overall responsibility for System Safety management of assigned systems to include System Safety Risk Assessments (SSRAs).

b. Project Managers (PMs) will prepare the appropriate risk management documentation (SSRAs, Risk Determinations, etc.) for their applicable systems. The attached PEO, Aviation System Safety Management Decision Authority Matrix will be used to manage risk and determine level of authority for risk acceptance. The PMs will provide this matrix to those organizations supporting risk assessments and risk determinations.

c. Aviation Engineering Directorate (AED) will provide the Project Manager technical failure analysis and airworthiness issues that support the risk documents (SSRA, Risk Determinations, etc) in a Materiel Airworthiness Impact Statement. Quantitative probabilities will be used whenever supporting data is available. Recommendations involving engineering fixes/studies should include: airworthiness data/concerns, estimated costs, expected effects on aircraft performance and mission capabilities.

SFAE-AV-PI
SUBJECT: Program Executive Officer (PEO), Aviation Policy Memorandum Number 03-02, Risk Management Process

d. Any agency that identifies a potential hazard will notify the PM. The PM will notify the appropriate System Safety Working Group (SSWG) members. The SSWG will collectively validate the hazard and recommend a course of action and level to which the issue needs to be elevated if required.

5. Procedures:

a. Once a PM receives notification of a potential safety issue, the PM will validate the issue to identify the hazard. When a hazard is identified that has potentially significant impact on Army training or operations, a hazard Executive Summary (EXSUM), including a hazard description, will be submitted in accordance with PEO Aviation Policy Memorandum Number 03-03. The initial PM assessment will take the component failure data provided by the AED or the contractor and assess the component functional failure to determine the failure effect on the component, the subsystem, and the aircraft system. This assessment will include a hazard description, which systematically identifies the probability and severity of the hazard at the aircraft system level. Particular attention should be paid to those failures that can result in a catastrophic mishap (greater than $1 million damage, loss of aircraft, loss of life or permanent total disability). SSRAs will be accomplished in accordance with PEO, Aviation Policy Memorandum Number 03-04. The following items will be considered in order to support risk documentation:

(1) Historical data (accident/incidents, Hazard Tracking System, FMECA, etc.).

(2) AED failure data (qualitative and quantitative), and Materiel Airworthiness Impact Statement which should include the amount of time estimated until the next failure.

(3) Component failure modes.

(4) System Safety Tools (e.g., probabilistic fault tree modeled after the aircraft subsystem) will be used, if available.

(5) Critical function contribution of the component failure, propagate the failure to the highest severity level (catastrophic, critical, etc.) to determine if the failure results in more than one outcome, mutually exclusive outcomes, etc.

(6) Mission analysis; assumptions of usage (operational modes and states of the system) (time of exposure, operation environment, emergency procedure application and effectiveness, Tactics, Techniques, Procedures (TTPs), etc).

(7) Mitigation efforts identified and implemented during validation of reliability level in system specification as well as those imposed during the operational phase of the life cycle will

be considered. Additionally, when evaluating new mitigation efforts, PMs will ensure that these efforts are evaluated for potentially introducing additional risk or new hazards. PM/PEO in concert with the safety community will develop a resource plan to implement fixes.

(8) Evaluate the fleet impact (number of affected aircraft, fleet life remaining, etc).

b. Upon completion of the hazard analysis, the PM will determine the worst credible combination of severity and probability. Probability will be based on aircraft fleet (number of aircraft) affected and fleet life remaining or a specified timeframe. Hazard probabilities will be specified as a rate of events per 100,000 flying hours (whenever possible) or other method of measurement (e.g., number of rounds fired). A Risk Assessment Code (RAC) will be assigned using the attached PEO, Aviation System Safety Management Decision Authority Matrix.

c. The statement of probability scale fits all categories of severity. A less severe outcome with a higher probability may indicate a higher risk level. When dealing with Category 1 severity (catastrophic) hazards, the PEO will take appropriate action to reduce the risk so that the event will not propagate past the next forecast event, which may include elevating the issue to higher authority. When a System Safety Risk Assessment is categorized with a RAC of "1D", the Army Safety Action Team principals will be notified in a hazard Executive Summary (EXSUM).

d. The PM will ensure that the hazard is completely identified. This requires a brief narrative description of the human, machine, and environmental conditions leading to a mishap. These conditions are parlayed into three elements to express the hazard. These elements (source, mechanism, and outcome) provide the structure by which hazard identification will be standardized. A source is an activity or a condition that serves as the root cause. A mechanism is a condition enabling the hazard outcome (i.e., enablers that allow the source to progress to the undesired outcome). The outcome is the potential consequence of the hazard such as damage to equipment, injury, death. Outcomes shall be considered at the system level (aircraft, crew, crew ability and skills, operational environment). Hazards containing multiple sources, mechanisms, or outcomes shall be broken down into individual hazards. PMs will prepare appropriate documentation as required with the intent to assure that the hazard has been properly identified, analyzed, and mitigated or controlled to a minimum acceptable level.

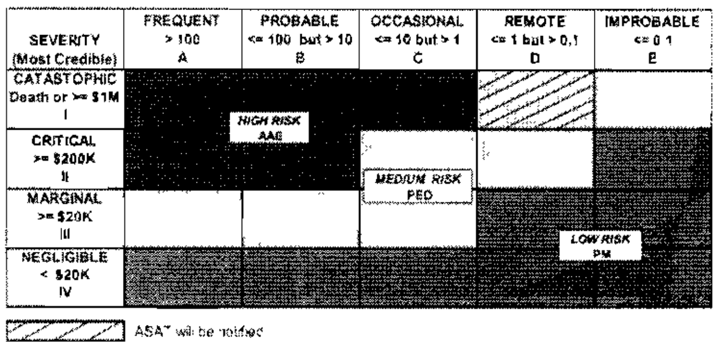
JOSEPH L. BERGANTZ
Major General, USA
Program Executive Officer, Aviation

SFAE-AV-PI
SUBJECT: Program Executive Officer (PEO), Aviation Policy Memorandum Number 03-02, Risk Management Process

DISTRIBUTION:
SFAE-AV-P
SFAE-AV-S
SFAE-AV-A
SFAE-AV-AAH
SFAE-AV-CH
SFAE-AV-RAH
SFAE-AV-AS
SFAE-AV-UAVS
SFAE-AV-UH
AMSAM-SF
AMSAM-RD-AE

SFAE-AV-PI
SUBJECT: Program Executive Officer (PEO), Aviation Policy Memorandum Number 03-02, Risk Management Process

PEO AVIATION
SYSTEM SAFETY MANAGEMENT DECISION AUTHORITY MATRIX



Hazard Severity Categories

Category	Description
1	Catastrophic: Death or permanent total disability; system loss or $1,000,000 property damage or more
2	Critical: Severe injury or severe occupational illness (permanent partial disability); $200,000 property damage or more but less than $1,000,000
3	Marginal: Minor injury or minor occupational illness (no permanent effect) or $20,000 property damage or more but less than $200,000
4	Negligible: Less than minor injury or occupational illness (no lost workdays) or less than $20,000 property damage

Hazard Probability Levels

Level	Description	Probability (mishaps per 100,000 flight hours)
A	Frequent	Greater than 100
B	Probable	Less than or equal to 100 and greater than 10
C	Occasional	Less than or equal to 10 and greater than 1
D	Remote	Less than or equal to 1 and greater than 0.1
E	Improbable	Less than or equal to 0.1

APPENDIX D

EXAMPLE OF A MINI-WEAPONS SURVEY (MWS)

D.1 SCOPE

D.1.1 Scope. For this example, assume that a second fire control computer (FCC) has been added to a helicopter in order to provide redundancy and decrease combat vulnerability. The intent is, if one FCC is shot and disabled, the other FCC will automatically take over and enable the crew to perform their mission. Call this program the Dual FCC Program.

D.2 REQUIREMENT

D.2.1 Purpose. To verify that the Dual FCC aircraft integration will safely perform its intended function and not degrade the existing aircraft and its subsystems.

D.2.2 Compatibility test. A compatibility test will be conducted to verify that all weapon systems will safely function properly for all configurations and firing modes. The test will also verify that no errors will be introduced during actual modification. Analysis, modeling/simulation and aircraft ground tests may be used to supplement aircraft flight tests.

D.3 WEAPONS COMPATIBILITY FIRING MATRICES

D.3.1 Turreted Gun System Firing Matrix

TABLE D-I. Turreted gun system compatibility test matrix

Test Point	Replications	Target Azimuth (Deg)	Aircraft Airspeed (KT)	Aircraft Maneuver	Target Range (KM)	Target Type	Rounds per Burst
1C	1	-45	0	Hover	1	Vertical	50
2C	1	-80	0	Hover	1	Vertical	50
3C	1	45	0	Hover	1	Vertical	50
4C	1	80	0	Hover	1	Vertical	50
5C	1	0	0	Hover	2	Horizontal	50
6C	1	0	0	Hover	3	Horizontal	50
7C	1	N/A	80	Left Veer	1	Vertical	20
8C	1	N/A	80	Right Veer	1	Vertical	20

D.3.2 Rocket System Firing Matrix

TABLE D-II. Rocket system compatibility test matrix

Test Point	Replications	Airspeed (KIAS)	Range (KM)	Rocket	Warhead	Fuze	Tracking Sensor	No. of Rockets
1	2	0	6.0	MK66	M257 flare	M442	FLIR	4
2	2	0	1.0	MK66	M151	M423	FLIR	4
3	1	0	4.0	MK66	XM264 smoke	M439	FLIR	2
4	1	0	4.0	MK66	XM264 smoke	M439	Day TV	2
5	2	0	3	MK66	M255E1			4
6	2	0	3	MK66	IR Flare M278			4

1. Test Points 1 and 2 will be fired at night.
2. Altitude for all firing is between 90 and 150 Ft. AGL.
3. The selected sight is FLIR Narrow Field-Of-View with image auto track (IAT) for all launches.

D.3.3 Missile System Firing Matrix

TABLE D-III. Missile system compatibility test matrix

Type Missile	Range	A/C Maneuver	Tracking Sensor	Mode
Model A	5 Km	HOVER	Day TV (day)	LOAL
Model B	4 Km	HOVER	FLIR (night)	LOBL

D.4 DOCUMENTATION

D.4.1 Compatibility test plan. Submit test plan to Government for review and approval.

D.4.2 Compatibility test report. Submit test report to Government for review and approval.

APPENDIX E

METHODOLOGY FOR CALCULATING WEAPON SYSTEM ACCURACY

E.1 SCOPE

E.1.1 Scope. This appendix describes the methodology for obtaining weapon firing test data from a rotorcraft and how to calculate weapon system accuracy from the test data.

E.2 MEASURES of ACCURACY. The methodology chosen to determine accuracy from test data must provide results that can be compared to the measure of accuracy stated in the military requirement. Calculations of accuracy must include both the dispersion of the round impacts about the Mean Point of Impact (MPI) and the offset of the MPI from the aim point. Common measures of dispersion are the variance, standard deviation and probable error of a population. Common measures of accuracy are Probability of Hit (Ph), Root Mean Square (RMS) and Circular Error Probable (CEP).

E.2.1 Methods for estimating round dispersions and Mean-Point-of-Impact.

Sample: A group of shots that is fired from a weapon (gun, rocket, or missile)
Population: A production ammunition, rocket, or missile lot.

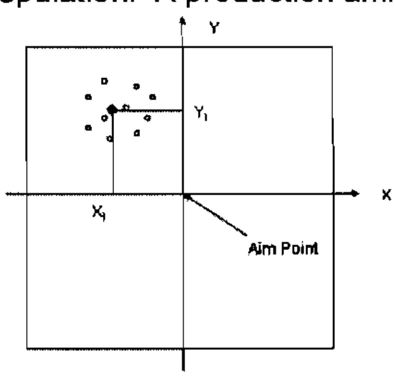


FIGURE E-1. Scoring coordinate system

When a sample of n-rounds of ammunition is fired at a vertical target, the horizontal (x) and vertical (y) coordinates of the impacts are scored with the origin located at the aim point. For rockets or missiles, a ground target is used down-range (y) and cross-range (x) coordinates (Figure E-1).

Shown in Figure E-2, the center-of-impact or mean point-of-impact (MPI) of the burst is defined as:

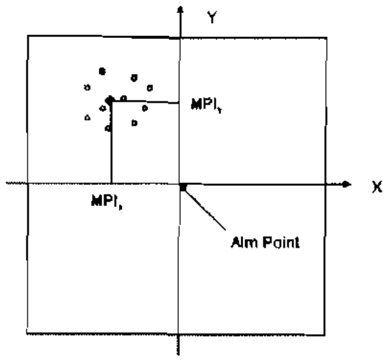


FIGURE E-2. Mean point-of impact

$$MPI_{xk} = \frac{1}{n}\sum_{i=1}^{n} X_{ki} \quad \text{and} \quad MPI_{yk} = \frac{1}{n}\sum_{i=1}^{n} Y_{ki}$$

Where n is a number of rounds in a k^{th} sample.

The sample variances and standard deviations in the x-direction and the y-direction are computed as:

$$S_{xk}^2 = \frac{1}{n-1}\sum_{i=1}^{n}(X_{ki} - MPI_{xk})^2 \quad \text{and} \quad S_{xk} = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(X_{ki} - MPI_{xk})^2}$$

$$S_{yk}^2 = \frac{1}{n-1}\sum_{i=1}^{n}(Y_{ki} - MPI_{yk})^2 \quad \text{and} \quad S_{yk} = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(Y_{ki} - MPI_{yk})^2}$$

Population means, variances and standard deviations in the x-direction and the y-direction are computed as by the equations:

$$\mu_x = \frac{1}{N}\sum_{i=1}^{N} X_i \quad \text{and} \quad \mu_y = \frac{1}{N}\sum_{i=1}^{N} Y_i$$

$$\sigma_x{}^2 = \frac{1}{N}\sum_{i}^{N}(X_i - \mu_x)^2 \quad \text{and} \quad \sigma_y{}^2 = \frac{1}{N}\sum_{i}^{N}(Y_i - \mu_y)^2$$

$$\sigma_x = \sqrt{\frac{1}{N}\sum_{i}^{N}(X_i - \mu_x)^2} \quad \text{and} \quad \sigma_y = \sqrt{\frac{1}{N}\sum_{i}^{N}(Y_i - \mu_y)^2}$$

Where: N is total number of rounds in the lot.

Generally, N is very large. It is not practical to compute means and standard deviations for the entire population. It is practical to use a number of small samples of size n to estimate μ_x, μ_y, $\sigma_x{}^2$, and $\sigma_y{}^2$.

From statistical theory, the sample variances, S_{xk}^2 and S_{yk}^2, are on the average equal to the population variance, $\sigma_x{}^2$ and $\sigma_y{}^2$. S_{xk}^2 and S_{yk}^2 are called the unbiased estimates of population's variances. For small size samples, S_{xk}^2 and S_{yk}^2 vary from one sample to another. It is necessary to have sufficient number of samples to produce good estimates of ${\sigma_x}^2$ and ${\sigma_y}^2$.

From a large number of samples, μ_x, μ_y, ${\sigma_x}^2$, and ${\sigma_y}^2$ can be estimated by

$$\mu_x \approx MPI_x = \frac{1}{N}\sum_{k=1}^{N} MPI_{xk} \qquad \mu_y \approx MPI_y = \frac{1}{N}\sum_{k=1}^{N} MPI_{yk}$$

$${\sigma_x}^2 \approx S_x^2 = \frac{1}{N}\sum_{k=1}^{N} S_{xk}^2 \qquad {\sigma_y}^2 \approx S_y^2 = \frac{1}{N}\sum_{k=1}^{N} S_{yk}^2$$

Where: *N* is the number of bursts.

E.2.2 <u>Probability density function</u>. It is widely assumed that the distribution of impacts is approximately normal or Gaussian in character. Thus, the probability density functions of impact locations in the x-direction and y-direction may be described by

$$f(x) = \frac{1}{\sqrt{2*\pi}*\sigma_x}\exp(-\frac{(x-\mu_x)^2}{2\sigma_x^2}) \quad \text{and} \quad f(y) = \frac{1}{\sqrt{2*\pi}*\sigma_y}\exp(-\frac{(y-\mu_y)^2}{2\sigma_y^2})$$

If X and Y are independent in the statistical sense, the appropriate bivariate normal distribution density function would be

$$f(x,y) = \frac{1}{\sqrt{2\pi}\sigma_x\sigma_y}\exp(-\frac{(X-\mu_x)^2}{2\sigma_x^2} - \frac{(Y-\mu_y)^2}{2\sigma_y^2})$$

E.3 <u>SAMPLE METHODOLOGY FOR CALCULATING GUN SYSTEM ACCURACY</u>. This section describes a sample set of flight firing conditions and calculation techniques that can be used to determine accuracy for gun systems fired from a rotorcraft. The gun system's accuracy, as fired from an aircraft, is specified in the aircraft specification or other contractual agreement. The accuracy can be specified in a variety of ways such as the number of milliradians in cross-range and down-range errors, probability of hit, and number of hits in a defined target area on the ground. The following sample illustrates the latter two methods of accuracy measurement.

Table E-I is a typical set of test conditions for verifying accuracies of a helicopter turreted gun system.

TABLE E-I. Turreted gun system accuracy test matrix

Test Point	Iterations	Target Azimuth (Deg)	Aircraft Airspeed (KT)	Aircraft Maneuver	Target Range (KM)	Target Type	Rounds per Burst
1	10	0	0	Hover	1	Vertical	20
2	10	-45	0	Hover	1	Vertical	20
3	10	-80	0	Hover	1	Vertical	20
4	10	45	0	Hover	1	Vertical	20
5	10	80	0	Hover	1	Vertical	20
6	10	0	0	Hover	2	Horizontal	20
7	10	0	0	Hover	3	Horizontal	20
8	10	N/A	80	Left Veer	1	Vertical	20
9	10	N/A	80	Right Veer	1	Vertical	20
10	10	N/A	80	Left Veer	2	Horizontal	20
11	10	N/A	80	Right Veer	2	Horizontal	20
12	10	0	0	Hover	1	Moving	50
13	10	0	80	Level flt	1	Moving	50

1. Conduct boresight alignment prior to the start of firing.
2. Wind limitations at 2 & 3 Km points is 5-Kts. Max wind at 1Km test point is 10-Kts.
3. Altitude for all firing is between 90 and 150 Ft. above ground level (AGL).
4. Veers should start from within 20 meters of the opposite lateral side of the target run in line. Veer is the result of moving from an original 0 deg target bearing towards a 60 deg bearing at a maximum stabilized bank angle of 30 deg at the specified altitude and speed.
5. Moving target will operate between 20 and 25 MPH.
6. Conduct boresight retention evaluation of the gun after each day of firing.
7. Stop all firing if more than half of test points do not score any hits during the first three iterations.
8. Direction of moving target should be changed after each iteration.
9. Auto target tracking is required for most of the firing.

The matrix consists of thirteen test points. Test points 1 through 11 have stationary targets. Test points 12 and 13 have moving targets. Vertical or moving targets are 3m x 3m vertical target with an aim point at center of the target. The horizontal target is a 50m x 50m square on ground with an aim point at center of the 3m x 3m vertical board that is at the center of the square. Ground cameras will capture impacts on the target while overhead cameras will capture those that miss the target but impact the ground. The impact locations must be converted to X and Y coordinates on the vertical target before computing MPI and standard deviations.

The number of locations that are captured from fixed-size bursts is not always equal to sample size *n*. For this reason, it is necessary to have a different procedure for estimating μ_x, μ_y, σ_x , and σ_y . The following equations will be used to estimate μ_x, μ_y, σ_x , and σ_y when a complete set of impact locations is impossible to obtain:

$$MPI_{xk} = \frac{1}{n_k}\sum_{i=1}^{n_k} X_{ki} \qquad MPI_{yk} = \frac{1}{n_k}\sum_{i=1}^{n_k} Y_{ki}$$

$$\mu_x \approx MPI_x = \frac{1}{N_T}\sum_{k=1}^{N} n_k MPI_{xk} \qquad \mu_y \approx MPI_y = \frac{1}{N_T}\sum_{k=1}^{N} n_k MPI_{yk}$$

$$\sigma_x{}^2 \approx S_x^2 = \frac{1}{N_T - N}\sum_{k=1}^{N}(n_k - 1)S_{xk}^2 \qquad \sigma_y{}^2 \approx S_y^2 = \frac{1}{N_T - N}\sum_{k=1}^{N}(n_k - 1)S_{yk}^2$$

Where: n_k is a number of scored impacts in a k^{th} burst.

N is a number of bursts and $N_T = \sum_{k=1}^{N} n_k$ N_T is the total number of impacts for all test points.

The accuracy calculation for each test point:

For 1 Km-target test points, the accuracy is calculated as the composite cumulative probability of hit (Ph_C).

$$Ph_C = 1 - (1 - P_{SSC})^n$$

Where: P_{SSC} is the composite single shot probability of hit and n is the average number of rounds per burst in the test segment (nominal burst size is 50).

$$P_{SSC} = \frac{1}{2\pi\sigma_x\sigma_y}\iint_T \exp[-\frac{1}{2}\{(\frac{X-\mu_x}{\sigma_x})^2 + (\frac{Y-\mu_y}{\sigma_y})^2\}]dxdy$$

For 2 and 3 Km-stationary-target test points, the accuracy is calculated as the composite expected number of hits (Eh_C) on a horizontal 50m x 50m ground target.

$$Eh_C = nP_{SSC}$$

Where: n is the average number of rounds per burst in the test segment (nominal burst size is 50).

E.4 SAMPLE METHODOLOGY FOR CALCULATING UNGUIDED ROCKET ACCURACY. The rocket accuracy requirement is usually expressed in terms of cross-range (azimuth) and down-range (elevation) errors. The errors are expressed in terms of milliradians (mrad) at required ranges and for aircraft flight conditions such as hover and 90 knots (forward flight).

A typical set of flight firing conditions for verifying accuracy of a helicopter rocket system is shown in Table E-II. Rockets will be fired in pairs. In order for an iteration to be accepted, both impact points of the pair must be located.

TABLE E-II. Rocket System Accuracy Test Matrix

Test Point	Iterations (pairs)	Airspeed (KIAS)	Range (KM)	Rocket	Warhead	Fuze	Aircraft Maneuver
1	10	0	1.0	MK66	M151	M423	Hover
2	10	0	2.0	MK66	M151	M423	Hover
3	10	0	3.0	MK66	M151	M423	Hover
4	10	0	3.5	MK66	M151	M423	Hover
5	10	90	1.0	MK66	M151	M423	Forward Flight
6	10	90	1.4	MK66	M151	M423	Forward Flight

1. Max wind should be no greater than 5 knots.
2. Altitude for all firings is between 90 and 150 ft. above ground level (AGL).
3. Matrix will be executed in cooperative (precision) delivery mode, with the pilot aligning to the aircraft and the copilot-gunner firing the rockets (CPG).
4. CPG will use day TV target acquisition, narrow field-of-view with image auto track (IAT) for all launches.
5. A pylon boresight will be performed prior to firing.
6. Conduct boresight retention evaluation after each day of launches.

A ground target will be used as an aim point. Impact locations of pairs will be determined using an overhead camera. Coordinates of pairs will be measured with origin at the aim point. Cross-range error (X) in mrad will be calculated by dividing cross-range error in meters by the range in kilometers. For methodology to convert down-range error (Y) in meters to milliradians, see MIL-HDBK-799 for guidance.

Cross-range (*x*) and down-range (*y*) errors (milliradians) for the MPI of each test point with respect to the aim point are computed according to the following equations:

$$MPI_{xk} = \frac{X_{k1} + X_{k2}}{2} \quad \text{and} \quad MPI_{yk} = \frac{Y_{k1} + Y_{k2}}{2}$$

$$MPI_x = \frac{1}{n}\sum_{k=1}^{n} MPI_{xk} \quad \text{and} \quad MPI_y = \frac{1}{n}\sum_{k=1}^{n} MPI_{yk}$$

Where *k* is the reference number of an iteration (pair) within a test point. *k1* and *k2* are the two rockets of the *kth* pair and *n* is the number of pairs in a test point.

Then the standard deviation σ (cross-range *x* and down-range *y*) among the MPI's are calculated for each test point:

$$\sigma_x = \frac{1}{n-1}\sum_{k=1}^{n}(MPI_{xk} - MPI_x)^2 \quad \text{and} \quad \sigma_y = \frac{1}{n-1}\sum_{k=1}^{n}(MPI_{yk} - MPI_y)^2$$

Then the Root Mean Square (*RMS)* is calculated for the cross-range and down-range errors:

$$RMS_x = \sqrt{MPI_x^2 + \sigma_x^2} \quad \text{and} \quad RMS_y = \sqrt{MPI_y^2 + \sigma_y^2}$$

The RMS values in milliradians can then be compared to the accuracy requirements in milliradians.

E.5 SAMPLE METHODOLOGY FOR CALCULATING MISSILE SYSTEM ACCURACY. The missile system accuracy requirement is usually specified in terms of Circular Error Probable (CEP) or Probability of Hit (Ph). Due to the high cost of missile systems, as compared to gun ammunition and rockets, there are usually less rounds available than desired to obtain flight firing data. As such, calculations of system accuracy from firing test data are usually heavily supplemented by modeling and simulation.

E.5.1 Circular Error Probable (Circular Normal Distribution). Shown in Figure E-III, the Circular Error Probable (CEP) is a measure of dispersion about the true MPI. The CEP has been developed primarily for circular normal distributions with $\sigma_x = \sigma_y = \sigma$. When a very large number of rounds are fired onto the target area, CEP is defined as the radius of the circle about the true center-of-impact (μ_x , μ_y) which includes 50% of the impacts.

With $\sigma_x = \sigma_y = \sigma$, the bivariate normal distribution would be a circular bivariate normal distribution

$$f(x,y) = \frac{1}{2\pi\sigma^2}\exp(-\frac{(x-\mu_x)^2 + (y-\mu_y)^2}{2\sigma^2})$$

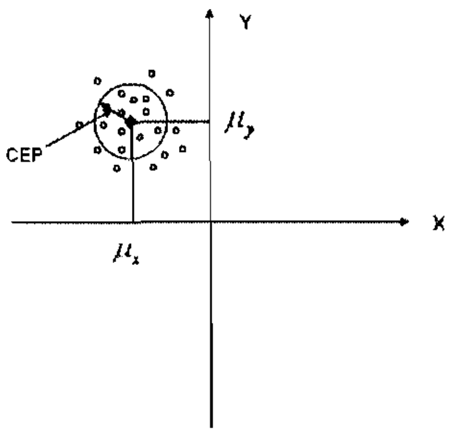


FIGURE E-3. Circular Error Probable

With the origin is at (μ_x, μ_y), the circular normal density distribution is given as

$$f(x,y) = \frac{1}{2\pi\sigma^2}\exp(-\frac{x^2 + y^2}{2\sigma^2})$$

Using the transformation of variables
$x = r\cos(\theta)$ and $y = r\sin(\theta)$, $0 \le \theta \le 2\pi$,
the CEP can be derived from the equation

$$\frac{1}{2\pi\sigma^2}\int_0^{R_{0.50}}\int_0^{2\pi} d\theta \exp(-\frac{r^2}{2\sigma^2}) r dr = 0.50$$

$$CEP = R_{0.50} = 1.177\sigma$$

The CEP values calculated from the impact coordinates can then be compared to the CEP accuracy requirement.

If all the impacts are projected onto the x-axis (or y-axis), the interval about both side of the mean, which include 50% of the impacts, is called the Probable Error (PE).

$$PE = 0.6745\sigma$$

E.5.2 Circular Error Probable (Non-Circular Normal Distribution). With $\sigma_x \neq \sigma_y$, the *CEP* can be found by using the approximate chi-square theory:

$$CEP = R_{0.50} = \sigma_T(1 - \frac{\nu}{9m^2})^{\frac{3}{2}}$$

Where: $\sigma_T^2 = \sigma_x^2 + \sigma_y^2$ $\quad m = 1 + (\frac{\mu_x^2 + \mu_y^2}{\sigma_T})$ $\quad \nu = 2\frac{\sigma_x^4 + \sigma_y^4}{\sigma_T^2} + 4\frac{(\sigma_x^2\mu_x^2 + \sigma_y^2\mu_y^2)}{\sigma_T^4}$

E.5.3 Single-Shot Hit Probability (P_{SSH}). The single-shot probability of hit is the probability that in the firing of a single missile, the trajectory of the missile will intersect the target volume. Statistical techniques for calculating P_{SSH} can be found in MIL-HDBK-799 on fire control systems.