?FOOT-POUND?

ADS-63-SP
11 July 2001
CAGE Code 18876

# AERONAUTICAL DESIGN STANDARD

## STANDARD PRACTICE

## RADAR SYSTEM AIRWORTHINESS QUALIFICATION AND VERIFICATION REQUIREMENTS

AMSC N/A

ADS-63-SP

AERONAUTICAL DESIGN STANDARD

RADAR SYSTEM AIRWORTHINESS
QUALIFICATION AND VERIFICATION REQUIREMENTS

FUNCTIONAL DIVISION: _____
LEWIS E. WILLIAMS
Chief, Mission Equipment
Division

SUBMITTED BY: _____
BARRY J. BASKETT
Director of Aviation Engineering

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

DATE: 6 Dec 01

## Certification Record

Board date: XX XXX XXXX

Document Identified and Title:

ADS-63-SP, Aeronautical Design Standard, Standard Practice, Radar System Airworthiness Qualification and Verification Requirements

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 | Nonconcur | Date |
|---|---|---|---|
| Division Chief<br>Lewis E. Williams | | | 8/30/2001 |
| AMCOM Standardization Branch Chief<br>William J. Smith | | | 12/3/2001 |
| Director, Aviation Engineering<br>Barry J. Baskett | | | 9/5/01 |
| | | | |
| | | | |
| AMCOM and PEO, Aviation Standards Executive<br>Tony D. Hodgens | | | |

Table of Contents

# RADAR SYSTEM PERFORMANCE AND AIRWORTHINESS QUALIFICATION REQUIREMENTS

1.0 SCOPE. This document establishes the verification methods and qualification requirements for radar systems installed on U.S. Army aircraft. A combination of analyses, component testing, ground testing, and flight testing, will verify the design, installations and performance of the radar subsystem prior to the formal Airworthiness Qualification Release. The Airworthiness Qualification program encompasses:

a. Design reviews.

b. Engineering design substantiation analyses.

c. Contractor development and airworthiness qualification tests, including component, subsystem and system testing.

d. Government systems development and airworthiness qualification testing, including:

(1) Preliminary Airworthiness Evaluation (PAE).

(2) Airworthiness and Flight Characteristics Test (A&FC).

e. Government Operational Testing (OT) if required by the approved Test Engineering Master Plan (TEMP).

2.0 APPLICABLE DOCUMENTS.

2.1 General. The documents listed in this section are specified in sections 3, 4, and 5 of this standard. This section does not include documents cited in other sections of this standard or recommended for information or as examples. While every effort has been made to ensure the completeness of this list, document users are cautioned that they must meet all specified requirements documents cited in sections 3, 4, or 5 of this standard, whether or not they are listed.

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.

| | |
|---|---|
| MIL-STD-810 | Environmental Test Methods and Engineering Guidelines |
| MIL-STD-882 | Standard Practice for System Safety |
| MIL-STD-1472 | Human Engineering Design Criteria |
| MIL-STD-2525 | Common Warfighting Symbology |
| MIL-STD-464 | Electromagnetic Environmental Effects Requirements for Systems |
| MIL-STD-461 | Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment |
| MIL-STD-469 | Radar Engineering Design Requirements, Electromagnetic Compatibility |
| MIL-E-7016 | Electrical Load and Power Source Capacity Analysis |
| MIL-HDBK-781 | Handbook for Reliability Test Methods, Plans and Environments for Engineering, Development, Qualification and Production |
| MIL-HDBK-1908 | Definitions of Human Factors Terms |

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. Unless otherwise specified, the issues are those cited in the solicitation.

| | |
|---|---|
| AMCP 706-203 | Engineering Design Handbook for Army Aircraft |
| JSSG-2010-5 | Joint Services Crew Systems Aircraft Lighting Handbook |
| ADS-37-PRF | Electromagnetic Environmental Effects Performance and Verification Requirements |

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

## 3.0 DEFINITIONS

| | |
|---|---|
| AWR | Airworthiness Release |
| AQS | Airworthiness Qualification Standard |
| EMI | Electromagnetic Interference |
| EMC | Electromagnetic Compatibility |
| EMV | Electromagnetic Vulnerability |
| HFE | Human Factors Engineering |
| IGE | In Ground Effect |
| OGE | Out of Ground Effect |
| RAM | Reliability, Availability, And Maintainability |

## 4.0 GENERAL REQUIREMENTS

4.1 System Safety. All component tests and subsystem tests shall be planned and conducted in accordance with MIL-STD-882. Hazard analyses and safety statements shall be an integral and essential factor in the preparation, planning, and conduct of all such tests. Tests shall provide for the assessment of test item hazards associated with further development and testing. System safety reviews shall be an integral part of program design review.

4.2 Human Factors Engineering (HFE). Surveys, ground, and flight tests cited herein shall be used to demonstrate the incorporation of HFE design requirements and criteria in accordance with MIL-STD-1472 and the Airworthiness Qualification Standard (AQS). Radar display symbology shall be demonstrated to be in accordance with MIL-STD-2525.

4.3 Reliability, Availability, And Maintainability (RAM) Substantiations and Verifications. For new or modified components, a combination of substantiation, verification, and demonstration requirements are applicable to the RAM requirements. Reliability requirements shall be evaluated against the test program results. Maintainability characteristics will be evaluated during Government tests. MIL-HDBK-781 shall be used for guidance.

4.4 Engineering Analyses. The following engineering analyses shall be conducted.

4.4.1 Electrical Loads Analysis. An electrical loads analysis shall be conducted in accordance with MIL-E-7016. This analysis may be an update to an existing (baseline) electrical loads analysis. Per MIL-E-7016, the analysis shall demonstrate the impact of the new system(s) on all aircraft operating modes.

4.4.2 Human Factors Analyses. The following human factors analyses shall be conducted.

4.4.2.1 Gross Analysis of Tasks. This analysis shall be performed for all mission scenarios, as defined in MIL-HDBK-1908, where crew task loadings and coordination requirements approach maximum.

4.4.2.2 Displays and Controls Optimization Study. Trade-off and simulation studies shall be conducted to demonstrate optimization of control/display relationships in accordance with MIL-STD-1472. Target display symbology shall be in accordance with MIL-STD-2525.

4.4.2.3 Crew Vision. Analysis and test shall be used to demonstrate that vision required for safe flight is maintained during operation with and without night vision goggles.

4.4.2.4 Lighting. Analysis and test shall be used to demonstrate that the lighting requirements of JSSG-2010-5 (including night vision goggle compatibility) are used for guidance.

4.4.3 Structural Analyses. For the newly designed or modified components; these analyses shall be conducted as described below.

4.4.3.1 Fatigue Analysis. A fatigue substantiation analysis shall demonstrate the impact of the radar subsystem on component fatigue lives.

4.4.3.2 Loads and Stress Analysis. This analysis shall be conducted on the radar system including crash conditions.

4.4.4 Reliability and Maintainability (RAM) Analysis. A RAM analysis shall be conducted using test data, estimates, and all qualification testing. MIL-HDBK-781 shall be used for guidance.

4.4.5 Weight and Center-of-Gravity Analysis. Analysis of weight control shall be conducted in accordance with SAWE Recommended Practice 7 (RP7), Weight and Balance Control System (for Aircraft and Rotorcraft). This analysis shall demonstrate that the aircraft weight and center of gravity remain within acceptable limits with the radar system installed.

4.4.6 Hazards of Electromagnetic Radiation to Personnel (HERP). A HERP analysis shall be performed in accordance with ADS-37-PRF to determine the distance that personnel must remain from the radar while it is operating.

4.4.7 Jettison analysis. A jettison analysis shall be conducted to ensure that no radar components lie in the jettison path of any external stores.

5.0 DETAILED REQUIREMENTS

5.1 Radar System Performance. Ground tests, flight tests, surveys and demonstrations shall be used to verify radar system performance.

Required radar performance parameters shall be as listed in Appendix A of this specification.

5.2 Electromagnetic Environment. Analyses and tests shall be used to demonstrate that the radar is compatible with the electromagnetic environment as specified below.

5.2.1 Radar Specific Requirements. Analysis and test shall be used to demonstrate that the radar design complies with the special provisions in MIL-STD-469, the requirements in MIL-STD-461 and ADS-37-PRF, as tailored for the frequency band of the radar system.

5.2.2 EMC Control Plan. Analysis shall be used to demonstrate how EMI and EMC will be controlled, in accordance with MIL-STD-461.

5.2.3 Electromagnetic Interference (EMI). Testing shall be used to demonstrate that the radar system meets all of the EMI requirements of MIL-STD-461 as modified by ADS-37-PRF.

5.2.4 Electromagnetic Compatibility (EMC). Testing shall be used to demonstrate that the radar system, when installed in the aircraft, is electromagnetically compatible with the existing aircraft system equipment in accordance with ADS-37-PRF.

5.2.5 Electromagnetic Vulnerability (EMV). The radar system, when installed in the aircraft, shall survive and meet performance requirements while subjected to an electromagnetic environment composed of field levels per MIL-STD-464, and field modulations per ADS-37-PRF.

5.3 Ground and Flight Testing. Analyses, tests, and demonstrations shall be conducted using AMCP 706-203 for guidance to substantiate safe and satisfactory radar subsystem operation (in accordance with Appendix A of this document) over the range of flight and environmental conditions.

5.3.1 Ground Tests. Ground tests shall be conducted using AMCP 706-203 for guidance. These tests shall include all items required to verify flight safety. Required tests include, but are not limited to, the following:

5.3.1.1 Environmental Conditions. Component level testing in accordance with MIL-STD-810 shall be performed to verify correct operation throughout the range of conditions specified in the aircraft system specification.

5.3.1.2 Electromagnetic Interference (EMI). Component level EMI testing shall be conducted in accordance with MIL-STD-461, as modified by ADS-37-PRF. RS103 testing shall be conducted using field levels from MIL-STD-464 and field modulations from ADS-37-PRF.

5.3.1.3 Electromagnetic Compatibility (EMC). Ground EMC testing shall be conducted in accordance with ADS-37-PRF to ensure that the radar system

is electromagnetically compatible with other aircraft subsystems, prior to flight tests. Testing shall include, but is not limited to, the following:

a. Electrical bonding measurements.

b. Compatibility testing in accordance with a test matrix. Radar system shall be tested as a source and victim against aircraft navigation and communication systems, flight test instrumentation, electro-explosive devices, and all other flight critical systems.

5.3.1.4 Airframe Vibration Testing. Vibration testing shall be performed in accordance with MIL-STD-810 with the radar system installed on the aircraft to verify that the radar is compatible with the resonant frequencies of the aircraft, both structurally and operationally.

5.3.1.5 Radar Operations. Analysis and test shall be used to verify cockpit procedures utilizing the installed radar control system. Radar to aircraft control logic interface shall be demonstrated. Functional checkout of target acquisition/designation subsystem modes (including symbology) shall be conducted.

5.3.1.6 Radar Boresighting. Analysis and test shall be used to demonstrate boresighting procedures and boresight retention. Particular attention should be paid to the elements of the target acquisition/designation subsystem and boresight accuracy.

5.3.1.7 Aircraft Integration. Analysis and test shall be used to evaluate the joint functioning of installed subsystem such as fire control computer/weapons processor, target acquisition/designation subsystem, etc. Validate computer software functionality (accuracy, correctness).

5.3.1.8 Radar Performance. When possible, elements of radar performance, as given in Appendix A, shall be tested on the ground before being tested in flight.

5.3.2 Flight Tests. Flight tests shall be conducted within the design operational flight envelope, as defined by the aircraft Operators Manual, or other appropriate reference. These tests shall include hover (IGE/OGE), cruise and VH conditions. The testing shall encompass those items requiring design verification prior to the formal demonstrations. The testing shall include formal demonstration of radar performance as defined in the system specification. The items examined should include, but are not limited to, the following.

5.3.2.1 Aircraft Flight Performance. Analysis and test shall be used to determine the effects of the radar subsystem installation on aircraft performance, stability and control throughout the flight envelope of the aircraft, including hover, low speed translation flight, take off and

landing, climb, level flight, maneuvering flight, jettisoning, and autorotation.

5.3.2.2 Radar to Aircraft Interface. Analysis and test shall be used to verify the following elements of the radar to aircraft interface:

a. Boresight retention.

b. Ability to handover a target from the radar to the aircraft, for all target types.

c. Weapons firing. Determine effects of weapons firing on radar system performance, including effects from vibration, smoke, and debris.

5.3.2.3 Electromagnetic Compatibility (EMC). Flight EMC testing shall be performed in accordance with ADS-37-PRF to ensure that the radar system is electromagnetically compatible with other aircraft subsystems, prior to flight tests.

5.3.2.4 Radar Performance. Analysis and test shall be used to verify radar performance parameters defined by the system specification. Testing should be conducted with both ground and flight tests, with parameters being tested on the ground first, where possible.

5.4 Other Testing and Verification.

5.4.1 Radar Spectrum Verification. The radar system shall be tested in accordance with MIL-STD-469 to verify that the radar system spectrum requirements are met.

5.4.2 Electromagnetic Vulnerability (EMV). The radar system, while installed in the aircraft, shall be tested to demonstrate that it can survive and meet performance requirements while subjected to the electromagnetic environment composed of field levels per MIL-STD-464 and field modulations per ADS-37-PRF.

5.5 Demonstrations

5.5.1 General. In addition to the tests and analysis called out above, demonstration tests can be used to show compliance with system specifications. Demonstrations shall include, but are not limited to, those listed below.

5.5.2 Electrical Demonstration. An electrical demonstration shall be conducted to evaluate the effect of the radar system on the aircraft electrical system. Ripple voltage, transients, harmonics, and power shall be measured on the affected busses.

5.5.3 Flight Vibration Demonstration. If deemed necessary based on the results of airframe vibration testing, or analysis of the resonant modes of the radar system, a flight demonstration should be performed to

verify that flight vibration levels do not adversely affect the performance of the radar system.

5.6 Instrumentation and Data Analysis. Test instrumentation shall be used to record appropriate radar, fire control, weapons processor, and aircraft data to establish qualification test compliance.

## 6.0 NOTES

Not applicable to this document.

Appendix A – Radar Performance Parameters

A.1 General. This Appendix is intended as a general guide for persons developing and/or reviewing detailed radar system specifications. Listed here are generic (although biased towards airborne radar) requirements that should be defined in the detailed item specification, and tested as part of the System Qualification process. Not all parameters will be applicable to all radar designs, and this list should be tailored to the particular operational requirements of the radar system. Conversely, it would not be possible to list every possible detailed requirement, so this list is meant only as a guide, and not a comprehensive reference.

Due to the ever evolving and wide variety of radar technologies, it would be a nearly impossible task to define performance parameters for each type of design and each application of that design. Instead, this Appendix defines general radar performance parameters, independent of system implementation. To accomplish this, several generalizations are made:

a. No distinction is made between scanning and tracking modes, since the modes designed in to the radar depend on the radar operational requirements.

b. No distinction is made between measured parameters and calculated parameters. Calculated parameters will still have accuracies associated with measurement noise, etc., and so are lumped together with measured parameters for simplicity. Also, the set of calculated and measured parameters will vary between radar designs, depending on cost, size, and complexity of design.

c. Mechanical details such as slew rates are not included. Rather, event timelines are defined. Parameters such as slew rate would likely be included in the detailed specification, but only to the extent required to meet timeline requirements.

Note that each of these parameters may be dependent on the operating mode of the radar. In this case, the system specifications and test plans should contain matrices of those parameters versus operating mode.

A.2 Radar Performance Parameters.

1. Maximum radial range, maximum azimuth sweep and maximum elevation sweep.

2. Radial range, azimuth and elevation accuracy.

3. Radial, cross range and elevation velocity accuracy. Although cross range and elevation velocities are calculated, they are included here since they depend on measured values, as well as the quality of the

scan-to-scan correlation, measurement noise, etc. Having a single accuracy specification makes this item less implementation specific.

4. Minimum detectable target size.

5. Probability of detection (Pd). Measured over the set of all detectable targets.

5a. Probability of reacquisition. This is the probability of reacquiring a previously detected target. This is a special case of item 5, applicable only for radars that optimize for reacquisition (for example, when tracking high priority targets).

6. Probability of False Detection (Pfd). This is the probability of falsely detecting a target when none is present.

7. Probability of correct classification (Pcc). Only applicable if the radar performs target classification. The specification should contain tabulated values for each type of target the radar is supposed to classify. For consistency and ease of tabulation, Pcc is defined as the probability of correctly classifying a detected target. It is implicitly conditional upon Pd, since the probability of correctly classifying a non-detected target is zero. The detailed specification may also define different levels of classification, ranging from simple determination of vehicle type, up to exact identification of vehicle.

8. Maximum number of targets that can be tracked at a time, if applicable to the radar design.

8a. Priority Schemes. This defines the method (or methods) of prioritizing targets when multiple targets are being tracked.

9. Target (or Differential) Resolution. This is defined as the ability of the radar to distinguish multiple closely spaced targets. Two different definitions are given below. The applicable definition should be used.

9a. Ideally, target resolution would be specified in each orthogonal dimension, as given below:

1. Differential range resolution: The minimum radial distance two objects must be separated by to be detected as distinct targets by the radar, assuming both targets have the same azimuth and elevation.

2. Differential azimuth resolution: The minimum cross range distance two objects must be separated by to be detected as distinct targets by the radar, assuming both targets have the same radial range and elevation.

3. Differential elevation resolution: The minimum vertical distance two objects must be separated by to be detected as distinct

targets by the radar, assuming both targets have the same radial range and azimuth.

9b. In the event that the radar design does not allow for such orthogonal resolution measurements, the resolution requirements should be specified as:

1. Differential range resolution (non-orthogonal): The minimum radial distance two objects must be separated by to be detected as distinct targets by the radar, given a specified minimum separation value in azimuth and elevation.

2. Differential azimuth resolution (non-orthogonal): The minimum cross range distance two objects must be separated by to be detected as distinct targets by the radar, given a specified minimum separation in radial range and elevation.

3. Differential elevation resolution (non-orthogonal): The minimum vertical distance two objects must be separated by to be detected as distinct targets by the radar, given a specified minimum separation in radial range and azimuth.

10. Timelines. Due to the uncertainty in time delays caused by aircraft software processing, data transmission, etc., the timelines defined below measure only the time it takes to get the data directly from the radar. This allows for a clean analysis of bandwidth and latency requirements. The radar system designer should include a method of directly measuring these delays, to avoid inaccuracies caused by attempting to measure them indirectly over the aircraft system bus.

a. Detection: Time required to detect a new (not seen before) target.

b. Reacquisition: Time required to reacquire a previously detected/tracked target that has been dropped. This is applicable to radars that optimize reacquisition. For other radars, this may be the same as the detection time.

c. Automatic Handover: Time required from the time the target is detected, until it is handed over to an external bus. This assumes that targets are handed over automatically, as they are detected, without operator intervention.

d. Manual Handover: Time required to hand over an already detected/tracked target. This applies when the radar does not automatically handover the target, but waits for an operator to pick a target to handover. This is the time between the radar receiving the operator input, and the handover of the target to an external bus. This does not count delays introduced by an operator input device, e.g. a touch panel.

A.3 Maximum Operating Envelope and Operation in Degraded Conditions. The following items should be specified in the detailed item specification:

1. Flight conditions

a. Maximum yaw, pitch, and roll angle for which the radar system will continue to meet its performance requirements.

b. Maximum yaw, pitch, and roll velocities for which the radar system will continue to meet its performance requirements.

c. Maximum yaw, pitch, and roll accelerations for which the radar system will continue to meet its performance requirements.

2. Aircraft alignment.

a. Physical. This defines the required accuracy of the physical alignment of the radar to the airframe in order to meet radar performance requirements.

b. Inertial. This defines the required accuracy of the inertial reference between aircraft and radar.

2. Clutter environment. Tabulated clutter conditions versus percent degradation in radar performance.

3. Weather. Weather conditions under which the radar will continue to meet its performance requirements.

4. Obscurants. Should be a tabulated value showing levels of different obscurants versus percent degradation in performance.

5. Threat environment. The specification should define what types of threats the radar might encounter, and describe the radar performance in each condition. This includes passive threats such as decoys or obscurants, and active threats such as jammers. The specification should take into account current and forecasted threats at the time the specification is written.

A.4 Radar subtypes/modes. This Appendix, up to this point, applies to radars that perform detection and/or tracking of air and ground targets. However, the radar may have special modes, or be of an entirely different design, for which the above guidance is not relevant. An attempt is made below to give guidance about what should be written into the specification for these special modes or radars.

1. Terrain following. Radars for following terrain, as an aid to navigation, are moderately specialized, but have some common characteristics that should be included in the detailed specification.

a. Maximum range, azimuth and elevation.

b. Minimum safe flying height and speed, in tabular form if appropriate.

c. Types of objects identified (foliage, buildings, wires, etc.), and, very importantly, whether the radar identifies these objects itself, or relies on an external database of previously surveyed data.

2. Imaging. Imaging radars are often used in mapping applications where real-time target detection/identification isn’t required. However, with advances in technology, it is envisioned that imaging radars will be able to perform these tasks eventually. The parameters in paragraph A.2 should be general enough to cover the case of imaging radars performing target detection and/or tracking.

3. Weather radars. When used as navigational aids, the following parameters should be required as a minimum in the detailed specification.

a. Maximum range, azimuth, and elevation.

b. Ability to identify precipitation, both type and severity, along with the associated accuracies.

c. Ability to identify severe climatic activity, such as high winds or other dangerous conditions, along with the associated accuracies.