

AEROSPACE INFORMATION REPORT

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Equivalence of Equipment Environmental Qualification Standards for Civil and Military Aircraft Equipment

RATIONALE

Due to the prevalence of equipment being utilized in both civil and military applications, the aerospace industry has strongly desired the guidance presented in this document so that it can be used as an aid when making equivalency assessments between the qualification requirements of civil and military equipment. This document enumerates the similarities and differences between the military and civil testing standards, normalizes the analysis methods, and ensures consistent evaluations of equipment qualification requirements to deliver confidence in the appropriateness of the equipment qualification strategy.

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1. SCOPE

This document provides guidance for applying aircraft equipment electromagnetic, electrical, and mechanical qualification standards (i.e., DO-160, MIL-STD-461, MIL-STD-704, and MIL-STD-810) to civil aircraft certification intended for military use and for military aircraft equipment installed on civil aircraft. The guidance identifies where the equipment environmental qualification standards meet the intent of both the civil or military aircraft certification requirements. Conversely, the guidance will identify where the equipment environmental qualification standards have differences that do not meet the intent of the civil or military aircraft certification requirements and when these differences matter based on equipment criticality, installation location, and/or other variables.

1.1 Introduction

Section 3 outlines the typical certification process for installing military qualified equipment on civil certified aircraft (see 3.1) and installing civil qualified equipment on military certified aircraft (see 3.2). The remaining sections of this document attempt to evaluate the similarities and differences between the military and civil equipment qualification standards in order to provide recommendations where either standard could be used to meet aircraft certification requirements. Section 4 presents the evaluations between MIL-STD-461G and the electromagnetic environments of DO-160G. Section 5 presents the evaluations between MIL-STD-704F/MIL-HDBK-704 and the electrical environments of DO-160G. Section 6 presents the evaluations between MIL-STD-810G and the mechanical environments of DO-160G.

The aforementioned equipment qualification standards are the only standards addressed in this document and only addresses those revisions of DO-160 and the referenced MIL-STDs listed above. Other civil and military standards are not included in the guidance. This document is not to be used for conducting tests. Refer to the applicable version of each standard for detailed test procedures. The evaluations provided in this document are based upon the methods as written. Test plans can be altered and amended via test specifications which are beyond the scope of this evaluation. Care must be taken when applying these evaluations to existing test results, to discern if material deviations from the standard test methods occurred that might affect the assessment.

There will undoubtedly be instances where final certification may require aircraft level testing or system level testing because the equipment level testing will not be considered sufficient. Reasons for this may be due to the levels and interactions with other equipment on the aircraft or the criticality of the system to the aircraft. In addition, civil aircraft requirements for electrical and electronic systems lightning and HIRF protection drive safety assessments that can result in different equipment level criticality and testing than would result from ARP4761 or ARP4754. The safety classification of the aircraft function for the safety assessment is what is used to determine lightning and HIRF certification level in lieu of the equipment safety assessment.

2. REFERENCES

2.1 Applicable Documents

The following publications form a part of this document to the extent specified herein. The latest issue of SAE publications shall apply. The applicable issue of other publications shall be the issue in effect on the date of the purchase order or certification project application. In the event of conflict between the text of this document and 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.

2.1.1 RTCA Publications

Available from RTCA, Inc., 1150 18th Street, NW, Suite 910, Washington, DC 20036, Tel: 202-833-9339, www.rtca.org.

DO-160G Environmental Conditions and Test Procedures for Airborne Equipment

DO-186B Minimum Operational Performance Standards for Airborne Radio Communications Equipment

2.1.2 U.S. Government Publications

Copies of these documents are available online at <https://quicksearch.dla.mil>.

MIL-STD-461G	Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment
MIL-STD-464C	Electromagnetic Environmental Effects Requirements for Systems
MIL-HDBK-516C	Airworthiness Certification Criteria
MIL-STD-704F	Aircraft Electric Power Characteristics
MIL-STD-810G	Environmental Engineering Considerations and Laboratory Tests

2.1.3 FAA Publications

Available from Federal Aviation Administration, 800 Independence Avenue, SW, Washington, DC 20591, Tel: 866-835-5322, www.faa.gov.

FAA Advisory Circulars (AC): Available from Federal Aviation Administration, 800 Independence Avenue, SW, Washington, DC 20591, Tel: 866-835-5322, www.faa.gov.

US Code of Federal Regulations 14 CFR Parts 23, 25, 27, 29, 31, 33

AC 20-136B	Aircraft Electrical and Electronic System Lightning Protection
AC 20-158A	The Certification of Aircraft Electrical and Electronic Systems for Operation in the High-intensity Radiated Fields (HIRF) Environment
AC 20-169	Guidance for Certification of Military and Special Mission Modifications and Equipment for Commercial Derivative Aircraft (CDA)
AC 21-16G	RTCA Document DO-160 versions D, E and F, Environmental Conditions and Test Procedures for Airborne Equipment
AC 23.1309-1E	System Design and Analysis
AC 25.1309-1A	System Design and Analysis
AC 27-1B	Certification of Normal Category Rotorcraft
AC 29-2C	Certification of Transport Category Rotorcraft
FAA Order 8110.101A	Type Certification Procedures for Military Commercial Derivative Aircraft

FAA System Safety Handbook, December 2000

2.1.4 SAE Publications

Available from SAE International, 400 Commonwealth Drive, Warrendale, PA 15096-0001, Tel: 877-606-7323 (inside USA and Canada) or +1 724-776-4970 (outside USA), www.sae.org.

ARP4754	Guidelines for Development of Civil Aircraft and Systems
ARP4761	Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment
ARP5415	User's Manual for Certification of Aircraft Electrical/Electronic Systems for the Indirect Effects of Lightning

ARP5583 Guide to Certification of Aircraft in High-Intensity Radiated Field (HIRF) Environment

ARP60493 Guide to Civil Aircraft Electromagnetic Compatibility (EMC)

2.2 Abbreviations

14 CFR Title 14, Code of Federal Regulations

CAT Catastrophic

CW Continuous Wave

HAZ Hazardous

MAJ Major

MIN Minor

NSE No Safety Effect

SW Square Wave

2.3 Acronyms

AFCS Audio Frequency Conducted Susceptibility

CS Conducted Susceptibility

CTI Critical Safety Item

EEE (E³) Electromagnetic Environmental Effects

EMI Electromagnetic Interference

ESD Electrostatic Discharge

EUT Equipment Under Test

FAA Federal Aviation Administration

LISN Line Impedance Stabilization Network

MCDA Military Commercial Derivative Aircraft

MOC Means of Compliance

MFR Military Flight Release

MOPS Minimum Operational Performance Standard

MTC Military Type Certificate

PRF Pulse Repetition Frequency

RS Radiated Susceptibility

3. GENERAL APPLICABILITY

3.1 Military Qualified Equipment Installed on a Civil Certified Aircraft

Figure 1 illustrates a high-level process that can be used to determine if a piece of equipment that has been qualified using various MIL-STD tests can be qualified for a civil aircraft installation without performing additional environmental tests.

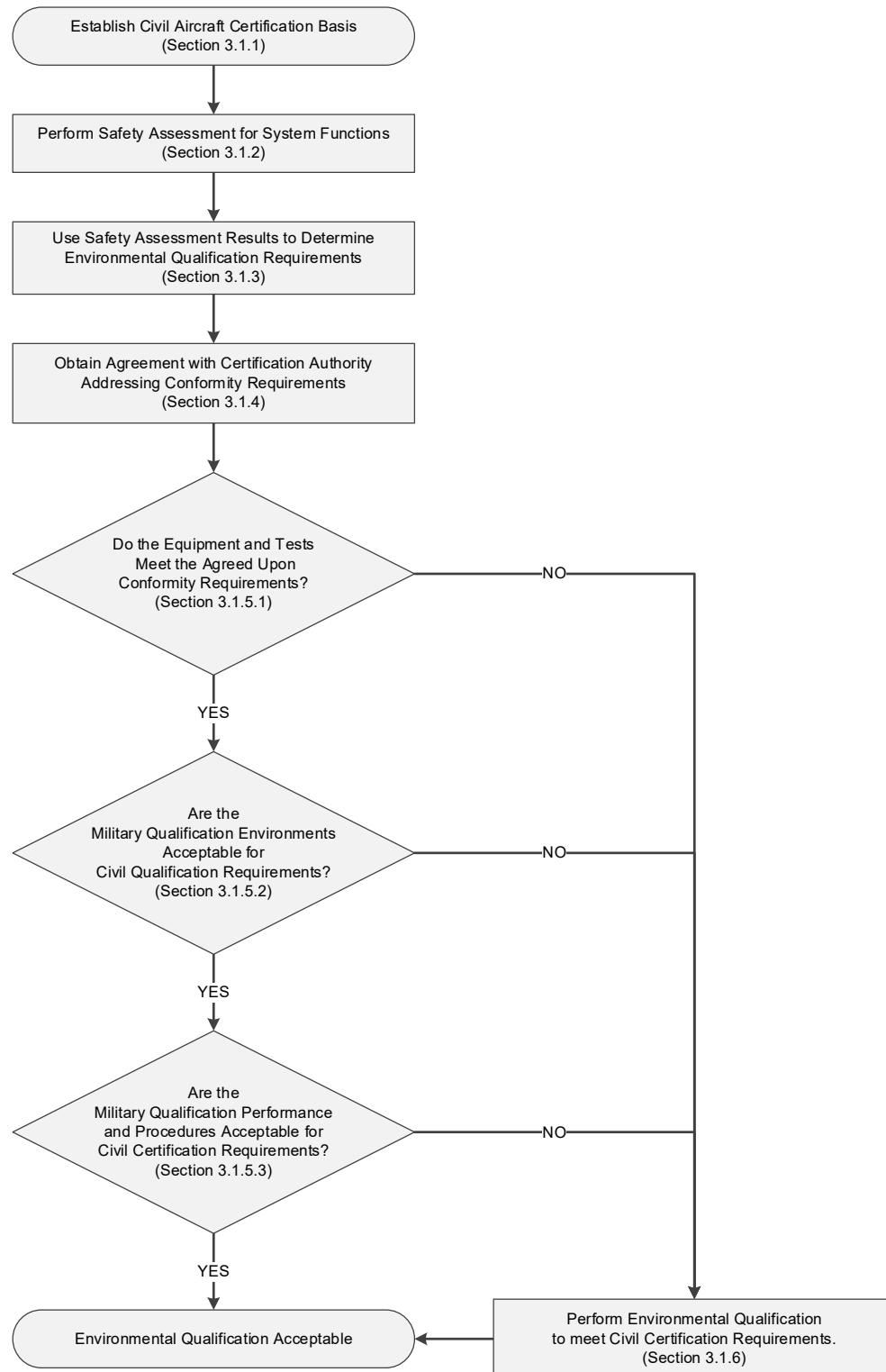


Figure 1 - Process for a military qualified piece of equipment to be qualified for a civil aircraft installation



3.1.1 Establish Civil Aircraft Certification Basis

The overall Military Commercial Derivative Aircraft (MCDA) airworthiness certification process is documented in FAA Order 8110.101A, which supplements the civil aircraft airworthiness process. AC 20-169 is presented as companion material to the procedures outlined in FAA Order 8110.101A. The current revisions of these FAA documents supersede the guidance in this document. The process outlined in FAA Order 8110.101A describes four levels of FAA approval as Full, Limited, Safe Carriage, and Provisional. Each of these levels are available to the applicant, as necessary, to achieve an FAA approval for installation of military qualified equipment performing military operations on a civil aircraft and to obtain an FAA Type Certificate or Supplemental Type Certificate. Each of these levels of approvals are unique to the system being installed and determine the extent of environmental testing required. As indicated in the order, the limited extent of approval is the military operation of the function performed by that equipment. However, while operating in this military mode, all FAA airworthiness requirements must still be met for that equipment.

For any civil aircraft in which military-qualified equipment may be installed, the appropriate regulations and means of compliance (MOCs) must first be established. This can be accomplished by examining the certification basis of the aircraft project or certification plans for any modifications to be installed on existing certified aircraft.

3.1.2 Perform Safety Assessment for System Functions

A Safety Assessment (refer to ARP4761) should be performed to establish the criticality of the system's functions. The corresponding equipment criticality and the equipment location on the aircraft are used to determine what environments a piece of equipment is tested against.

In those cases where a system has CAT failure modes, system level testing may be required. For those situations, MIL-STD-464, MIL-HDBK-516, AC 20-136B, and AC 20-158A may be used.

3.1.2.1 Criticalities Applicable to Civil Aircraft Installations

Equipment installed on modern aircraft perform a variety of functions. Some of those functions have a greater impact on the safety of the aircraft than do other functions. To address the differences in these functions, both the military and civil certification processes assign criticality classifications to a piece of equipment. The criticality nomenclature is defined by the FAA AC 23.1309-1E, AC 25.1309-1A, AC-27-1B, AC-29-2C and Section 3 of the FAA System Safety Handbook for civil criticalities:

CAT – Catastrophic: Results in multiple fatalities and/or loss of the system.

HAZ – Hazardous: Reduces the capability of the system or the operator ability to cope with adverse conditions to the extent that there would be:

- Large reduction in safety margin or functional capability.
- Crew physical distress/excessive workload such that operators cannot be relied upon to perform required tasks accurately or completely.
- Serious or fatal injury to small number of occupants of aircraft (except operators).
- Fatal injury to ground personnel and/or general public.

MAJ – Major: Reduces the capability of the system or the operators to cope with adverse operating condition to the extent that there would be:

- Significant reduction in safety margin or functional capability.
- Significant increase in operator workload.
- Conditions impairing operator efficiency or creating significant discomfort.

- Physical distress to occupants of aircraft (except operator) including injuries.
- Major occupational illness and/or major environmental damage, and/or major property damage.

MIN – Minor: Does not significantly reduce system safety. Actions required by operators are well within their capabilities. Includes:

- Slight reduction in safety margin or functional capabilities.
- Slight increase in workload such as routine flight plan changes.
- Some physical discomfort to occupants or aircraft (except operators).
- Minor occupational illness and/or minor environmental damage, and/or minor property damage.

NSE - No Safety Effect: No impact on safety.

3.1.3 Use Safety Assessment Results to Determine Environmental Qualification Requirements

The applicant will use the safety classification of the aircraft function in the safety assessment to determine the criticality of the equipment. Using this criticality in conjunction with the specific environment the equipment will be exposed to in its installation location on the aircraft, the environmental requirements will be established.

3.1.4 Obtain Agreement with Certification Authority Addressing Conformity Requirements

Both the military and civil certification authorities have processes for managing configuration control. The military's configuration control process is similar but not identical to the civil certification authority's conformity process. Consequently, the differences between these two processes need to be identified and these differences resolved for acceptance by the civil certification authority. It is recommended that the applicant consult with their civil certification authority and establish a method for managing configuration control of the equipment early in the project schedule.

3.1.5 Verification of Military Qualification Data for Use in a Civil Aircraft Certification

The following three sub-sections help to determine the validity of the military qualification data for use in a civil aircraft certification. These sub-sections may be performed at the same time.

3.1.5.1 Do the Equipment and Tests Meet the Agreed Upon Conformity Requirements?

The applicant will need to review the supplied military qualification data for its credibility. The applicant should review this data for completeness including the following items:

- Equipment and test setup description, diagrams, photos, etc.
- Test monitoring and functions of the equipment evaluated, meet the appropriate performance criteria.
- Evidence of configuration control for the equipment and tests. This should include an analysis of any modifications or deviations that occurred during or after the qualification tests.

3.1.5.2 Are the Military Qualified Environments Acceptable for Civil Certification Requirements?

The applicant will need to review the supplied data to ensure the military qualification data demonstrates that the environments meet or exceed the civil aircraft certification requirements. See Section 4, Section 5, and Section 6 for further information.

3.1.5.3 Are the Military Qualification Performance and Procedures Acceptable for Civil Certification Requirements?

The applicant will need to review the supplied data to ensure that the military qualification data demonstrates that the procedures, performance criterion, and test setup requirements are comparable to the civil aircraft certification requirements.

Section 4, Section 5, and Section 6 of this document provide guidance in determining if existing MIL-STD-461, MIL-STD-704, and MIL-STD-810 equipment qualification test data can be utilized in lieu of required DO-160 equipment qualification data. Within those sections, evaluations of differences, similarities, and establishing adequacy (or lack thereof) are made between MIL-STD and DO-160 test and environmental exposure requirements to determine if a particular MIL-STD test satisfies the intent of a corresponding DO-160 environment under evaluation.

3.1.6 Perform Environmental Qualification to meet Civil Certification Requirements

If any aspect of the military qualification data is determined to be inadequate for meeting the intent of the civil aircraft requirements, the applicant will have to demonstrate alternate means of satisfying the civil aircraft certification requirements (e.g., DO-160 test, analysis, ARP5415, ARP5583, ARP60493, etc.). It should be noted, it may be acceptable to utilize portions of the military qualification data to satisfy applicable civil aircraft certification requirements.

3.2 Civil Qualified Equipment Installed on a Military Certified Aircraft

Similar to 3.1 of this document, Figure 2 illustrates a high-level process that can be used to determine whether or not a piece of equipment, qualified using DO-160, can be qualified for a military aircraft installation without performing additional tests.

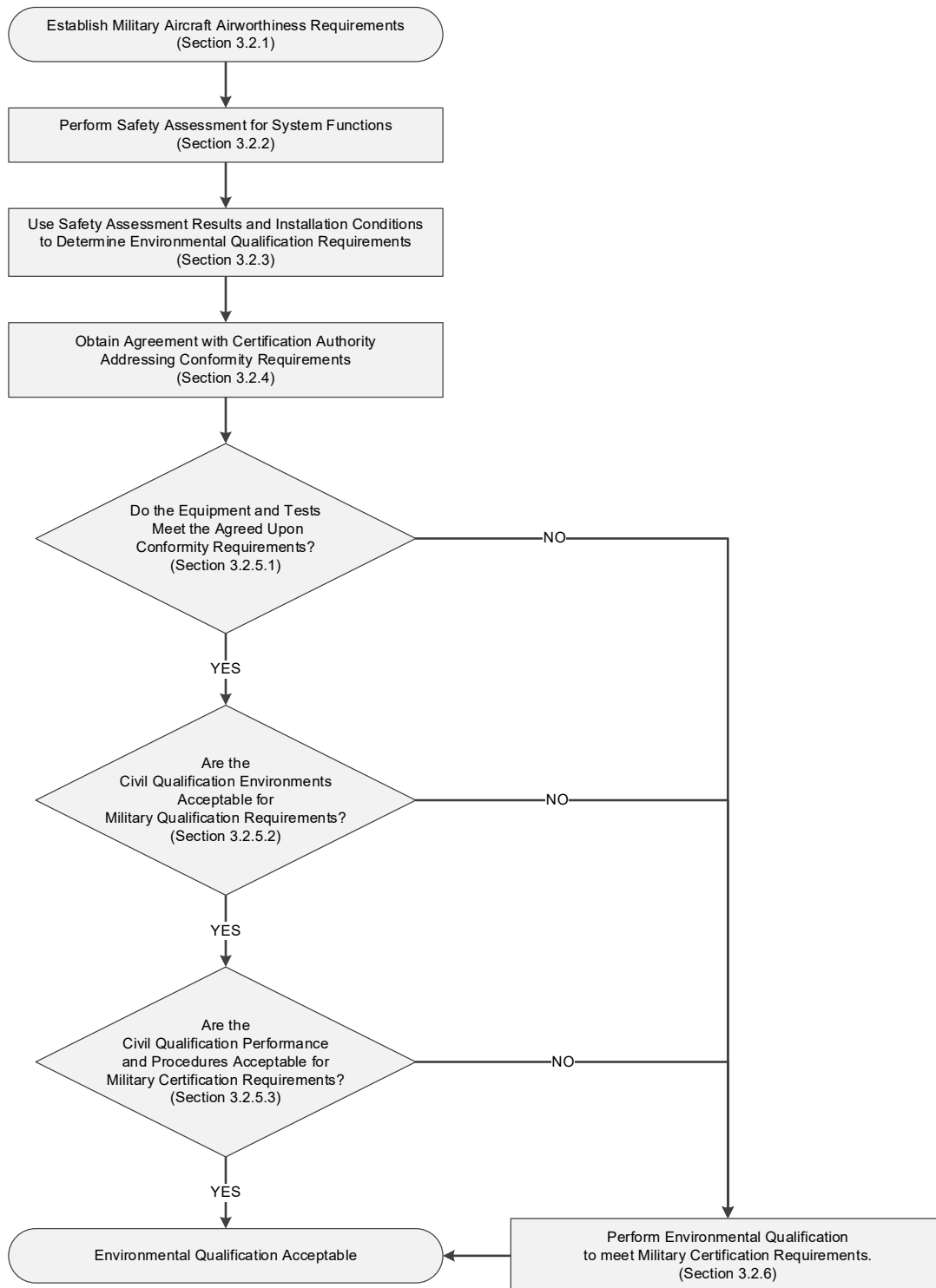


Figure 2 - Process for a civil qualified piece of equipment to be qualified for a military aircraft installation

3.2.1 Establish Military Aircraft Airworthiness Requirements

The military aircraft airworthiness certification process is defined within MIL-HDBK-516C. This document defines the steps and processes required for validating the airworthiness of either new aircraft or modifications to an existing aircraft by satisfying a defined criterion. The military aircraft airworthiness requirements are developed from criteria which are principles for evaluating the airworthiness. In order to substantiate a criterion, adequate data artifacts are provided as evidence of compliance as defined by the methods of compliance. This is a tri-service agreement for all military aircraft to use for acquiring a Military Flight Release (MFR) or a Military Type Certificate (MTC) and enables certified aircraft to accomplish the objectives of the flight program as defined and limited within the release or certification.

MIL-HDBK-516C is divided into 21 separate sections to cover the various aspects pertinent to airworthiness.

Section 12 has defined criteria to address electrical power system power quality and associated equipment level interface requirements/criteria and associated methods of compliance.

Section 13 is dedicated to Electromagnetic Environmental Effects (EEE) which envelopes both aircraft and equipment level criteria. Specific equipment Electromagnetic Interference (EMI) and lightning susceptibility is covered by 13.1.1, 13.1.2, and 13.1.3. Aircraft level criteria is addressed in 13.2.1 through 13.2.9.

The equipment requirements/criteria for substantiation of other environmental environments per MIL-STD-461, MIL-STD-704, and MIL-STD-810 are distributed in various sections of the equipment criteria of MIL-HDBK-516C.

For any military aircraft in which commercially qualified equipment may be installed, the appropriate regulations and means of compliance (MOCs) must first be established. This can be accomplished by examining the contractual verification methods defined for the applicable airworthiness requirements.

3.2.2 Perform Safety Assessment for System Functions

A safety assessment should be performed to establish the criticality of the system's functions. MIL-HDBK-516C refers to this as System Safety and is addressed in Section 14 of that document. The corresponding equipment criticality and the equipment location are used to determine what environments a piece of equipment is tested against.

In those cases where a system has CAT failure conditions, system or aircraft level testing may be required. For those situations, MIL-STD-464, MIL-HBK-516, AC 20-136, and AC 20-158 may be used. MIL-HDBK-516C refers to CAT as Critical Safety Item (CTI).

3.2.2.1 Criticalities Applicable to Military Aircraft Installations

Equipment installed on modern aircraft perform a variety of functions. Some of those functions have a greater impact on the safety of the aircraft than do other functions. To address the differences in these functions, both the military and civil certification processes assign criticality classifications to a piece of equipment. The criticality nomenclature is defined by the United States General Accounting Office for military criticalities. MIL-HDBK-516C also defines the following criticality nomenclatures:

Flight Critical: A term applied to any condition, event, operation, process, or item whose proper recognition, control, performance, or tolerance is essential to achieving or maintaining controlled flight of an aircraft.

Safety Critical: A safety classification given to any condition, event, operation, process, or item whose proper recognition, control, performance, or tolerance is essential to safe system operation and support (e.g., safety critical function, safety critical path, safety critical software, or safety critical component). Safety Critical is a broader definition of the categorizations of safety and includes flight critical but may not be limited to controlling flight.

For the remainder of this document only the term Safety Critical will be used since it also includes the Flight Critical classification, per the definition provided above. Note that non-flight critical or non-safety critical equipment must also not affect the safe operation of flight critical or safety critical equipment.

The military also uses a third category called Mission Critical. However, equipment receiving a Mission Critical classification is not addressed in this document as they do not impact the continued safe flight of the aircraft.

3.2.3 Use Safety Assessment Results to Determine Environmental Qualification Requirements

The applicant will use the safety assessment to categorize the criticality of the equipment. Using this criticality in conjunction with the specific environment the equipment will be exposed to in its installation, the environmental requirements will be established.

3.2.4 Obtain Agreement with Certification Authority Addressing Requirements

Both the military and civil authorities have processes for managing configuration control. The military's configuration control process is similar but not identical to the civil certification authority's conformity process. It is recommended that the applicant consult with their military certification authority and establish a method for managing configuration control of the equipment early in the project schedule.

3.2.5 Verification of Civil Qualification Data for Use in a Military Aircraft Installation

The following three sub-sections help to determine the validity of the civil qualification data for meeting military aircraft airworthiness requirements.

3.2.5.1 Do the Equipment and Tests Meet the Agreed Upon Requirements?

The applicant will need to review the supplied DO-160 data for its credibility. The applicant should review this data for completeness including the following items:

- Equipment and test setup description, diagrams, photos, etc.
- Test oversight by appropriate technical representative(s) [recommended but not required].
- Evidence of configuration control for the equipment and tests. This should include an analysis of any modifications or deviations that occurred during or after the qualification tests.
- Test monitoring and functions of the equipment evaluated meet the appropriate performance criteria for each environment.

3.2.5.2 Are the Civil Qualification Environments Acceptable for Military Qualification Requirements?

The applicant will need to review the supplied data to ensure the civil qualification data demonstrates the environments meet or exceed the military aircraft certification requirements.

3.2.5.3 Are the Civil Qualification Performance and Procedures Acceptable for Military Qualification Requirements?

The applicant will need to review the supplied data to ensure the civil qualification data demonstrates the procedures and test setup requirements are comparable to the intended installation and installed configuration of the military aircraft airworthiness requirements. Section 4, Section 5, and Section 6 of this document provide guidance in determining if existing DO-160 equipment qualification test data can be utilized in lieu of required MIL-STD equipment qualification data. Within those sections, evaluations of differences, similarities and establishing adequacy (or lack thereof) are made between MIL-STD and DO-160 test and environmental exposure requirements to determine if a particular DO-160 test satisfies the intent of a corresponding MIL-STD test under evaluation.

3.2.6 Perform Environmental Qualification to Meet Military Qualification Requirements

If any aspect of the civil qualification data is determined to be inadequate for meeting the intent of the military aircraft airworthiness requirements, the applicant will have to demonstrate alternate means of satisfying the military aircraft airworthiness requirements (e.g., MIL-STD test, analysis, etc.). It should be noted, it may be acceptable to utilize portions of the civil qualification data to satisfy applicable military aircraft airworthiness requirements.

4. MIL-STD-461G AND DO-160G EVALUATION

4.1 Introduction

This section presents the evaluations between MIL-STD-461G and the electromagnetic environments of DO-160G. Table 1 lists each environment discussed in this section and then identifies the applicable method number for MIL-STD-461G or section number for DO-160G that is being evaluated. A dash in one of the columns denotes that there is not a comparable test section in either standard. The information contained in each environmental section includes:

- a. A summary of the test method being discussed.
- b. An evaluation of the DO-160G and MIL-STD-461G tests and how they may or may not compare. This section may include tables and figures that compare the two test methods, highlighting differences that may affect acceptance.
- c. A recommendation of how an EUT qualified to MIL-STD-461G might be able to be used on civil aircraft and how an EUT certified for use on a civil aircraft might be able to be used on a MIL-STD-461G aircraft.
- d. A rationale justifying the recommendations made.

Table 1 - Section index

AIR6811 Section	Description	MIL-STD-461G Method	DO-160G Section
4.3.1	Conducted Emissions, Audio Frequency Currents, Power Leads	CE101	--
4.3.2	Conducted Emissions, Radio Frequency Potential, Power Leads (MIL-STD-461G) Conducted RF Emissions (DO-160G)	CE102	21.4
4.3.3	Conducted Emissions, Antenna Port	CE106	--
4.3.4	Conducted Susceptibility, Power Leads (MIL-STD-461G) Audio Frequency Conducted Susceptibility – Power Inputs (DO-160G)	CS101	18
4.3.5	Conducted Susceptibility, Antenna Port, Intermodulation	CS103	--
4.3.6	Conducted Susceptibility, Antenna Port, Rejection of Undesired Signals	CS104	--
4.3.7	Conducted Susceptibility, Antenna Port, Cross Modulation	CS105	--
4.3.8	Conducted Susceptibility, Structure Current	CS109	--
4.3.9	Conducted Susceptibility, Bulk Cable Injection (MIL-STD-461G) Conducted Susceptibility (DO-160G)	CS114	20.4
4.3.10	Conducted Susceptibility, Bulk Cable Injection, Impulse Excitation (MIL-STD-461G) Spikes Induced into Interconnecting Cables (DO-160G)	CS115	19.3.5
4.3.11	Conducted Susceptibility, Damped Sinusoidal Transients, Cables and Power Leads	CS116	--
4.3.12	Conducted Susceptibility, Lightning Induced Transients, Cables and Power Leads (MIL-STD-461G) Lightning Induced Transient Susceptibility (DO-160G)	CS117	22
4.3.13	Personnel Borne Electrostatic Discharge (MIL-STD-461G) Electrostatic Discharge (DO-160G)	CS118	25
4.3.14	Radiated Emissions, Magnetic Field	RE101	--
4.3.15	Radiated Emissions, Electric Field (MIL-STD-461G) Radiated RF Emissions (DO-160G)	RE102	21.5, 21.6
4.3.16	Radiated Emissions, Antenna Spurious and Harmonic Outputs	RE103	--
4.3.17	Radiated Susceptibility, Magnetic Field	RS101	--
4.3.18	Radiated Susceptibility, Electric Field (MIL-STD-461G) Radiated Susceptibility (DO-160G)	RS103	20.5, 20.6
4.3.19	Radiated Susceptibility, Transient Electromagnetic Field	RS105	--
4.3.20	Magnetic Effect	--	--

AIR6811 Section	Description	MIL-STD-461G Method	DO-160G Section
4.3.21	Magnetic Fields Induced into the Equipment	--	19.3.1
	Electric Fields Induced into the Equipment	--	19.3.2
	Magnetic Fields Induced into Interconnecting Cables	--	19.3.3
	Electric Fields Induced into Interconnecting Cables	--	19.3.4
4.3.22	Lightning Direct Effects	--	23

4.2 General Test Setup Differences

4.2.1 Basic Test Setup

- MIL-STD-461G states in each test method that it is necessary to “maintain the basic test setup” in Figures 2 to 5 and 4.3.8 of the standard, granting only the latitude to make changes that are directly required to induce the specified stimulus or make specified measurements for the method being performed on the EUT.
- The “electromagnetic” sections of DO-160G are generally accepted to be Section 15, Section 18, Section 19, Section 20, Section 21, Section 22, Section 23, and Section 25. Note that Section 20.3 contains the general setup details regarding cable routing and equipment installation on the ground plane. The other sections reference Section 20.3 for their test setup or have their own defined setup. DO-160G, Section 16 and Section 17 are evaluated in Section 5 of this document.
- Ground wires and power returns should be representative of aircraft installation. The correlations in this document assume similar installations and cable configurations.

4.2.2 Ground Plane

- Both MIL-STD-461G and DO-160G have requirements for installing the EUT on a conductive ground plane. The guidance in this document is based on testing on conductive ground planes.

4.2.3 Line Impedance Stabilization Networks (LISNs)

- The use of LISNs is to add impedance to test configurations to better simulate platform power line installations and to standardize testing across laboratories. The use of a 5 μ H LISN or a 50 μ H LISN establishes a 50 Ω matched impedance for RF noise measurements.
- MIL-STD-461G generally requires the use of a 50 μ H LISN on each power input and dedicated returns.
- DO-160G generally requires the use of a 5 μ H LISN with an external 10 μ F capacitor on its input be used on each power input and return lead. However, LISNs are not required on local grounds shorter than 1 m.
- There are instances where the 5 μ H LISN is allowed by MIL-STD-461G based on guidance in MIL-STD-461G, Appendix A.

4.2.4 Cable Routing

- The power input leads for the DO-160G Section 20.3 basic setup are required to be installed parallel to, and 10 cm back from, the front edge of the ground plane for a distance of 1 m from the EUT, at which point a LISN is to be inserted in the power lead. MIL-STD-461G requires the same configuration, but with a lead length of 2 m before insertion of the LISN in the power lead. This may change the frequency response of the cables.
- In cases where power leads are part of a cable bundle in the installation, DO-160G allows that those leads remain within the cable bundle if required by the installation. MIL-STD-461G, on the other hand, requires that the power leads be separated from the cable bundle, and routed parallel to the interconnect wiring along the front edge of the ground plane, as described above.

- Interconnecting cables in DO-160G shall be routed with no less than 1 m of cable length parallel to the front of the ground plane. MIL-STD-461G requires at least 2 m of cable be routed parallel to the front of the ground plane.
- MIL-STD-461G requires the EUT to be on one end of the table and all wiring to be laid out together (with 2 cm separation measured from their outer circumference) across the table. It is permissible to configure the DO-160G test setup in the same manner as MIL-STD-461G; however, the 1 m of power cable would mean that the LISN would then need to be installed in the center of the test cable run, creating reflections and other test setup concerns. For this reason, it is accepted that it is most convenient to configure DO-160G test setups with the EUT in the center of the bench with cables spreading out in separate directions, which, coincidentally, appears as a “worst case” setup, with the power and interconnect cables acting as the two legs of a dipole to better radiate any emissions from the EUT.
- DO-160G recommends that cables be no longer than 15 m. MIL-STD 461G recommends that at least 10 m of cabling be included.

4.3 Individual Environments

Each section includes Comparison, Recommendations, and other sub-sections describing the similarities/differences. There is also a summary sub-section included as necessary. Only sections relating to MIL-STD 461G CS114, CS117, and RS103 include comparison tables with DO-160G regarding safety critical items.

4.3.1 MIL-STD-461G, CE101

4.3.1.1 Summary

Conducted emission tests for equipment power leads are described in MIL-STD-461G CE101, conducted emissions, audio frequency currents, power leads.

4.3.1.2 Evaluation

CE101 measures low frequency, 30 Hz to 10 kHz, emissions from EUT power leads.

4.3.1.3 Recommendation

Application of MIL-STD-461G Qualified Equipment to a Civil Certification Environment

CE101 does not have an equivalent applicable test in DO-160G.

Application of DO-160G Certified Equipment to a Military Qualified Environment

To qualify DO-160G equipment to MIL-STD-461G, CE101 would need to be performed.

4.3.1.4 Rationale

The primary purpose of CE101 is to protect power quality of the host platform in the case of ships and army aircraft, and to protect sensitive equipment, in the case of anti-submarine warfare aircraft. Because of the intended purpose of CE101, the frequency range of test is not equivalent to any DO-160G emissions tests.

4.3.2 MIL-STD-461G, CE102, and DO-160G, Section 21.4

4.3.2.1 Summary

Conducted emission tests for equipment power leads are described in MIL-STD-461G CE102, Conducted Emissions, Radio Frequency Potential, Power Leads and DO-160G, Section 21.4 Conducted RF emissions.

4.3.2.2 Evaluation

Table 2 and the following outlines details for comparison between Conducted Emission tests from MIL-STD-461G CE102 and DO-160G, Section 21.4. Also consider the following when evaluating evidence of compliance of a product's requirements of a military standard with similar requirements for similar equipment.

Table 2 - DO-160G, section 21.4 versus MIL-STD-461G CE102

Parameter	MIL-STD-461G	DO-160G
Test Method:	CE102	Section 21.4
Measurement Type:	Voltage	Current
Basis for Limit:	Based on EUT Source Voltage	Classification by Installation Location
Test Frequency Range:	10 kHz to 10 MHz	150 kHz to 152 MHz
Measurement Unit:	dBμV	dBμA

Frequency Range: MIL-STD-461G specifies a frequency measurement range of 10 kHz to 10 MHz. DO-160G specifies frequency range of 150 kHz to 152 MHz. The overlap between the radiated and conducted emissions frequency ranges should be considered.

Measurement Bandwidth (Resolution Bandwidth - RBW): Both DO-160G and MIL-STD-461G use a 6 dB defined bandwidth for measurements. See Table 3 for bandwidth and measurement ranges:

Table 3 - Conducted emissions bandwidth comparison

DO-160G		MIL-STD-461G	
Frequency Range	Resolution BW	Frequency Range	Resolution BW
<i>No testing below 150 kHz</i>		10 kHz-150 kHz	1 kHz
150 kHz- 10 MHz	1 kHz	150 kHz- 10 MHz	10 kHz
10 MHz- 30 MHz	1 kHz	<i>No conducted testing above 10 MHz, see radiated requirements</i>	
30 MHz-152 MHz	10 kHz		

Measurement of Conducted Emission Level:

- MIL-STD-461G measures voltage interference present on each power lead attached to EUT. The voltage is developed through the standardized impedance of the 50 μH LISN, using the measurement port of the LISN. Only power leads can be measured individually.
- DO-160G uses a current measuring transducer placed around a lead or group of leads at a location very near the EUT. EUT power and interconnecting leads are measured in this manner.

Methodology:

- As noted previously, MIL-STD-461G measures voltage interference originating from the EUT on each power supply lead. The location where this emission is measured represents the location where the EUT is attached to the power distribution bus. CE102 measures the voltage interference produced by a EUT that could affect other devices common to the relevant power bus. MIL-STD-461G measures voltage interference produced by a EUT.
- DO-160G measures current interference produced by a EUT. The measurement location is very close to the EUT. The ultimate effect of these currents produced by the EUT define current loop areas that produce magnetic fields that couple to adjacent interconnecting bundles and/or other devices and aircraft structural elements. The measurement location allows for current measurement before coupling to adjacent bundles and/or aircraft structural elements occur. All interconnecting bundles and power leads are analyzed. DO-160G measures current interference produced by the EUT.

Test Setup: See 4.2.

4.3.2.3 Recommendation

Application of MIL-STD-461G Qualified Equipment to a Civil Certification Environment

It is recommended that because of differences in the standards (frequency range and cables tested), CE102 AND RE102 data must be considered together. Passing test results from both tests for the intended installation would satisfy the civil certification requirement.

Application of DO-160G Certified Equipment to a Military Qualified Environment

It is recommended that equipment that has met the requirements of DO-160G environment be considered acceptable for use in the MIL-STD-461G environment (for intended installation) unless there are receivers below 150 kHz. For aircraft with receivers below 150 kHz, additional testing may be necessary if using DO-160G certified equipment in order to protect those receivers.

4.3.2.4 Rationale

Although there are differences between DO-160G and MIL-STD-461G, the intent of the tests is the same and the data collected by either method can be used to determine the impact to onboard receivers. Use of the overall emissions picture of the radiated and conducted emissions may be sufficient to evaluate the emissions performance against the installed environment.

4.3.3 MIL-STD-461G, CE106

4.3.3.1 Summary

This requirement is applicable from 10 kHz to 40 GHz for the antenna ports of transmitters, receivers, and amplifiers.

4.3.3.2 Evaluation

NO EQUIVALENT DO-160G TEST – Covered by MOPS, not under DO-160G.

4.3.3.3 Recommendation

Application of MIL-STD-461G Qualified Equipment to a Civil Certification Environment

CE106 does not have an equivalent applicable test in DO-160G.

Application of DO-160G Certified Equipment to a Military Qualified Environment

Equipment that meets the Minimum Operation Performance Standard (MOPS) may meet CE106. See rationale below for details.

4.3.3.4 Rationale

For civil aircraft, antenna port emissions are generally covered by the MOPS for transmitters and/or receivers (antenna connected equipment).

CE106 is generally levied directly to the transmitter and/or receiver manufacturers. For VHF/COMMs radios, if equipment has been tested to the MOPS requirements of DO-186B, Section 2.3.7, it may be worthwhile to compare the test results against any potential CE106 requirements for that particular piece of equipment; however, because there is not a directly equivalent test method prescribed, it will be up to the procuring activity or contractor to make the final determination as to the suitability of the equipment for its intended installation.

CE106 requires harmonics, except the second and third, and all other spurious emissions to be at least 80 dB down from the level at the fundamental. The second and third harmonics shall be suppressed to a level of -20 dBm or 80 dB below the fundamental, whichever requires less suppression. DO-186B MOPS VHF/COMMOPS indicates 60 dB down from the level at the fundamental; if CE106 is satisfied, this implies that the MOPS guidelines have been followed.

4.3.4 MIL-STD-461G, CS101, and DO-160G, Section 18

4.3.4.1 Summary

Conducted Susceptibility tests are described in MIL-STD-461G CS101, Conducted Susceptibility, Power Leads, and DO-160G, Section 18, Audio Frequency Conducted Susceptibility - Power inputs.

4.3.4.2 Evaluation

Comparison:

Both DO-160G, Section 18 and MIL-STD-461G CS101 provide test requirements and methods for audio frequency susceptibility equipment qualification. The following provides the differences, similarities, and a brief summary as it pertains to these two test standards.

Differences:

Test Calibration: MIL-STD 461G CS101 requires a calibration into a $0.5\ \Omega$ resistor that generates a power limit to be used during the test. DO 160G, Section 18 has a 36 A peak-to-peak current limit during the test. The objective of both tests is to achieve the required test voltage or limit level, whichever is reached first.

Supporting Test Equipment Differences: Although the test equipment used for DO-160G, Section 18 will perform the testing required by MIL-STD-461G CS101, there is a difference in the LISNs required for test between the two test standards:

- 50 μH LISN for MIL-STD-461G CS101
- No LISN required for DO-160G, Section 18

NOTE: While the prescribed LISN requirement for the two tests will present different impedances at the frequencies of test for this method, it is important to note that the 10 μF capacitor placed across the power lead and its associated return is intended to present a much lower impedance to the Audio Frequency Conducted Susceptibility (AFCS) test signal. This lower impedance to the AFCS test signal, though Kirchhoff's Voltage Law, will then result in more of the induced audio frequency energy being induced into the EUT, as opposed to being lost across the power source impedance. Figure 3, V1, the induced AFCS voltage *must* be equal to the sum of V2 + V3. By lowering the impedance of the capacitor/power source, V3 will shrink, and V2 will increase, assuming the V1 is held constant.

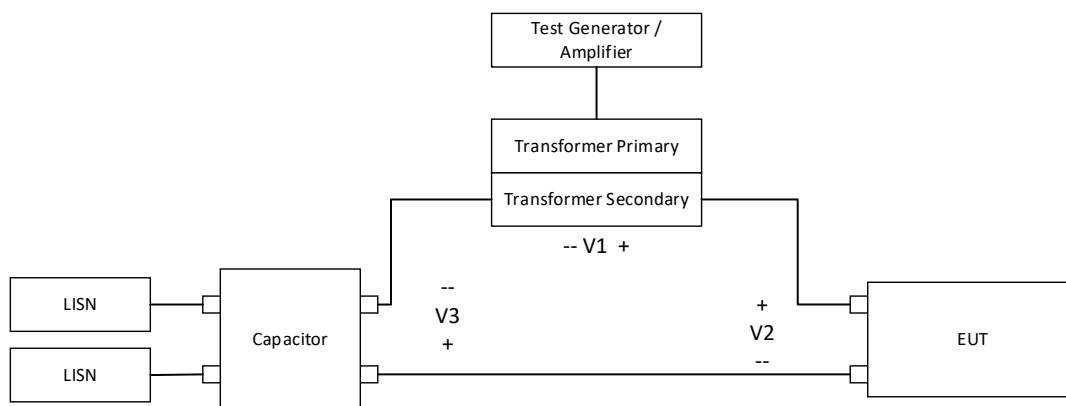


Figure 3 - 28 VDC AFCS voltage drops

DO-160G recognizes this effect, which is why 28 VDC equipment utilizes a much larger (10000 μ F or larger) capacitor across the power leads under test. This capacitor presents a *much* lower impedance to the AFCS signal, and projects that much more across the EUT in cases where the 100 W test limit is achieved before reaching the required test voltage. While not in the main body of the MIL-STD-461G CS101 test method, the MIL-STD-461G appendix does mention that in cases where the CS101 secondary power limit is reached before achieving the required test voltage, the capacitor across the power leads should be changed from the required 10 μ F capacitor to a much larger value, which is commensurate to the required capacitor in DO-160G. For this reason, it should be considered permissible, and even recommended, to utilize the larger capacitor value for ALL MIL-STD-461G CS101 testing of DC equipment.

Application of the Test Conditions: The DO-160G, Section 18 test has slower sweep rates/longer dwell times than the MIL-STD-461G CS101.

Documentation:

- MIL-STD-461G CS101 requires the choice of either graphical or tabular data for frequencies and levels tested. DO-160G, Section 18 does not have specific documentation requirements.
- MIL-STD-461G CS101 requires thresholding data for any susceptibilities that may have occurred: amplitude, frequency, description of failure, recovery time. DO-160G, Section 18 allows for documenting susceptibility data without thresholding data, although this approach is not recommended.

Similarities:

Although there are numerous differences between MIL-STD-461G CS101 and DO-160G, Section 18, there are similarities to note between these two tests for consideration in applying data from MIL-STD-461G CS101 to DO-160G, Section 18 (and vice-versa). The similarities between these two test standards are provided below.

- Test equipment used during the actual test of the EUT are the same, except for the LISN impedance and the bypass capacitor placed across the EUT power leads during test. See discussion above.
- The DO-160G, Section 18 test includes the entire frequency range of the MIL-STD 461G CS101 test (Category B, however, has a smaller frequency range than MIL-STD-461G CS101).

Summary:

Both DO-160G, Section 18 and MIL-STD-461G CS101 are very similar in test setup and methods; however, there are differences between the two test standards that result in DO-160G, Section 18 test data to not be directly applicable to MIL-STD CS101. These differences do not mean that equipment qualified to DO-160G, Section 18 will result in test failures when qualifying this equipment to MIL-STD-461G CS101. In practice, the failure rate for this test is low since design to the requirement is easily quantifiable and easily simulated.

4.3.4.3 Recommendations

DO-160G, Section 18 fully meets the intent of MIL-STD-461G CS101. This relationship is completely reciprocal.

It is recommended that equipment that has met the requirements of MIL-STD-461G CS101 be considered acceptable for use within a DO-160G environment. Likewise, 28 VDC equipment meeting the requirements of DO-160G Category R, K, and Z should be considered acceptable for MIL-STD-461G installations. DO-160G Category B has a limited frequency coverage with same amplitude levels.

For 115 V AC systems, equipment that has met the requirements of CS101 should be considered acceptable for use in DO-160G environments. Likewise, 115 V AC equipment meeting the requirements of DO-160G should be considered acceptable for MIL-STD-461G installations.

For other voltages, refer to the standards for specifics; however, overall conclusions are the same as above.

4.3.4.4 Rationale

While CS101 has a higher voltage requirement (for DC equipment), it is important to note that, according to MIL-STD-461G:

"[CS101] limits are based on a review of the power quality standards with emphasis toward the spectral content curves present in MIL-STD-704F. Rather than having a separate curve for each possible power source voltage, only two curves are specified. The voltage amplitude specified is approximately 6 dB above typical power quality limits..."

For 28 VDC equipment, the DO-160G limit closely approximates the MIL-STD-704F curve, so it is expected that effects will be closely approximated; however, the 6 dB margin will not be in place for that equipment. Figure 4 shows the DC limits for CS101 and Section 18, along with the MIL-STD-704F ripple limit.

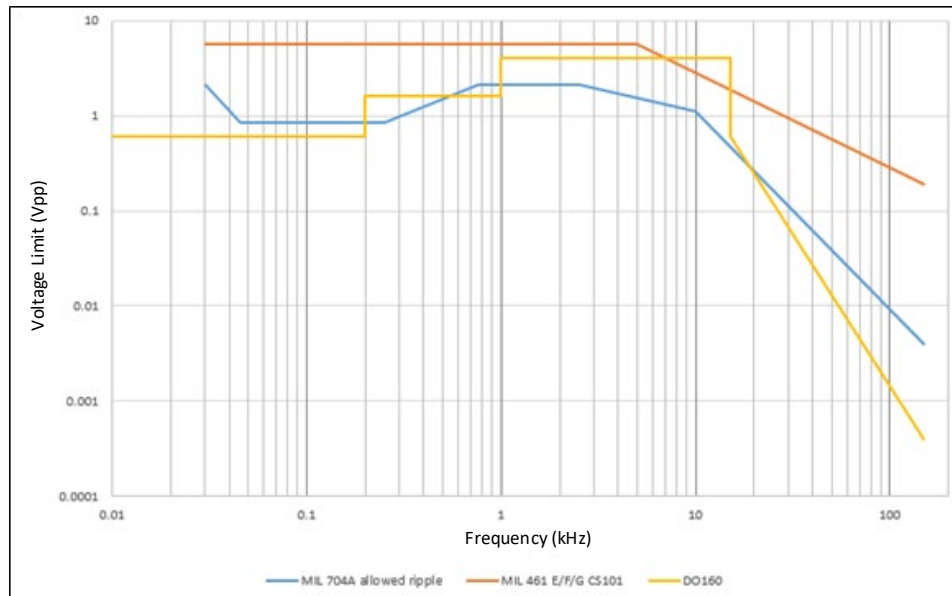


Figure 4 - 28 VDC equipment susceptibility levels

For 115 V AC equipment, it should be considered that the primary purpose of AFCS testing is to protect the equipment from any potential power generation system harmonics (i.e., harmonics of the aircraft 115 V AC 400 Hz generators – 800 Hz, 1200 Hz, 2400 Hz, etc.), with the secondary concern being emissions from equipment on the power bus. Since the DO-160G limit is higher than the MIL-STD-461G CS101 limit (albeit, limited in frequency), equipment that meets the DO-160G requirement will meet the requirements of MIL-STD-461G. The one main difference is that DO-160G has a flat voltage limit, whereas MIL-STD-461G CS101 has a limit with a flat component but decreases in amplitude as a function of frequency above 5 kHz. This limit shape more closely represents the spectral energy that will be present in a power generation system.

4.3.5 MIL-STD-461G, CS103

4.3.5.1 Summary

Conducted Susceptibility tests are described in MIL-STD-461G CS103, Conducted Susceptibility, Antenna port, intermodulation.

4.3.5.2 Evaluation

CS103 is receiver front end susceptibility requirement and is applicable from 15 kHz to 10 GHz for equipment and subsystems.

4.3.5.3 Recommendation

CS103 does not have an equivalent applicable test in DO-160G. In cases where civil equipment is to be installed on a military platform, analysis and/or additional testing will be required to show compliance to any platform installation requirements for CS103.

4.3.5.4 Rationale

CS103 is generally levied directly to the transmitter and/or receiver manufacturers.

4.3.6 MIL-STD-461G, CS104

4.3.6.1 Summary

Conducted Susceptibility tests are described in MIL-STD-461G CS104, Conducted Susceptibility, Antenna port, rejection of undesired signals.

4.3.6.2 Evaluation

CS104 is a receiver front end susceptibility requirement and is applicable from 30 Hz to 20 GHz for equipment and subsystems, such as communication receivers.

4.3.6.3 Recommendation

CS104 does not have an equivalent applicable test in DO-160G. In cases where civil equipment is to be installed on a military platform, analysis and/or additional testing will be required to show compliance to any platform or installation requirements for CS104.

4.3.6.4 Rationale

CS104 is generally levied directly to the transmitter and/or receiver manufacturers.

4.3.7 MIL-STD-461G, CS105

4.3.7.1 Summary

Conducted Susceptibility tests are described in MIL-STD-461G CS105, Conducted Susceptibility, Antenna Port, cross modulation.

4.3.7.2 Evaluation

CS105 is a receiver front-end susceptibility requirement and is applicable from 30 Hz to 20 GHz and only for receivers that normally process amplitude modulated RF signals.

4.3.7.3 Recommendation

CS105 does not have an equivalent applicable test in DO-160G. In cases where civil equipment is to be installed on a military platform, analysis and/or additional testing will be required to show compliance to any platform or installation requirements for CS105.

4.3.7.4 Rationale

CS105 is generally levied directly to the transmitter and/or receiver manufacturers.

4.3.8 MIL-STD-461G, CS109

4.3.8.1 Summary

Conducted Susceptibility tests are described in MIL-STD-461G CS109, Conducted Susceptibility, structure current.

4.3.8.2 Evaluation

CS109 is applicable from 60 Hz to 100 kHz for equipment and subsystems that have an operating frequency of 100 kHz or less and an operating sensitivity of 1 μ V or better. CS109 has limited applicability for surface ship and submarine applications.

4.3.8.3 Recommendation

CS109 does not have an equivalent applicable test in DO-160G. In cases where civil equipment is to be installed on a military platform, analysis and/or additional testing will be required to show compliance to any platform or installation requirements for CS109.

4.3.8.4 Rationale

CS109 is generally leveled against shipboard and submarine equipment.

4.3.9 MIL-STD-461G, CS114 and DO-160G, Section 20.4

4.3.9.1 Summary

RF conducted susceptibility tests applied to equipment wire bundles are described in MIL-STD-461G CS114, Conducted Susceptibility, Bulk Cable Injection and DO-160G, Section 20 Radio Frequency Susceptibility (Conducted and Radiated) Section 20.4 Conducted Susceptibility (CS) Test.

4.3.9.2 Evaluation

CS114 and Section 20.4 are very similar. However, the highest test frequencies of the two standards differ, where CS114 covers frequencies from 10 kHz to 200 MHz, while Section 20.4 covers 10 kHz to 400 MHz. The MIL-STD-461G appendix discusses why the upper CS114 frequency limit was changed from 400 MHz to 200 MHz:

“The optional frequency range of 200 MHz to 400 MHz is deleted because of the questionable validity of performing bulk cable measurements at higher frequencies.”

From MIL-STD-461G:

“The basic relationship for the limit level in the resonance (flat) portion of the curve is 1.5 mA per V/m that is derived from worst-case measurements on aircraft. For example, 110 dBμA corresponds to 200 V/m. At resonance, the effective shielding effectiveness of the aircraft can be zero. Application of these results to other platforms is reasonable.”

This is the same general requirement used in Categories T, R, W and Y in DO-160G where, for example, CAT R requires 20 V/m, the conductive current is 30 mA.

1. Both Section 20.4 and CS114 apply 1 kHz square wave Pulse Modulation. Section 20.4 also applies a Continuous Wave (CW), where CS114 does not.
2. CS114 requires 40 dB depth of modulation, while Section 20.4 requires greater than 90% or 20 dB depth of modulation.
 - The fast rise and fall times of the pulse causes the signal to have significant harmonic content high in frequency and can be detrimental to digital circuits.
 - Starting in MIL-STD-461G, verification of the presence of correct modulation by monitoring output signals is specified in the CS114 and RS103 sections.
3. Section 20.4 covers frequencies from 10 kHz to 400 MHz. CS114 covers frequencies from 10 kHz to 200 MHz. However, as discussed above, both methods are combined with radiated (RS) testing to cover the same basic frequency ranges. DO-160G, Section 20.4 requires testing at known EUT frequencies (i.e., LO, IF, clock frequencies, etc.), while MIL-STD-461G does not.

The MIL-STD-461G step sizes are smaller than the minimum allowed DO-160G step sizes, which are subject to justification. See DO-160G, Section 20.3.e:

“Sweep or step rates shall be selected with consideration of equipment under test (EUT) response time, EUT susceptibility bandwidths, and monitoring test equipment response time. The scan rate selected shall be justified by this criteria and documented in the test report.”

Table 4 - DO-160G, section 20.4 versus MIL-STD-461G CS114 frequency steps

MIL-STD-461G CS114	DO-160G, Section 20.4
10 kHz-1 MHz, 0.05f ₀ 1 MHz-30 MHz, 0.01f ₀ 30 MHz-400 MHz, 0.005f ₀	100 steps per decade, minimum

4. CS114 uses a minimum 3 second dwell time while DO-160G, Section 20.4 uses a minimum dwell time of 1 second.
5. Section 20.4 allows for the power and return leads normally bundled with the control/signal leads shall remain in the cable bundle and only be separated from the bundle as close as possible to the cable bundle exiting the test area. CS114 requires testing on both entire power cables and power cables with the returns removed to evaluate common mode coupling to configurations which may be present in different installations.
6. Calibration is similar but the test is run differently as described in Table 5.

Table 5 - DO-160G, section 20.4 versus MIL-STD-461G CS114 test limits

Parameter	MIL-STD-461G	DO-160G**
Primary Test Limit ("Test to")	Forward Power = Calibration Forward Power for selected curve	Test Induced current = Calibration current
Secondary Test Limit ("OR test to")	Induced current = a flat level 6 dB greater than the highest current for the specified limit*	Forward Power = Calibration Forward Power plus 6 dB
*Previous editions of MIL-STD-461G (E, F) used a level that was 6 dB above the applicable calibration curve at each frequency, as opposed to a flat limit		
**Previous editions of DO-160G tested to Calibration forward power OR a flat limit based on category		

7. DO-160, Section 20.4 current limits are specified in milliamperes (mA), while CS114 current limits are specified in terms of decibels relative to one microampere (dBμA). Equation 1 or Equation 2 can be used to convert between dBμA and mA.

$$mA = 10^{\frac{dB\mu A - 60}{20}} \quad (\text{Eq. 1})$$

$$dB\mu A = (20 * \log_{10} mA) + 60 \quad (\text{Eq. 2})$$

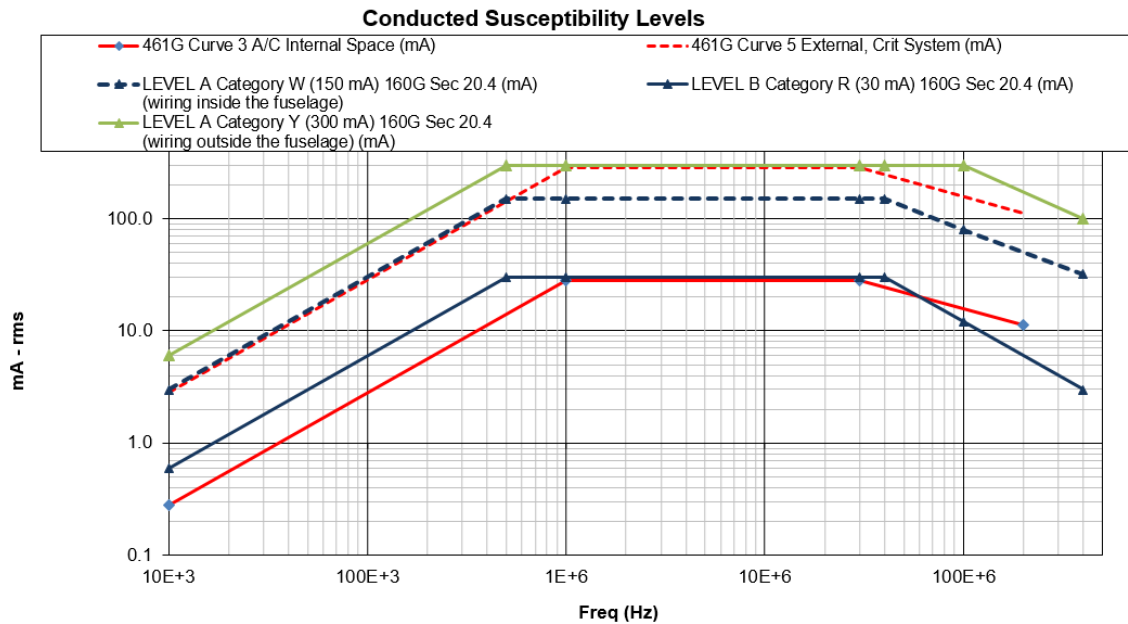


Figure 5 - Conducted RF susceptibility levels

The discussion above highlights specific differences in the test methods between CS114 and Section 20.4, but the overall procedures and test levels have significant similarity. The significant differences are the current amplitudes defined in the test levels in CS114 and Section 20.4, as shown in Figure 5. DO-160G, Section 20.4 requires continuous wave testing, in addition to a 1 kHz modulation with a 50% duty cycle (square wave). CS114 only requires square wave modulation. Table 6 summarizes the key characteristics and parameters for CS114 and DO-160G, Section 20.4.

In Table 7, the row for Curve 3 Figure CS114-1 applied to equipment is part of system with Hazardous failure conditions, says that this is conditionally acceptable, and an equivalent level of safety finding should be requested based on justification described below. The regulations specify Equipment HIRF Test Level 1, with conducted susceptibility currents up to 30 mA. CS114 Curve 3 has conducted susceptibility currents up to 28 mA. Obviously Curve 3 does not satisfy 30 mA. However, this current is 93% of the current in Equipment HIRF Test Level 1, and the CS114 test procedures set a secondary test limit of 56 mA. Above 100 MHz, the equipment will also be subject to radiated RF susceptibility tests. Therefore, equipment qualified to CS114 Curve 3 in combination with the radiated RF susceptibility tests provide an equivalent level of safety, when demonstrating equipment conducted RF immunity, to Equipment HIRF Test Level 1.

If equipment is qualified using DO-160G Paragraph 20.4, Table 8 shows how the qualification data can be used to support installation on a military certified aircraft.

Table 6 - DO-160G, section 20.4 versus MIL-STD-461G CS114

Standard	Frequency Range	Application	Test Levels	Modulation
MIL-STD-461G CS114	10 kHz to 200 MHz	Aircraft – Safety Critical or external equipment installation	Up to 282 mA – Curve 5 Figure CS114-1	1 kHz with 50% duty cycle
	10 kHz to 200 MHz	Aircraft – internal equipment installation	Army – Up to 282 mA – Curve 5 Figure CS114-1 Air Force – Up to 28 mA – Curve 3 Figure CS114-1 Navy - Up to 282 mA – Curve 5 Figure CS114-1 Except for 10 kHz to 2 MHz (Curve 3)	1 kHz with 50% duty cycle
DO-160G Paragraph 20.4	10 kHz to 400 MHz	Systems with CAT failure conditions – applicable categories determined by aircraft test or analysis	Cat M – up to 70 mA Cat O – up to 250 mA Cat W – up to 150 mA Cat Y – up to 300 mA	1 kHz with 50% duty cycle and continuous wave
	10 kHz to 400 MHz	Systems with HAZ failure conditions	Cat R – Up to 30 mA	1 kHz with 50% duty cycle and continuous wave
	10 kHz to 400 MHz	Systems with MAJ failure conditions	Cat T – Up to 7.5 mA	1 kHz with 50% duty cycle and continuous wave

Table 7 - Equipment qualified using MIL-STD-461G CS114

Equipment Qualification	Test Levels	Equipment Installed on Civil Certified Aircraft	Comments
MIL-STD-461G CS114	Up to 282 mA – Curve 5 Figure CS114-1	Equipment is part of system with CAT failure conditions	Conditionally Acceptable – FAA regulations require verification that conducted susceptibility test levels exceed actual conducted currents determined for aircraft installation. The tests must also represent the system, not just the individual equipment.
	Up to 282 mA – Curve 5 Figure CS114-1	Equipment is part of system with HAZ or MAJ failure conditions	Acceptable
	Up to 28 mA – Curve 3 Figure CS114-1	Equipment is part of system with CAT failure conditions	Conditionally Acceptable – FAA regulations require verification that conducted susceptibility test levels exceed actual conducted currents determined for aircraft installation. The tests must also represent the system, not just the individual equipment.
	Up to 28 mA – Curve 3 Figure CS114-1	Equipment is part of system with HAZ failure conditions	Conditionally Acceptable – FAA regulations require test level up to 30 mA. An equivalent level of safety finding should be requested based on justification described below.
	Up to 28 mA – Curve 3 Figure CS114-1	Equipment is part of system with MAJ failure conditions	Acceptable
	Any curve from Figure CS114-1	Equipment is part of system with MIN or NSE failure conditions	Acceptable – Any curve from Figure CS114-1, or no RF susceptibility qualification at all

Table 8 - Equipment qualified using DO-160G, section 20.4

Equipment Qualification	Test Levels	Equipment Installed on Military Certified Aircraft	Comments
DO-160G Paragraph 20.4	Cat Y	Equipment is part of system that is Safety Critical, installed externally, or installed internally	Acceptable
	Cat O	Equipment is part of system that is Safety Critical, installed externally, or installed internally	Conditionally Acceptable – Specific program management deviation should be requested for conducted RF susceptibility tests using Cat O (up to 250 mA) instead of Curve 5 (up to 282 mA), which demonstrates similar equipment immunity. Acceptable – Air Force aircraft internal
	Cat M, R, or W	Equipment is part of system that is installed internally on Air Force aircraft	Acceptable
	Cat S or T	--	Not Acceptable

4.3.9.3 Recommendation

If equipment is qualified using MIL-STD-461G CS114, Table 7 shows how the qualification data can be used to support installation on a civil certified airplane. Civil certified aircraft must meet the HIRF regulations in §§ 23.1308(b), 23.2520(b), 25.1317, 27.1317 and 29.1317. These HIRF regulations define explicit HIRF environments and HIRF test levels, and as such, they do not allow flexibility in these definitions if the equipment is part of any system with catastrophic, hazardous, or major failure conditions. Any deviation from these regulations requires specific project exemptions, equivalent level of safety findings, or exceptions based on § 21.101.

4.3.9.4 Rationale

CS114 and RS103 of MIL-STD-461G complement each other – exposing equipment to the effects of coupling from RF sources.

DO-160G, Section 20.4 (Conducted Susceptibility Tests), Section 20.5 and Section 20.6 (Radiated Susceptibility Tests) also complement each other, with the same intent to demonstrate equipment immunity to RF fields.

4.3.10 MIL-STD-461G, CS115 and DO-160G, Section 19.3.5

4.3.10.1 Summary

Conducted susceptibility tests applied to equipment wire bundles are described in MIL-STD-461G CS115, Conducted Susceptibility, Bulk Cable Injection, Impulse Excitation and DO-160G, Section 19.3.5, Spikes Induced into Interconnecting Cables.

4.3.10.2 Evaluation

CS115 was developed to remove the uncontrolled nature of the “chattering relay” test which was nearly identical to DO-160G, Section 19.3.5 Spikes into Cables. CS115 requires testing on individual cables and power inputs by themselves. DO-160G, Section 19 performs testing on all cables at the same time; power leads tested under DO-160G, Section 18 are exempt from this test.

They are both creating a fast rise-time transient to couple onto cable bundles.

Although the amount of transient signal induced onto a cable is not directly relatable between CS115 and Section 19 due to differences in current, voltage, and faster rise time, the intent is same.

CS115 performs the test by requiring a calibration of 5 A of current into a 100 Ω loop and you apply the drive required to generate the calibrated 5 A to the individual line under test without regard to the actual level being applied to the line under test. If you have susceptibility you need to determine a threshold by lowering the generator output and then place the injection probe back into the calibration fixture (100 Ω loop) at the reduced generator output and determine the value.

Coupled signal levels are highly dependent on impedances on both ends of the cable under test. Both CS115 and Section 19.3.5 can couple hundreds of volts onto a cable, but this is dependent on how the cable is shielded, if it is at all.

4.3.10.3 Recommendation

Application of MIL-STD-461G Qualified Equipment to a Civil Certification Environment

It is recommended that equipment that has met the requirements of MIL-STD-461G CS115 be considered acceptable for use when DO-160G, Section 19.3.5 is required.

Application of DO-160G Certified Equipment to a Military Qualified Environment

It is not recommended that equipment that has met the requirements of DO-160G, Section 19.3.5 be considered acceptable for use within a MIL-STD-461G environment requiring CS115.

4.3.10.4 Rationale

DO-160, Section 19.3.5 and MIL-STD-461G CS115 are not directly equivalent tests. However, since CS115 is specifically designed to meet the intent of tests like DO-160G, Section 19.3.5 it should be considered an acceptable alternative in the Civil Certification Environment. DO-160G, Section 19.3.5 should not be considered an acceptable alternative in the Military Qualified Environment due to the concern over the validity of this type of test as stated in Appendix A of MIL-STD-461G:

“The [CS115] requirement is intended to replace ‘chattering relay’ type requirements (RS06 in MIL-STD-461C) commonly used in procurements of equipment for aircraft applications in the past. The chattering relay has been criticized as unscientific and non-repeatable. The CS115 requirement has a defined waveform and a repeatable coupling mechanism.

4.3.11 MIL-STD-461G, CS116

4.3.11.1 Summary

CS116 is a conducted susceptibility, damped sinusoidal transient requirement for cables and power leads.

4.3.11.2 Evaluation

No equivalent DO-160G test.

4.3.11.3 Recommendation

Application of MIL-STD-461G Qualified Equipment to a Civil Certification Environment

CS116 does not have an equivalent applicable test in DO-160G.

Application of DO-160G Certified Equipment to a Military Qualified Environment

To qualify DO-160G equipment to MIL-STD-461G, CS116 would need to be performed if required.

4.3.11.4 Rationale

The intent of CS116 is to verify the ability of the EUT to withstand damped sinusoidal transients coupled onto EUT associated cables and power leads. Damped sine waveforms (sometimes complex combinations) are a common occurrence on platforms from both external stimuli such as lightning and electromagnetic pulse and from platform electrical switching phenomena. Waveforms appearing on cables can be due to the cable itself resonating or to voltage and current drives resulting from other resonances on the platform. Wide frequency coverage is included to account for a wide range of conditions. Transients caused from switching actions within the platform can also result in similar waveforms.

Section 22, Waveform 3 does not test the frequency range or amplitudes required by CS116, therefore equivalency between the standards is not possible in this scope. The intent of DO-160G, Section 22 is to verify the capability of equipment to withstand tests intended to represent the induced effects of lightning. Section 22 consists of two groups of tests, a damage tolerance test using a pin injection method, and a functional upset tolerance of equipment test using transients applied to interconnecting cable bundles.

Waveform Considerations:

- CS116 uses a damped sine wave. The waveform is calibrated into a 100 Ω loop.
- DO-160G, Section 22 consists of six defined waveforms, including a damped sine wave. The waveforms are calibrated into an open circuit and short circuit. Refer to DO-160G, Section 22 for the other waveforms.

Amplitude Considerations:

- Figure CS116-2 in MIL-STD-461G provides the test levels over frequency for CS116. The standard amplitudes and frequencies tested are 10 kHz at 100 mA, 100 kHz at 1 A, 1 MHz at 10 A, 10 MHz at 10 A, 30 MHz at 10 A, and 100 MHz at 3 A.
- Waveform 3 of DO-160G, Section 22 consists of five test levels and two frequencies, 1 MHz and 10 MHz.

Frequency:

CS116 is stepped at 0.01, 0.1, 1.0, 10.0, 30.0, and 100.0 MHz. Additional frequencies may also be required, if applicable.

4.3.12 MIL-STD-461G, CS117 and DO-160G, Section 22

4.3.12.1 Summary

Lightning induced transient susceptibility tests are described in MIL-STD-461G CS117, Conducted Susceptibility, Lightning Induced Transients, Cables and Power Leads and DO-160G, Section 22, Lightning Induced Transient Susceptibility.

4.3.12.2 Evaluation

Both DO-160G, Section 22 and MIL-STD-461G CS117 provide test methods, waveforms, and levels for testing lightning induced transient susceptibility resulting from lightning strikes to the aircraft.

Pin Injection Tests:

- MIL-STD-461G CS117: addresses cable bundle tests only.
- DO-160G, Section 22: provides a pin injection test method.

Cable Bundle Tests:

- MIL-STD-461G CS117: provides a combined single stroke and multiple stroke test.
- DO-160G, Section 22: allows for the single-stroke, multiple stroke, and multiple-burst cable bundle tests to be performed independently if multiple stroke/multiple burst testing is required to be performed.

Test Environment Considerations:

- MIL-STD-461G CS117: induced test levels are based on whether the unit and cables are internal or external to the aircraft. MIL-STD-461G, Appendix A provides details on classifying internal versus external.
- DO-160G, Section 22: induced test levels are based on the aircraft-level hazard classification of failures and transient levels and waveforms observed on the aircraft, along with guidance on levels within lightning zones of the aircraft.

Power Input Wires: There are differences in the grouping of the power leads.

- Test Wire Harness Lengths
 - MIL-STD-461G CS117: cable length to be per the actual aircraft installation. If actual aircraft installation is longer than 10 m use at least 10 m.
 - DO-160G, Section 22: cable length to be per the actual aircraft installation, but if the length is not specified it will be at least 3.3 m, not to exceed 15 m.

Cable length can be critical for shielded cables since the voltage induced on the inner conductor has a linear relationship with the length of the cable, which is demonstrated in Equation 3:

$$V_i = Z_{CPL} * L * I \quad (\text{Eq. 3})$$

where:

V_i = voltage induced on the inner conductor (V)

Z_{CPL} = coupling impedance of the cable (mΩ/m)

L = length of the cable (m)

I = current induced on the shield by the test generator (A)

Test Equipment:

Although the test equipment used for DO-160G, Section 22 will perform the testing required by MIL-STD-461G CS117, there is a difference in LISNs required for test between the two test standards. Refer to general introductory discussion on LISNs. However, the impact of the LISN is minimal for lightning susceptibility testing.

Additional MIL-STD-461G CS117 Documentation:

- MIL-STD-461G CS117: requires probe and attenuator factors if these factors are not automatically loaded into the measuring oscilloscope.
- MIL-STD-461G CS117: requires threshold levels for any failures.

The large number of waveform sets, waveforms, and test methods make comparison and application of CS117 and Section 22 complicated. In addition, the FAA regulations in 14 CFR 25/27/29.1316 impose more stringent requirements for electrical and electronic system lightning protection compliance.

Table 9 - Key characteristics and parameters for lightning susceptibility tests

Standard	Test Type	Application	Waveforms	Test Levels
MIL-STD-461G CS117 TABLE VII	Cable Bundle Injection, Single Stroke & Multiple Stroke	All equipment installations – Internal Equipment Levels	Waveform 2 (WF2)/ Waveform 1 (WF1)	First Stroke: $V_L = 300 \text{ V (WF2)}$ $I_T = 600 \text{ A (WF1)}$ Subsequent Strokes: $V_L = 150 \text{ V (WF2)}$ $I_T = 150 \text{ A (WF1)}$
		All equipment installations – Internal Equipment Levels	Waveform 3 (WF3), 1 MHz and 10 MHz	First Stroke: $V_T = 600 \text{ V (WF3)}$ $I_L = 120 \text{ A (WF3)}$ Subsequent Strokes: $V_T = 300 \text{ V (WF3)}$ $I_L = 60 \text{ A (WF3)}$
	Cable Bundle Injection, Multiple Burst	All equipment installations – Internal Equipment Levels	Waveform 3 (WF3), 1 MHz and 10 MHz	$V_T = 360 \text{ V (WF3)}$ $I_L = 6 \text{ A (WF3)}$
		Equipment installations that utilize short, low impedance cable bundle installations – Internal Equipment Levels	Waveform 6 (WF6)	$V_L = 600 \text{ V (WF6)}$ $I_T = 30 \text{ A (WF6)}$
	Cable Bundle Injection, Single Stroke & Multiple Stroke	Equipment installations routed in areas with composite skin/structure - Internal Equipment Levels	Waveform 4 (WF4)/ Waveform 5A (WF5A)	First Stroke: $V_L = 300 \text{ V (WF4)}$ $I_T = 1000 \text{ A (WF5A)}$ Subsequent Strokes: $V_L = 75 \text{ V (WF4)}$ $I_T = 200 \text{ A (WF5A)}$
		All equipment installations – External Equipment Levels	Waveform 2 (WF2)/ Waveform 1 (WF1)	First Stroke: $V_L = 750 \text{ V (WF2)}$ $I_T = 1500 \text{ A (WF1)}$ Subsequent Strokes: $V_L = 375 \text{ V (WF2)}$ $I_T = 375 \text{ A (WF1)}$
	Cable Bundle Injection, Multiple Burst	All equipment installations – External Equipment Levels	Waveform 3 (WF3), 1 MHz and 10 MHz	First Stroke: $V_T = 1500 \text{ V (WF3)}$ $I_L = 300 \text{ A (WF3)}$ Subsequent Strokes: $V_T = 750 \text{ V (WF3)}$ $I_L = 150 \text{ A (WF3)}$
	Cable Bundle Injection, Single Stroke & Multiple Stroke	Equipment installations routed in areas with composite skin/structure – External Equipment Levels	Waveform 4 (WF4)/ Waveform 5A (WF5A)	First Stroke: $V_L = 750 \text{ V (WF4)}$ $I_T = 2000 \text{ A (WF5A)}$ Subsequent Strokes: $V_L = 187.5 \text{ V (WF4)}$ $I_T = 375 \text{ A (WF5A)}$
	Cable Bundle Injection, Multiple Burst	All equipment installations – External Equipment Levels	Waveform 3 (WF3), 1 MHz and 10 MHz	$V_T = 900 \text{ V (WF3)}$ $I_L = 15 \text{ A (WF3)}$
		Equipment installations that utilize short, low impedance cable bundle installations – External Equipment Levels	Waveform 6 (WF6)	$V_L = 1500 \text{ V (WF6)}$ $I_T = 75 \text{ A (WF6)}$

Standard	Test Type	Application	Waveforms	Test Levels
DO-160G, Section 22	Pin Injection	Systems with CAT, HAZ, and MAJ failure conditions	Category A, Waveforms 3/3 & 4/1 Category B, Waveforms 3/3 & 5A/5A	Table 22-2
	Cable Bundle Injection, Single Stroke & Multiple Stroke	Systems with CAT, HAZ, and MAJ failure conditions	Category G, Waveforms 2 & 3 Category H, Waveforms 2, 3, & 4 Category J, Waveforms 1 & 3 Category K, Waveforms 3 & 5A	Table 22-3 & Table 22-4
	Cable Bundle Injection, Multiple Burst	Systems with CAT, HAZ, and MAJ failure conditions	Category L, Waveform 3 Category M, Waveform 6	Table 22-5

Table 10 - Equipment qualified using MIL-STD-461G CS117

Equipment Qualification	Equipment Criticality on Civil-Certified Aircraft	Test Levels	Comments
MIL-STD-461G CS117	Equipment is part of system with CAT failure conditions	Any from TABLE VII	Conditionally Acceptable – FAA regulations require integrated system lightning tests, and require waveforms and amplitudes based on aircraft tests or analyses.
	Equipment is part of system with HAZ or MAJ failure conditions installed inside primarily aluminum aircraft	TABLE VII Internal Equipment Level	Acceptable for cable bundle testing
	Equipment is part of system with HAZ or MAJ failure conditions installed inside primarily composite aircraft or external to fuselage	TABLE VII External Equipment Level	Acceptable for cable bundle testing
	Equipment is part of system with MIN or NSE failure conditions	Any from TABLE VII	Acceptable – Any test level from Table VII, or no lightning susceptibility qualification at all

Table 11 - Equipment qualified using DO-160G, section 22

Equipment Qualification	Flight/Safety Critical Equipment Installed on Military-Certified Aircraft	Test Levels	Comments
DO-160G, Section 22	Equipment that is installed internally, but not in areas with composite skin or structure	Waveform Sets G plus L Level 3, 4, or 5	Acceptable
	Equipment that is installed internally, but in areas with composite skin or structure	Waveform Sets H plus L Level 3, 4, or 5	Acceptable
	Equipment that is installed externally, but not in areas with composite skin or structure	Waveform Sets G plus L Level 4 or 5	Acceptable
	Equipment that is installed externally, but in areas with composite skin or structure	Waveform Sets H plus L Level 4 or 5	Acceptable
	Equipment that is installed internally, but not in areas with composite skin or structure	Waveform Sets J plus L Level 3, 4, or 5	Conditionally Acceptable – Deviation should be requested if all wire bundles are shielded
	Equipment that is installed internally, but in areas with composite skin or structure	Waveform Sets K plus L Level 3, 4, or 5	Conditionally Acceptable – Deviation should be requested if all wire bundles are shielded
	Equipment that is installed externally, but not in areas with composite skin or structure	Waveform Sets J plus L Level 4 or 5	Conditionally Acceptable – Deviation should be requested if all wire bundles are shielded
	Equipment that is installed externally, but in areas with composite skin or structure	Waveform Sets K plus L Level 4 or 5	Conditionally Acceptable – Deviation should be requested if all wire bundles are shielded
	Any equipment installation	Waveform Sets A, B, C, D, E, F or qualified with levels less than those listed above	Not Acceptable

4.3.12.3 Recommendation

Application of MIL-STD-461G Qualified Equipment to a Civil Certification Environment

Hazardous and Major failure conditions for equipment criticality: It is recommended that CS117 be considered sufficient in place of DO-160G, Section 22 for cable bundle tests as long as the conditions described in Table 10 are met. Delta testing will be necessary to perform DO-160G, Section 22 pin injection testing as MIL-STD-461G does not have pin injection requirements.

It is not recommended that CS117 be considered sufficient in place of DO-160G, Section 22 for equipment and systems with Catastrophic failure conditions. FAA regulations require integrated system lightning tests, and require waveforms and amplitudes based on aircraft tests or analyses.

Application of DO-160G Certified Equipment to a Military Qualified Environment

DO-160G, Section 22 (Level 3 or above for internal equipment, Level 4 or above for external equipment) meets the intent of MIL-STD-461G CS117. See Table 11.

4.3.12.4 Rationale

The intent of DO-160G, Section 22 and MIL-STD-461G CS117 are to verify the capability of equipment to withstand tests intended to represent the indirect effects of lightning. Section 22 consists of two groups of tests, a damage tolerance test using a pin injection method, and a functional upset tolerance of equipment test using transients applied to interconnecting cable bundles. CS117, however, does not have pin injection methods and uses some but not all the cable bundle requirements found in Section 22.

4.3.13 MIL-STD-461G, CS118 and DO-160G, Section 25

4.3.13.1 Summary

Electrostatic Discharge tests applied to equipment are described in MIL-STD-461G CS118, Personnel Borne Electrostatic Discharge and DO-160G, Section 25, Electrostatic Discharge (ESD).

4.3.13.2 Evaluation

Comparison of MIL-STD-461G CS118 to DO-160G, Section 25

CS118 versus Section 25 Test Levels:

- CS118 - 2, 4, 6, 8, 15 kV Air, 8 kV contact
- Section 25 - There is only one category (A), Air discharge with a test level of 15 kV

Number of pulses:

- CS118 - 5 pulses (positive and negative polarity)
- Section 25 - 10 pulses (positive and negative polarity)

Calibration:

- CS118 - Air discharge levels have a peak output of $\pm 10\%$ at each level, while the contact discharge has $\pm$ limits for first peak current, rise time, current at 30 ns, and 60 ns.
- Section 25 - Air discharge calibrate the generator until you produce a positive and negative 15 kV (+10%, -0%) peak output pulse, then use that generator setting when testing EUT.

Air Discharge Tip/Electrode: Both the CS118 and Section 25 ESD tips have the same nominal dimensions; however, the tolerances given in Section 25 are tighter than those given in CS118.

Discharge network: Both CS118 and Section 25 use the same 330 Ω , 150 pF discharge network.

4.3.13.3 Recommendation

Application of MIL-STD-461G Qualified Equipment to a Civil Certification Environment

MIL-STD-461G CS118 meets the *intent* of DO-160G, Section 25. For Hazardous and Major failure conditions for equipment criticality (and below), it is recommended that CS118 be considered sufficient in place of DO-160G, Section 25. For Catastrophic failure conditions, it is **NOT** recommended that CS118 be considered sufficient in place of DO-160G, Section 25. To be DO-160G, Section 25 compliant consider:

- Number of discharge pulses
- Air versus contact discharge
- Calibration and test levels

MIL-STD-461G CS118 is applicable to man-machine interfaces. Section 25 is applicable to equipment and surfaces which are accessible during normal operation and/or maintenance of the aircraft.

Application of DO-160G Certified Equipment to a Military Qualified Environment

It is recommended that DO-160G, Section 25 be considered sufficient in place of CS118.

4.3.13.4 Rationale

DO-160G, Section 25 may be used to satisfy MIL-STD-461G CS118 requirements, with the following caveats:

- CS118 includes contact discharge method which is not included in Section 25.
- Given that the discharge network is identical, slight air discharge probe tip tolerance variances are not deemed enough to change test results.

4.3.14 MIL-STD-461G, RE101

4.3.14.1 Summary

Magnetic field radiated emission tests are described in MIL-STD-461G RE101, Radiated Emissions, magnetic field.

4.3.14.2 Evaluation

There is not an equivalent DO-160G test for MIL-STD-461G RE101.

4.3.14.3 Recommendation

Analysis of possible interactions between equipment (as well as potential testing) will be required for installation of equipment on platforms requiring MIL-STD-461G RE101 testing.

4.3.14.4 Rationale

This requirement is specialized and is intended primarily to control magnetic fields from 30 Hz to 100 kHz for applications where equipment is present in the installation which is potentially sensitive to magnetic induction at lower frequencies. Generally, this equipment (Anti-Submarine Warfare equipment, Magnetic Azimuth Detectors, etc.) are not items that will be found in civilian aircraft, so there are no requirements for this environment in the civilian aircraft certification realm.

4.3.15 MIL-STD-461G, RE102 and DO-160G, Section 21.5 and 21.6

4.3.15.1 Summary

Radiated emissions tests are described in MIL-STD-461G RE102, Radiated Emissions, Electric Field and DO-160G, Section 21.5, Radiated Emissions, Electric Field.

4.3.15.2 Evaluation

The following outlines details for comparison between radiated emission tests from MIL-STD-461G RE102 and DO-160G, Section 21.5. Also consider the following when evaluating evidence of compliance for a product to requirements of a military standard with similar requirements for similar equipment.

Table 12 - DO-160G, section 21.5 versus MIL-STD-461G RE102 frequency of test

Parameter	MIL-STD-461G	DO-160G
Test Method:	RE102	Section 21.5
Test Frequency Range:	2 MHz-18 GHz (10 kHz-18 GHz for some applications)	100 MHz-6 GHz

Measurement Bandwidth (Resolution Bandwidth -- RBW): Both DO-160G and MIL-STD-461G use a 6dB defined bandwidth for measurements.

If emissions are observed that have a bandwidth wider than those defined in the standards, then these should be noted, and the effects should be evaluated in the actual installation. Neither DO-160G nor MIL-STD-461G allow the use of correction factors for larger bandwidths.

Table 13 - DO-160G, section 21.5 versus MIL-STD-461G RE102 RBW

Frequency Range	DO-160G Resolution BW	MIL-STD-461G Resolution BW
<i>Below 150 kHz undefined</i>		1 kHz
150 kHz-10 MHz	1 kHz	10 kHz
10 MHz-30 MHz	1 kHz	10 kHz
30 MHz-400 MHz	10 kHz	100 kHz
400 MHz-960 MHz	100 kHz	100 kHz
960 MHz-1000 MHz	1 MHz	100 kHz
1 GHz-6 GHz	1 MHz	1 MHz
The list above applies to both conducted and radiated emissions.		

Methodology: MIL-STD 461 does not allow for reverberation chamber measurements.

Test Setup: See Section 4.2 discussed previously.

Emissions Levels: Both DO-160G and MIL-STD-461G have their own limits.

A comparison of the emission limits is shown in Figure 6 where "Int GT" is for fixed wing internal greater than or equal to 25 m nose to tail and "Int LT" is for fixed wing internal less than 25 m nose to tail (Figure 7 is an enlargement of the 100 MHz to 10 GHz frequency range).

Apart from the three notches, shown in Figure 7 for reference, at 1164 MHz to 1215 MHz, 1559 MHz to 1610 MHz, and 5020 MHz to 5100 MHz the MIL-STD-461G External limit meets or is more stringent than any of the DO-160G limits. The notches are intended to ensure radios and other receivers are not interfered with.

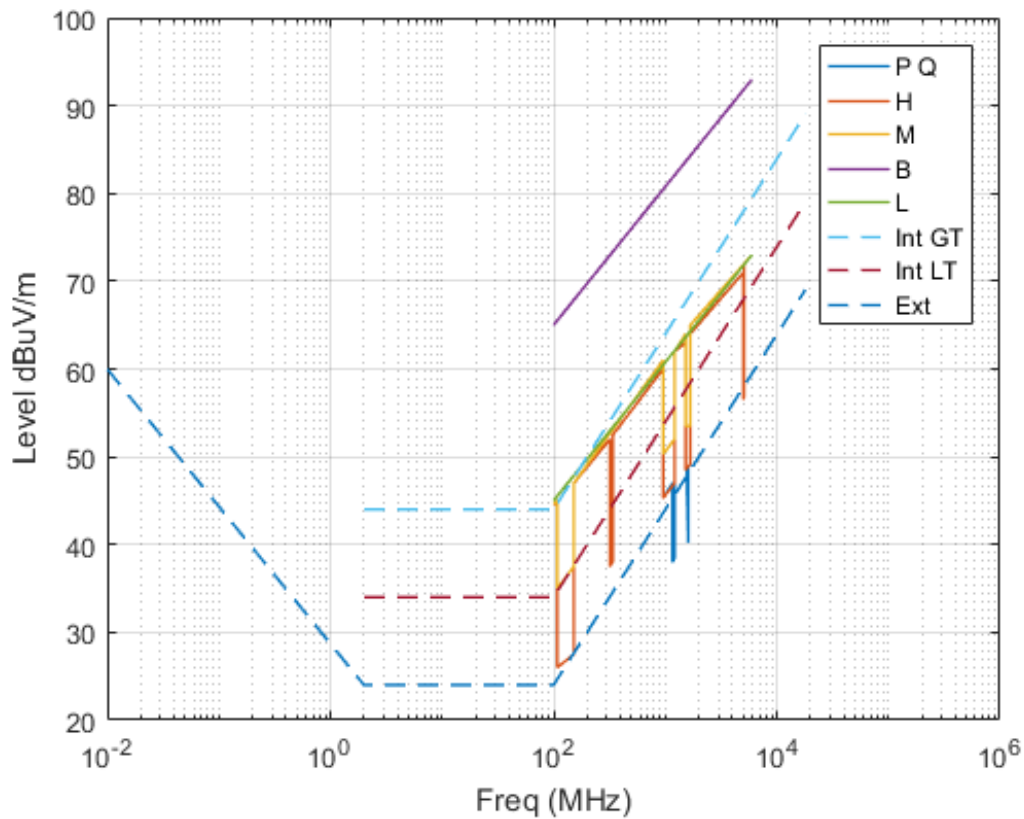


Figure 6 - Comparison of emission limits

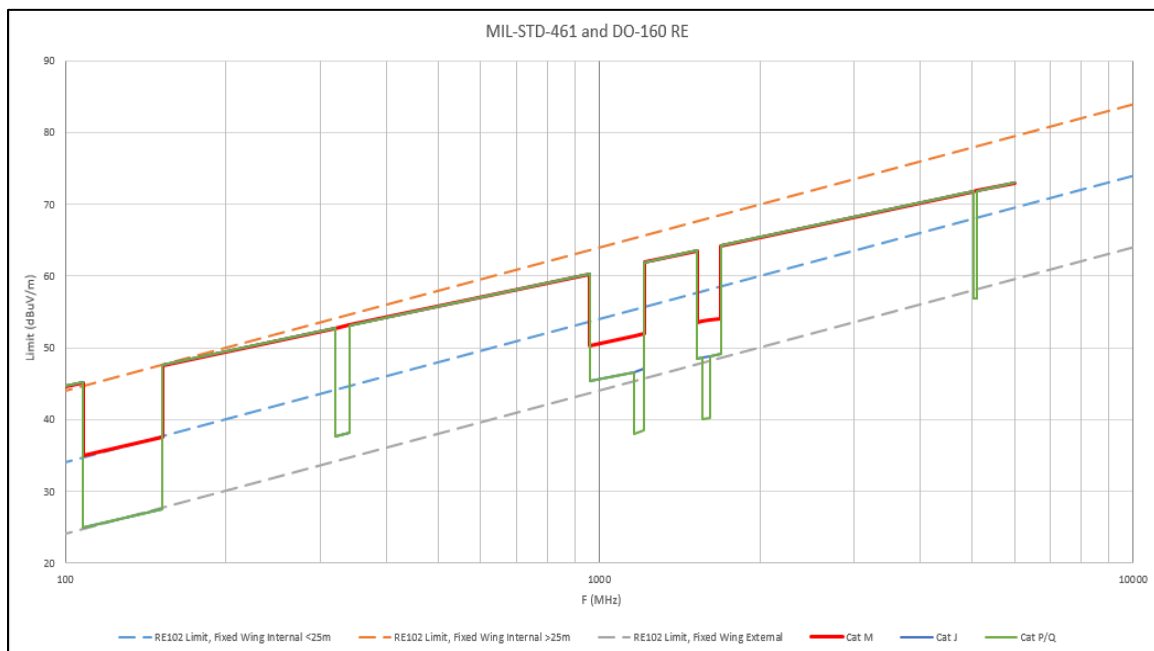


Figure 7 - Radiated emissions limits, 100 MHz to 10 GHz

4.3.15.3 Recommendation

Application of MIL-STD-461G Qualified Equipment to a Civil Certification Environment

Equipment tested using the methods in MIL-STD-461G should be considered acceptable for use in DO-160G installations. However, it is important that the user consider how the equipment will be installed, and what DO-160G category will be applicable.

Application of DO-160G Certified Equipment to a Military Qualified Environment

CAUTION: DO-160G does not cover frequencies below 100 MHz or above 6 GHz for the radiated environment; therefore, additional analysis or testing may be required. Below 100 MHz conducted emission data may be considered.

4.3.15.4 Rationale

The primary purpose of radiated emissions limits is to ensure that equipment does not cause interference to RF receivers on board the host aircraft. There is not a correlation between radiated emissions limits or radiated susceptibility limits, so there is no reason to believe that an unintentional emission would cause interference to a non-radio receiver piece of equipment. The intent of the basic testing methodologies is the same; data collected is valid for either application (except for reverberation chamber measurements).

4.3.16 MIL-STD-461G, RE103

4.3.16.1 Summary

Radiated emissions tests are described in MIL-STD-461G RE103, Radiated Emissions, antenna spurious and harmonic outputs.

4.3.16.2 Evaluation

This requirement may be used as an alternative for CE106 when testing transmitters with their included antennas that cannot be removed. CE106 is the preferred requirement for devices where the antenna can be removed, and the measurements can be made at the antenna terminal.

4.3.16.3 Recommendation

There is not an equivalent DO-160G test for RE103.

4.3.16.4 Rationale

See CE106 discussion in Section 4.3.3.

4.3.17 MIL-STD-461G, RS101

4.3.17.1 Summary

Radiated Susceptibility tests are described in MIL-STD-461G RS101, Radiated Susceptibility, magnetic field.

4.3.17.2 Evaluation

There is not an equivalent DO-160G test for RS101.

4.3.17.3 Recommendation

Analysis of possible interactions between equipment (as well as potential testing) will be required for installation of equipment on platforms requiring RS101 testing.

4.3.17.4 Rationale

RS101 is generally a requirement unique to Army equipment and Navy shipboard equipment. This is not an environment that civil equipment will be subjected to, therefore, there is no applicable equivalent civil aircraft certification environment.

4.3.18 MIL-STD-461G, RS103 and DO-160G, Section 20.5 and 20.6

4.3.18.1 Summary

Radiated RF susceptibility tests are described in MIL-STD-461G RS103, Radiated Susceptibility, Electric Field, and DO-160G, Section 20 Radio Frequency Susceptibility (Conducted and Radiated) Section 20.5, Radiated Susceptibility (RS) Test – Anechoic Chamber Method and Section 20.6, Radiated Susceptibility (RS) Test; Alternate Procedure – Reverberation Chamber Method.

4.3.18.2 Evaluation

The RS103 frequency range is wider than the Section 20.5 and Section 20.6 frequency range.

RS103 uses smaller frequency step sizes than Section 20.5 and Section 20.6.

RS103 uses a minimum 3 second dwell time, while Section 20.5 and Section 20.6 use a minimum dwell time of 1 second.

DO-160G, Sections 20.5 and Section 20.6 require testing at known EUT frequencies (i.e., LO, IF, clock frequencies, etc.), while MIL-STD-461G does not.

In considering using DO-160G RS/CS test data for MIL-STD test data, it should be noted that the DO-160G step sizes can be much larger than the MIL-STD step sizes. Several frequencies would be skipped, resulting in the possibility of a missed response if the response occurs over a very narrow band of frequencies.

RS103 requires 40 dB depth of modulation, while Section 20.5 requires greater than 90% or 20 dB depth of modulation.

The MIL-STD-461G alternative method uses a mode-tuned approach to reverberation chamber testing while DO-160G uses a mode stirred approach.

Comparison between Radiated Susceptibility tests from MIL-STD-461G RS103 and DO-160G, Section 20.5:

Frequency Range: See Table 15.

Frequency Step Size: The MIL-STD-461G step sizes are smaller than the minimum allowed DO-160G step sizes, which are subject to justification. See DO-160G, Section 20.3.e:

Sweep or step rates shall be selected with consideration of equipment under test (EUT) response time, EUT susceptibility bandwidths, and monitoring test equipment response time. The scan rate selected shall be justified by this criteria, and documented in the test report.

Table 14 - DO-160G, section 20 versus MIL-STD-461G RS103 frequency steps

MIL-STD-461G RS103	DO-160G, Section 20.5 and 20.6
2 MHz-30 MHz, 0.01f ₀ 30 MHz-1 GHz, 0.005f ₀ 1 GHz-40 GHz, 0.0025f ₀	100 steps per decade, minimum

Measurement of Radiated Test Level:

- In MIL-STD-461G, the EUT is present as the field level is applied and measured with an E-Field probe.
- In DO-160G, the EUT is removed and the field level is measured with an E-Field probe. The calibrated power level into the transmit antenna required to reach the test level is recorded at each frequency step. This calibrated power level is then replayed with the EUT in place.

Modulation: See Table 15.

Test Setup: MIL-STD -461G and DO160G have different test item setup requirements. This includes but is not limited to the items mentioned in the general test setup of Section 4.2.

Table 15 - DO-160G, section 20 versus MIL-STD-461G RS103

Standard	Frequency Range	Application	Test Levels	Modulation
MIL-STD-461G RS103	30 MHz to 18 GHz 2 MHz to 30 MHz optional for Air Force 18 GHz to 40 GHz optional	Aircraft – Safety Critical or external equipment installation, or Army	200 V/m	1 kHz square-wave with 50% duty cycle
	30 MHz to 18 GHz 2 MHz to 30 MHz optional 18 GHz to 40 GHz optional	Air Force Aircraft – internal equipment installation	30 MHz to 1 GHz – 20 V/m 1 GHz to 18 GHz – 60 V/m	1 kHz square-wave with 50% duty cycle
	2 MHz to 18 GHz 18 GHz to 40 GHz optional	Navy Aircraft – internal equipment installation	2 MHz to 18 GHz – 200 V/m 18 GHz to 40 GHz – 60 V/m	1 kHz square-wave with 50% duty cycle
DO-160G, Section 20.5 or Section 20.6	100 MHz to 18 GHz	Systems with CAT failure conditions – applicable categories determined by aircraft test or analysis	Cat B – 20 to 38 V/m Cat D – 25 to 75 V/m Cat F – 25 to 150 V/m Cat G – 50 to 300 V/m Cat L – 200 to 490 V/m Cat W – 100 V/m Cat Y – 200 V/m	1 kHz square-wave with 50% duty cycle and continuous wave
	400 MHz to 18 GHz	Systems with CAT failure conditions – applicable categories determined by aircraft test or analysis	Cat B – 150 to 375 V/m Cat D – 175 to 750 V/m Cat F – 350 to 1500 V/m Cat G – 700 to 3000 V/m Cat L – 730 to 7200 V/m	400 MHz to 4 GHz – 4 µs pulse width with 1 kHz PRF 4 GHz to 18 GHz – 1 µs pulse width with 1 kHz PRF
	100 MHz to 400 MHz	Systems with HAZ failure conditions	Cat R – 20 V/m	1 kHz square-wave with 50% duty cycle and continuous wave
	400 MHz to 8 GHz	Systems with HAZ failure conditions	Cat R – 150 V/m	4% duty cycle with 1 kHz PRF, switched on and off at 1 Hz with 50% duty cycle
	100 MHz to 8 GHz	Systems with MAJ failure conditions	Cat T – 5 V/m	1 kHz square-wave with 50% duty cycle and continuous wave
	100 MHz to 2 GHz	--	Cat S – 1 V/m	1 kHz square-wave with 50% duty cycle and continuous wave

Table 16 - Equipment qualified using MIL-STD-461G RS103

Equipment Qualification	Test Levels	Equipment Installed on Civil-Certified Aircraft	Comments
MIL-STD-461G RS103	200 V/m – TABLE XI	Equipment is part of system with CAT failure conditions	Not acceptable – FAA regulations require an integrated system test, and require pulse tests based on peak field strengths
	20 to 60 V/m – TABLE XI	Equipment is part of system with CAT failure conditions	Not acceptable – FAA regulations require an integrated system test, and requires pulse tests based on peak field strengths
	200 V/m – TABLE XI	Equipment is part of system with HAZ or MAJ failure conditions	Conditionally Acceptable - FAA regulations require additional modulations (continuous wave and pulsed, as identified in Table 15). The use of RS103 test data must demonstrate that the square-wave levels tested meet the average and peak requirements from DO-160G Cat R (Hazardous) or Cat T (Major).
	20 to 60 V/m – TABLE XI	Equipment is part of system with HAZ failure conditions	Conditionally Acceptable – FAA regulations require pulse tests to 150 V/m and continuous wave tests from 100 – 400 MHz. The square wave testing performed under RS103 may be used to satisfy the DO-160G square wave requirement from 100 – 400 MHz.
	20 to 60 V/m – TABLE XI	Equipment is part of system with MAJ failure conditions	Conditionally Acceptable - FAA regulations require additional modulations (continuous wave and pulsed, as identified in Table 15). The use of RS103 test data must demonstrate that the square-wave levels tested meet the average and peak requirements from DO-160G Cat R (Hazardous) or Cat T (Major).
	Any test level from TABLE XI	Equipment is part of system with MIN or NSE failure conditions	Acceptable – Any test level from Table XI, or no RF susceptibility qualification at all

Table 17 - Equipment qualified using DO-160G, section 20

Equipment Qualification	Test Levels	Equipment Installed on Military-Qualified Aircraft	Comments
DO-160G, Section 20.5 or Section 20.6	Cat Y or L	Equipment is part of system that is Safety Critical or is installed externally on aircraft	Conditionally Acceptable – Deviation should be granted for frequency range of 30 MHz to 100 MHz, because conducted RF susceptibility tests adequately cover this range
	Cat G	Equipment is part of system that is Safety Critical or is installed externally on aircraft	Conditionally Acceptable – Deviation should be granted for frequency range of 30 MHz to 1 GHz, because conducted RF susceptibility tests and pulse modulated tests at levels of 700 to 3000 V/m range of 100 to 700 MHz adequately cover the differences
	Cat F, G, L, W, or Y	Equipment is part of system that is installed internally on Air Force aircraft	Acceptable
	Cat D	Equipment is part of system that is installed internally on Air Force aircraft	Conditionally Acceptable – Deviation should be granted to accept test levels of 50 V/m in combination with pulse modulated tests at levels of 175 V/m to 750 V/m
	Cat S or T	--	Not Acceptable

4.3.18.3 Recommendation

It is recommended that equipment tested to the 200 V/m (External or Safety Critical) requirement of MIL-STD-461G be considered acceptable for equipment requiring testing to Categories W, T, S, and R. For testing to Category Y, the difference in modulation requirements needs to be considered.

It is recommended that equipment tested to DO-160G Category Y (Sections 20.4 CS and 20.5/20.6 RS) be considered acceptable for equipment installed in applications requiring MIL-STD-461G RS103 200 V/m environments as the DO-160G, Section 20.4 testing would cover the 2 MHz-100 MHz frequency range.

It is recommended that equipment tested to DO-160G Category W and Y (Sections 20.4 CS and 20.5/20.6 RS) be considered acceptable for equipment installed in applications requiring MIL-STD-461G RS103 20/60 V/m (Air Force Internal) environment as the DO-160G, Section 20.4 testing would cover the 2 to 100 MHz frequency range.

4.3.18.4 Rationale

CS114 and RS103 of MIL-STD-461G complement each other – exposing equipment to the effects of coupling from RF sources.

DO-160G, Section 20.4 (Conducted Susceptibility Tests), Section 20.5 and Section 20.6 (Radiated Susceptibility Tests) also complement each other, with the same intent to demonstrate equipment immunity to RF fields.

4.3.19 MIL-STD-461G, RS105

4.3.19.1 Summary

Radiated susceptibility tests are described in MIL-STD-461G RS105, Radiated Susceptibility, transient electromagnetic field.

4.3.19.2 Evaluation

RS105 does not have an equivalent applicable test in DO-160G.

4.3.19.3 Recommendation

Equipment qualified to civil standards may need RS105 testing if required.

4.3.19.4 Rationale

RS105 is an Electromagnetic Pulse test. This is a military concern and does not drive a civil aircraft certification requirement.

4.3.20 DO-160G, Section 15

4.3.20.1 Summary

Section 15 is a magnetic field test used to determine how close the EUT may be installed to magnetically sensitive equipment, such as compasses or compass sensors.

4.3.20.2 Evaluation

Section 15 does not have an equivalent applicable test in MIL-STD-461G.

4.3.20.3 Recommendation

Application of MIL-STD-461G Qualified Equipment to a Civil Certification Environment

MIL-STD-461G does not have a test directly equivalent to DO-160G, Section 15. Performing Section 15 should be considered if the equipment will be installed within 3 m of magnetically sensitive equipment and cannot be evaluated on the aircraft.

Application of DO-160G Certified Equipment to a Military Qualified Environment

Section 15 does not have a MIL-STD-461G equivalent, therefore no additional testing is required.

4.3.20.4 Rationale

The primary purpose of Section 15 is to protect magnetic sensors by ensuring that equipment installation is limited based on static magnetic fields due to equipment operation. This test characterizes equipment, and defines a category based on test results, rather than starting out with a desired category and defining a pass/fail result afterwards. The result of the test is a standoff distance which must be maintained between the EUT intended installation location and the aircraft compass or magnetic sensors.

4.3.21 DO-160G, Section 19

4.3.21.1 Summary

Section 19 is an induced signal susceptibility test used to test the EUT to induced voltages related to power frequency and harmonics, audio frequency signals, and electrical transients generated by other on-board equipment and systems.

4.3.21.2 Evaluation

There is no equivalent environment in MIL-STD-461G.

4.3.21.3 Recommendation

Application of MIL-STD-461G Qualified Equipment to a Civil Certification Environment

MIL-STD-461G does not have a test directly equivalent to DO-160G, Section 19. Performing Section 19 should be considered if the equipment and wiring will be installed close to wiring that may have high levels of interfering electrical signals or transients that cannot be evaluated on the aircraft.

Application of DO-160G Certified Equipment to a Military Qualified Environment

DO-160G, Section 19 does not have a direct MIL-STD-461G equivalent; therefore, no additional testing is required.

4.3.21.4 Rationale

The primary purpose of DO-160G, Section 19 is to ensure that equipment is not adversely affected by operation of other equipment due to signals induced by nearby high voltages, currents, or transient events. This environment is broken into several specific tests:

- 19.3.1 Magnetic fields induced into equipment
- 19.3.2 Electric fields induced into equipment
- 19.3.3 Magnetic fields induced into interconnecting cables
- 19.3.4 Electric fields induced into interconnecting cables
- 19.3.5 Spikes induced into interconnecting cables

Earlier revisions of MIL-STD-461G (C and before) and MIL-STD-462 had similar tests under test method RS02; however, they were removed as of MIL-STD-461GD. As discussed in CS115 (see Section 4.3.10), DO-160G, Section 19.3.5 is similar in nature to the effects of MIL-STD-461G CS115, so there is a degree of equivalency for that test, though it is not a direct correlation. It has been noted that MIL-STD-461G RS101 is vaguely similar to DO-160G 19.3.1 and/or 19.3.3; however, there are vast differences in the way the two tests are run and the frequency ranges of interest. The purpose of RS101 is to understand the effects of shipboard operation, whereas DO-160G 19.3.1 and 19.3.3 are concerned with the effects of a high current power system being placed near the EUT. The frequency ranges of the two tests are very different, as are the methods. For this reason, there is not considered to be any commonality between the DO-160G, Section 19 methods and MIL-STD-461G, beyond that described under the CS115 discussion, herein.

4.3.22 DO-160G, Section 23

4.3.22.1 Summary

Section 23 is the lightning direct effects test for externally mounted equipment.

4.3.22.2 Evaluation

There is no equivalent environment in MIL-STD-461G.

4.3.22.3 Recommendation

Application of MIL-STD-461G Qualified Equipment to a Civil Certification Environment

MIL-STD-461G does not have a test directly equivalent to DO-160G, Section 23. Additional testing may be required based on the lightning zone that the equipment is installed on the aircraft.

Application of DO-160G Certified Equipment to a Military Qualified Environment

DO-160G, Section 23 does not have a direct MIL-STD-461G equivalent. Additional testing may be required based on the lightning zone that the equipment is installed on the aircraft.

4.3.22.4 Rationale

DO-160G, Section 23 provides a test method for externally mounted equipment. Platform level direct effect lightning requirements are in MIL-STD-464 and not in MIL-STD-461G.

5. MIL-STD-704F AND DO-160G EVALUATION

5.1 Introduction

This section presents the evaluations between MIL-STD-704F/MIL-HDBK-704 and the electrical environments of DO-160G. Since this document is meant to provide guidance and is not to be considered a standard, emphasis is on requirements comparisons rather than detailed test execution comparisons. Therefore, descriptions are more focused on voltages and frequency ranges rather than test methodology or procedural differences. However, similarities and differences of the tests are necessarily discussed in detail as appropriate, including level differences, test comparison coverage omissions and suggested “delta testing” for civil aircraft certification intended for military use and for military aircraft equipment installed on civil aircraft.

5.1.1 Overview of Power Quality and Testing Documents

To prepare a proper comparison between a civil and military aircraft equipment testing methods, two military documents, MIL-STD-704F and MIL-HDBK-704, are necessary to evaluate the differences with DO-160G, Section 16, Section 17, and Section 18. Below are the descriptions for each of the documents that will be discussed in this section.