



U.S. Department
of Transportation
**Federal Aviation
Administration**

Advisory Circular

Subject: Aircraft Electrical and Electronic
System Lightning Protection

Date: 9/7/11
Initiated by: AIR-130

AC No: 20-136B

1. Purpose.

a. This advisory circular (AC) provides you with information and guidance on how you can protect aircraft electrical and electronic systems from the effects of lightning. This AC describes a means, but not the only means, for you to show compliance with Title 14 of the Code of Federal Regulations (14 CFR) 23.1306, 25.1316, 27.1316, and 29.1316, *Electrical and electronic system lightning protection*, as they pertain to the type or supplemental type certification of your aircraft.

b. This AC is not mandatory and does not constitute a regulation. However, if you use the means described in this AC to comply with 14 CFR 23.1306, 25.1316, 27.1316, and 29.1316, you must follow it in its entirety.

c. The term “must” is used to indicate mandatory requirements when following the guidance in this AC in its entirety. The terms “should” and “recommend” are used when following the guidance is recommended but not required to comply with this AC.

d. Appendix 1 addresses related documents. Appendix 2 addresses definitions. Appendix 3 defines acronyms.

2. Applicability. This AC applies to all applicants for a new type certificate (TC) or a change to an existing TC when the certification basis requires you to address the certification requirements of 14 CFR 23.1306, 25.1316, 27.1316, and 29.1316.

3. Scope.

a. This AC provides guidance for complying with 14 CFR 23.1306, 25.1316, 27.1316, and 29.1316 for the effects on electrical and electronic systems due to lightning transients induced or conducted onto equipment and wiring.

b. Applicants must also comply with 14 CFR 23.1306, 25.1316, 27.1316, and 29.1316 for the effects on electrical and electronic systems when lightning directly attaches to equipment, components, or wiring. This AC addresses the functional aspects of these effects for aircraft electrical and electronic equipment, components, or wiring. However, this AC does not address

lightning effects such as burning, eroding, and blasting of aircraft equipment, components, or wiring. For showing compliance for these effects, we recommend using SAE ARP 5577, *Aircraft Lightning Direct Effects Certification*.

c. For information on fuel ignition hazards, see AC 20-53, *Protection of Aircraft Fuel Systems Against Fuel Vapor Ignition Caused By Lightning*. This AC does not address lightning zoning methods, lightning environment definition, or lightning test methods. For information on lightning zoning methods and lightning environment definition, see AC 20-155, *SAE Documents To Support Aircraft Lightning Protection Certification*. For information on lightning test methods, see SAE ARP 5416, *Aircraft Lightning Test Methods*, or RTCA/DO-160, Section 22, *Lightning Induced Transient Susceptibility*, and Section 23, *Lightning Direct Effects*.

Note: When complying with 14 CFR 23.1306, 25.1316, 27.1316, and 29.1316, use RTCA/DO-160D, Change Notice 3, or later revisions.

4. Cancellation. AC 20-136A, *Protection of Aircraft Electrical/Electronic Systems Against the Indirect Effects of Lightning*, dated December 21, 2006, is cancelled.

5. Background.

a. Regulatory Applicability. The standards for aircraft electrical and electronic system lightning protection are based on the aircraft's potential for lightning exposure and the consequences of system failure. The regulations require lightning protection of aircraft electrical and electronic systems with catastrophic, hazardous, or major failure conditions for aircraft certificated under 14 CFR parts 25 and 29. The requirements also apply to 14 CFR part 23 airplanes and part 27 rotorcraft approved for operations under instrument flight rules. Those 14 CFR part 23 airplanes and part 27 rotorcraft approved solely for operations under visual flight rules require lightning protection of electrical or electronic systems having catastrophic failure conditions.

b. Regulatory Requirements. Protection against the effects of lightning for aircraft electrical and electronic systems, regardless of whether these are 'indirect' or 'direct' effects of lightning, are addressed under 14 CFR 23.1306, 25.1316, 27.1316, and 29.1316. The terms 'indirect' and 'direct' are often used to classify the effects of lightning. However, the regulations do not, and are not intended to, differentiate between the effects of lightning. The focus is to protect aircraft electrical and electronic systems from effects of lightning. The regulations listed in this paragraph introduce several terms which are further explained below, including:

(1) System. A system can include equipment, components, parts, wire bundles, software, and firmware. Electrical and electronic systems consist of pieces of equipment connected by electrical conductors, all of which are required to perform one or more functions.

(2) Function. The specific action of a system, equipment, and flight crew performance aboard the aircraft that, by itself, provides a completely recognizable operational capability. For

example, “display aircraft heading to the pilots” is a function. One or more systems may perform a specific function or one system may perform multiple functions.

(3) Adverse Effect. A lightning effect resulting in system failure, malfunction, or misleading information to a degree that is unacceptable for the specific aircraft function or system addressed in the system lightning protection regulations.

(4) Timely Manner. The meaning of “in a timely manner” depends upon the function performed by the system being evaluated, the specific system design, interaction between that system and other systems, and interaction between the system and the flight crew. The definition of “in a timely manner” must be determined for each specific system and for specific functions performed by the system. The applicable definition should be included in the certification plan for review and approval by the certification authorities.

6. Steps for Showing Compliance.

a. The following seven steps describe how you may comply with 14 CFR 23.1306, 25.1316, 27.1316, and 29.1316 requirements for your aircraft’s electrical and electronic systems:

- (1) Identify the systems to be assessed.
- (2) Determine the lightning strike zones for the aircraft.
- (3) Establish the aircraft lightning environment for each zone.
- (4) Determine the lightning transient environment associated with the systems.
- (5) Establish equipment transient design levels (ETDLs) and aircraft actual transient levels (ATLs).
- (6) Verify compliance to the requirements.
- (7) Take corrective measures, if needed.

b. The steps above should be performed to address lightning transients induced in electrical and electronic system wiring and equipment, and lightning damage to aircraft external equipment and sensors that are connected to electrical and electronic systems, such as radio antennas and air data probes. Additional guidance on lightning protection against lightning damage for external equipment and sensor installations can be found in SAE ARP 5577.

c. Identify the Systems to be Assessed.

(1) General. The aircraft systems requiring lightning assessment should be identified. Address any lightning-related electrical or electronic system failure that may cause or contribute to an adverse effect on the aircraft. The effects of a lightning strike, therefore, should be

assessed in a manner that allows for the determination of the degree to which the aircraft and/or its systems safety may be influenced. This assessment should cover:

(a) All normal aircraft operating modes, stages of flight, and operating conditions; and

(b) All lightning-related failure conditions and their subsequent effect on aircraft operations and the flightcrew.

(2) Safety Assessment. A safety assessment related to lightning effects should be performed to establish and classify the system failure condition. Based on the failure condition classification established by the safety assessment, the systems should be assigned appropriate lightning certification levels, as shown in Table 1. The failure condition classifications and terms used in this AC are consistent with those used in AC 23.1309-1, *System Safety Analysis and Assessment for Part 23 Airplanes*, and AC 25.1309-1, *System Design and Analysis*. Further guidance on processes for performing safety assessments can be found in those ACs, and AC 27-1, *Certification of Normal Category Rotorcraft*, AC 29-2, *Certification of Transport Category Rotorcraft*, SAE ARP 4754, *Guidelines for Development of Civil Aircraft and Systems*, and ARP 4761, *Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment*. The specific aircraft safety assessment related to lightning effects required by 14 CFR 23.1306, 25.1316, 27.1316 and 29.1316 takes precedence over the more general safety assessment process described in AC 23.1309-1, AC 25.1309-1, AC 27-1, and AC 29-2 . Lightning effects on electrical and electronic systems are generally assessed independently from other system failures that are unrelated to lightning, and do not need be considered in combination with latent or active failures unrelated to lightning.

Table 1. Lightning Failure Conditions and Certification Levels

Lightning Requirement Provisions From: 14 CFR 23.1306, 25.1316, 27.1316, 29.1316	Failure Condition	System Lightning Certification Level
(a) Each electrical and electronic system that performs a function, for which failure would prevent the continued safe flight and landing of the <i>aircraft</i>	Catastrophic	A
(b) Each [... each] electrical and electronic system that performs a function, for which failure would reduce the capability of the <i>aircraft</i> or the ability of the flightcrew to respond to an adverse operating condition,....	Hazardous Major	B C

(a) Level A Systems. The system safety assessment should consider effects of lightning-related failures or malfunctions on systems with lower failure classification that may affect the function of Level A systems. You should show that any system with wiring connections to a Level A system will not adversely affect the functions with catastrophic failure conditions performed by the Level A system when the aircraft is exposed to lightning. Redundancy alone cannot protect against lightning because the lightning-generated electromagnetic fields, conducted currents and induced currents in the aircraft can simultaneously induce transients in all electrical wiring on an aircraft.

(b) Level B or C Systems. Simultaneous and common failures due to lightning exposure generally do not have to be assumed for Level B or C systems incorporating redundant, spatially separated installations in the aircraft. This is because aircraft transfer function tests and in-service experience have shown these redundant and spatially separated installations are not simultaneously exposed to the maximum lightning induced transients. For example, redundant external sensors may mitigate direct lightning attachment damage, if there is acceptable separation between the sensors to prevent damage to multiple sensors so that the function is maintained. Therefore, simultaneous loss of all of these redundant and spatially separated Level B or C systems due to lightning exposure do not need to be considered. However, if multiple Level B or C systems are designed and installed within the same location in the aircraft, or share a common wiring connection, then the combined failure due to lightning exposure should be assessed to determine if the combined failures are catastrophic. If so, these systems should be designated as Level A systems.

(c) Failure Conditions. The safety assessment may show that some systems have different failure conditions in different phases of flight. Therefore, different lightning requirements may have to be applied to the system for different phases of flight. For example, an automatic flight control system may have a catastrophic failure condition for autoland, while automatic flight control system operations in cruise may have a hazardous failure condition.

d. Determine the Lightning Strike Zones for the Aircraft. The purpose of lightning zoning is to determine those areas of the aircraft likely to experience lightning channel attachment and those structures that may conduct lightning current between lightning attachment points. You should determine the lightning attachment zones for your aircraft configuration, since the zones will be dependent upon the aircraft's geometry, materials, and operational factors. Lightning attachment zones often vary from one aircraft type to another.

Note: AC 20-155 provides guidance to determine the lightning attachment zones for your aircraft.

e. Establish the Aircraft Lightning Environment for Each Zone. Zones 1 and 2 identify where lightning is likely to attach and, as a result, the entrance and exit points for current flow through the aircraft. The appropriate voltage waveforms and current components to apply in those zones should be identified. By definition, Zone 3 areas carry lightning current flow between initial (or swept stroke) attachment points, so they may include contributions from all of the current components. We accept analysis to estimate Zone 3 current levels that result from the external environment. The external lightning environment is:

- (1) Caused by the lightning flash interacting with the exterior of the aircraft.
- (2) Represented by combined waveforms of the lightning current components at the aircraft surface.

Note: AC 20-155 provides guidance for selecting the lightning waveforms and their applications.

f. Determine the Lightning Transient Environment Associated with the Systems.

(1) The lightning environment, as seen by electrical and electronic systems, consists of voltages and currents produced by lightning current flowing through the aircraft. The voltages and currents that appear at system wiring interfaces result from aperture coupling, structural voltages, or conducted currents resulting from direct attachments to equipment and sensors.

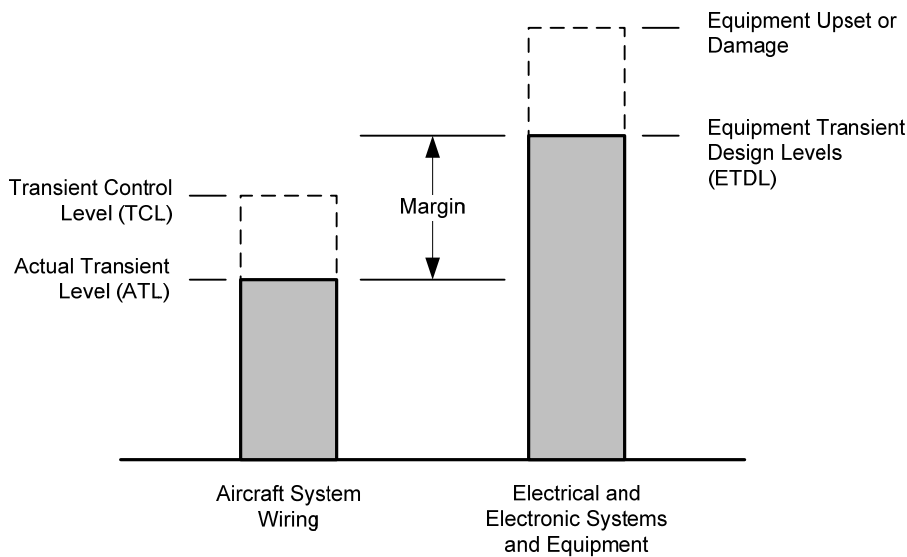
(2) Determine the lightning voltage and current transient waveforms and amplitudes that can appear at the electrical and electronic equipment interface circuits for each system identified in paragraph 6.c. You may determine the lightning transients in terms of the wire bundle current, or the open circuit voltage and the short circuit current appearing at system wiring and equipment interface circuits. The voltage and current transient waveforms and amplitudes are dependent upon the loop impedances of the system and its interconnecting wiring.

g. Establish Equipment Transient Design Levels (ETDLs) and Aircraft Actual Transient Levels (ATLs). The regulations in 14 CFR 23.1306, 25.1316, 27.1316, and 29.1316 define requirements in terms of functional effects that are performed by aircraft electrical and electronic systems. From a design point of view, lightning protection for systems is shared between protection incorporated into the aircraft structure and wiring, and protection incorporated into the equipment. Therefore, requirement allocations for the electrical and electronic system lightning protection can be based on the concept of ETDLs and ATLs.

(1) Determine and specify the ETDLs for the electrical and electronic equipment that make up the systems to be assessed. The ETDLs set qualification test levels for the systems and equipment. They define the voltage and current amplitudes and waveforms that the systems and equipment must withstand without any adverse effects. The ETDLs for a specific system depend on the anticipated system and wiring installation locations on the aircraft, the expected shielding performance of the wire bundles and structure, and the system criticality.

(2) The ATLs are the voltage and current amplitudes and waveforms actually generated on the aircraft wiring when the aircraft is exposed to lightning, as determined by aircraft test, analysis, or similarity. The difference between an ETDL and ATL is the margin. Figure 1 shows the relationship among the ATL and ETDL. You should evaluate the aircraft, interconnecting wiring, and equipment protection to determine the most effective combination of ATLs and ETDLs that will provide acceptable margin. Appropriate margins to account for uncertainties in the verification techniques may be required as discussed in paragraph 8.i of this AC.

Figure 1. Relationships Among Transient Levels



(3) Typically, you specify the ETDLs prior to aircraft certification lightning tests or analyses to determine the aircraft ATLs. Therefore the expected aircraft transients must be based upon results of lightning tests on existing aircraft, engineering analysis, or knowledgeable estimates. These expected aircraft lightning transient levels are termed transient control levels (TCL). Specify the TCLs voltage and current amplitudes and waveforms based upon the expected lightning transients that would be generated on wiring in specific areas of the aircraft. The TCLs should be equal to or greater than the maximum expected aircraft ATLs. The TCLs for a specific wire bundle depend on the configuration of the aircraft, the wire bundle, and the wire bundle installation. You should design your aircraft lightning protection to meet the specified TCLs.

h. Verify Compliance to the Requirements.

(1) You should show that the systems comply with the applicable requirements of 14 CFR 23.1306, 25.1316, 27.1316, or 29.1316.

(2) You should show that the ETDLs exceed the ATLs by the margin established in your certification plan.

(3) Verification may be accomplished by tests, by analysis, or by demonstrating similarity with previously certified aircraft and systems. The certification process for Level A systems is discussed in paragraph 8. The certification process for Level B and C systems is discussed in paragraph 9.

(4) Submit your certification plan early in the program to the cognizant aircraft certification office (ACO) for review. Experience shows, particularly with aircraft using new technology or those that have complex systems, that early agreement on the certification plan benefits both the applicant and the cognizant ACO. The plan should define acceptable ways to resolve critical issues during the certification process. Analysis and test results during the certification process may warrant modifications in the design or verification methods. When significant changes are necessary, update the certification plan accordingly. The plan may include the items listed in Table 2.

i. Take Corrective Measures. If tests and analyses show that the system did not meet the pass/fail criteria, review the aircraft, installation or system design and improve protection against lightning.

Table 2. Items Recommended for a Lightning Certification Plan

Item	Discussion
Description of systems	Describe systems' installation, including unusual or unique features; the system failure condition classifications; the operational aspects; lightning attachment zones; lightning environment; preliminary estimate of ETDs and TCLs; and acceptable margins between ETDs and ATs.
Description of compliance method	Describe how to verify compliance. Typically, your verification method includes similarity, analytical procedures, and tests. If using analytical procedures, describe how to verify them. (See paragraph 8d of this AC.)
Acceptance criteria	Determine the pass/fail criteria for each system by analyzing how safe the system is. During this safety analysis, assess the aircraft in its various operational states; account for the failure and disruption modes caused by the effects of lightning.
Test plans	Plan each test you include as part of your certification process. As an applicant, you can decide if your test plans are separate documents or part of the compliance plan. Your test plans should state the test sequence.

7. Effects of Transients. Lightning causes voltage and current transients to appear on equipment circuits. Equipment circuit impedances and configurations will determine whether lightning transients are primarily voltage or current. These transient voltages and currents can degrade system performance permanently or temporarily. The two primary types of degradation are component damage and system functional upset.

a. Component Damage. This is a permanent condition in which transients alter the electrical characteristics of a circuit. Examples of devices that may be susceptible to component damage include:

- (1) Active electronic devices, especially high frequency transistors, integrated circuits, microwave diodes, and power supply components;
- (2) Passive electrical and electronic components, especially those of very low power or voltage rating;
- (3) Electro-explosive devices, such as squibs and detonators;
- (4) Electromechanical devices, such as indicators, actuators, relays, and motors; and
- (5) Insulating materials (for example, insulating materials in printed circuit boards and connectors) and electrical connections that can burn or melt.

b. System Functional Upset.

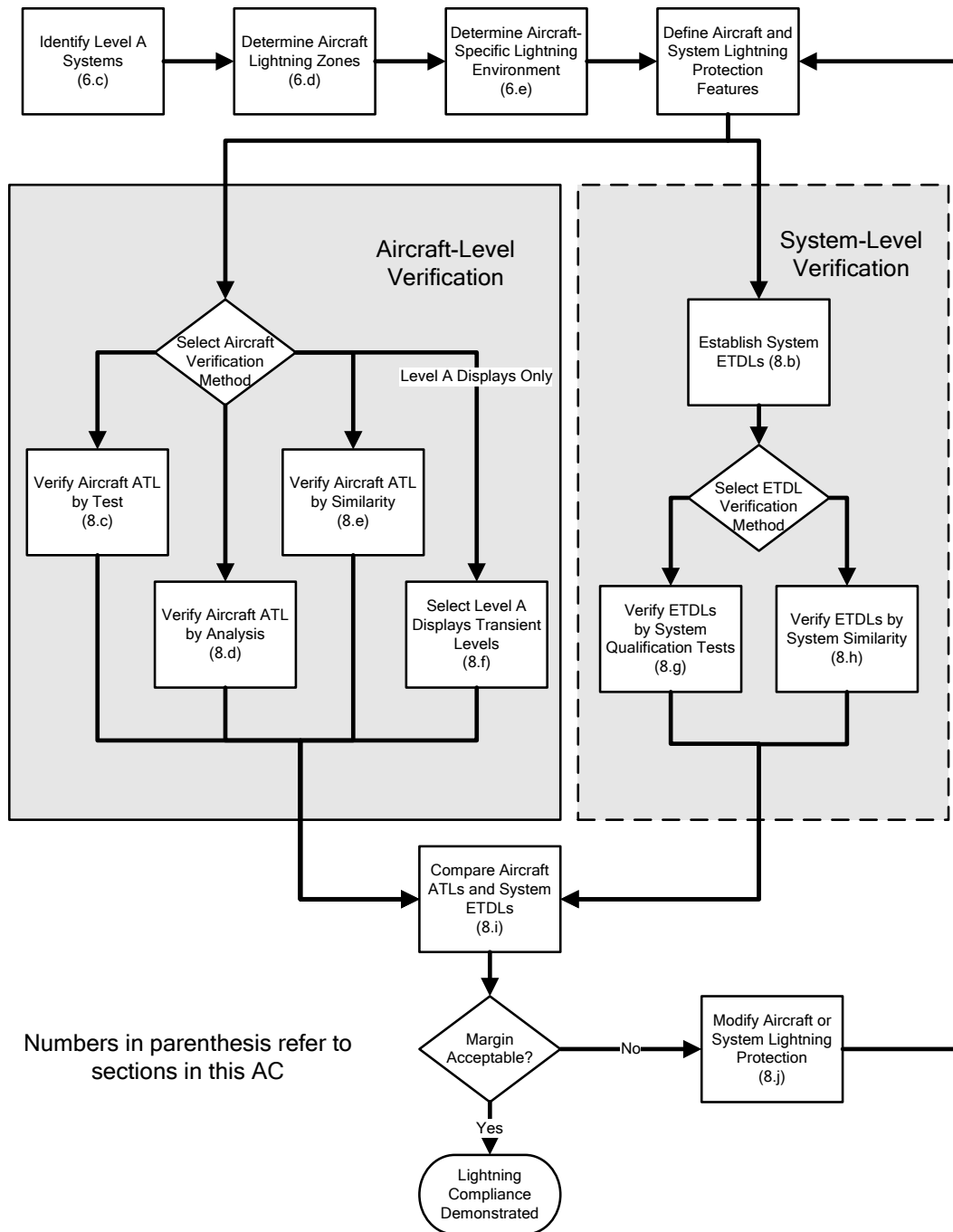
(1) Functional upset is mainly a system problem caused by electrical transients. It may permanently or momentarily upset a signal, circuit, or a system component, which can adversely affect system performance enough to compromise flight safety. A functional upset is a change in digital or analog state that may or may not require manual reset. In general, functional upset depends on circuit design and operating voltages, signal characteristics and timing, and system and software configuration.

(2) Systems or devices that may be susceptible to functional upset include computers and data/signal processing systems; electronic engine and flight controls; and power generating and distribution systems.

8. Level A System Lightning Certification. Figure 2 illustrates a process that you can use to show that your level A system complies with 14 CFR 23.1306, 25.1316, 27.1316, and 29.1316.

a. Identify Level A Systems. Identify your Level A systems as described in paragraph 6.c. Define the detailed system performance pass/fail criteria. An ACO should concur on this criterion before you begin testing or analyzing your Level A system. Identify specific equipment, components, sensors, power systems and wiring associated with each Level A system in order to perform the ETDL verification discussed in paragraphs 8.g and 8.h.

Figure 2. Typical Compliance Process for Level A Systems



b. Establish System ETDLs. Establish the aircraft system ETDLs from an evaluation of expected lightning transient amplitudes and waveforms for the system installation, structure and wiring configuration on a specific aircraft. You should establish ETDLs that exceed the ATLs by acceptable margin. In general, the ETDLs for equipment in a complex system will not be the same for all wire bundles connecting them to other equipment in the system. You may use results of lightning tests on existing similar aircraft, engineering analysis, or knowledgeable estimates to

establish appropriate system ETDLs. While specific aircraft configurations and system installations may lead to ETDLs that have amplitudes and waveforms different than those defined in RTCA/DO-160 Section 22, ETDLs are often specified using the information from Section 22. The ETDLs must exceed the ATLs by an acceptable margin.

c. Determine ATLs Using Aircraft Tests. See SAE ARP 5415, *User's Manual for Certification of Aircraft Electrical/Electronic Systems Against the Indirect Effects of Lightning*, and SAE ARP 5416 for guidance on how to determine the ATLs.

d. Determine ATLs Using Analysis. See SAE ARP 5415 for guidance on how to analyze aircraft to determine the ATLs. Acceptance of the analysis method you choose depends on the accuracy of the method. You should confirm your analysis method accuracy using experimental data, and gain agreement with your analysis approach from the cognizant ACO.

e. Determine ATLs Using Similarity.

(1) You may use similarity to determine the ATLs when there are:

(a) Only minor differences between the previously certified aircraft and system installation, and the aircraft and system installation to be certified; and

(b) There is no unresolved in-service history of problems related to lightning strikes to the previously certified aircraft.

(2) If significant differences are found that will affect the aircraft ATLs, you should perform more tests and analyses to resolve the open issues.

(3) To use similarity, you should assess the aircraft, wiring, and system installation differences that can adversely affect the system susceptibility. When assessing a new installation, consider differences affecting the internal lightning environment of the aircraft and its effects on the system. The assessment should cover:

(a) Aircraft type, equipment locations, airframe construction, structural materials, and apertures that could affect attenuation of the external lightning environment;

(b) System wiring size, length, and routing; wire types (whether parallel or twisted wires), connectors, wire shields, and shield terminations;

(c) Lightning protection devices such as transient suppressors and lightning arrestors; and

(d) Grounding and bonding.

(4) You cannot use similarity for a new aircraft design with new systems.

f. Determine Transient Levels Using RTCA/DO-160 Section 22 Guidance for Level A Displays Only.

(1) You may select ETDLs for your Level A display system using guidance in this section, without specific aircraft test or analysis. Level A displays involve functions for which the pilot will be in the loop through pilot/system information exchange. Level A display systems typically include the displays; symbol generators; data concentrators; sensors (such as attitude, air data, and heading sensors); interconnecting wiring; and associated control panels.

(2) This approach should not be used for other Level A systems, such as control systems, because failures and malfunctions of those systems can more directly and abruptly contribute to a catastrophic failure event than display system failures and malfunctions. Therefore, other Level A systems require a more rigorous lightning transient compliance verification program.

(3) You should use the information in Table 3 to evaluate your aircraft and system installation features to select appropriate ETDLs for your system. Table 3 defines test levels for ETDLs, based on RTCA/DO-160 Section 22, Tables 22-2 and 22-3. Provide the cognizant ACO with a description of your aircraft and display system installation features and compare these to the information in Table 3 to substantiate the ETDL selected for your aircraft and Level A display system installation. When selecting ETDLs using guidance provided in Table 3, acceptable margin between anticipated ATLs for display system installations is incorporated in the selected ETDLs.

Table 3. Equipment Transient Design Levels - Level A Displays

RTCA/DO-160 Section 22 Level	Display System Installation Location
Level 5	<p>Use this level when the equipment under consideration, its associated wire bundles, or other components connected by wiring to the equipment are in aircraft areas exposed to <i>very severe</i> lightning transients. These areas are:</p> <ul style="list-style-type: none"> • Areas with composite materials whose shielding is not very effective; • Areas where there is no guarantee of structural bonding; and • Other open areas where there is little shielding. <p>You can also use this level to cover a broad range of installations.</p> <p>You may need higher ETDs when there are high current density regions on mixed conductivity structures (such as wing tips, engine nacelle fin, and so on) because the system wiring may divert some of the lightning current. If you are the system designer, apply measures to reduce the need for higher ETDs.</p>
Level 4	<p>Use this level when the equipment under consideration, its associated wire bundles, or other components connected by wiring to the equipment, are in aircraft areas exposed to <i>severe</i> lightning transients. We define these areas as outside the fuselage (such as wings, fairings, wheel wells, pylons, control surfaces, and so on).</p>
Level 3	<p>Use this level when the equipment under consideration, its associated wire bundles, and other components connected by wiring to the equipment are entirely in aircraft areas with <i>moderate</i> lightning transients. We define these areas as the inside metal aircraft structure or composite aircraft structure whose shielding without improvements is as effective as metal aircraft structure. Examples of such areas are avionics bays not enclosed by bulkheads, cockpit areas, and locations with large apertures (that is, doors without electromagnetic interference (EMI) gaskets, windows, access panels, and so on).</p> <p>Current-carrying conductors in these areas (such as hydraulic tubing, control cables, wire bundles, metal wire trays, and so on) are not necessarily electrically grounded at bulkheads. When few wires exit the areas, either use a higher level (that is, <i>Level 4</i> or <i>5</i>) for these wires or offer more protection for these wires.</p>
Level 2	<p>Use this level when the equipment under consideration, its associated wire bundles, and other components connected by wiring to the equipment are entirely in <i>partially protected</i> areas. We define these areas as the inside of a metallic or composite aircraft structure whose shielding is as effective as metal aircraft structure, if you take measures to reduce the lightning coupling to wires.</p> <p>Wire bundles in these areas pass through bulkheads, and have shields that end at the bulkhead connector. When a few wires exit these areas, use either a higher level (that is, <i>Level 3</i> or <i>4</i>) or provide more protection for these wires. Install wire bundles close to the ground plane, to take advantage of other inherent shielding from metallic structures. Current-carrying conductors (such as hydraulic tubing, control cables, metal wire trays, and so on) are electrically grounded at all bulkheads.</p>
Level 1	<p>Use this level when the equipment under consideration, its associated wire bundles, and other components connected by wiring to the equipment are entirely in <i>well-protected</i> aircraft areas. We define these areas as electromagnetically enclosed.</p>

g. Verify System ETDLs Using System Qualification Tests.

(1) You should identify the equipment, components, sensors, power systems, and wiring associated with the Level A system undergoing ETDL verification tests, specifically considering the system functions whose failures have catastrophic failure consequences. For complex Level A systems, the system configuration may include redundant equipment, multiple power sources, multiple sensors and actuators, and complex wire bundles. Define the system configuration used for the ETDL verification tests. You should obtain the cognizant ACO approval of your system configuration for ETDL verification tests.

(2) You should verify the ETDLs using single stroke, multiple stroke, and multiple burst tests on the system wire bundles. Use waveform sets and test levels for the defined ETDLs. Show that the system operates within the defined pass/fail criteria during these tests. No equipment damage should occur during these system tests or during single stroke pin injection tests using the defined ETDLs. RTCA/DO-160 Section 22 provides acceptable test procedures and waveform set definitions. In addition, SAE ARP 5416 provides acceptable test methods for complex and integrated systems.

(3) You should evaluate any system effects observed during the qualification tests to ensure they do not adversely affect the system's continued performance. The Level A system performance should be evaluated for functions of which failures or malfunctions would prevent the continued safe flight and landing of the aircraft. Other functions performed by the system of which failures or malfunctions would reduce the capability of the aircraft or the ability of the flightcrew to respond to an adverse operating condition should be evaluated using the guidance in Section 9. You should obtain the cognizant ACO approval of your evaluation.

h. Verify System ETDLs Using Existing System Data (Similarity).

(1) You may base your ETDL verification on similarity to previously certified systems without performing more tests. You may do this when:

(a) There are only minor differences between the previously certified system and installation, and the system and installation to be certified;

(b) There are no unresolved in-service system problems related to lightning strikes on the previously certified system; and

(c) The previously certified system ETDLs were verified by qualification tests.

(2) To use similarity to previously certified systems, you should assess differences between the previously certified system and installation and the system and installation to be certified that can adversely affect the system susceptibility. The assessment should cover:

(a) System interface circuits;

- (b) Wire size, routing, arrangement (parallel or twisted wires), connector types, wire shields, and shield terminations;
- (c) Lightning protection devices such as transient suppressors and lightning arrestors;
- (d) Grounding and bonding; and
- (e) System software, firmware, and hardware.

(3) If you are unsure how the differences will affect the systems and installations, you should perform more tests and analyses to resolve the open issues.

(4) You should assess every system, even if it uses equipment and installation techniques that have previous certification approval.

(5) You should not use similarity for a new aircraft design with new systems.

i. Verify Compliance to the Requirements. You should compare the verified system ETDLs with the aircraft ATLs and determine if an acceptable margin exists between the ETDLs and ATLs. Margins account for uncertainty in the verification method. As confidence in the verification method increases, the margin can decrease. An ETDL exceeding the ATL by a factor of two is an acceptable margin for Level A systems, if this margin is verified by aircraft test or by analysis supported by aircraft tests. For Level A display systems where the ETDLs are determined using guidance provided in Table 3, an acceptable margin is already incorporated in the selected ETDLs. For other verification methods, the margin should be agreed upon with the cognizant ACO.

j. Take Corrective Measures.

(1) When your system fails to meet the certification requirements, corrective actions should be selected. The changes or modifications you make to the aircraft, system installation or the equipment may require more testing and analysis.

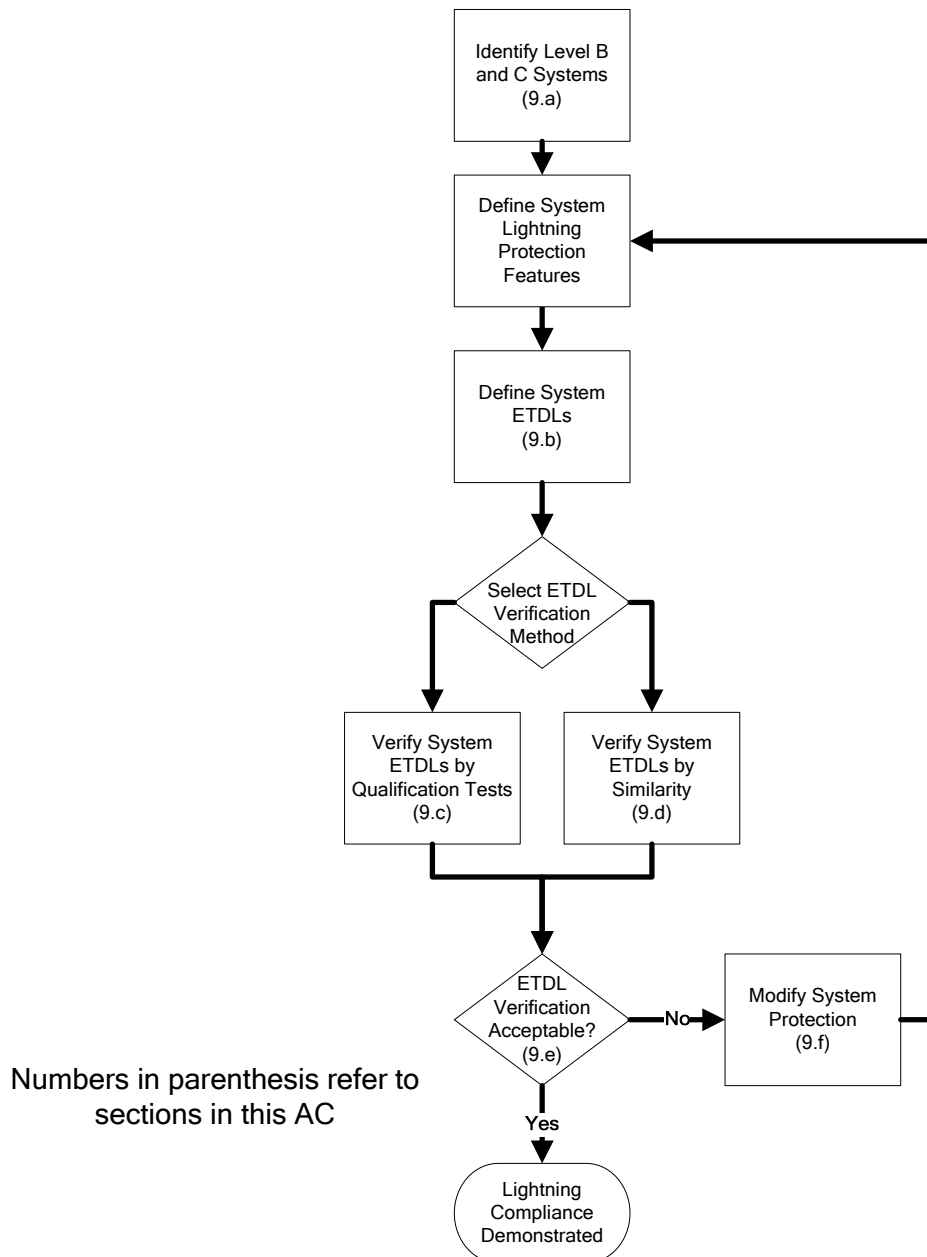
(2) To meet the certification requirements, you may need to repeat system qualification testing, or aircraft testing and analysis (in whole or in part). You also may need to modify the system or installation to get certification. You should review these changes or modifications with the cognizant ACO to determine if they are significant. If these changes or modifications are significant, update your lightning certification plan accordingly. The updated certification plan should be resubmitted to the ACO for review.

9. Level B and C System Lightning Certification.

a. Identify Level B and C Systems.

- (1) Identify your Level B and C systems as described in paragraph 6.c.
- (2) Define the detailed system performance pass/fail criteria. You should get ACO concurrence on this criterion before you start testing or analyzing your Level B and C systems.
- (3) Figure 3 illustrates a process you can use to show that your Level B and C systems comply with 14 CFR requirements.

Figure 3. Typical Compliance Process for Level B and C Systems



b. Establish ETDLS.

(1) You may use the ATLS determined during aircraft tests or analyses performed for Level A systems to establish appropriate ETDLS for Level B and C systems.

(2) Alternatively, you may use the definitions in RTCA/DO-160, Section 22 to select appropriate ETDLS for your Level B and C systems. The following should be considered when selecting an appropriate level:

(a) Use RTCA/DO-160, Section 22, Level 3 for most Level B systems.

(b) For Level B systems and associated wiring installed in aircraft areas with more severe lightning transients, use RTCA/DO-160, Section 22, Level 4 or 5 as appropriate to the environment. Examples of aircraft areas with more severe lightning transients are those external to the fuselage, areas with composite structures showing poor shielding effectiveness, and other open areas.

(c) Use RTCA/DO-160, Section 22, Level 2 for most Level C systems.

(d) For Level C systems installed in aircraft areas with more severe lightning transients, use RTCA/DO-160, Section 22, Level 3. Examples of aircraft areas with more severe lightning transients are those external to the fuselage, areas with composite structures showing poor shielding effectiveness, and other open areas.

(e) Provide the cognizant ACO with a description of your aircraft and system installation features to substantiate the RTCA/DO-160, Section 22 levels selected for your system.

c. Verify System ETDLS Using Equipment Qualification Tests.

(1) You should perform equipment qualification tests using the selected test levels and single stroke, multiple stroke, and multiple burst waveform sets. Show that the equipment operates within the defined pass/fail criteria during these tests. No equipment damage should occur during these equipment qualification tests or during single stroke pin injection tests using the defined ETDLS. RTCA/DO-160, Section 22, provides acceptable test procedures and waveform set definitions.

(2) You should evaluate any equipment effects observed during the qualification tests to ensure these do not adversely affect the system's continued performance. You should obtain the cognizant ACO approval of your evaluation.

(3) Multiple stroke and multiple burst testing is not required if an analysis shows that the equipment is not susceptible to upset or, that the equipment may be susceptible to upset, but a reset capability exists so the system recovers in a timely manner.

d. Verify System ETDLS Using Existing Equipment Data (Similarity).

(1) You may verify ETDLs by similarity to previously certified systems without performing more tests. You may do this when:

- (a) There are only minor differences between the previously certified system and installation, and the system and installation to be certified;
- (b) There are no unresolved in-service system problems related to lightning strikes on the previously certified system; and
- (c) The previously certified system ETDLs were verified by qualification tests.

(2) The assessment should cover:

- (a) Equipment interface circuits;
- (b) Wire size, routing, arrangement (parallel or twisted wires), connector types, wire shields, and shield terminations;
- (c) Lightning protection devices such as transient suppressors and lightning arrestors;
- (d) Grounding and bonding; and
- (e) Equipment software, firmware, and hardware.

(3) If significant differences are found that will affect the systems and installations, you should perform more tests and analyses to resolve the open issues.

e. Verify Compliance to the Requirements. You should show that the Level B and C systems meet their defined acceptance criteria during the qualification tests at the selected system ETDLs.

f. Take Corrective Measures. When your system fails to meet the certification requirements, you should decide on corrective actions. If you change or modify the system or installation, you may need to repeat equipment qualification testing. You should review these changes or modifications with the cognizant ACO to determine if they are significant. If these changes or modifications are significant, update your lightning certification plan accordingly. The updated certification plan should be resubmitted to the ACO for review.

10. Maintenance and Surveillance.

a. You should identify the minimum maintenance required for the aircraft electrical and electronic system lightning protection in the instructions for continued airworthiness (ICA). You should define the requirements for periodic and conditional maintenance and surveillance of lightning protection devices or features to ensure acceptable protection performance while the

aircraft is in service. Avoid using devices or features that may degrade with time because of corrosion, fretting, flexing cycles, or other causes. Alternatively, identify when to inspect or replace these devices.

b. You should define the inspection techniques and intervals needed to ensure that the aircraft and system lightning protection remains effective in service. Also, identify built-in test equipment, resistance measurements, continuity checks of the entire system, or other means to determine your system's integrity periodically and conditionally.

c. See SAE ARP 5415 for more information on aircraft lightning protection maintenance and surveillance.



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Appendix 1. Related Documents and How to Get Them

1. Title 14 of the Code of Federal Regulations (14 CFR). You can get copies of the following 14 CFR sections from the Superintendent of Documents, Government Printing Office, Washington, D.C. 20402-9325. Telephone 202-512-1800, fax 202-512-2250. You can also access copies from the Government Printing Office (GPO), electronic CFR Internet website at www.access.gpo.gov/ecfr/.

a. Part 23, Airworthiness Standards: Normal, Utility, Acrobatic, and Commuter Category Airplanes:

- § 23.867 Electrical bonding and protection against lightning and static electricity
- § 23.901 Installation
- § 23.954 Fuel system lightning protection
- § 23.1301 Function and installation
- § 23.1309 Equipment, systems, and installations
- § 23.1306 Electrical and electronic system lightning protection
- § 23.1529 Instructions for continued airworthiness

b. Part 25, Airworthiness Standards: Transport Category Airplanes:

- § 25.581 Lightning protection
- § 25.901 Installation
- § 25.954 Fuel system lightning protection
- § 25.1301 Function and installation
- § 25.1309 Equipment, systems, and installations
- § 25.1316 Electrical and electronic system lightning protection
- § 25.1529 Instructions for continued airworthiness

c. Part 27, Airworthiness Standards: Normal Category Rotorcraft:

- § 27.610 Lightning and static electricity protection
- § 27.901 Installation
- § 27.954 Fuel system lightning protection
- § 27.1301 Function and installation
- § 27.1309 Equipment, systems, and installations
- § 27.1316 Electrical and electronic system lightning protection
- § 27.1529 Instructions for continued airworthiness

d. Part 29, Airworthiness Standards: Transport Category Rotorcraft:

- § 29.610 Lightning and static electricity protection
- § 29.901 Installation
- § 29.954 Fuel system lightning protection
- § 29.1301 Function and installation
- § 29.1309 Equipment, systems, and installations
- § 29.1316 Electrical and electronic system lightning protection
- § 29.1529 Instructions for continued airworthiness

e. Part 33, Airworthiness Standards: Aircraft Engines:

- § 33.28 Engine control systems
- § 33.53 Engine system and component tests (*Reciprocating aircraft engines*)
- § 33.91 Engine system and component tests (*Turbine aircraft engines*)

2. Federal Aviation Administration (FAA) Advisory Circulars (AC). You can access copies of the following ACs at www.faa.gov/regulations_policies/advisory_circulars/.

Note: The ACs referenced in this document refer to the current revisions.

- a. AC 20-155, *SAE Documents to Support Aircraft Lightning Protection Certification*.
- b. AC 21-16, RTCA Document DO-160 Versions D, E, F, and G, *Environmental Conditions and Test Procedures for Airborne Equipment*.
- c. AC 23-17, *Systems and Equipment Guide for Certification of Part 23 Airplanes and Airships*.
- d. AC 23.1309-1, *System Safety Analysis and Assessment for Part 23 Airplanes*.
- e. AC 25.1309-1, *System Design and Analysis*.
- f. AC 27-1, *Certification of Normal Category Rotorcraft*.
- g. AC 29-2, *Certification of Transport Category Rotorcraft*.

3. Industry Documents.

Note: The industry documents referenced in this section refer to the current revisions or regulatory authorities accepted revisions.

a. **European Organization for Civil Aviation Equipment (EUROCAE).** You can get copies of the following documents from EUROCAE, 17 rue Hamelin, 75116 Paris, France. Telephone 33 (0) 1 4505 7188, fax 33 (0) 1 4505 7230, website www.eurocae.net.

(1) EUROCAE ED-14, *Environmental Conditions and Test Procedures for Airborne Equipment*.

(2) EUROCAE ED-105, *Aircraft Lightning Test Methods*.

(3) EUROCAE ED-113, *Aircraft Direct Effects Certification*.

b. **RTCA.** You can get copies of RTCA/DO-160, *Environmental Conditions and Test Procedures for Airborne Equipment*, from RTCA, Inc., 1150 18th Street NW, Suite 910, Washington, D.C. 20036. Telephone 202-833-9339, fax 202-833-9434, website www.rtca.org.

This document is technically equivalent to EUROCAE ED-14. Anywhere there is a reference to RTCA/DO-160, EUROCAE ED-14 may be used.

Note: Use of RTCA/DO-160D, Change Notice 3, or later revisions are acceptable.

c. SAE International. You can get copies of the following documents from SAE Customer Service, 400 Commonwealth Drive, Warrendale, PA 15096-0001. Telephone 724-776-4970, fax 724-776-0790, website www.sae.org.

(1) Aerospace Recommended Practice (ARP) 4754, *Guidelines for Development of Civil Aircraft and Systems*.

(2) ARP 4761, *Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment*.

(3) ARP 5412, *Aircraft Lightning Environment and Related Test Waveforms*.

(4) ARP 5414, *Aircraft Lightning Zoning*.

(5) ARP 5415, *User's Manual for Certification of Aircraft Electrical/Electronic Systems Against the Indirect Effects of Lightning*.

(6) ARP 5416, *Aircraft Lightning Test Methods*. This document is technically equivalent to EUROCAE ED-105. Anywhere there is a reference to ARP 5416, EUROCAE ED-105 may be used.

(7) ARP 5577, *Aircraft Lightning Direct Effects Certification*.

Appendix 2. Definitions

The following definitions apply to this AC:

TERM	DEFINITION
<i>Actual Transient Level (ATL)</i>	The level of transient voltage or current that appears at the equipment interface circuits because of the external environment. This level may be less than or equal to the transient control level, but should not be greater.
<i>Aperture</i>	An electromagnetically transparent opening.
<i>Attachment Point</i>	A point where the lightning flash contacts the aircraft.
<i>Component Damage</i>	A condition in which transients permanently alter the electrical characteristics of a circuit. Because of this, the component can no longer perform to its specifications.
<i>Continued Safe Flight and Landing</i>	The aircraft can safely abort or continue a takeoff, or continue controlled flight and landing, possibly using emergency procedures. The aircraft must do this without requiring exceptional pilot skill or strength. Some aircraft damage may occur because of the failure condition or on landing. For transport airplanes, the pilot must be able to land safely at a suitable airport. For Part 23 airplanes, it is not necessary to land at an airport. For rotorcraft, the rotorcraft must continue to cope with adverse operating conditions, and the pilot must be able to land safely at a suitable site.
<i>Direct Effects</i>	Physical damage to the aircraft or electrical and electronic systems. Direct attachment of lightning to the system's hardware or components causes the damage. Examples of direct effects include tearing, bending, burning, vaporization, or blasting of aircraft surfaces and structures, and damage to electrical and electronic systems.
<i>Equipment</i>	Component of an electrical or electronic system with interconnecting electrical conductors.
<i>Equipment Transient Design Level (ETDL)</i>	The peak amplitude of transients to which you qualify your equipment.
<i>External Environment</i>	The natural lightning environment, outside the aircraft, for design and certification purposes. See AC 20-155, which references documents that provide additional guidance on aircraft lightning environment and related waveforms.
<i>Indirect Effects</i>	Electrical transients induced by lightning in aircraft electrical or electronic circuits.

TERM	DEFINITION
<i>Internal Environment</i>	The potential fields and structural voltages inside the aircraft produced by the external environment.
<i>Lightning Flash</i>	The total lightning event. It may occur in a cloud, among clouds, or between a cloud and the ground. It can consist of one or more return strokes, plus intermediate or continuing currents.
<i>Lightning Strike</i>	Attachment of the lightning flash to the aircraft.
<i>Lightning Strike Zones</i>	Aircraft surface areas and structures that are susceptible to lightning attachment, dwell time, and current conduction. See AC 20-155, which references documents that provide additional guidance on aircraft lightning zoning.
<i>Lightning Stroke (Return Stroke)</i>	A lightning current surge that occurs when the lightning leader (the initial current charge) makes contact with the ground or another charge center. A charge center is an area of high potential of opposite charge.
<i>Margin</i>	The difference between the equipment transient design levels and the actual transient level.
<i>Multiple Burst</i>	A randomly spaced series of bursts of short duration, low amplitude current pulses, with each pulse characterized by rapidly changing currents. These bursts may result as the lightning leader progresses or branches, and are associated with the cloud-to-cloud and intra-cloud flashes. The multiple bursts appear most intense when the initial leader attaches to the aircraft. See AC 20-155.
<i>Multiple Stroke</i>	Two or more lightning return strokes during a single lightning flash. See AC 20-155.
<i>Transient Control Level (TCL)</i>	The maximum allowable level of transients that appear at the equipment interface circuits because of the defined external environment.

Appendix 3. Acronyms

We use the following acronyms throughout this AC:

14 CFR	Title 14 of the Code of Federal Regulations
AC	Advisory Circular
ACO	Aircraft Certification Office
ARP	Aerospace Recommended Practice
ATL	Actual Transient Level
ETDL	Equipment Transient Design Level
EASA	European Aviation Safety Agency
EUROCAE	European Organization for Civil Aviation Equipment
FAA	Federal Aviation Administration
ICA	Instructions for Continued Airworthiness
TCL	Transient Control Level