Notice of Proposed Amendment 2017-09

Update of AMC-20

‘In-flight entertainment, lead-free soldering, harmonisation of safety assurance and software development criteria’

RMT.0561

EXECUTIVE SUMMARY

The objective of this NPA is to address issues related to those parts of AMC-20 that contain provisions on airworthiness for various systems that can be installed on different aircraft categories. As the industry state of the art is constantly evolving, the European Aviation Safety Agency (EASA) needs to keep the pace and propose appropriate guidance to the applicants for certification and operation of such systems.

This NPA proposes to:

— amend AMC 20-1, 20-2 and 20-3 to harmonise across them the criteria for safety assurance and software development;

— create a new AMC 20-30 on lead-free soldering as well as amend AMC 21.A.608; and

— create a new AMC 20-19 on in-flight entertainment (IFE) systems, as well as amend or create relevant AMC to Annex III (Part-ORO) and Annex IV (Part-CAT) to Regulation (EU) No 965/2012 (hereinafter referred to as the ‘Air OPS Regulation’) for the operation of these systems.

The proposed changes are expected to provide an updated AMC-20 reflecting the industry state of the art, thus facilitating the certification process. Overall, this would bring safety, environmental, and economic benefits, and have no social impacts.

Action area:	Regular updates		
Affected rules:	— AMC-20; — AMC/GM to Part-21; — AMC/GM to Part-ORO; — AMC/GM to Part-CAT		
Affected stakeholders:	Aircraft operators, manufacturers of aircraft and equipment		
Driver:	Efficiency/proportionality	**Rulemaking group:**	Yes
Impact assessment:	Light	**Rulemaking Procedure:**	Standard

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1. About this NPA

1.1. How this NPA was developed

EASA developed this NPA in line with Regulation (EC) No 216/2008[1] (hereinafter referred to as the 'Basic Regulation') and the Rulemaking Procedure[2]. This rulemaking activity is included in the EASA 5-year Rulemaking Programme[3] under rulemaking task (RMT).0561. The text of this NPA has been developed by EASA, based on the input of the Rulemaking Group (RMG) RMT.0561. It is hereby submitted to all interested parties[4] for consultation.

1.2. How to comment on this NPA

Please submit your comments using the automated **Comment-Response Tool (CRT)** available at **http://hub.easa.europa.eu/crt/**[5].

The deadline for submission of comments is **22 September 2017**.

1.3. The next steps

Following the closing of the public commenting period, EASA will review all comments.

Based on the comments received, EASA will develop a decision to which the related acceptable means of compliance (AMC)/guidance material (GM) will be annexed.

The comments received and the EASA responses will be reflected in a comment-response document (CRD). The CRD will be annexed to the decision.

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[1] Regulation (EC) No 216/2008 of the European Parliament and of the Council of 20 February 2008 on common rules in the field of civil aviation and establishing a European Aviation Safety Agency, and repealing Council Directive 91/670/EEC, Regulation (EC) No 1592/2002 and Directive 2004/36/EC (OJ L 79, 19.3.2008, p. 1) (http://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1467719701894&uri=CELEX:32008R0216).

[2] EASA is bound to follow a structured rulemaking process as required by Article 52(1) of Regulation (EC) No 216/2008. Such a process has been adopted by the EASA Management Board (MB) and is referred to as the 'Rulemaking Procedure'. See MB Decision No 18-2015 of 15 December 2015 replacing Decision 01/2012 concerning the procedure to be applied by EASA for the issuing of opinions, certification specifications and guidance material (http://www.easa.europa.eu/the-agency/management-board/decisions/easa-mb-decision-18-2015-rulemaking-procedure).

[3] http://easa.europa.eu/rulemaking/annual-programme-and-planning.php

[4] In accordance with Article 52 of Regulation (EC) No 216/2008 and Articles 6(3) and 7) of the Rulemaking Procedure.

[5] In case of technical problems, please contact the CRT webmaster (crt@easa.europa.eu).

2. In summary — why and what

2.1. Why we need to change the rules — issue/rationale

AMC-20 group provisions on airworthiness for various systems that can be installed on aircraft of different categories. As the industry state of the art is constantly evolving, EASA needs to keep the pace and propose appropriate guidance to the applicants for certification and operation of such systems. This would allow both to maintain a high level of safety, when applicable, and to avoid unnecessary cost, by preventing the development of unacceptable designs at an early stage. This NPA addresses the following areas:

(a) Harmonisation of safety assurance and software development criteria across AMC 20-1, 20-2, and 20-3

During the NPA 2012-11 'Recognition of ED-12C/DO-178C in EASA AMC 20-115' public consultation period , several stakeholders submitted comments about safety considerations and the software development level in AMC 20-1, 20-2, 20-3, 20-4, and 20-27. In the corresponding CRD 2012-11, EASA envisaged possible changes in AMC 20, within the framework of this RMT.0561.

The operational aspects of AMC 20-4 and 20-27 (both related to performance-based navigation (PBN)) are covered by RMT.0257, while the technical aspects are dealt with by RMT.0520.

The scope of this NPA is hence limited to the harmonisation of safety assurance and software development criteria across AMC 20-1, 20-2, and 20-3.

(b) AMC 20-30 on lead-free soldering

In 2003, the European Parliament and the Council issued Directive 2002/95/EC (later replaced by Directive 2011/65/EU[6]), which required that all new electrical and electronic equipment and systems put on the market after 1 July 2006 do not contain lead (Pb) or other environmentally hazardous materials. Lead was used as surface plating for soldering purposes (e.g. tin/lead solder alloys) on discrete electrical and electronic components, including integrated circuits, semiconductors, capacitors, resistors, and other electronic circuitry, widely used on aircraft.

Pb-free solders and finishes inappropriate to withstand the extreme aviation operating environment may decrease the reliability of systems or subsystems, and ultimately have a negative impact on safety and system performance.

The objective of this NPA is hence to provide guidance for the transition to lead-free soldering, considering applications for new type certificates as well as changes to existing type certificates.

(c) AMC 20-19 on IFE systems

Aircraft IFE systems pose, due to their nature and the technologies used, several challenges which should be addressed in order to minimise safety issues during certification as well as operation of these systems. If these systems suffer a malfunction, this could lead to electrical arcing posing a fire hazard.

[6] Directive 2011/65/EU of the European Parliament and of the Council of 8 June 2011 on the restriction of the use of certain hazardous substances in electrical and electronic equipment (OJ L 174, 1.7.2011, p. 88) (http://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1496308907074&uri=CELEX:02011L0065-20160715).

The development of IFE systems towards open platforms interacting with portable electronic devices (PEDs), either deployed by the aircraft operator or carried on board by the passengers, also leads to more electromagnetic emissions than before.

Since the first inception of IFE systems, technology has shifted away from simple systems towards more complex ones, which are now becoming increasingly mobile and interactive.

As the IFE technology is constantly evolving, the regulatory framework should keep the pace and be updated accordingly. Therefore, the objective of this NPA is to provide guidance for the approval of installation of IFE systems.

2.2. What we want to achieve — objectives

The overall objectives of the EASA system are defined in Article 2 of the Basic Regulation. This proposal will contribute to the achievement of the overall objectives by addressing the issues outlined in Section 2.1. The specific objective of this proposal is to:

- harmonise the criteria for safety assurance and software development;
- provide guidelines for assessing the impact of the transition to lead-free-soldered electronics on the airworthiness of aircraft parts and appliances; and
- provide guidelines for the initial- and continued-airworthiness aspects of IFE systems.

2.3. How we want to achieve it — overview of the proposals

The proposed changes to AMC-20 are the following:

- AMC 20-1 is amended to AMC 20-1A;
- AMC 20-2A is amended to AMC 20-2B;
- AMC 20-3A is amended to AMC 20-3B;
- a new AMC 20-30 on lead-free soldering is created; and
- a new AMC 20-19 on IFE systems is created.

The following AMC/GM to the Air OPS Regulation are proposed to be amended:

- AMC1 to ORO.GEN.110 (f)(h);
- AMC1 to ORO.CC.125 (c);
- AMC1 to ORO.CC.125 (d);
- AMC1 to ORO.CC.135;
- GM1 to ORO.CC.115;
- AMC1 CAT.OP.MPA.170; and
- AMC3 CAT.OP.MPA.170 (new).

During the development of AMC 20-30, it was identified that the recording of the lead-free technology in the declaration of design and performance (DDP) would help the installer to deal appropriately with this technology. Consequently, the recording in the DDP of whether the lead-free technology is used, is proposed to be introduced through an amendment to AMC 21.A.608.

2.4. What are the expected benefits and drawbacks of the proposals

Overall, the proposed amendments are expected to increase safety by proposing guidance for the certification of IFE and lead-free soldered systems. They would also have a positive environmental impact and economic benefits, by streamlining the certification process, while reflecting the industry state of the art.

No social impact is expected.

3. Proposed amendments and rationale in detail

The text of the amendment is arranged to show deleted text, new or amended text as shown below:

— deleted text is ~~struck through~~;

— new or amended text is highlighted in grey;

— an ellipsis '[…]' indicates that the rest of the text is unchanged.

3.1. Draft certification specifications (Draft EASA decision)

3.1.1. AMC 20-1

1. AMC 20-1 is amended as follows:

AMC 20-1A
Certification of Aircraft Propulsion Systems Equipped with Electronic Control Systems

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[…]

4 PRECAUTIONS

a) General

The introduction of electrical and electronic technology can entail the following:

- a greater interdependence of the Engine, or Propeller, and ~~on the~~ Aircraft owing to the ~~use~~exchange of electrical power and/or data between them~~supplied from the Aircraft~~.
- an increased integration of control and related indication functions,
- a~~n increased~~ risk of significant Failures common to more than one Engine or Propeller of the Aircraft which might, for example, occur as a result of:
  - Insufficient protection from electromagnetic disturbance (lightning, internal or external radiation effects),
  - Insufficient integrity of the Aircraft electrical power supply,
  - Insufficient integrity of data supplied from the Aircraft,
  - Hidden design Faults or discrepancies contained within the design of the propulsion system control software or ~~complex~~airborne electronic hardware (AEH), or
  - Omissions or errors in the system/software/AEH specification.

~~Special~~Appropriate design and integration precautions should therefore be taken to minimise these risks.

[…]

e) Software and ~~Programmable Logic Devices~~airborne electronic hardware (AEH)

The acceptability of levels and methods used for development and verification of software and ~~Programmable Logic Devices~~AEH which are part of the Engine and Propeller type designs should have been agreed between the Aircraft, Engine and Propeller designers prior to certification activity.

f) Environmental effects

The validated protection levels for the Engine and Propeller electronic control systems as well as their emissions of radio frequency energy are established during the Engine and Propeller certification and are contained in the instructions for installation. For the Aircraft certification, it should be substantiated that these levels are appropriate.

5 INTER-RELATION BETWEEN ENGINE, PROPELLER AND AIRCRAFT CERTIFICATION

a) Objective

To satisfy the Aircraft certification specifications, such as CS 25.901, CS 25.903 and CS 25.1309, an analysis of the consequences of failures of the system on the Aircraft has to be made. It should be ensured that the software levels, AEH development assurance level (DAL) and safety and reliability objectives for the electronic control system are consistent with these requirements.

b) Interface Definition

The interface has to be identified for the ~~hardware~~AEH and software aspects between the Engine, Propeller and the Aircraft systems in the appropriate documents.

The Engine/Propeller/Aircraft documents should cover in particular:

- The software ~~quality~~ level and AEH DAL (per function if necessary),
- The reliability objectives for loss of Engine/Propeller control or significant change in thrust, (including IFSD due to control system malfunction), transmission of faulty parameters,
- The degree of protection against lightning or other electromagnetic effects (e.g. level of induced voltages that can be supported at the interfaces),
- Engine, Propeller and Aircraft interface data and characteristics, and
- Aircraft power supply and characteristics (if relevant).

c) Distribution of Compliance Demonstration

The certification tasks of the Aircraft propulsion system equipped with electronic control systems may be shared between the Engine, Propeller and Aircraft certification. The distribution between the different certification activities should be identified and agreed with the Agency and/or the appropriate Engine and Aircraft Authorities: (an example is given in paragraph (6)).

Appropriate evidence provided for Engine and Propeller certification should be used for Aircraft certification. For example, the quality of any Aircraft function software, AEH and Aircraft/Engine/Propeller interface logic already demonstrated for Engine or Propeller certification should need no additional substantiation for Aircraft certification.

Aircraft certification should deal with the specific precautions taken in respect of the physical and functional interfaces with the Engine/Propeller.

6. TABLE

An example of distribution between Engine and Aircraft certification. (When necessary, a similar approach should be taken for Propeller applications).

TASK	SUBSTANTIATION UNDER CS-E	SUBSTANTIATION UNDER CS-25	
		with Engine data	with Aircraft data
ENGINE CONTROL AND PROTECTION	- Safety objective - Software level and AEH DAL	- Consideration of common mode effects (including software and AEH) - Reliability - Software level and AEH DAL	
MONITORING	- Independence of control and monitoring parameters	- Monitoring parameter reliability	- Indication system reliability - Independence Engine/ Engine
AIRCRAFT DATA	- Protection of Engine from Aircraft data failures - Software level and AEH DAL		- Aircraft data reliability - Independence Engine/ Engine
THRUST REVERSER CONTROL/ MONITORING	- Software level and AEH DAL	- System reliability - Architecture - Consideration of common mode effects (including software and AEH)	- Safety objectives
CONTROL SYSTEM ELECTRICAL SUPPLY	- Reliability or quality Requirement of Aircraft supply, if used		- Reliability of quality of Aircraft supply, if used - Independence Engine/ Engine
ENVIRONMENTAL CONDITIONS	- Equipment protection	- Declared capability	- Aircraft design
LIGHTNING AND OTHER ELECTROMAGNETIC EFFECTS	- Equipment protection Electromagnetic emissions	- Declared capability - Declared emissions	- Aircraft wiring protection and electromagnetic compatibility
FIRE PROTECTION	- Equipment protection	- Declared capability	- Aircraft design

3.1.2. AMC 20-2A

1. <u>AMC 20-2A is amended as follows</u>:

AMC 20-2~~A~~B
Certification of Essential APU Equipped with Electronic Controls

[…]

4 PRECAUTIONS

4.1 *General*

The introduction of electronic technology can entail the following:

(a) A greater interdependence of the ~~APU~~Engine, or Propeller, and~~ on the~~ ~~a~~Aircraft owing to the ~~use~~exchange of electrical power and/or data between them~~ supplied from the aircraft~~,

(b) Risk of significant failures which might, for example, occur as a result of -

(i) Insufficient protection from electromagnetic disturbance (lightning, internal or external radiation effects),

(ii) Insufficient integrity of the aircraft electrical power supply,

(iii) Insufficient integrity of data supplied from the aircraft,

(iv) Hidden design faults or discrepancies contained within the design of the APU control software/airborne electronic hardware (AEH),

or

(v) Omissions or errors in the system specification.

~~Special~~Appropriate design and integration precautions must therefore be taken to minimise these risks.

4.2 *Objective*

The introduction of electronic control systems should provide for the aircraft at least the equivalent safety, and the related reliability level, as achieved by essential APU equipped with hydro-mechanical control and protection systems.

This objective, when defined during the aircraft/APU certification for a specific application, will be agreed with the Agency.

4.3 *Precautions relating to APU control, protection and monitoring*

The software and AEH associated with APU control, protection and monitoring functions must have a software level and AEH development assurance level (DAL) and architecture appropriate to their criticality~~ (see paragraph 4.2)~~.

For digital systems, any residual errors not activated during the software/AEH development and certification process could cause an unacceptable failure. The latest edition of AMC 20-115 (or ED-80 for AEH) constitutes an acceptable means of compliance for software (or AEH) development, verification and software (or AEH) aspects of certification. The APU software level and AEH DAL should be determined by the APU and Aircraft/system safety assessment process; ED-79A/ARP4754A and ARP 4761 provide guidance on how to conduct an Aircraft/APU/system safety assessment processat least level B according to the industry documents referred in the latest edition of AMC 20-115. In some specific cases, level A may be more appropriate.

It should be noted the software disciplines described in the latest edition of AMC 20-115 (or AEH in ED-80) may not, in themselves, be sufficient to ensure that the overall system safety and reliability targets have been achieved. This is particularly true for certain critical systems, such as fully authority digital control systems. In such cases it is accepted that other measures, usually within the system, in addition to a high level of software/AEH discipline may be necessary to achieve these safety objectives and demonstrate that they have been met.

It is outside the scope of the latest edition of AMC 20-115 to suggest or specify these measures, but in accepting that they may be necessary, it is also the intention to encourage the development of software/AEH techniques which could support meeting the overall system safety objectives.

[…]

5 INTERRELATION BETWEEN APU AND AIRCRAFT CERTIFICATION

5.1 *Objective*

To satisfy the CS aircraft requirements, such as CS 25A901, CS 25A903 and CS 25.1309, an analysis of the consequences of failures of the system on the aircraft has to be made. It should be ensured that the software levels, AEH DAL and safety and reliability objectives for the electronic control system are consistent with these requirements.

5.2 *Interface definition*

The interface has to be identified for the hardwareAEH and software aspects between the APU and aircraft systems in the appropriate documents.

The APU documents should cover in particular -

(a) The software quality level and AEH DAL (per function if necessary),

(b) The reliability objectives for -

APU shut-down in flight,

Loss of APU control or significant change in performance,

Transmission of faulty parameters,

(c) The degree of protection against lightning or other electromagnetic effects (e.g. level of induced voltages that can be supported at the interfaces),

(d) APU and aircraft interface data and characteristics, and

(e) Aircraft power supply and characteristics (if relevant).

5.3 *Distribution of compliance demonstrations*

The certification of the APU equipped with electronic controls and of the aircraft may be shared between the APU certification and aircraft certification. The distribution between the APU certification and the aircraft certification must be identified and agreed with the Agency and/or the appropriate APU and aircraft Authorities (an example is given in appendix).

Appropriate evidence provided for APU certification should be used for aircraft certification. For example, the quality of any aircraft function software/AEH and aircraft/APU interface logic already demonstrated for APU certification should need no additional substantiation for aircraft certification.

Aircraft certification must deal with the specific precautions taken in respect of the physical and functional interfaces with the APU.

APPENDIX

An example of tasks distribution between APU and aircraft certification

FUNCTIONS OR INSTALLATION CONDITIONS	SUBSTANTIATION UNDER CS-APU	SUBSTANTIATION UNDER CS-25	
APU CONTROL AND PROTECTION	- Safety objective - Software level and AEH DAL	- Reliability - Software level and AEH DAL	
MONITORING	- Independence of control and monitoring parameters	- Monitoring parameter reliability	- Indication system reliability
AIRCRAFT DATA	- Protection of APU from aircraft data failures - Software level and AEH DAL		- Aircraft data reliability
CONTROL SYSTEM ELECTRICAL SUPPLY			- Reliability and quality of aircraft supply if used

3.1.3. AMC 20-3A

1. AMC 20-3A is amended as follows:

AMC 20-3~~A~~B
Certification of Engines Equipped with Electronic Engine Control Systems

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(d) Acceptable LOTC/LOPC rate (i) For turbine Engines

(i) For turbine Engines

(ii) For piston Engines

(e) LOTC/LOPC Analysis

(f) Commercial or Industrial Grade Electronic Parts.

(g) Single Fault Accommodation

(h) Local Events

(8) SYSTEM SAFETY ASSESSMENT

(a) Scope of the assessment

(b) Criteria

(i) Compliance with CS-E 510 or CS-E 210, as appropriate.

(ii) For Failures leading to LOTC/LOPC events

(iii) For Failures affecting Engine operability but not leading to LOTC/LOPC events

(iv) The consequence of the transmission of a faulty parameter

(c) Malfunctions or Faults affecting thrust or power.

(9) PROTECTIVE FUNCTIONS

(a) Rotor Over-speed Protection.

(b) Other protective functions

(10) SOFTWARE and AEH DESIGN AND IMPLEMENTATION

(a) Objective

(b) Approved Methods

(c) Software/AEH ~~L~~level of software design assurance

(d) On-Board or Field Software Loading and Part Number Marking

(e) Software Change Category

(f) Software Changes by Others than the TC Holder

(11) PROGRAMMABLE LOGIC DEVICES

(12) AIRCRAFT-SUPPLIED DATA

(a) Objective

(b) Background

(c) Design assessment

(d) Effects on the Engine

(e) Validation

(13) AIRCRAFT SUPPLIED ELECTRICAL POWER

(a) Objective

(b) Electrical power sources

(c) Analysis of the design architecture

(d) Aircraft-Supplied Power Reliability

(e) Aircraft Supplied Power Quality

(f) Effects on the Engine

(g) Validation

(14) PISTON ENGINES

(15) ENGINE, PROPELLER AND AIRCRAFT SYSTEMS INTEGRATION AND INTER-RELATION BETWEEN ENGINE, PROPELLER AND AIRCRAFT CERTIFICATION ACTIVITIES

(a) Aircraft or Propeller Functions Integrated into the Engine Control System

(b) Integration of Engine Control Functions into Aircraft Systems

(c) Certification activities

(i) Objective

(ii) Interface Definition and System Responsibilities

(iii) Distribution of Compliance Tasks

[…]

(2) SCOPE

This acceptable means of compliance is relevant to Engine certification specifications for EECS, whether using electrical or electronic (analogue or digital) technology. This is in addition to other acceptable means of compliance such as AMC E 50 or AMC E 80.

It gives guidance on the precautions to be taken for the use of electrical and electronic technology for Engine control, protection, limiting and monitoring functions, and, where applicable, for integration of aircraft or Propeller functions. In these latter cases, this document is applicable to such functions integrated into the EECS, but only to the extent that these functions affect compliance with CS-E specifications.

The text deals mainly with the thrust and power functions of an EECS, since this is the prime function of the Engine. However, there are many other functions, such as bleed valve control, that may be integrated into the system for operability reasons. The principles outlined in this AMC apply to the whole system.

This document also discusses the division of compliance tasks for certification between the applicants for Engine, Propeller (when applicable) and aircraft type certificates. This guidance relates to issues to be considered during engine certification. AMC 20-1 addresses issues associated with the engine installation in the aircraft.

The introduction of electrical and electronic technology can entail the following:

- a greater dependence of the Engine on the aircraft owing to the increased use of electrical power or data supplied from the aircraft,
- an increased integration of control and related indication functions,
- an increased risk of significant Failures common to more than one Engine of the aircraft which might, for example, occur as a result of:

– Insufficient protection from electromagnetic disturbance (lightning, internal or external radiation effects) (see CS-E 50 (a)(1), CS E-80 and CS-E 170),

– Insufficient integrity of the aircraft electrical power supply (see CS-E 50 (h)),

– Insufficient integrity of data supplied from the aircraft (see CS-E 50 (g)),

– Hidden design Faults or discrepancies contained within the design of the propulsion system control software or ~~complex~~airborne electronic hardware (AEH) (see CS-E 50 (f)), or

– Omissions or errors in the system/software/AEH specification (see CS-E 50 (f)).

Special design and integration precautions should therefore be taken to minimise any adverse effects from the above.

[…]

(6) SYSTEM DESIGN AND VALIDATION

[…]

(e) Environmental conditions

Environmental conditions include EMI, HIRF and lightning. The environmental conditions are addressed under CS E-80 and CS-E 170. The following provides additional guidance for EMI, HIRF and lightning.

(i) Declared levels

When the installation is known during the Engine type certification programme, the Engine Control System should be tested at levels that have been determined and agreed by the Engine and aircraft applicants. It is assumed that, by this agreement, the installation can meet the aircraft certification specifications. Successful completion of the testing to the agreed levels would be accepted for Engine type certification. This, however, may make the possibility of installing the Engine dependent on a specific aircraft.

If the aircraft installation is not known or defined at the time of the Engine certification, in order to determine the levels to be declared for the Engine certification, the Engine applicant may use the external threat level defined at the aircraft level and use assumptions on installation attenuation effects.

If none of the options defined above are available, it is recommended that the procedures and minimum default levels for HIRF testing are agreed with the Agency.

(ii) Test procedures

(A) General

The installed Engine Control System, including representative Engine-aircraft interface cables, should be the basis for certification testing.

Electro-Magnetic Interference (EMI) test procedures and test levels conducted in accordance with MIL-STD-461 or EUROCAE ED 14/DO-160 have been considered acceptable.

The applicant should use the HIRF test guidelines provided in EUROCAE ED 14/RTCA DO-160 or equivalent. However, it should be recognised that the tests defined in EUROCAE ED 14/RTCA DO-160 are applicable at a component test level, requiring the applicant to adapt these test procedures to a system level HIRF test to demonstrate compliance with CS-E 80 and CS-E 170.

For lightning tests, the guidelines of SAE ARP 5412, 5413, 5414, and 5416 and EUROCAE ED 14/RTCA DO-160 would be applicable.

Pin Injection Tests (PIT) are normally conducted as component tests on the EECS unit and other system components as required. PIT levels are selected as appropriate from the tables of EUROCAE ED 14/DO-160.

Environmental tests such as MIL-STD-810 may be accepted in lieu of EUROCAE ED-14/DO-160 tests where these tests are equal to or more rigorous than those defined in EUROCAE ED 14/DO-160.

(B) Open loop and Closed loop Testing

HIRF and lightning tests should be conducted as system tests on closed loop or open loop laboratory set-ups.

The closed loop set-up is usually provided with hydraulic pressure to move actuators to close the inner actuating loops. A simplified Engine simulation may be used to close the outer Engine loop.

Testing should be conducted with the Engine Control System controlling at the most sensitive operating point, as selected and detailed in the test plans by the applicant. The system should be exposed to the HIRF and lightning environmental threats while operating at the selected condition. There may be a different operating point for HIRF and lightning environmental threats.

For tests in open and closed loop set ups, the following factors should also be considered:

- If special EECS test software is used, that software should be developed at a level determined by the Engine safety assessment process~~and implemented by guidelines defined for software levels of at least software level C as defined in the industry documents referred in the latest edition of AMC 20-115~~.
- The Engine control system should be tested at levels that have been determined and agreed by the Engine and aircraft applicants. It is assumed that by this agreement, the installation meets the aircraft certification specifications. In some cases, the application code is modified to include the required test code features.

- The system test set-up should be capable of monitoring both the output drive signals and the input signals.
- Anomalies observed during open loop testing on inputs or outputs should be duplicated on the Engine simulation to determine whether the resulting power or thrust perturbations comply with the pass/fail criteria.

(iii) Pass/Fail Criteria

The pass/fail criteria of CS-E 170 for HIRF and lightning should be interpreted as 'no adverse effect' on the functionality of the system.

The following are considered adverse effects:

- A greater than 3 % change of Take-off Power or Thrust for a period of more than two seconds.
- Transfers to alternate channels, Back-up Systems, or Alternate Modes.
- Component damage.
- False annunciation to the crew which could cause unnecessary or inappropriate crew action.
- Erroneous operation of protection systems, such as over-speed or thrust reverser circuits.

~~Hardware~~AEH or ~~S~~software design changes implemented after initial environmental testing should be evaluated for their effects with respect to the EMI, HIRF and lightning environment.

(iv) Maintenance Actions

CS-E 25 requires that the applicant prepare Instructions for Continued Airworthiness (ICA). This includes a maintenance plan. Therefore, for any protection system that is part of the type design of the Engine Control System and is required by the system to meet the qualified levels of EMI, HIRF and lightning, a maintenance plan should be provided to ensure the continued airworthiness for the parts of the installed system which are supplied by the Engine type certificate holder.

The maintenance actions to be considered include periodic inspections or tests for required structural shielding, wire shields, connectors, and equipment protection components. Inspections or tests when the part is exposed may also be considered. The applicant should provide the engineering validation and substantiation of these maintenance actions.

(v) Time Limited Dispatch (TLD) Environmental Tests

Although TLD is only an optional requirement for certification (see CS-E 1000 and CS-E 1030), EMI, HIRF and lightning tests for TLD are usually conducted together with tests conducted for certification. Acceptable means of compliance are provided in AMC E 1030.

[…]

(10) SOFTWARE AND AEH DESIGN AND IMPLEMENTATION

(a) Objective

For Engine Control Systems that use software/AEH, the objective of CS-E 50 (f) is to prevent as far as possible software/AEH errors that would result in an unacceptable effect on power or thrust, or any unsafe condition.

It is understood that it may be impossible to establish with certainty that the software/AEH has been designed without errors. However, if the applicant uses the software/AEH level appropriate for the criticality of the performed functions and uses approved software/AEH development and verification processes, the Agency would consider the software/AEH to be compliant with the requirement to minimise errors. In multiple Engine installations, the possibility of software/AEH errors common to more than one Engine Control System may determine the criticality level of the software/AEH.

(b) Approved Methods

Methods for developing software/AEH, compliant with the guidelines contained in the latest edition of AMC 20-115 and ED-80 are acceptable methods. Alternative methods for developing software/AEH may be proposed by the applicant and are subject to approval by the Agency.

Software/AEH which was not developed using the version of ED-12 referenced in the latest edition of AMC 20-115 or ED-80 is referred to as legacy software/AEH. In general, changes made to legacy software/AEH applicable to its original installation are assured in the same manner as the original certification. When legacy software/AEH is used in a new aircraft installation that requires the latest edition of AMC 20-115 or ED-80, the original approval of the legacy software/AEH is still valid, assuming equivalence to the required software/AEH level can be ascertained. If the software/AEH development method equivalence is acceptable to the Agency taking into account the conditions defined in the latest edition of AMC 20-115 or ED-80 for AEH, the legacy software/AEH can be used in the new installation that requires AMC 20-115 software or ED-80 for AEH. If equivalence cannot be substantiated, all the software changes should be assured through the use of the latest edition of AMC 20-115 for software or ED-80 for AEH.

(c) Software/AEH Level of software design assurance

In multiple Engine installations, the design, implementation and verification of the software in accordance with Level A (as defined in the industry documents referred in the latest edition of AMC 20-115) is normally needed to achieve the certification objectives for aircraft to be type certificated under CS-25, CS-27-Category A and CS-29-Category A.

The criticality of functions on other aircraft may be different, and therefore, a different level of software development assurance may be acceptable. For example, in the case of a piston engine in a single-engine aircraft, level C (as defined in the industry documents referred in the latest edition of AMC 20-115) software has been found to be acceptable.

The software/AEH level is determined by the Engine safety assessment process. ED-79A/ARP4754A and ARP 4761 provide guidance on how to conduct an aircraft/Engine/system safety assessment process. The Engine software/AEH should be developed at levels that have been determined and agreed by the Engine and aircraft applicants. It is assumed that by this agreement, the aircraft certification specifications are met.

Determination of the appropriate software/AEH level may depend on the Failure modes and consequences of those Failures. For example, it is possible that Failures resulting in significant thrust or power increases or oscillations may be more severe than an Engine shutdown, and therefore, the possibility of these types of Failures should be considered when selecting a given software/AEH level.

It may be possible to partition non-critical software from the critical software and design and implement the non-critical software to a lower level as defined by the industry documents referred in the latest edition of AMC 20-115. The adequacy of the partitioning method should be demonstrated. This demonstration should consider whether the partitioned lower software levels are appropriate for any anticipated installations including appropriate AEH levels. Should the criticality level be higher in subsequent installations, it would be difficult to raise the software/AEH level.

[…]

(11) AIRBORNE ELECTRONIC HARDWARE (AEH)~~PROGRAMMABLE LOGIC DEVICES~~

CS-E 50 (f) applies to devices referred to as AEH components~~Progammable Logic Devices~~.

Because of the nature and complexity of systems containing digital logic, the AEH components~~Programmable Logic Devices~~ should be developed using a structured development approach, commensurate with the hazard associated with Failure or malfunction of the system in which the device is contained.

RTCA DO-254/ EUROCAE ED-80 which describes the standards for the criticality and design assurance levels associated with AEH components~~Programmable Logic Devices~~ development, is an acceptable means, but not the only means, for showing compliance with CS-E 50 (f).

For off-the-shelf equipment or modified equipment, service experience may be used in showing compliance to these standards. This should be acceptable provided the worst case Failure or malfunction of the device for the new installation is no more severe than that for original installation of the same equipment on another installation. Consideration should also be given to any significant differences related to environmental, operational or the category of the aircraft where the original system was installed and certified.

[…]

(15) ENGINE, PROPELLER AND AIRCRAFT SYSTEMS INTEGRATION AND INTER-RELATION BETWEEN ENGINE, PROPELLER AND AIRCRAFT CERTIFICATION ACTIVITIES

[…]

(c) Certification activities

(i) Objective

To satisfy the aircraft specifications, such as CS 25.901, CS 25.903 and CS 25.1309, an analysis of the consequences of Failures of the Engine Control System on the aircraft has to be made. The Engine applicant should, together with the aircraft applicant, ensure that the software/AEH levels and safety and reliability objectives for the Engine electronic control system are consistent with these specifications.

(ii) Interface Definition and System Responsibilities

System responsibilities as well as interface definitions should be identified for the functional and hardware and software aspects between the Engine, Propeller and the aircraft systems in the appropriate documents.

- The Engine/Propeller/aircraft documents should cover in particular:
- Functional requirements and criticality (which may be based on Engine, Propeller and aircraft considerations)
- Fault Accommodation strategies
- Maintenance strategies
- The software/AEH level (per function if necessary),
- The reliability objectives for:
  - — LOTC/LOPC events
  - — Transmission of faulty parameters
- The environmental requirements including the degree of protection against lightning or other electromagnetic effects (e.g. level of induced voltages that can be supported at the interfaces)
- Engine, Propeller and aircraft interface data and characteristics
- Aircraft power supply requirements and characteristics (if relevant).

(iii) Distribution of Compliance Tasks

The tasks for the certification of the aircraft propulsion system equipped with Electronic Engine Control Systems may be shared between the Engine, Propeller and aircraft applicants. The distribution of these tasks between the applicants should be identified and agreed with the appropriate Engine, Propeller and aircraft authorities. For further information refer to AMC 20-1.

The aircraft certification should deal with the overall integration of the Engine and Propeller in compliance with the applicable aircraft specifications.

The Engine certification will address the functional aspects of the Engine Control System in compliance with the applicable Engine specifications.

Appropriate evidence provided for Engine certification should be used for aircraft certification. For example, the quality of any aircraft function software/AEH and aircraft/Engine interface logic already demonstrated for Engine certification should need no additional substantiation for aircraft certification.

Two examples are given below to illustrate this principle.

(A) Case of an EECS performing the functions for the control of the Engine and the functions for the control of the Propeller.

The Engine certification would address all general requirements such as software/AEH quality assurance procedures, EMI, HIRF and lightning protection levels, effects of loss of aircraft-supplied power.

The Engine certification would address the functional aspects for the Engine functions (safety analysis, rate for LOTC/LOPC events, effect of loss of Aircraft-Supplied Data, etc.). The Fault Accommodation logic affecting the control of the Engine, for example, will be reviewed at that time.

The Propeller certification will similarly address the functional aspects for the Propeller functions. The Fault Accommodation logic affecting the control of the Propeller, for example, will be reviewed at that time.

In this example, the Propeller functions and characteristics defined by the Propeller applicant, that are to be provided by the Engine Control System, would normally need to be refined by flight test. The Propeller applicant is responsible for ensuring that these functions and characteristics, that are provided for use during the Engine certification programme, define an airworthy Propeller configuration, even if they have not yet been refined by flight test.

With regard to changes in design, agreement by all parties involved should be reached so that changes to the Engine Control System that affect the Propeller system, or vice versa, do not lead to any inadvertent effects on the other system.

(B) Case of an aircraft computer performing the functions for the control of the Engine.

The aircraft certification will address all general requirements such as software/AEH quality assurance procedures, EMI, HIRF and lightning protection levels.

The aircraft certification will address the functional aspects for the aircraft functions.

The Engine certification will address the functional aspects for the Engine functions (safety analysis, rate for LOTC/LOPC events, effect of loss of Aircraft-Supplied Data, etc.) The Fault Accommodation logic affecting the control of the Engine, for example, will be reviewed at that time.

3.1.4. AMC 20-19

1. New AMC 20-19 is added as follows:

AMC 20-19

Passenger service and in-flight entertainment (IFE) systems

TABLE OF CONTENTS

0 PREAMBLE

This document provides acceptable means of compliance to obtain approval for the installation of in-flight entertainment (IFE) systems. It has been developed on the basis of the Joint Aviation Authorities (JAA) Temporary Guidance Leaflet (TGL) No 17, and addresses the following concerns:

(a) increase in the complexity of the system due to the additional cables as well as in the power needed for the IFE systems;

(b) potential consequences on the aircraft or passengers of system/electrical faults, including risk of smoke, fire and interference with aircraft systems; these concerns are validated by adverse service experience on different types of aircraft;

(c) potential consequences on the aircraft systems due to the transmitting capability of the IFE systems; and

(d) lack of specific guidance on installation of IFE systems as these systems are categorised as non-essential services even though those systems may affect compliance with applicable seat and emergency evacuation provisions.

1 PURPOSE

This AMC has been created to provide guidance to aircraft installers and equipment manufacturers on the airworthiness of IFE systems and equipment installed on civil aircraft. It does not constitute a regulation. It highlights safety concerns about IFE systems and contains acceptable means compliance to address those concerns and obtain airworthiness approval of such systems. An applicant for such an approval may choose an alternative means of compliance provided that the objectives of this AMC are met to the satisfaction of the Agency.

2 RELATED CERTIFICATION SPECIFICATIONS (CSs)

The provisions to which this AMC applies are shown below. These lists are intended for reference only and should not be considered to be comprehensive. Additional CS-25 provisions are referenced where applicable. Provisions with the same number (e.g. CS 25.301) are generally read across the other CSs (e.g. CS 23.301, 27.301, and 29.301). However, please note that in some cases, the same topic is addressed by different provisions (e.g. for a specific CS-25 provision, the corresponding CS-23 provision may have a different number):

- CS 25.301, 303, 305, 307, 333, 337, 341, 365(g), 471, 561, 562, 581, 601, 603, 605, 609, 611, 785, 787, 789, 791, 811, 831, 853, 863, 869, 899, 1301, 1309, 1327, 1351, 1353, 1357, 1360, 1423, 1431, 1441, 1703, 1705, 1707, 1709, 1715, 1719, 1721, 1723;
- CS 23.561, 562, 785, 787, 791, 811, 867, 899, 1301, 1309, 1327, 1328, 1351, 1353, 1357, 1359, 1360, 1431, 1441;
- CS 27.561, 562, 610, 785, 787, 807, 853, 1301, 1309, 1327, 1351, 1353, 1357, 1365; and
- CS 29.561, 562, 610, 785, 787, 807, 853, 1301, 1309, 1327, 1351, 1353, 1357, 1359, 1431.

3 REFERENCE DOCUMENTS

(a) Certification Specifications: CS-23, CS-25, CS-27, CS-29, CS-ETSO.

(b) ED Decision 2013/026/R, AMC-20 — Amendment 10, AMC 20-115C, Software Considerations for Certification of Airborne Systems and Equipment, 12 September 2013.

(c) ED Decision 2014/029/R, AMC and GM to Part-CAT — Issue 2, Amendment 1, Portable electronic devices, 24 September 2014.

(d) EASA Certification Memorandum No CM-ES-001, Certification of Power Supply Systems for Portable Electronic Device, Issue 1, 7 June 2012.

(e) Annex I (Part-21)to Regulation (EU) No 748/2012.

(f) Annex III (Part-ORO) and Annex III (Part-CAT) to Regulation (EU) No 965/2012 (Air Operations).

(g) International Civil Aviation Organization (ICAO) Doc 9284-AN/905, Instructions for the safe transport of dangerous goods by air (Addendum No 2), 30 June 2005.

(h) Federal Aviation Administration (FAA) Advisory Circular (AC) 21-16, RTCA DO-160, Revision G, Environmental Conditions and Test Procedures for Airborne Equipment, December 2010.

(i) FAA Policy Memorandum PS-ANM100-2000-00105 (also numbered 00-111-160), Interim Policy Guidance for Certification of In-Flight Entertainment Systems on Title 14 CFR Part 25 Aircraft (Policy Number 00-111-160), 18 September 2011.

(j) FAA AC 91.21-1C, Use of Portable Electronic Devices Aboard Aircraft, 7 May 2015.

(k) FAA AC 20.168, Certification Guidance for Installation of Non-Essential, Non-Required Aircraft Cabin Systems & Equipment (CS&E), 21 July 2010.

(l) FAA AC 20.115C, Airborne Software Assurance, 19 July 2013.

(m) FAA AC 21.49, Gaining Approval of Seats with Integrated Electronic Components, 9 February 2011.

(n) European Organization for Civil Aviation Equipment (EUROCAE) ED-80, Design Assurance Guidance for Airborne Electronic Hardware, 19 April 2000.

(o) EUROCAE ED-14, RTCA DO-160, Environmental Conditions and Test Procedures for Airborne Equipment, December 2010.

(p) EUROCAE ED-12, RTCA DO-178 Software Considerations in Airborne Systems and Equipment Certification, 1 December 1992.

(q) EUROCAE ED-130, Guidance for the Use of Portable Electronic Devices (PEDs) on Board Aircraft, 1 December 2006.

(r) Radio Technical Commission for Aeronautics (RTCA) DO-254, Design Assurance Guidance for Airborne Electronic Hardware, 19 April 2000.

(s) RTCA DO-199, Potential Interference to Aircraft Electronic Equipment from Devices Carried Aboard (Vols I and II), 16 September 1988.

(t) RTCA DO-227, Minimum Operational Performance Standards for Lithium Batteries, 23 June 1995.

(u) RTCA DO-294, Guidance on Allowing Transmitting Portable Electronic Devices, Revision C, 12 December 2008

(v) RTCA DO-307, Aircraft Design and Certification for Portable Electronic Device (PED) Tolerance, Revision A, 11 October 2007

(w) RTCA DO-313, Certification Guidance for Installation of Non-Essential, Non-Required Aircraft Cabin Systems and Equipment, 2 October 2008.

(x) Society of Automotive Engineers Aerospace Recommended Practice (SAE ARP) 5475, Abuse Load Testing for In-Seat Deployable Video Systems, 20 June 2005.

(y) Aeronautical Radio, Incorporated (ARINC) 628, Cabin Equipment Interfaces, 27 December 1993.

(z) MIL-STD-1472G, Human Engineering, 11 January 2012.

3.1 Abbreviations

The following abbreviations are used in this AMC:

AC	advisory circular
AFM	aircraft flight manual
AMC	acceptable means of compliance
AMM	aircraft maintenance manual
ARP	aerospace recommended practice
CB	circuit breaker
CCOM	cabin crew operation manual
COTS	commercial off-the-shelf
CRI	certification review item
CSs	certification specifications
DAH	design approval holder
DDP	declaration of design and performance
DBS	direct-broadcast satellite
ELA	electrical-load analysis
EMI	electromagnetic interference
ESD	electrostatic discharge
ETSO	European technical standard order
EWIS	electrical-wiring interconnection system
FCOM	flight crew operation manual
FDAL	functional development assurance level
FHA	functional hazard assessment

GM	guidance material
GSM	global system for mobile communications
GUI	graphical user interface
ICA	instructions for continued airworthiness
ICAO	International Civil Aviation Organization
IDAL	item development assurance level
IEEE	Institute of Electrical and Electronics Engineers
IFE	in-flight entertainment
LAN	local area network
MCA	mobile communications on aircraft
MMEL	master minimum equipment list
MOC	means of compliance
OEM	original-equipment manufacturer
PA	public address
PABX	private automatic branch exchange
PED	portable electronic device
PFIS	passenger flight information system
PSS	power supply system
RTCA	Radio Technical Commission for Aeronautics
R/T	real-time
SAE ARP	Society of Automotive Engineers Aerospace Recommended Practice
SP	special condition
STC	supplemental type certificate
SWPM	standard wiring practices manual
TC	type certificate
T-PED	transmitting portable electronic device
USB	universal serial bus
VAC	volts alternating-current
VDC	volts direct-current
Wi-Fi	wireless fidelity
WLAN	wireless local area network

3.2 Definitions

The following definitions are used in this AMC:

Term	Definition
Installer	Type certificate (TC), supplemental type certificate (STC) or design approval holder (DAH)
Agency	European Aviation Safety Agency (EASA)
COTS equipment	Equipment not designed and manufactured for use in aircraft, but purchased by the installer for use in a particular aircraft system

4 SCOPE

Communication, information and entertainment systems are often provided for the convenience of aircraft passengers. As customer services improve, those systems are becoming more sophisticated and complex. Subsystem design features are often unique, based on the needs of operators, thus leading to many different possible IFE system configurations that depend both on specific operator requirements and cabin layout.

Within the scope of this AMC, IFE systems are defined as 'on-board systems providing passengers with (safety) information, connectivity and entertainment'.

The following non-exhaustive list contains some examples of IFE systems:

(a) systems providing passengers with audio entertainment and the related controls;

(b) systems providing passengers with video entertainment and the related controls;

(c) passenger flight information systems (PFISs);

(d) systems providing passengers with information, e.g. safety videos;

(e) interfaces to, and functions of, systems for controlling some cabin environment parameters as, for example, reading lights, general cabin illumination, crew call buttons, air vents, etc.;

(f) systems providing passengers with wired and/or wireless data distribution for entertainment connectivity including television (TV), communication access (i.e. telephone, internet); and

(g) systems providing passengers with power supply with various outlet types (e.g. 220 volts alternating-current (VAC), 5 volts direct-current (VDC) with universal serial bus (USB), etc.).

The aim of this AMC is to provide general criteria for the approval of such systems and equipment as installed in aircraft. The following aspects are addressed: mechanical installation, electrical installation, software/hardware aspects, electromagnetic compatibility, as well as assessment of the potential hazards. In some cases, the application of this AMC, in conjunction with the certification basis for the product, is deemed sufficient.

For certain systems and equipment, additional certification material may be needed to address aspects not covered by this AMC. Below some examples:

- IFEs with wireless-communication capabilities (wireless fidelity (Wi-Fi) access points, mobile-phone systems);
- electrical outlets installed in the cabin for connection of portable electronic devices (PEDs);
- lithium batteries;
- data-loading systems;
- data communication systems (satellite TV, radio, passenger telephone systems, etc.); and
- large monitors/displays.

5 APPROVAL CONSIDERATIONS (AT AIRCRAFT LEVEL)

Section 6 below provides a summary of the issues pertinent to the safety of the aircraft, its occupants and maintenance personnel, which the equipment manufacturer and the installer should consider. Since IFE installations are typical for commercially-used large aeroplanes, it is expected that the approach to be followed for General Aviation (GA) aircraft is different. Section 6.7 below provides guidance in this regard. Some general considerations are presented below:

(a) The applicant for approval of an IFE system should demonstrate continued compliance with the aircraft certification basis. The applicable airworthiness provisions depend on the aircraft on which the IFE system is to be installed. The installed system should function as intended and no 'credit' should be given for its performance capability. Substantiation is required to demonstrate that the IFE system and equipment in their installation and operation do not interfere with the operation of other aircraft systems, or cause any hazard to the aircraft, its occupants, and maintenance personnel.

(b) Where part of an IFE system is designed to transmit required safety information (e.g. passenger briefing), the replacement system should also meet the safety objectives required for that function. The installer should identify these safety objectives depending on the type of function the IFE is used for.

(c) The applicant may use existing approvals for interfacing equipment (e.g. IFE parts mounted in seat). However, the applicant should ensure that all applicable airworthiness provisions are addressed. For example, European technical standard orders (ETSOs) on seats do not contain electrical provisions, therefore, the electrical aspects of the seat should be reviewed to ensure that the installation of IFE equipment does not invalidate the original seat ETSO.

(d) If other aircraft system installations are affected by the installation of the IFE system equipment, then the applicable requirements for these affected systems should be taken into account.

(e) Where an IFE system is designed to be available for the operating crew, the Agency should approved the related flight operation limitations.

(f) The applicant should demonstrate that all non-essential equipment (which includes equipment installed for the purpose of passenger entertainment), as installed:

  – is not a source of danger in itself;

  – is not a prejudice to the proper functioning of an essential service; and

– does not in any way reduce the airworthiness of the aircraft to which it is fitted even in the event of failure to perform its intended functions.

For example, large aeroplanes should demonstrate compliance with CS 25.1309. A functional hazard assessment should be performed to identify the IFE system failure scenarios and worst possible consequences on aircraft and occupants (e.g. electrical shock). This assessment should take into account electrical, electronic, and component faults that may result in a short circuit, and/or electrical arcing, and/or release of smoke. Particular attention should be given to the likelihood of the following:

– accidental damage due to exposure of wirings and components in the cabin, such as pinched wires in the seat track;

– misuse of the equipment by passengers, such as incorrect stowage of video screens, stepping on or kicking the seat electronic box, spilling liquids, etc.;

– electronic-component breakdown; and

– wire chafing.

(g) The installer should demonstrate that the IFE system equipment has been installed in accordance with the equipment manufacturer's declaration of design and performance (DDP) and installation instructions. Demonstration may, in addition, involve examination and testing of the equipment. Subpart O 'EUROPEAN TECHNICAL STANDARD ORDER AUTHORISATIONS' of Annex I (Part-21) to Regulation (EU) No 748/2012 and the related AMC 21.A.608 provide, respectively, requirements and guidance on drafting and formatting the DDP.

(h) If an operator allows passengers to use PEDs on board the aircraft, it should have procedures in place to control the use of those PEDs. Regulation (EU) No 965/2012 and the related ED Decisions contain, respectively, requirements and associated AMC/GM on PEDs. For commercial air transport (CAT) operations, the corresponding requirement is CAT.GEN.MPA.140.

(i) In case an environmental testing of the IFE system equipment is required, RTCA DO-160 'Environmental Conditions and Test Procedures for Airborne Equipment' may be followed. This is addressed in Section 0 below.

6 SYSTEMS INSTALLATION

6.1 Mechanical system aspects

6.1.1 Equipment location

The equipment and its controls should be positioned in locations where they do not impede flight crew and cabin crew movement (including crew rest areas) and their duties, as well as normal passenger movement.

(a) In a light aircraft, for example, if audio entertainment is audible to the pilot, means to control the sound level should be provided to the pilot. Visual-entertainment equipment should be located where it does not distract the crew.

(b) Equipment should be located and, where necessary, protected to minimise the risk of injury to the occupants of the aircraft during a normal flight or an emergency landing. For equipment with cords in large aeroplanes, for example, the cords' length should be determined by its possible effect on the egress capability. The cords should not span across a main aisle such that they may be entangled in other features (such as armrests), thus impeding egress. Means for proper and easy stowage should be provided.

(c) Equipment used for screens should not obscure required notices and information signs (e.g. 'Exit', 'No Smoking', 'Fasten Seat Belt' signs, etc.). For video monitors in large-aeroplane installations, the following should apply:

(i) For video monitors installed above the aisle:

– all installations should be such that the required exit signs are still visible whether the monitors are fixed or retractable; if this is not possible, additional signs are required;

– fixed video monitors should be such that the minimum distance between cabin floor and the lowest point of the monitor is 185 cm (73 in.); and

– retractable video monitors not meeting the 185-cm (73-in.) limit in the deployed position should not have sharp edges or should be padded, and they should be able to be stowed manually without requiring exceptional strength.

(ii) For video monitors installed underneath overhead compartments:

– all installations should be such that the required signs (e.g. 'No Smoking', 'Fasten Seat Belts' signs, etc.) are visible whether the monitors are fixed or retractable; if this is not possible, additional signs are required;

– fixed video monitors should be padded and not be installed above and between seat backs of seat rows bordering the access to emergency exits; and

– retractable video monitors should be able to be stowed manually without requiring exceptional strength and not be installed above and between seat backs of seat rows bordering the access to emergency exits.

(d) Connecting units for wired on-board data exchange (USB, local area network (LAN), etc.) should be designed so that their use is obvious to the crew and passengers. Placards close to their outlet units should describe their capabilities and functions.

Units with capability of power supply with:

- voltage higher than or equal to 42 V; or
- power higher than 10 W; or
- current higher than 2 A

should be treated as power outlets.

(e) For individual video monitors attached to the seats (e.g. seat armrest, seat back, movable hinge arms), the protection of seat occupants as well as of crew and passengers moving about the cabin should be considered. Video monitor installations should be such that injury due to contact with sharp edges/corners during normal operation and turbulence is avoided. Abuse loading of video monitors (e.g. if a passenger leans on the monitor when taking or leaving the seat) should be accounted for. The criteria of SAE ARP 5475 'Abuse Load Testing for In-Seat Deployable Video Systems' or alternatives, as agreed by the Agency, may be used in assessing designs from this aspect.

6.1.2 Construction and attachment strength

(a) Any seat/monument installation, after modification, should continue to comply with the original certification basis.

(b) Equipment, attachments, supporting structures, and their constituent parts should be constructed such that they do not break loose when subjected to the loads (both for flight and emergency alighting) prescribed in the relevant CSs. Commercial off-the-shelf (COTS) equipment may not comply with these provisions and may need to be strengthened before being installed in an aircraft (see Section 6.6 below on COTS equipment).

(c) The design of IFE system-related antennas, their location and manner of attachment should be such that there is no adverse effect on aircraft systems and no danger to the aircraft under all foreseeable operating conditions.

Remark: in case of installation of external antennas, the applicant should address the corresponding certification aspects, for which specific guidance is available (i.e. antenna in pressurised areas, installation of big and/or deployable antennas, etc.). The certification approach of such external antenna installations should be agreed with the Agency.

(d) As far as practicable, the equipment should be positioned so that if it breaks loose, it is unlikely to cause injury or nullify escape facilities for use after an emergency landing or alighting on water. When such positioning is not practicable, each such item of equipment should be restrained under any load up to the prescribed ultimate inertia forces for the emergency landing conditions. Furthermore, for each item of equipment that is subject to frequent installation and removal, the local attachments of these items should be designed to withstand 1.33 times the specified loads (see CS 25.561(c)(2)). Compliance to CS 25.365(g) should also be considered.

Note 1: the structural provisions applicable to equipment can vary dependent upon the type and size of the aircraft in which the equipment is installed; if the equipment is designed to be installed in any aircraft, then the applicant should consult all the relevant airworthiness CSs and create an envelope of conditions for design purposes.

Note 2 : in case an STC holder installs the equipment, they may need to consult the TC holder to obtain data on the vertical-acceleration factors (resulting from gusts and aircraft manoeuvres) applicable to an aircraft type and to the proposed equipment location.

(e) If the IFE system is installed in a seat or monument adjacent to a seat, the installation may need to be reapproved for structural integrity and, if appropriate, for the emergency-landing dynamic conditions, including occupant injury criteria. For large aeroplanes, for example, to avoid head injury (CS 25.562(b) and CS 25.562(c), as referenced in CS 25.785) caused by seat-back-mounted IFE equipment, compliance with CS 25.562(c)(5) should be shown for a fully equipped seat back in the take-off and landing position.

(f) Weight and stress assessments should be made in case of already embodied shelves that need to be relocated.

(g) Glass surfaces may be part of IFE system components, e.g. in display units. The potential hazard of large sheets of glass for the occupants in case of breakage should be considered. The approach that the applicant should follow should be agreed with the Agency. Compliance to CS.25.365(g) should also be considered.

6.2 Electrical system aspects

6.2.1 Power supplies

The IFE equipment should be powered by a non-essential power supply (busbar) of the aircraft, i.e. an electrical busbar that does not supply power to aircraft systems necessary for continued safe flight and landing.

The IFE system should be designed to provide circuit protection from overloads and short circuits by means of suitable protective devices.

(a) The method of connection of the equipment to the aircraft electrical system and the operation of the equipment should not adversely affect the reliability and integrity of the electrical system or any other electrical unit or system essential for safe operation.

(b) If applicable, the aircraft electrical system should be protected from any unacceptable electromagnetic interference caused by a connected PED.

(c) The flight/cabin crew should be provided with a clearly labelled and conspicuous means to disconnect an IFE system from its source of power at any time and as close as practical to the source of power. The disabling/deactivating of component outputs should not be considered an acceptable means to cut off power, i.e. the disabling/deactivating of the output of a power supply unit, seat electronic box, etc., as opposed to cutting off the input power of the system. Moreover, pulling system circuit breakers (CBs) as the sole means to cut-off the IFE system power is not considered acceptable. This is because CBs are not normally designed to be used as switches. Pulling and resetting of CBs over a period of time may degrade their trip characteristic and the CBs may not trip when required.

(d) An electrical-load analysis should be carried out, taking into account the maximum load that the IFE may utilise, to substantiate that the aircraft electrical-power generating system has sufficient capacity to safely provide the maximum amount of power required by the IFE to operate properly. The applicant should base the IFE system electrical-load analysis (ELA) on an ELA that accurately reflects the aircraft’s electrical loads prior to the IFE system installation. If this is not available, the applicant should make measurements of the aircraft’s condition prior to the IFE system installation, and use these measurements for the IFE system ELA.

(e) The potential cumulative effect of the installation of multiple IFE units on the harmonic content of the electrical-power supply should be considered. There have been cases where the installation of multiple IFE units with switch mode power supplies has changed the shape of the alternating current (AC) voltage waveform to the extent that the operation of the aircraft electrical power supply system (PSS) has been affected.

(f) Where batteries are used, consideration should be given to stored energy and provisions should be made for protection from short-circuits and other potential failure modes.

The safety issues associated with the use in the IFE system of batteries whose technology may pose hazards not covered by the current provisions should be addressed by additional provisions to be agreed with the Agency (e.g. lithium batteries technology).

6.2.2 Bonding

The electrical bonding as well as the protection against static discharge of the installed system and equipment should be such to:

(a) prevent dangerous accumulation of electrostatic charge; and

(b) minimise the risk of electrical shock to crew, passengers and maintenance personnel.

The system bonding arrangements should be in accordance with the aircraft manufacturer's standard practices and suitable for the conduction of any current, including fault current, which may be necessary to conduct. The designer should take into account bond connections in the system design such that loss of a single bond does not result in the loss of more than one essential circuit or in the dangerous inadvertent operation of any aircraft system.

Cabin equipment designers should adhere to the standard practices for bonding, grounding and shielding, as well as to other methods for eliminating or controlling electrostatic discharge (ESD).

All electrical and electronic equipment and/or components should be installed so as to provide a continuous low-resistance path from their metallic enclosures and wiring to the aircraft bonding structure.

6.2.3 Interference

6.2.3.1 Magnetic effect

Whether the installed IFE equipment is operating or not, the aircraft compass systems should continue to meet the prescribed accuracy standards. Where other equipment approved as part of the aircraft is installed, the installer should take account of the declared compass safe distance at the stage of the installation design.

Account should be taken of the compass safe distance in respect of both the compass and the flux detector. The installer should also consider potential interference of the installed IFE equipment with the relatively low-level signal of the compass system interconnecting cables.

6.2.3.2 Electromagnetic interference (EMI)

The levels of conducted and radiated interference generated by the equipment via power supply feeders, by system interfacing or by EMI should not cause an unacceptable degradation of performance of other aircraft systems. Where equipment or functions are not used, the applicable system function should be properly disabled and/or terminated to prevent interference with other aircraft systems.

(a) Antennas

Antennas for entertainment systems should not be located where an unacceptable reduction in performance of a mandatory radio system would result. In addition, the effects of a lightning strike on these antennas should be considered to ensure that essential services are not disrupted by electrical transients conducted to the aircraft via these antenna leads.

(b) Cumulative interference effect

The actual interference effect in an aircraft receiver may be the cumulative effect of many potentially interfering signals. For this reason, a system consisting of multiple units should be operable even in the worst-case orientation when interference tests/demonstrations are conducted. Tests/demonstrations should take into account critical configurations of use of the IFE system, including critical configurations of passengers' portable electrical or electronic devices connected to the IFE System. The test configuration should be agreed with the Agency.

(c) Flight phases

If the whole IFE system or parts thereof are to be active during critical flight phases (take-off and landing), particular attention should be paid to the demonstration of non-interference during these flight phases. Performing tests as per EUROCAE ED-14/ RTCA DO-160, Section 21 is an acceptable means of demonstrating compliance.

6.2.4 Electrical shock

Occupants should be protected against the hazard of electrical shock. Therefore, the applicant should demonstrate the means to minimise the risk of electrical shock as per CS 25.1360(a). Particular attention should be given to high-voltage equipment. If high- or low-voltage power outlets are available for passenger use, the aspects related to the use of PSSs for PEDs should be considered.

6.2.5 Wiring harness and routing

The electrical-wiring interconnection system (EWIS) associated with the IFE system should be installed, as all other electrical systems, in accordance with the provisions of CS-25, Subpart H, or any equivalent document accepted by the Agency. In order to meet these provisions, the applicant should adhere to the following guidelines:

- the wiring installation should be in accordance with the standard wiring practices manual (SWPM) of the aircraft or any equivalent standard accepted by the Agency;
- standard original-equipment manufacturer (OEM) wiring or compatible types of wiring should be used;
- all data necessary to define the design, including installation drawings and wiring diagrams, should be available, in accordance with 21.A.31 (Annex I (Part-21) to Regulation (EU) No 748/2012); and
- where the IFE system EWIS is routed through standard aircraft wiring looms, spacers or equivalent separation means should be used to keep a minimum distance from any other electrical system in accordance with the SWPM of the aircraft.

In the absence of more specific guidelines in the SWPM of the aircraft, 230 VAC voltage power supply wires should not be routed through standard aeroplane wiring looms. As the EWIS connected to the IFE system is present throughout the cabin (exposed in some cases), the potential for system faults is increased by the wide exposure to varying hazards (e.g. EWIS chafing in the seat tracks, passengers stepping on or kicking the seat electronic box, spilled liquids, etc.). Since these systems are exposed to hazards, the potential to adversely affect other systems necessary for safe operation significantly increases, as well as the possibility of shock hazards to people. Special consideration should be given to the protection against damage to IFE EWIS components installed in the seat itself: they should have appropriate protection means so that passengers cannot damage them with their feet or access them with their hands. Engineering data controlling the installation of IFE EWIS and equipment should contain specific and unambiguous provisions for the routing, support and protection of all IFE EWIS and equipment and should specify all parts necessary for those installations.

Care should be taken to ensure that any electrical IFE equipment installed in aeroplane seat assemblies does not invalidate the seat certification (e.g. applicable ETSO). In addition, it should be noted that compliance with any applicable ETSO on seats does not cover on its own the electrical-equipment-installation aspects of the IFE system.

6.3 Aircraft interaction and interfaces

Where an IFE system is electrically interfaced with other aircraft systems, the performance and integrity of those aircraft systems should not be degraded. Appropriate means to isolate the IFE system from the aircraft systems should be provided.

(a) When an IFE system is connected to the aircraft avionics system (or any other system that may have a safety-related function), the installer should demonstrate that no malfunction of the IFE system may affect the aircraft avionics system. The installer should conduct a safety analysis to substantiate this. Supplementary to this safety analysis, special attention may be required due to cybersecurity issues, where a special condition (SC) may be needed. The installer should assess the information security and take a decision agreed with the Agency.

(b) Where an IFE system is interfacing with the public address (PA) function, the use of this system should not impair audibility of crew commands and instructions. A PA override feature should be considered to allow cabin announcements to be heard by passengers.

(c) Where an IFE system is available for the operating crew, the operation of this system should not interfere with, or adversely affect, the crew’s ability to operate other aircraft systems and respond to alerting systems. The aircraft flight manual (AFM) should contain appropriate limitations and procedures.

The applicant should consider the following design interface features as acceptable means of compliance:

(i) no access to any form of visual entertainment equipment;

(ii) automatic muting of entertainment systems when any cockpit aural caution or warning is sounding; there should be no perceptible delay between muting of the entertainment system and activation of the caution/warning;

(iii) automatic muting of entertainment systems when any real-time (R/T) transmission or reception is in progress; there should be no perceptible delay between muting of the entertainment system and activation of the R/T transmission or reception; and

(iv) readily available controls such that the volume of the entertainment system is easily reduced.

(d) Where an IFE system includes wireless capabilities (wireless local area network (WLAN), mobile phone, Bluetooth, etc.) to connect with other aircraft equipment and/or passenger or crew transmitting portable electronic devices (T-PEDs), the installer should address the aircraft electromagnetic compatibility with the intentional emissions of the IFE system, and the approach to be followed in that respect should be agreed with the Agency.

Note: the responsibility of establishing the suitability of use of a PED on an aircraft model continues to rest with the operator, as required by CAT.GEN.MPA.140 (Annex IV (Part-CAT) to Regulation (EU) No 965/2012).

The design interface features used to comply with the above should be designed with a development rigour depending on the function that is being interfaced or replaced by the IFE.

6.4 Software/hardware

6.4.1 Software architecture

The software architecture of IFE components should consider the following distinction between:

- core software as part of the functional scope defined in the component specification (e.g. operating system, hardware driver, functional applications such as PA), including all required core software configuration data (the core software may be field-loadable); and
- content data, including content configuration data (it may be field-loadable by the aircraft operator); for IFE equipment, the aircraft operator is usually required to make some adjustments and/or changes in the short term; such changes may be related to content data and/or content configuration data — some examples of the latter are the following:
  – selection of passenger-accessible graphical user interface (GUI) elements;
  – activation of predefined GUI designs; and
  – selection of regional information data (e.g. different country borderlines).

A change in the core software requires a component modification or re-design (change of part number), and therefore, leads to a change in the aircraft configuration.

A change in the content data remains in the operational responsibility of the aircraft operator (field-loadable software), and therefore, does not lead to a change in the aircraft configuration.

6.4.2 Software development assurance

The item development assurance level (IDAL) required for the IFE software should be determined through the functional hazard assessment (FHA) that identifies the worst failure the software may contribute to. If the IDAL is equal to IDAL D or greater, AMC 20-115 provides guidance for production of airborne-systems and -equipment software that performs its intended function with a level of confidence in safety compliant with airworthiness provisions. This is an acceptable standard and should be taken into consideration for software in IFE systems, in particular those replacing or interfacing with required functions of the aircraft.

6.4.3 Airborne electronic hardware development assurance

The functional development assurance levels (FDALs) identified through the FHA should be used, in conjunction with system architecture considerations, in order to determine the IDAL to be used for the development of airborne electronic hardware, and to identify the rigour of the development processes used.

For hardware development of IFE systems that replace or interface with required functions of the aircraft, the provisions of CS-ETSO, Subpart A, Section 2.3 apply.

6.5 Other risks

For risks associated with hazards that may be caused by the IFE equipment due to the operating environment of the aircraft, the standard environmental and operational test conditions and test procedures of RTCA/DO-160 may be used in combination with FAA AC 21-16.

The responsibility for selection of the appropriate environmental and operational test conditions and test procedures lies with the installer. Section 6.5.1 below provides guidance on the selection of the test types. Sections 6.5.2, 6.5.3, 6.5.4 below address other associated risks.

6.5.1 Environmental qualification

When the IFE equipment is not linked to other aircraft systems and only connected to a non-essential power busbar, the following is recommended as a minimum list of environmental tests:

- temperature and altitude,
- temperature variation,
- operational shocks and crash safety,
- vibration,
- power input,
- voltage spike, and
- emission of radio frequency energy.

The installer is responsible for selecting the appropriate testing conditions and for agreeing them with the Agency. The assessment of the installation may prove that some of the above test types are unnecessary or, contrarily, that additional tests should be performed.

6.5.2 Touch temperature

In addition to CS 25.1360(b), the following should be considered: hot surfaces of IFE components accessible to crew or passengers should not be exposed where inadvertent contact may pose a hazard.

The definition of MIL-STD-1472G ‘HUMAN ENGINEERING’ applies:

Equipment which, in normal operation, exposes personnel to surface temperatures greater than:

- *For momentary contact: 60°C for metal, 68°C for glass, 85°C for plastic or wood;*
- *For prolonged contact: 49°C for metal, 59°C for glass, 69°C for plastic or wood;*

Or less than 0°C should be appropriately guarded.

6.5.3 Fluid exposure

Where the equipment is mounted in a position where exposure to fluid is possible, for example on or under a passenger seat, or where catering operations take place or liquid cleaning agents are used regularly, it should be established that fluid spillage does not render the equipment hazardous. Where possible, installations in areas susceptible to moisture should be avoided. Otherwise, consideration should be given to minimise the hazard of liquid ingress, e.g. inclusion of drip loops in wiring harnesses and installation of drip trays.

When the approach described above is followed, the fluid susceptibility test may be disregarded.

6.5.4 Rapid decompression and high-altitude operation

The installer should ensure that no arcing causing a fire risk or unacceptable levels of interference will occur in the equipment when the equipment is subjected to an atmospheric pressure corresponding to the maximum operating altitude of the aircraft. Alternatively, means should be provided to automatically disconnect the electrical supply to the equipment when the cabin pressure reduces to a level below which the safe operation of the equipment is not ensured (e.g. rapid decompression). The guidance of RTCA DO-313 in this area may also be followed.

This Section should be followed in addition to the testing conditions of Section 6.5.1.

6.5.5 Explosion, fire, fumes and smoke

(a) The installer should pay particular attention to the quality and design of components such as transformers, motors and composite connectors in order to minimise the risk of overheating. The design of the mounting provisions for IFE components installed in the passenger cabin (e.g. passenger seats, closet/cabin partition walls, overhead compartments, etc.) should fully reflect the cooling provisions for the equipment, including heat sinking, ventilation, proximity to other sources of heat, etc.

(b) All materials should meet the appropriate flammability provisions. Inadvertent blockage (passengers' coats, luggage or litter) of any cooling vents should be prevented either by means of design or by means of operational procedures. Appropriate protection against overheating should be part of the design of such in-seat systems.

(c) For the installation of IFE components in racks, located in the equipment bay, which are not accessible in flight, the installer should address the potential hazard to other essential or critical systems/equipment located in the equipment bay, in case of IFE malfunction. The installer should substantiate that the worst-case scenario of possible malfunction of the IFE system does not affect the components located in the equipment bay, which are necessary for safe flight and landing. This demonstration should account for the risk of:

- overheating,
- smoke release,
- electrical failure, and
- fire propagation.

For large aeroplanes, for example, the following is considered an acceptable means of compliance in that respect: a hazard analysis to demonstrate that all potential ignition risks originating from IFE system malfunctions do not pose a risk of sustained fire in any area where IFE components are located; this demonstration should account for the:

- fire containment properties of the equipment,
- non-fire-propagating properties of adjacent materials, and

- detectability of fire/smoke.

(d) The installer should consider protecting IFE components located in the cabin to ensure that fault conditions will not result in the failure of components within a unit that may generate smoke or fumes (e.g. when using tantalum capacitors). In addition, power supplies should have current-limiting output protection at a suitable level (e.g. seat equipment, power outlets). The IFE system installation should comply with the applicable fire and smoke provisions of CS 25.831(c), CS 25 853(a), CS 25.863, and CS 25.869(a).

(e) Procedures should be established to terminate the operation of the system at any time, in case of smoke/fire/explosion. The crew should maintain the overall control over the system. If the control over the system is possible via cabin controls only, appropriate procedures should address cockpit/cabin coordination.

The guidance of RTCA DO-313 in this area may also be followed.

6.6 Commercial off-the-shelf (COTS) equipment

This Section provides guidance for the cases where the installer uses COTS equipment as part of an IFE system modification.

In principle, the installation of a COTS equipment, as of all other IFE equipment, should follow the guidance provided in this document. It is nevertheless recognised that COTS equipment is supplied from a market whose industry standards differ from the aviation ones. As a consequence, it may be difficult to follow some of the guidance of this document.

The main impediments are the following:

- traceability and configuration control; and
- it is burdensome to perform most of the testing in accordance with state-of-the-art aviation standards (e.g. RTCA/DO-160).

In certain cases, the installer may directly follow the guidance provided in this document by using specific design features/adaptations and mitigations in terms of design or operational instructions.

The steps described below compose a roadmap that the installer may follow to apply for the approval of a COTS equipment as part of an IFE system:

- Firstly, the installer should perform a safety assessment of the potential hazards associated with the installation of the COTS equipment, either during normal operation of the equipment or in case of its failure.
- Based on the identified hazards, some evidence of environmental qualification for the equipment may be required. This could be achieved either by testing or by providing alternative laboratory standards to which the equipment has been tested, or industry standards to which the equipment has been certified. The acceptability of these standards should be agreed with the Agency.
- A design solution may be developed in some cases to provide means of compliance alternative to testing, e.g.:

  – hosting of the COTS component in a 'shelter case' (air-tightly-sealed housing) with electrical isolation of all needed interfaces; or

  – a declaration of 'loose equipment' that is temporarily brought on board and is permanently accessible and visible by the crew.

- It should be ensured that the design specifications of the COTS equipment manufacturer are followed (in terms of operating environmental conditions, cooling, etc.).

- Configuration control: quality control criteria should be provided for those aspects of the COTS equipment where malfunctions may create hazards. If detailed design data are not available for such aspects, the applicant should propose a process by which the control of the configuration design is maintained, and should ensure that changes in design or any non-compliance introduced during manufacturing are identified. Critical characteristics of COTS equipment may include power, dimensions, weight, electrical power, software and hardware parts, material flammability behaviour, etc. This should also encompass subsequent changes to those parts.

The above points should help the installer in the certification of the COTS equipment. RTCA DO-313, Appendix D follows a similar approach and is considered an acceptable alternative.

6.7 Approach for General Aviation (GA) aircraft

This Section provides guidance for the cases where the IFE equipment is installed in GA aircraft.

As an alternative to the full use of this AMC, the installer might follow the approach described below :

- An assessment of the potential hazards associated with the installation of the IFE equipment should be performed.

- The list of hazards and possible safety issues created through either normal operation of the IFE equipment or its failure should be identified.

- The hazards and issues described in Section 6 of this AMC may be used as a reference, but it is not expected that the applicant demonstrates the same level of compliance as required for large aircraft. Some evidence of environmental qualification (and/or testing) may be needed, but it is expected that in many cases, alternative compliance solutions may be provided. Some examples are the following:

  – specific-installations solutions or use of mitigations (via limitation and/or placards) may provide an adequate level of safety and circumvent environmental testing; and

  – industry standards and/or laboratory standards may provide an acceptable alternative.

  The acceptability of the above should be agreed with the Agency.

- It should be ensured that the design specifications of the IFE equipment manufacturer are followed (in terms of operating environmental conditions, cooling, etc.).

- Configuration control: the configuration of the IFE equipment should be identified, at least for those design features where malfunctions may create hazards.

It is worth mentioning that in many cases, the IFE equipment installed in GA aircraft is COTS equipment, thus the described approach largely reflects the approach to COTS equipment in Section 6.6 above.

7 DOCUMENTATION

This Section provides guidance on the documentation that should be developed for IFE installations. Such documents should meet the requirements of Annex I (Part-21) to Regulation (EU) No 748/2012 and make use of the related AMC/GM.

7.1 Certification documentation

The certification documentation may consist of, but it is not limited to:

- equipment specifications,
- system description,
- analysis report,
- test reports, and
- a DDP.

It should include references to the standards met.

The installer should demonstrate that they have taken proper account of the equipment manufacturer's DDP and installation instructions. Demonstration may, in addition, involve examination and testing of the equipment. 21.A.608 (Subpart O of Annex I (Part-21) to Regulation (EU) No 748/2012) and AMC 21.A.608 provide, respectively, requirements and guidance on the drafting and formatting of the DDP.

Appropriate documentation should be provided to define the designer's responsibilities for equipment installed in non-IFE components of the cabin (e.g. IFE equipment installed in seats or galleys, in-seat wiring harnesses). A DDP should be provided to confirm that the installation of the IFE equipment does not invalidate the existing equipment approval (e.g. seat ETSOs, galley certification).

Wire routing should be specified in detail to minimise variability in manufacture, installation and maintenance in order to avoid the risk of wire chafing and damage.

7.2 Operations and training manuals

The design and installation of the IFE system should be such to minimise its impact on operational procedures. However, since flight or cabin crew procedures should comply with the applicable airworthiness provisions, these procedures should be included in the corresponding manufacturer documentation to be provided to operators and, if appropriate, in the AFM.

7.3 Instructions for continued airworthiness (ICA)

For IFE installations on board an aircraft, the installer should draft appropriate ICA and submit them to the Agency for review/approval. The installer should accomplish this task not only at aircraft but also at equipment level.

7.3.1 Equipment level

At equipment level, the manufacturer should provide to the installer the necessary information for the safe operation and maintenance of the component. In particular, it should be highlighted if a component requires scheduled maintenance or contains life-limited parts or has any other limitation affecting its continued airworthiness.

Suitable means of providing ICA information at equipment level are the following (examples only):

- operator guides,
- CMMs,
- illustrated parts catalogues,
- dedicated ICA manuals.

The documents containing ICA for the component/equipment should be referenced in the corresponding DDP and cross-referenced in the documentation at aircraft level.

7.3.2 Aircraft level

At aircraft level, CS 25.1529, CS 25.1729 (or an equivalent SC if contained in the certification basis) and Appendix H of CS-25, as applicable to the installation under consideration, determine the format and minimum content of the ICA. The ICA for an IFE system may include the following:

- system descriptions and operating instructions such as (non-exhaustive list):
  - AFM supplements,
  - a master minimum equipment list (MMEL) supplement,
  - supplements to the flight crew operation manual (FCOM), and
  - supplements to the cabin crew operation manual (CCOM); and
- maintenance instructions (including information on testing, inspections, troubleshooting, servicing, replacement of parts, lifetime limitations, tooling and software loading) via supplements to the following (non-exhaustive list):
  - aircraft maintenance manual (AMM),
  - wiring manual,
  - illustrated parts catalogue,
  - maintenance planning document, and
  - service manual.

The amount and content of the necessary ICA may vary depending on the kind of installation.

7.3.3 Scheduled maintenance tasks

The installer should draft the ICA following the method applied during the certification process of the aircraft, including the development of scheduled maintenance tasks. However, some of these methods may not properly address the specific operational and technical conditions of the IFE installations:

- in-service occurrences have shown that failures in or damages to the IFE installation may become a potential source of ignition and heat, creating a smoke hazard and/or fire hazard;
- particular attention should be given to in-seat equipment and wiring that is vulnerable to damage induced by passengers, servicing personnel, crew, changes to cabin configuration or

maintenance actions, which therefore may become a potential source of an electrical shock or other risks due to degraded or damaged electrical insulation; and

- contamination by dust, debris and spilled liquids in the cabin may cause overheating and risk of smoke or fire.

These kinds of potential causes of failure, especially if the failure or damage is not easily detectable by the crew and maintenance personnel while performing their normal duties, should also be considered when defining the scheduled maintenance tasks for IFE installations.

Scheduled maintenance for IFE installations may include, but is not limited to, the following tasks:

- functional checks of latent systems (e.g. power shutdown function and/or IFE-specific smoke detection function);
- inspections (e.g. condition of system cabling and/or seat-mounted components; correct position of physical protections, such as insulation, ducting, covers and/or drip trays);
- discarding/replacement of components (e.g. air filters and/or IFE batteries); and
- restoration tasks (e.g. cleaning of cooling vents or filters, removal of dust and debris).

8 OPERATIONAL PROCEDURES

The regulatory requirements related to air operations are specified in Regulation (EU) No 965/2012 (see also the related AMC/GM). The operator should ensure that:

- flight crew and cabin crew are fully familiar with the operation of the IFE system (see ORO.GEN.110);
- to that end, the operator should create a detailed programme and syllabus for each training course (see ORO.CC.115);
- the aircraft-specific training and operator conversion training should cover, among other elements, all systems installed that are relevant to cabin crew duties (see ORO.CC.125 and ORO.CC.135); and
- when the IFE system is handled by passengers, the passengers should be provided with appropriate information on the restrictions of its use in normal, abnormal and emergency conditions (see CAT.OP.MPA.170 and the related AMC/GM), which should also cover the use of PEDs (see CAT.GEN.MPA.140 and the related AMC/GM).

3.1.5. AMC 20-30

1. New AMC 20-30 is added as follows:

AMC 20-30

Lead-free soldering in airborne electronic systems

TABLE OF CONTENTS

1 BACKGROUND

Avionics and other electronic applications with high-reliability requirements, when operated in airborne environments, differ in significant ways from the vast majority of commercial and consumer electronic applications. For example, airborne electronics are expected to perform reliably in environments under often extreme conditions: high altitude, high levels of shock and vibration, rapid temperature changes, high humidity, etc.

Unlike most commercial and consumer electronics, avionics' lifetimes are often measured in decades, rather than years. Avionics are routinely maintained through repair activities that may even include replacing individual components on a printed circuit assembly (PCA).

Most importantly, the failure of aircraft equipment may have safety consequences.

For over 50 years, the electronics industry has relied on tin-lead (Sn-Pb) solder as the primary means of interconnection between the electronic components and the printed circuit board (PCB) substrates.

More than 10 years ago, Directive 2002/95/EC[7] of the European Parliament and of the Council on the 'Restriction of Hazardous Substances' (RoHS) (repealed and replaced by Directive 2011/65/EU[8]) obliged the electronics industry to use lead-free solders and termination finishes for PCAs and PCB substrates. Similar legislation is in place or to be adopted in countries outside the EU. While aerospace and defence electronics are yet not subject to these lead-free requirements, many of their electronic-components suppliers are. Even those suppliers and electronic-manufacturing services (EMSs) that may initially continue to produce traditional Sn-Pb components and use lead process assemblies for aerospace applications may find the cost of maintaining separate production lines too burdensome to keep on doing so. In any case, the introduction and proliferation of RoHS-based components and PCBs throughout manufacturers' supply chains is unavoidable and underway.

Based on the scientific information available today, several lead-free-soldered alloys appear to be a replacement for Sn-Pb-soldered alloy and have a similar level of performance and reliability expected for specific applications. While various alternatives are available, their reliability, when used in airborne electronics, may be reduced if their implementation is not properly controlled.

The potential risks, by decreasing order of impact, include:

- reduced soldered-joints' integrity and reliability if lead-free design and assembly processes on PCAs are not properly qualified and controlled for the dedicated environment;
- reduced long-term PCA reliability under high-stress environments if a mixed-alloy assembly is used and inefficiently controlled;
- reduced service life due to the higher temperatures required to assemble individual components on circuit boards when using lead-free alloys if materials' properties are not compatible with a lead-free soldering process; and
- spontaneous formation of 'tin whiskers' from pure-tin finishes if the risk is not mitigated.

[7] Directive 2002/95/EC of the European Parliament and of the Council of 27 January 2003 on the restriction of the use of certain hazardous substances in electrical and electronic equipment (OJ L 37, 13.2.2003, p. 19) (http://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1496735865846&uri=CELEX:02002L0095-20130103).

[8] Directive 2011/65/EU of the European Parliament and of the Council of 8 June 2011 on the restriction of the use of certain hazardous substances in electrical and electronic equipment (OJ L 174, 1.7.2011, p. 88) (http://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1486643338682&uri=CELEX:32011L0065).

There are also risks associated with repair activities due to the incompatibility between lead-free and Sn-Pb alloys. The repair procedures and materials for lead-free alternatives are not the same as for traditional Sn-Pb alloys. Mixing Sn-Pb and lead-free repair methods and/or materials may result in flawed soldered joints. Care needs to be exercised to ensure that the repair methods and materials are appropriate for the specific technology.

Finally, suitable reliability models (e.g. thermal-cycling testing as well as vibration/shock) for assessing the reliability of lead-free-soldered joints in the aviation-specific operational environments are still under development. Traditional test methods and qualification tests may need to be tuned to be appropriate for correctly assessing the reliability and lifetime of lead-free-soldered PCAs.

2 INTRODUCTION

2.1 Purpose and scope

This acceptable means of compliance (AMC) provides a means to demonstrate that the use of lead-free-soldered electronics does not jeopardise the reliability of airborne equipment.

Compliance with this AMC is not mandatory and hence an applicant may elect to use alternative means of compliance (AltMoC). However, those AltMoC must meet the related certification specifications (see Section 2.3 below), ensure an equivalent level of safety and be approved by the Agency.

This AMC applies to lead-free-soldered electronics that may have unacceptable system safety repercussions identified by the applicant if the solder were to fail.

Unacceptable system safety repercussions are defined as situations where a non-controlled lead-free soldering process impairs confidence in reliability figures used in system safety assessments (SSAs) or preliminary system safety assessments (PSSAs), thus jeopardising compliance with the safety objectives of CS 23.1309, CS 25.1309, CS 27.1309 or CS 29.1309.

In particular, this AMC contains guidelines for assessing the impact of the transition to lead-free-soldered electronics on the airworthiness of aircraft parts and appliances. It also supports applicants in appropriately mitigating identified risks and provides guidance for demonstrating compliance with the applicable requirements.

2.2 Who is affected by this AMC

This AMC is in technical terms applicable to all products, parts and appliances with electronics using lead-free soldering technology. Consequently, this AMC is applicable to any initial-airworthiness project (type certificate (TC), change to TC, or supplemental type certificate (STC), European technical standard order (ETSO) authorisations) that needs to comply with the provisions of Section 2.3 below.

To control the potential impact on reliability, it is recommended that each original equipment manufacturer (OEM) considers this guidance and addresses the subject as early as possible in the supply chain even though not formally being the applicant (except in the case of ETSO authorisations), and thus not directly responsible for compliance demonstration. The differentiation between, on the one hand, OEM and other parties (subcontractors for instance) in the supply chain and, on the other hand, the applicant to whom this guidance is addressed in the first place is maintained in this AMC in order to best identify which party is able to follow the guidance in the easiest way.

Therefore, organisations are advised to develop their approach to this AMC at company level rather than at project level to ensure consistency in managing the transition to lead-free soldering.

Furthermore, the applicant for a dedicated project should determine those aspects of their designs that may significantly impact compliance with the safety objectives if the lead-free solder were to fail. This determination should result from the system safety analysis.

2.3 Related certification specifications (CSs)

Reference	Title	CS
CS 23.1301, CS 25.1301, CS 27.1301, CS 29.1301	Function and installation	CS-23 Normal, Utility, Aerobatic and Commuter Category Aeroplanes, CS-25 Large Aeroplanes, CS-27 Small Rotorcraft, CS-29 Large Rotorcraft
CS 23.1309, CS 25.1309, CS 27.1309, CS 29.1309	Equipment, system and installations	CS-23, CS-25, CS-27, CS-29
CS 23.1529, CS 25.1529, CS 27.1529, CS 29.1529	Instructions for Continued Airworthiness	CS-23, CS-25, CS-27, CS-29
CS-E 25	Instructions for Continued Airworthiness	CS-E Engines
CS-E 50 (c)	Engine Control System Failures	CS-E
CS-E 70	Materials and Manufacturing Methods	CS-E
CS-E 80	Equipment	CS-E
CS-E 210	Failure Analysis	CS-E
CS-E 510	Safety Analysis	CS-E
CS-APU 90 (b)	APU Control System	CS-APU Auxiliary Power Units
CS-APU 210	Safety analysis	CS-APU
CS-P 40	Instructions for Continued Airworthiness	CS-P Propellers
CS-P 170	Materials and Manufacturing Methods	CS-P
CS-P 230 (a) (2)	Propeller Control System	CS-P
CS-P 440	Propeller Systems and Components	CS-P
CS-ETSO, Subpart A	2.1 Environmental standard 2.4 Failures conditions classification and development assurance	CS-ETSO European Technical Standard Orders

2.4 Reference documents

Reference	Title	Date
International Electrotechnical Commission IEC/TS 62647-1 or Government Electronics & Information Technology Association GEIA-STD-0005-1 (Revision A)	Process management for avionics — Aerospace and defence electronic systems containing lead-free solder — Part 1: Preparation for a lead-free control plan Performance Standard for Aerospace and High Performance Electronic Systems Containing Lead-free Solder	2012-08 2012-03
IEC/TS 62647-2 or GEIA-STD-0005-2 (Revision A)	Process management for avionics — Aerospace and defence electronic systems containing lead free solder — Part 2: Mitigation of deleterious effects of tin Standard for Mitigating the Effects of Tin Whiskers in Aerospace and High Performance Electronic Systems	2012-11 2012-05
IEC/TS 62647-3 or GEIA-STD-0005-3 (Revision A)	Process management for avionics — Aerospace and defence electronic systems containing lead-free solder — Part 3: Performance testing for systems containing lead-free solder and finishes Performance Testing for Aerospace and High Performance Electronic Interconnects Containing Pb-free Solder and Finishes	2014-02 2012-12
Directive 2011/65/EU	Directive 2011/65/EU of the European Parliament and of the Council on the restriction of the use of certain hazardous substances in electrical and electronic equipment (the 'RoHS 2 Directive')	2011-06
European Organization for Civil Aviation Equipment (EUROCAE) ED-14 (Revision G) or Radio Technical Commission for Aeronautics (RTCA) DO-160 (Revision G)	Environmental Conditions and Test Procedures for Airborne Equipment	2010-12

2.5 Abbreviations

The following abbreviations are used in this AMC:

AEH	airborne electronic hardware
AMC	acceptable means of compliance
CMM	component maintenance manual
COTS	commercial off-the-shelf
CSs	certification specifications
DDP	declaration of design and performance
EMS	electronic manufacturing service
ETSO	European technical standard order
ICA	instructions for continued airworthiness
IEC	International Electrotechnical Commission
GEIA	Government Electronics and Information Technology Association
LFCP	lead-free control plan
OEM	original-equipment manufacturer
Pb	lead (chemical element)
PCA	printed circuit assembly
PCB	printed circuit board
RoHS	restriction of hazardous substances
SB	service bulletin
VSB	vendor service bulletin
Sn	tin (chemical element)
Sn-Pb	tin-lead (alloy)
SSA	system safety assessment
PSSA	preliminary system safety assessment
SPM	standard praxis manual
TC	type certificate
STC	supplemental type certificate

2.6 Definitions

The following definitions are used in this AMC:

Term	Definition
Tin whiskers	A conductive crystalline outgrowth from near pure tin coatings
Printed circuit assembly	A printed circuit board (PCB) substrate populated with electronic components, also called PCB assembly or circuit card assembly

3 OBJECTIVE AND GUIDANCE

3.1 Objective

The objective of this AMC is to:

- make type certificate (TC) or supplemental type certificate (STC) applicants and their suppliers (OEMs) aware of the need to assess the impact of lead-free-soldered electronics on the airworthiness of airborne systems so that they implement appropriate mitigation measures;
- specify the applicable requirements;
- provide guidance for complying with the applicable requirements; and
- make OEMs aware of the need to assess the impact of lead-free-soldered electronics on the airworthiness of airborne systems so that they implement appropriate mitigation measures in case of ETSOs.

The applicants should conduct lead-free soldering technology assessments for the airborne systems based on the OEM documentation, which could be a lead-free control plan (LFCP) or any similar documents.

The LFCP is defined in International Electrotechnical Commission (IEC) documents, referred to as reference documents.

3.2 Related CSs

This AMC should be considered when demonstrating compliance with the related CSs listed in Section 2.3 above.

Installed equipment should be able to perform its intended functions under any foreseeable operating conditions.

This includes:

- the ability to withstand critical operational and environmental conditions; and
- an equipment reliability such that the safety objectives are met.

The correct handling procedures should be addressed in the maintenance instructions. OEMs are encouraged to provide and maintain accurate maintenance and repair design data (e.g. standard praxis manuals (SPMs), vendor service bulletins (VSBs), component maintenance manuals (CMMs)) for adequately managing lead-free soldering technologies.

Note: The mention of SPM, VSB and CMM in this Section as well as the reference to instructions for continued airworthiness (ICA)-related CSs in Section 2.3 of this AMC do not generally imply that SPMs, VSBs and CMMs are ICA.

3.3 Guidance

To demonstrate compliance with the above-mentioned CSs, the applicants should provide the associated documentation.

The reference documents listed in Section 2.4 above provide valuable inputs on the current industry understanding of the various ways to control the use of lead-free solders in airborne electronics as well on the relevant industry recommendations.

These reference documents have been drafted with the cooperation of the members of a large industry community, including stakeholders having more stringent environmental or industrial constraints than the ones on air transport.

The applicant has the responsibility to select the relevant guidance provided in these documents according to the nature of the application. The Agency does not require a one-to-one compliance with those recommendations, but their spirit should be followed.

In the following sections, this AMC provides guidance on:

- initial design using lead-free technology;
- soldering process changes in existing designs; and
- maintenance instructions.

3.3.1 Initial design using lead-free technology

The applicant should create a management plan for lead-free technology (or any similar document).

The TC or STC applicant, OEM, electronic manufacturing service (EMS) and subcontractors should take special care to ensure that the implementation of lead-free soldering is under control along the whole global supply chain.

In such a plan, the applicant describes what has been implemented to comply with the CSs and to ensure the safe use of lead-free-soldered electronics.

OEMs that use lead-free-soldered electronics, following an internal soldering process or subcontracting to an EMS with its own soldering process, or purchasing commercial off-the-shelf (COTS) sub-assemblies, should demonstrate that all the relevant measures have been taken to correctly manage the lead-free soldering implementation with regard to components selection, process validation, tin whiskers mitigation, or any other relevant aspects.

In the following sections, objectives, guidance, as well as demonstration methods to achieve those objectives are described.

3.3.1.1 Reliability demonstration

3.3.1.1.1 Objectives

The objective is to demonstrate that the lead-free-soldered technology is suitable for its intended use, i.e. behaves as expected in the aeronautical environment throughout its required service.

3.3.1.1.2 Available demonstration methods

The OEM should perform a lead-free soldering technology qualification testing to validate the following:

- soldering alloy,
- components and PCB materials,
- board layout design, and
- soldering process.

As reliability models are not yet available, the OEM should experimentally assess reliability through technology qualification testing or justify it through analysis.

The OEM should consider the following types of constraints:

- environmental criteria:
  - temperature,
  - temperature variation,
  - vibration, and
  - humidity; and
- components packaging.

Depending on some specific environmental conditions of the product, the OEM may consider the following additional types of constraints:

- mechanical shocks, and
- salt spray.

Guidance for applicants on how to demonstrate the reliability objectives is available in the following reference documents:

- IEC/TS 62647-1, Section 6.2, or
- GEIA-STD-0005-1, Section 6.1.

Guidance for applicants on how to define a lead-free technology qualification plan is available in the following reference documents:

- IEC/TS 62647-3, or
- GEIA-STD-0005-3.

3.3.1.1.3 Criteria for the choice of methods

The applicant should demonstrate reliability by testing, similarity or analysis after a risk analysis that should consider the following:

- equipment contribution to any catastrophic, hazardous or major failure conditions;
- available industry feedback on, and experience gathered with, the technology used; and

- similar lead-free-soldered assembly behaviour already demonstrated under the same environmental operating conditions.

3.3.1.2 Tin whiskers risk mitigation

3.3.1.2.1 Objectives

Tin whiskers may grow as a potential effect resulting not from the transition to lead-free soldering but from the presence of pure tin in the device or board finishing.

The OEM should identify and implement relevant mitigation solutions.

3.3.1.2.2 Available demonstration methods

The following non-exhaustive mitigation solutions are considered relevant:

- circuit design precaution (spacing),
- physical barrier,
- coating,
- hard potting, and
- varnishes.

The OEM should justify the relevance of any other proposed mitigation solution.

See reference documents IEC/TS 62647-2 or GEIA-STD-0005-2 (or GEIA-STD-0005-1, Section 6.4).

3.3.1.2.3 Criteria for the choice of methods

Depending on the specific nature of the implementation and its contribution to any catastrophic, hazardous or major failure conditions, the OEM may have to propose one or several mitigation solutions.

3.3.1.3 Environmental qualification

3.3.1.3.1 Objectives

The OEM should consider the environmental qualification testing constraints (method and level) before selecting a soldering process.

The objective of environmental qualification is to ensure that the equipment functions properly in its aeronautical environment when submitted to qualification tests (e.g. as per EUROCAE ED-14/RTCA DO-160).

3.3.1.3.2 Available demonstration methods

When implementing the applicable qualification methods at the applicable levels, the OEM should consider the following types of constraints:

- temperature,
- temperature variation, and
- vibration.

Depending on some specific environmental conditions of the product, the OEM may consider the following additional types of constraints:

- mechanical shocks, and
- salt spray.

3.3.1.3.3 Criteria for the choice of methods

Not applicable.

3.3.2 Soldering changes in existing designs

Soldering changes (either transition to lead-free soldering or changes to the lead-free soldering alloys) are likely to occur during the life of equipment.

The TC or STC applicant, OEM, EMS and subcontractors should take special care to ensure that the implementation of lead-free soldering is under control along the whole global supply chain.

OEMs that transition into lead-free-soldered electronics or change the lead-free soldering alloy, following an internal soldering process or subcontracting to an EMS with its own soldering process, or purchasing COTS sub-assemblies, have the responsibility to demonstrate that the objectives described in the following sections are met.

In the following sections, objectives, guidance, as well as demonstration methods to achieve those objectives are described.

3.3.2.1 Information

3.3.2.1.1 Objectives

The OEM should inform the TC or STC holder when a transition to lead-free soldering or a change to the lead-free soldered alloys is planned.

3.3.2.1.2 Available demonstration methods

The OEM should use the methods they consider relevant to correctly inform the TC or STC holder.

See reference documents IEC/TS 62647-1, Section 6.3.3 or GEIA-STD-0005-1, Section 6.2.4.

3.3.2.1.3 Criteria for the choice of methods

The OEM should communicate to the TC or STC holder any change to lead-free soldered alloys.

3.3.2.2 Reliability demonstration

3.3.2.2.1 Objectives

The objective is to demonstrate that the change of the soldering process does not jeopardise the conclusions of reliability assessments previously performed within the initial safety assessment.

3.3.2.2.2 Available demonstration methods

Usable demonstrations methods are the same as the ones described above for the initial lead-free design (see Section 3.3.1.1.1).

3.3.2.2.3 Criteria for the choice of methods

The criteria for the choice of methods are the same as the ones described above for the initial lead-free design (see Section 3.3.1.1.2).

3.3.2.3 Environmental qualification

3.3.2.3.1 Objectives

The objective is to ensure that the change of the soldering process does not jeopardise the conclusions of environmental qualification testing previously performed.

3.3.2.3.2 Available demonstration methods

Usable demonstrations methods are the same as the ones described above for the initial lead-free design (see Section 3.3.1.1.1).

3.3.2.3.3 Criteria for the choice of methods

The applicant should ensure the environmental qualification by testing, similarity or analysis after a risk analysis that should consider the following in order of priority:

- equipment contribution to any catastrophic, hazardous or major failure conditions;
- available industry feedback on, and experience gathered with, the technology used; and
- similar lead-free-soldered assembly behaviour already demonstrated under the same environmental operating conditions.

3.3.3 Configuration control and product identification

3.3.3.1 Objectives

The correct PCA identification should be sufficient to avoid any mix of technology during production, maintenance, or repair.

3.3.3.2 Available demonstration methods

The OEM should put in place appropriate PCA markings or identification to avoid any misunderstanding or misinterpretation.

See reference documents IEC/TS 62647-1, Section 6.3 or GEIA-STD-0005-1, Section 6.2.

3.3.3.3 Criteria for the choice of marking methods

Each lead-free-soldered PCA should have appropriate marking methods to allow its correct identification.

3.3.4 Maintenance and repair instructions

The OEM should ensure that the maintenance instructions (e.g. SPM, VSB, CMM) contain maintenance instructions for lead-free-soldered electronics, including:

- maintenance instructions developed in line with the used technology; this may imply several different sets of instructions if several different technologies are used; and
- means for maintenance operators to distinguish between Sn-Pb- and lead-free-soldered components and PCAs, such as dedicated part numbers, appropriate marking or any other appropriate means, in order to avoid inappropriate mixing of the maintenance procedures.

See IEC/TS 62647-1, Section 6.6 or GEIA-STD-0005-1, Section 6.5.

Note: The mention of SPM, VSB and CMM in this Section as well as the reference to ICA-related CSs in Section 2.3 of this AMC do not generally imply that SPMs, VSBs and CMMs are ICA.

4. OVERVIEW TABLE

The following template table provides an overview of:

- objectives;
- for each objective, further guidance to meet it (see reference documents);
- methods selected by the applicant to meet the objective; and
- data issued by the applicant to demonstrate that objectives are met.

Objectives	Further guidance to meet the objectives (reference document)	Methods used to meet the objective	Data showing that the objectives are met
Reliability demonstration	IEC/TS 62647-1, Section 6.2 GEIA-STD-0005-1, Section 6.1 IEC/TS 62647-3 GEIA-STD-0005-3	(*)	(*)
Tin whiskers risk mitigation	IEC/TS 62647-1, Section 6.5 GEIA-STD-0005-1, Section 6.4 IEC/TS 62647-2 GEIA-STD-0005-2	(*)	(*)
Environmental qualification	Applicable qualification standard (i.e. RTCA DO-160 or other)	(*)	(*)
Configuration control and product identification	IEC/TS 62647-1, Section 6.3 GEIA-STD-0005-1, Section 6.2	(*)	(*)
Information	IEC/TS 62647-1, Section 6.3.3 GEIA-STD-0005-1, Section 6.2.4	(*)	(*)
Repair	IEC/TS 62647-1, Section 6.6 GEIA-STD-0005-1, Section 6.5	(*)	(*)

(*) To be completed, as relevant, by the applicant.

As data showing that the objectives of the above table are met, the TC or STC applicant should request from the OEM, within the compliance documentation, an LFCP or any similar document such as:

- an equipment environmental qualification: reports or justification/analysis;
- equipment reliability data, when affected; or
- an equipment declaration of design and performance (DDP), when applicable.

The same applies for the OEM in case of ETSO authorisations. The level of visibility in these data provided by the applicant to the Agency depends on the nature of their already established working arrangements. The Agency may request to review these data within a certification project.

3.2. Draft acceptable means of compliance and guidance material (Draft EASA decision)

3.2.1. AMC/GM to Part-21

1. AMC 21.A.608 is amended as follows:

AMC 21.A.608 Declaration of Design and Performance

STANDARD FORM

DDP No. ....

ISSUE No. ....

1. Name and address of manufacturer.
2. Description and identification of article including:

   Type No

   Modification Standard

   Master drawing record

   Weight and overall dimensions
3. Specification reference, i.e., ETSO No. and Manufacturer's design specification.
4. The rated performance of the article directly or by reference to other documents.
5. Particulars of approvals held for the equipment.
6. Reference to qualification test report.
7. Service and Instruction Manual reference number.
8. Statement of compliance with the appropriate ETSO and any deviations therefrom.
9. A statement of the level of compliance with the ETSO in respect of the ability of the article to withstand various ambient conditions or to exhibit various properties.

The following are examples of information to be given under this heading depending on the nature of the article and the specifications of the ETSO.

(a) Environmental Qualification

- i. Temperature and Altitude
- ii. Temperature Variation
- iii. Humidity
- iv. Operational Shocks and Crash Safety
- v Vibration
- vi. Explosion Proofness
- vii. Waterproofness
- viii. Fluids Susceptibility
- ix. Sand and Dust
- x. Fungus Resistance
- xi. Salt Spray

xii. Magnetic Effect

xiii. Power Input

xiv. Voltage Spike

xv. Audio Frequency Conducted Susceptibility - Power Inputs

xvi. Induced Signal Susceptibility

xvii. Radio Frequency Susceptibility (Radiated and Conducted)

xviii. Emission of Radio Frequency Energy

xix. Lightning Induced Transient Susceptibility

xx. Lightning Direct Effects

xxi. Icing

xxii. Electrostatic Discharge

xxiii. Fire, Flammability

(Note: The manufacturer should list environmental categories for each of the sections of the issue of EUROCAE ED-14/RTCA DO-160 that was used to qualify the article.)

(b) For radio transmitters the transmitting frequency band, maximum transmitting power, and emission designator.

(c) Working and ultimate pressure or loads.

(d) Time rating (e.g., continuous, intermittent) or duty cycle.

(e) Limits of accuracy of measuring instruments.

(f) Any other known limitations which may limit the application in the aircraft e.g., restrictions in mounting attitude.

10. A statement of the software level(s) used or ‘None’ if not applicable.

(Note: Software levels (software development assurance levels (DAL)) are those defined in the industry document referred in the latest edition of AMC 20-115)

11. A statement of design assurance level for complex hardware or a statement indicating whether complex hardware is embedded or not in the product.

(Note: Complex hardware design assurance levels are those defined in the applicable issue of EUROCAE ED–80/RTCA DO-254.)

12. A statement whether lead-free soldering technology is used.

(Note: AMC 20-30 provides guidance on the introduction and use of lead-free soldering technology.)

~~12~~13. The declaration in this document is made under the authority of

………..(name of manufacturer)

(Manufacturer’s name) cannot accept responsibility for equipment used outside the limiting conditions stated above without their agreement.

Date: ……………Signed…………………………………………………(Manufacturer’s authorised representative)

3.2.2. AMC/GM to Part-ORO

1. AMC1 to ORO.GEN.110(f)(h) is amended as follows:

AMC1 ORO.GEN.110(f)(h) Operator responsibilities
ESTABLISHMENT OF PROCEDURES

(a) An operator should establish procedures to be followed by cabin crew covering at least:

(1) arming and disarming of slides;

(2) operation of cabin lights, including emergency lighting;

(3) in-flight entertainment (IFE) systems (where applicable);

~~(3)~~(4) prevention and detection of cabin, oven and toilet fires;

~~(4)~~(5) actions to be taken when turbulence is encountered; and

~~(5)~~(6) actions to be taken in the event of an emergency and/or an evacuation.

(b) When establishing procedures and a checklist system for cabin crew with respect to the aircraft cabin, the operator should take into account at least the following duties:

Duties	Pre-take off	In-flight	Pre-landing	Post-landing
(1) Briefing of cabin crew by the senior cabin crew member prior to commencement of a flight or series of flights	x			
(2) Check of safety and emergency equipment in accordance with operator's policies and procedures	x			
(3) Security checks as applicable	x			x
(4) Passenger embarkation and disembarkation	x			x
(5) Securing of passenger cabin (e.g. seat belts, cabin cargo/baggage, in-flight entertainment (IFE) system)	x		x	
(6) Securing of galleys and stowage of equipment	x	if required	x	
(7) Arming of door/exit slides	x			

(8) Safety briefing/information to passengers	x	x	x	x
(9) 'Cabin secure' report to flight crew	x	if required	x	
(10) Operation of cabin lights	x	if required	x	x
(11) Operation of the in-flight entertainment (IFE) system	x	x	x	x
(~~11~~12) Cabin crew at assigned crew stations	x	if required	x	x
(~~12~~13) Surveillance of passenger cabin	x	x	x	x
(~~13~~14) Prevention and detection of fire in the cabin (including the combi-cargo area, crew rest areas, galleys, lavatories and any other cabin remote areas) and instructions for actions to be taken	x	x	x	x
(~~14~~15) Actions to be taken when turbulence is encountered		x		
(~~15~~16) Actions to be taken in case of in-flight incidents (e.g. medical emergency)		x		
(~~16~~17) Actions to be taken in the event of emergency situations	x	x	x	x
(~~17~~18) Disarming of door/exit slides				x
(~~18~~19) Reporting of any deficiency and/or un-serviceability of equipment and/or any incident	x	x	x	x

(c) The operator should specify the contents of safety briefings for all cabin crew members prior to the commencement of a flight or series of flights.

2. GM1 ORO.CC.115 is amended as follows:

GM1 ORO.CC.115 Conduct of training courses and associated checking
EQUIPMENT AND PROCEDURES

The following definitions apply for the purpose of training programmes, syllabi and the conduct of training and checking on equipment and procedures:

(a) 'Safety equipment' means equipment installed/carried to be used during day-to-day normal operations for the safe conduct of the flight and protection of occupants (e.g. seat belts, child restraint devices, safety card, safety demonstration kit).

(b) 'Emergency equipment' means equipment installed/carried to be used in case of abnormal and emergency situations that demand immediate action for the safe conduct of the flight and protection of occupants, including life preservation (e.g. drop-out oxygen, crash axe, fire extinguisher, protective breathing equipment, manual release tool, slide-raft).

(c) 'Normal procedures' means all procedures established by the operator in the operations manual for day-to-day normal operations (e.g. pre-flight briefing of cabin crew, pre-flight checks, passenger briefing, securing of galleys and cabin, cabin surveillance during flight, in-flight entertainment (IFE) system).

(d) 'Emergency procedures' means all procedures established by the operator in the operations manual for abnormal and emergency situations. For this purpose, 'abnormal' refers to a situation that is not typical or usual, deviates from normal operation and may result in an emergency.

3. AMC1 ORO.CC.125(c) is amended as follows:

AMC1 ORO.CC.125(c) Aircraft type specific training and operator conversion training
TRAINING PROGRAMME — AIRCRAFT TYPE SPECIFIC TRAINING

The following aircraft type specific training elements should be covered as relevant to the aircraft type:

(a) Aircraft description

(1) type of aircraft, principal dimensions, narrow or wide bodied, single or double deck;

(2) speed, altitude, range;

(3) passenger seating capacity;

(4) flight crew number and minimum number of required cabin crew;

(5) cabin doors/exits location and sill height;

(6) cargo and unpressurised areas as relevant;

(7) aircraft systems relevant to cabin crew duties;

(8) flight crew compartment — general presentation, pilot seats and their mechanism, emergency exits, storage;

(9) required cabin crew stations;

(10) flight crew compartment security — general: door components and use;

(11) access to avionics bay where relevant;

(12) lavatories — general: doors, systems, calls and signs; and

(13) least risk bomb location.

(b) Safety and emergency equipment and aircraft systems installed

Each cabin crew member should receive realistic training on, and demonstration of, the location and use of all aircraft type specific safety and emergency equipment and aircraft systems installed, with emphasis on the following:

(1) slides, and where non-self-supporting slides are carried, the use of any associated assisting evacuation means;

(2) life-rafts and slide-rafts, including the equipment attached to, and/or carried in, the raft;

(3) drop-out oxygen system;~~ and~~

(4) communication equipment~~.~~; and

(5) in-flight entertainment (IFE) system.

(c) Operation of doors and exits

This training should be conducted in a representative training device or in the actual aircraft and should include failure of power assist systems where fitted and the action and forces required to operate and deploy evacuation slides. Training should also include operation and actual opening of the flight crew compartment security door when installed.

(d) Fire and smoke protection equipment

Each cabin crew member should be trained in using fire and/or smoke protection equipment where fitted.

(e) Evacuation slide training

(1) Each cabin crew member should descend an evacuation slide from a height representative of the aircraft main deck sill height.

(2) The slide should be fitted to a representative training device or to the actual aircraft.

(3) A further descent should be made when the cabin crew member qualifies on an aircraft type in which the main deck exit sill height differs significantly from any aircraft type previously operated.

(f) Operation of equipment related to pilot incapacitation

The training should cover any type specific elements or conditions relevant to cabin crew actions to be taken in case of pilot incapacitation. Each cabin crew member should be trained to operate all equipment that must be used in case of pilot incapacitation.

4. AMC1 ORO.CC.125(d) is amended as follows:

AMC1 ORO.CC.125(d) Aircraft type-specific training and operator conversion training

TRAINING PROGRAMME — OPERATOR CONVERSION TRAINING

The following training elements should be covered as relevant to the aircraft type and the related operator's specifics:

(a) Description of the cabin configuration

The description should cover all elements specific to the operator's cabin configuration and any differences with those previously covered in accordance with AMC1 ORO.CC.125(c), including:

(1) required and additional cabin crew stations — location (including direct view), restraint systems, control panels;

(2) passenger seats — general presentation and associated operator's specific features and equipment;

(3) designated stowage areas;

(4) lavatories — operator's specific features, equipment and systems additional to the aircraft type specific elements;

(5) galley — location, appliances, water and waste system, including shut-off, sinks, drains, stowage, control panels, calls and signs;

and where applicable

(6) crew rest areas — location, systems, controls, safety and emergency equipment;

(7) cabin dividers, curtains, partitions;

(8) lift location, use, controls;

(9) stowage for the containment of waste; ~~and~~

(10) passenger hand rail system or alternative means~~.~~; and

(11) in-flight entertainment (IFE) system.

(b) Safety and emergency equipment

[…]

5. AMC1 ORO.CC.135 is amended as follows:

AMC1 ORO.CC.135 Familiarisation

FAMILIARISATION FLIGHTS AND AIRCRAFT FAMILIARISATION VISITS

[…]

(c) Aircraft familiarisation visits

(1) Aircraft visits should enable the cabin crew member to become familiar with the aircraft environment and its equipment. Accordingly, aircraft visits should be conducted by

appropriately qualified persons. The aircraft visit should provide an overview of the aircraft's exterior, interior and aircraft systems with emphasis on the following:

(i) interphone and public address systems;

(ii) evacuation alarm systems;

(iii) emergency lighting;

(iv) smoke detection systems;

(v) safety and emergency equipment;

(vi) flight crew compartment;

(vii) cabin crew stations;

(viii) lavatories;

(ix) galleys, galley security and water shut-off;

(x) cargo areas if accessible from the passenger compartment during flight;

(xi) circuit breaker panels located in the passenger compartment;

(xii) crew rest areas; ~~and~~

(xiii) doors/exits location and environment~~.~~; and

(xiv) in-flight entertainment (IFE) system.

(2) An aircraft familiarisation visit may be combined with the aircraft type specific training or operator conversion training required by ORO.CC.125.

[…]

3.2.3. AMC/GM to Part-CAT

1. AMC1 CAT.OP.MPA.170 is amended as follows:

AMC1 CAT.OP.MPA.170 Passenger briefing
PASSENGER BRIEFING

Passenger briefings should contain the following:

(a) Before take-off

(1) Passengers should be briefed on the following items if applicable:

(i) smoking regulations;

(ii) back of the seat to be in the upright position and tray table stowed;

(iii) location of emergency exits;

(iv) location and use of floor proximity escape path markings;

(v) stowage of hand baggage;

(vi) the use and stowage of portable electronic devices, including in-flight entertainment (IFE) systems; and

(vii) the location and the contents of the safety briefing card; and

(2) passengers should receive a demonstration of the following:

(i) the use of safety belts or restraint systems, including how to fasten and unfasten the safety belts or restraint systems;

(ii) the location and use of oxygen equipment, if required. Passengers should also be briefed to extinguish all smoking materials when oxygen is being used; and

(iii) the location and use of life-jackets, if required.

(b) After take-off

[…]

2. New AMC3 CAT.OP.MPA.170 is inserted as follows:

AMC3 CAT.OP.MPA.170 Passenger briefing

IN-FLIGHT ENTERTAINMENT (IFE) SYSTEMS

When IFE systems are available by means of equipment that can be handled by passengers, including portable electronic devices (PEDs) provided by the operator for the purpose of IFE, appropriate information should be made available to passengers. This information should contain, but is not limited to:

(a) instructions on how to safely operate the IFE system for personal use in normal conditions;

(b) restrictions, including stowage of retractable or loose items of equipment (e.g. screens or remote controls) during taxiing, take-off and landing, and in abnormal or emergency conditions; and

(c) the instruction to alert the cabin crew members in case of IFE system failure.

4. Impact assessment (IA)

4.1. How the objectives of this NPA could be achieved — options

Table 1: Selected policy options

Option No	Short title	Description
0	Do nothing	No policy change (no change to the rules; risks remain as outlined in the issue analysis).
1	Amend AMC-20	(a) Amend AMC 20-1, 20-2 and 20-3 to harmonise across them the criteria for safety assurance and software development. (b) Create a new AMC 20-30 on lead-free soldering. (c) Create a new AMC 20-19 on IFE systems and create/update relevant AMC to Part-ORO and Part-CAT.

4.2. What are the impacts

4.2.1. Option 0

The impacts of Option 0 are expected to be negative:

(a) the safety risks (identified in Section 2.1 above) related to IFE or lead-free soldering would remain unchanged or even increase (e.g. 122 IFE malfunction occurrences reported in 2016 against 17 in 2010);

(b) the negative economic effect (also identified in Section 2.1 above) of having non-updated AMC-20 would remain unchanged or would even increase; and

(c) EASA would not be supporting industry to comply with Directive 2011/65/EU on the environment.

4.2.2. Option 1

4.2.2.1. Safety impact

A safety benefit is expected by:

— reducing the risk of malfunction of an IFE system, which could ultimately pose a fire hazard; and

— reducing the risk of having components with inappropriate soldering, which could decrease the reliability of aircraft systems or subsystems, leading to a serious incident or accident.

4.2.2.2. Environmental impact

Providing guidance for the certification of lead-free soldering would complement compliance with Directive 2011/65/EU that requires that new equipment and systems do not contain lead (Pb) or other environmentally hazardous materials.

Although the aviation industry is exempted from that Directive, the industrial supply chain for standard parts is bound to comply with the national (Member States) legislations having transposed the Directive.

Providing guidance on the certification of lead-free soldering is therefore necessary to that extent, and could also even prevent industry from using the aviation exemption provided for in the Directive.

Hence, the proposal is expected to have a positive environmental impact.

4.2.2.3. Social impact

Not applicable.

4.2.2.4. Economic impact

AMC reflecting the industry state of the art and best practices would facilitate the design and certification process, thereby reducing costs.

Applicants will benefit from prior awareness of the EASA expectations, by having the corresponding material directly available in AMC-20. This may prevent the development of unacceptable designs in the early stage of projects. A positive economic impact is therefore expected.

4.2.2.5. General Aviation (GA) and proportionality issues

The existing guidance on IFE is mainly focused on IFE systems installed on large aircraft used in commercial air transport (CAT). As a consequence, this guidance is incommensurate or more difficult to follow with GA aircraft. Through this NPA's proposal, GA would also benefit from the proportionate guidance introduced in AMC 20-19.

4.3. Conclusion

4.3.1. Comparison of options

The overall impact of Option 0 is negative, while Option 1 is expected to bring safety, environmental, and economic benefits.

Option 1 only would allow to meet the EASA objectives.

Therefore, Option 1 is the preferred one.

5. Proposed actions to support implementation

N/a

6. References

6.1. Related regulations

— Commission Regulation (EU) No 965/2012 of 5 October 2012 laying down technical requirements and administrative procedures related to air operations pursuant to Regulation (EC) No 216/2008 of the European Parliament and of the Council (OJ L 296, 25.10.2012, p. 1)

— Commission Regulation (EU) No 748/2012 of 3 August 2012 laying down implementing rules for the airworthiness and environmental certification of aircraft and related products, parts and appliances, as well as for the certification of design and production organisations (OJ L 224, 21.8.2012, p. 1)

6.2. Affected decisions

— Decision No. 2003/12/RM of the Executive Director of the Agency of 5 November 2003 on general acceptable means of compliance for airworthiness of products, parts and appliances ('AMC-20')

— Decision N° 2012/020/R of the Executive Director of the Agency of 30th October 2012 on acceptable means of compliance and guidance material for the airworthiness and environmental certification of aircraft and related products, parts and appliances, as well as for the certification of design and production organisations ('AMC and GM to Part 21')

— Decision 2014/017/R of the Executive Director of the Agency of 24 April 2014 adopting Acceptable Means of Compliance and Guidance Material to Part-ORO of Regulation (EU) No 965/2012 and repealing Decision 2012/017/R of the Executive Director of the Agency of 24 October 2012 'AMC and GM to Part-ORO — Issue 2'

— Decision 2014/015/R of the Executive Director of the Agency of 24 April 2014 adopting Acceptable Means of Compliance and Guidance Material to Part-CAT of Regulation (EU) No 965/2012 and repealing Decision 2012/018/R of the Executive Director of the Agency of 24 October 2012 'AMC and GM to Part-CAT — Issue 2'

6.3. Other reference documents

— CS-23 Normal, Utility, Aerobatic and Commuter Aeroplanes

— CS-25 Large Aeroplanes

— CS-27 Small Rotorcraft

— CS-29 Large Rotorcraft

— CS-ETSO European Technical Standard Orders

— EASA Certification Memorandum CM-ES-001, Certification of Power Supply Systems for Portable Electronic Devices, Issue 1, 7 June 2012

— EASA CM-SWCEH-001, Development Assurance of Airborne Electronic Hardware, Issue 1, Revision 1, 11 August 2011

— JAA Temporary Guidance Leaflet (TGL) No 17, Passenger Service and In-Flight Entertainment (IFE) Systems

— United Kingdom Civil Aviation Authority (UK CAA) Airworthiness Notice No 60, Continuing Airworthiness and Safety Standards of Passenger Service and In-Flight Entertainment Systems, Issue 2

— Transport Canada Advisory Circular (AC) No. 500-022, In-Flight Entertainment Systems, Issue 1, 8 November 2006

— FAA Policy Memorandum PS-ANM100-2000-00105 (also numbered 00-111-160), Interim Policy Guidance for Certification of In-Flight Entertainment Systems on Title 14 CFR Part 25 Aircraft (Policy Number 00-111-160), 18 September 2011

— FAA AC 91.21-1C, Use of Portable Electronic Devices Aboard Aircraft, 7 May 2015

— FAA Memorandum No AIR100-2011-120-003, Assessing the Reliability and Certification Procedures for Electrical and Electronic Equipment and Systems Using Lead-Free Solder and Lead-Free Finishes on Components, 20 July 2011

— FAA AC 20-152, RTCA Inc. Document RTCA/DO-254, Design Assurance Guidance for Airborne Electronic Hardware, 5 July 2005

— FAA Order 8110.105, Simple and Complex Electronic Hardware Approval Guidance, 23 September 2008

— European Organization for Civil Aviation Equipment (EUROCAE) ED-14, Radio Technical Commission for Aeronautics (RTCA) DO-160, Environmental Conditions and Test Procedures for Airborne Equipment, Revision G, 8 December 2010

— EUROCAE ED-130, Guidance for the Use of Portable Electronic Devices (PEDs) on Board Aircraft, 1 December 2006

— RTCA DO-199, Potential Interference to Aircraft Electronic Equipment from Devices Carried Aboard (Vols I and II), 16 September 1988

— RTCA DO-227, Minimum Operational Performance Standards for Lithium Batteries, 23 June 1995

— RTCA DO-294, Guidance on Allowing Transmitting Portable Electronic Devices, Revision C, 16 December 2008

— RTCA DO-307, Aircraft Design and Certification for Portable Electronic Device (PED) Tolerance, Revision A, 15 December, 2016

— Aeronautical Radio, Incorporated (ARINC) 628, Cabin Equipment Interfaces

— Government Electronics & Information Technology Association (GEIA)-STD-0005-1, Performance Standard for Aerospace and High Performance Electronic Systems Containing Lead-free Solder, Revision A, 1 March 2012

— GEIA-STD-0005-2, Standard for Mitigating the Effects of Tin Whiskers in Aerospace in High Performance Electronic Systems, Revision A, 1 May 2012

— GEIA-STD-0005-3, Performance Testing for Aerospace and High Performance Electronic Interconnects Containing Pb-Free Solder and Finishes, Revision A, 1 December 2012

— International Electrotechnical Commission (IEC)/TS 62647-1, 'Process management for avionics — Aerospace and defence electronic systems containing lead-free solder — Part 1: Preparation of a lead-free control plan, 1st Edition, 1 August 2012

— IEC/TS 62647-2, Process management for avionics — Aerospace and defence electronic systems containing lead-free solder — Part 2: Mitigation of deleterious effects of tin, 1st Edition, 1 November 2012

— IEC/TS 62647-3, Process management for avionics — Aerospace and defence electronic systems containing lead-free solder — Part 3: Performance testing for systems containing lead-free solder and finishes, 1st Edition, 1 February 2014

7. Appendix

N/a