EASA	NOTIFICATION OF A PROPOSAL TO ISSUE A CERTIFICATION MEMORANDUM
	EASA Proposed CM No.: **EASA Proposed CM - AS – 004 Issue: 01** **Issue Date: 30th of July 2014** **Issued by: Avionics Systems section** **Approved by: Head of Certification Experts Department** **Regulatory Requirement(s): CS-23, CS-25, CS-APU, CS-E & CS-P**

In accordance with the EASA Certification Memorandum procedural guideline, the European Aviation Safety Agency proposes to issue an EASA Certification Memorandum (CM) on the subject identified below.

All interested persons may send their comments, referencing the EASA Proposed CM Number above, to the e-mail address specified in the "Remarks" section, prior to the indicated closing date for consultation.

EASA Certification Memoranda clarify the European Aviation Safety Agency's general course of action on specific certification items. They are intended to provide guidance on a particular subject and, as non-binding material, may provide complementary information and guidance for compliance demonstration with current standards. Certification Memoranda are provided for information purposes only and must not be misconstrued as formally adopted Acceptable Means of Compliance (AMC) or as Guidance Material (GM). Certification Memoranda are not intended to introduce new certification requirements or to modify existing certification requirements and do not constitute any legal obligation.

EASA Certification Memoranda are living documents into which either additional criteria or additional issues can be incorporated as soon as a need is identified by EASA.

Subject

Single Event Effects (SEE) Caused by Atmospheric Radiation

Certification Considerations and an Analysis Method to Demonstrate the Acceptability of Effects on Aircraft, Engine, APU and Propeller Systems and Equipment, caused by Atmospheric Radiation

Log of Issues

Issue	Issue date	Change description
01	30.07.2014	First issue.

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1. INTRODUCTION

1.1. PURPOSE AND SCOPE

Atmospheric radiation is a generic term which refers to all types of electromagnetic radiation which can penetrate the earth's atmosphere. The main contributors to atmospheric radiation are solar and galactic radiation. Solar radiation is emitted from the sun and galactic radiation originates from outside our solar system. Both types of radiation can be affected (distorted or bent) by the earth's magnetic field.

Single Event Effects (SEE) occur when atmospheric radiation, comprising high energy particles, collide with specific locations on semiconductor devices contained in aircraft systems. Memory devices, microprocessors and FPGAs are most sensitive to SEE.

Note: throughout this Certification Memorandum, any reference to 'aircraft systems' also includes Engines, APU's and Propeller Systems.

Some examples of these types of effects are Single Event Upsets (SEU), Multiple Bit Upset (MBU), Single Event Gate Rupture (SEGR) and Single Event Burnout (SEB). However, SEU and MBU are the two single effects that present the largest potential threat to aircraft systems (see **Section 1.4** for description of SEE types).

The rate of SEE are likely to be greater on aircraft flying at high altitudes and high geographic latitudes. This is due to the effects of atmospheric absorption and magnetic deflection of solar and galactic radiation.

Although the intensity of atmospheric radiation varies with altitude and geographic latitude, the high energy particles are randomly distributed at any given location. Due to this, the predicted SEE rates can be derived based on the characteristics of the aircraft equipment (number of vulnerable elements) and operating conditions (altitude, latitude).

The effect of atmospheric radiation is one factor that could contribute to equipment malfunction. From a system safety perspective, the existing methodology covering random failures which is described in SAE ARP 4761(Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment) could be used in the assessment of atmospheric radiation effect rates.

Extreme space weather includes the effects of solar flares which can result in large bursts of solar particles arriving in the atmosphere creating an increase in atmospheric radiation of short duration (order of hours). During solar flare activity, the atmospheric radiation may rise to significantly higher levels than that normally expected and could increase by a factor of 300 or more (see document IEC62396-1, Section 5.6). This Certification Memorandum considers the **normal** atmospheric radiation levels, which could be experienced during a typical flight, and not those which could be experienced during a solar flare. It is expected that some prior notification of high solar activity, and thus possible solar flares, will be available to the operator of an aircraft via solar weather information websites. This should result in operational limitations relating to the routing of the flight (i.e. avoiding high latitudes). Further information regarding extreme space weather can be found in the following report: *Extreme Space Weather – Impacts on Engineered Systems and Infrastructure. Royal Academy of Engineering – February 2013 and EASA Safety Information Bulletin SIB No. 2012-09 Effects of Space Weather on Aviation.*

The applicant should demonstrate that aircraft systems, whose failure could have a safety effect, are adequately mitigated against SEE. Such mitigation can be achieved through architectural system considerations, equipment design, component selection, component testing or suitable combination thereof.

This Certification Memorandum provides guidelines for an acceptable method of demonstrating compliance with certification requirements when considering the effects of SEE on systems and equipment and is applicable to aircraft, engines, propellers and auxiliary power units certified in accordance with, but not limited to, CS-23, CS-25, CS-E, CS-P and CS-APU (and their associated AMCs).

EASA has also issued a Safety Information Bulletin (SIB) No. 2012-10 *Single Event Effects (SEE) on Aircraft Systems caused by Cosmic Rays* which informs aircraft operators, aircraft manufacturers, avionic system designers, electronic equipment and component manufacturers of the fault conditions that could be caused by SEE.

1.2. REFERENCES

It is intended that the following reference materials be used in conjunction with this Certification Memorandum:

Reference	Title	Code	Issue	Date
EUROCAE ED 79/SAE ARP 4754	Guidelines for Development of Civil Aircraft and Systems. Note: Applicants are advised to use the latest standard – ED79A/SAE ARP 4754A.	---	---	---
SAE ARP 4761	Guidelines and Methods for Conducting the Safety Assessment Process on Civil Airborne Systems and Equipment.	---	---	01/12/1996
CS 2x.1301*	Function and Installation	CS-23 CS-25	---	---
CS 2x.1309*	Equipment, system and installations	CS-23 CS-25	---	---
IEC 62396	Process management for avionics - Atmospheric radiation effects, Parts 1 to 5	---	Ed 1.0	23/05/2012
---	Extreme Space Weather: Impacts on Engineered Systems and Infrastructure. Royal Academy of Engineering - Summary report	---	---	February 2013
EASA Safety Information Bulletin SIB No. 2012-09	Effects of Space Weather on Aviation	---	---	23/05/2012
EASA Safety Information Bulletin SIB No. 2012-10	Single Event Effects (SEE) on Aircraft Systems caused by Cosmic Rays	---	---	23/05/2012

* Associated Acceptable Means of Compliance and Guidance Material where applicable.

1.3. ABBREVIATIONS

The following abbreviations are used in this Certification Memorandum:

Abbreviation	Meaning
AEH	Airborne Electronic Hardware
AFM	Aircraft Flight Manual
APU	Auxiliary Power Unit
ARP	Aerospace Recommended Practice
DDP	Declaration of Design and Performance
EASA	European Aviation Safety Agency
ETSO	European Technical Standard Order
FAA	Federal Aviation Administration
FADEC	Full Authority Digital Engine Control
FHA	Functional Hazard Assessment
FPGA	Field-programmable Gate Array
HF	High Frequency
IEC	International Electrotechnical Commission
IC	Integrated Circuit
MBU	Multiple Bit Upsets
PSSA	Preliminary System Safety Assessment
SAE	Society of Automotive Engineers
SEB	Single Event Burn-out
SEE	Single Event Effects
SEFI	Single Event Functional Interrupt
SEGR	Single Event Gate Rupture
SEL	Single Event Latchup
SEU	Single Event Upset
SRAM	Static Random-Access Memory
SSA	System Safety Assessment

Abbreviation	Meaning
TC	Type Certificate
VHF	Very High Frequency

1.4. Description of SEE types and consequences

The following definitions are used in this Certification Memorandum:

Single Event Effect Type	Description
Single Event Upset	Occurs in a semiconductor device when the radiation absorbed by the device is sufficient to change a cell's logic state.
Multiple Bit Upset	Occurs when the energy deposited in the silicon of an electronic component by a single ionizing particle causes upset to more than one bit in the same logical word.
Multiple Cell Upset	Occurs when the energy deposited in the silicon of an electronic component by a single ionizing particle induces several bits in an IC to fail at one time.
Single Event Latchup	* Occurs in a four or more layer semiconductor device (typically a CMOS device) when the radiation absorbed by the device is sufficient to cause a node within the powered semiconductor device to be held in a fixed state whatever input is applied until the device is de-powered, such latch up may be destructive or non-destructive.
Single Event Gate Rupture	Occurs in the gate of a powered insulated gate component when the radiation charge absorbed by the device is sufficient to cause gate rupture, which is destructive.
Single Event Burnout	Occurs when a powered electronic component or part thereof is burnt out as a result of the energy absorption triggered by an individual radiation event.
Single Event Transient	A spurious signal or voltage induced by the deposition of charge by a single particle that can propagate through the circuit path during one clock cycle.
Single Event Functional Interrupt	Upset usually in a complex device, for example, a microprocessor, such that a control path is corrupted, leading the part to cease to function properly.

The information in the above tables (except *) is provided with permission from the IEC (IEC 62396 Part 1).

2. BACKGROUND

2.1. APPLICABILITY

Typically, aircraft systems installed on aircraft that fly above 29000 feet should consider SEE. The applicability reflects the need to address large transport and business aircraft, which tend to fly globally and at higher altitudes where SEE are more likely to occur.

When considering this Certification Memorandum, the types of component technology used and previous 'in service' history may be taken into account. Generally, applicants whose was equipment was previously installed on EASA certificated or validated aircraft do not need to demonstrate compliance to this Certification Memorandum.

The applicability may need to be revised depending on the future development of systems and equipment and their susceptibility to SEE.

2.2. DISCUSSION

This Certification Memorandum is intended for use by designers of aircraft, engines, APUs, propellers, systems and equipment) hereafter referred to as the applicant.

Applicants will be responsible for demonstrating, to the Agency, that SEE are adequately addressed in a system (or equipment) and that the effects (if any) at aircraft/engine level are acceptable. Part of this responsibility may require an assessment of the equipment manufacturer to ensure adequate procedures are in place, and are/were followed, to address SEE.

An Equipment Manufacturer may also wish to use this Certification Memorandum to demonstrate the equipment robustness to SEE, independently of a request from an Aircraft Manufacturer, Engine/APU Manufacturer, Propeller Manufacturer or a System Designer. Although not currently specifically mentioned in ETSO 'approval standards', a SEE analysis may be referenced in certification testing documentation provided to the Agency for obtaining an equipment ETSO authorisation.

The IEC 62396 Parts 1 to 5 provide useful information relating to atmospheric radiation effects, testing, and accommodation of SEE by optimisation of system design.

The applicant is requested to consider the relevant paragraphs of this Certification Memorandum when addressing SEE. Note that this Certification Memorandum provides a means of compliance which would be acceptable to the Agency, however, the applicant may propose an alternative means of compliance.

2.3. EFFECTS OF ATMOSPHERIC RADIATION ON SYSTEMS AND EQUIPMENT IN AIRCRAFT, ENGINES, APUS OR PROPELLERS

The impact of a SEE on aircraft systems can vary and may be transitory or permanent. They may, or may not, produce noticeable functional effects.

Occasionally the effect(s) may cause the loss or malfunctioning of a system. Although the crew may report the system loss or malfunction, the subsequent re-test on the ground or in the air may not reproduce the effect. This results in a 'no fault found' entry in the aircraft technical log. The system/equipment may continue, thereafter, to operate correctly with no further system malfunctions. It is also possible that the malfunction may not be detected/detectable and could contribute to misleading information presented to the crew.

Typical systems which may be affected include:

i. Aircraft control systems which use fly-by-wire technology,

ii. Autopilot,

iii. Flight warning,

iv. Communication (High Frequency (HF), Very High Frequency (VHF), Satellite voice),

v. Navigation

vi. Displays

vii. FADEC (Full Authority Digital Engine Control)

viii. Engine (including APU) or Propeller control systems

ix. Any other electronic or electrical system containing semiconductor device(s).

Note that all systems containing semiconductor devices could be affected to varying degrees. It is not expected, however, that the **normal** levels of atmospheric radiation activity could affect several systems simultaneously. SEE are random and independent events and effects that do not introduce any new common cause for systemic failure.

3. EASA CERTIFICATION POLICY

3.1. CERTIFICATION PROCESS

3.1.1. The applicant should have a procedure to address SEE. This procedure may be incorporated into an 'existing' overall design process.

3.1.2. In accordance with Part 21.A.20(b) the applicant should provide a Certification Programme, describing the system or equipment operation (or major change/modification). The Certification Programme should also include the certification basis and how compliance to the SEE certification guidance, given in Section 3.2, will be met. This Certification Programme should be provided to the Agency at an early stage in the project.

3.1.3. The certification specifications which could be applicable are, but not limited to, CS-23, CS-25, CS-E, CS-P and CS-APU (and their associated AMCs). The following certification requirements are considered applicable within the context of this Certification Memorandum:

i. CS 23.1301, CS 23.1309,

ii. CS 25.1301, CS 25.1309,

iii. CS-E 50, CS-E 210, CS-E 510,

iv. CS-P 150,

v. CS-APU 90, CS-APU 210.

3.1.4. The classification of the failure conditions, introduced by the system or equipment operation (or major change/modification), may be assessed in accordance with Eurocae ED 79A/SAE ARP 4754A and detailed in a Functional Hazard Assessment which should be made available to the Agency (the applicant may also refer to SAE ARP 4761 for guidance of how to produce a Functional Hazard Assessment). Where the classification of the failure is not directly known, an assumption should be made and stated in a certification document such as a Certification Programme and/or a Declaration of Design and Performance (DDP).

3.1.5. The susceptibility to SEE for each system or piece of equipment capable of causing or contributing to Catastrophic or Hazardous failure conditions should be considered.

Equipment, Engine, APU and Propeller Systems designers may need to consider the failure classification at aircraft level if their system/equipment could contribute to a Catastrophic or Hazardous failure condition.

Note 1: *The susceptibility to SEE of systems or equipment with Major, Minor or No Safety Effect failure conditions may be addressed on a voluntary basis, but otherwise they do not need to be considered.*

Note 2: *Architectural system considerations (e.g. dual systems), equipment design and/or component selection may mitigate the impact of SEE events on a function within a system or piece of equipment.*

3.1.6. For each system or piece of equipment which is susceptible to SEE, the equipment-level, system-level and aircraft-level failure effects of each susceptible component should be determined. This determination should take into consideration any architecture or design features that would reduce or eliminate the effects or susceptibility to SEE. These architecture or design features, and any supporting assumptions, should be documented in a PSSA, SSA, or similar document (Safety Analysis Report) following standard praxis.

3.1.7. The applicant should provide a summary document describing the tasks accomplished to meet the objectives of this guidance. The summary document should include references to the Safety Analysis Report and any other reports where qualitative or quantitative SEE analysis is documented.

3.2. SEE Analysis Method to Assess the Safety Of Systems and Equipment in Aircraft, Engines, APUs or Propellers

This section describes a method to assess the potential contribution of Atmospheric Radiation effects, as an aspect of the overall system safety assessment process. This contribution could be used together with the other safety aspects identified by classical safety analysis (FMEA, FHA, SSA etc). This method is acceptable to the Agency, but should not be considered as the only method. A flow diagram is provided in Annex A to assist in understanding the SEE analysis method.

3.2.1. Initial assessment

The functional hazard assessment (FHA) for the aircraft, engine, APU or propeller and their associated systems should be reviewed (see **Section 3.1.4**). For each system or function with one or more failure conditions classified as Catastrophic or Hazardous, a list should be established containing all the equipment in the system which could contribute to the failure condition.

3.2.2. SEE analysis

3.2.2.1 An analysis should be performed for each equipment, which contributes to a Catastrophic or Hazardous failure condition. A parts list should be produced based on the components in the equipment.

3.2.2.2 Information from relevant component data sheets should be used to determine the level of susceptibility to SEE for each component. Where the data sheet does not contain sufficient information regarding susceptibility to SEE, a conservative determination of SEE susceptibility should be made based on the 'type' of technology used within the component (i.e., logic device, memory device, FPGA, or other types of semiconductor devices which are susceptible to SEE). IEC 62396 Part 1 contains guidance regarding conservative values of generic SEE data based on component basic technology.

3.2.3. Qualitative assessment process

A qualitative assessment should be performed for the components which were identified, in **Section 3.2.2.2**, as potentially affected by SEE. These components should be reviewed and any mitigations, as a result of architecture or system design, should be identified and recorded. It may be possible that certain components, for which there exists sufficient qualitative mitigation, may be exempt from the subsequent quantitative assessment.

3.2.4. Quantitative assessment process

3.2.4.1 A quantitative assessment should be performed for the remaining components where no mitigation or only partial mitigation, against the effects of SEE, was identified.

In accordance with IEC 62396 Part 1, a neutron flux of 6000 n/cm2 (which is equivalent to a typical flight envelope of 40,000 feet and latitude of 45 degrees), should be used. Deviations to this typical flight envelope should be stated in a Declaration of Design and Performance (DDP) document and/or the Aircraft Flight Manual (AFM) or, for Engines and Propellers, it should be stated in the respective manuals as required by CS-E 20 and CS-P 30.

3.2.4.2 The quantitative assessment should use the available component SEE rates (from the component data sheets) or, if not available, a conservative SEE rate should be used.

3.2.4.3 When the quantitative assessment indicates an unacceptably high probability that the component could be affected by SEE, compared to the classification of the failure, the following options should be considered:

i. a re-design of the component or use of a different component (different specification or technology) **or**

ii. architecture re-design to include additional mitigation(s) **or**

Note: *At this stage, an architecture or system design change may provide mitigation thus removing the need to perform a quantitative assessment.*

iii. radiation testing of the component to confirm the SEE rate (see **Section 3.2.5**).

Note: *Previously obtained radiation testing data, for the component may also be used if this data was shown to be relevant. This would negate the need to repeat radiation testing for this component.*

3.2.5. Component radiation testing

Radiation Testing should be performed when the quantitative assessment indicates an unacceptably high probability that the component could be affected by SEE, compared to the classification of the failure, and a re-design of the component (or use different component) or an architecture re-design to include additional mitigation(s) is not possible, for example.3.2.5.2, Radiation testing of the component to determine the SEE rate should be performed (refer to IEC 62396-2 for further details regarding radiation testing).

3.2.5.3 If the radiation testing results indicate an unacceptably high component failure rate then a system/equipment redesign, or use of different component(s), will be necessary.

3.3. MANAGEMENT AND CONTROL OF PARTS

The applicant should ensure that a plan is in place to address SEE issues in the initial parts selection and also in continued airworthiness of the system, equipment and/or component. A process should be in place to ensure that new parts, selected to replace obsolescent parts, are analysed to ensure that the original SEE mitigation remains valid.

3.4. GROUND AND FLIGHT TESTING

No ground or flight testing is required unless the applicant wishes to take certification credit for additional SEE testing.

3.5. WHO THIS CERTIFICATION MEMORANDUM AFFECTS

This Certification Memorandum is intended for use by designers of aircraft, engines, APUs, propellers, systems and equipment).

4. REMARKS

1. This EASA Proposed Certification Memorandum will be closed for public consultation on the **11th of September 2014**. Comments received after the indicated closing date for consultation might not be taken into account.
2. Comments regarding this EASA Proposed Certification Memorandum should be referred to the Certification Policy and Planning Department, Certification Directorate, EASA. E-mail CM@easa.europa.eu or fax +49 (0)221 89990 4459.
3. For any question concerning the technical content of this EASA Proposed Certification Memorandum, please contact:

   Name, First Name: Hallworth, Kevin

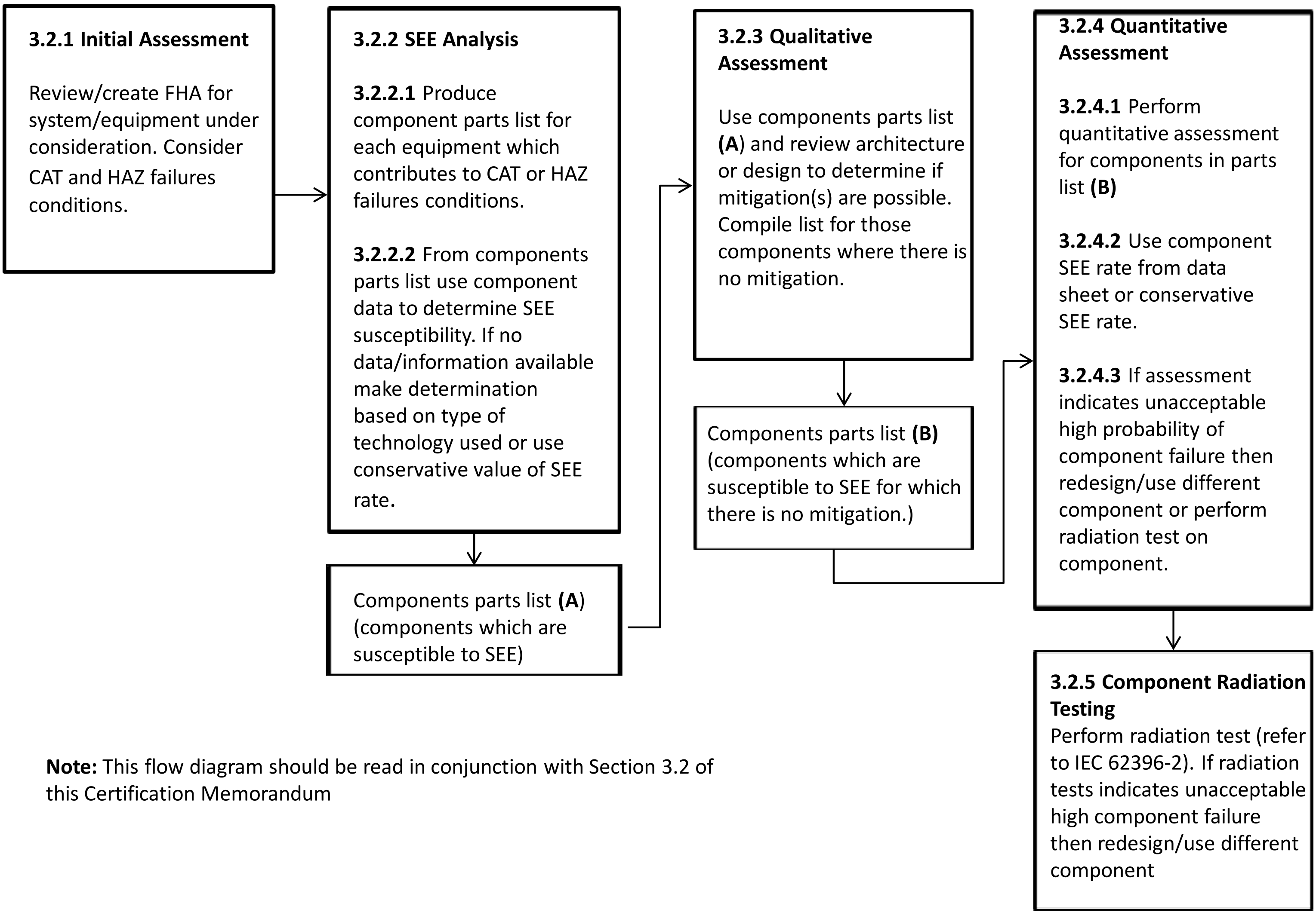
   Function: Avionics Systems Expert

   Phone: +49 (0)221 89990 4050

   Facsimile: +49 (0)221 89990 4550

   E-mail: kevin.hallworth@easa.europa.eu

ANNEX A SEE ANALYSIS METHOD TO ASSESS THE SAFETY OF SYSTEMS AND EQUIPMENT IN AIRCRAFT, ENGINES, APUS OR PROPELLERS



Note: This flow diagram should be read in conjunction with Section 3.2 of this Certification Memorandum