EASA Proposed CM-AS-004 Issue 01 – Single Event Effects (SEE) Caused by Atmospheric Radiation – Comment Response Document

Comment				Comment summary	Suggested resolution	Comment is an observation or is a suggestion*	Comment is substantive or is an objection**	EASA comment disposition	EASA response
NR	Author	Section, table, figure	Page						
1	*Garmin*	Section 2.1, 2nd Paragraph, 2nd sentence	8	There is a typo in this sentence: "Generally, applicants whose **was** equipment was previously installed on EASA certificated or validated aircraft do not need to demonstrate compliance to this Certification Memorandum."	Delete the 1st "was".	Yes		Agreed	
2	*Garmin*	Annex A, Flow Diagram, Section 3.2.2.2	13	The following is included in the 3.2.2 SEE Analysis box: "3.2.2.2 From components parts list use component data to determine SEE susceptibility. If no data/information available make determination based on type of technology used or use conservative value of SEE rate." It is not necessary to perform the quoted 3.2.2.2 task until the Component parts list (B) is created. The quantitative analysis does not need to be done until after creating a Components parts list (B). The quantitative analysis is already covered in 3.2.4.2.	Suggest one of these resolutions: 1. Remove the quoted 3.2.2.2 text from the 3.2.2 SEE Analysis box and include a reference to 3.2.2.2 in the 3.2.4 Quantitative Assessment box. 2. Remove the quoted 3.2.2.2 text from the 3.2.2 SEE Analysis box and move the 3.2.2.2 information, e.g., IEC reference, etc., to 3.2.4.2 in the main section of the document.		Yes	Not Agreed	Not sure how para 3.2.3 could be performed before para 3.2.2.2. since knowledge of the components, which are affect by SEE, needs to be determined before the design architecture is assessed or initial design commences. Components Parts List A is a list of all components susceptible to SEE. From this list, a review of the design should take place to see which of these components may be eliminated due to design mitigation. The remaining components are referred to as 'parts list B'.
3	*University of Surrey Space Centre* *Professor Clive Dyer*	1.1, Para 1		It is good that greater attention will be focussed on problems arising from single event effects in avionics and gratifying that IEC TS-62396 is serving as the basis. As one of the major contributors to this standard and the Royal Academy of Engineering study on Extreme Space Weather, I offer the following comments: Suggest delete electromagnetic. Gamma rays are a minor component cf protons and heavier ions. Might be worth pointing out that the solar particles in general have lower energy cf GCRs and hence a steeper dependence on geomagnetic latitude.				Partially Agreed	Comment Nr. 63 also addresses this point. I would propose to use the following wording in line with comment nr 63: 'Atmospheric radiation is a generic term which refers to all types of ionizing radiation, including neutrons, penetrating or generated within the earth's atmosphere."
4	*University of Surrey Space Centre* *Professor Clive Dyer*	1.1, para 4		You should also highlight single event latchup and single event functional interrupt as they are very important. In fact although SEUs and MBUs are the most common effects, they are more easily mitigated and the greatest threats arguably come from SEL, SEB and SEFI. SEL can lead to burnout if not controlled by current limiting etc and there is the widespread phenomenon of microlatch whereby portions of a device cannot be addressed. Both types of SEL have given problems in both spaceborne and aviation systems. In modern devices SEFI is giving bursts of errors which are difficult to correct.				Agreed	Text changed to include single event latchup and single event functional interrupt.
5	*University of Surrey Space Centre* *Professor Clive Dyer*	1.1, para 5		Geomagnetic latitudes rather than geographic. For instance New York is significantly more exposed than London despite being at lower geographic latitude.				Not Agreed	Geomagnetic latitudes are not widely used in the area of flight operations. Your comment is however recognised as a true fact.

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6	*University of Surrey Space Centre* *Professor Clive Dyer*	1.1, para 8		I am concerned that this CM covers only normal conditions and not solar particle enhancements. The factor of 300 increase was based on the event of 23 February 1956 but this is an average and the factor was probably more like 1500 in certain regions, including UK airspace. It is considered likely that a worst case event (1 in 150 years) as represented by the Carrington event of 1859 could be a factor 4 worse again. This can imply mean times between upsets of minutes or less and high probabilities of hard failures. A lot of faith is being placed in the avoidance of such events via prior notification and warnings. At the present time there are no systems in place to do this and little prospect in the near future.				Agreed	This point was discussed many times and it was decided that the CM would only cover the normal atmospheric radiation levels.
7	*University of Surrey Space Centre* *Professor Clive Dyer*	2.1, para 2		It is not clear why previously certificated aircraft should be exempt to this CM if previous processes did not include SEE. Typo on "was" in front of "equipment".				Agreed	Generally, we are assuming that equipment which was previously installed on EASA certificated or validated aircraft is assumed to have already had significant exposure to normal 'atmospheric radiation' and any serious vulnerabilities would have been identified. This text will be added to the CM.
8	*University of Surrey Space Centre* *Professor Clive Dyer*	2.3, final para		I agree that it should be rare for normal levels to affect several systems simultaneously. However it is not impossible if rates are high enough, or if a shower of particles envelopes a large area. For severe solar enhancements SEEs could occur sufficiently close together in time on the same aircraft to give additional problems.				Agreed	Comment agreed. No change to text.
9	*University of Surrey Space Centre* *Professor Clive Dyer*	3.2.4.1, para 2		The neutron flux figure is per hour. Also the energy threshold (> 10 MeV) needs stating. Note that unless assurance can be given that the devices do not contain Boron-10 and thermal neutron testing has not been done, a safety margin of 7 must be applied to allow for SEEs via thermal neutron capture. Also for more modern devices the contribution of neutrons below 10 MeV becomes increasingly significant and further correction factors are required. Requested deviations are going to be common if latitude of 45 degrees is taken. I suggest that it would be better to use a figure that covered all latitudes and maybe altitudes to the maximum for most civil transport (?44000 feet). This figure would not be much higher. Of course Executive Jets and military would exceed this.				Partially Agreed	Text corrected to refer to 600 n/cm2 per hour and added the energy threshold of 10MeV. It is common to record deviations to 'other' environmental requirements in a Declaration of Design and Performance (DDP). It should be no different for deviations to the requested neutron flux level.
10	*University of Surrey Space Centre* *Professor Clive Dyer*	3.2.4.3, iii and note		Need to be careful here to test components from same manufacturer's lot as large variations can occur (bitter experience of space industry).				Agreed	Comment agreed. No change to text.
11	*University of Surrey Space Centre* *Professor Clive Dyer*	3.4		Not clear what is meant by ground testing here as component testing is required in section 3.				Agreed	Ground testing refers to any form of testing (on the ground) at aircraft level. It may be possible, in the future, to subject the aircraft as a whole (as opposed to, or to complement, component or system/equipment level testing. Wording will be modified to explain this.

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12	*GAMA*		4	Why is this a CM instead of an AMC, given the statement at the bottom of page 4?			Yes	Agreed	A CM is 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). Wording changed to reflect the above.
13	*GAMA*	Section 2.1, 2nd Paragraph, 2nd sentence	8	There is a typo in this sentence: "Generally, applicants whose **was** equipment was previously installed on EASA certificated or validated aircraft do not need to demonstrate compliance to this Certification Memorandum."	Delete the 1st "was".	Yes		Agreed	
14	*GAMA*	Section 2.2		First sentence has a closing parenthesis instead of a comma.	Change to comma	Yes		Agreed	
15	*GAMA*	Annex A, Flow Diagram, Section 3.2.2.2	13	The following is included in the 3.2.2 SEE Analysis box: "3.2.2.2 From components parts list use component data to determine SEE susceptibility. If no data/information available make determination based on type of technology used or use conservative value of SEE rate." It is not necessary to perform the quoted 3.2.2.2 task until the Component parts list (B) is created. The quantitative analysis does not need to be done until after creating a Components parts list (B). The quantitative analysis is already covered in 3.2.4.2.	Suggest one of these resolutions: 1. Remove the quoted 3.2.2.2 text from the 3.2.2 SEE Analysis box and include a reference to 3.2.2.2 in the 3.2.4 Quantitative Assessment box. 2. Remove the quoted 3.2.2.2 text from the 3.2.2 SEE Analysis box and move the 3.2.2.2 information, e.g., IEC reference, etc., to 3.2.4.2 in the main section of the document.		Yes	Not Agreed	Component list B cannot be compiled before Component list A is established.
16	*GAMA*	Section 3.2.3		It is unclear how to determine the sufficiency of any mitigation without a quantitative assessment. For example, an applicant could claim to have mitigation because the system design includes an independent SEE monitor, even though the monitor detects only 10% of SEE faults.	Clarify what mitigations might be acceptable with only a qualitative assessment.		Yes	Not Agreed	The CM should not be too prescriptive in this area since it could influence the design choice, however paragraph 3.1.5 does provide some examples of mitigations which could be considered.
17	*Embraer*	1.1	4	Definition of atmospheric radiation is not precise since this type of radiation is composed by a variety of particles such neutrons, which are not electromagnetic radiation.	Review phrase "... is a generic term which refers to all types of electromagnetic radiation which can penetrate the earth's atmosphere" in order to give a more accurate definition of atmospheric radiation. It would be interesting to highlight that many of these particles are generated due to the interaction of cosmic rays (solar and galactic radiation) with the atmosphere.	Yes	No	Agreed	Text changed
18	*Embraer*	1.1	4	Atmospheric radiation encompasses a wide range of energy levels, containing thermal neutrons which have lower energy when compared to protons coming from galactic sources.	Review phrase "... when atmospheric radiation, comprising high energy particles, ..." to include low energy particles, since thermal neutrons have high probability of interacting with boron 10 isotope, which is present in semiconductor devices as a dopant.	Yes	No	Agreed	Text changed.

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19	*Embraer*	1.1	4	Single event upsets (SEU) and multiple bit upsets (MBU) are the most common type of single event effects (SEE) and are not the "largest potential threat to aircraft systems", as the text suggests. SEU are the most frequent SEE, since they are caused by the deposition of charge in a device by a single particle that is sufficient to change the logic state of a single bit from one binary state to the other. MBU, which refers to multiple bits that are in the same logical word being upset during the same SEE interaction, are not as frequent as SEU, however are becoming more recurrent, as geometries shrink. As for the threat aspect: error correction code (ECC) and other design techniques (e.g.: memory interleaving associated with ECC) are able to address SEU and MBU, mitigating the associated risks and consequences.	The text passage: "However, SEU and MBU are the two single effects that present the largest potential threat to aircraft systems (…)." should be changed to: "However, SEU and MBU are the two most frequent single effects ~~**that present the largest potential threat**~~ to aircraft systems (…)."	Yes	No	Agreed	Text changed
20	*Embraer*	1.1	4	Radiation levels are not homogeneous along the same latitude, being higher at the South-Atlantic Anomaly (SAA). Operational limitations could apply to aircraft flying this region during high solar activity, and not only at high latitudes.	Evaluate if SAA region should be included in the phrase: "This should result in operational limitations relating to the routing of the flight (i.e. avoiding high latitudes)".	Yes	No	Not Agreed	It is accept that radiation levels are not homogeneous along the same latitude, being higher at the South-Atlantic. It is, however, considered that the current testing requirement stated in the CM should be sufficient to cover average neutron flux exposure taking into account the length of time the aircraft in this region compared to the rest of the flight.
21	*Embraer*	1.1	4	Although the applicant is responsible for demonstrating compliance to the applicable aviation regulations, the applicant cannot perform such a task without the aid of the other involved stakeholders (e.g.: suppliers, suppliers' subtiers). Therefore, this Certification Memorandum should explicitly acknowledge this fact.	The text passage: *"The applicant should demonstrate that aircraft systems, whose failure could have a safety effect, are adequately mitigated against SEE."* should be changed to: *"The applicant, with support from the other involved parties (such as system supplier and its subtiers) , should demonstrate that aircraft systems, whose failure could have a safety effect, are adequately mitigated against SEE."*	Yes	No	Partially Agreed	The applicant, (e.g. an aircraft manufacturer) may require support from system suppliers, however the responsibility to demonstrate that SEE is adequately mitigated remains with the applicant. No text changed.
22	*Embraer*	2.1	8	There is a typographical error: the word "was" is repeated twice *(… whose was equipment was …).*	*"Generally, applicants whose* ~~***was***~~ *equipment was previously installed on EASA certificated or validated aircraft do not need to demonstrate compliance to this Certification Memorandum."*	Yes	No	Agreed	
23	*Embraer*	3.2.3	10	Mitigation techniques against SEE include software error detection and correction. Section 3.2.3 could indicate if this type of mitigation can be considered for the qualitative assessment process.	Specify if error detection and correction can be considered a valid approach to mitigate SEE. DO 178 may be addressed in the document.	Yes	No	Agreed	Paragraph 3.1.5, Note 2 amended to include software error detection and correction as a possible mitigation.
24	*Embraer*	3.2.4.1	11	Although this memorandum describes on section 1.1 "Purpose and Scope" that SEE rates depend on operating conditions (i.e. altitude, latitude) and solar events, the certification policy defines a default radiation environment: "typical flight envelope of 40,000 feet and latitude of 45 degrees" and that deviations should be stated.	The definition of the radiation environment (as IEC/TS 92396 – Part 1 –Section 9 suggests) prior to EASA's proposed assessment could eliminate the obligation to state a special SEE envelop on Declaration of Design and Performance (DDP) or Product Manuals.	Yes	No	Not Agreed	The applicant can elect to use a different neutron flux than that mentioned in the Certification Memorandum, however any differences should be mentioned in the DDP or equivalent document.

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25	*Embraer*	3.2.4.2	11	Section 3.2.4.2 do not specify the source of conservative SEE rates if data is not available from the component data sheet.	Section 3.2.4.2 could indicate if SEE rates for quantitative assessment can be estimated by computational simulation (e.g. using MCNPX, Geant4 or other simulation platform), based on the technology and characteristics of the semiconductor devices used in the equipment.	Yes	No	Not Agreed	This Certification Memorandum provides guidance and it is not prescriptive. It is up the applicant to determine a suitable conservative SEE rate and to justify this.
26	*Embraer*	3.2.4.2	11	"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." This Item limits the sources of data that could be used to perform quantitative assessment	"IEC/TS 62396 – Part 2 – Section 6" discusses the sources of available SEE data. It is known that research centers, government agencies or even private companies that do note publish SEE data on component datasheets may possess relevant data that could be used on the quantitative assessment.	Yes	No	Agreed	The 'conservative' SEE rate could be derived from other sources such as research centers, government agencies or private companies. This should, however, be documented in the safety analysis document. It is considered that no changes to this section are required.
27	*Embraer*	3.2.5	11	Missing content . Seems to be missing items between 3.2.5 and 3.2.5.3. There is a mention to 3.2.5.2 and there is no such item on the document.	Review Item 3.2.5 and fill in with the missing content.	Yes	No	Agreed	
28	*UK CAA*	2.1	8	Comment: The second paragraph's second sentence infers that in service history can be taken into account. The underlined text is ambiguous "Generally, applicants whose was equipment was previously installed on EASA certificated or validated aircraft do not need to demonstrate compliance to this Certification Memorandum." A proposed amendment is presented below. Justification: Clarification of sentence. The equipment manufacturer may not be the applicant, and that equipment may have been installed in several aircraft by various applicants.	The underlined text is proposed: "Generally, applicants for installation of systems or equipment whose systems or equipment were previously installed on EASA certificated or validated aircraft do not need to demonstrate compliance to this Certification Memorandum."			Agreed	
29	*UK CAA*	2.2	8	Comment: The first paragraph implies that the designers of aircraft, engines, APUs, propellers, systems and equipment can be referred to, in EASA certification terms, as "the applicant", which is a term usually reserved for those parties applying for certification or a product, changed product or item approval. Justification: Clarification of term "applicant" in so far as this is used in relation to the applicant for "certification".	The underlined text is proposed: "This Certification Memorandum is intended for use by designers of aircraft, engines, APUs, propellers, systems and equipment in their support of those who are applying for certification of the product, changed product or equipment approval who are hereafter referred to as the applicant."			Not Agreed	Current text is proposed as it is less confusing than the alternative text provided by this commenter.
30	*Softwair Assurance*	3.2.2		Section 3.2.2 – this should say something about catastrophic (DAL A) versus hazardous (DAL B) since the more severe condition is when SRAM devices are used in Level A systems and can't meet the "no single event can result in a catastrophic hazard" aspect of 25.1309.				Not Agreed	If a device is used in a Level A system, that can't meet the "*no single event can result in a catastrophic hazard*" then a redesign of the system would be required – irrespective of the type of failure.
31	*Softwair Assurance*	3.2.4		Section 3.2.4 – the quantitative effect of an SEE/SEU could also be factored into a fault tree, which is a standard analysis performed by Level A/B LRUs.				Agreed	No change to Certification Memorandum but see section 3.1.6.

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32	*Softwair Assurance*	3.2.5		Please fix errors in the document: - Section 3.2.5 references Section 3.2.5.2, which does not exist - Typo: "for example.3.2.5.2" - Sections 3.2.5.1 and 3.2.5.2 are missing (there's a 3.2.5 then a 3.2.5.3)				Agreed	
33	*Rockwell Collins France*	2.1	8	"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."	Remove "and".	Yes	No	Not Agreed.	The text of the CM is only an indicative statement
34	*Rockwell Collins France*	2.1	8	"Generally, applicants whose was equipment was previously installed on EASA certificated or validated aircraft do not need to demonstrate compliance to this Certification Memorandum." In service history could only be used for similar application (similar flight profiles).	Could be replaced by "Generally, applicants whose equipment was previously installed on EASA certificated or validated aircraft do not need to demonstrate compliance to this Certification Memorandum, as far as the atmospheric radiation environment is similar or less stringent for the new application". Remove the first "was".	Yes	No	Partially Agreed	. Wording changed to 'Generally, applicants for installation of systems or equipment whose systems or equipment were previously installed on EASA certificated or validated aircraft do not need to demonstrate compliance to this Certification Memorandum. **Note**: equipment which was previously installed on EASA certificated or validated aircraft is assumed to have already had significant exposure to normal atmospheric radiation and any serious vulnerabilities would have been identified.'
35	*Rockwell Collins France*	2.2	8	"This Certification Memorandum is intended for use by designers of aircraft, engines, APUs, propellers, systems and equipment) hereafter referred to as the applicant."	Remove "("	Yes	No	Agreed	
36	*Rockwell Collins France*	2.2	8	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." SEE analysis usually does not provide testing results. To be part of the overall certification documentation.	Remove "testing" word.	Yes	No	Agreed	
37	*Rockwell Collins France*	3.2.4.1	11	"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." The neutron flux should be commensurate with the altitude and latitude of the aircraft.	Could be replaced by "In accordance with IEC 62396 Part 1, the neutron flux depends on both altitude and latitude. As a reference a neutron flux of 6000 n/cm2 could be used for a flight envelope of 40,000 feet and latitude of 45 degrees."	No	Yes	Not Agreed	The applicant is already able to use the neutron flux applicable to the flight envelope of their aircraft (refer to section 3.2.4.1), however values of neutron flux which differ from 6000 n/cm2 per hour should be stated in the DDP and/or Aircraft Flight Manual.
38	*Rockwell Collins France*	3.2.4.1	11	"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…" The flight envelope of an aircraft is how it is specified, not sure the flight envelope could be limited for an SEE concern. The aircraft manufacturer should derive the neutron flux from the specified flight envelope and the IEC reference.	This sentence could be replaced by "The aircraft manufacturer should specify a neutron flux derived from the specified flight envelope and the IEC reference."	No	Yes	Not Agreed	The applicant is invited to use the default values of neutron flux or suggest alternative value. In the later case it should be recorded in the DDP. This should simplify the process for the applicant and user of the data/equipment.

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39	*Rockwell Collins France*	3.2.5	11	"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." Re-design is always possible, but may be not practical from an industrial point of view.	Replace "possible" by "practical".	Yes	No	Agreed	
40	*Rockwell Collins France*	3.2.5.2	11	Numbering issue.	Remove "3.2.5.2"	Yes	No	Agreed	
41	*Rockwell Collins France*	Annex A	13	Box 3.2.5 "Component Radiation Testing" seems to require systematic radiation testing.	Remove the box 3.2.5 and change the text of 3.2.4.3 in "If assessment indicates unacceptable high probability of component failure then redesign/use different component or perform radiation test on component, and finally reassess the SEE rates. Proceed until getting an acceptable probability."	No	Yes	Agreed	Flow diagram changed accordingly
42	*FAA*	2.1	8	The limitation at 29K feet is causing some concern. There is no technical support for a difference between 29K and 30K up to 40K. An explanatory note that identifies that this altitude combined with the limitation in the next sentence (Transport and Business aircraft) is the current thinking to not include GA and Rotorcraft. This way as we learn more with regards to the evolution of the semiconductors and greater and greater sensitivity, we can change our position on the exclusions.	Add an explanatory note	Yes	No	Agreed	Agreed. Text modified to remove reference to 29,000 ft.
43	*FAA*	2.2	8	Paragraph 3 At first the first sentence was not clear in terms of purpose. It is obviously true and it is good advice, I was not sure why it should be included in the CM. However, reading the second sentence it appears that this paragraph is targeted at ETSO manufacturers.	Be more direct or clear in the first sentence and direct it to the ETSO manufacturers.	Yes	No	Not Agreed	This paragraph is not only directed towards equipment manufacturers who will apply for ETSO. There are many equipment manufacturers who decide not to apply for ETSO – or there is no ETSO for that particular equipment.
44	*FAA*	2.3	9	Last subparagraph in 2.3 This note is helpful. I am inclined to add to the text that all of the comments with regards to "…the **normal** levels of atmospheric radiation activity … " and "…effects that do not introduce any new common cause for systemic failure" , also assure that the rate of mitigation of SEE is not too high. The rationale is that many of the mitigation techniques are time dependent. That is, they recover in a timely fashion to assure that the system is recovered before another event occurs.	Add a sentence at the end of this note: "To support this conclusion the system rate of mitigation covered SEE's must be shown to be low with regards to the recovery time for the mitigation."	Yes	No	Not Agreed	The 'system rate of mitigation' is not clear. A mitigation should be available at all times and not associated to a rate.

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45	*Honeywell*	2.1	8	Section 2.1, the 1st paragraph presents the 29000 feet criteria for considering SEE – justification is: "…higher altitudes where SEE are more likely to occur". Section 1.1, the 6th paragraph states: "…the predicted SEE rates can be derived based on the characteristics of the aircraft equipment (number of vulnerable elements) and operating conditions (altitude, latitude)". Concern: since the SSE rates are determined by both equipment and operating conditions, the criteria for considering SEE should include the characteristics of the equipment as well.	Adding the equipment characteristics to the criteria would affectively mean to consider SEE for any equipment. Resolution is therefore to completely remove the 29000 feet criteria.	No	Yes	Agreed	Agreed. Reference to 29000 ft removed.
46	*Honeywell*	3.1.5	9	The 1st paragraph limits the scope to Catastrophic and Hazardous failure conditions. SEE is a real threat to the aircraft, so either Major and Minor failure conditions must be included as well or there must be a strong justification why those failure conditions can be excluded. It has been a common practice to address Major failure condition qualitatively only – justification lies in a proper part selection and from selected suppliers, good service history, etc. Thus the failure rates of the components can be expected to not exceed (too much) the required 1E-5/fh quantitative requirement. However, similar argument cannot be used for the SEE – in many cases, the SEE rates will be significantly higher than 1E-5/fh.	Extend the scope of the SEE analysis to include Major failure conditions.	No	Yes	Not Agreed	Major failure conditions, due to SEE, could result in a significant increase in workload for the crew, but should not result in a large reduction of functional capabilities or safety margins with respect to the aircraft (see AMC to CS 25.1309). The CM will be reviewed in the future to see if the major/minor criteria need to be addressed. For this version, only Catastrophic and Hazardous failure conditions will be considered with respect to SEE.
47	*Airbus*	1.1 PURPOSE AND SCOPE	4	Section 1.1 states "that SEU and MBU present the largest potential threat to aircraft systems" Section 3 ignores this statement and is applicable to any SEE. SEL, SEGR, SEB are addressed as part of the reliability assessments. For the other SEE types, only SEU and MBU effects are quantifiable, this is the reason why the analyses should focus on SEU and MBU only	**Beyond the sentence of § 1.1** "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)" **replace everywhere in the document** SEE by SEU and MBU. Assuming proposed text above is retained by EASA, it is suggested to complete the paragraph 1.1 including the following rational. SEL, SEGR, SEB are addressed as part of the reliability assessments. For the other SEE types, only SEU and MBU effects are quantifiable, this is the reason why the analyses should focus on SEU and MBU only.		Yes	Partially Agreed	Sentence changed to reflect that *SEU and MBU are the two 'most frequent' single effects to aircraft systems'* as opposed to saying that SEU and MBU *'present the largest potential threat to aircraft systems'.* Referring to Section 3, the applicant should review all types of SEE and provide a rationale for the type(s) of analysis performed on the component/system.
48	*Airbus*	3.2.2 SEE analysis 3.2.3 "qualitative assessment process" and 3.2.4 "quantitative assessment process"	10 11	There is a need to clarify that 3 ways of proceeding can be followed: - Qualitative then Quantitative analyses, - Qualitative analyses only, - Quantitative analyses only.	**Create a new paragraph 3.2.2.3 that introduces the notion developed below**. Text proposal: 3 ways of proceeding can be followed: - Qualitative then Quantitative analyses, - Qualitative analyses only, - Quantitative analyses only.		Yes	Not Agreed	It is assumed that the applicant will 1. Attempt to demonstrate, in the first instance, that their equipment does not contain and components which are susceptible to SEE. 2. If the equipment does contain components which are susceptible to SEE, the applicant will attempt to demonstrate sufficient mitigation 3. If insufficient mititigation

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49	*Airbus*	3.2.4.1 Quantitative assessment process	11	Units is missing time i.e. 6000n/cm2/h DDP's are used to confirm that product is compliant with Specification. AFM is definitively not practicable nor relevant to address this concern.	**Replace**: 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. **By:** IEC 62396 Part 1 introduces a mean neutron flux of 6000 n/cm2/h (which is equivalent to a typical flight envelope of 40,000 feet and latitude of 45 degrees). This figure of 6000 n/cm²/s should be used as a minimum value. Use of a lower value should be justified by the applicant to the Agency.		Yes	Agreed	
50	*Airbus*	1.2 Reference Table	5	Only part 1 and 2 of IEC 62396 should be used as a reference.	**Replace** "Process management for avionics – Atmospheric radiation effects, Parts 1 to 5" **By** "Process management for avionics – Atmospheric radiation effects, Part 1 and Part2"		Yes	Not Agreed	The reader of this CM may benefit from reading Part 3, 4 and 5
51	*Airbus*	1.4. DESCRIPTION OF SEE TYPES AND CONSEQUENCES	7	SEU doesn't create failure but only data modification	**Replace** 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. **By** Multiple Cell Upset: Occurs when the energy deposited in the silicon of an electronic component by a single ionizing particle induces several bits **upsets** in an IC at one time.		Yes	Agreed	
52	*Airbus*	2.1. APPLICABILITY	8	SEE analysis should be made for new development but also in case of evolution (obsolescence management, upgrade) of previously certified equipment.	**Replace** The applicability may need to be revised depending on the future development of systems and equipment and their susceptibility to SEE **By** The applicability may need to be revised depending on the future **evolution or new** development of systems and equipment and their susceptibility to SEE		Yes	Agreed	

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53	*Airbus*	3.2.5. Component radiation testing And 3.2.5.3	11	- paragraphs 3.2.5.1 and 3.2.5.2 don't exist - SEE doesn't create Failure	**Replace** …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… 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. **By** **3.2.5.1** if the radiation testing results indicate an unacceptably high component **SEE** rate then a system/equipment redesign, or use of different component(s), will be necessary.		Yes	Agreed	This section was modified based on, similar, previous comments.
54	*Airbus*	1.2. REFERENCES	5		For SAE ARP 4761, the date of issue has been provided, but not the issue number	Yes		Not Agreed	The document held in EASA Library does not have an issue number allocated to it.
55	*Airbus*	1.3. ABBREVIATIONS	6	The AEH abbreviation is not used in the document	**Delete** AEH abbreviation	Yes		Agreed	
56	*Airbus*	2.1. APPLICABILITY	8	Existing text with CM discusses "compliance to this Certification Memorandum" when the CM is intended for guidance and should be non-binding material? Intended meaning of this existing text is not clear and needs to be clarified	**Replace:** 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. **By:** Generally, for equipment previously installed on EASA Certificated or Validated aircraft, that are intended for re-use on a new aircraft type, there is no need to provide additional, specific consideration to SEE	Yes		Agreed	
57	*Airbus*	2.2 DISCUSSION	8	Text concerns development, not manufacturing.	**Replace:** 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. **By:** Part of this responsibility may require an assessment of the equipment **supplier** to ensure adequate procedures are in place, and are/were followed, to address SEE.		Yes	Agreed	

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58	*Airbus*	3.1.2	9	Compliance with CM does not make sense, as CM is non-binding guidance	**Replace:** 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. **By** 3.1.2 The Certification Programme should also include the certification basis and how the recommendations introduced by this certification guidance, are taken into account. This Certification Programme should be provided to the Agency at an early stage in the project		Yes	Agreed	Agreed but 1st sentence of this section is maintained. Proposed wording for second and third sentence is agreed.
59	*Airbus*	3.2.4. Quantitative assessment process 3.2.4.3 i	11	It is not *probable* that the applicant would re-design individual electronic components, and so it is suggested deleting that part of the above bullet-point.	**Replace:** i. a re-design of the component or use of a different component (different specification or technology) or **By** i. use of a different component (different specification or technology) or	Yes		Not Agreed	Allow not probable, it is possible for the applicant to request some form of 'hardening' from the component manufacturer.
60	*Airbus*	3.2.5. Component radiation testing	11	Radiation testing should be a sub-section of 3.2.4 (Quantitative Assessment Process) and does not merit having the same hierarchical level as Qualitative and Quantitative analysis. Testing should not be limited to cases where redesign "is not possible" (as stated above). Testing should be performed whenever the development authority considers radiation-testing a viable alternative that may negate the need for different component selection or circuit/system re-design. There is no section "3.2.5.2" There is no section 3.2.5.1	**Modify 3.2.4** to include the radiation testing chapter (and delete from 3.2.5)		Yes	Agreed	Flow diagram and relevant section changed.
61	*Airbus*	Annex A	13	Typo	ENGINES, APUSs OR PROPELLERS	Yes		Agreed	

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62	*Airbus*	Annex A	13	Radiation testing should be a sub-section of 3.2.4 (Quantitative Assessment Process) and does not merit having the same hierarchical level as Qualitative and Quantitative analysis. The flowchart has been developed for analysis of electronic components on equipment. This was one of the basic assumptions used during compilation of the flowchart. When box 3.2.3 refers to "reviewing architecture" in order to identify "mitigation", it should be clear that this is being performed on electronic components on an equipment, and that "architecture" and "mitigation" is at that level only. Subsequent analysis at system level (when several equipment are being integrated) can exploit visibility to system level architecture and visibility to system level safety requirements.	**Modify the Flowchart** to the version of the diagram as developed within the AIR 6218, where Testing was considered as a subset of Quantitative assessment.		Yes	Agreed	
63	*S. P. Platt* *School of Computing, Engineering and Physical Sciences University of Central Lancashire*	1.1	4	Section 1.1 begins "Atmospheric radiation is a generic term which refers to all types of electromagnetic radiation which can penetrate the earth's atmosphere." That is incorrect or at least incomplete. In the context of single-event effects caused by atmospheric radiation "atmospheric radiation" refers to ionizing particles which are normally not electromagnetic radiation. For example, the particles of most concern are neutrons (although neutrons are not directly ionizing, they are indirectly ionizing, the ionization being mediated by nuclear reactions). Furthermore, the neutron and most other components of the atmospheric radiation field are generated as secondary particles during interactions between primary cosmic radiation particles and the atmosphere.	Rephrase the opening sentence as follows: "Atmospheric radiation is a generic term which refers to all types of ionizing radiation, including neutrons, penetrating or generated within the earth's atmosphere."	No	Yes	Agreed	Text changed
64	*S. P. Platt* *School of Computing, Engineering and Physical Sciences University of Central Lancashire*	1.1	4	Paragraph 2 of section 1.1 begins: "Single Event Effects (SEE) occur when atmospheric radiation, comprising high energy particles, collide…" The reference here to "particles" is correct, but the reference to "high-energy" is not. There is a very well-known phenomenon whereby low-energy neutrons can interact with boron (a technologically important material in electronic components) to cause SEE (see e.g. IEC 62396 and references therein).	Rephrase the opening sentence of paragraph 2 as follows: "Single Event Effects (SEE) occur when atmospheric radiation interacts with the material of semiconductor devices in such a way as to generate spurious charge, thereby disrupting device operation."	No	Yes	Agreed	Text changed.
65	*S. P. Platt* *School of Computing, Engineering and Physical Sciences University of Central Lancashire*	1.1	4	In paragraph 4 of section 1.1, "SEU and MBU are the two single effects that present the largest potential threat to aircraft systems", is not justified without significant caveat. For example, if this were to be true in a particular context that would be likely to be because design steps had been taken to mitigate the threat from other SEE types (for example SEL, SEB and SEGR, all of which lead to hard errors), for example by screening or derating. SEU and MBU typically lead to a residual SEE rate for which further mitigation, normally through some kind of redundancy, may be required to ensure adequate reliability of a system. For example, without suitable mitigation another mechanism (e.g. SEB) might lead to catastrophic failure of a system and that might be assessed as the greatest SEE threat to the aircraft.	Remove this description of SEU and MBU, so that the paragraph reads as follows: "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). See Section 1.4 for description of SEE types."	No	Yes	Partially Agreed	Text changed. See comment 19.

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66	*S. P. Platt* *School of Computing, Engineering and Physical Sciences University of Central Lancashire*	1.1	4	Paragraph 8 of section 1.1 refers incorrectly to solar flares. There is widespread tendency (I mean, not just in this document, also, for example, in IEC 62396, cited here) to elide solar flares and other manifestations of solar activity, for example coronal mass ejections (CMEs). Solar flares and CMEs are both significant for space weather. Sometimes they go together; sometimes they do not. It's very complicated, and the references in this paragraph (RAEng report and SIB bulletin) explain things quite well. So something less specific would be helpful here, to reduce the risk of confusion.	Replace the first two sentences of this paragraph with the following: "Solar activity can result in transient large increases in atmospheric radiation, for example, by a factor of 300 or more over a duration of a few hours (see document IEC 62396-1, Section 5.6)."	Yes	No	Not Agreed	The description of 'solar flares' was kept as simple as possible to enable understanding at all levels. For further information the reader is asked to refer to the IEC document.
67	*S. P. Platt* *School of Computing, Engineering and Physical Sciences University of Central Lancashire*	1.1	4	Paragraph 8 of section 1.1 continues: "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)." This is misguided for two reasons. First, it is by no means certain that such prior notification would be available. The highest-energy particles emitted in a solar particle event, being relativistic and travelling close to the speed of light, arrive at earth within a few minutes of leaving the sun. It is not currently possible, and might never be possible, to predict eruptions. Although much effort is being expended on developing space weather forecasting (including near-time forecasting, or "nowcasting"), this is challenging and is not practical with current or near-term technologies and might never be achieved. For example, from the RAEng report cited in this paragraph: "Forecasting a solar storm is a challenge, and contemporary techniques are unlikely to deliver actionable advice" Secondly, the techniques for mitigating against SEE due to atmospheric radiation are largely independent of the atmospheric radiation flux. I discuss these briefly below; in summary, there is simply no need explicitly to exclude space weather from SEE analysis and to do so would contradict IEC 62396.	Delete the third, fourth and fifth sentences of this paragraph "~~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).~~" If this and my preceding recommendation are adopted, paragraph 8 would read as follows: "Solar activity can result in transient large increases in atmospheric radiation, for example, by a factor of 300 or more over a duration of a few hours (see document IEC 62396-1, Section 5.6). 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."	No	Yes	Partially Agreed	The following wording is proposed: *Some prior notification of high solar activity, such as solar flares, may 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). In some circumstances, however, prior notification may not be available due to the short notice period. Further guidance may need to be developed to deal with exceptional conditions such as solar flares.*

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68	*S. P. Platt* *School of Computing, Engineering and Physical Sciences University of Central Lancashire*	2.1	8	This section begins "Typically, aircraft systems installed on aircraft that fly above 29000 feet should consider SEE" This seems to imply that SEE is not a concern below 29000 feet. That would not be justified. There is nothing special about 29000 feet; the atmospheric radiation field varies gradually with altitude. Typically, atmospheric radiation experts might consider "flying at 30,000 feet" as an example because, conventional wisdom has it, that's a typical application domain, not because there's anything special about the environment at (or above) that altitude. Designers of aircraft systems need to take into account SEE among other threats to reliability throughout their aircraft flight envelopes, whatever they are. In the case of some aircraft with restricted flight envelopes (especially, restricted in altitude) it might be straightforward to demonstrate that SEE is not a significant failure mechanism. But it will never be as easy as saying "the ceiling is below 29000 feet".	Replace the first sentence with "Aircraft systems need to have demonstrable robustness to SEE throughout their flight envelope."	No	Yes	Not Agreed	The CM wording will be changed to remove the reference to 29,000 feet, however initially the CM will be issued to address large aircraft and business jets which tend to fly at higher altitudes and possibly higher latitudes. The scope of the CM could be expanded in future to cover 'all' aircraft.
69	*S. P. Platt* *School of Computing, Engineering and Physical Sciences University of Central Lancashire*	2.1	8	From the second paragraph of this section: "Generally, applicants whose was [sic] equipment was previously installed on EASA certificated or validated aircraft do not need to demonstrate compliance with this Certification Memorandum". I have some concerns about this statement, although as this issue might be outside my field of competence I make this as an observation rather than a substantive criticism. I appreciate that certification might not be able to be withdrawn, and also that flight heritage is extremely valuable evidence for reliability, but I observe that SEE has been implicated in the 2008 in-flight incident on Quantas flight 72, the subject of ASTB report AO-2008-070. The failing system in that case was, apparently as a consequence of the shortage of radiation test facilities (a situation now improved and improving), subject to a limited SEE analysis of the kind encouraged by the memorandum. Fortunately, there were no fatalities.		Yes	No	Agreed	Your concerns are noted and understood. The safety benefit of re-certifying equipment and systems which have already demonstrated reliability through in-service experience needs to be considered. In the case of the Qantas incident there was no evidence to support the theory that SEE was a contributing factor.

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70	*S. P. Platt* *School of Computing, Engineering and Physical Sciences University of Central Lancashire*	3.1.5 3.2.1 3.2.2.1 Annex A	9-10 10 11 13	The memorandum encourages designers to neglect SEE in systems contributing to Major failure conditions. This is in contradiction to IEC 62396, which provides graduated guidelines for designing for CAT ("Level A"), HAZ ("Level B") and MAJ ("Level C") failure conditions (IEC 62396-1 section 7 refers). The memorandum should be made consistent with IEC 62396.	Change the first sentence of section 3.1.5 to the following: "The susceptibility to SEE for each system or piece of equipment capable of causing or contributing to Catastrophic, Hazardous or Major failure conditions should be considered" Change Note 1 of section 3.1.5 to the following: "The susceptibility to SEE of systems or equipment with Minor or No Safety Effect failure conditions may be addressed on a voluntary basis, but otherwise they do not need to be considered." Change the second sentence of section 3.2.1 to the following: "For each system or function with one or more failure conditions classified as Catastrophic, Hazardous or Major, a list should be established…" Change the first sentence of section 3.2.2.1 to the following: "An analysis should be performed for each equipment that contributes to a Catastrophic, Hazardous or Major failure condition." Annex A should be amended as follows: Add "MAJ" to "CAT" and "HAZ" (in two places)	No	Yes	Not Agreed	Major failure conditions, due to SEE, could result in a significant increase in workload for the crew, but should not result in a large reduction of functional capabilities or safety margins with respect to the aircraft (see AMC to CS 25.1309). The CM will be reviewed in the future to see if the major/minor criteria need to be addressed. For this version, only Catastrophic and Hazardous failure conditions will be considered with respect to SEE.
71	*S. P. Platt* *School of Computing, Engineering and Physical Sciences University of Central Lancashire*	3.2 Annex A	10-11 13	The SEE analysis method described in the memorandum is inconsistent with that in IEC 62396. It gives the impression of inverting the procedure of IEC 62396, in which application of a conservative estimate for SEE cross-section is a last resort for catastrophic and hazardous failure conditions. It also gives the impression that only component testing is possible in radiation beams (system and equipment testing is also possible and should be encouraged).	Section 3.2 and the Annex should be reviewed and revised to ensure consistency with the IEC standard and encourage system and equipment testing for SEE.	No	Yes	Not Agreed	Annex A provides a consistent and logical guidance to applicants who may not be conversant, or have a copy, of the IEC documents.
72	*S. P. Platt* *School of Computing, Engineering and Physical Sciences University of Central Lancashire*	3.2 Annex A	10,11 13	Reference to data sheets should be avoided, and replaced with "data". "Data sheet" is likely to imply data provided by component manufacturers or suppliers. Commercial electronics components rarely have manufacturer's data on SEE, although radiation-hardened components from specialist manufacturers generally do have some data which might be useful. However, data may be available from other sources, including prior experience (e.g. radiation testing from earlier projects) and even, in some cases, open publications.	Rephrase section 3.2.2.2 as follows: "Analysis should use component data, from radiation testing or other reliable sources, where available. Where such data are not available, a conservative determination of SEE susceptibility should be made, following the guidance of IEC 62396 Part 1." Rephrase section 3.2.4.2 as follows: "The quantitative assessment should use the available component SEE rates (from component data) or, if not available, a conservative SEE rate should be used." Delete "sheet" in Annex A.	No	Yes	Agreed	

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73	*S. P. Platt* *School of Computing, Engineering and Physical Sciences University of Central Lancashire*	3.2.4.1	11	This section refers to a neutron flux of 6000 n/cm^2. The units are wrong, defining a fluence, not a flux (or fluence rate – "fluence rate" is more precise than "flux"). I suppose this must be a typographical error (6000 n/cm^2/h is meant, here). Furthermore, the value, taken from IEC62396 is both nominal and for the limited energy range above 10MeV.	Replace "neutron flux of 6000 n/cm^2" with "nominal neutron flux above 10 MeV of 6000 n/cm^2/h"	No	Yes	Agreed	
74	*S. P. Platt* *School of Computing, Engineering and Physical Sciences University of Central Lancashire*	3.2.4.1	11	This section refers to a typical flight "envelope" of 40,000 feet and latitude of 45°. A single point does not define an envelope, and this section seems to imply a limit of 40,000 feet and 45° latitude (I am sure this is not what was intended). Furthermore, the fluence rate given in IEC 62396 and referenced here is merely a nominal fluence rate, for illustrative purposes. Although useful, it is given as general guidance only. The memorandum should recommend that the entire aircraft flight envelope should be considered and the worst-case environment used in analysis. If a single point is used that point is likely to be a corner of the envelope at high latitude and altitude. Alternatively, a worst-case flight path (e.g. transpolar) could be used.	Redraft section 3.2.4.1	No	Yes	Agreed	Wording changed based on other 'similar' comments.

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75	*S. P. Platt* *School of Computing, Engineering and Physical Sciences University of Central Lancashire*	3.2.4	11	This section should be modified to include space weather considerations. Advice should be taken from the Technical Experts of the IEC TC107 Atmospheric Radiation Working Group, which is currently updating IEC standard 62396 to include a part on space weather considerations. Currently, IEC 62396 recommends a degree of enhancement due to solar activity should be "defined by the user". This degree of enhancement should be expressed as a particle fluence, rather than a particle flux. Background atmospheric radiation due to galactic cosmic rays and quiescent solar particle radiation is to a first approximation constant, usefully described by a flux (fluence rate). The likelihood of system failure in such an environment is usefully described by means of a FIT rate (failures in time). Solar particle events might, also to a first approximation, be considered to be a radiation impulse superimposed on the background level, and more usefully defined by a fluence (integrated flux). The likelihood of system failure in such an environment is usefully described by means of a failure probability. Suppose we have particle fluence Φ, predicted probability of failure P, and confidence limit C. We wish to ensure that the system failure probability resulting from fluence Φ, that is, P(Φ), is less than some acceptable limit P_{max}, with confidence greater than some acceptable limit C_{min}. The fluence comes from our description of the environment. Limits P_{max} and C_{min} come from our system reliability analysis. The probability, P, comes from our SEE analysis: preferably, from measurement, in the worst case, from a conservative calculation. In essence, this is no different from the quiescent situation: we need to determine the SEE cross-section. We need a sufficiently wide (greater than C_{min}) one-sided prediction interval on the likely failure probability whose upper limit is below P_{max}. Preferably, we expose a system (LRU or component) to a white neutron beam with sufficient fluence and observe sufficiently few SEEs. To first-order, we can probably neglect differences between particle spectra in quiescent and active cases and use the same cross-section in each case. By analogy with the nominal fluence rate identified for quiescent conditions, a nominal fluence could be identified as the environment within which to assess SEE performance in the presence of a solar particle event. Such a fluence might be of the order of 10^7 n/cm^2 above 10MeV (cf. the nominal flux of 6×10^3 n/cm^2/h for the quiescent case).	Redraft section 3.2.4.1	No	Yes	Agreed	Please could you provide some suitable words for this section based on your comments? These comments could be included in the next version of the Certification Memorandum. Unfortunately, it is unlikely that dialog with Atmospheric Radiation Working Group will be possible before the release of issue 1 of this Certification Memorandum.

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76	*S. P. Platt* *School of Computing, Engineering and Physical Sciences University of Central Lancashire*	3.2.5	11	The numbering has gone horribly wrong here. Probably, the first paragraph should have been numbered 3.2.5.1, 3.2.5.2 should identify a new paragraph, and 3.2.5.3 is correct.	Correct the numbering.	Yes	No	Agreed	
77	*S. P. Platt* *School of Computing, Engineering and Physical Sciences University of Central Lancashire*	passim	passim	The terms "component", "equipment" and "system" are used in ways which sometimes seem to imply a distinction, but that distinction, if real, isn't clear. For example, if "component" means an electronic device considered at the small scale, such as a transistor or memory, and "equipment" means a system of such devices for example at LRU level, then not just components can and should be radiation tested (cf. 3.2.4.3.iii). This terminology should be made clearer. (For example, equipment suppliers ought to be testing LRUs, especially as test facilities continue to become more widely available. IEC 62396 refers.) In the IEC standard, a "component" is something that cannot be disassembled without being broken, an "equipment" is an assembly of components, and a "system" is a functional arrangement of components and equipment. (My paraphrase.)	Review use of "component", "equipment" and "system" throughout. Refer the reader to IEC 62396 if necessary.	Yes	No	Agreed	Your definition of "component", "equipment" and "system" is correct. The Certification Memorandum will be reviewed again to ensure consistency.
78	*S. P. Platt* *School of Computing, Engineering and Physical Sciences University of Central Lancashire*	1.1	4	Typographical error or error of punctuation affecting sense.	Replace "The applicant should demonstrate that aircraft systems, whose failure could have a safety effect, are adequately mitigated against SEE." With, e.g. "The applicant should demonstrate that those aircraft systems whose failure could have a safety effect are adequately mitigated against SEE."	Yes	No	Agreed	
79	*S. P. Platt* *School of Computing, Engineering and Physical Sciences University of Central Lancashire*	2.3	8	Typographical error or error of punctuation affecting sense.	Replace "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." With. E.g. "The impact of a SEE on aircraft systems can vary and may be transitory or permanent. Noticeable functional effects might or might not be produced."	Yes	No	Agreed	
80	*S. P. Platt* *School of Computing, Engineering and Physical Sciences University of Central Lancashire*	3.2.5	11	Typographical error.	Replace "(or use different component)" with "(or use of a different component)"	Yes	No	Agreed	

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81	*Faculty of Engineering and Physical Sciences* *University of Surrey*	1.1	5	Description of atmospheric radiation as "electromagnetic" in first paragraph. Atmospheric radiation in this context should not be described as "electromagnetic" as that implies only photons (gamma rays), whereas the radiation of most interest in this context is subatomic particles – i.e. neutrons and protons.	Remove the term "electromagnetic" and rephrase to "…term which refers to various different types of primary and secondary radiation in the atmosphere, including protons, neutrons, electrons and others".	Yes	Yes	Agreed	Paragraph re-worded.
82	*Faculty of Engineering and Physical Sciences* *University of Surrey*	1.1	5	List of vulnerable components in second paragraph should also include power devices such as MOSFETs and IGBTs.	Amend sentence to "Memories, high power transistors (e.g. MOSFETs), microprocessors and FPGAs are…"	Yes	Yes	Agreed	Sentence added at the end of the paragraph.
83	*Faculty of Engineering and Physical Sciences* *University of Surrey*	1.1	5	SEUs are MBUs are not necessarily the most important effects.	Include a sentence along the lines of "Some effects, such as SEU, are non-destructive and can be partially mitigated through software algorithms. Others, such as SEB and SEGR are destructive and cause permanent damage to avionics systems.	Yes	Yes	Agreed	Paragraph updated.
84	*Faculty of Engineering and Physical Sciences* *University of Surrey*	1.1	5	8th paragraph (on extreme space weather) is misleading when it implies that enhanced environments during solar flares (or, more correctly, "solar energetic particle events") can be avoided through prior warnings – there is NO such system in place that is reliable and even if there were it would not apply to all types of events.	It must be made clear that exposure to extreme space weather events is unavoidable in many instances, regardless of space weather forecasting and monitoring. Very enhanced radiation environments will occur (though rarely) and this must be acknowledged.	Yes	Yes	Agreed	Paragraph updated.
85	*Faculty of Engineering and Physical Sciences* *University of Surrey*	2.1	9	SEE can (and do) occur at ground level. Thus aircraft flying below 29000 feet should also consider SEE.	Amend to text to make it clear that although the intensity of the radiation environment decreases at lower altitude, aircraft flying below 29000 feet are also susceptible to SEE, albeit at lower rates.	Yes	Yes	Agreed	Reference to 29000 feet removed.
86	*Faculty of Engineering and Physical Sciences* *University of Surrey*	2.1	9	Applicants with equipment already installed appears to be exempted in the 2nd paragraph. There is no justification for this as such equipment could also be susceptible to SEE. Retrospective compliance may be involve a different approach, but it should not be dismissed.	Remove the sentence advising that applicants with previously installed equipment do not need to comply with this memorandum.	Yes	Yes	Not Agreed	On balance the costs to industry, of re-certification versus the safety benefits, do not support addressing already installed systems.
87	*Faculty of Engineering and Physical Sciences* *University of Surrey*	3.2.4.1	12	The figure of 6000 n/cm2 should actually be hourly, i.e. 6000 n/cm2/h. Also this refers to neutrons above a threshold energy of 10 MeV and this should be stated explicitly.	Amend text accordingly.	Yes	Yes	Agreed	
88	*Faculty of Engineering and Physical Sciences* *University of Surrey*	3.2.4.1	12	There is no mention of thermal neutron effects. IEC recommends thermal (very low energy) neutrons are separately taken into account as in some technologies these can dominate over the 6000 n/cm2/h fast (high energy) neutron figure.	Include reference to thermal neutron effects and the need for separate risk assessment as described in IEC 62396 part 5.	Yes	Yes	Agreed	New sentences added to section 3.2.4.1.
89	*Faculty of Engineering and Physical Sciences* *University of Surrey*	3.2.4.3 (iii)	12	Caution should be taken when using previously obtained radiation test data as changes in the manufacturing process can significantly affect SEE sensitivity, even for components with the same part number.	Clarify note to make it clear that it is inadvisable to negate testing based on previous test data unless it can be shown that the components tested were from exactly the same batch and lot as the components of interest, not just same part number.	Yes	Yes	Not Agreed	It is up to the 'applicant' to demonstrate, to the Agency, that previous test data is usable.

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90	*Faculty of Engineering and Physical Sciences* *University of Surrey*	3.4	12	Statement that "no ground or flight testing is required" is confusing as SEE testing is often referred to as "ground testing".	Clarify what is meant by "ground testing" in this context.	Yes	Yes	Agreed	Clarification provided.
91	*Honeywell*	1.1, paragraph 4	4	1. The current list omits two significant SEE – SEFI and SEL. 2. Disagree with the statement that SEU/MBU are the most significant SEE.	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), Single Event Functional Interrupt (SEFI) and Single Event Latch-up (SEL). ~~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).		X	Agreed	Paragraph updated.
92	*Honeywell*	1.1, paragraph 8	4	Disagree with the statement that the normal atmospheric radiation levels *could* be experienced. This levels will be experienced; they are a steady state condition.	This Certification Memorandum considers the normal atmospheric radiation levels, which ~~could be~~ are experienced during a typical flight, and not those which could be experienced during a solar flare.		X	Agreed	Paragraph updated.
93	*Honeywell*	2.1, paragraph 1	8	There is not a great deal of difference in the atmospheric radiation environment, specifically the neutron flux levels, between 40K ft and 28k ft. Therefore, technically it doesn't make sense to provide relief for aircraft flying at 29K ft or below. Currently there are automotive and medical device manufacturers and high reliability terrestrial systems designers addressing SEE at terrestrial levels, which are 300X less than those measured at 40K ft..	~~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.~~		X	Agreed	Text changed to remove 29000 feet.
94	*Honeywell*	3.2.2.2, paragraph 1	10	Test data should also be considered for component SEE susceptibilities.	Information from relevant component data sheets, and test data, should be used to determine the level of susceptibility to SEE for each component.		X	Agreed	Text included.
95	*Honeywell*	3.2.4.2, paragraph 1	11	Test data should also be considered for component SEE susceptibilities.	The quantitative assessment should use the available component SEE rates (from the component data sheets and test data) or, if not available, a conservative SEE rate should be used.		X	Agreed	This sentence has been amended to take into account a similar comment.
96	*Honeywell*	Annex A	13	Test data should also be considered for component SEE susceptibilities.	**Box 3.2.2 SEE Analysis** 3.2.2.2 From components parts list use component data to determine SEE susceptibility. If no data/information or test results available make determination based on type of technology used or use conservative value of SEE rate.		X	Agreed	
97	*Honeywell*	Annex A	13	Diagram does not match the associated text in Section 3.2.4.1 regarding partial mitigation as well as the stated absence of any mitigations.	**3.2.3 Qualitative Assessment** Use components parts list (A) and review architecture or design to determine if mitigation(s) are possible. Compile list for those components where there is partial or no mitigation.		X	Agreed	Flow diagram updated.
98	*Honeywell*	Annex A		Diagram does not match the associated text in Section 3.2.4.1 regarding partial mitigation as well as the stated absence of any mitigations.	Components parts list (B) (components which are susceptible to SEE for which there is partial or no mitigation.)		X	Agreed	

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99	*Honeywell*	Annex A	13	Test data should also be considered for component SEE susceptibilities.	**3.2.4 Quantitative Assessment** 3.2.4.2 Use component SEE rate from data sheet, test data, or conservative SEE rate.		X	Agreed	Sentence modified in accordance with similar comment received.
100	*Honeywell*	2.1, paragraphs 2 and 3	8	The final two paragraphs of this Applicability Section need further clarification. Is it the intent of the author that currently certified programs do not need to address this memo? And if so, what happens if there is a design change or a component is replaced due to obsolescence.	"If currently certified equipment is updated, due to system design change or component replacement, the Certification Memorandum may need to be considered."		X	Agreed	The intent of the CM is to not require applicants to have to re-certify systems or/and equipment already certified. Your comment on system design change or component replacement is noted and will be included in the CM.
101	*Honeywell*	2.2, paragraph 4	8	Part 3 of the IEC 62396 Standard contains System Design information and direction which may be an issue. This Part is also currently under review.	Reference Part 1 only and not Parts 2 -5	X			
102	*Honeywell*	3.2.4.1, paragraph 2	11	1. The neutron flux definition is incomplete. The definition should also take into account the correlation between neutron flux to be considered and component feature size. 2. The flight should be defined for the "average" profile.	1. Add the following text "a neutron flux of 6000 n/cm2/hr, for >10MeV" 2. Change "typical flight envelope" to "average flight condition"		X	Agreed	1. Agreed 2. Not Agreed. IEC 62396-1 refers to a 'typical in flight envelope'.
103	*Honeywell*	Annex A	13	A step (or box) is missing in the diagram to describe what is to be done with the information from the Quantitative Assessment.	Add a final step which illustrates the step described in the opening paragraph of Section 3.2.		X	Agreed	
104	*Honeywell*	1.) 1.1, paragraph 3 2.) 1.3 Table, 4th entry 3.) 1.3 Table, new entry 4.) 2.1, paragraph 2 5.) 2.2, paragraph 1 6.) 2.3, last paragraph 7.) 3.2.5, list 8.) 3.5, paragraph 1		Spelling / Grammar	1.Change APU's to APUs 2. *ARP* Font size is not consistent with the rest of the table 3. Add AMC to this list 4. Delete the word "was' from second sentence 5. Change *equipment)* to *equipment* 6. Change "effects that do not introduce any new" to "their effects do not introduce any new" in last sentence 7. Paragraph structure is not correct. Sub-paragraphs 3.2.5.1 and 3.2.5.2 appear to be missing. 8. Change equipment) to equipment	X		Agreed	1. Agreed 2. Agreed 3.Agreed 4. Agreed 5. Agreed 6. Agreed 7. Agreed 8. Agreed
105	*Honeywell*	1.1, paragraph 8	4	For the following text *"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.*	Comment: So pilots must go to solar information websites to find out whether they are about to embark on a course that has solar flare danger. These upsets are infrequent and it is most likely pilots will not do this prior to a flight as a matter of standard practice. It seems that a better way to warn pilots should be devised rather than gamble they will look something up that seldom occurs and may seem like a waste of time even though it is not.	X		Agreed	This section has been re-worded based on other, similar, comments.
106	*Honeywell*	1.4, Table	7	Multiple Cell Upset definition	Clarify that Multiple Cell Upset is different from Multiple Bit Upset in that an MCU can affect multiple logical words, while an MBU only affects one logical word.		X	Agreed	

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107	*Honeywell*	3.1.2, paragraph 1	9	In accordance with Part 21.A.20(b) the applicant should provide a Programme, describing the system or equipment operation (or major Certification change/modification).	Comment: Of what? What is this referring to?	X		Information	Part 21.A.20(b) is referring to a document which should be provided by the applicant to describe the certification basis and the system or equipment operation (or major Certification change/modification).
108	*Honeywell*	3.1.7, paragraph 1	10	For the following text *The applicant should provide a summary document describing the tasks accomplished to meet the objectives of this guidance.*	Comment: Over and above the safety analysis--seems like unnecessary overhead if the SA addresses the same information.		X	Not Agreed	The 'applicant' may wish to provide a summary document which links all the relevant documents rather than provide this information in the safety analysis.
109	*Honeywell*	3.2.2.2, paragraph 1	10	For the following text *Information from relevant component data sheets should be used to determine the level of susceptibility to SEE for each component.*	Comment: The data provided by the device manufacturers (when even available) tends to be overly optimistic, and should not be used as the basis for analysis. There is no standardization to data sheet results from different manufacturers, so it is not a good choice for a data source	X		Not Agreed	The equipment/system supplier has no other reference other than actual component testing. Currently, data provided by the component manufacturer will be accepted by the Agency unless the equipment /system supplier knows this data is overly optimistic.
110	*Honeywell*	3.1.5, Note 1 3.1.6	9-10	SEE concerns are limited to Catastrophic and Hazardous and as stated in Section 3.1.5 do not include Major. Section 3.1.6 indicates the Cert Memo applies *For each system or piece of equipment which is susceptible to SEE,* This statements needs further clarification.	Change Section 3.1.5 "The susceptibility to SEE for each system or piece of equipment capable of causing or contributing to Catastrophic or Hazardous, or Major failure conditions should be considered." 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."		X	Not Agreed	Major failure conditions, due to SEE, could result in a significant increase in workload for the crew, but should not result in a large reduction of functional capabilities or safety margins with respect to the aircraft (see AMC to CS 25.1309). The CM will be reviewed in the future to see if the major/minor criteria need to be addressed. For this version, only Catastrophic and Hazardous failure conditions will be considered with respect to SEE.
111	*Honeywell*	2.1, paragraph 2	8	For the following text *Generally, applicants whose equipment was previously installed on EASA certificated or validated aircraft do not need to demonstrate compliance to this Certification Memorandum.*	Comment: Need to clarify this statement to address the issue of design changes and component replacements for previously certified equipment. This issue is partially addressed in Section 3.3 - *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.*		X	Agreed	Text modified accordingly.
112	*TRAD*	1.1	4	SEL and SEFI are very critical effects	Mention these effects also in the example description	Yes		Agreed	
113	*TRAD*	1.2	4	High solar activity needs a short but not immediate delay (hour(s)) to be detected and information to be transmitted Is the expectation that prior notice delivery is not an issue really true ?				Partially Agreed	Changed modified based on other comments made on the same subject.
114	*TRAD*	2.1	8	Applicability: Typically, aircraft systems installed on aircraft that fly above 29000 feet should consider SEE.	Other altitudes should also be considered since effect can occur also below 29000 feet	Yes		Agreed	Reference to 29000 feet removed.
115	*TRAD*	2.1	8	Slight changes in component Date Code or Manufacturer for a given part type can induce drastic changes in SEE sensitivity	Modulate the fact that already certified aircraft equipment shall be re-investigated if such changes (date code, manufacturer) occur	Yes		Agreed	Text modified to include 'changes to design or components' may require re-assessment iaw the CM.
116	*TRAD*	3.2.2.2	10	Data on SEE sensitivity is scarcely mentioned in data sheets				Agreed	This could be an issue. 'Test data' has also been added to this sentence which may help the applicant.

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117	*TRAD*	3.2.5	11	3.2.5.3 is a bad paragraph number 3.2.5.1doesn't exist and 3.2.5.2 is misplaced	Correct this paragraph	Yes		Agreed	
118	*Dassault-aviation*	General		It is difficult to comment a Certification Memo when the international groups (WG 63 and S 18) that have raised the subject are still debating the conditions under which the SEE should be treated. As of today, the consensus is not reached. Current status is that the SEE would not be part of the ED-135A/ARP 4761A and might be dealt in a AIR, which is a document at a level lower than the ARP. In the CM, EASA considers the CM as an AMC which definitively overrules the current status of the AIR. From a technical aspect, EASA has deliberately chosen the most conservative approach which might be a high burden without commensurate positive impact on safety.	Wait until the Working Groups have finished their work and re-submit the CM in line (both technical and procedure) with the outputs of WG. If this path is not retained, then the following applies		Yes	Not Agreed	Although 'not agreed', due to the number of comments received on the CM and the time taken to disposition comments the Working Group may be close to completing their task at the same time the CM is issued. The AIR and CM should be, to a certain extent, harmonised.
119	*Dassault-aviation*	3.1.1-3.1.3		Certification Process : § 3.1.1 is sufficient in itself "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 up to § 3.1.3 is usual Part 21 business.	Remove §3.1.2 to §3.1.3		Yes	Not Agreed	Section 3.1.2 and 3.1.3 re-inforce what is expected from the applicant. Although a competent DOA should not need this additional information, it may assist the reader of this document who may not be familiar with Part 21.
120	*Dassault-aviation*	3.1.4		The way the "safety part" is written (FHA , failure effect, failure rate) is quite misleading and the reader is lost, even if he is safety specialist.	Replace the paragraph by "SEE does not create other failure mode than those already taken into account in the Safety analysis"		Yes	Not Agreed	This section (3.1.4) was reviewed and accepted by safety specialists. The suggested replacement wording does not cover the intent of this section.
121	*Dassault-aviation*	3.1.6		This paragraph seems in contradiction with Note 2: of § 3.1.5. Dassault Aviation would be more in favour to have a system top-down approach (Architecture path) rather that a bottom-up approach, more in line with Note 2.	Remove "For each system or piece of equipment …system-level".		Yes	Not Agreed	A 'top down' approach should provide an indication of those systems which could contribute to a catastrophic or hazardous failure conditions (based on the FHA). At some point the equipment identified, as forming part of the system, which could contribute to a catastrophic or hazardous failure needs to be identified. This equipment then needs to be assessed for components which could be susceptible to SEE.
122	*Dassault-aviation*	3.1.7		The request for a « summary document » for the SEE subject seems contradictory with § 3.1.1.	Remove § 3.1.7 as this activity will fall into an an 'existing' overall design process and the result of this activity will be naturally part of 'existing' overall design process summary		Yes	Not Agreed	This is additional information which may assist the reader, of this document, when considering how to use this guidance.
123	*Dassault-aviation*	3.2.1 and 3.2.2		Based on the system top-down approach, these two sections constitute an undue burden as long as the architecture protects from the effect of SEE.	A complete rewording of these sections is necessary to make it compatible with a system top down approach. In particular "potentially affected by SEE" should not be present anymore When the architecture mitigation against SEE is not demonstrated satisfactory for given items, then those items should be subject to further analysis.		Yes	Partially Agreed	Some changes were made to these sections based on similar comments, but not a complete re-write.
124	*Dassault-aviation*	3.2.4		As per our knowledge, any quantitative analysis will lead to unrealistic failure rates compared to Dassault-Aviation own experience.	Remove the paragraph		Yes	Not Agreed	Any 'unrealistic failure rates' need to be discussed with the Agency.
125	*Dassault-aviation*	3.3		As long as the system architecture is unchanged (with relationship with SEE mitigation), it is not anticipated that the system will become SEE sensitive after items replacement. This is a too stringent requirement with a system top-down approach.	Remove the paragraph		Yes	Not Agreed	Replacement of components due to, for example, obsolescence needs to be taken into account when considering SEE.

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126	*Dassault-aviation*	3.5		Dassault-Aviation would have thought that a Certification Memorandum would also apply to DOA organization.	If the CM is released, Dassault-Aviation expects it apply also to DOA organization.	Yes		Partially Agreed	Designers of systems could be DOA organisations?
127	*Textron Aviation*	1.1/Para 7		Purpose and scope should better recognize that existing ARP4761 based analysis for random errors is sufficient.	is "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." Should be "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) is an acceptable means for the assessment of atmospheric radiation effect rates."			Agreed	Text changed.
128	*Textron Aviation*	3.1.4		Classification of hazard for SEE analysis guidance does not account for "partitioning" of functions describe in ARP4754	Amend 3.1.4 to state: "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). The use of partitions should be considered when establishing the hazard class of failure conditions related to random errors from influences such as SEE. 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)." Amend 3.1.5 to state: "The susceptibility to SEE for each system or piece of equipment, or partition when applicable, capable of causing or contributing to Catastrophic or Hazardous failure conditions should be considered."			Not Agreed	The applicant should be aware of partitioning when using Eurocae ED 79A/SAE ARP 4754A. It does not need to be further explained in this section.

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129	*Textron Aviation*	3.2		The proposed analysis method is an unnecessary burden for part 25 General Aviation aircraft which may use a more conservative method for ensuring the aircraft and systems are appropriately design to cope with random errors.	Amend preamble to section 3.2 to state: "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. The applicant may elect not to perform a specific SEE analysis, if a conservative approach is used to account for random hardware and software errors in the safety analysis used for the aircraft." Amend 3.2.4.1 to state: "A quantitative assessment should be performed for the remaining components where no mitigation or only partial mitigation, against the effects of SEE, was identified. If the applicant does not perform an analysis specific to SEE, then the quantitative rate for erroneous operation of an affected component or software partition shall be conservatively set to 10% of the overall failure rate of the component (e.g. microprocessor) as demonstrated by service history or analysis."			Not Agreed	This could be a mitigation method, if the applicant is able to demonstrate this to the Agency.
130	*Boeing Commercial Airplanes*			We are especially concerned about our comment #4 (ref. CM CRD comment # 134) requesting that CS-ETSO should apply also, not merely CS-23 and CS-25. We request that EASA reconsider this specific issue in your preparation of the final version of the CM. Reconsideration of the other rejected comments also would be greatly appreciated.				Not Agreed	In addition to the comments made in your earlier e-mail (There is no requirement in the current ETSOs covering SEE. The expectation is that the aircraft manufacturer will request the equipment supplier to include compliance to this CM or, the equipment manufacturer may, unilaterally, decide to demonstrate compliance with this CM.) EASA may include the requirements to consider SEE as a general statement in future ETSOs.
131	*Boeing Commercial Airplanes*			***General comment*:** EASA CM-SWCEH-001 Issue 01 section 6 already provides guidance on SEE. The relationship of the new proposed guidance and the prior guidance in SWCEH-001 is unclear. The two memos should be harmonized to represent a common approach. We (I) believe that the existing EASA CM provides sufficient guidance on SEE and if not, that memo should be revised and a new memo should not be created.				Agreed	~~The (SEE) Certification Memo addresses SEE particularly through the aircraft certification route whereas EASA CM-SWCEH-001 is discussed in the context of development assurance of airborne electronic hardware.~~ To avoid duplication the SEE material has been removed from the CM-SWCEH-001 through an editorial change. EASA is currently working on a Rulemaking task (RMT.0643) to establish an AMC 20.152 that intends to replace EASA CM-SWCEH-001. During this rulemaking task, EASA will further consider SEE to evaluate the need if ~~establish~~ guidance focused on the AEH level which will complement the SEE Certification Memo is needed.

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132	*Boeing Commercial Airplanes*			***General comment:*** ETSO applicants should be held to the same standard as applicants for type design. The ETSO applicant has the detailed knowledge of the equipment and the capability to design in the appropriate SEE mitigating features. A type certificate holder, as an installer, will not have the technical data as part of the ETSO furnished data package, to determine that the equipment will operate correctly in the radiation environment.				Not Agreed	There is no requirement in the current ETSOs covering SEE. The expectation is that the aircraft manufacturer will request the equipment supplier to include compliance to this CM or, the equipment manufacturer may, unilaterally, decide to demonstrate compliance with this CM.)
133	*Boeing Commercial Airplanes*	1.1	4	***Second paragraph:*** The text states: *"Memory devices, microprocessors, and FPGAs are most sensitive to SEE."* What is "most sensitive" in technology is changing constantly; this document should survive beyond technology changes.	Delete this sentence.		Yes	Not Agreed	The CM will be updated periodically to account for technology changes.
134	*Boeing Commercial Airplanes*	1.2	5	In the list of regulations, CS-ETSO should apply also, not merely CS-23 and CS-25. Again, only the ETSO applicant has the detailed knowledge of the equipment design features and characteristics to perform the appropriate design analysis and testing of their equipment.	This data should be included in the list of furnished data provided for installers under CS-23 and CS-25. Note that many TSOs / ETSOs include the hazard classification. The hazard classification in some systems, such as TCAS, is significant, as it relates to the hazard levels beyond a single aircraft.		Yes	Not Agreed	There is no requirement in the current ETSOs covering SEE. The expectation is that the aircraft manufacturer will request the equipment supplier to include compliance to this CM or, the equipment manufacturer may, unilaterally, decide to demonstrate compliance with this CM.)
135	*Boeing Commercial Airplanes*	1.4	7	***First Table, 4th entry:*** "Single Event Latchup" – the definition of this as occurring in a *"four layer semiconductor device"* is technically confused.	This should be reworded to be clearer.	Yes		Not Agreed	This definition was discussed within a specialist group as the original definition, taken from the IEC document, was found to be confusing. This definition was found to be the most easily understood – although it could be improved.
136	*Boeing Commercial Airplanes*	2.1	8	***First sentence:*** The 29,000 foot threshold is arbitrary.	The altitude number should be removed altogether, and the CM applied to classes of aircraft, such as commercial passenger transport in general, rather than ceiling capability. This would not be difficult; these environment models are widely available.		Yes	Agreed	Threshold was originally chosen to match RVSM requirements (above 29000 feet). This threshold, however has now been removed from the CM.
137	*Boeing Commercial Airplanes*	2.1	8	***Third paragraph:*** The phrase *"…..may need to be revised"* is ill-defined.	We recommend either leaving it out or defining it.	Yes		Not Agreed	This sentence is to inform the reader that the CM may be updated at a later date.
138	*Boeing Commercial Airplanes*	2.3	8-9	Remove the system list.	Any system (per paragraph ix) is sufficient.		Yes	Not Agreed	Provides the reader with some examples of systems which may be affected by SEE.
139	*Boeing Commercial Airplanes*	3.1.1	9	Considering the details provided in 3.2, it will be difficult for the aerospace electronics supply chain to comply with this sub-clause.	The resources required include technical expertise in atmospheric radiation and its effects on system design; analysis capabilities, processes, and tools; access to appropriate radiation testing facilities; and expertise in system and equipment design methods to mitigate effects of atmospheric radiation. Some time will be required for the supply chain to develop this level of capability.		Yes	Agreed	It may be possible for the aerospace supplier(s) to contract the SEE investigation to a competent body.
140	*Boeing Commercial Airplanes*	3.1.5.	9-10	It is as important to understand the assumptions of a cert process as it is to understand the results.	For example, if it is a supplier's assumption to categorically rule out all components of type 'x' or memories of type 'y' as insensitive or unimportant to SEE, then these assumptions should be stated as part of the CP or DDP.		Yes	Agreed	Any assumptions used by the applicant should be stated in the safety analysis or SEE Summary Document (see section 3.1.7). No changes to the text are proposed.

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141	*Boeing Commercial Airplanes*	3.1.7.	10	This sub-clause identifies a certification summary document as a regulatory deliverable. The certification summary document in the US is used primarily for TSO equipment installation approval and is not generally used on non-TSO approvals.	Reword this to allow compliance data to be embodied in another vehicle, such as a system safety analysis.		Yes	Agreed	The section has been re-worded.
142	*Boeing Commercial Airplanes*	3.2.2.	10	As stated in the proposed CM, SEE analysis is not sufficiently defined to assure that all analyses performed by multiple applicants will have the same level of rigor, or will yield the same quality of results.	Clarity/specificity is needed.	Yes		Not Agreed	The CM is not prescriptive and therefore allows the applicant to define the analysis method to be used. The method, however, must be acceptable to the Certifying Agency.
143	*Boeing Commercial Airplanes*	3.2.2.	10	Currently, very few electronic part data sheets contain the information described here; furthermore, this type of information is not readily available from part manufacturers.	This should be taken into consideration in the finalization of this CM.		Yes	Agreed	Para 3.2.2.2 changed to include the words 'test data'.
144	*Boeing Commercial Airplanes*	3.2.4.	11	Quantitative assessments of part susceptibility to SEE and its impact on the systems are highly dependent on the way the part is used in the system design, the state of the system when a SEE occurs, and other factors.	This assessment may raise more questions than it answers. Please reconsider or clarify.		Yes	Not Agreed	The applicant is invited to discuss their assessment of SEE with the Agency if there it is dependent of the use of the system. The Certification Memorandum should not be too prescriptive in this area.
145	*Boeing Commercial Airplanes*	3.2.5.	11	Radiation testing needs to be defined more completely, including the energy range of the beam, time of exposure, items to be tested, e.g., sub-assembly, equipment), and other system design and operation-related factors.	More specific definition is needed.		Yes	Not Agreed	Paragraph 3.2.5 refers to IEC 62396-2 for details regarding radiation testing. It was not the intent of this CM to go into any depth regarding radiation testing.
146	*Boeing Commercial Airplanes*	3.2.5.	11	The test capability required by this CM may exceed the current capability and capacity available to the aerospace industry.	This should be taken into consideration in the finalization of this CM.		Yes	Agreed	Your comment is noted.
147	*Boeing Commercial Airplanes*	3.2.2.2.	10	This sub-clause states that information from component data sheets can be used to determine the level of SEE sensitivity, and then points to the IEC paper.	Applicants should be allowed to use other acceptable data sources, which could include field service history data.		Yes	Agreed	In service history may be taken into account when considering this CM. See paragraph 2.1.
148	*Boeing Commercial Airplanes*	3.2.4.1.	11	The CM process should include all commercial passenger aircraft, but with appropriate requirement levels. The approved flight envelope of the aircraft will drive the specific requirements. Numbers such as "6000 n/cm^2/hour" are inappropriate in the CM: they presume a flight environment which may be significantly higher or lower depending on altitude and latitude. This sub-clause does provide for deviations to this typical number, but some routes will have higher environment fluxes, not lower, and suppliers should provide analysis at the appropriate environment.	Instead of allowing deviations, the CM should call for the quantitative assessment at the average peak of the certified flight envelope of the specific aircraft. Obviously lower altitude aircraft systems will have an easier time complying with the CM process. *(NOTE: As an aside, fluctuations in the background radiation flux rate are possible; however, it is appropriate that they do not currently appear in the CM. If there are other reviewers calling for EASA to consider enhanced levels over short times, then the CM might include a paragraph to the effect that "The qualitative analysis will describe how the system design will be expected to support safe flight when operated in an extreme environment of 300x the nominal background level". This is not a strong statement: it doesn't even require the LRU to operate in an extreme environment, only to not hinder safe aircraft flight.)*		Yes	Not Agreed	The Certification Memorandum provides a default value of neutron flux and also allow the applicant to propose another value (higher or lower).
149	*Boeing Commercial Airplanes*	3.2.4.2.	11	These data are generally not available and there is no agreed-on industry methodology to produce such data sheets.	This wording should be deleted and replaced with *"component supplier data."*		Yes	Agreed	Wording changed based on similar comment.

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150	*Boeing Commercial Airplanes*	3.2.4.3.	11	This sub-clause should state that when the system is unacceptable affected by SEE, not the component.	Revise as suggested.		Yes	Agreed	
151	*Boeing Commercial Airplanes*	3.2.5.	11	It is insufficient to simply state that mitigation 'x' will be used without quantitatively assessing the actual (imperfect) effect on the resulting SEE rate.	The efficacy of system design architectures or upset mitigations must be described and quantified.		Yes	Not Agreed	It is assumed that the applicant will perform the task of mitigation through architecture design.
152	*Boeing Commercial Airplanes*	3.2.5.	11	For safety critical systems, some data should be required for some SEE types, e.g., single event latchup, which is difficult to predict in some device families.	The CM should note that the required data may be in the form of past flight experience on a previous aircraft program with the same legacy part, or it may be in the form of facility-based radiation testing.		Yes	Agreed	Section 2.1 covers this point.
153	*Boeing Commercial Airplanes*	3.2.5.3	11		Revise to state that radiation testing to account for the operational environment should be performed only if there is a significant difference between the operational environment and the environment used by the analysis or previous tests, such that it is not valid to extrapolate between the two cases.		Yes	Not Agreed	If the environment used by the analysis or previous tests is similar to operational environment then it could be argued that no testing is required. This would be a statement provided by the applicant to support no radiation testing. No change to the current CM is therefore required.
154	*Boeing Commercial Airplanes*	3.3.	11	Aerospace electronics manufacturers that have Electronic Component Management Plans compliant to IEC TS 62239-1 or SAE EIA-4899 already have these Plans in place.	These documents should be included in the References.		Yes	Not Agreed	This Certification Memorandum should not be too prescriptive in this area and as such mentioning these standards may be interpreted as a 'requirement'.
155	*Boeing Commercial Airplanes*			***A final question:*** Compliance with this CM will require significant testing and in-service data, and it will be expensive to collect and maintain such data. If each individual applicant collects the same data from the same parts independently of other applicants, there will be significant redundant costs and risks to our industry as a whole. Would EASA be interested in working with the aerospace industry to develop a common database for SEE effects?			Yes	Agreed	EASA would support a common database for components which could be used within the aerospace industry.
156	*GE Aviation* *Mike Noorman*	2.1	8	Paragraph 2 should be written so that it applies to the equipment previously installed, and not to applicants.	Change to: "Generally, equipment that was previously…"	Yes	Yes	Agreed	Text revised to address other commentators remarks. The changes may also address this comment.
157	*GE Aviation* *Mike Noorman*	2.2	8	Paragraph 3; suggest adding "the principles of" since only portions of this CM may apply at the equipment level.	Change to "…wish to use the principles of this Certification Memorandum…"	Yes	No	Not Agreed	Equipment manufacturers can elect to apply for ETSO or perform their own testing. The CM applies to systems and/or equipment.
158	*GE Aviation* *Mike Noorman*	2.2	8	Paragraph 4; suggest clarifying more specifically what IEC 62396 information should be applied. For example, part 1 has information stating that SEE rates and controls vary according to DAL, which is not correct. The CM correctly ties the level of SEE analysis to the failure condition classification and not the DAL.	Either caveat the existing text, or add more specific references to what in the IEC documents aligns with and supports the CM.	Yes	Yes	Not Agreed	The reference to the IEC documents is for information only.
159	*GE Aviation* *Mike Noorman*	3.1.5	10	Note 1; Why doesn't the SEE guidance align with the AMC25.1309 in terms of level of analysis required for Major failure conditions?	Clarify position on Major failure conditions.	Yes	Yes	Agreed	Further clarification of why major failure conditions are not considered in this CM will be added to this section. The scope may be revised in the future to include Major failure conditions. Currently, it is assumed that the crew will have a significant increase in workload but not such that it will impair their ability to perform tasks (see AMC to CS 25.1309).

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160	*GE Aviation* *Mike Noorman*	3.1.7	10	Is there an expectation that this be a separate data item or is the expectation for content to be provided?	Clarify expectation for documentation.	Yes	No	Information	The applicant can decide to provide a separate summary document, as detailed in section 3.1.7, or to include the detail in another document such as a safety analysis.
161	*GE Aviation* *Mike Noorman*	3.2.1	10	This paragraph suggests a format of an analysis (e.g. "a list"), but this is could be part of the existing safety process and documentation (e.g. function allocation to equipment).	Clarify expectation for documentation.	Yes	No	Not Agreed	The Certification Memorandum provides guidance and the applicant can follow this or suggest alternative means. This is also true for certification documentation.
162	*GE Aviation* *Mike Noorman*	3.2.3	10	With respect to the statement "for which there exists sufficient qualitative mitigation", what is meant by "sufficient"?	Suggest discussing mitigations in the context of preventing the failure condition under analysis. If the mitigation prevents the failure condition from occurring it is clearly sufficient. However, what about when a mitigation reduces the probability of a failure condition, but does not totally prevent it? Would that be considered "sufficient" in a qualitative assessment?	Yes	Yes	Agreed	Discussions are currently underway to define what is meant by the term 'sufficient'. The outcome of these discussions will be reflected in the final text.
163	*GE Aviation* *Mike Noorman*	3.2.4.2	11	Should there be something here specifying what makes a given SEE rate applicable (e.g. SEE rates need to be representative of the environment discussed in section 3.2.4.1).	Add clarification to ensure SEE rates used, either from component suppliers or previous testing, is representative of the environment discussed in section 3.2.4.1.	Yes	Yes	Agreed	This section has been changed based on similar comments received.
164	*GE Aviation* *Paul O'Donovan*	1.4	8	Definition of MCU should be consistent with IEC62396.	Update as per MCU definition in IEC62396			Agreed	The definition has been updated based on similar comments. It does not exactly match the definition contained in the IEC document.
165	*GE Aviation* *Paul O'Donovan*	2.2	9	Para 1: Incorrect use of ")".	Replace ")" with a comma.			Agreed	
166	*GE Aviation* *Paul O'Donovan*	3.2.4	12	There is no guidance on how to derive a SEE rate from the flux density or what the apportionment to MBU and other SEE effects should be.	Add some text to indicate that the SEE rate is a product of the SEE cross section and flux density and where the SEE cross-section should be derived from (e.g. IEC62396). Also consider adding some guidance on SEU rate apportionment vs MBU rate apportionment.			Agreed	Text revised
167	*GE Aviation* *Paul O'Donovan*	3.2.4.1	12	Para 2: The flux density to consider depends on the feature size of the technology being used. If the feature size is less than 150nm then a flux rate of 9200 n/cm2-hour should be used.	Should either simply point to the IEC document or provide EASAs wider interpretation of the IEC document.			Not Agreed	The applicant may propose a flux density different to that given in the Certification Memorandum, based on the IEC document.
168	*GE Aviation* *Paul O'Donovan*	3.2.4.2	12	What constitutes a conservative SEE rate and where would an applicant obtain such a rate.	Provide a reference to the IEC document and let the applicant decide on a rate, or provide an EASA accepted rate for applicants to use, but with a caveat that the applicant may propose their own SEE rate with justification.			Agreed	Section 3.2.4.2 amended accordingly.
169	*University of Surrey* *Keith Ryden*	General		The development of the memorandum is a sensible step forward.				Agreed	

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170	*University of Surrey* *Keith Ryden*	1.1		- The vulnerability extends to high voltage (power) transistors and diodes, not just to memories, microprocessots etc – this should be pointed out. - SEL, SEB and SEFI are at least equally significant risks if not greater. - 6th para: clarify meaning of randomly distributed – in space, time, energy?? - 8th para: Remove word 'extreme' since ordinary space weather can do the same. The RAEng report addresses the extreme 1 in 200 year event, but many events are not so extreme. - Warning of such events affecting atmospheric radiation are difficult to achieve but should be worked on in conjunction with Met agencies.				Agreed	High voltage (power) transistors and diodes added to the list. 6th para – randomly distributed means randomly distributed in space. The term 'Extreme' was used to distinguish between the 'normal' atmospheric radiations levels and higher radiation level caused by, for example, solar flares. In this context the term 'Extreme' is helpful for the reader.
171	*University of Surrey* *Keith Ryden*	2.1		Explain rationale for 29kft limit? – SEE occurs below this level too.				Agreed	Aircraft that wish to fly above 29000 feet must also meet the requirements of RVSM (Required Vertical Separation Minima), therefore this altitude is a 'breakpoint' that is recognised within the aerospace community. Notwithstanding the above explanation, is limit of 29000 feet has now been removed.
172	*University of Surrey* *Keith Ryden*	3.1.6		Praxis?				Not Agreed	Praxis = established custom or habitual practice
173	*University of Surrey* *Keith Ryden*	3.2.2.2		Data sheets do not normally have SEE information.				Agreed	
174	*University of Surrey* *Keith Ryden*	3.4		Please also consider the role for SEE testing at equipment level as part of the validation process – i.e. an environmental test. This should be possible in Europe after opening of the ChipIR facility.				Agreed	
175	*Rolls-Royce* *(Robert Edwards)*	Section, 1.1 paragraph 3	4	Although SEU and MBU may have the higest rate of occurrence, effects like SEFI and SEL which affect functionality and large areas of the chip may have a greater impact on the SSA. In the Space indusry devices which exhibit SEL are not preferred	Replace "However, SEU and MBU are the two single effects that present the largest potential threat to aircraft systems" with "However, SEU and MBU together with effects that corrupt device function and operation are the single event effects that present the largest potential threat to aircraft systems	No	Yes	Agreed	Similar comments received and test amended.
176	*Rolls-Royce* *(Andy Ward)*	1.1, paragraph 8	4	Solar flares represent a specific risk and we are unclear about what would cause an operator to apply limitations. There will be insufficient time to take any avoiding action regarding highly energetic charged particles.	It is therefore proposed to remove the sentence starting "This should result in operational limitations ..." Consider replacing with words about extreme weather not needing to be considered because it represents a specific risk rather than average flight.	No	Yes	Agreed	Wording changed based on other comments received on same subject.
177	*Rolls-Royce* *(Andy Ward)*	1.1	4	Throughout the CM there is potential for confusion between the words "sensitive" and "susceptible" to SEE. Also, section 3.2.3 says "components which are identified … as potentially affected by SEE"	Provide a definition of these terms and then use them consistently	Yes	No	Agreed	Use of word 'sensitive' removed (x1) and replaced by susceptible.

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178	*Rolls-Royce (Kees Vugts)*	1.1	4	The first paragraph also states "the main contributors to atmospheric radiation are solar and galactic radiation." It is perhaps better to state that the main drivers are … because the main threat is posed by the secondary particles that are generated by the solar and cosmic radiation.	The main drivers behind atmospheric radiation are solar and galactic radiation.	Yes	No	Agreed	Wording changed based on other comments received on same subject.
179	*Rolls-Royce (Kees Vugts)*	1.1	4	The definition of atmospheric radiation is wrong (electro-magnetic) and conflict with paragraph 2 which refers to high energy particles.	Atmospheric radiation is a generic term which refers to all types of electromagnetic and particle radiation that can penetrate the earth's atmosphere as well as secondary particle radiation within the atmosphere resulting from interaction of extra-terrestrial radiation with particles and materials within the atmosphere.	No	Yes	Agreed	Wording changed based on other comments received on same subject.
180	*Rolls-Royce (Kees Vugts)*	1.1	4	The second paragraph now suggests that atmospheric radiation comprised high energy particles which is not correct, they are only one of the constituents. "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.	Single Event Effects (SEE) can occur when a high energy particle interacts with a specific location in a semiconductor device. Complex small feature components such as memory devices, micro-processors, FPGAs etc. are likely to be most susceptible to SEE.	No	Yes	Agreed	Wording changed based on other comments received on same subject.
181	*Rolls-Royce (Kees Vugts)*	1.1	4	Paragraph 4 is somewhat confusing in the way the different effects are listed. "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). " The second part of the paragraph is not strictly correct. "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)."	Some examples of SEE are Single Event Upsets (SEU) and Single Event Latch-up (SEL), both of which can affect either a single bit or multiple bits (MBU), Single Event Gate Rupture (SEGR) and Single Event Burnout (SEB). SEU and SEL present the largest potential threat to aircraft systems, SEU because it is the most prevalent and SEL because although less prevalent, is persistent until the equipment is de-powered. (see Section 1.4 for description of SEE types).	Yes	No	Agreed	Wording changed based on other comments received on same subject.
182	*Rolls-Royce (Kees Vugts)*	1.1	4	This paragraph 5 is not strictly correct and could be made clearer. "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."	For equipment that is susceptible to SEE, the probability of an SEE occurring and thus the rate of SEE occurrence is proportional to the particle flux density. This means that the SEE rate for such equipment typically increases with altitude and latitude because the particle flux density generally decreases with altitude due to atmospheric absorption, and increases with latitude due to deflection of the extra terrestrial radiation towards the poles by the earths magnetic field.	No	Yes	Agreed	Wording changed
183	*Rolls-Royce (Kees Vugts)*	1.1	4	Paragraph 5 fist sentence "Although the intensity of atmospheric radiation varies with altitude and geographic latitude…." what is the role of the word "geographic", but altitude and latitude refer the earth.	Suggest remove word "geographic"	Yes	No	Not Agreed	Evidently the term 'geomagnetic' latitude also exists. See comment No. 5.

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184	*Rolls-Royce* *(Kees Vugts)*	1.1	4	Paragraph 6 is not correct. SAE ARP4761 cannot be used to assess the atmospheric radiation effect rates, but can be used to assess the safety impact resulting from the effects of single event effects. "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."	The effect of atmospheric radiation is a 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 safety assessment of SEE due to atmospheric radiation.	No	Yes	Agreed	Wording changed based on similar comment.
185	*Rolls-Royce* *(Kees Vugts)*	1.1		The second part of paragraph 7 should be reworded. I don't believe that there is an established practice for monitoring space weather, nor an established and mandated response mechanism that has been demonstrated to result in safe operation of all equipment. "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)." Would it not be better to state that the current proposal covers "normal" conditions only, and that further guidelines and practice may need to be developed to deal with exceptional conditions such as solar flares. Such practice could perhaps be based on specific operational restrictions guided by prior notification of possible solar flares.	Further guidelines and practice may need to be developed to deal with exceptional conditions such as solar flares. One could envisage a practice where specific operational restrictions are enforced based on prior notification of possible solar flares, examples of which are rerouting of flights to comply with restrictions in altitude or latitude. If any guidance does exist, then please reference this.	No	Yes	Agreed	Wording changed based on similar comment.
186	*Rolls-Royce* *(Kees Vugts)*	1.1	4	Paragraph 8. The issue is not mitigating against SEE but ensuring that the system is sufficiently robust / immune to the failure effects of an SEE. "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."	The applicant shall demonstrate that in all permitted operating configurations the probability of an aircraft system effect, that could have a safety effect, occurring as a result of a SEE is sufficiently low. Such SEE robustness can be achieved through architectural system considerations, equipment design, component selection, component testing or suitable combination thereof.	No	Yes	Not Agreed	Throughout the Certification Memo, the term 'mitigation' is used and not 'robustness'. Both terms are essentially the same References to 'sufficiently' low are to be avoided in certification Memos since there is no definition of the tern 'sufficient'.
187	*Rolls-Royce* *(Robert Edwards)*	Section, 1.2 Table Row 5	5	Thee IEC 62396 group of standard includes 5 parts, the issue and date are for the part 1 only the other parts 2 to 5 have been issued in 2013 and 2014. Suggest to add a note with availability for part(s) 2 to 5 , Alternatively quote each standard with title issue & date separately	Suggest Row to be reference : "IEC 62396-1" Title: "Process management for avionics - Atmospheric radiation effects, Part 1 - Accomodation of atmospheric radiation effects via single event effects within avionics electronic equipment" to 5" add NOTE: Additional parts IEC 62396-2 to IEC 62396-5 have been issued with additional information.	Yes	No	Agreed	

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188	*Rolls-Royce (Andy Ward)*	1.2	5	There is a danger that by referencing IEC 62396 the CM my be effectively reflecting the requirements that it (the IEC doc) imposes. For example Part 1 Section 7 contains a number of "shall" requirements	Whenever IEC 62396 is referenced the specific relevant section should be identified	No	Yes	Not Agreed	Para 2.2 clearly states that the IEC documents 'provide useful information' and the Certification Memo does not introduce any requirements based on this/these documents.
189	*Rolls-Royce (Andy Ward)*	1.2	5	The References no longer include CS-E, CS-P and CS-APU – I assume this is an oversight as they are mentioned later within the CM	Include refs to CS-E, CS-P and CS-APU	Yes	No	Agreed	
190	*Rolls-Royce (Robert Edwards)*	Section, 1.3 Table Row 4	6	ARP is wrong font size	Correct font size ARP	Yes	No	Agreed	Well Spotted!
191	*Rolls-Royce (Robert Edwards)*	Section, 1.3 Table Row 15	6	Upsets should be upset as Table in section 1.4	Correct to Multiple Bit Upset	Yes	No	Agreed	
192	*Rolls-Royce (Robert Edwards)*	Section, 1.3 Table Row 22	7	Latchup should be consistent in the IEC document it is "latch-up"	Suggest use "latch-up" or else make "latchup" consitent	Yes	No	Agreed	
193	*Rolls-Royce (Robert Edwards)*	Section, 1.4 Table Row 3	7	The word fail is incorrect and not part of the IEC definition, the data can be re-written.	Replace "fail" with "upset"	No	Yes	Agreed	
194	*Rolls-Royce (Robert Edwards)*	Section, 1.4 Table Row 4	7	Latchup should be consistent, in the IEC document it is "latch-up"	Suggest use "latch-up" or in description change "latch up" to "latchup"	Yes	No	Agreed	
195	*Rolls-Royce (Mal Atherton)*	1.4	7	There is inconsistency in the use of some terms indicating failure. For example, SEU leads to a "change in a cell's logic state", MBU causes "upset" and MCU causes several bits in an IC to "fail". It is not clear whether the use of different terms is significant or just a matter of preference by differing authors. But it can lead to confusion.	Adopt consistent terms which are themselves defined.	Yes	No	Not Agreed	Most of these definitions were taken from the IEC document. There are several statements which are used to indicate a failure but the description adequately describes the type of failure.
196	*Rolls-Royce (Kees Vugts)*	1.4	8	The various definitions are not always correct and are not consistent.		Yes	No	Agreed	Changes were made to some definitions based on other comments received.
197	*Rolls-Royce (Kees Vugts)*	1.4	8	Single Event Upset	An interaction between a radiation particle and a semiconductor device that results in a reversible change of state of one or more elements within that device that has an observable functional impact, for example a change in the logic state of a memory cell.	Yes	No	Agreed	Most of these definitions were taken from the IEC document. The alternative definition you have provided is noted and may be used is future revisions of this Certification Memo.
198	*Rolls-Royce (Kees Vugts)*	1.4	8	Multiple Bit Upset	A subset of Single Event Upsets in which the state of more than one functional element (typically a bit in a memory device) is affected. Sometimes this sub set is further restricted to those where more than one bit is affected in a single data element, for example more than one bit in a single byte, word etc.	Yes	No	Agreed	Most of these definitions were taken from the IEC document. The alternative definition you have provided is noted and may be used is future revisions of this Certification Memo.
199	*Rolls-Royce (Kees Vugts)*	1.4	8	Multiple Cell Upset	A sub set of Single Event Upsets in which the state of more than one data / logic cell is affected. For example the state of more than one flip-flop is affected in an FPGA.	Yes	No	Agreed	Most of these definitions were taken from the IEC document. The alternative definition you have provided is noted and may be used is future revisions of this Certification Memo.

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200	*Rolls-Royce (Kees Vugts)*	1.4	8	Single Event Latch-up	An interaction between a radiation particle and a semiconductor device that results in a change of state of one or more elements within that device that is persistent and cannot be changed until the device is de-powered. For example a change in the logic state of a memory cell that cannot be corrected until the device is de-powered. Such latch-ups could be destructive or non-destructive.	Yes	No	Agreed	Most of these definitions were taken from the IEC document. The alternative definition you have provided is noted and may be used is future revisions of this Certification Memo.
201	*Rolls-Royce (Kees Vugts)*	1.4	8	Single Event Gate Rupture	An interaction between a radiation particle and a semiconductor device that produces an event in the device that results in permanent damage to the gate of an insulated gate device.	Yes	No	Agreed	Most of these definitions were taken from the IEC document. The alternative definition you have provided is noted and may be used is future revisions of this Certification Memo.
202	*Rolls-Royce (Kees Vugts)*	1.4	8	Single Event Burnout	An interaction between a radiation particle and a semiconductor device that produces a local over current event in the device that results in permanent damage to the device.	Yes	No	Agreed	Most of these definitions were taken from the IEC document. The alternative definition you have provided is noted and may be used is future revisions of this Certification Memo.
203	*Rolls-Royce (Kees Vugts)*	1.4	8	Single Event Transient	An interaction between a radiation particle and a semiconductor device that results in a spurious signal or voltage that can propagate through the circuit path during one clock cycle.	Yes	No	Agreed	Most of these definitions were taken from the IEC document. The alternative definition you have provided is noted and may be used is future revisions of this Certification Memo.
204	*Rolls-Royce (Kees Vugts)*	1.4	8	Single Event Functional Interrupt	An interaction between a radiation particle and a semiconductor device that results in incorrect operation for example due to corruption of the internal control path of a complex device such as a micro-processor.	Yes	No	Agreed	Wording changed
205	*Rolls-Royce (Robert Edwards)*	Section 2.1 paragraph 1	8	The first paragraph suggests that SEE does not need to be considered for systems flown below 29,000 feet. The SEE sensitivity of modern electronic components are such that they can have an impact even at sea level. There is evidence that in the Automotive and Telecommunication Industries for high integrity systems / safety impact systems not only is the SEE impact addressed but also equipment is radiation testsed tested by manufacturers.	Change first sentence to "Typically, aircraft flight systems installed on aircraft should consider SEE." and add new sentence after second sentence. Add "However interested paties e.g. customer or equipment manufacturer may require the mitigation of any potential electronic component SEE in an application are addressed."	No	Yes	Agreed	Text modified to reflect the typically types of aircraft which are potentially more exposed/affected by SEE – namely large and business jet aircraft. The CM may be extended at a later date to include other types of aircraft.
206	*Rolls-Royce (Mal Atherton)*	2.1	8	The guidance that aircraft flying above 29,000ft should consider SEE is inconsistent with existing Regulatory guidance which does not provide an altitude threshold. It is assumed that this threshold was chosen to separate the case of rotorcraft which operate at low altitudes.	Restate to recognize that SEE is a threat at any altitude, but the risk is greater at higher altitudes, therefore, it could be stated that the risk is recognized to be lower for those categories of aircraft which do not operate at high altitudes, such as rotorcraft which operate below 29,000ft. But I do not recommend a statement that implies no action is required for any aircraft, just a statement that risks are greater on some types than others.	Yes	No	Agreed	29000 feet discriminant removed. This sentence has been reworded.
207	*Rolls-Royce (Robert Edwards)*	Section 2.1 paragraph 2	8	The word "was" after "whose" and before "equipment" in second sentence should be removed	Remove the word "was" after "whose" and before "equipment"	Yes	No	Agreed	
208	*Rolls-Royce (Robert Edwards)*	Section 2.1 paragraph 2	8	(second sentence) this condition is only acceptable if the new application is the same as the existing one or less severe from an atmospheric radiation aspect.	After "aircraft" add "with a similar or more severe application radiation environment"	No	Yes	Agreed	Wording revised in line with other, similar, comments.

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209	*Rolls-Royce (Kees Vugts)*	2.1	9	It is not correct to suggest an arbitrary altitude (29000 ft), an arbitrary latitude or to arbitrarily exclude certain aircraft. This decision should be made depending upon the susceptibility of the equipment to SEE, the potential consequence of the effect and the radiation density in which the aircraft is allowed to operate.	This memorandum should as a minimum apply to all aircraft systems installed on large transport and business aircraft. Equipment on specific aircraft could be exempt if their operation is explicitly restricted to altitudes and latitude for which it has been demonstrated that the atmospheric radiation flux is sufficiently low relative to the specific equipment installed to substantiate that the possible failure contribution due to SEE is insignificant.	No	Yes	Agreed	Wording revised in line with other, similar, comments.
210	*Rolls-Royce (Mal Atherton)*	2.2	8	typo - closing bracket with no opening bracket in first paragraph.		Yes	No	Agreed	
211	*Rolls-Royce (Andy Ward)*	2.2	8	The definition of applicant in the second paragraph is incorrect. The applicant is the person or organisation seeking approval and a type certificate	Need to distinguish between an "applicant" and a supporting organisation e.g. supplier who may well be carrying out some of this activity	Yes	No	Not Agreed	The definition, for the purposes of this CM, is clearly given in this paragraph.
212	*Rolls-Royce (Kees Vugts)*	2.2	9	The wording should be stronger so that appropriate evidence shall be produced. The potential process audit should be able to extent to suppliers and sub-contractors where appropriate, as for much of the evidence the applicant is likely to rely on the supply chain / component specifications and specialist resources.	Applicants shall provide evidence to the Agency that all potential equipment or system effects that could result from SEE have been adequately addressed and that the effects (if any) at aircraft/engine level are acceptable. Such body of evidence may require an assessment of the equipment Manufacturer, their supply chain and sub-contractors to ensure adequate procedures are in place, and are/were followed, to address SEE.	Yes	No	Not Agreed	The proposed wording is too prescriptive for a CM.
213	*Rolls-Royce (Kees Vugts)*	2.3	10	The note on the bottom of the paragraph states: "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." Whilst this is true, it should be recognised that a an SEU can persist for a prolonged period of time if the SEU results in an element in one of the systems entering a state from where timely regular recovery is not available. It is possible that due to interactions between systems this could expose a particular vulnerability in another system or other part of the system.	"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." However it should be recognised that a an SEU can persist for a prolonged period of time if the SEU results in an element in one of the systems entering a state from where timely regular recovery is not available. It is possible that due to interactions between systems this could expose a particular vulnerability in another system or other part of the system.	Yes	No	Agreed	Similar wording incorporated
214	*Rolls-Royce (Andy Ward)*	3.1.2	9	Talks about demonstrating compliance with this "guidance material".	Propose reword to something like: "... How the issues of SEE guidance in section 3.2 will be addressed." Comment is observational suggestion only	Yes	No	Agreed	Re-worded
215	*Rolls-Royce (Mal Atherton)*	3.1.3	9	This list omits CS-27 (small rotorcraft) and CS-29 (large rotorcraft). Does this imply that SEE provisions are assumed not to be needed for helicopters?	Suggest rationalising with the comment against section 2.1 above which seems to imply an exclusion for rotorcraft.	Yes	No	Agreed	Altitude discriminant of 29,000ft now removed so CS 27 and CS 29 are included in section 3.1.3.
216	*Rolls-Royce (Andy Ward)*	3.1.5	9	Supplier designers will often not know whether their equipment contributes to a Catastrophic or Hazardous effect at aircraft level. So they will be reliant on the airframer to know whether they are required to follow this process.	Change of emphasis to place the responsibility on the "applicant"	No	Yes	Agreed	Additional sentence added to this paragraph to request the aircraft manufacturer to supply this information to the equipment manufacturers.

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217	*Rolls-Royce (Mal Atherton)*	3.1.5	10	The description of what constitutes mitigation (against the effects of SEE) needs more detail to aid understanding and expand on the examples (e.g. dual channel systems). It appears that Note 2 is the only place that describes what mitigations are being considered, and given that this is an important part of the process described here (and shown in Annex A), I think it needs more treatment.	The description could include some examples to show how architectural considerations like a dual channel system provide mitigation.	Yes	No	Agreed	Note 2 has been changed to include the words 'dual channels, etc'. Generally the Certification Memorandum tries not to be too prescriptive.
218	*Rolls-Royce (Robert Edwards)*	Section 3.1.5 note 1	10	The availability of redundancy can be affected while equipment is recovering from SEE. [ref. section 8.5 IEC 62396-1]. Recommend remove "Major" from list of exceptions.	Remove "Major" from list of exceptions	No	Yes	Not Agreed	If the availability of redundancy is affected, while equipment is recovering, then as long as it results in 'only' a major failure condition then this is considered acceptable and no further investigation is required. An investigation can, however, be conducted on a voluntary basis.
219	*Rolls-Royce (Andy Ward)*	3.1.6	10	This appears to contradict 3.1.5 which says you only need to do it for Cat & Haz. But 3.1.6 talks about "each system or piece of equipment" irrespective of failure condition classification	Clarification in 3.1.6 that this is only required as per 3.1.5.	Yes	No	Agreed	Link between the two sections added.
220	*Rolls-Royce (Robert Edwards)*	Section 3.2.2 last sentence	10	IEC 62396-2 clause 5.2 also contains details on obtaining SEE data	Suggest after IEC 62396-1 add IEC 62396-2	Yes	No	Agreed	
221	*Rolls-Royce (Andy Ward)*	3.2.2.2	10	The component data sheet is unlikely to contain any information about SEE susceptibility	Change "data sheet" to "data sources", to include data sheet, testing, etc.	Yes	No	Agreed	Wording changed based on similar comments.
222	*Rolls-Royce (Andy Ward)*	3.2.3	10	Doesn't quite tie up with the Figure (Annex A) regarding no mention of List (B), for example	Ensure that Annex A is consistent with the wording in section 3	Yes	No	Not Agreed	Annex A is flow diagram that should be read in conjunction with section 3.2.3. For ease of understanding the flow diagram introduces Component List A & B.
223	*Rolls-Royce (Robert Edwards)*	Annex A Top box 3.2.3 (A)	13	Any mitigation needs to be effectively introduced in the design.	At end after "no mitigation " add "or incomplete mitigation in the design"	No	Yes	Agreed	Sentence changed in accordance with similar comment received.
224	*Rolls-Royce (Robert Edwards)*	Annex A box below 3.2.3 (B)	13	Any mitigation needs to be effectively introduced in the design.	At end after "no mitigation " add "or incomplete mitigation in the design"	No	Yes	Agreed	
225	*Rolls-Royce (Andy Ward)*	3.2.3 & 3.2.4 General	10 & 11	If there is insufficient mitigation the quantitative route permits a rate-based argument that should not be permitted for high severity FCCs. (Cat & Haz).	Confirm that no single failure due to SEE is permitted to result in a Catastrophic (or Hazardous in case of engines) irrespective of rate	Yes	No	Not Agreed	This should be part of the System Safety Analysis to ensure that no single failure due to SEE is permitted to result in a Catastrophic (or Hazardous in case of engines) irrespective of rate
226	*Rolls-Royce (Ulrich Fräbel)*	3.2.4.1	11	There is the assumption of 6000n/sec recommended at Alt=40.000ft at Lat=45°. Solar radiation varies very much over the time, (statistically 9 years solar cycle) and on the latitude. Most critical latitudes are on the polar regions due to magnetic inclination.	The recommendation is questionable. Information about qualified information sources from which tendencies of development of cosmic radiation (e.g. meteorological services etc.) could be helpful, especially for continued airworthiness to proof in service products.	Yes	No	Agreed	For the purposes of the Certification Memorandum the default value of neutron flux density is maintained. For continued airworthiness it may be helpful review the solar weather from day to day.
227	*Rolls-Royce (Andy Ward)*	3.2.4.1	11	We need to be clear about the meaning of mitigation, which is a risk reduction but does not necessarily mean elimination. Where the mitigation by the architecture does not eliminate system level effects, there is potential for quantification because there is the possibility of a combination of failures resulting in a Cat or Haz from a double failure viz: failure due to SEE AND failure of the mitigation.	Determine whether the mitigation represents complete elimination or merely a partial reduction in risk. In the former case quantification would be required.	Yes	No	Agreed	It is difficult to precisely define the word 'mitigation' . The context in this Certification Memo mitigation should ensure that the risk of a SEE is reduced such that there is no effect at system level. No change to the current text is proposed.

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228	*Rolls-Royce (Andy Ward)*	3.2.4.1	11	The "typical flight envelope" wording is imprecise as it is an average point in a flight profile and is neither typical nor an envelope.	Propose something like "… which is equivalent to an average flight condition of ..."	Yes	No	Not Agreed	Default values are maintained. The applicant may propose different values based on average flight profile. This needs to be agreed with the Agency.
229	*Rolls-Royce (Andy Ward)*	3.2.4.1	11	Such information is not normally included in the AFM and DDP	Perhaps any "deviations" should be captured in the Safety Analysis Report mentioned in section 3.1.6?	Yes	No	Not Agreed	The Safety Analysis Report may not be readily available to the end user (e.g. STC 'House'), however the DDP should be made available to the airline, STC House and any other organisation that has a legitimate need.
230	*Rolls-Royce (Robert Edwards)*	Section 3.2.5, subclause numbering	11	Sub clause numbering is incorrect should be 3.2.5.1 and 3.2.5.2.	Renumber sub-clauses 3.2.5.1 and 3.2.5.2.	Yes	No	Agreed	
231	*Rolls-Royce (Ulrich Fräbel)*	3.2.5	11	Guidance on how to conduct representative radiation testing would be valuable		Yes	No	Not Agreed	Section 3.2.5 refers the reader to IEC 623996-2 for more information regarding radiation testing.
232	*Rolls-Royce (Andy Ward)*	3.2.5	11	There is a contradiction between the Draft CM and IEC 63296 in terms of when testing is required. The CM only requires testing after all other avenues have been explored if there is still a safety concern. But there are words in the IEC, Part 1, section 7.4.2.2 which is applicable to Level A type 1 systems, i.e. highest integrity, no pilot intervention. These words state that SEE rate data needs to come ideally from neutron testing of components, alternatively from proton testing or from system in the loop testing. Only where such testing/data is not available or practical can the methods for the level A type II system be used, including the less accurate methods (factor of 10) such as generic SEE data for part types.	Reconsider whether the proposed CM approach is considered to be satisfactory	Yes	No	Agreed	Para 3.2.2.2 changed to introduce the term 'test data'. Although not explicit stated, the applicant to choose to test the component and use this data to support the qualitative assessment.
233	*Rolls-Royce (Andy Ward)*	3.2.5	11	There is a slight problem with section numbering in section 3.2.5. The first para does not have a number but should presumably be 3.2.5.1. The section number 3.2.5.2 does appear but is buried within the first para. My question is whether there are some words missing from the start of 3.2.5.2, because it used to start with "Taking into account the operational envelope of the aircraft (see Section 9.1.1), radiation testing …"?	Resolve per comment summary	Yes	No	Agreed	
234	*Rolls-Royce (Andy Ward)*	Annex A box 3.2.2.2	13	The box should not talk about "use conservative value of SEE rate" as at this stage there may not be a need to go to the quantitative stage.	Ensure that Annex A is consistent with the wording in section 3	Yes	No	Agreed	Use of 'test data' inserted into Annex A box 3.2.2.2. This is in line with the text in section 3.
235	*Rolls-Royce (Andy Ward)*	Annex A box 3.2.3	13	It says "where there is no mitigation"	But it should say something like "no or only partial mitigation"	Yes	No	Agreed	
236	*Rolls-Royce (Andy Ward)*	Annex A box 3.2.4	13	This box appears to only be quantitative at component level, but where is the system level safety assessment performed? Has the system level (e.g. Fault Tree) already been performed as part of the "mitigation" question in box 3.2.3?	Annex to resolve ambiguity between component level and system level	No	Yes	Not Agreed	Annex A requests the applicant to provide a components list (B). These components are assumed, based on previous assessment, to be part of equipment/systems which contribute to catastrophic or hazardous failure conditions.

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237	*Rolls-Royce* *(Mal Atherton)*	Annex A	13	Regarding the removal of components from list A to create list B based on whether they have mitigation may place too much emphasis on engineering judgment. Where the mitigation is in the form of redundancy provided through architecture, then a quantitative analysis (via fault trees for example) should be used as a means to show how the redundancy provides a reduction in the top level rates of hazardous effects.	Change diagram to remove the use of mitigation, as a filtering mechanism for which components require quantitative analysis, or else provide much more clarity (and rules) on what constitutes the form of mitigation which can justify adopting a qualitative approach.	No	Yes	Not Agreed	The Certification Memo provides guidance and as such it should not be too prescriptive regarding what constitutes an acceptable form of mitigation. It is up to the applicant to decide whether or not the mitigation is acceptable and too explain this to the Certification Agency.