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Space product assurance

Radiation Hardness Assurance

Change log

ESA-TEC-QE/2009/22	First issue

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1 Scope

This standard defines the requirements for ensuring Radiation Hardness Assurance (RHA) of ESA space projects. These requirements form the basis for a RHA program that is required for all space projects in conformance to ECSS-Q-ST-60. RHA program is project specific. Therefore, these requirements can be tailored depending on the project.

This standard addresses the three main radiation effects on electronic components: Total Ionizing Dose (TID), Displacement Damage or Total Non Ionizing Dose (TNID), and single event effects (SEE). Some of these effects may not be applicable for some projects. Spacecraft charging effects are out of the scope of this standard.

In this standard the word “component” refers to Electrical, Electronic, and Electromechanical (EEE) components only. Other fundamental constituents of space hardware units and sub-systems such as solar cells, optical materials, adhesives, polymers, and any other material are not covered by this standard..

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this Standard. For dated references, subsequent amendments to, or revision of any of these publications do not apply, However, parties to agreements based on this Standard are encouraged to investigate the possibility of applying the more recent editions of the normative documents indicated below. For undated references, the latest edition of the publication referred to applies.

ECSS-S-ST-00	ECSS system – Description and implementation
ECSS-S-ST-00-01	ECSS system – Glossary of terms
ECSS-Q-ST-60	Space product assurance - Electrical, electronic, and electromechanical (EEE) components
ECSS-Q-ST-30-11	Space product assurance – Derating – EEE components
ECSS-Q- ST-30	Space product assurance – Dependability
ECSS-E-ST-10-04	Space engineering – Space environment
ECSS-E-ST-10-12	Space engineering - Evaluation of radiation effects
ESCC22900	ESCC Basic Specification: Total Dose Steady State Irradiation Test Method
ESCC25100	ESCC Basic Specification: Single Event Effect Test Method and Guidelines
MIL-STD-750E method 1080	MIL-STD: Single Event Burnout and Single Event Gate Rupture Testing
MIL-HDBK-814 (February 1994)	Ionizing Dose and Neutron Hardness Assurance Guidelines for Microcircuits and Semiconductor Devices
MIL-PRF-38535 (September 2007)	Performance specification, Integrated circuits manufacturing general specification

3 Terms, definitions and abbreviated terms

3.1 Terms from other standards

For the purpose of this Standard, the terms and definitions from ECSS-S-ST-00-01 apply, in particular for the following terms:

Applicable document

Approval

Assurance

Derating

EEE component

Environment

Equipment

Failure

Information

Outage

Recommendation

Required function

Requirement

Review

Risk

Specification

Standard

Subsystem

System

Test

Traceability

Validation

Verification

For the purpose of this Standard, the terms and definitions from ECSS-Q-ST-60 apply, in particular for the following terms:

Characterization

Commercial Component

Screening

Space qualified parts

For the purpose of this Standard, the terms and definitions from ECSS-E-ST-10-04 apply, in particular for the following terms:

Dose

Equivalent fluence

Fluence

Flux

Linear Energy Transfer (LET)

For the purpose of this Standard, the terms and definitions from ECSS-E-ST-10-12 apply, in particular for the following terms:

Cross section

Displacement damage

Multiple cell upset (MCU)

(total) non-ionising dose, (T)NID, or non-ionising energy loss (NIEL) dose

NIEL

Projected range

Radiation design margin (RDM)

Sensitive volume (SV)

Single event burnout (SEB)

Single event dielectric rupture (SEDR)

Single event effect (SEE)

Single event functional interrupt (SEFI)

Single event gate rupture (SEGR)

Single event latchup (SEL)

Single event transient (SET)

Single event upset (SEU)

Solar energetic particle event (SEPE)

Total ionizing dose (TID)

3.2 Terms specific to the present standard

3.2.1 LET threshold

minimum LET that a particle should have to cause a SEE in a circuit when going through a device sensitive volume.

3.2.2 Radiation Verification Testing (RVT) or Radiation Lot Acceptance Test (RADLAT)

radiation tests performed on sample coming from the same diffusion lot than the flight parts.

3.2.3 Enhanced Low Dose Rate Sensitivity (ELDRS)

increased electrical parameter degradation of a part when it is irradiated with a lower dose rate.

3.2.4 Component type TID sensitivity (TIDS)

Component Type TID sensitivity (TIDS) is defined by comparing part parametric/functional requirements with TID test data. The part parametrical/functional requirements shall be based on the parametric & functional limits given in detail specification or manufacturer data book, or the maximum parameter degradation acceptable ensuring equipment operation compliant with equipment specification at the end of overall lifetime (EOL).

Component Type TIDS may then be defined as:

1. “Worst Case” Approach: Total Dose Level at which the worst case part of the worst case lot exceeds its limits, as defined above, or
2. “Statistical” Approach” as defined in MIL-HDBK-814

NOTE Statistical approach is based on the one sided tolerance limit that assumes that TID degradation of electrical parameters follow a log normal distribution law. There is a probability P with a confidence limit C that a given electrical parameter does not exceed the following limits:

- Delta XL = <delta x > + K σ, for increasing total dose shift
- Delta XL = <delta x > - K σ, for decreasing total dose shift
- <delta x> is the mean shift among tested population of n samples. σ is the standard deviation of the shift. K is the one sided tolerance limit factor. It depends on the number of tested samples n, the probability of success P and the confidence limit C. K values are in available in MIL-HDBK-814.

3.2.5 Component type TNID sensitivity (TNIDS)

Component TNID sensitivity (TNIDS) is defined based on comparison between parametric/functional requirements and characterization of components behaviour following ground based TNID testing. The part parametrical/functional requirements shall be based on the parametric & functional type limits given in detail specification or manufacturer data book, or the maximum parameter degradation acceptable ensuring equipment operation compliant with equipment specification at EOL.

Component Type TNIDS may then be defined as:

1. "Worst Case" Approach: Total Dose Level at which the worst case part of the worst case lot exceeds its limits, as defined above, or
2. "Statistical" Approach" as defined in MIL-HDBK-814

3.3 Abbreviated terms

For the purpose of this Standard, the abbreviated terms from ECSS-S-ST-00-01 and the following apply:

Abbreviation	Meaning
APS	Active Pixel Sensor
ASIC	Application Specific Integrated Circuit
CCD	Charge Coupled Device
CDR	Critical Design Review
DCL	Declared Part List
ELDRS	Enhanced Low Dose Rate Sensitivity
EOL	End Of Lifetime
LET	Linear Energy Transfer
MCU	Multiple Cell Upset
MOS	Metal Oxide Semiconductor
NIEL	Non Ionizing Energy Loss
PDR	Preliminary Design Review
RADLAT	Radiation Lot Acceptance Testing
RDM	Radiation Design Margin
RHA	Radiation Hardness Assurance
RVT	Radiation Verification Testing
SEB	Single Event Burnout
SEE	Single Event Effect
SEFI	Single Event Functional Interrupt
SEGR	Single Event Gate Rupture
SEL	Single Event Latchup
SET	Single Event Transient

SEU	Single Event Upset
TID	Total Ionizing Dose
TIDS	Total Ionizing Dose Sensitivity
TIDL	Total Ionizing Dose Level
TNID	Total Non Ionizing Dose
TNIDS	Total Non Ionizing Dose Sensitivity
TNIDL	Total Non Ionizing Dose Level
WCA	Worst Case Analysis

4 Principles

4.1 Overview of RHA process

Survival and successful operation of space systems in the space radiation environment cannot be ensured without careful consideration of the effects of radiation. RHA consists of all those activities undertaken to ensure that the electronics of a space system perform to their specification after exposure to the space radiation environment. A key element of RHA is the selection of components having a sufficient tolerance to radiation effects for their application. However, RHA process is not confined to the part level. It has implications with system requirements and operations, system and subsystems circuit design, and spacecraft layout. Figure 4- 1 shows an overview of the process. The RHA process follows an iterative and top-down approach where mission radiation environment is calculated from mission requirements and the radiation environments models and rules defined in ECSS-E-ST-10-04. Top level requirements derived from mission radiation environment specification are employed as the starting point. Then, when necessary, radiation environment is transferred to component level via sector analysis or Monte Carlo analysis according to the methods described in ECSS-E-ST-10-12. Radiation sensitivity of each component is defined and its impact on equipment performance is analyzed. An equipment electronic design is validated when the equipment can fulfil its performance requirements under exposure to the mission space environment with a sufficient RDM.

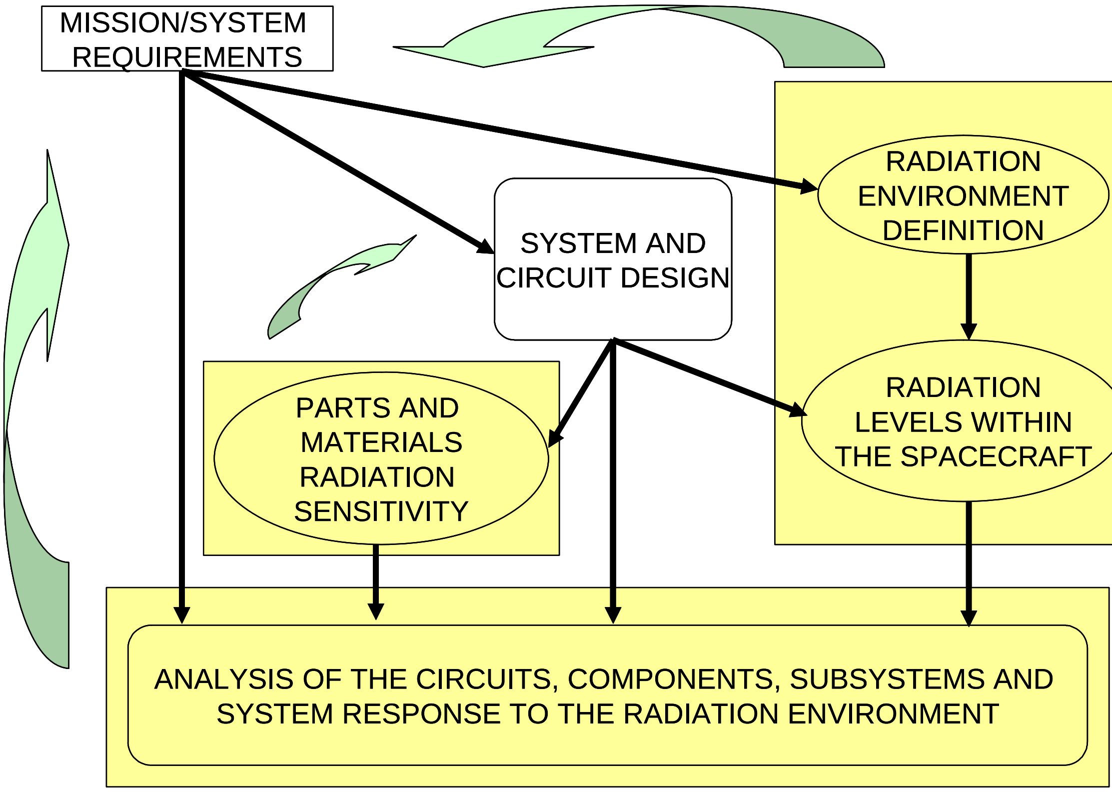

Figure 4- 1: RHA process overview

4.2 Radiation Effects on Components

A comprehensive compendium of radiation effects is provided in ECSS-E-HB-10-12 clause 3. Radiation effects that are important to consider for instrument and spacecraft design fall roughly into three categories: degradation from TID, degradation from TNID, or NIEL or DDD, and SEE. TID in electronics is a cumulative, long term degradation mechanism due to ionizing radiation—mainly primary protons and electrons and secondary particles arising from interactions between these primary particles and spacecraft materials. It causes threshold shifts, leakage current and timing skews. The effect first appears as parametric degradation of the device and ultimately results in functional failure. It is possible to reduce TID with shielding material that absorbs most electrons and lower energy protons. As shielding is increased, shielding effectiveness decreases because of the difficulty in slowing down the higher energy protons. When a manufacturer advertises a part as “rad-hard”, he is almost always referring to its total ionizing dose characteristics. Rad-hard does not usually imply that the part is hard to non-ionizing dose or single event effects. In some cases, a “rad-hard” part may perform significantly worse in the space radiation environment than in the test environment (e.g. Enhanced Low Dose Rate Sensitivity in linear bipolar devices.)

Displacement damage is cumulative, long-term non-ionizing damage due to protons, electrons, and neutrons. These particles produce defects mainly in optoelectronics components such as APS, CCDs, and optocouplers. Displacement damage also affects the performance of linear bipolar devices but to a lesser extent. The effectiveness of shielding depends on the location of the device. Increasing shielding beyond a critical threshold, however, is not usually effective for optoelectronic components because the high-energy protons penetrate the most feasible spacecraft electronic enclosures. For detectors in instruments it is necessary to understand the instrument technology and geometry to determine the vulnerability to the environment.

SEEs result from ionization by a single charged particle as it passes through a sensitive junction of an electronic device. SEEs are caused by heavier ions, but for some devices, protons can also contribute. In some cases SEEs are induced through direct ionization by the proton, but in most instances, proton induced effects result from secondary particles produced when the proton scatters off of a nucleus in the device material. Some single event effects are non-destructive, as in the case of SEUs, single event transients SETs, multiple bit errors MCUs, SEFI, etc. Single event effects can also be destructive as in the case of single event SELs, SEGR, and SEBs. The severity of the effect can range from noisy data to loss of the mission, depending on the type of effect and the criticality of the system in which it occurs. Shielding is not an effective mitigator for SEEs because they are induced by very penetrating high energy particles. The preferred method for dealing with destructive failures is to use SEE-hard parts. When SEE-hard parts are not available, latchup protection circuitry is sometimes used in conjunction with failure mode analysis. (Note: Care is necessary when using SEL protection circuitry, because SEL may damage a microcircuit and reduce its reliability even when it does not cause outright failure.) For non-destructive effects, mitigation takes the form of error-detection and correction codes (EDACs), filtering circuitry, etc.

Knowledge of parts radiation sensitivity is an essential part of the overall RHA program.. For the total dose environment, the damage is caused by the ionization energy absorbed by the sensitive materials, measured in rad or in gray (1 gray = 100 rad). This implies that a number of ionization sources can be used for simulation of space environment at ground level. However, the total dose response is also a strong function of the dose rate. Displacement damage can be simulated for any particle by using the value of NIEL. This implies that the effects of the displacement are to a first approximation, only proportional to the total energy loss through displacements and not on the nature of the displacements. The single particle environment is usually simulated by the particle LET. For heavy ions this seems to be a reasonable measure of the environment as long as the particle type and energy are adjusted to produce the appropriate range of the ionization track. For protons, however, the LET is not the primary parameter since the upsets result primarily from secondary particles resulting from the interaction of proton with device's atoms. Thus for the proton environment, the simulations must be conducted with protons of the appropriate energy.

4.3 Evaluation of radiation effects.

For assessing TID and TNID damages, electrical parameter drift values of each single individual component are derived from TID levels and TNID levels with an appropriate RDM. These drifts are then used as input for WCA as defined in ECSS-Q-ST-30 clause 6.4.2.7. Rationale for establishing RDM for TID and TNID is provided in ECSS-E-ST-10-12.

SEE are anomalies and thus not a variation factor considered in WCA. Operational impact of each single individual component SEE is analyzed and its criticality is assessed. Based on this analysis and functional requirements at component/function level acceptable SEE rate of occurrence can be defined. The design of an electronic function is validated when all SEE rates occurring in the components used to realize this function are within the acceptable SEE rates with an appropriate RDM. Rationale for establishing RDM for SEE is provided in ECSS-E-ST-10-12.

4.4 Phasing of RHA with the different space program phases

4.4.1 Phase 0, Phase A

Mission environment is defined and top level radiation requirements can be derived. Preliminaries radiation characterization studies can be started to help technology selection and design trade-off activities.

4.4.2 Phase B

Mission environment is finalized as well as top level radiation requirements. Electronic design and spacecraft layout are defined. Preliminary shielding analyses can be started as well as radiation characterization activities.

4.4.3 Phase C

Radiation characterization tests are performed. Equipment shielding analyses are finalized. Circuit design analyses (WCA, SEE analysis) are performed. At the end of phase C, for the CDRs, most of the RHA work is completed.

4.4.4 Phase D

Remaining RHA activities are Radiation tests on flight lots (RVT or RADLAT). At this stage of program development radiation effects issues resulting in redesign activities are very costly.

5 Requirements

5.1 TID Hardness Assurance

a. No effect due to TID shall cause degradation of performance to a system or subsystem outside its technical specification limits.

b. Each EEE part belonging to families listed in Table 5-1 shall be assessed for sensitivity to TID effects.

NOTE Hybrids may also be treated as an electronic box. In this case, RHA requirements, as listed in this document, are applicable to every die used in the hybrid.

EEE part family	Sub family	TIDL
Diodes	Voltage reference	all
	Switching, rectifier, schottky	> 300 Krad-Si
Diodes microwave		all
Integrated Circuits		all
Integrated Circuits microwave		> 300 Krad-Si
Oscillators (hybrids)		all
Charge Coupled devices (CCD)		all
Opto discrete devices, Photodiodes, LED, Phototransistors, Opto couplers		all
Transistors		all
Transistors microwave		> 300 Krad-Si
Hybrids		all

Table 5-1 List of EEE part families potentially sensitive to TID

c. If component TID test data does not exist, ground testing shall be performed.

d. TID testing shall be performed in conformance to ESCC22900.

e. Devices that contain bipolar transistors (e.g. BICMOS) shall be tested at a dose rate of 36 rad/h.

NOTE Analog bipolar parts are potentially sensitive to ELDRS

f. Mission TID radiation environment shall be defined in conformance to ECSS-E-ST-10-04 and documented in Mission Radiation Environment Specification. A draft version of the Mission Radiation Environment Specification shall be available at SRR and final version shall be available at PDR.

NOTE The mission radiation environment specification could be a self standing document or part of the overall project environment specification.

g. Component received TID level (TIDL) shall be calculated in conformance to ECSS-E-ST-10-12.

h. If worst case models have been used to define the mission environment and then TIDL, and if TIDS is based on statistical analysis of test data to guarantee a probability of survival Ps of at least 90% with a confidence level of at least 90%, Radiation Design Margin (RDM), defined as the ratio of TIDS over TIDL, shall be greater than 1. In all other cases RDM shall be greater than 2.

i. For any component that is estimated to have on-orbit performance degradation due to TID, a WCA of the function where it is used shall be performed according to ECSS-Q-ST-30 . WCA shall demonstrate that the function performs within EOL technical specification limits.

j. If requirements 5.1 h and i cannot be met, mitigation shall be implemented to eliminate the possibility of damage to or degradation of equipment performance outside its technical specification limits.

k. Mitigation shall be verified by analysis or test.

l. Radiation verification testing (RVT) (or RadLAT) on flight lot shall be performed according to Table 5-2.

m. TID analysis shall be documented in the equipment radiation analysis report in conformance to Annex A.

Family	Sub-family	ECSS class	RHA qualification level {as defined MIL-PRF-38535	RDM	RVT requirement
diodes		1			No testing required
		2		>10	No testing required
				>1 <10	RVT if test data > 4years
		3			RVT if test data > 4years
integrated circuits	Silicon Monolithic CMOS	1			No testing required
		2	M or higher		No testing required
			-	> 10	No testing required
				>1 <10	RVT if test data > 4years
		3			every lot
	Silicon Monolithic Bipolar	1	M or higher	> 10	No testing required
				>1 <10	RVT if manufacturer test performed at HDR
			-	> 10	RVT if test data > 4years
				>1 <10	every lot
		2	M or higher	> 10	No testing required
				>1 <10	RVT if manufacturer test performed at HDR
			-	> 10	RVT if test data > 4years
				>1 <10	every lot
		3	-		every lot
transistors	Low power NPN Low power PNP High power NPN High power PNP	1	M or higher	> 10	No testing required
				>1 <10	RVT if manufacturer test performed at HDR
			-	> 10	RVT if test data > 4years
				>1 <10	every lot
		2	M or higher	> 10	No testing required
				>1 <10	RVT if manufacturer test performed at HDR
			-	> 10	RVT if test data > 4years
				>1 <10	every lot
		3	-		every lot
	FET N channel FET P channel	1			No testing required
		2	M or higher		No testing required
			-	> 10	No testing required
				>1 <10	RVT if test data > 4years
		3	-	> 10	RVT if test data > 4 years
				>1 <10	every lot
CCD, CMOS APS opto discrete devices		1	M or higher		No testing required
			-	> 10	No testing required
				>1 <10	RVT if test data > 4years
		2	M or higher		No testing required
			-	> 10	RVT if test data > 4years
				>1 <10	every lot
		3	-		every lot

Table 5-2: TID RVT screening matrix

5.2 TNID Hardness Assurance

a. No effect due to TNID shall cause permanent damage to a system or subsystem, or degrade its performances outside its specification limits.

b. Each EEE part belonging to families listed in Table 5-3 shall be assessed for sensitivity to TID effects.

Family	**Sub-Family**	**TNIDL**
CCD, CMOS APS, opto discrete devices	all	all
Integrated circuits	Silicon monolithic bipolar or BiCMOS	> $2x10^{11}$ p/cm^2 50 MeV equivalent proton fluence
Diodes	Zener Low leakage Voltage reference	> $2x10^{11}$ p/cm^2 50 MeV equivalent proton fluence
Transistor	Low power NPN Low power PNP High power NPN High power PNP	> $2x10^{11}$ p/cm^2 50 MeV equivalent proton fluence

Table 5-3: List of EEE part families potentially sensitive to TNID

c. If component test data does not exist, ground testing shall be performed.

d. TNID irradiation test plans shall be submitted to customer for approval.

NOTE This is because no standard method exists for TNID testing.

e. TNID irradiations should be performed with protons and preferably at several proton energies encompassing the specified mission radiation environment

NOTE This is because of the limitations of NIEL calculations,

f. TNID irradiations tests shall be performed on a minimum of 5 test samples.

g. Mission TNID radiation environment shall be defined according to ECSS-E-ST-10-04 and documented in Mission Radiation Environment Specification. A draft version of the Mission Radiation Environment

Specification shall be available at SRR and final version shall be available at PDR.

h. Component TNID level (TNIDL) shall be calculated in conformance to ECSS-E-ST-10-12.

i. If worst case models have been used to define the mission environment and then TIDL and if TIDS is based on statistical analysis of test data to guarantee a probability of survival Ps of at least 90% with a confidence level of at least 90%, Radiation Design Margin (RDM), defined as the ratio of TIDS over TIDL, shall be greater than 1. In all other cases RDM shall be greater than 2.

j. For any component that is estimated to have on-orbit performance degradation due to TNID, a WCA of the function where it is used shall be performed according to ECSS-Q-ST30 to demonstrate that the function performs within specification despite radiation induced drifts in its constituent part parameters at EOL.

k. Both TNID and TID degradations shall be combined to define the component parameter drifts for WCA. Combined TNID and TID tests may also be used to get the combined TID/TNID sensitivity. Such test plans shall be submitted for approval.

NOTE Generally, TNID sensitive components are also sensitive to TID.

l. If above requirements 5.2 i and j can not be met, mitigation shall be implemented to eliminate the possibility of damage to or degradation of equipment performance outside its specification limits. Mitigation shall be verified by analysis or test.

m. RVT on flight lot shall be performed according to Table 5-4**Error! Reference source not found.**.

n. TNID analysis shall be documented in the equipment radiation analysis report in conformance to Annex A.

Family	Sub-Family	ECSS class	RDM	RVT requirement
CCD, CMOS APS, opto discrete devices		all		Every lot
Integrated Circuits	Silicon monolithic bipolar Or BiCMOS	1,2	> 10	No testing required
			> 1 < 10	Every lot
		3	> 10	RVT if test data > 4 years
			> 1 < 10	Every lot
Diodes	Zener Low leakage Voltage reference	1, 2	> 10	No testing required
			> 1 < 10	Every lot
		3	> 10	RVT if test data > 4 years
			> 1 < 10	Every lot
Transistor	Low power NPN Low power PNP High power NPN High power PNP			Every lot

Table 5- 4: TNID RVT screening matrix

5.3 SEE Hardness Assurance

a. No SEE shall cause damage to a system or a subsystem or induce performance anomalies or outages.

b. Each EEE part belonging to families listed in Table 5-5 shall be assessed for sensitivity to SEE effects.

Family	Sub-family
Integrated Circuits	all
Integrated Circuits Microwave	all
Transistors	FET N channel FET P channel
Transistors Microwave	all
CCD, CMOS APS, opto discrete devices	all

Table 5-5: List of EEE part families potentially sensitive to SEE

c. If component test data does not exist, heavy ion ground testing shall be performed .

NOTE It is common practice to use a worst case SET model for the SET criticality analysis of analog ICs. This approach may be used as long as application is not critical.

d. If a component is not procured to a quality level that guarantees traceability and process change control (e.g. ECSS class 3), testing shall be performed on every flight lot.

e. All SEE testing shall be performed in conformance to ESCC25100.

f. Testing conditions shall be worst case or representative of application conditions. This shall include, but is not limited to: bias conditions, clock frequency…….

g. SEL testing shall be performed at temperature equal to or higher than the maximum application temperature.

h. SEB/SEGR testing of power MOSFET shall be performed in conformance to MIL-STD-750E, method 1080.

i. The survival drain-source voltage (V_{DS}) shall be established from exposure at normal incidence to a minimum fluence of 10^5 ions/cm^2 with a minimum surface LET of 32 MeVcm^2/mg and a range that is sufficient to penetrate the depletion depth of the device at its maximum voltage.

j. In case device depletion depth is not known, the minimum ion range as a function of rated V_{DS} is given in Table 5-6.

Max rated Vds (V)	Minimum ion range (μm)
Up to 100	60
101 to 200	90
201 to 400	150
401 to 1000	200

Table 5- 6: minimum ion range as a function of rated V_{DS}

k. For power MOSFET, the application shall be derated in function of established SEB and/or SEGR survival voltage in conformance to ECSS-Q-ST-30-11.

l. For all other parts analysis and possibly proton testing shall take place based on LET threshold (LETth) of the candidate devices as described in Table 5- .

NOTE Above a LETth of 60 MeVcm^2/mg, the parts can be considered as immune to SEE in space and no further analysis is necessary .

m. Below a LETth level of 60 MeVcm^2/mg , SEE analysis shall be performed.

n. Below a LETth of 15 MeVcm^2/mg proton induced sensitivity analysis shall be analyzed as well. Therefore, proton ground testing shall be performed if data is not available.

NOTE Note: The LETth of 15 MeVcm^2/mg for performing proton SEE tests is not an absolute value. For components employing high-Z material in the vicinity of sensitive volumes the proton LETth may be higher. Thus, if it is identified or suspected that a radiation hardened component employs high-z materials in the vicinity of sensitive volumes, proton SEE data is not available and SEE mitigation is not implemented, proton testing shall be considered.

o. The LETth level as described in 5.3.l and 5.3.m shall be recalculated for other material devices (i.e. GaAs).

NOTE The limits in Table 5-7 only apply for Silicon devices

Component LETth ($MeVcm^2/mg$)	**Environment to be assessed**
LETth < 15	Heavy ions (GCR, solar event ions) Protons (trapped, solar event protons)
LETth= 15-60	Heavy ions (GCR, solar event ions)
LETth>60	No analysis required

Table 5- 7: Environment to be assessed based on LETth

p. For any component that is not immune to destructive SEE, e.g. SEL, an analysis shall demonstrate that the probability of occurrence is negligible in the mission environment.

NOTE SEL rate is negligible means when it does not impact the reliability rate of equipment.

q. For non destructive events like SEU, SET, and MBU, the criticality of a component in its specific application shall be defined including all possible impacts at higher, subsystem and system, levels.

r. SEE mission event rate shall be calculated in conformance to the methods described in ECSS-E-ST-10-12.

s. The mission event rate shall be calculated for the mission background environment and a solar event environment as defined in mission radiation environment specification.

t. A RDM of 10 shall be applied to heavy ion induced event rates.

u. The calculated event rates, with the margin, shall be acceptable for the application.

v. If above requirements 5.2 u can not be met, mitigation shall be implemented to eliminate the possibility of damage to or degradation of equipment performance outside its specification limits. Mitigation shall be verified by analysis or test.

w. All data and analysis shall be documented in Radiation Analysis report in conformance to Annex A

Annex A (normative) Radiation Analysis - DRD

A.1 DRD identification

A.1.1 Requirement identification and source document

This DRD is called from, requirements 5.1m, 5.2m and 5.3w

A.1.2 Purpose and objective

The purpose of the equipment Radiation Analysis report is to document in a single place all baseline information (data, assumptions, methods and techniques) used for the radiation analyses, and the results obtained.

A.2 Expected response

A.2.1 Contents

<1> Identification of parts sensitive to radiation effects

a. The radiation analysis report shall list all active parts, extracted from the DCL.

b. The list shall include the full component number, manufacturer information, and date code(s) of flight lots.

<2> TID analysis

a. The radiation analysis report shall provide TID tolerance of each sensitive component with reference of test report, date code of tested parts, and date of test.

b. The radiation analysis report shall include the description of mechanical model, assumption, method and tools used for ray trace or Monte Carlo analysis, and results obtained.

c. The radiation analysis report shall present the component parameter drifts used as an input for WCA as well as reference of WCA report.

d. The radiation analysis report shall present TIDL and TIDS for each part as well as RDM.

e. The radiation analysis report shall identify the parts submitted to RVT, provide test result and reference of test report.

<3> TNID analysis

a. The radiation analysis report shall provide TNID tolerance of each sensitive component with reference of test report, date code of tested parts, and date of test.

b. If applicable, The radiation analysis report shall include the description of mechanical model, assumption, method and tools used for ray trace or Monte Carlo analysis, and results obtained.

c. The radiation analysis report shall present the component parameter drifts used as an input for WCA as well as reference of WCA report.

d. The radiation analysis report shall present TNIDL and TNIDS for each part as well as RDM

e. The radiation analysis report shall identify the parts submitted to RVT, provide test result and reference of test report.

<4> SEE analysis

a. The radiation analysis report shall provide SEE tolerance of each sensitive component with reference of test report, date code of tested parts, and date of test.

b. The radiation analysis report shall describe the assumptions, methods and tools used for SEE rate predictions as well as SEE rates.

c. The radiation analysis report shall present SEE criticality analysis results.

d. The radiation analysis report shall identify the parts submitted to RVT, provide test result and reference of test report.

A.2.2 Special remarks

a. A draft radiation analysis report shall be part of PDR data package.

b. An update of radiation analysis report shall be issued for CDR.

NOTE At that stage all RHA activities except RVTs are completed.

c. At the end of phase D, a final radiation analysis report shall be issued. It shall include RVT (RADLAT) results.

d. All radiation test reports, including RVT reports, shall be available for review at customer premises.