ESA Mission Classification and project adoption of new microelectronics development

Presentation to be made at AMICSA 2022

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Agenda

- Part 1: ESA Mission Classification
  - Background
  - Main assumptions
  - Management decisions & implementation plan
  - ECSS-Q Branch Status & Statistics
  - ECSS-E Branch Status
- Part 2: project adoption of new microelectronics development

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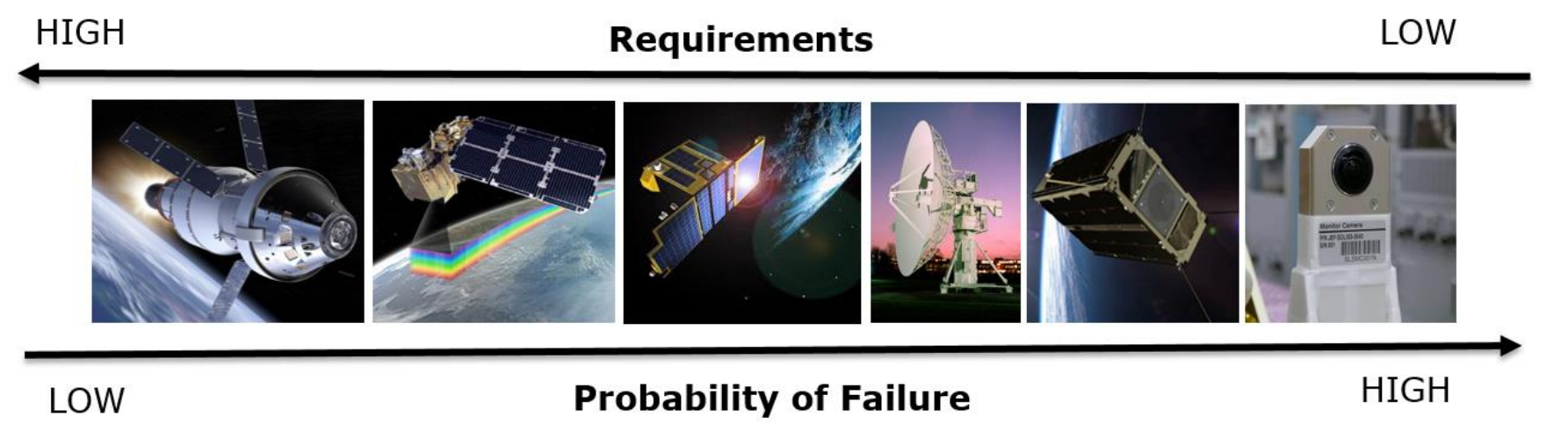
BACKGROUND

During ESA Executive Board (EB) in 2019 a go-ahead was given to prepare an ESA mission classification similar to what is already adopted by NASA.

A proposal for an ESA Mission Classification scheme was presented to EB in 2020. In the meeting, a go-ahead was given to establish the pre-tailoring of (ECSS) requirements for each class of mission per dedicated Working Groups, and to define the implementation rules for an EB decision by Mid 2021.

Outcomes presented to ESA Project Managers Forum and to ESA Senior Programme Managers Board before and after pre-tailoring activities. Final endorsement by ESA EB took place on 19 July 2021.



ESA MISSION CLASSIFICATION TABLE

Class type	I	II	III	IV	V
Mission Criteria and Marking					
Criticality to Agency strategy (Flagship mission, Internationnal cooperation, Impact on ESA strategic goals, and image)	Extremely high Criticality	High Criticality	Medium Criticality	Low Criticality	Educational purposes
Marking					
Mission Objectives (Directorate priority and purpose, e.g in orbit demonstration, educational)	Extremely high Priority	High Priority	Medium Priority	Low Priority	Educational purposes
Marking					
Cost (Cost at Completion, Including Phase E1)	>700 M€	200 - 700M€	50 - 200M€	1- 50M€	< 1M€
Marking					
Mission Lifetime (Nominal mission life duration)	> 10 years	5-10 years	2-5 years	2 years - 3 Months	< 3 Months
Marking					
Mission Complexity (Design interfaces unique payloads, New technology development)	High	High to Medium	Medium	Medium to Low	Low
Marking					

I - Critical safety issue (e.g. manned missions, Space Situational Awareness, operations center)

II - Performances should be met whatever it takes

III - Finding the best compromise between risk and cost to deliver the mission

IV - Mission is designed according to a hard cost limit (affordability approach)

V - Almost full delegation to industry (e.g. newspace service contract, Public-Private Partnerships)

MAIN ASSUMPTIONS

- For ECSS Q-Branch, ECSS fully applicable to Class I (and to a large extent to Class II)
- ESA mission classification should encompass one-off missions (man, non-manned missions), recurring operational spacecraft, in-orbit demonstration / validation and cubesats. Satellite mega-constellations are not addressed
- A specific mission class can contain units/payloads with different classes. Namely, mission class is originally defined at project/mission level, but it's possible to conceive different classes for different mission elements. Potential differentiation between critical and non-critical equipment to be addressed by the project
- More flexibility is given to industry as a function of class of the mission (highest flexibility for class V), but also more reliance on contractor's internal processes, more simplification of the documentation and required reporting, at the cost of the less visibility given to ESA and more delegation of responsibility and of risk is given to industry
- Possibility to combine deliverable documents mainly for class IV and V missions
- Requirements do not necessarily depend if an equipment is recurrent or not. Heritage will be reflected in equipment category defined during Equipment Qualification Status Review with a conclusion as well on the need, or not, to perform additional qualification activities
- Security and safety (incl. space debris requirements/policy) are not subject to tailoring – do no harm principle

ESA MISSION CLASSIFICATION - Marking and Classification

Proposed Mission: EXAMPLESAT

- **Extremely critical to the Agency (Criticality is then Class I)**
- **Mission objectives considered High Priority (Objectives in Class II)**
- **Cost of the mission: 300 to 400 M€ (Class II)**
- **Mission lifetime: 7 years nominal (Lifetime is then Class II)**
- **Mission complexity: medium (Complexity is then Class III)**

1 <= Total <= 1,5 -------- = Class I
1,5 <Total <= 2,5 -------- = Class II
2,5 < Total <= 3,5 -------- = Class III
3,5 < Total <= 4,5 -------- = Class IV
4,5 < Total <= 5 --------- = Class V

Mission Characteristics Criteria & Related Weighting Factors:	Class Level >>>	I	II	III	IV	V	Input Score (1/2/3/4/5)	Weighted Score
Criticality to Agency Strategy		Extremely High Criticality	High Criticality	Medium Criticality	Low Criticality	Educational Purpose		
WF (10/20/30 %):	30	x					1	0.30
Mission Objectives		Extremely High Priority	High Priority	Medium Priority	Low Priority	Educational Purpose		
WF (10/20/30 %):	20		x				2	0.40
Cost		> 700 M€	200 – 700 M€	50 – 200 M€	< 50 M€	< 1 M€		
WF (10/20/30 %):	10		x				2	0.20
Mission Lifetime		> 10 years	5-10 years	2-5 years	< 2 years	< 3 months		
WF (10/20/30 %):	10		x				2	0.20
Mission complexity		High	High to Medium	Medium	Medium to Low	Low		
WF (10/20/30 %):	30			x			3	0.90
Total % (must be 100):	100						Total (*):	2.00
							CLASS:	II

ESA decisions (July 2021)

- On 19 July 2021 ESA Executive Board decided to:
  - Endorse the work done on ECSS Q-Branch (see previous slides)
  - Endorse the ESA Mission Classification Plan (see next slide)
  - Endorse the future work proposed until the end of 2021
    - Produce aligned Product Assurance & Safety Requirements Document (PARD) templates for each ESA Mission Class
    - Extend pre-tailoring activities to ECSS engineering standards and management
    - Develop associated training/awareness material
  - Advise to communicate externally (delegations, industry, etc.) on the ESA Mission Classification

ESA decisions (July 2021)

- The implementation plan proposes to introduce the class very early in the project. This could be revisited and, if necessary updated, by the project team as part of the Preliminary Project Plan prior to publishing ITT for project implementation phase
- From 2022, and for a period of 2 years
  - Identify new ESA missions (pilot cases) for execution of the ESA Mission Classification and associated pre-tailoring
- By the end of 2024
  - Present to the EB the outcomes of the pilot cases carried out over 2 years and decide on the applicability of ESA Mission Classification to all future ESA projects

STATUS ECSS-Q Branch – May 2022

- Previous work endorsed by EB in July 2021
- One PARD (PA requirements Document) prepared for each Class of Mission
  - Work fully completed for Product Assurance (PA) / Quality Assurance (QA), Reliability Availability Maintainability Safety (RAMS) / Dependability, EEE components & Radiation Hardness Assurance (RHA)
  - For Software PA, work is still in progress for Class V (Educational Cubesat) but Class I, II, III and IV are completed
  - Work still to be completed for materials & processes

Example - Sub-WG EEE & RHA - EEE

Topics	Class II	Class III	Class IV	Class V
ECSS-Q-ST-60 EEE	Class 2 Components fully applicable	Class 3 Components fully applicable	Mix of applicable, not applicable and tailored.	Key requirements kept, focused on do no harm and know what you fly.
ECSS-Q-ST-60-13 Commercial components	Class 2 Components fully applicable	Class 3 Components fully applicable	Additional families added. Relaxed requirements for evaluation, screening, LAT and DPA. Board/unit level testing may be suggested.	Modified to address only radiation, traceability and storage conditions.
Documentation and organisation	Fully applicable	Fully applicable	Justification documents can be combined and not required for some automotive qualified passives. Relaxed requirements for component control plan.	Modified to address only identification of EEE contact point and simplified Declared Component List.
Pure tin mitigations	Fully applicable	Fully applicable	Relaxed	Not Applicable
Derating	Fully applicable	Fully applicable	Fully applicable	Maximum ratings shall not be exceeded Note: de-rating is highly recommended (especially for operational duration > 3 months or when design is intended to be used in Mission Class < V).
EEE quality level	Class 2 Components fully applicable	Class 3 Components fully applicable	Lower grade options added for semiconductors, oscillators, wires, connectors and resistors.	Not Applicable

Fully Applicable | Partial Applicable, i.e. tailored | Not Applicable, i.e. under industry responsibility

N.B: For Mission Class I ECSS-Q-ST-60 & ECSS-Q-ST-60-13 Class 1 requirements are fully applicable. Current tailoring is based on ECSS-Q-ST-60C Rev.2 and ECSS-Q-ST-60-13C. Both standards are expected to be updated and released in Q2 2022

Example - Sub-WG EEE & RHA – RHA 1/2

Topics	Class II	Class III	Class IV	Class V
TID tests	Fully applicable	TIDL<5Krad testing recommended TIDL>5Krad testing required at part or board level	TIDL<5Krad testing recommended TIDL>5Krad testing required at part or board level	TIDL<5Krad no testing required TIDL>5Krad testing recommended
TID RDM	Fully applicable	1.2 with test at part level & traceability established 2 with test at part level and no traceability 3 with test at board level	1.2 with test at part level & traceability established 2 with test at part level and no traceability 3 with test at board level	RDM=2
TID RVT	Fully applicable	Applicable when RDM<2 Not applicable when testing is performed at board level	Not applicable	Not applicable
TNID tests	Fully applicable	Fully applicable	Test of optoelectronics required	Test of optoelectronics recommended
TNID RDM	Fully applicable	1.2 with test at part level & traceability established 2 with test at part level and no traceability	1.2 with test at part level & traceability established 2 with test at part level and no traceability 3 with test at board level	Not applicable
TNID RVT	Fully applicable	Fully applicable	Not applicable	Not applicable
Heavy ion SEE test	Fully applicable	Fully applicable	Recommended Required for MOSFETs>200V	Not required, except for MOSFETs > 200V
Proton SEE test	Fully applicable	Fully applicable	Required at component or board level	Recommended

Fully Applicable | Partial Applicable, i.e. tailored | Not Applicable, i.e. under industry responsibility

Example - Sub-WG EEE & RHA – RHA 2/2

Topics	Class II	Class III	Class IV	Class V

SEE analysis	Fully applicable	SEE analysis needed as class I and II for LETth<38 MeVcm2/mg	• When only proton data is available:
			  • Parts sensitive to destructive events induced by protons shall not be used
			  • Derating of MOSFETs < 200V to 30% of their max rated voltage
			  • SEE mitigation shall be implemented for non destructive events
			• When heavy ion data is available, same as class III
				• Potential SEL to be mitigated for all CMOS and BiCMOS based devices
				• Derating of MOSFET<200V to 30% of their max rated voltage
				• Mitigation to be implemented for non destructive events

Radiation Analysis	Fully applicable	Fully applicable	Fully applicable	Fully applicable
Radiation drifts in WCA	Fully applicable	Applicable when TID tests are performed at part level Not applicable when TID tests are performed at board level (if tests are done on parts from the same procurement batch that will fly)	No formal delivery of WCA for RHA aspects. Margin on component max/min ratings and performances should be considered in the design to account for component parametric drift due to radiation.	No formal delivery of WCA for RHA aspects. Margin on component max/min ratings and performances should be considered in the design to account for component parametric drift due to radiation.
Radiation reviews	Fully applicable	Fully applicable	Fully applicable	Not applicable

Fully Applicable | Partial Applicable, i.e. tailored | Not Applicable, i.e. under industry responsibility

Example - Sub-WG Software PA

Topics	Class II	Class III	Class IV	Class V
Modified tailoring per software criticality category	ECSS fully applicable	Reduction of criticality level requirements “one level”	Reduction of criticality level requirements “one level”	Starting point to define the tailoring for Class V: •STR-283 – Product Assurance Guidelines for Cubesat Projects (Draft) •Product and Quality Assurance Requirements for In-Orbit demonstration CubeSat Projects. TEC-SY/129/2013/SPD/RW. Iss. 1, Rev. 2. •Tailored ECSS Engineering Standards for In-Orbit Demonstration CubeSat Projects. TEC-SY/128/2013/SPD/RW. Iss. 1, Rev. 3. (On-going)
Access to software documentation	ECSS fully applicable	Major changes allowing electronic access to information in certain cases (avoiding “traditional” documentation). Not constrained by DRDs.	Major changes allowing electronic access to information in certain cases (avoiding “traditional” documentation). Not constrained by DRDs.	
Content of software documentation	ECSS fully applicable	Significant merging of documents	Significant merging of documents	
Software reviews	ECSS fully applicable	Reduction of reviews	Encourage reduction of reviews, and relaxing the level of formality of reviews	
Requirements on software testing	ECSS fully applicable	Reduction in documentation needed for software unit and integration testing	Streamlined approach of software unit and integration testing	
Requirements on reused software	ECSS fully applicable	Reduction in documentation needed for reused software	Streamlined approach for reused software	

Note: Tailoring covers both ECSS-Q-ST-80 and ECSS-E-ST-40

Fully Applicable | Partial Applicable, i.e. tailored | Not Applicable, i.e. under industry responsibility

ECSS-Q Branch - Statistics

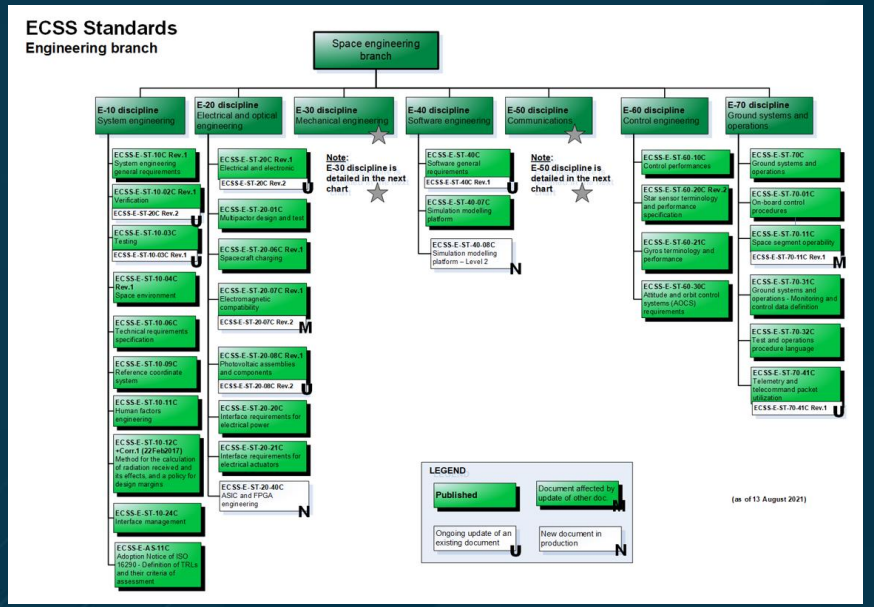
A	M	N
Applciable	Modified	Not Applicable

Class in percentages	Class I			Class II			Class III			Class IV			Class V		
	A	M	N	A	M	N	A	M	N	A	M	N	A	M	N
ECSS-Q-ST-10C Rev.1	100%	0%	0%	93%	7%	0%	75%	18%	7%	15%	60%	25%	5%	53%	42%
ECSS-Q-ST-10-04C	100%	0%	0%	100%	0%	0%	100%	0%	0%	2%	32%	66%	0%	32%	68%
ECSS-Q-ST-10-09C Rev. 1	100%	0%	0%	100%	0%	0%	100%	0%	0%	13%	25%	62%	0%	10%	90%
ECSS-Q-ST-20C Rev.2	100%	0%	0%	100%	0%	0%	94%	0%	5%	24%	40%	36%	7%	51%	42%
ECSS-Q-ST-20-08C	100%	0%	0%	100%	0%	0%	100%	0%	0%	8%	30%	62%	5%	34%	62%
ECSS-Q-ST-20-10C	100%	0%	0%	100%	0%	0%	86%	5%	9%	29%	6%	65%	11%	14%	75%
ECSS-Q-ST-30C Rev.1	99%	1%	0%	99%	1%	0%	91%	13%	0%	61%	39%	0%	80%	20%	0%
ECSS-Q-ST-60-13C	100%	0%	0%	100%	0%	0%	100%	0%	0%	89%	4%	7%	75%	4%	21%
ECSS-Q-ST-60C Rev. 2	100%	0%	0%	100%	0%	0%	100%	0%	0%	90%	4%	7%	75%	3%	21%
ECSS-Q-ST-60-15C	85%	11%	5%	85%	11%	5%	72%	21%	7%	60%	21%	19%	52%	24%	25%
ECSS-Q-ST-80C Rev.1	100%	0%	0%	100%	0%	0%	97%	2%	0%	97%	2%	2%	0%	0%	0%
TOTAL	**99%**	**0%**	**0%**	**99%**	**1%**	**0%**	**96%**	**2%**	**2%**	**65%**	**15%**	**21%**	**47%**	**17%**	**36%**

- No differences in terms of requirements on Class I & Class II
- Class III still has a high number of applicable requirements (majority of tailoring to be left to project). Class III remains an “in-between” class (between “standard” ESA missions and “NewSpace” type missions)
- Biggest tailoring is seen for Class IV and Class V

ECSS-E Branch Status

- Strong support from top management on E-Branch exercise
- E-Branch KO on 12.2021 and aims to be completed by end 2022
- As per request of ESA DG focus on Class IV (as baseline of ESA approach towards NewSpace)
- Sub-WGs to be confirmed. As input to different sub-WGs existing ESA Projects E-branch tailoring is provided



Part 1 - Conclusions

- **What's next?**
  - Conclude work on ECSS Q and ECSS E Branch
  - Work to establish a link between ESA Mission Classification and Project Corporate Reviews policy
  - ECSS M-Branch pre-tailoring: to be defined
  - Continue work with Systems Engineering in order to align ESA Mission Classification with the 3 categories of Cubesats (operational -> Class IV, demonstrator -> Class IV/V and educational -> Class V)
  - Presentation to EB (end of 2022)

Project adoption of new microelectronics development (EEE aspects, 1)

- **REMINDER from previous slides:**

Topics	Class II	Class III	Class IV	Class V
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Documentation and organisation	Fully applicable	Fully applicable	Justification documents can be combined and not required for some automotive qualified passives. Relaxed requirements for component control plan.	Modified to address only identification of EEE contact point and simplified Declared Component List.
Derating	Fully applicable	Fully applicable	Fully applicable	Maximum ratings shall not be exceeded Note: de-rating is highly recommended (especially for operational duration > 3 months or when design is intended to be used in Mission Class < V).
EEE quality level	Class 2 Components fully applicable	Class 3 Components fully applicable	Lower grade options added for semiconductors, oscillators, wires, connectors and resistors.	Not Applicable

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N.B: For Mission Class I ECSS-Q-ST-60 & ECSS-Q-ST-60-13 Class 1 requirements are fully applicable. Current tailoring is based on ECSS-Q-ST-60C Rev.2 and ECSS-Q-ST-60-13C. Both standards are expected to be updated and released in Q2

Project adoption of new microelectronics development (EEE aspects, 2)

- **What does it all mean?**
  - ECSS requirements tend to be ‘user-centric’ : what does the OEM, Prime contractor or End user (agency, commercial, final customer) need to implement in procurement controls, documentation, etc
  - ESCC requirements tend to be ‘product-centered’ : what does the product need to pass in inspections and tests, what needs to be verified and how

- **Consequences for microelectronics development (in Europe):**
  - For **Classes I, II and III, requirements are set in ECSS-Q-ST-60C** (since 2013, next revision due soon), for Classes IV and V, work needs to advance to deliver unambiguous requirements.
  - **ESCC** components (meaning listed in QPL, EPPL, see next slides) can be ‘good enough’ for all missions, regardless their classification

Project adoption of new microelectronics development (EEE aspects, 3)

- **What do customers and projects want in terms of assurance for your new microcircuit?**

(Reading ECSS-Q-ST-60C from the perspective a microcircuits' supplier, a not-exhaustive view…)

Mission class:	Class I	Class II	Class III
(Eq. ECSS Q 60 class:)	1	2	3
Selection	Maximize use of **EPPL and QPLs** + Engineering restrictions	**No explicit reference**, but minimize efforts + Engineering restrictions	**No explicit reference**, but minimize efforts + Engineering restrictions
Evaluation	**Audit** , Testing, Construction Analysis	Testing, Construction Analysis	Testing, Construction Analysis
Screening	ESCC / **MIL Class V**	ESCC / **MIL Class Q+PIND**	ESCC **/ MIL TM Class B + PIND**
Other procurement inspections	**Full LAT / QCI, DPA, inspections** (but almost none if qualified)	**To be agreed, no DPA**	**To be agreed, no DPA**
ASIC – specific	ECSS-Q-ST-60-02C	ECSS-Q-ST-60-02C	ECSS-Q-ST-60-02C
Specifications	Required	Required	Required

Project adoption of new microelectronics development (EEE aspects, 4)

- **Where is the technical risk / challenge and where is the increase in procurement risk (cost /schedule)**

(where can it go wrong - a VERY subjective assessment)

Mission class:	Class I	Class II	Class III
(Eq. ECSS Q 60 class:)	1	2	3
Selection	Maximize use of EPPL and QPLs + Engineering restrictions	**No explicit reference**, but minimize efforts + Engineering restrictions	**No explicit reference**, but minimize efforts + Engineering restrictions
Evaluation	Audit , **Testing,** Construction Analysis	**Testing**, Construction Analysis, **no audit required**	**Testing,** Construction Analysis, **no audit required**
Screening	ESCC / MIL Class V	ESCC / MIL Class Q+PIND	ESCC / MIL TM Class B + PIND
Other procurement inspections	**Full LAT / QCI, DPA, inspections (if not qualified)**	**To be agreed, no DPA**	**To be agreed, no DPA**
ASIC – specific	ECSS-Q-ST-60-02C	ECSS-Q-ST-60-02C	ECSS-Q-ST-60-02C
Specifications	Required	Required	Required

Project adoption of new microelectronics development (RHA aspects)

- **REMINDER from previous slides:**

Topics	Class II	Class III	Class IV	Class V
TID tests	Fully applicable	TIDL<5Krad testing recommended TIDL>5Krad testing required at part or board level	TIDL<5Krad testing recommended TIDL>5Krad testing required at part or board level	TIDL<5Krad no testing required TIDL>5Krad testing recommended
TID RDM	Fully applicable	1.2 with test at part level & traceability established 2 with test at part level and no traceability 3 with test at board level	1.2 with test at part level & traceability established 2 with test at part level and no traceability 3 with test at board level	RDM=2
TID RVT	Fully applicable	Applicable when RDM<2 Not applicable when testing is performed at board level	Not applicable	Not applicable
TNID tests	Fully applicable	Fully applicable	Test of optoelectronics required	Test of optoelectronics recommended
TNID RDM	Fully applicable	1.2 with test at part level & traceability established 2 with test at part level and no traceability	1.2 with test at part level & traceability established 2 with test at part level and no traceability 3 with test at board level	Not applicable
TNID RVT	Fully applicable	Fully applicable	Not applicable	Not applicable
Heavy ion SEE test	Fully applicable	Fully applicable	Recommended Required for MOSFETs>200V	Not required, except for MOSFETs > 200V
Proton SEE test	Fully applicable	Fully applicable	Required at component or board level	Recommended

Project adoption of new microelectronics development (EEE aspects and RHA)

- **Some suggestions to consider (1):**
  - ESCC components (EPPL listed) are suitable for all missions regardless their classification, ESCC qualified components (QPL) come with a significantly reduced risk (technical, cost and schedule) for the user and customer chain. As a positive side-effect, QPL parts come with agencies QA supervision.
  - Sufficient awareness of the ongoing microcircuits developments among OEMs may vary a lot; not every user and final project gets to have all the information when they need it in order to make the best choice in parts selection, level of integration, availability of samples, roadmaps, etc. The closer to the component final user(s), the better for the success of the project, from as early as possible!
  - Increase / maintain awareness and understanding of European efforts in EEE components technology harmonization, standardization and qualification (=ESCC)

Project adoption of new microelectronics development (EEE aspects and RHA)

- **Some suggestions to consider (2):**
  - A basic ‘clearance’ is obtained vs technical risks through component evaluation testing (endurance, mechanical, environmental, assembly compatibility, radiation hardness evaluation). This can also open the door to the EPPL listing of a product, which makes it visible to a wide range of potential users.
  - Supplying devices in die-form may also fit customer’s needs if the integration to be obtained is desirable and perceived as added-value.
  - Mission-specific devices can also benefit from a qualified status if capabilities of the supply chain have been demonstrated sufficiently:
    - Pre-qualified IPs (analog blocks) have been qualified in one case already.
    - Some assembly and test suppliers have demonstrated capabilities. The ESCC Process Capability Approval scheme, as introduced to AMICSA in 2012, was developed and achieved the certification of several European manufacturers since then (currently 1 assembly and test house, 1 supplier of non-hermetic modules and 6 suppliers of hermetic hybrids)
  - European standards related to space components and listings of preferred and qualified space components and technologies can be found at https://escies.org


THANK YOU !
QUESTIONS ?