Considerations and Challenges in the Use of AEC-Q Components for Space Missions

AEC - Reliability Workshop

Bordeaux. October 9th 2025

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Content:

- Motivation.
- Space applications Risks and requirements.
- ESCC system introduction:

  Tasks: Executive function and harmonization

  Roles and responsibilities: SCSB, CTB, PSWG,...

  Structure of ESCC specifications. Levels

  Specs examples.
- Comparison AEC-Q / ESCC:

  High Level systems comparison.

  Example of detailed comparison for Integrated Circuits
- Space EEE Procurement requirements:

  Overview ECSS-Q-ST-60

  COTS Procurement - ECSS-Q-ST-60-13
- Final Remarks

Motivation:

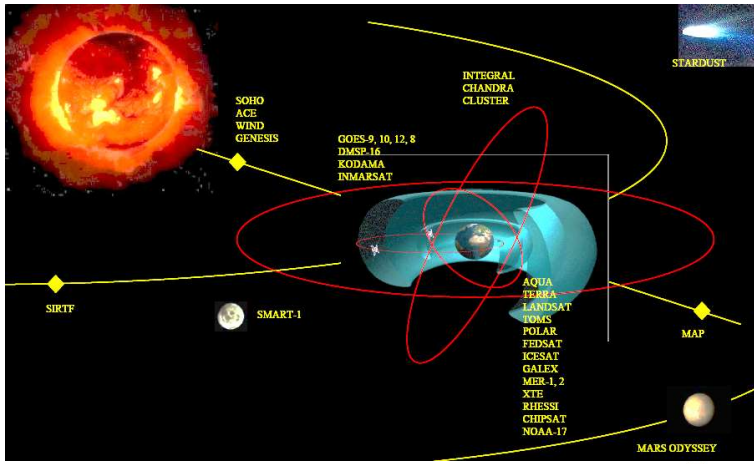
- Take benefit of overall EEE market offer.
- Some space missions accept higher risks levels (constellations,..., etc.)
- Look for improved / SOA EEE electrical performances.
- Availability:
  - Easier access
  - Shorter lead time
  - No export restrictions
- SWaP-C:
  - Size
  - Weight
  - Power
  - and Cost (keep overall owner cost in mind)
- Concept trend: good enough for the application instead of best Quality & Reliability product.

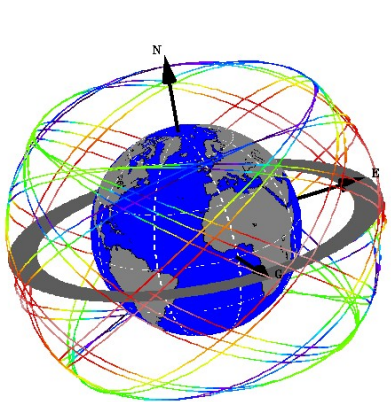
Space Environment

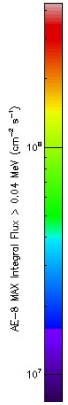
Orbit Type	LEO	MEO	GEO	Other
	Low Earth Orbit	Medium Earth Orbit	Geostationary Orbit	Planetary and deep space
Approx. Altitude	300 - 2000km	2000 - 36000km	36000km	-
Extreme Temperature	¨-150°C to	`-170°C to	-150°C to +120°C"	-180°C to +260°C"
	`+120°C	-140°C"		
Cycles per day	12-16 approx.	2-12 approx.	one per day	Variable
Vacuum	10^{-4} to 10^{-9} mbar	10^{-9} to 10^{-11}mbar	10^{-11} to 10^{-12} mbar	Down to 10^{-15} mbar
Outgassing	Yes	Yes	Yes	Yes
Vibration	Vibration & mechanical Shocks during launch, stage separation and payload release, operation and internal vibrations.			
Radiation	Low -middle	Middle Van Allen belts Solar activity and flares Cosmic Rays	End Van Allen belts Solar activity and flares Cosmic Rays	Solar activity and flares Cosmic Rays
	Van Allen belts			
	Solar activity and flares			
Plasma	Boreal aurora and cold plasma	Cold and hot plasma	Hot plasma	
Risk Impact	Micrometeorites / Space debris	Micrometeorites / Space debris	Micrometeorites / Space debris	
Others	Atomic Oxygen			Reactive gases in planets atmosphere,...

High cost to put equipments in service

No options to repair

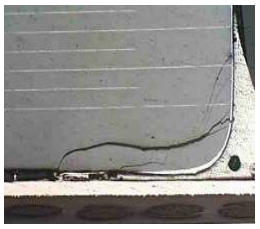


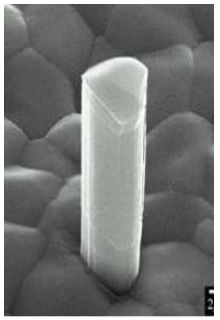


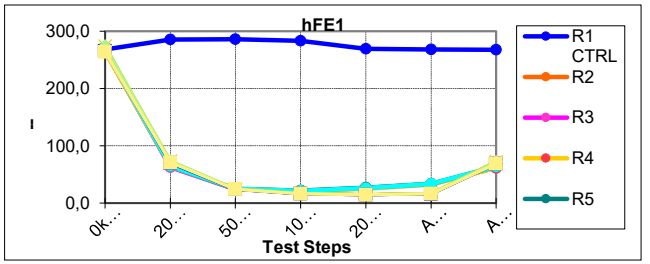


Risks when using Non Space qualified parts

- Operating temperatures and thermal cycling.
- Mechanical robustness: vibrations, accelerations and shocks.
- Device behavior under space radiation: SEE effects, TID & DD.
- Resistant to atomic oxygen degradation and other gases.
- Vacuum, rapid depressurization tolerance & Outgassing characteristics.
- Forbidden materials: bright pure tin,..
- Package: new packages, processes and the use of unproven technologies...
- Product traceability, lot variability, variability within a lot,...
- Access to Qualification & Reliability data.
- Counterfeit risk, obsolescence,...
- Final owner cost: unit price+ NRC.







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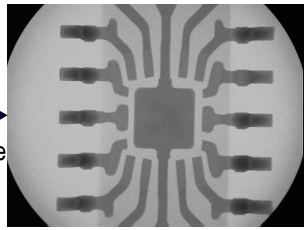


ESA Space Mission Classification – notions I/II

Acceptable Risk *Risk of not fulfilling some or all of the mission objectives*		LOW ACCETTABLE RISK HIGH Alpha	Beta	Gamma	Delta	Input Score (1 to 4)	Weighted Score
Criticality to Agency Objectives, Strategy and Image *Flagship mission, international co-operation, impact on strategic ESA goals and image*		**Extremely Critical**	**Highly Critical**	**Medium Criticality**	**Low Criticality**		
Weight (10/25/30%):	25		X			2	0,50
Cost *Cost at completion inc. Phase E1*		**> 400 M€**	**200 – 400 M€**	**25 – 200 M€**	**< 25 M€**		
Weight (10/25/30%):	25		X			2	0,50
Mission Lifetime *Nominal mission life duration*		**> 7 years**	**5 – 7 years**	**2 – 5 years**	**< 2 years**		
Weight (10/25/30%):	25			X		3	0,75
Mission complexity *Design interfaces, unique payloads, new technology development*		**Extremely Complex**	**Highly Complex**	**Medium Complexity**	**Low Complexity**		
Weight (10/25/30%):	25		X			2	0,50
Total % (must be 100):	100					**Total (*):**	**2,25**

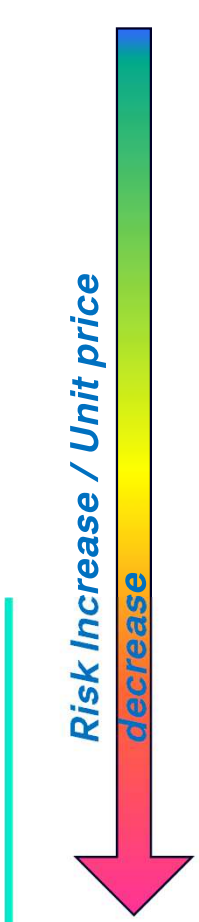
Grading System

1 <= Total <= 1,75 = **Alpha**
1,75 < Total <= 2,5 = **Beta**
2,5 < Total <= 3,25 = **Gamma**
3,25 < Total <= 4,0 = **Delta**

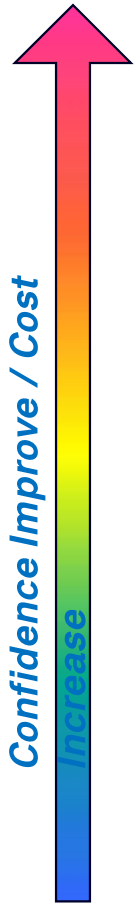
ESA Space Mission Classification – notions II/II

Class	Alpha	Beta	Gamma	Delta
Typical mission in class	*JUICE*	*Harmony*	*Cheops New Space*	*EDU/ Nano IOD/IOV/ CubeSats*
Success Prob	max	95%	80%	40%
Nominated saving	0%	15%	40%	90%
Schedule Savings	0%	20%	50%	80%
Requirements (Q+E Branch)				
ESA Team Risk Mindset				

EEE Available Quality Levels in the Market



- Qualified
  ESCC - QML V - JAXA
- Non-Qualified
  Equivalent Space
- QML Q
- MFR EP
  Enhanced products
- AEC –Q / IEC-CECC
- Industrial
- Commercial, ...



ESCC
European Space Components Coordination

JAXA

Automotive Electronics Council
Component Technical Committee

IEC

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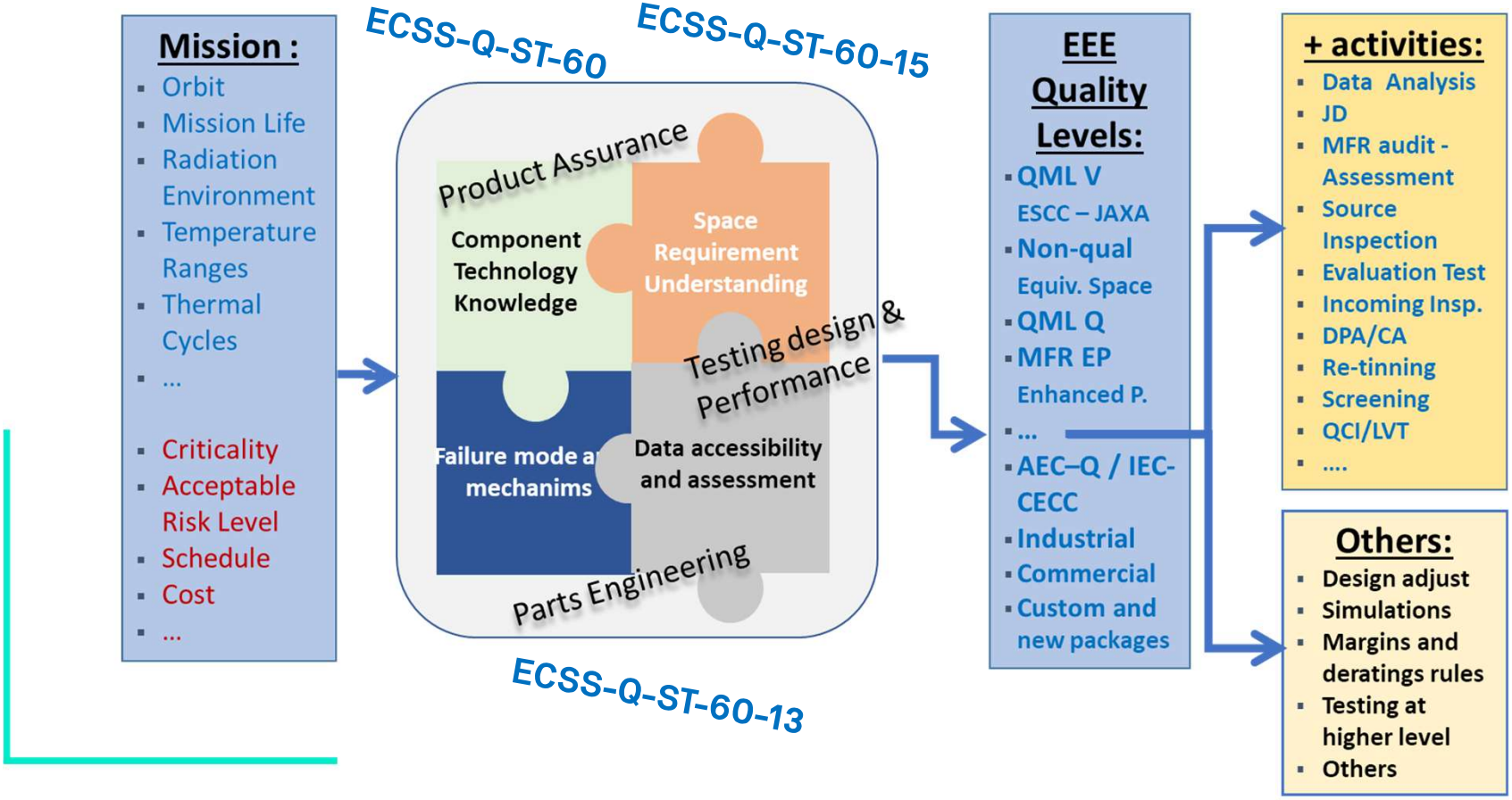
Comparison of Qualification / Test requirements

		Space Grade Parts	Automotive Parts
General	Production Volume	Low	High
	How reach Component Confidence	By testing	By process controls + SPC
	Manufacturing Line Certification	Yes as part of the Qualification	No. Internal or by customer
Test	Evaluation Test	Yes	No
	Screening 100% testing	Yes	No
	LAT/LVT	Yes	No
	Qualification	Yes	Yes
	Maantenance for qualification	Yes. Periodically	When changes
	Qualification entity	External entity: third party. Space Agency	Self-Certification
	Customer Source Inspection options: Precap / Buy-Off	Yes	No
Data & Documents	CoC	Yes	Yes
	Qualification and relaibility Data	Yes	No
	Available Detail specification	Yes	No (Data sheet)
	Traceability: wafer, wafer fab, assembly,..., etc	Yes	Typically no
	Device serialization	Yes	No
Environment	Operating Temperature grades	.-55°C to +125°C	AEC-Q100 Grade 0-40°C to +150°C Grade 1-40°C to +125°C Grade 2-40°C to +105°C Grade 3-40°C to +85°C Grade 4 0°C to +70°C
	Radiation environment (RHA)	Yes - Severe	No - Minimum
	Humidity, dast, sun	Low relevance	Relevant
	Vaccum	Yes. Outgassing	No

EEE Parts Selection & Procurement for Space



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Brief System Introduction

European Space Components Coordination (ESCC) – Fundation and TASKS

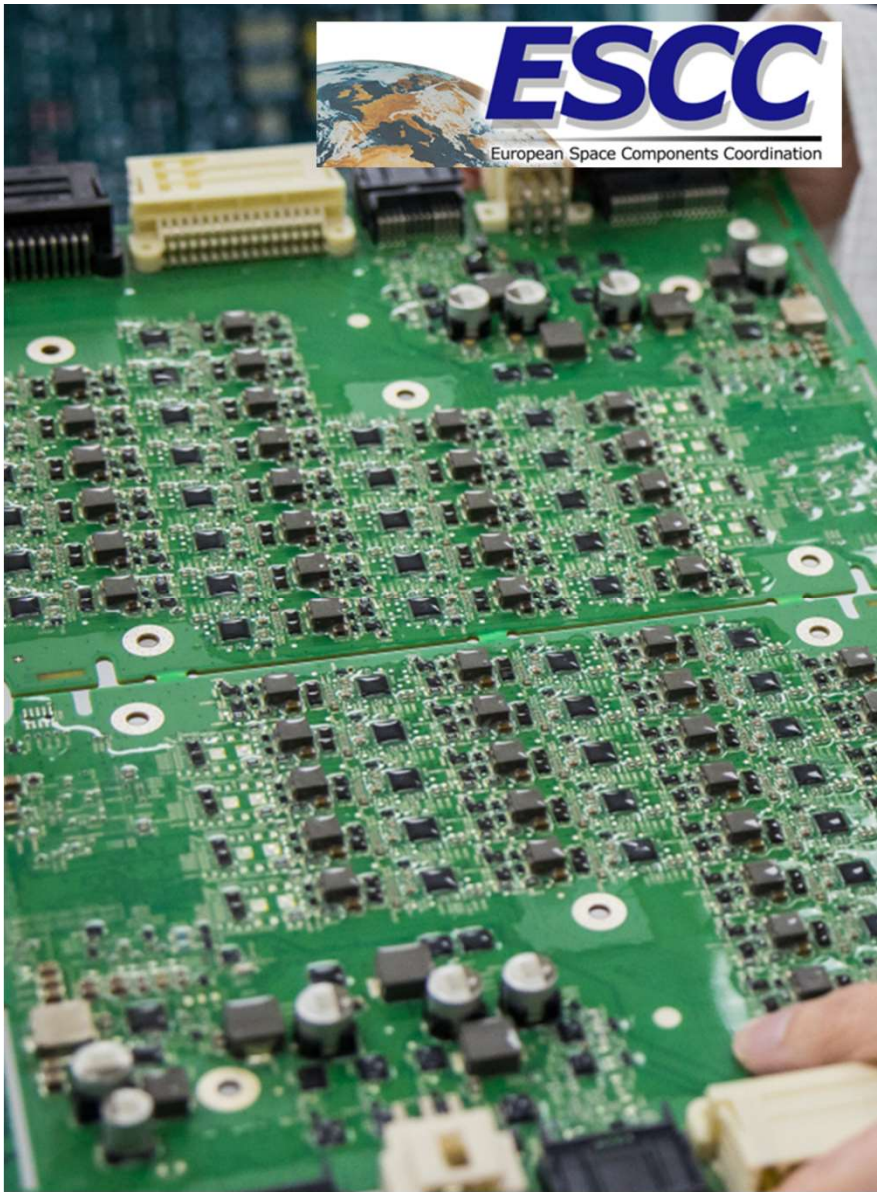
The ESCC Founding Act was signed on 8 October 2002 by the ESA Director General and representatives of CNES, ASI, DLR, BNSC (now UK Space Agency), Manufacturers and Eurospace association.

A) Executive:

- Specification System
- Advise on component policy
- Manage Evaluation qualification,... activities
- Non-conformance control
- Specifications and Document custody
- Training and system promotion

B) Harmonization:

- Definition of Component Policies
- EEE Standards
- EEE technologies R&D programmes



European Space Components Coordination (ESCC) - Organisation

(SCSB)
Space Components Steering Board

(CTB)
Component Technology Board

(PSWG)
Policy and Standardisation Working Group

CTB WGs
- CTB Passive
- RF Passive
- Silicon
- RF & Microwave
- Hybrid & Packaging
- Photonics
- Radiation
- PCB/SMT,…

Ad hoc
Working Groups
Specific Tasks

Members from:
- Space Agencies: ESA, CNES, DLR, ASI…
- Component manufacturers: Active and passive
- Users and service providers (Eurospace)

SCSB

(Space Components Steering Board)

- Overall direction and management of the ESCC system.
- Implementation.
- Custody
- System promotion and disemination

ESCC European Space Components Coordination

CTB

(Component Technology Board)

- Formulate programmes
- Identify strategies and roadmaps
- Identification and anticipation of user needs.
- Maximize co-ordination of all space component technology research and development activities.
- Maximum coverage of all required component technologies.
- Maintenance of a practical awareness of both the technical and commercial trends of relevant component technologies.

PSWG

(Policy and Standards Working Group)

- Provide assistance to the CTB with the selection of components for evaluation and qualification.
- Provide the necessary links with the ESCIES and EPPL functions.
- Formulate and elaborate measures which ensure the maximum use of existing space component data in setting policy.
- Propose performance metrics for the ESCC Specification System.
- Prepare ESCC Procedures.
- Prepare ESCC Basic and Generic specifications.
- Prepare component related ECSS standards.

The PSWG shall also assist with the implementation of SCSB policy and with its overview of the ESCC Specification System.

ESCC specification system

ESCC differentiates 5 document levels:

- Level 0 ESCC Charter and Policy.
- Level 1
  - Organisation: 10XXX
  - Support: 11XXX
  - Implementation: 12XXX
- Level 2 Basic Specifications: 2xxxx & 2XXXXXX
- Level 3 Generic Specifications: 3XXX to 9XXX
- Level 4 Details Specifications: XXXX/XXX

Free access to all ESCC documents is available at:
https://escies.org/specfamily/view

ESCC specification examples Level 1&2

- **Level 1**
  - 11XXX

- ESCC 1100. “ESCC Procedure for Configuration Management”.
- ESCC 11100. “Internal Audit Procedure for the ESCC System”.
- ESCC 11102. “Procedure for Complaints and Appeals”.
- ESCC 11300. “Management of the ESCC Web Site”.
- ESCC 11301. “Preparation of Newsletter”.
- ESCC 11302. “Organisation of the European Space Components Conference”.

  - 12XXX

- ESCC 12001. “The ESCC Documentation System.
- ESCC 12002. “Procedure for ESCC Document and Specification Management”.
- ESCC12003. “Procedure for ESCC Document and Specification Administration”.
- ESCC 12100. “ESCC Procedure for Qualifications”.
- ESCC 12101. “ESCC Procedure for the ESA Certifications of Qualifications”.
- ESCC 12102. “Procedure for Non-conformance Management”.
- ESCC 12200. “ESCIES Management Procedure”.
- ESCC 12300. “The European Preferred Parts List (EPPL) and its Management”.

ESCC specification Levels 2, 3 & 4:

- **Level 2, Basic Specifications: 2xxxx & 2XXXXXX**
  - Policy requirements
  - Test method, inspections and guidelines: general and ancillary for specific families.
  - Evaluation requirements, flows,..., etc.

- **Level 3, Generic specification.**
  - Production requirements
  - Screening flows
  - LAT
  - Applicable test method
  - Lot acceptance criteria

- **Level 4, Detail specifications: X**
  - Device maximum ratings
  - Device drawing, dimensions, weights, materials, finishes,...
  - Detailed electrical performances
  - Burn-in, Life Test, ... biasing conditions and environmental
  - Dedicated test stress levels: for vibration, ..., etc
  - Deviation from generic and for specific manufacturers

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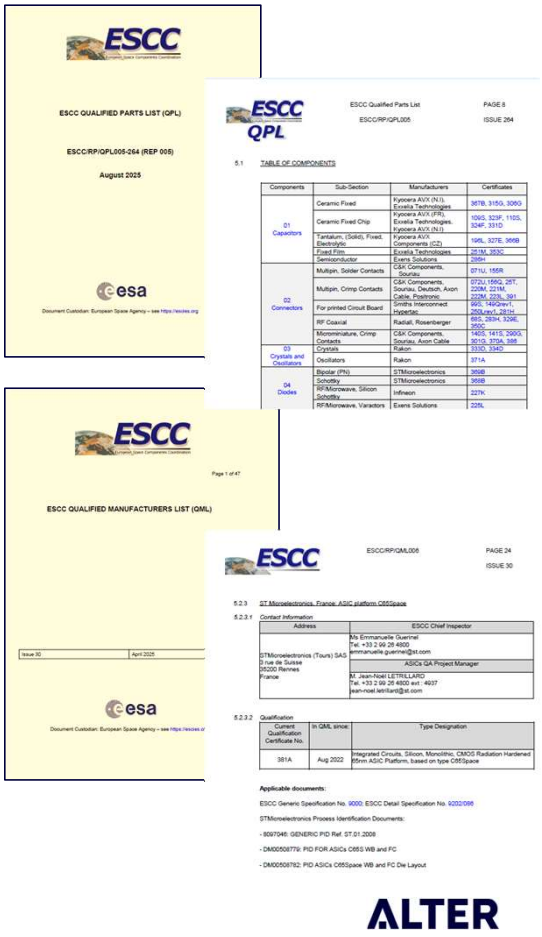
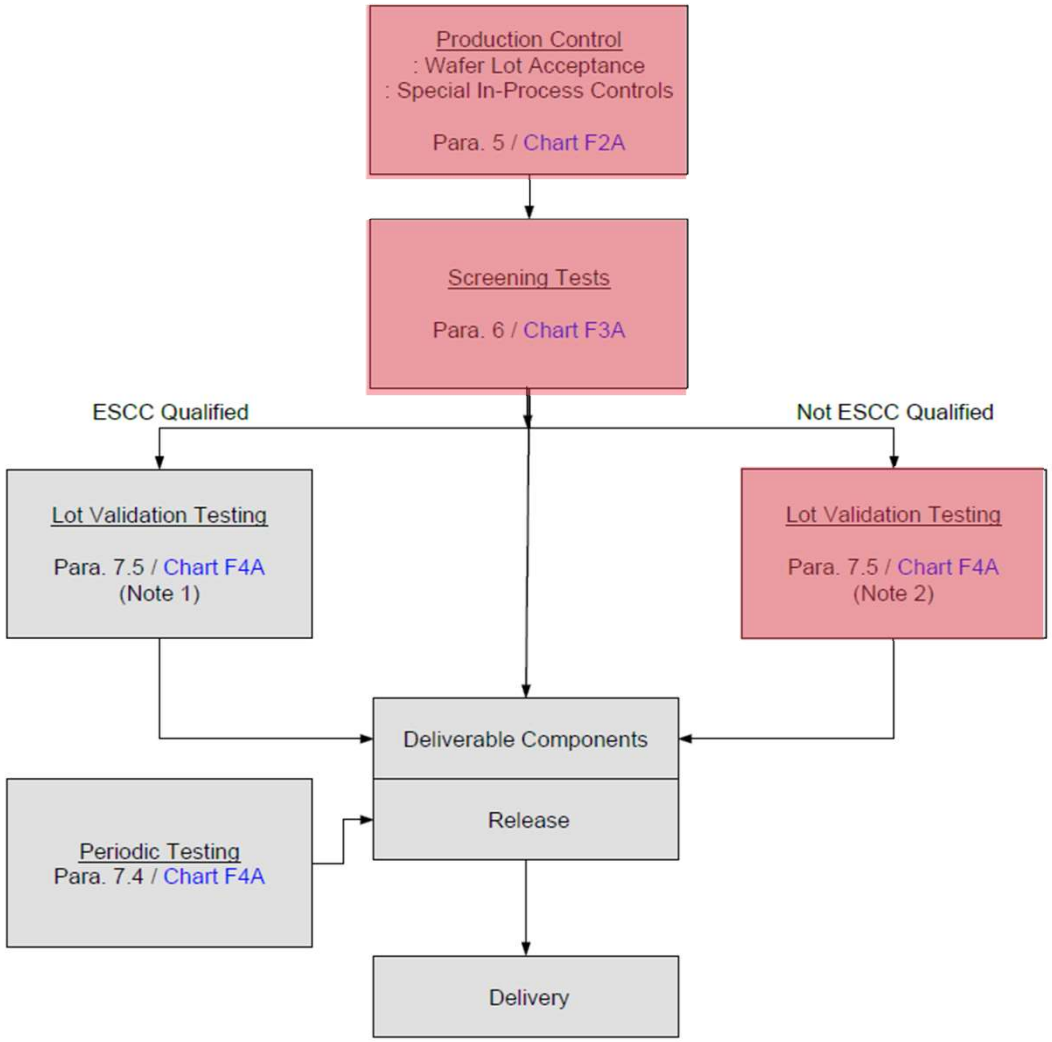
ESCC qualification options

- ESCC Component Qualification. To qualify individual types / or group of types
  - ESCC 20100 “Requirements for Qualification of Standard Electronic Components for Space Application. Qualified part types are within the QPL
- ESCC Capability Approval ESCC 24300
  - Escc 24300 “Requirements for the Capability Approval of Electronic Component Technologies for Space Application”.
- ESCC Technology Flow ESCC 25400
  - ESCC 25400” Requirements for the Technology Qualification of Electronic Components for Space Applications” Qualified manufacturer are in QML



ESCCC 9000 Chart F1A General Flow for Procurement of Packaged Integrated Circuits



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Partially Covered by AEC-Q 100

AEC-Q cover of exceed by AEC-Q

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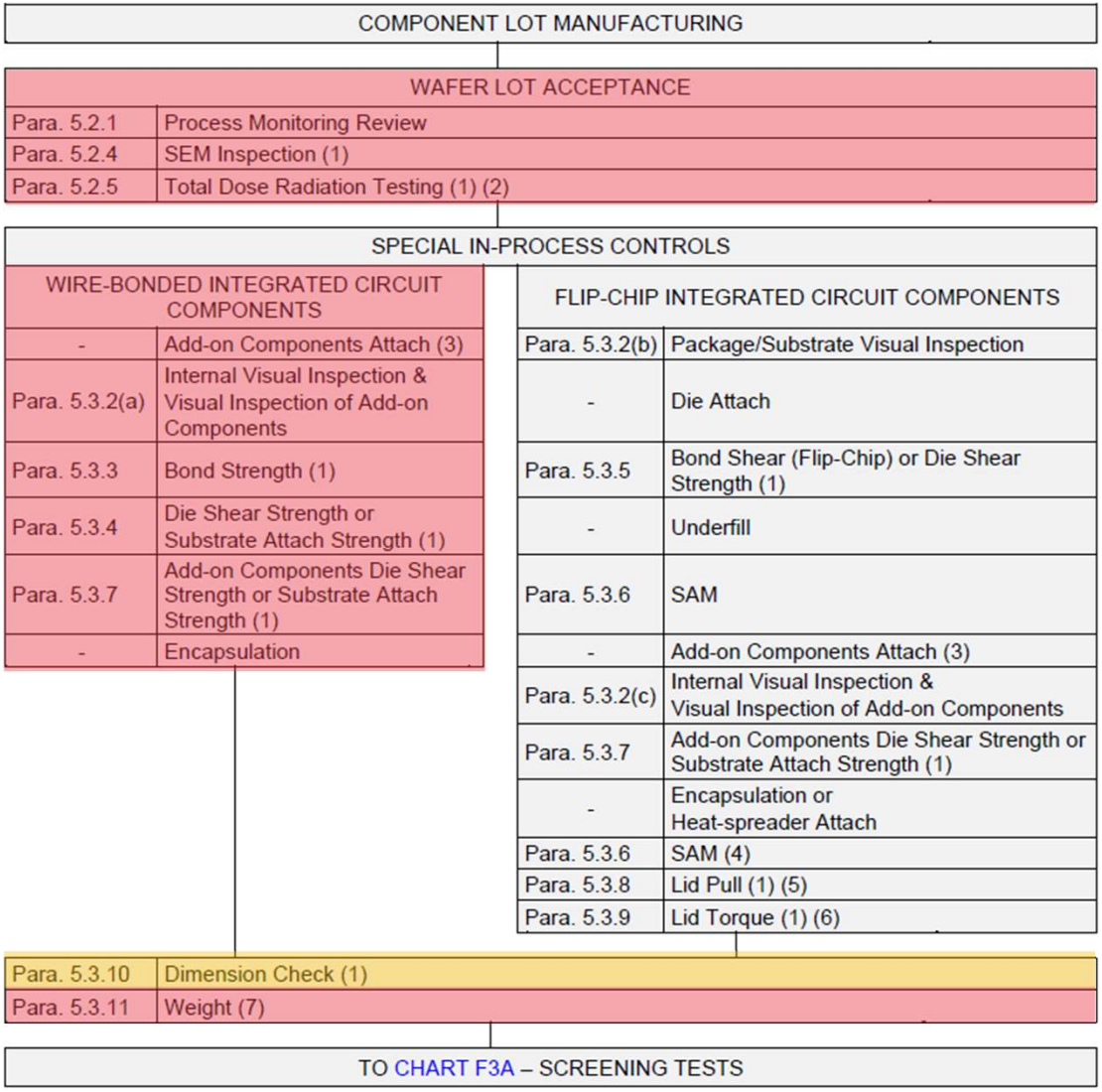
ESCCC 9000 Chart F2A Production Control for Packaged Devices



COMPONENT LOT MANUFACTURING	
WAFER LOT ACCEPTANCE	
Para. 5.2.1	Process Monitoring Review
Para. 5.2.4	SEM Inspection (1)
Para. 5.2.5	Total Dose Radiation Testing (1) (2)
SPECIAL IN-PROCESS CONTROLS	
WIRE-BONDED INTEGRATED CIRCUIT COMPONENTS	
-	Add-on Components Attach (3)
Para. 5.3.2(a)	Internal Visual Inspection & Visual Inspection of Add-on Components
Para. 5.3.3	Bond Strength (1)
Para. 5.3.4	Die Shear Strength or Substrate Attach Strength (1)
Para. 5.3.7	Add-on Components Die Shear Strength or Substrate Attach Strength (1)
-	Encapsulation
FLIP-CHIP INTEGRATED CIRCUIT COMPONENTS	
Para. 5.3.2(b)	Package/Substrate Visual Inspection
-	Die Attach
Para. 5.3.5	Bond Shear (Flip-Chip) or Die Shear Strength (1)
-	Underfill
Para. 5.3.6	SAM
-	Add-on Components Attach (3)
Para. 5.3.2(c)	Internal Visual Inspection & Visual Inspection of Add-on Components
Para. 5.3.7	Add-on Components Die Shear Strength or Substrate Attach Strength (1)
-	Encapsulation or Heat-spreader Attach
Para. 5.3.6	SAM (4)
Para. 5.3.8	Lid Pull (1) (5)
Para. 5.3.9	Lid Torque (1) (6)
Para. 5.3.10	Dimension Check (1)
Para. 5.3.11	Weight (7)
TO CHART F3A – SCREENING TESTS	

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ESCCC 9000 Chart F3A Screening Test for Packaged Integrated Circuits

PACKAGED COMPONENTS FROM PRODUCTION CONTROL	
Para. 6.1	Serialisation
Para. 8.10	High Temperature Stabilisation Bake
Para. 8.11.1	Constant Acceleration (1)
Para. 8.12.1	Temperature Cycling
Para. 8.13	Particle Impact Noise Detection (PIND) (2)
Para. 8.14.1	Parameter Drift Values (Initial Measurements)
Para. 8.15	High Temperature Reverse Bias Burn-in
Para. 8.14.1	Parameter Drift Values (Final Measurements for HTRB Burn-in; Initial Measurements for Power Burn-in) (3)
Para. 8.16	Power Burn-in
Para. 8.14.1	Parameter Drift Values (Final Measurements) (3)
Para. 8.14.2	High and Low Temperatures Electrical Measurements (3)
-	Hot Solder Dip / Ball Attach / Column Attach (as applicable)
Para. 8.14.3.2	Room Temperature Electrical Measurements (3) (5)
Para. 6.4.1	Check for Lot Failure (6)
Para. 8.17	Seal (Fine and Gross Leak)
Para. 8.18	External Visual Inspection
Para. 8.19	Solderability (3) (8)
TO CHART F4A WHEN APPLICABLE	

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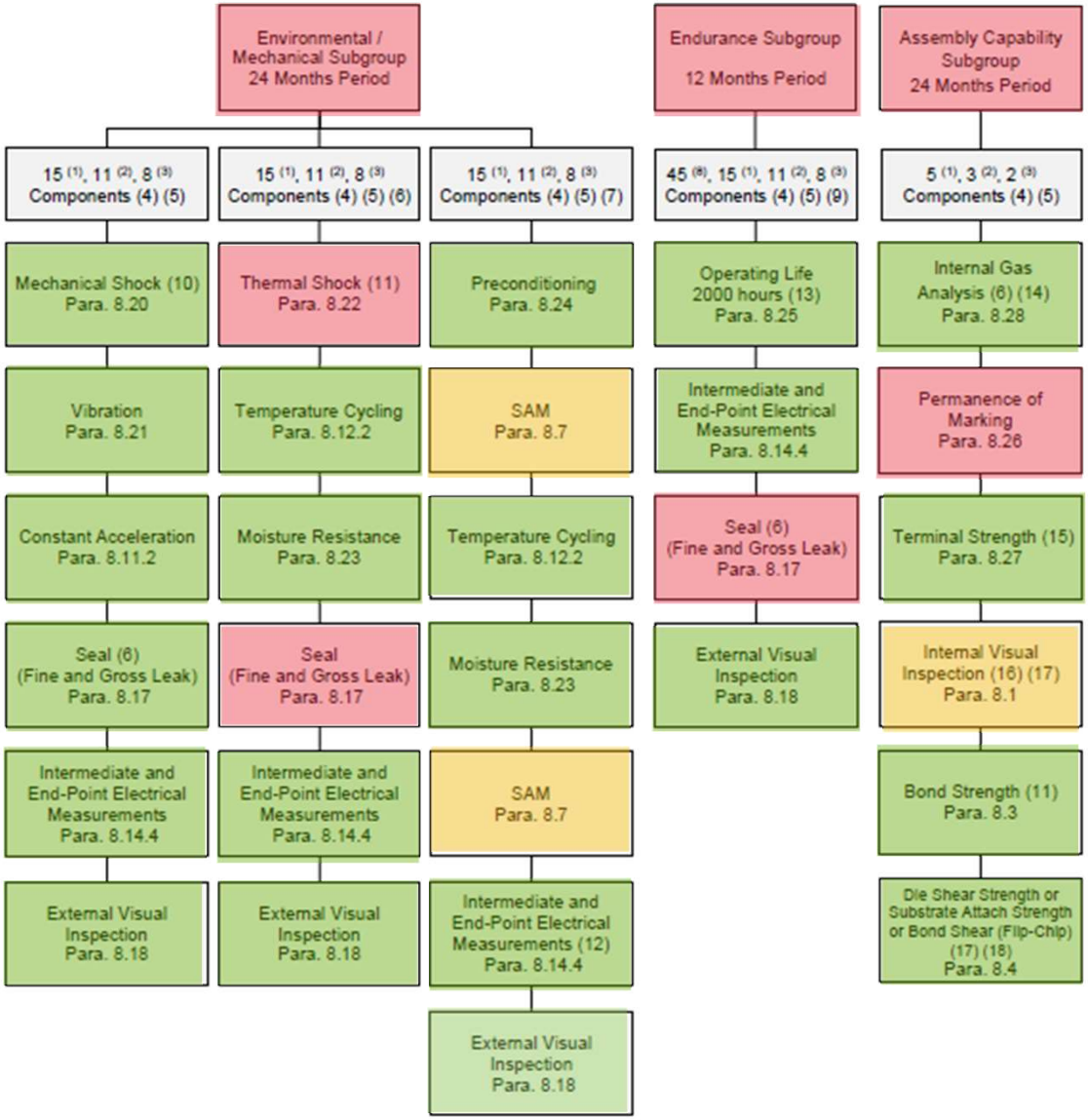
ESCCC 9000 Chart F4A
Qualification, Periodic Testing and Lot Validation for Packaged Devices Integrated Circuits



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Difficult Direct Comparison:

- Different Test structure, groups
- Various test sample sizes
- Inspection methods
- Used test conditions,....

AEC-Q100 versus ESCC 9000 includes:

- More Severe Moisture Test
- Power Temperature Cycling
- Process Average Testing & SPC
- Group D – Die Fabrication Reliability test

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ECSS Standards ECSS-Q-ST-60 Branch EEE Components

ECSS-Q-ST-60

This standard defines the requirements for selection, control, procurement and usage of EEE components for space projects.

This standard differentiates between three classes of components through three different sets of standardization requirements (clauses) to be met.

ECSS-Q-ST-60-13

This standard defines the requirements for selection, control, procurement and usage of EEE commercial components for space projects.

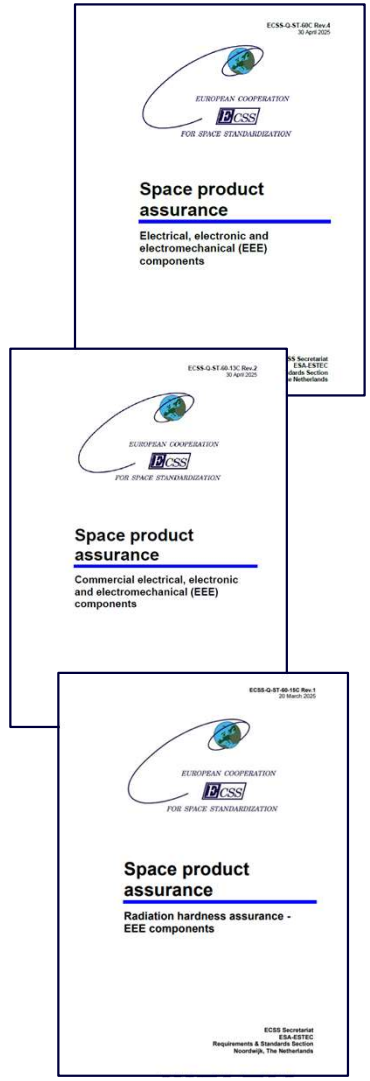
This standard is applicable to commercial parts from selected families:

Ceramic capacitors chips, Solid electrolyte tantalum capacitors chips, Discrete parts, Fuses, Magnetic parts, Microcircuits , Resistors chips, Thermistors.

ECSS-Q-ST-60-15

This standard specifies the requirements for ensuring radiation hardness assurance (RHA) of 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.

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).



https://ecss.nl/standards/active-standards/

ECSS Standard ECSS-Q-ST-60

This standard defines the requirements for selection, control, procurement and usage of EEE components for space projects.
This standard differentiates between three classes of components through three different sets of standardization requirements (clauses) to be met.

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Table 8–6: Procurement test table for microcircuits

Microcircuits									
Automotive grade	Class 1	Class 2	Class 3	Category	Test type	Sample size	Test Procedure	Specific Test condition	Note
AEC-Q grd 0/1	X	X	X	Evaluation	Radiation evaluation		i.a.w. ECSS-Q-ST-60-15		
AEC-Q grd 0/1	X	X	X	Evaluation	Construction Analysis	5	i.a.w. Annex H + outgassing		Note (d)
AEC-Q grd 0/1	X			Evaluation	Life Test 2000h	15	TM from Table 8-9	2000h LT	Note (a)
AEC-Q grd 0/1	X	X	X	Screening	Hermeticity	all	TM from Table 8-10 and 8-13		for hermetic parts
AEC-Q grd 0/1	X	X	X	Screening	PIND test	all	TM from Table 8-10 and 8-13		for parts with cavity
AEC-Q grd 0/1	X			Screening	Complete screening	all	TM from Table 8-10	240h burn-in	Note (b)
AEC-Q grd 0/1	X	X	X	LAT	RVT		i.a.w. ECSS-Q-ST-60-15		
AEC-Q grd 0/1	X	X	X	LAT	Construction Analysis	5	i.a.w. Annex H		
AEC-Q grd 0/1	X	X		LAT	Life test 1000h	15	TM from Table 8-11 and 8-14	1000h LT	Note (c)
No	X	X	X	Evaluation	Radiation evaluation		i.a.w. ECSS-Q-ST-60-15		
No	X	X	X	Evaluation	Construction Analysis	5	i.a.w. Annex H + outgassing		Note (d)
No	X	X		Evaluation	Complete Evaluation	see tables	TM from Table 8-9 and 8-12		Note (a)
No	X	X	X	Screening	Hermeticity	all	TM from Table 8-10 and 8-13		for hermetic parts
No	X	X	X	Screening	PIND test	all	TM from Table 8-10 and 8-13		for parts with cavity
No	X	X		Screening	Complete screening	all	TM from Table 8-10 and 8-13	240/168h duration in class 1/2	Note (b) in class 2
No	X	X	X	LAT	RVT		i.a.w. ECSS-Q-ST-60-15		
No	X	X	X	LAT	Construction Analysis	5	i.a.w. Annex H		

- Note (a): see 8.2b: *Based on the review of representative data, as per 8.2f, the supplier may propose an adaptation and a minimization of these evaluation tests, to be submitted to customer for approval through the JD's approval process.*
- Note (b): see 8.2c: *Based on representative data, as per 8.2f, collected in evaluation tests and in the JD, the supplier may propose an adaptation and a minimization of these screening tests to be submitted to customer for approval through the JD's approval process.*
- Note (c): see 8.2d: *The supplier may propose an adaptation and a minimization of these LAT tests, to be submitted to customer for approval through the JD's approval process, based on representative data, as per 8.2f, on parts not older than 2 years.*
- Note (d): see 8.2e: *Outgassing test shall only be applied if all the three following conditions are met: 1.part package is based on organic material, AND 2.weight of one part > 100 mg, AND, 3.test required by the user program or critical applications.*

Final Remarks:

- AEC-Q EEE parts are not designed for space applications, but they may support space missions under certain constraints.
- Space Component users must take benefit of overall EEE market offer, AEC-Q parts provide added value compared to other commercial products.
- The selection and procurement of AEC-Q parts for space applications must follow a process, including additional testing (when necessary), to ensure they meet the mission requirements.
- Cross-fertilization between AEC-Q and ESCC systems presents valuable opportunities for mutual benefit.
- AEC-Q representatives are encouraged to participate and engage in future space component forums and conferences, such as ACCEDE | ESCCON.

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¡Thanks for your attention!

¿Are there any question?

Gonzalo Fernandez.