ECSS-Q-ST-60
EEE Components in ESA missions (and beyond)

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2021

Summary

- Product Assurance … let's set the scene
- 1/ What is EEE?
- 2/ Space Environment: what a wonderful world for EEE !!
- 3/ The tablets of Law: EEE standards and specifications
- 4/ Major failure mechanisms and reliability testing
- 5/ EEE DERATING
- 6/ Requirements for EEE parts in space projects
- 7/ COTS … and a few words about New Space
- 8/ Conclusions

Preamble: Product Assurance, what for ?

Q-ST-60: Space Product Assurance for EEE parts

A discipline devoted to the study, planning and implementation of activities intended to assure that the design, controls, methods and techniques in a project result in a satisfactory level of quality in a product (ECSS-S-ST 00-01C)

Now let's try to formulate a more practical version:

To make as sure as possible that all the EEE parts used in ESA missions will

- Perform their required functions
- In the defined mission conditions
- When you need and for as long as you need
  - i.e. they are **RELIABLE** in their application

To help achieve that purpose, there is rules/requirements, based on years of experience, and failure, from many experts in Europe, and translated into **ECSS Standards**

Why do we need standards and specifications ?

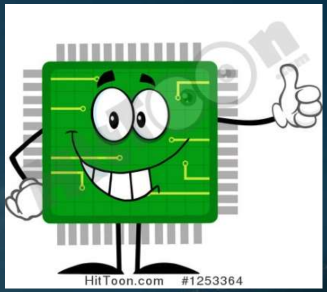
- Standards provide people and organizations with a basis for mutual understanding, and are used as tools to facilitate **communication**, **measurement** and **manufacturing**.

- Standards are everywhere and play an important role, by:
  - facilitating interaction
  - enabling companies to comply with relevant requirements
  - providing interoperability between new and existing products and processes

- Standards also disseminate knowledge in industries where products and processes supplied by various providers must interact with one another.

- For space activities major standards and specifications are ECSS (Europe, all space domains) , ESCC (Europe, EEE components). US-MIL (US, EEE components)

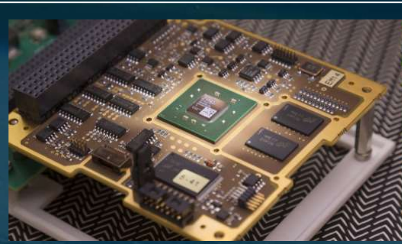
1/ But first …
what do we mean by EEE?



1.1 What do we mean by EEE ?

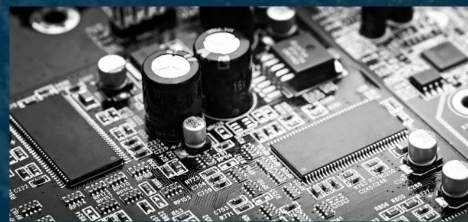
Many different families !

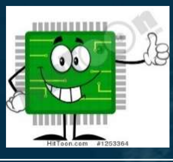
- Silicon based
- Radio Frequency
- Hybrid
- Photonics
- Micro / Nano tech.
- Passive
- Electro-mechanical
- Connectivity



X 10000€ each

~10€ each
(space grade)





Significant part of an equipment cost , up to ~ 20-40% (down to ~10% if the launch cost is included)

1.2 ECSS families – to be found in DCLs

Passive parts

1. Capacitors / 3. Crystals / 5. Filters / 6. Fuses / 7. Magnetics (e.g. inductors, transformers, including in-house products) / 11. Resistors, heaters / 14. Thermistors

Connectivity

2. Connectors / 15. Wires and Cables

Electromechanical

10. Relays / 13. Switches (including mechanical, thermal)

Hybrid

9. Hybrid circuits

Active parts

4. Discrete semiconductors (diodes and transistors) / 8. Monolithic Microcircuits (including MMICs (RF)) / 16. Optoelectronic Devices

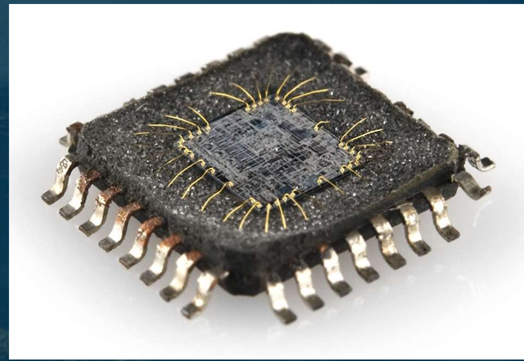
RF passive parts

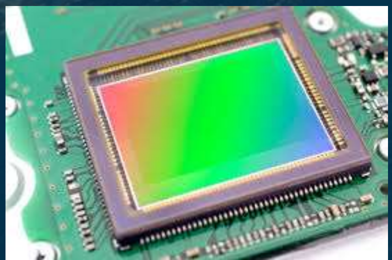
12. Surface acoustic wave devices / 17. Passive Microwave Devices

1.3

Semiconductor based, not RF:

- *Discrete*: diodes , transistors, power Mosfets, power diodes
- *Integrated*: digital (FPGAs, microprocessors, memories, ASICs, etc.), analog (Amplifiers, comparators, references etc.), conversion (DAC & ADCs), power management (e.g. PWMs) and sensing.



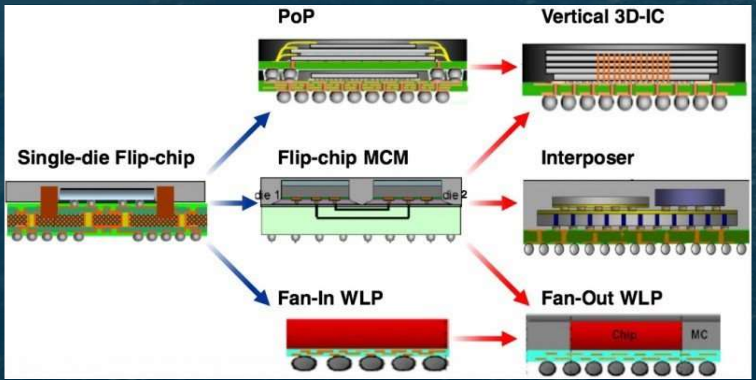


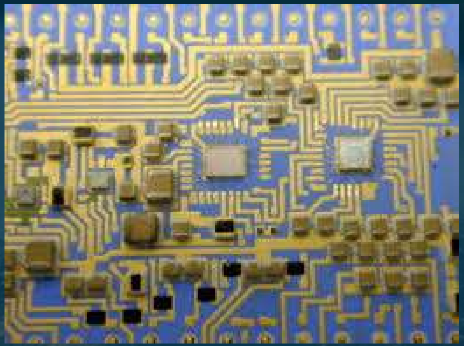
Photonics:

- Light Sources: lasers, LEDs …
- Light Detection: diodes PIN and APD (Active Pixel Diode)
- Fiber optics links and Fiber Based Communication systems
- Laser pumped optical Atomic Clocks
- Quantum Technologies
- Detectors: CCD, CMOS...from UV to far IR

Hybrid Components and Packaging:

Hybrid circuits include; thin and thick film technologies with integrated and discrete passives and active components as well as the associated packaging, sealing, die attach and wiring techniques.





Passive and RF passive components:

resistors, capacitors, connectors & cables, relays, switches, circulator & isolators (RF), crystals, oscillators, SAW filters etc.

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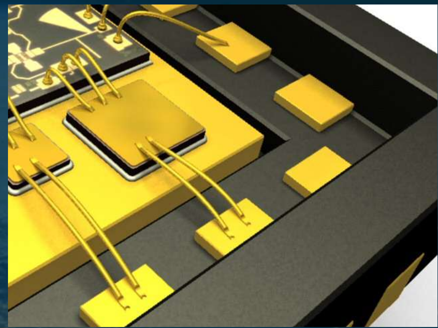
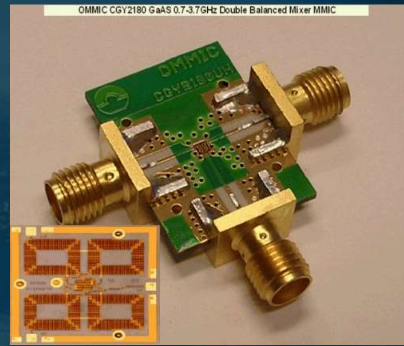
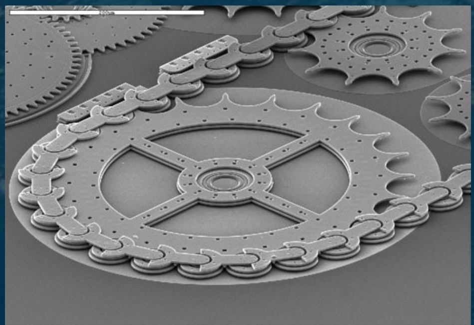




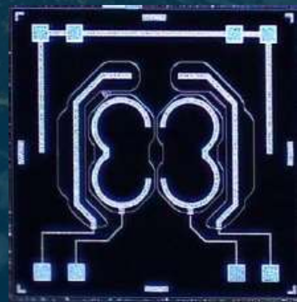
RF, Microwave, mmwave and sub-mmwave devices and MMICs:

GaAs components, Si, SiGe devices, and Wide Bandgap (GaN and SiC) semiconductor technologies. Including discrete components and MMICs (Microwave Monolithic Integrated Circuits).

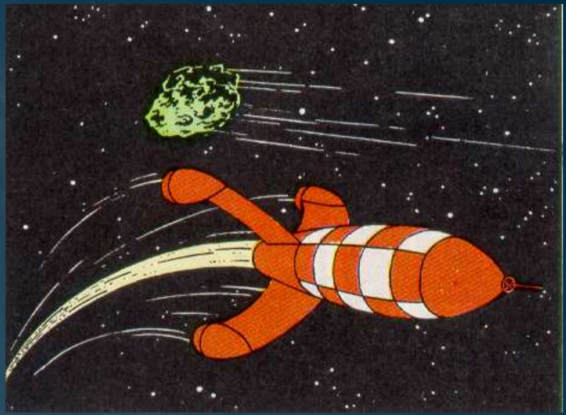


MNT Components:

MEMS devices (*AOCS*: MEMS accelerometers, gyroscopes, IMUs, magnetometers. *Propulsion*: pressure sensors, Nozzles, Gas Filters, Thrusters *RF MEMS:* RF Switches and matrices, MEMS RF filters, varactors, phase shifters,



2/ SPACE ENVIRONMENT
What a wonderful world !
(another reason behind the need for PA)



2.1 Space Environment

- Each space mission remains a challenge
  - Large financial investments
  - Long duration, some years to 15/18 years (Geo Telecom)
  - Harsh environment
  - Complex technologies, large number of components
  - Limited production (except for constellations)
- Reliability assessment & ground testing are essential
  - Remoteness = no repair
  - Qualification = Verification that every component will survive the mission(s)
  - Reliability testing addressing all the constraints (pre-launch, launch. Flight incl. cruise if significant)

Keep in mind the complete mission profile

2.2 Space Environment

- Pre-launch: assembly, testing, humidity, ESDs etc.

- At launch, some typical values:
  - Launch shock ~ 15g, 8-10 ms, sawtooth
  - Launch "steady state" acceleration
  - ~ up to 10g (A5 ~5g, Saturn ~8g)
  - Vibrations ~ 15g rms
  - Acoustic Env. ; up to 140 dB (A5) -> pressure waves, random vib.
  - Pyro shocks (stages separation) ~ 3000g, 0.25 ms

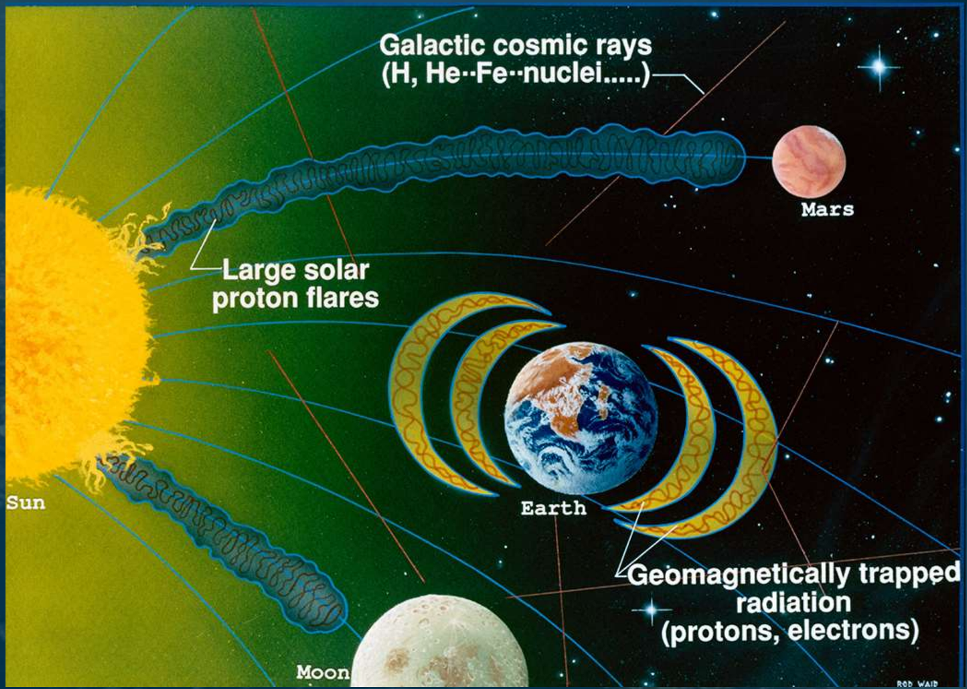
source IEEE

- In flight
  - Thermal cycling ~ -20°C to 60/70°C (controlled interior)
    - ~ -160°C to 220°C (uncontrolled ext.)
  - Vacuum → outgassing , thermal dissipation problems
  - On / Off cycles
  - Radiation (Sun, Earth Belts, Deep Space)
  - Atomic oxygen (low orbits)
  - Specific conditions for deep space missions
  - Corona and multipactor effects
  - High Voltages (specific applications but increasing trend)
  - Space debris

2.3 Radiation

The causes

- Solar Events - protons & heavy ions
  - solar cycle ~ 11 years with max activity ~ 7 years
  - solar wind - continuous flux of very low energy p^+
  - solar flares – a few days each, high energy p^+ & HI
- Earth's Radiation Belts – protons & electrons
  - e^- : inner belt ~ 10^4km ; outer ~ 4.10^4km
  - p^+: between 600 and 10^4 km
  - high energies: e^- up to 7 MeV; p^+ up to 400 MeV
- Cosmic Rays – 85% p^+ ;14% α ; 1% HI
  - Very high energy levels (up to 10 GeV per nucleon)



A long time ago in a galaxy far, far away…

3/ The tablets of Law: ECSS standards

3.1 ECSS

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- **ECSS**:
  - The European Cooperation for Space Standardization was established to develop a coherent, single set of standards for use in all European space activities

EUROPEAN COOPERATION
ECSS
FOR SPACE STANDARDIZATION

- **ECSS-Q-ST-60:** Focussed on EEE components
- It defines *what to do*, not necessarily *how to do*
  - It addresses, whatever the class:
    - Section 4/5/6.1: Component management (PCB, DCL, PADs and GSE)
    - Section 4/5/6.2: Component selection, evaluation and approval
    - Section 4/5/6.3: Procurement (specifications, screening, precap, LAT, DPA, RVT, relifing)
    - Section 4/5/6.4: Handling, storage
    - Section 4/5/6.5: QA aspects (Non-conformances, Alerts, traceability, lot homogeneity)
    - Section 4/5/6.6: Specific Components (ASICs, Hybrids, One time prog., Microwave parts)

3.2 ECSS

ECSS-Q-ST-60C Rev.2
21 October 2013

EUROPEAN COOPERATION
ECSS
FOR SPACE STANDARDIZATION

Space product assurance

Electrical, electronic and electromechanical (EEE) components

ECSS Secretariat
ESA-ESTEC
Requirements & Standards Division
Noordwijk, The Netherlands

From scope:

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

This standard differentiates between 3 classes of components through three different sets of standardization requirements (classes) to be met.

The three classes provide for three different levels of trade-off between assurance and risk."

Following the COTS WG works, a couple of additional classes may be created for low cost / accepted high risk missions

3.3 ECSS

- For each class and for each type of component, the ECSS standard specifies the baseline in terms of acceptable quality level as defined in recognized international systems:
  - US-MIL (QML, QPL, JAN, FR etc.) or ESCC
  - and how to achieve an equivalent level for parts without formal qualification or commercial

	Class 1	Class 2	Class 3
Screening level examples	QML V, K JANS FR R, C ESCC B	QML Q, K JANTXV FR R, C ESCC B	QML Q, H JANTXV FR R, C ESCC B
LAT/QCI on qualified product	None		
LAT/QCI on non-qualified product	Required, 2 year old data can be accepted	To be agreed	To be agreed
Precap on qualified product	Relays, crystals, oscillators, hybrids	None	
Precap on non-qualified product	Extensive list	Relays, crystals, oscillators, hybrids	None

3.4 ECSS

	Class 1	Class 2	Class 3
DPA on qualified product	Relays and oscillators	None	
DPA on non-qualified product	Extensive list	Relays, oscillators, commercial parts	Relays, commercial parts
Evaluation	"…in absence of an approved demonstration that a component has the ability to conform to the requirements …"		

	Class 1	Class 2	Class 3
Commercial components*	Extensive evaluation, screening and LAT.	Extensive evaluation. LAT and screening based on results.	Minimum evaluation; constructional analysis and radiation test.
Radiation	Reference to ECSS-Q-ST-60-15		
Organization	DCL, PAD, JD PCB		DCL, PAD, JD No PCB

* For standard monolithic active parts only (passive parts are in process to be included)

3.5 ECSS EEE related standards

- ECSS-Q-ST-60-02C – ASIC and FPGA development
- ECSS-Q-ST-60-05C Rev.1 – Generic procurement requirements for hybrids
-
- ECSS-Q-ST-60-12C – Design, selection, procurement and use of die form monolithic microwave integrated circuits (MMICs)
- ECSS-Q-ST-60-13C – Commercial electrical, electronic and electromechanical (EEE) components → see chapter 9
- ECSS-Q-ST-60-14C – Relifing* procedure
  - * Relifing is a term for assuring old (>7 years) parts still fit for flight
- ECSS-Q-ST-60-15C – Radiation hardness assurance
- ECSS-Q-ST-30-11 – Derating
- ECSS standards can be found on http://ecss.nl/

3.6 The International Systems for EEE parts - 1 / ESCC

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ESCC European Space Components Coordination

- ESCC stands for **European Space Components Coordination**
- The ESCC System is a self standing system which provides for
  - The technical specification of EEE parts
  - Methodologies for component evaluation and qualification
  - Outline of necessary test methods
  - Quality Assurance requirements
  - Operational provision
- All ESCC Specifications are freely available from the ESCIES web site. The web address is https://escies.org
- ESA and National Space Agencies resources manage the system
- Products are listed for reference on the ESCC QPL/QML
- An EPPL (European Preferred Part List) assists projects with type standardization and type diversity reduction taking advantage of successful results

3.7 The International Systems - 2 / US-PRF/STD

- Issued by DLA = Defence Logistics Agency

- Covers military and space
  –> Not all Mil parts are suitable for space!

- Generic and detailed specifications, standards and qualified parts/manufacturer lists

- Known concepts/levels:
  - JAN for diodes/transistors; JAN-S highest level on top of JAN-TXV
  - QML V and Q for microcircuits, V highest level
  - Class K and H for hybrids, K highest level
  - Established failure rates (S, R, P) or QPL for passive parts (T, M …)

- NASA has also Q60 equivalent documents, but often site specific (Glenn, Goddard, JPL, JSC etc.)

3.8 US- PRF/STD (2)

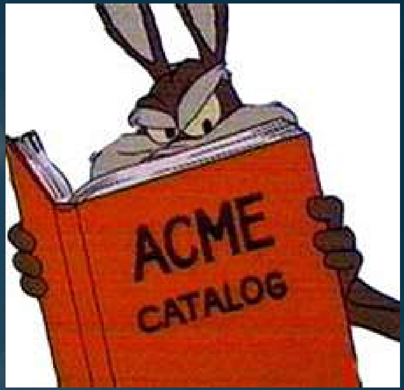
- **The MIL system is widely used for selection and procurement of parts for space applications**
- **Standards such as STD-883 and STD-750 are reference documents used in ESCC Specifications**

Reliability Level	SPACE	MILITARY	883B
Integrated Circuits MIL- PRF-38535	QML V	QML Q	Class M
	.Formerly Class S in M-38510 .Still associated with class S in MIL-STD-883	.Formerly Class B in M-38510 .Still associated with class B in MIL-STD-883	Not Qualified and not QML listed
Discrete MIL-PRF-19500	JAN S	JAN TXV	JANTX
Hybrids MIL-PRF-38534	Class K	Class H	

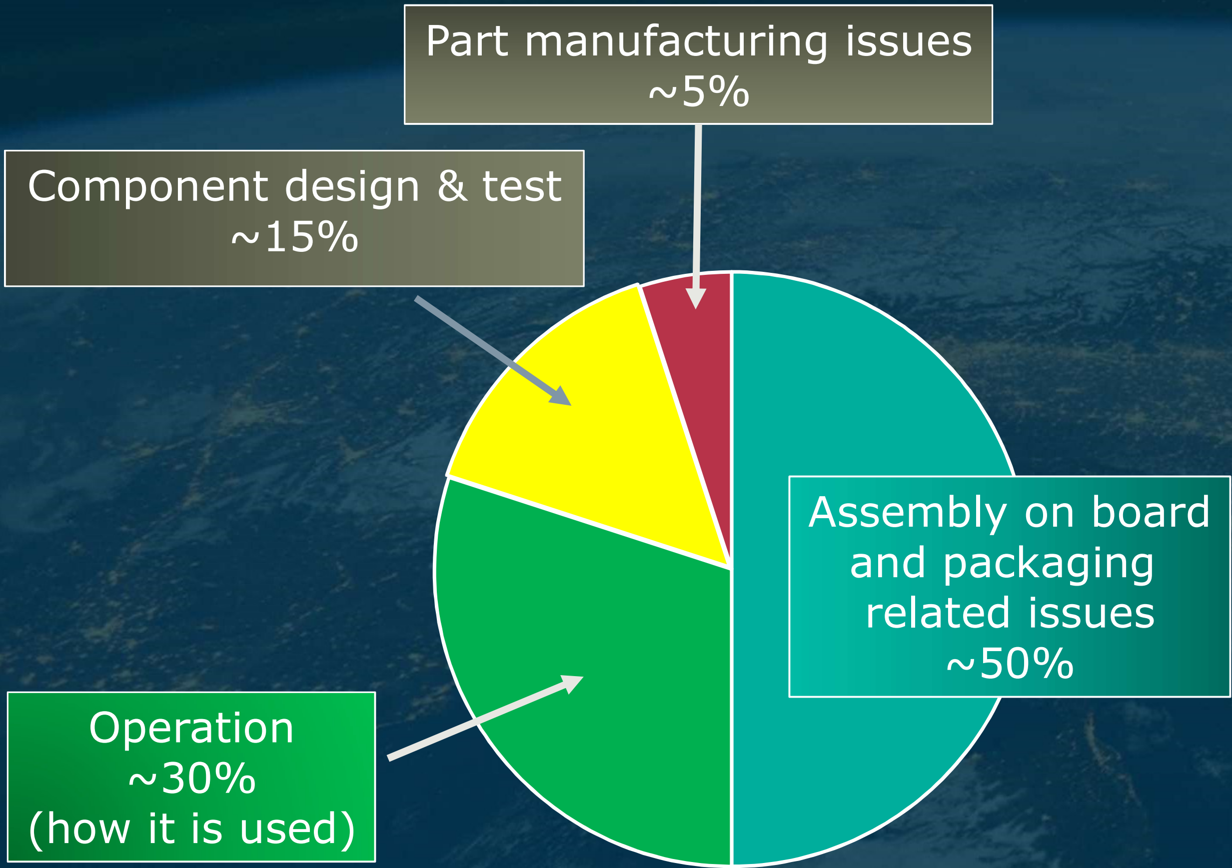
US Generic Spec. (PRF)

- Applicable to component families
- Several Reliability Levels
- Passive Parts: notion of Established Reliability (ER)
- To be read in conjunction with Standards (STD)
    - 38535 <-> STD 883
    - 19500 <-> STD 750

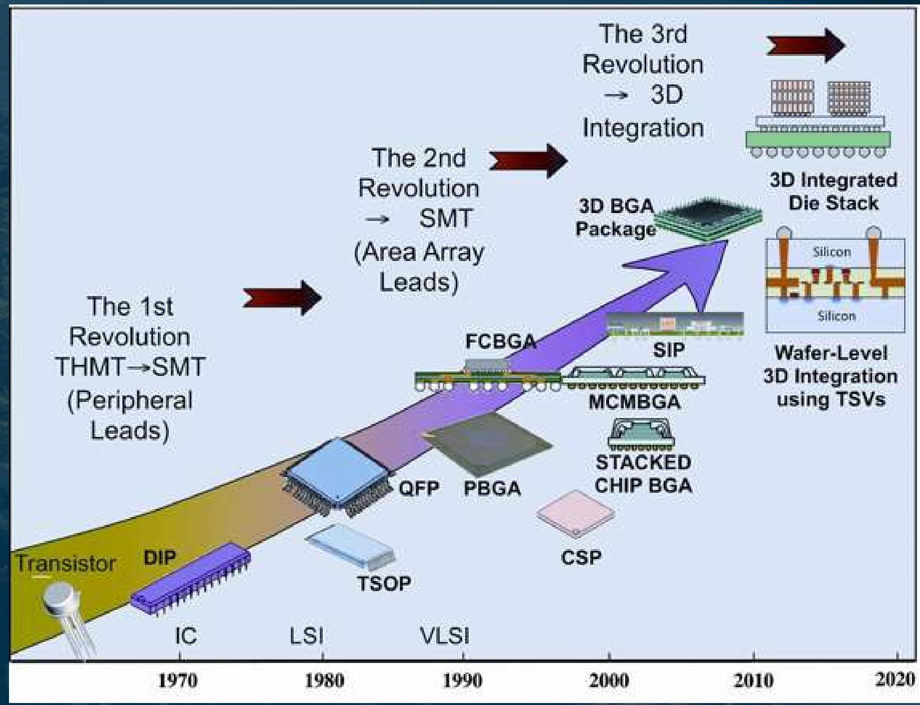
4/ A quick look into Major Failure Mechanisms and Reliability Testing



4.1 Main failure mechanisms



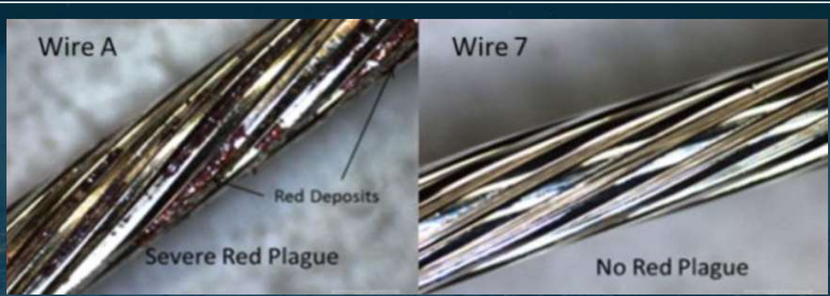
→ *One of the reasons for Derating*



Not to forget, *in a large majority of cases, EEE components failures are related to assembly on board/packaging defects followed by incorrect usage of the component*

4.2 A few examples for illustration

Damaged copper wire (harness)



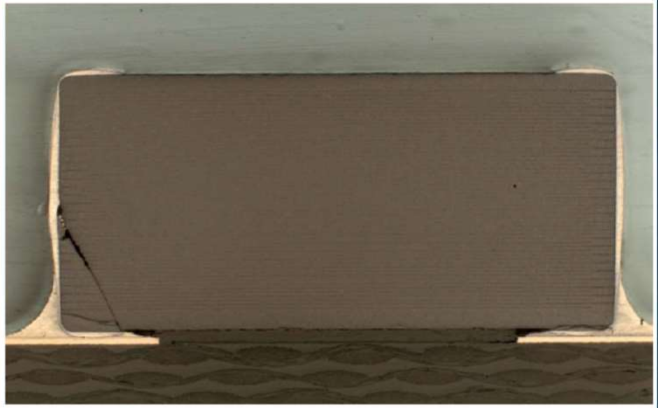
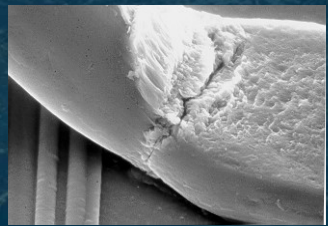
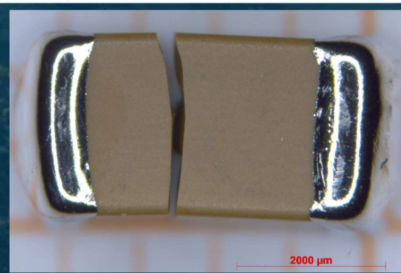
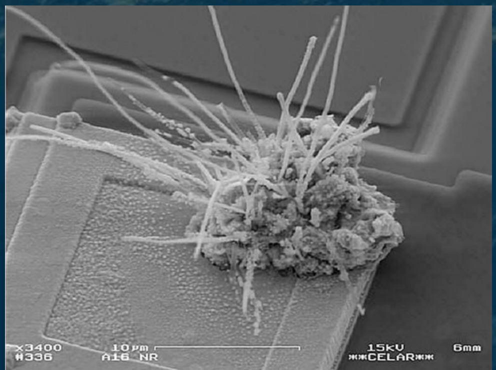


Figure 10: Optical micrograph of flex crack in MLCC

Wrong connector selection and "repair"

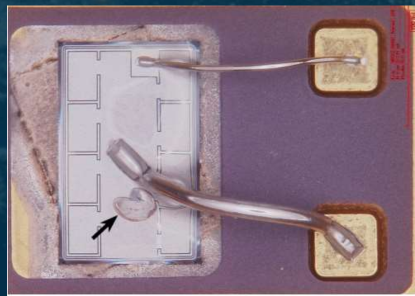






Purple plague formation (intermetallic AuAl) observed on a IC following Thallium contamination. Thallium is found at the needles extremity

Ta capacitor

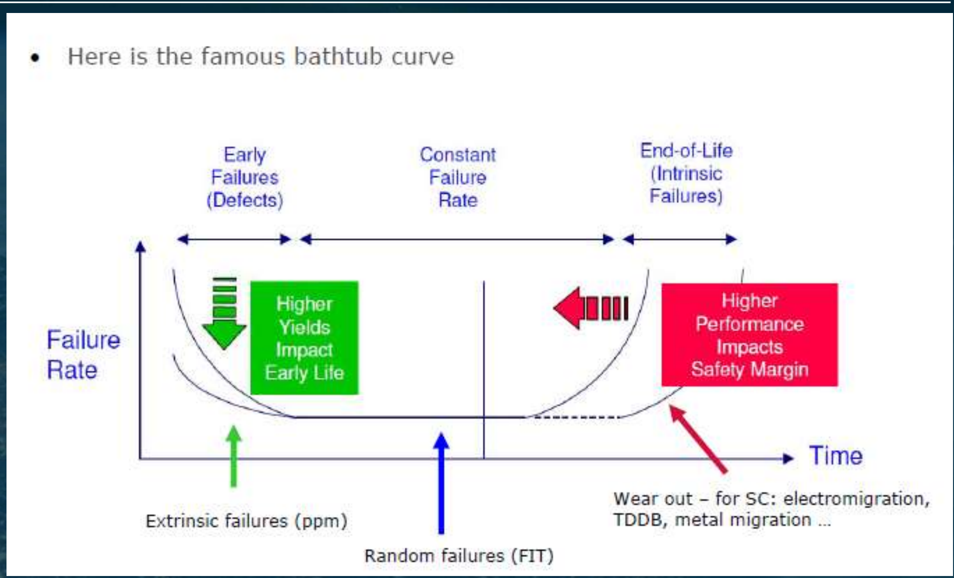


MOSFET die overstressed by external electrical stimulus

4.3 Reliability Testing

Failure Rate of components is normally inherently low but they have to survive during long periods without possibility of maintenance

Elevated stresses are used to produce the same Failure Mechanisms, but in much shorter periods, on components or test structures when necessary -> **Acceleration**



Some other tests do not identify direct Failure Mechanisms but conditions that would facilitate the occurrence of a failure (e.g. Seal test, RGA, DPAs …)

→ **Preventive**

A good experiment never exceeds the lifetime of the experimenter …
Chinese Wisdom

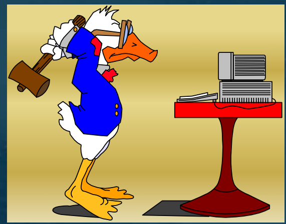
4.4 Reliability Testing

What is behind evaluation testing, screening and LATs ?

Endurance (Life Test)	Environment - Thermal	Environment - Mechanical	Radiation
Humidity	Assembly	Inspections (Visual, Xrays, CSAM…)	Outgassing
Construction Analysis / DPA	Package Tests	Intrinsic Reliability (semiconductor)	Specific (Corrosion, cryo, etc …)

Test methods are essentially drawn from the MIL-STD and IEC series

Highly accelerated endurance test



Acceleration models …. But remember they remain "only" models

Arrhenius for temperature driven phenomenon
Peck for temperature and humidity
Coffin-Manson for thermal cycling

4.5 And radiation ….

Total Ionizing Dose (TID)

- Cumulative long term effect
- Ionization of materials followed by charge trapping
- Dose is deposited by incident p^+ & e^- but also due to secondary effects (Bremmschtralung)
- Gradual Degradation of µelectronics and optoelectronics

Single Event Effects (SEE)

- Single charged particles (protons, heavy ions) passing through a semiconductor material and generating a high density of mobile charges along the track
- Can be at the origin of many different types of soft & hard errors with temporary or permanent (incl. destructive) effects
- Experimental sensitivity must be correlated with the environmental characteristics (orbit, duration, shielding effects …) to obtain the event rate probability.

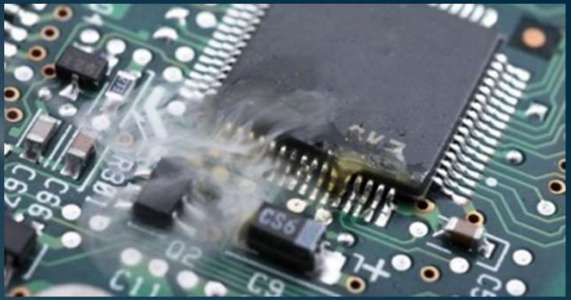
Total Non Ionizing Dose (TNID)

- Gradual Degradation of optoelectronics (GaAs, other III-V or II-VI …), CCDs, optical fibres, even bipolar technologies in very harsh environments

4.6 Radiation Hardness Assurane: Q-ST-60-15

- Very informative, contains lots of background knowledge on radiation.
- Also very good at describing what components are sensitive.
- Not defined and left for project to define:
  - Actual environment (obviously)
  - Radiation Design Margin
  - Definition of “acceptable data”
- Also not included is the nowadays more or less standard review through Radiation Control Board – this is defined by prime.

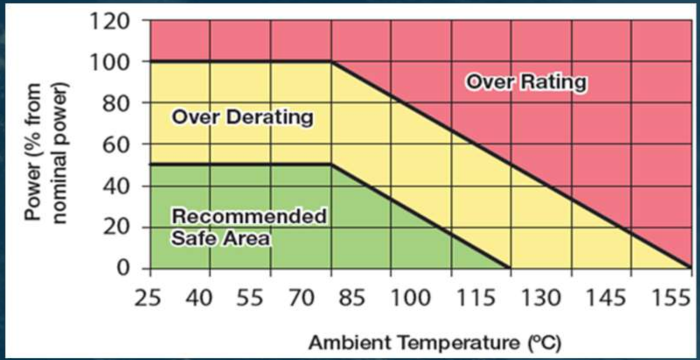
6/ DERATING



5.1 Derating

For practical reasons robustness may be more important to address than reliability, this leads into… Derating

- ECSS-Q-ST-30-11 is a dependability standard for derating, also called part stress analysis
- Definition: "process of designing a product such that its
- components operate at a significantly reduced level of
- stress to increase reliability and to insure useful life and
- design margins."
- The aim is to assure that all components are operating
  - well within their rated range in nominal conditions (normally at acceptance high temperature)
  - within maximum ratings in short durations, transients, equipment failure cases etc

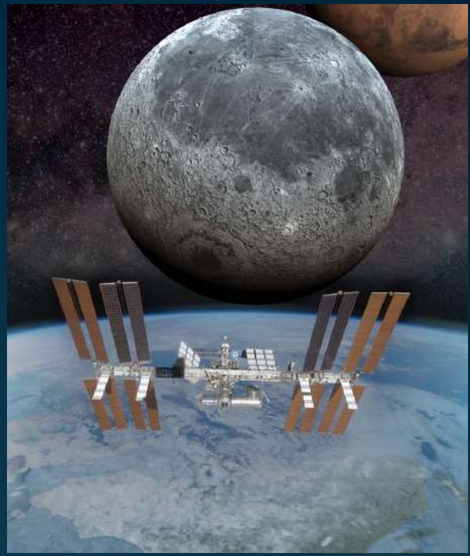


5.2 Derating

- Junction temperatures of Si semiconductor devices 40C below maximum rated temperature and in any case at maximum 110C.
- Capacitor voltage typically limited to 60% of maximum rated and temperature to 110C.
- Reverse voltages in semiconductors typically limited to 75% of maximum rated.
- Resistor voltage at 80% and power at 50% of maximum rated.
- N.B. “…only applies to approved components for which quality was proved after rigorous testing in accordance with ECSS-Q-ST-60”

Note: derating is aimed at saving lifetime but not only, that’s also a margin against unexpected events (e.g. transient signals, voltage/current spikes, short overload etc. , as maximum ratings should never be exceeded)

7/ Requirements for EEE parts in a space project



6.1 EEE requirements in space projects

- Find out what are the requirements !

Probably based on ECSS-Q-ST-60 class 1/2/3 but there can be considerable tailoring in all directions:

  - asking less, or more
  - But also what is the need i.e. project specific issues
    - Orbit / Environment (e.g. cryogenic temp., long term storage, high radiation constraint etc.)
    - Mission Class (from Microsats to Telecom Geo Sats)
    - Lifetime (from hours to decades)
    - Performances (qualified parts may not be available)

- In any ESA project, ESA would issue PA requirements, these are then reflected, and tailored by prime contractor into requirements for subcontractors

- *Cost and schedule* are also nowadays key parameters that impact the course of a project → serious risk related to shortcuts

- A qualification within a specific project does not mean necessarily pertinent heritage for an other project

6.2 EEE requirements in space projects

- Few problems with standard space/hirel parts (qualified or equivalent)
  - Where used as expected and in their derated range
  - 100% screened and regularly re-qualified by the manufacturers
  - Complete traceability
    - But high component cost
- There are many/more problems with non-standard parts (esp. commercial)
  - Lack of heritage, possible lack of traceability
  - Possible issues with the thermal range
  - Compatibility with assembly on the board / RoHS terminations
  - Radiation concern
  - Upscreening often necessary (screening + LAT/Eval)
    - A single part is far cheaper, but testing costs a lot
- The basic requirement to evaluate non-standard part is often overlooked!

Focus on the right parts!

6.3 EEE requirements in space projects - PCB

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Let's discuss !

- The key element is the **PCB – Part Control Board**
  - Mandatory for class 1 and 2
  - Not for 3 or informal support but strongly recommended
  - **-> call it whatever you want but do it !**
  - Should not be the old fashion "control only" board especially with companies presenting a limited experience
  - A privileged moment of direct contact with the suppliers where we can discuss, explain the requirements/needs, advise, give orientation, stop non-sense …
  - DO NOT rely only on RIDs "ping-pong" and formal Reviews -> ineffective
- **ESA EEE expert must be part of the PCB** (for ESA programs) → tendency to forget the "final customer" sometimes (or special agreement on a case by case)
- Review of the DCL(s) , PADs and associated documents necessary for the approval of the parts
- Recently appeared also the **RCBs** (Rad Control Boards)
  - → good but it does not mean that some rad data are not checked in PCB
  - → different role: PCB -> are they tested properly ? / RCB -> are the test results acceptable in the specific applications/designs considered ?

6.4 EEE requirements in space projects - DCL

DCL=Declared Component List Example

Detailed Specification	Issue	Quality Level	Space qualified	EPPL status	Procurement	RVT
ESCC 3009/003	-	ESCC C	EQPL	Part 1	CPPA	-

Example, number of line items in Consolidated satellite DCLs

- GAIA — 1984 including instrument (launched 2013)
- Lisa Pathfinder — 3590 including instrument (launched 2015)
- Exomars 2016 (orbiter + lander) — 4471 excluding instruments (launched 2016)
- Bepi Colombo (MTM+ MPO) — 6124 excluding instruments (to be launched 2018)

6.5 EEE req. in space projects – PADs/JDs

PAD=
Part Approval Document
Defines how part is procured and tested

DCL and PADs are reviewed during PCBs: Part Control Boards

A Justification Document (aka JD) is by essence very similar to PAD but more dedicated to commercial parts

PROJECT:............... Doc n°:.................. Prepared by: ....
Issue:...................... Date:....................

Approval requested by:...............................
Family:.................... Fcode [ ] Group:.................. Gcode [ ]
Component Number:..
Commercial Equivalent Designation:......................
Manufacturer/ Country:.................................
Technology/Characteristics (value or range of values with tolerance, voltage, package etc): ....
Pure tin free (Y/N) [ ]
Generic specification:......................
Detail specification:....................... Issue:..... Rev.:..... variant:.......
Specification amendment: .... Issue:..... Rev.:..... variant:.......
Quality level:......................... Procurement by:.............................

APPROVAL STATUS

EPPL Part 1/2 listed (1/2/N) [ ]
ESCC QPL or EQML listed. (Y/N) [ ]
MIL QPL or QML listed (Y/N) [ ] If yes: QPL/QML Reference:...............................
Other approvals/former usage ....
Evaluation programme required (Y/N) [ ]
If yes reference of the Evaluation Programme:...............................

PROCUREMENT INSPECTIONS and TESTS

Precap (Y/N) [ ]
Lot acceptance:
ESCC LAT/LVT level or subgroup [ ]
MIL QCI/TCI group [ ]
Buy-off (Y/N) [ ]
DPA (Y/N) [ ] if yes: sample size ....

Complementary tests ....

RADIATION HARDNESS DATA

Radiation Hardness Assurance Plan applicable (Y/N)[ ]
Doc. Ref.: ....

Total Dose Effects:
Evaluation Test Data (report) reference: ....

Single Event Effects: SEL/SEU/SET/SEFI/SEB/SEGR/others: *(cross out when non applicable)*
Evaluation Test Data (report) reference: ....

RVT required (Y/N)[ ]

REMARKS

Approval customer .... Date ....

Approval first-level supplier .... Date ....

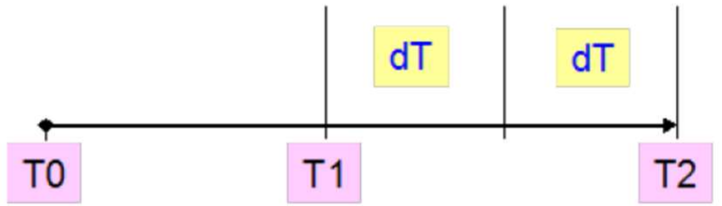
6.6 More from Q-60

- Parts for Ground Segment (GSE) – section 4/5/6.1.5
  - If interfacing with flight HW, parts (esp. connectors and savers) must be FFF compatible and manufactured from identical material, but don't need to be space qualified (e.g. C&K FR022)
- Parts and material restrictions – section 4/5/6.2.2.2
  - E.g. potentiometers, non passivated die, pure tin (<3%) but here things change, etc.
- Initial customer source inspection (precap) – section 4/5/6.3.4
  - Class 1/2 mainly for non qualified parts and/or critical components (e.g. relays, hybrids); not required for class 3
- Destructive physical analysis (DPA) , usually 3 parts / lot required (can be reduced for expensive ones)
  - Class 1: most non-qualified + Relays and oscillators
  - Class 2/3: on non qualified relays and oscillators (Class 2 only)
- Relifing: ECSS-Q-ST-60-14 updated recently; max. 15 years now but relifing requirement remains
- One Time Prog. Devices: PPBI no longer required (will also be removed for PROMs) but PP sequence remains necessary (typically @ board / equipment level, functional, 3 temperatures, full speed)

6.7 Q-ST-60-14 Relifing

- Relifing is a term for assuring old (>7 years) parts still fit for flight.
- Standard also addresses storage conditions.
- Rev 1 was issued 2019, there are rather major changes for example
  - Maximum age extended from 10 to 15 years
  - Different requirements for Class 1&2 and 3 respectively.

T1	T2	dT
7 years	15 years	4 years



T0	Original date code
T1	Maximum allowed storage period from T0 with no relifing control
T2	Maximum duration between the original date code of part and its mounting
dT	Maximum allowed storage period after a relifing control which can be repeated once

What needs to be done at T1&T2 varies with component family from nothing to 100% screening.

7/ COTS … and a few words about New Space

7.1 Commercial parts : ECSS-Q-ST-60-13

- We have very clear requirements for commercial components as long as we are talking about monolithic microcircuits, transistors and diodes (some passive parts will be included in the new revision)

- Requirements very demanding for Class 1 ranging to effectively only asking for radiation test and constructional analysis for Class 3.

- In any case ECSS-Q-ST-60-13 asks for the demonstration that a part suitable for the intended space application has been selected – it is not just a test specification!

•EEE definition of Commercial

  - “neither designed, nor manufactured with reference to military or space”

And keep in mind :
Derating,
Design margins,
Traceability,
Need careful control

7.2 ECSS-Q-ST-60-13

Q60-13
The 3 classes (of COTS up-screening)

	CLASS 1	CLASS 2	CLASS 3
EVALUATION	**COMPLETE** - Construction analysis - Electrical charact. (3T+10°C margin) - Meca shocks + Vib. + Const. Acc. *(for cavity package)* - Precond + HAST 96h or THB 1000h - Lifetest 2000h-125°C + DPA - Precond + 500T/C -55°C/+125°C - Radiation evaluation (TID, SEE)	**COMPLETE** - Construction analysis - Electrical charact. (3T+10°C margin) - Meca shocks + Vib. + Const. Acc. *(for cavity package)* - Precond + HAST 96h or THB 1000h - Lifetest 2000h-125°C + DPA - Precond + 500T/C -55°C/+125°C - Radiation evaluation (TID, SEE)	**LIMITED** - Construction analysis - Radiation evaluation (TID, SEE)
JD (Justification Doc)	**DATA COLLECTION** - Component manufacturer data - Approval status - Evaluation tests - Procurement inspection and test - Lot acceptance tests - Radiation hardness data and RVT	**DATA COLLECTION** - Component manufacturer data - Approval status - Evaluation tests - Procurement inspection and test - Lot acceptance tests - Radiation hardness data and RVT **DATA COLLECTED** *(EFR, lifetest, thermal cycling)* used for screening reduction	**DATA COLLECTION** - Component manufacturer data - Approval status - Evaluation tests - Procurement inspection and tests - Lot acceptance tests - Radiation hardness data and RVT **DATA COLLECTED** *(lifetest, HAST, thermal cycling)* used for lot test reduction
CUSTOMER PRECAP	no	no	no
SCREENING	**COMPLETE** - X-rays - Serialisation - 10T/C -55°C/+125°C - PIND test (if applicable) - Initial electrical test @ 25°C - Dynamic burn-in 240h-125°C - Final electrical test @ 3T° - PDA (5%) - Hermeticity (if applicable) - External visual inspection	**LIMITED** (if data collected) - PIND test (if applicable) - Hermeticity (if applicable) + If no data collected (see JD) - Serialisation - 10T/C -55°C/+125°C - Initial electrical test @ 25°C - Dynamic burn-in 160h-125°C - Final electrical test @ 3T° - PDA (5%) - External visual inspection	**LIMITED** - PIND test (if applicable) - Hermeticity (if applicable)
LOT TEST (on screened parts) (when applicable)	**COMPLETE** - Construction analysis - Meca shocks + Vib. + Const. Acc. *(for cavity package)* - Precond + HAST 96h or THB 1000h - Lifetest 2000h-125°C - Precond + 100T/C -55°C/+125°C - RVT (Radiation Verification test)	**COMPLETE** (but LT 1000h) - Construction analysis - Meca shocks + Vib. + Const. Acc. *(for cavity package)* - Precond + HAST 96h or THB 1000h - Lifetest 1000h-125°C - Precond + 100T/C -55°C/+125°C *(may be waived i.a.w. application)* - RVT (Radiation Verification test)	**LIMITED** (if data collected) - Construction analysis - RVT (Radiation Verification test) + If no data collected (see JD) - Precond + HAST 96h or THB 1000h - Lifetest 1000h-125°C - Precond + 100T/C -55°C/+125°C
CUSTOMER BUY-OFF	no (replaced by incoming)	no (replaced by incoming)	no (replaced by incoming)
INCOMING	yes	yes	yes

7.3 Q-ST-60-13 What is a JD ?

- JD stands for Justification Dossier
- Similar in essence to a PAD for COTS, with more details, as these parts are not manufactured and controlled based upon well defined military or space systems
- A JD provides details about:
  - The part type (manufacturer, package, temperature range, MSL, ESD level, lead finish, molding characteristics, data sheet / procurement spec. and associated documents (ANs, PCNs etc.))
  - Existing reliability data
  - Evaluation and procurement tests
  - Traceability information (wafer fab, die revision, assembly plant etc.)
- *In principle it describes also why such commercial part is needed (instead of a HiRel)*

7.4 Q-ST-60-13 Update

- This standard is being updated:
  - to include passive part families:
    - Ceramic chip capacitors
    - Tantalum chip capacitors
    - Film resistor chips
    - Magnetics
    - Fuses
    - Thermistors
  - to recognize (more explicitly) automotive qualified parts (require less activities for these)
  - to remove mandatory re-tinning and RFW when using pure tin plated parts (N.B. from EEE perspective only)

7.5 Commercial parts

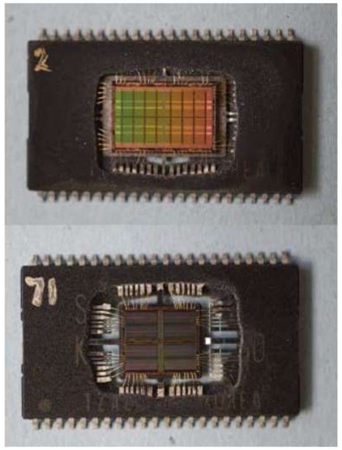
Plastic ≠ commercial, commercial ≠ plastic

- All plastic packaged parts are not commercial.
- Specially now many manufacturers are releasing various types of COTS+ radiation guaranteed components, sometime based on automotive parts.
- State of the art complex microcircuit may not be possible to package in ceramic/hermetic package, FPGAs an example.
- Plastic packaged parts are not, and have never been, forbidden in ESA missions for any class. There has sometimes been reluctance in the past though.
- So far plastic packaged parts have not been possible to formally qualify to space level, change is in progress (see following slide).
- NB ECSS-Q-ST-60-13 is a standard for procurement and test of procured commercial components. Route to approval is given for Class 1, 2 and 3.
- ECSS-Q-ST-60-13 does not fully address plastic packaged parts produced directly for space applications!

7.6 Typical problems with COTS

- Requirements not understood, e g commonly it is believed that (full) up-screening is always needed.
- Packaging and assembly including retinning to remove pure Sn
- Plastic package delaminations
- Data sheets trusted as if they were specifications – they are certainly not!
- Lot homogeneity and traceability
- Re-use of existing test data
- Derating
- No plan B for evaluation failures
- Common belief that different levels of the same component have the same robustness/quality
- Misunderstanding of reliability vs assurance

Memory where well known SRAM lot contained two different die revisions – one latch-up sensitive. Caused latch-up in orbit.



7.7 A word about New Space

Are we sailing to Terra Incognita ?

The term is a kind of “rag-bag” but distinct trends may be observed in Europe

1/ Classical space companies seeking mainly for

- high cost reduction
- more recent technologies (to some extent)

→ through the massive use of “good” commercial parts (like automotive i.e. AEC-Q) and a drastic evolution of existing rules

2/ New commercial players with often a limited or different experience

- targeting small satellites for low Earth orbits and short duration (but not only !)
- accepting a higher risk, even by using “black boxes” with “architectural reliability” approach (not always very clear in practice…)

3/ ESA is also working on the subject on its own (e.g. COTS & Mission Categories WGs) and with industry

7.8 A word about New Space

R. Baumann, "From COTS to Space Electronics: Improving Reliability for Harsh Environments," 2016 Single Event Effects (SEE) Symp. and the Military and Aerospace Programmable Logic Devices (MAPLD) Workshop, May 23-26, 2016.

	COTS / COTS+		Enhanced Intermediate Grades			Space Grade	
	Commercial	AEC-Q100	EP	QMLQ	Space EP	QML-V	QMLV-RHA
Packaging	PLASTIC	PLASTIC	PLASTIC	CERAMIC	PLASTIC	CERAMIC	CERAMIC
Single Controlled Baseline	NO	NO	YES	YES	YES	YES	YES
Bond wires	Au or Cu	Au or Cu	Au	Al	Au	Al	Al
Pure Sn Used	YES	YES	NO	NO	NO	NO	NO
Burn-in Performed	NO	NO	NO	NO	NO	YES	YES
Radiation Tested	NO	NO	NO	NO	YES	YES	YES
Radiation Assured	NO	NO	NO	NO	YES	NO	YES
Temperature Range	-40 to 85°C	-40 to 125°C (only grade 1)	-55 to 125°C (majority)	-55 to 125°C	-55 to 125°C (majority)	-55 to 125°C	-55 to 125°C
100% 3 Temp Test	NO	NO	NO	YES	25, 125°C	YES	YES
Extra Qual/Process Monitors	NO	YES	YES	YES	YES	YES	YES
Life Test per lot	NO	NO	NO	NO	NO	YES	YES

The move to the middle!

After Baumann, Radiation Effects on Components and Systems (RADECS) conference, Gothenburg, Sweden, September 16-21, 2018.

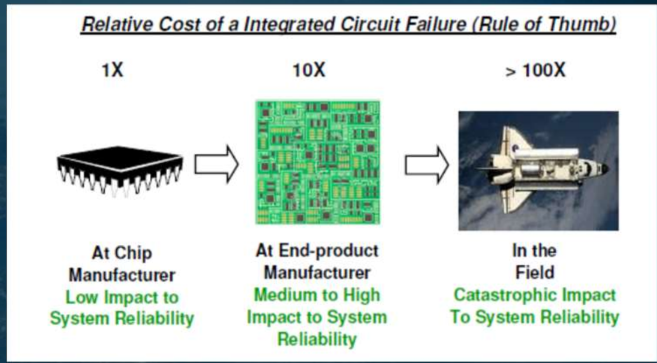
Classical	**New Space**
Hirel parts or fully upscreened parts	Mainly AEC or equivalent
100% screening at component level	Almost NO screening at component level, replaced (to some extent) by board/ equipment level screening *(see note 1)*
LAT: periodic (Hirel) or systematic (non qualified)	No LAT for AEC parts or equivalent, only for parts with very limited existing data *(see note 2)*
Active parts in hermetic package	Plastic packages
Assembly with SnPb processes	RoHS processes (lead free) *(note 3)*
Full traceability	Not systematic, it depends really of the commercial agreement with the supplier, some provide a complete traceability, some don't
Radiation guarantee or tests	Radiation tests systematic (ideally…) associated with a control of the process changes (efficient to some extent, cannot be anyway compared with full visibility as PCNs** only address measurable and visible changes, not necessarily all the manufacturing processes) *(notes 4)* ** PCN stands for Process Change Notification

One pitfall is to compare what is not directly comparable:
- Both Hi-Rel and automotive /enhanced commercial are quality parts, but different philosophies behind
  - --- roughly: statistical control vs systematic control
  - --- reliability is not an absolute notion
- Mass production parts are not "better":
  - --- Tightened electrical parameter distribution does not mean higher reliability

Classical vs "New"
Coarse overview (Geo-sat)

8 Conclusions

- Know your mission requirements before starting selecting your EEE components! All components do not work well in space environment - selection and verification are crucial!



- Think about reliability aspects and future application constraints as early as possible

- Cost and schedule impact the course of a project:
  Risks related to hasty shortcuts if you do not know where and how you can apply them safely

- Test for radiation first but not only!

- Many EEE components non-conformance and failures are still related to their assembly on board processes and/or their application conditions

- Pay attention to the notion of heritage, it does not mean necessarily relevant / appropriate heritage in your mission context !