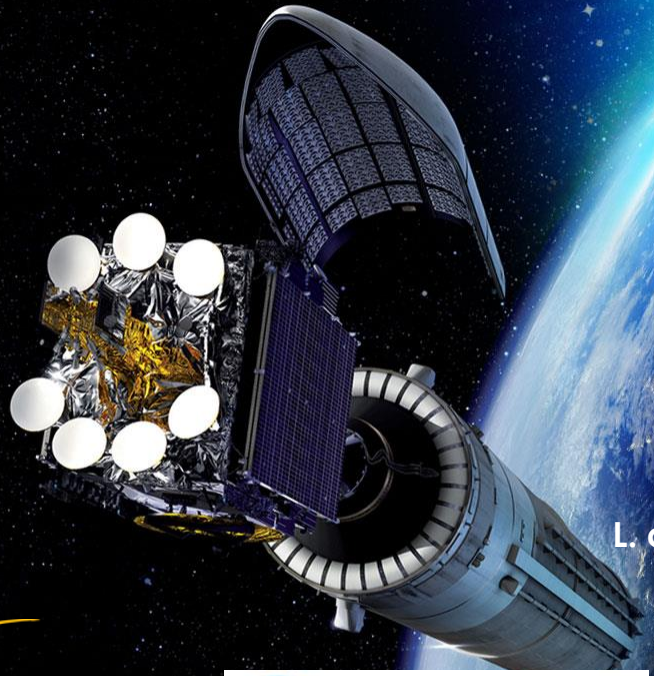

ACCEDE 2019
Assessment of Automotive EEE Components Suitability For Space Applications

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ACCEDE COTS2019
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Tyndall National Institute
Institiúid Náisiúnta

esa ESTEC

ThalesAlenia Space
a Thales / Leonardo company

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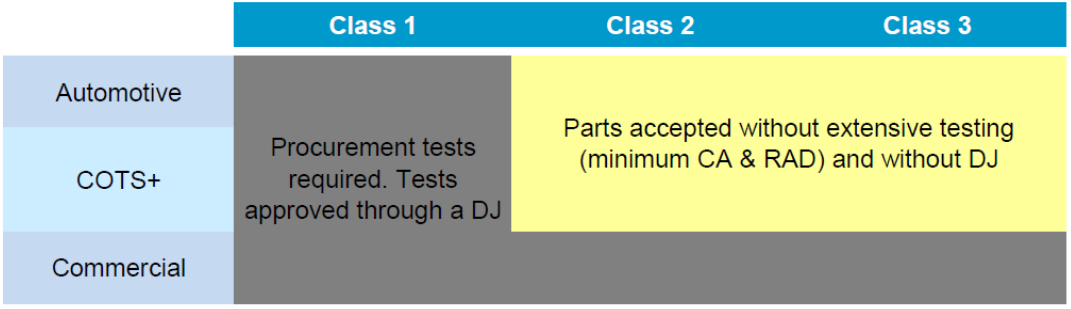
INTRODUCTION

- Thales Alenia Space in Spain and Tyndall National Institute Ireland get a Contract with ESA No. 4000126343/19/NL/hh for the Assessment of Automotive EEE Components Suitability For Space Applications.
- Goal is to get info by analysis, market survey and testing refine recommendations for use of AEC devices in Space application according to mission criticality



BACKGROUND

SPACE

Quality by Inspection: • 100% Screening • Lot Acceptance test • Customer Source Inspection & DPA
Very Large Initial Qualification Sampling
Partial Requalification for Changes
Temperature Range -55°C/+125°C
Lifetime: 20 years at 110°C (GEO) (all ON or all OFF)
Power ON/OFF cycles: • 50K to 150K for LEO
Radiation Environment: YES (electron, proton, neutron, gamma, heavy ions): TID, TNID, SEE
Humidty: NO
Vacuum, Rapid Depressuritation: Yes, $< 10^{-7}$ torr
Agency / US Government certification as per ESCC/MIL standards

Different missions, different strategies

but similar quality target, lifetime and thermal fatigue.

Same Components could meet both (if Radiation allow it)

AUTOMOTIVE

Quality by Process Control • SPC with zero failues (<ppm) • Cpk > 1.67
Small Initial Qulification
Partial Requalification for Changes
Temperature Range -40°C/+125°C
Lifetime: 15 years at 85°C 600 000 km 12000 hours Engine ON 3000 hours Engine OFF 116 400 hours Non Operating
Power ON/OFF cycles: • 50K (no Start-Stop) • > 300K (with Start-Stop)
Radiation Environment: NO
Humidty: Yes, 15% to 93% RH
Vacuum, Rapid Depressuritation: NO
Self-certification per IATF 16949 and AEC-Q standards

ASSESSMENT TASKS DESCRIPTION

WP1: AEC-Q MAPPING

- ❑ Compile an AEC QPL list based on the state of the art.
- ❑ Compile a list of the most demanded devices for Space applications.
- ❑ Generate an update of the AEC PPL for Space applications.
- ❑ Select candidates for test from the AEC PPL.

WP2: COMPARE AEC-Q & SPACE

- ❑ Compare AEC standards and flow versus Space standards (ESCC, MIL, ECSS and NASA).
- ❑ Define recommended delta-approval tests
- ❑ Procured 3 lots of each candidate within a 3 years of date code

WP3: TESTS

<u>Check for variability Lot to Lot and part to part:</u>

- ❑ Constructional Analysis, Glass transition (Tg) & CTE, Outgassing
- ❑ Life test
- ❑ HAST/THB
- ❑ Temperature Cycling

WP4: RECOMMENDATIONS

TASK#1 THE AUTOMOTIVE AEC-Q MAPPING. AEC-QPL

- Mapping Task: AEC Description. History. Standard. ISO16949 & IAT16949. The PPAP
- Compilation of an Almost exhaustive AEC-Q QPL with components published at web as being Qualified AEC-Q100, or AEC-Q101 or AEC-Q200:
  - 212288 items listed from the following 72 type families. 37K for AEC-Q100 +36K for AEC-Q101 + 176K for AEC-Q200. Total number estimated to be at 2019/09 around 600 000
  - Data source: Big manufacturers and Distributors
  - 117 manufacturers: with info about published certifications IATF16949 / PPAP available
  - No yet devices qualified by neither AEC-Q102 (Optoelectronics) nor AEC-Q103 (MEM Sensors) nor AEC-Q104 (MCM) reported by manufacturers or distributors.
  - Some families as Crystals, Oscillators and MEM's could be listed under AEC-Q100 or AEC-Q200. Even same device offered either AEC-Q100 or AEC-Q200
  - Most Optoelectronics are listed under AEC-Q101
  - Most MCM are listed under AEC-Q100
  - Most Sensors (pressure, temperature, accelerometers, gyroscopes, magnetic, proximity, hall effect..) are under AEC-Q100, other under AEC-Q200
  - More than 70% of the microcircuits meet the Military Temperature Range (grade-0 plus grade-1). Similar for discrete and passive.

TASK#1 THE AUTOMOTIVE AEC-Q MAPPING. AEC-QPL (Cont'd)

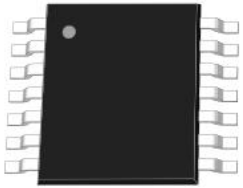
- Some passive rated at very high temperature (resistors, capacitors, current ssnor uop to 2001C to 275ºC)
- Packages: some dice. 78% in plastic package. But 20% are encapsulated in ceramic packages like LCC, or mounted in ceramic support (ceramic chip RCL, themristors, filters, diodes). Less than 1% is found in metal packages.
- Majority are non hermetic non cavity. Some hermetic by technology (Crystal, oscillators and MEM, SAW Filters). Some new RF/MW devices work better inside air cavity package, these "almost" hermetic adhesive sealed ceramic lid.
- Critical packages (BGA, QFN, DFN, CSP), recognized by the automotive community as assembly critical because more sensitive to thermal fatigue with power on/off thermal cycling represents around 14% of AEC-Q100 microcircuits. DFN/QFN very popular in RF/MW, BGA/LGA almost "omnipresent" for high count FPGA/DSP/uControllers.
- SMD versus Through Hole. SMD accounts for 97%, while 3% for DIP axial, etc…
- Standard Chip Sizes: 0402, 0603, 0805, 1206, 1210, extended from capacitor and resistors to inductors, thermistors, EMI filters, diodes (DFN-2). Same trend seems to be extended to transistors (DFN-3) and MEM oscillators (DFN-4).
- Most (97%) but not all are published as RoHs compliant. But some with exception for high temperature solders
- Most manufacturers are from US & Europe & Japan, but with manufacturing plants certified for automotive as per IATF16949 in Far East: mainly China and Taiwan.

TASK#1 THE AUTOMOTIVE AEC-Q MAPPING. AEC-QPL (Cont'd)

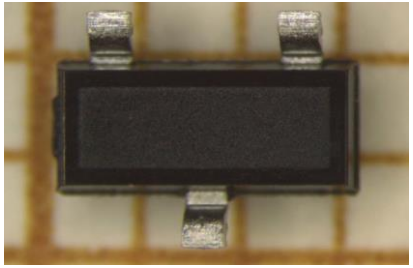
- Most manufacturers are from US & Europe & Japan, but with manufacturing plants certified for automotive as per IATF16949 in Far East: mainly China and Taiwan.
- Some European are very active as EPCOS/TDK, Fastron, Infineon Technologies, Jauch Quartz, RF360 (Qualcomm/TDK), ROHM Semiconductor, TDK-Micronas, Vishay / BC Components, Vishay / Beyschlag, Wurth Electronics (in Germany). ATMEL Microchip Technology; ST Microelectronics (in France). Melexis Technologies NV (in Belgium). IQD Frequency Products; Knowles / Syfer; TT Electronics; Welwyn Components / TT Electronics (in UK). Nexperia & NXP in Netherlands. Nordic Semiconductor in Norway. Micro Crystal in Switzerland.
- Top-10 IC suppliers accumulate 85% of automotive, and Top-19 around 95% for more than 70 suppliers.
- Some technologies almost not seen in Space: Power GaN; Power SiC; MEM (oscillators); Sensors: pressure, temperature, accelerometers, gyroscopes, ARM magnetic, proximity, hall effect, ambient light, angle and linear position, measuring Infrared Emitters; High End Memories (DDR, Flash, FRAM, MRAM), microprocessors and FPGAs; Very Low Voltage Logic Families (17SZ; 27WZ; 37WZ; 74ABT; 74AUP; 74AVC; 74AXC; LSF; TCB; TWL; TXB; TXS, etc..); Triacs, Thyristor, SCRs; Aluminium Capacitors; Safety capacitors (line to ground capacitors); Ceramic Disc capacitors; BAW Filters; Varistors; Resettable fuses; Battery chargers, battery management; USB protection, Lighting Protection Diodes; Transponder coils, etc.
- Some technologies forbidden for Space: Aluminium Electrolytic Capacitors; Non swept Quartz and Quartz-based Oscillators; fuses: Resettable PPTC & wire link; SCR / Thyristor; Varistors, etc.

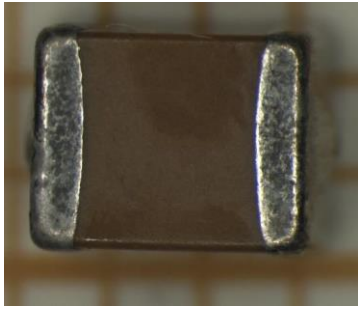
TASK#1 SELECT 3 AEC-Q CANDIDATES FOR TESTING

- All the three European ones per AEC-Q standard and from big manufacturers
- AEC-Q100: Op Amp, Output rail-to-rail, very low-noise, TSSOP-14 package
- AEC-Q101: Diode, Silicon, switching, high speed
- AEC-Q200: Capacitors, fixed, chip, ceramic dielectric type II, flexible termination based on type 1210



TSSOP14





TASK#2 COMPARISON AEC-Q AND SPACE – General Policy

STEP	AEC-Q	ECSS-Q-60-13C Grade-1 PEM-INST-001 Grade-1	ECSS-Q-60-13C Grade-3 PEM-INST-001 Grade-3	Enhanced Plastic	COTS for Space (Low) (1)	COTS for Space (High) (2)	ESCC QPL	MIL QML-Q/B/Y	MIL QML-V/K
Line Certification	IATF 16949 Self certification plus audits	NO	NO	NO	NO	NO	YES (QPL/QML)	YES	YES
Device Certifications	Self certification plus PPAP	NO (Custom)	NO (Custom)	Self certification	NO	NO	YES (QPL)	YES (QML)	YES (QML)
Single Controlled Baseline Document	No (Data Sheet)	No (Data Sheet)	No (Data Sheet)	VID	No (Data Sheet)	No (Data Sheet)	ESCC Spec	SMD	SMD
Pure Tin?	TYPICAL YES	TYPICAL YES	TYPICAL YES	NO (3)	NO (3)	NO (3)	NO	NO	NO
Operating Temperature Range	majority -40/125°C	Best Commercial	Best Commercial	MIL	Could be Best Commercial	MIL	MIL	MIL	MIL
Initial Device Qualification	YES (3 lots 77 pcs)	By Customer	By Customer	YES (similar Class N)	YES (similar to NASA/ECSS Grade-1)	YES (similar to NASA/ECSS Grade-1)	YES	YES	YES
Singe wafer fab location	Not always	NO	NO	TYPICAL YES	YES	YES	YES	YES	YES
Wafer Lot Acceptance Test (SEM)	NO	NO	NO	NO	NO	TYPICAL YES	YES	NO	YES
Singe assembly fab location	Not always	NO	NO	TYPICAL YES	YES	YES	YES	YES	YES
Pre-cap Customer Source Inspection	NO	NO	NO	NO	NO	NO	POSSIBLE	NO	NO
Serialisation	NO	By Customer	By Customer	NO	NO	POSSIBLE	NO	NO	YES
In process DPA	NO	By Customer	By Customer	NO	NO	POSSIBLE	LAT3 or By Customer	By Customer	QCI B
100% Screening	NO, or LIMITED	By Customer	Typically NO	NO	NO, or LIMITED	YES	YES	YES	YES
Lot Maximum Percent Defective during 100% Screening	NO	By Customer	By Customer	NO	NO	NO	YES	YES	YES
End of Line LAT/QCI	NO	By Customer	By Customer	NO	YES	YES	If Ordered	YES	YES
Life Test on Wafer Lot	NO	By Customer	By Customer	NO	YES	YES	If Ordered	NO	YES
Traceability: Wafer, Assembly Site & Date Code	YES	Not Always	Not Always	YES	YES	YES	YES	YES	YES
Lot Test Report	NO	By Customer	By Customer	NO	NO	NO	YES	If Ordered	If Ordered
CoC	YES	YES	YES	YES	YES	YES	YES	YES	YES
Requalification for Device Changes	YES	Not Always	Not Always	YES?	YES?	YES?	YES	YES	YES
Radiation Harness Assurance	NO	By Customer	By Customer	NO	Generic TID/SEL Only	TID on Wafer lot	When applicable	When applicable	When applicable
PCN/PDN (JEDEC JESD46D)	Upon requirements	Not always	Not always	Typically YES	Typically YES	Typically YES	Typically YES	Typically YES	Typically YES

TASK#2 COMPARISON AEC-Q AND SPACE – Test Method Comparison

- Test methods comparison between AEC, ESCC, MIL, ECSS-Q-ST-60-14 and NASA GSFC PEM-INST-001 as applicable for microcircuits (AEC-Q100), discrete semiconductors (AEC-Q101), and passive devices (AEC-Q200)
- Also comparison for Diodes & LEDs (AEC-Q102), MEM sensors (AEC-Q103) and MCM (AEC-Q104) are included.
- Detailed comparison for Qualification / LAT of AEC standard and ECSS-Q-ST-60-14, NASA GSFC PEMS-INT-001, ESCC / MIL as applicable
- Examples:

ABV	STRESS TEST	TEST METHOD		
		AEC Q101	ECSS-Q-ST-60-13C	ESCC 5000/5010
AC	Autoclave (Pressure Cooker Test)	JEDEC JESD22-A102	_	_
ACBV	AC blocking voltage	MIL-STD-750 TM 1040	_	_
AHTOL	Accelerated steady-state operation life	_	_	_
ALF	Adhesion to lead finish	_	_	_
BLT	Blocking Life Test	_	_	_
BP	Barometric Pressure (for >200V devices)	_	_	_
BURNIN	Burn-in	_	MIL-STD-750 TM 1038 & TM1039	MIL-STD-750 TM 1038 & 1039 & 1040 & 1042
BURNINPS	Preseal burn-in (open non hermetic)	_	_	_
CA	Constant Acceleration	MIL-STD-750 TM 2006	MIL-STD-750 TM 2006	MIL-STD-750 TM 2006
CAN	Constructional Analysis	_	ECSS-Q-ST-60-13C ANNEX-H	ESCC 21001
CHAR	Characterization	AEC Q003	ECSS-Q-ST-60-13C	_
CSAM	C-Mode Surface Acoustic Microscope	_	JEDEC J-STD-020	MIL-STD-883 TM 2030 ESCC 25200
DEL	Delidding	AEC-Q101 Appendix 6	N/A	_
DI	Dielectric Integrity	AEC-Q101-004 Section 3	_	_
DPA	Destructive Physical Analysis	AEC-Q101-004 Section 4	ECSS-Q-ST-60-13C ANNEX-H	ESCC 21001

TASK#2 COMPARISON AEC-Q AND SPACE – Test Method Comparison (Cont'd)

ABV	STRESS TEST	TEST METHOD		
		AEC Q200	ESCC 3001 to ESCC 3012 ESCC 3501 ESCC 4001 to ESCC 4005 ESCC 3201	MIL-PRF-55681; MIL-PRF-55365; MIL-PRF-83421; MIL-PRF-83401; MIL-PRF-55342; MIL-PRF-23648; MIL-PRF-14409; MIL-PRF-27; MIL-PRF-21038; MIL-PRF-3098; MIL-PRF-28861
AN	Acoustical noise	_	_	MIL-PRF-810 TM 515
AS	Acceleration Sensitivity	_	_	MIL-PRF-3098 Para.4.10.14.2
AS	Thermal frequency hysteresis	_	_	MIL-PRF-3098 Para.4.10.15
AT	AXIAL THRUST	_	ESCC 3010 Para. 8.13	_
BF	Board Flex	AEC Q200-005	_	_
BH/LVHT	Biased Humidity / Low Voltage Humidty Test	MIL-STD-202 TM 103	Generic ESCC3009 Para. 8.2 MIL-STD-202 TM 103	MIL-STD-202 TM 103
BLT	Beam Load Test	AEC-Q200-003	_	_
BURNIN	Burn-in Voltage Conditioning for MIL Capacitor. Power Conditioning for Resistors. Ageing for quartzs	_	IEC 384-1 Clause 4.23 (capacitors) ESCC 3501 (quartzs) IEC 115-1 Clause 4.25 (resistors) MIL-STD-202 TM 108 (inductors)	MIL-PRF-55681 Para. 4.8.3 MIL-STD-202 TM 108 MIL-PRF-27 Para. 4.7.5 MIL-PRF-3098 Para. 4.10.27
CAN	Constructional Analysis	_	ESCC 21001	_
CD	Corona Discharge	_	_	MIL-prf-27 Para. 4.7.14
CHAR	Characterization	AEC Q003	ESCC spec	_
COLD	Cold Test	_	IEC 68-2-1 Test Aa	_
CS	Climatic Sequence	_	IEC 384-1 Clause 22	_
CSAM	C-Mode Surface Acoustic Microscope	_	ESCC 25200	_
CT	Corrosion Test (hermetic devices only)	_	IEC 68-2-11 Test Ka	_
DHA	DAMP HEAT ACCELERATED	_	IEC 68-2-30 Test Db	_
DHSS	DAMP HEAT STEADY STATE	_	IEC 68-2-3 Test Ca IEC 68-2-72 Test Cab	_
DISC	Dissipation Constant (thermistors)	_	ESCC 4006 Para. 8.12	MIL-PRF-23648 Para. 4.8.10 MIL-PRF-28861 Para. 4.6.4.2
DPA	Destructive Physical Analysis	_	ESCC 21001	MIL-STD-1580 MIL-PRF-28861 Appendix B (EMI filetrs)
DPAMLCC	Destructive Physical Analysis. SMD Ceramics	EIA-469	ESCC 21001 ESCC 23400	_

TASK#3 PLANNED TESTING - ACTIVE

- 3 Lots being procured for each device spreading a manufacturing period of 3/4 years
- 5 pieces Constructional Analysis as per ECSS-Q-ST-60-13C
- 10 pieces THB (1000h 85C/85%RH with preconditioning) with parts soldered onto board
- 10 pieces High temperature Operating Life Test HTOL (1000hours 125°C) with parts soldered onto board
- 10 pieces Thermal Cycling TC (with preconditioning and 3 pieces C-SAM before and after test) 500 cycles -55°C to +125°C as per MIL-STD-883 TM1010 / MIL-STD-750 TM 1051 with parts soldered onto board
- Final C-SAM to be done without desoldering from board
- Glass Transition Temperature / CTE by DSC or TME (complete component with lead frame)
- Outgassing (only cut molding)

TASK#3 PLANNED TESTING – CHIP CAPACITORS

- NASA Alerted in 2016 about variability from lot to lot on Flexible/Non Flexible construction, and Some maverick lots failing Life test.
- NASA Alerted in 2018 of the fact that most sensitivity to cracking of MLCC capacitors is not detected on component alone but on component soldered onto board. We recommended to check variability from lot to lot in DPA & Life Test using capacitor soldered onto board, using polyimide boards, IR SnPb soldering.
- Testing proposed is
  - HTOL 10PCS 1000hour 125°C Maximum voltage rating. No moisture inside the oven.
  - Biased Humidity Test (Low Voltage Humidity Test). As per ESCC3009 1000h 85°C 95%RH 1.5V
  - For Rapid Change of Temperature : see comparative

TASK#3 PLANNED TESTING – CHIP CAPACITORS

AEC

- 1000 cycles -55°C/+125°C
- 1min transition time
- 30minutes dwell time

ESCC

- 10 cycles 55°C/+125°C
- 1min transition time
- 30minutes dwell time
- on soldered components

ECSS-Q-70-38C1

- 500 cycles 55°C/+100°C
- 5 to 12°C/min (or lower)
- 15minutes dwell time

- Use polyimides board as most representative of what used by most of Space industries.
- No preconditioning required
- Infrared Soldering by Tyndall
- Apply 500 thermal cycles, 5 to 10°C/min, 15 minutes dwell times at extremes
- Use these boards for DPA: cross Section. Looking for whiskers, delamination, cracks in soldering and inside ceramic edge, dielectric & electrodes, …

TASK#4 CONCLUSIONS & RECOMMENDATIONS : TO BE BUILT

Some Expected Results:

- No variability part to part and lot to lot (we hope!). No maverick lots/parts
- No difference in construction, materials
- Consistency for Tg/CTE /Outgassing results between lots
- No whisker longer than 15 to 25um on pure tin exposed areas after soldering onto board and 500 thermal cycles, Life & THB (JESD-201 class 2 requirements for the testing proposed)

Some expected recommendations:

- Constructional Analysis and Tg/CTE recommended to be done on each new lot to substantiate similarity in ECSS-Q-ST-60-38C1 mounting qualification (presently not allowed for COTS)
- Only Constructional Analysis needed for AEC parts for grade-2 & 3 mission.
- Full qualification needed only on 1st lot of AEC parts for grade-2 & 3 mission.
- No SnPb retinning needed based on JESD-201 class 2 and further preventive measures (coating, barriers, etc..)