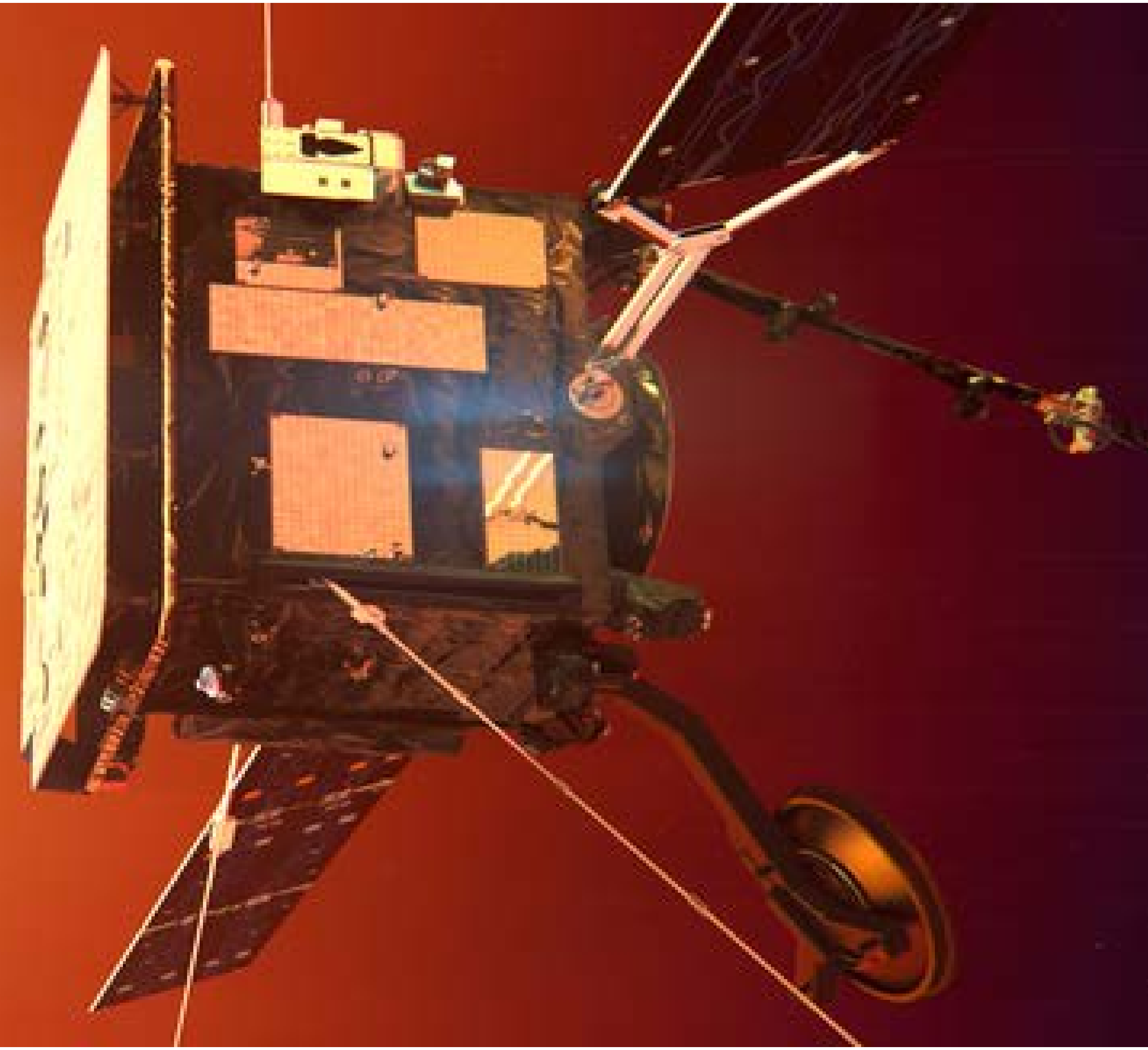
COTS APPROACH FOR SOLAR ORBITER

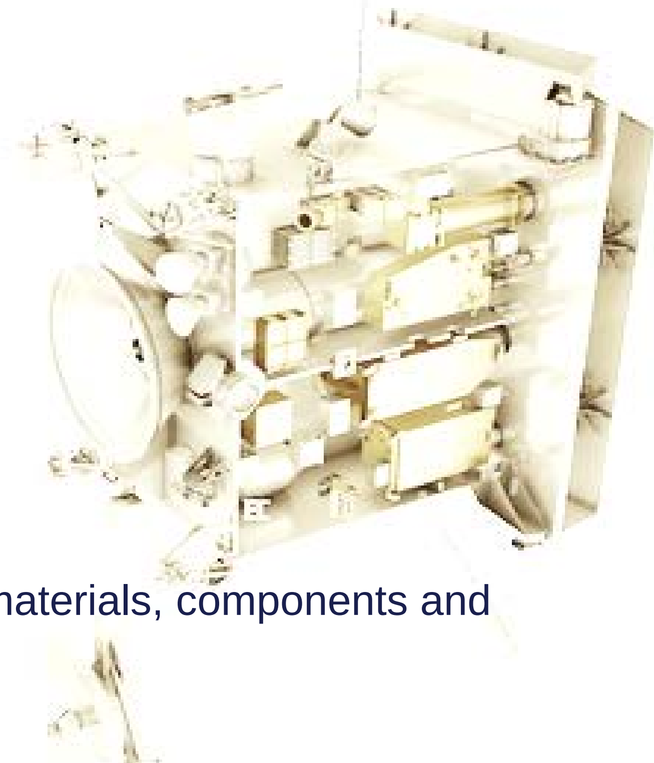


ESCCON 2016

Noordwijk 1st to 3rd March 2016

OUTLINE

- Overview of Solar Orbiter CPPA contract
- Statistical data
- Evaluation and screening test flow
- Technical experience and lesson learnt:
  - Case #1: issue of lack of verified data in data sheet
  - Case #2: CSAM failures and delamination issues
  - Case #3: Retinning process and solderability issue
  - Case #4: OTS complex device (identification of critical materials, components and production processes)
  - Case #5: Low temperature application
  - Case #6: lack of manufacturer awareness of product capability and performances



SOLAR ORBITER CPPA OVERVIEW

- Solar orbiter has a suite of 10 instruments split between in situ and remote sensing provided by national agencies and NASA to ESA
- During phase B1 many PI of European instruments expressed the wish to have a coordinated procurement scheme for EEE parts
- The negotiation with Solar Orbiter prime contractor was concluded without the agreement on setting-up a CPPA scheme
- Before the PDR cycle had started, some preliminary DCL were made available:
  - commercial components that could have been easily replaced with space qualified equivalent were listed
  - exotic components to cover specific performance needs were also highlighted
  - new technologies (at that time not qualified yet) were also requested
- Solar Orbiter requirements for instruments: Class 2+ and Class 1 for interface with the spacecraft
- Total design dose varying from instruments inside the spacecraft and instruments on the booms- safety margin = 2

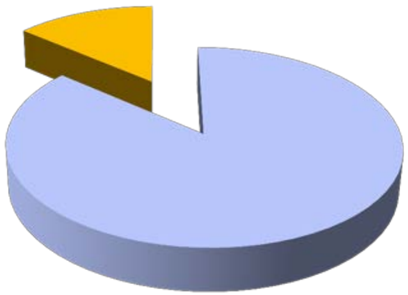
SOLAR ORBITER CPPA OVERVIEW

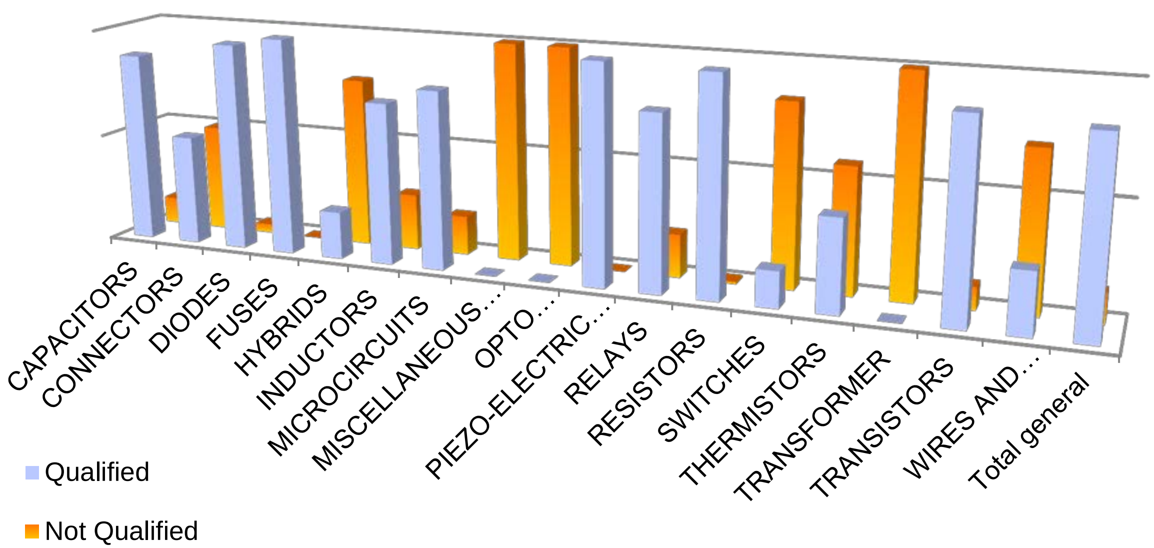
- ESA project decided to implement a CPPA for instruments considering high the risk associated to self procurement by complex consortia not necessarily experienced in EEE procurement for space
  - ITT was published in August 2011
  - Contract awarded by Alter - Seville
  - KO of the contract was in November 2011 with first user meeting held on 5th December 2011- before the PDR cycle of instruments
  - Contract managed directly by ESA technical officer working in synergy with ESA instrument team, product assurance and cost controller
  - ESA directed the CPPA to provide a wide range of services, especially covering the cases of “difficult procurement”
  - The CPPA contract was extended up to the end of Q1 2016 following the elongation of the overall project
- 9 instruments consortia used the CPPA services
  - 70 different users spread over 13 different countries

STATISTIC

- **3769 line items procured for FM**

Qualified	Not Qualified
86.26%	13.74%





	ESCC	MIL	NOT QUALIFIED
CAPACITORS	391	197	83
CONNECTORS	123	2	123
DIODES	76	131	9
FUSES	1		
HYBRIDS		16	57
INDUCTORS	50	2	18
MICROCIRCUITS	39	358	88
MISCELLANEOUS PARTS			2
OPTO ELECTRONICS			29
PIEZO-ELECTRIC DEVICES	3		
RELAYS	4		1
RESISTORS	859	796	21
SWITCHES		1	5
THERMISTORS	12	2	19
TRANSFORMER			14
TRANSISTORS	107	70	21
WIRES AND CABLES	11		28
Total	1676	1575	518

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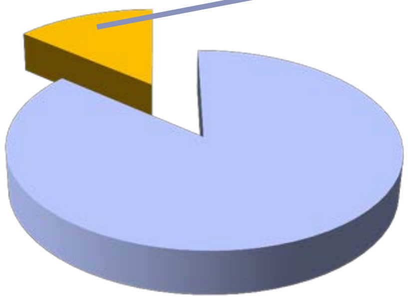
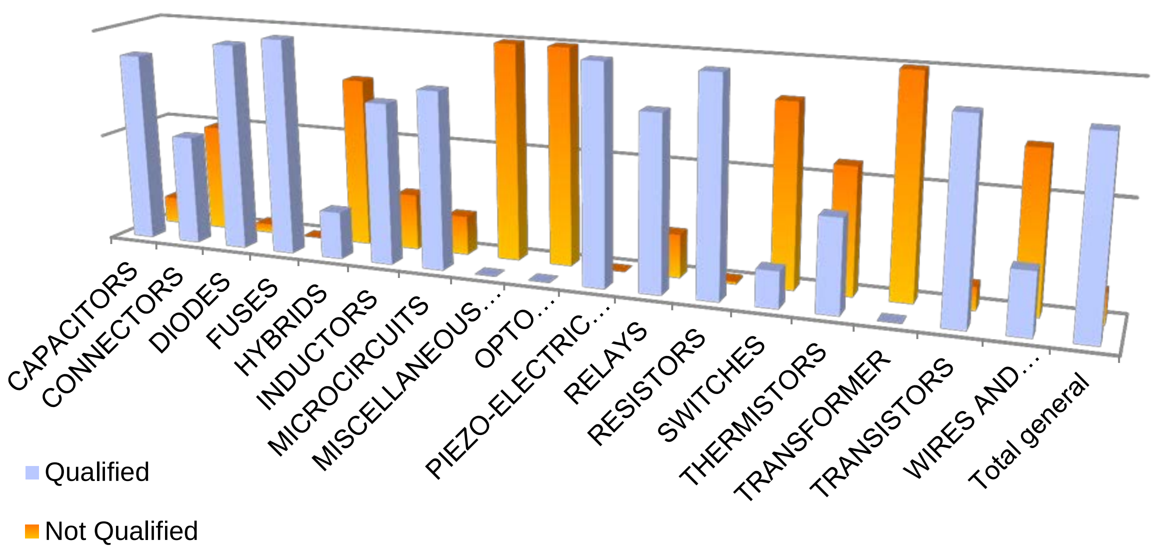


Limited figure thanks to the intense work of standardization that has been performed by CPPA/ESA before instruments PDR



	ESCC[illegible]	[illegible]	[illegible]FIED
CAPACITORS	391	197	[illegible]
CONNECTORS	[illegible]	[illegible]	123
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WIRES AND CABLE	[illegible]	[illegible]	28
Total	[illegible]	[illegible]	518

Mostly space OTS

Mostly oscillators

Mostly space OTS

Majority of items that needed a full evaluation

High voltage and flexible cable assy

STATISTIC

- **14 Evaluation performed by CPPA**
- **15 Line items were submitted to screening by CPPA**

08	Microcircuit	AD8005
12	Transistor	BF862
18	Optoelectronic	OZ150
18	Optoelectronic	SFH4253-Z PLCC-2
12	Transistor	2SK3320
08	Microcircuit	LT1352IS8
01	Capacitor	MKS4D024703C00KSSD
01	Capacitor	MKS4D021003C00KSSD
18	Optoelectronic	UVTOP255TO18FW
99	Miscellaneous	DW-AD-603-03-686
04	Diodes	MMBD1503
12	Transistor	U404
04	Diodes	BAV99S SOT-23
18	Optoelectronic	RZ677

- The figures herein reported are limited to those items that were fully commercial (manufacturers not equipped/interested to offer any upscreening/qualification activities)
- Additional delta qualifications were performed with the support of manufacturers and are not herein considered, however they constitutes the bulk of the 518 Not Qualified items procured by CPPA

EVALUATION & SCREENING FLOW

INCOMING (100%)

SERIALIZATION

PRE-EVALUATION (34 +2 ctrl)

Electrical @ 5T
(10 samples)

Finish material analysis
(5 samples)

TID
(12 samples)

DDEF
(12 samples)

Screening

EVALUATION (35 samples +3Ctrl)

Electrical @ high and low T

CA + retinning evaluation
(5 samples)

Humidity life
(10 samples)

Temperature cycles
(10 samples)

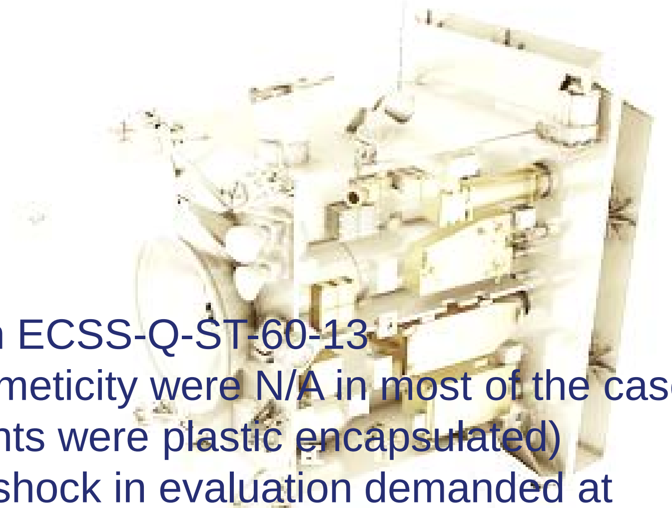
Life test
(10 samples)

DPA
(3 samples)

EVALUATION and SCREENING FLOW

SCREENING (100%)

- Retinning
- X-Ray
- Temperature cycling
- Electrical @ RT
- Burn-in
- Electrical @ RT, HT and LT
- PDA calculation
- External Visual Inspection



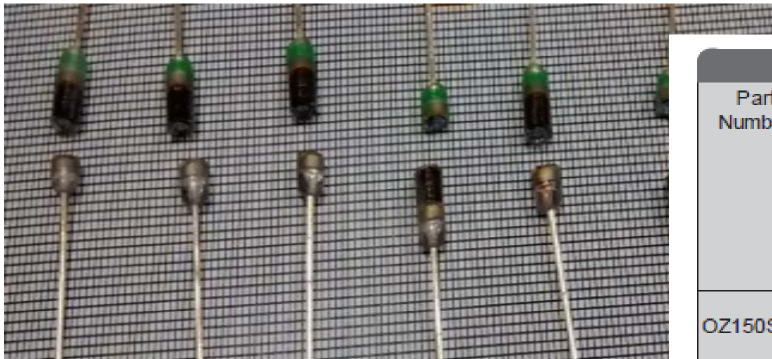
- Flow based on ECSS-Q-ST-60-13
- PIND and Hermeticity were N/A in most of the cases (the components were plastic encapsulated)
- Vibration and shock in evaluation demanded at assembly level (due to exotic packages and assembly techniques)
- Outgassing was also part of evaluation when the plastic compound figure was unknown
- Whenever no Single wafer lot was assured then TID and Life test sampling was increased by 40%

TECHNICAL ISSUE & LESSONS LEARNT

- COTS are very unlikely advantageous for cost point of view (at least for small quantities and for single design)
- COTS selection shall be driven by specific performance needs
- The selection of a potential COTS can't avoid a detailed manufacturer assessment
- The co-operation of the manufacturer is an important key for a successful implementation of any evaluation activity (especially for exotic parts or for OTS complex device)
- Definition of test limits and allowed drift is always quite problematic due to lack of data in the data sheet
- Tight co-operation with the user is also of benefit in defining specific test conditions in life test or in radiation test and in the evaluation of any NCR, tailoring the test somehow to the real application
- In the examples reported herein, the aim is to highlight class of technical issues that we have encountered during the evaluation and screening activities and not to focus on the specific part types or manufacturers

Case of OZ150: after 1 thermal cycling among 85°C to -40°C , 49 out 72 samples failed “structurally”

WRONG DATA in DATA SHEET



ELECTRICAL CHARACTERISTICS AND MAXIMUM RATINGS

Part Number	Working Reverse Voltage (Vrwm)	Average Rectified Current (Io)		Reverse Current @ Vrwm (Ir)		Forward Voltage (Vf)		1 Cycle Surge Current tp=8.3ms (Ifsm)	Repetitive Surge Current (Ifrm)	Reverse Recovery Time (3) (Trr)	Thermal Impedance $\theta_{J\text{-}L}$			Junction Cap. @50VDC @ 1kHZ (Cj)
		55°C(1)	100°C(2)	25°C	100°C	25°C		25°C	25°C	25°C	L=000	L=.125	L=.250	25°C
	Volts	Amps	Amps	µA	µA	Volts	Amps	Amps	Amps	ns	°C/W	°C/W	°C/W	pF
OZ150SG	15000	0.30	0.15	1.0	25	18	0.30	10	2.00	3000	6	9	18	5.0

(1)TL=[illegible] L=0.375" (2)TL=100°C L=0.375" (3)If=0.5A, Ir=1.0A, Irr=0.25A *Op.Temp.= -65°C to +175°C Stg.Temp.= -65°C to +200°C

*Op.Temp.= -65°C to +175°C Stg.Temp.= -65°C to +200°C

Manufacturer replied that they were told about similar failure by one other user and they had recently updated the data sheet with a tighter temperature range (-40 °C to + 70°C) and with the warning that this part should not see thermal cycling.

OZ150 rejected for flight

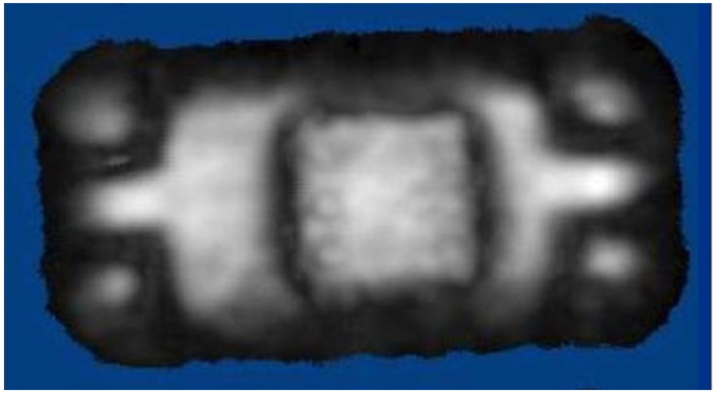
replaced by RZ677 (thinned glass version of OZ150)+ parylene coating that passed the screening and evaluation

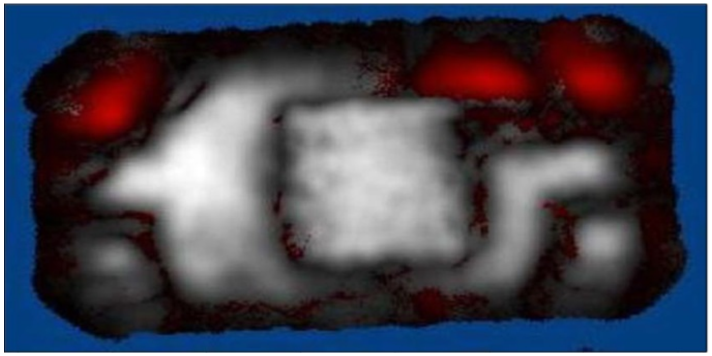
CSAM FAILURE & DELAMINATION

In several part types of PEM, CSAM failures due to delamination were detected at different stages of evaluation campaign

AD8005
CSAM failures detected after 100 Temp cycles

- CSAM introduced after 10 TC to check if initial delamination could occur during screening (CSAM OK)
- CSAM introduced at the end of life test. No delamination evolution observed
- NRB disposition: accepted for flight





Nb: CSAM is performed according the test method JEDEC J-STD-020E

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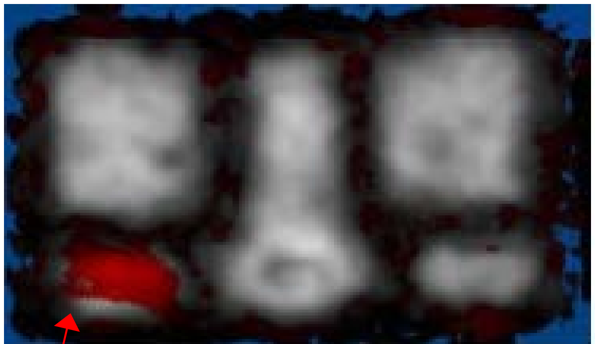
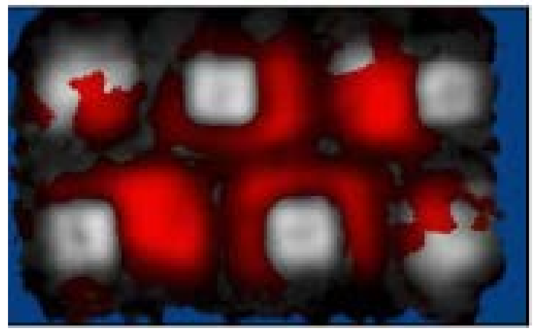


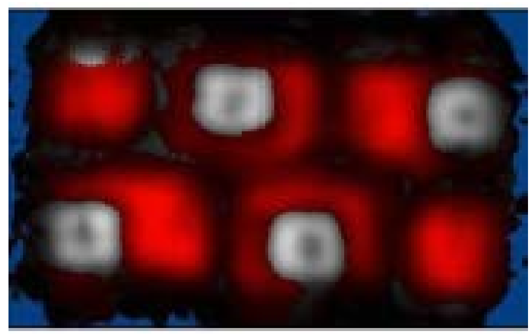
Decohesion indication on one pin

2SK3320

CSAM failure detected during CA

- CSAM performed during evaluation at different steps during thermal cycling and life test
- No evolution observed
- Lot accepted for flight





BAV99

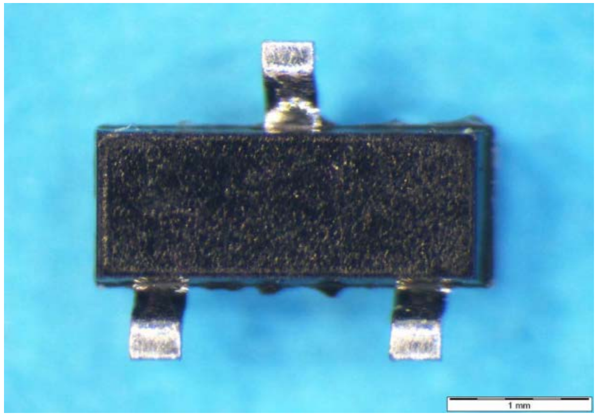
CSAM failure evolution after retinning

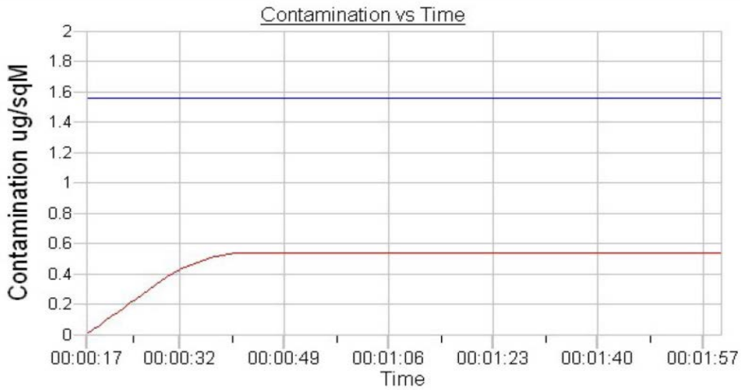
- Small evolution observed in temperature cycling
- Defects considered acceptable due to the benign application condition:
- Limited temperature cycles expected in orbit
- Diode polarized in reverse, no power dissipation

Nb: CSAM is performed according the test method JEDEC J-STD-020E

Most of the COTS selected by instruments had pure tin finish and needed to be submitted to PbSn retinning process without stand-off

RETINNING & SOLDERABILITY





BF862

After retinning parts were submitted to different test group and dewetting areas were detected – solderability test failure.

The standard RMA flux was not adequate to guarantee a good wetting

A new more active flux that contains amino-acid halide was used with successful results.

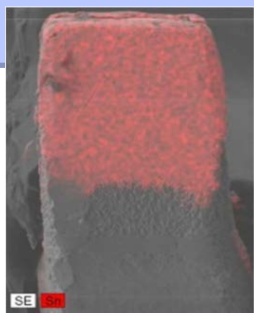
A ionic contamination analysis was performed on the retinned surface with the new flux to verify that no flux residuals have been left

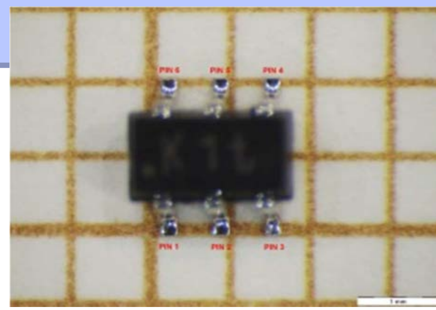
RETINNING & SOLDERABILITY

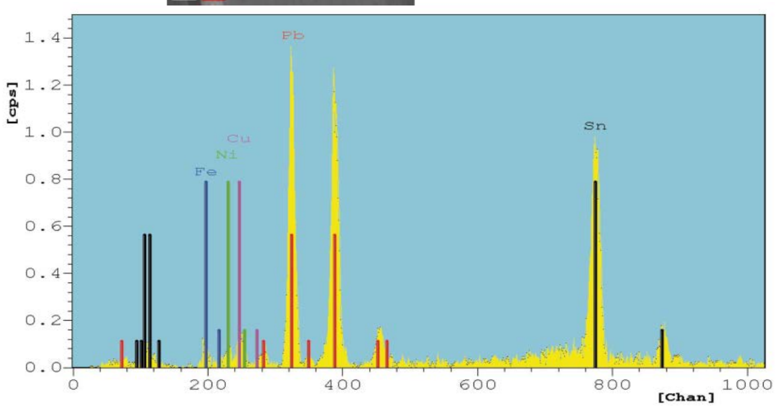
BAV99

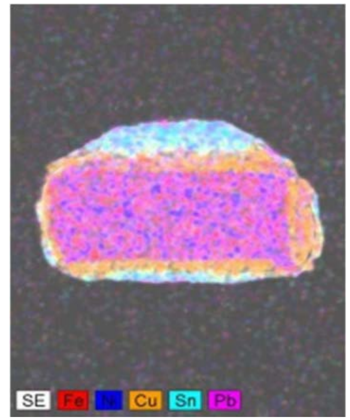
Solderability issue observed at assembly house on screened devices

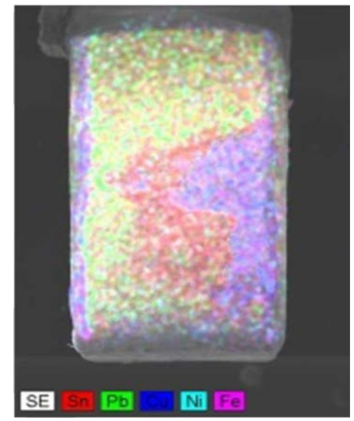
Parts were submitted to standard retinning process without stand-off and then submitted to Fischerscope and external visual inspection successfully.











The FM batch was submitted to screening and at the assembly house they found a very poor wettability and difficulties in solder the parts on the board.

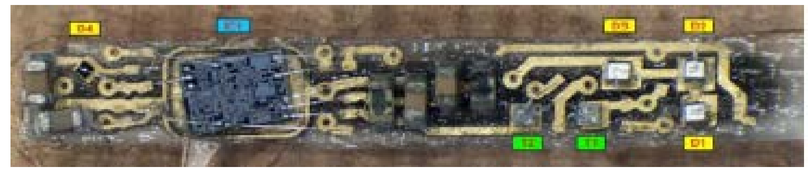
Additional analysis showed that the lead surface was highly degraded with exposure of underplating base material and Cu.
Defectivity increased with screening

OTS COMPLEX DEVICE

PHI instrument needed an inductive proximity sensor. The best candidate in terms of performances and dimensions was

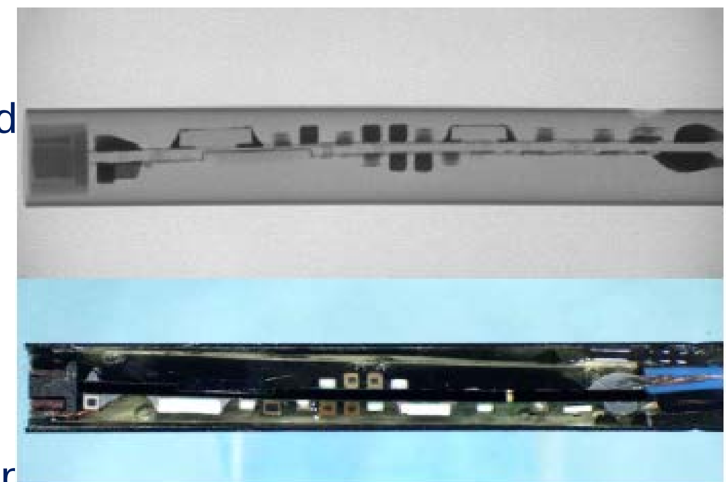
Contrinex **DW-AD-603-03-686**

hybrid on flexible PCB potted with naked dies + bipolar ASIC + passive and packaged discrete



The plan:

- Technical visit to manufacturer to assess technology, traceability, ASIC technology, materials, design analysis, manufacturing processes and quality system
- Manufacturer highly interested in co-operation, provided sensors and passive add on parts to perform ded
  - Constructional analysis at hybrid level
  - Constructional analysis of capacitors and resistors
  - Outgassing on Polyester Sensing Surface Material
  - Ionic Analysis Contamination on flexible PCBs
  - Standard PVC Cable replaced by ESCC qualified cable
    - Problems detected with the assembly of new cable to the rigidity), an alternative cable not ESA qualified but sp



(It is not an easy task to replace components/materials in standard product)

Process controls during the manufacturing of the lot was an important key for success

OTS COMPLEX DEVICE

ALTER inspector witnessed the production of Solar Orbiter lot:

- Assembly of all add-on components
- Automatic and manual Wire bonding process
- Soldering cable process
- Potting process
- Precap and Buy-off inspection

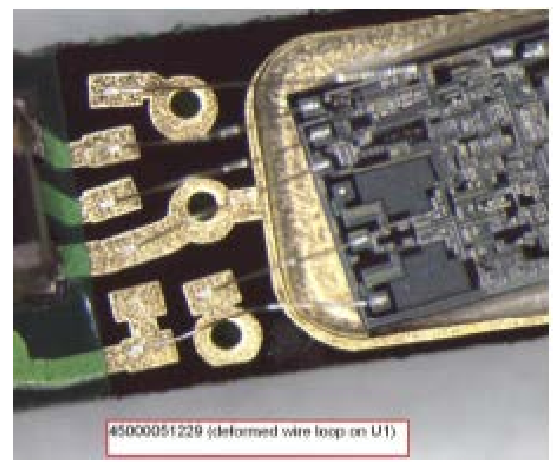
Some parts were rejected during the production by inspector

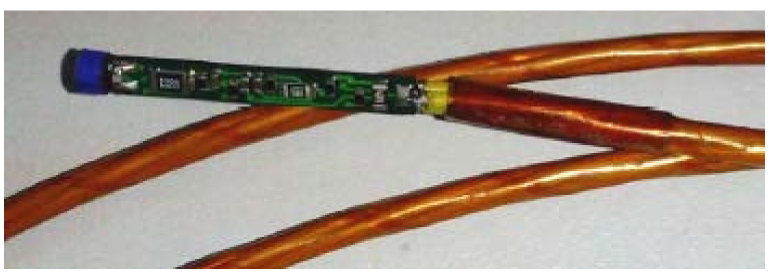
Updating of several internal procedures and introduction of additional tests not in standard production

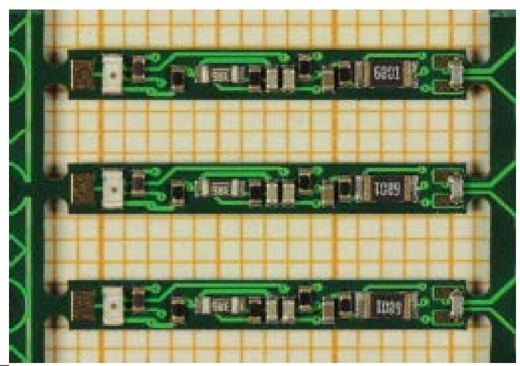
Calibration of equipment was controlled

Technical assessment provided during the manufacturing process

Specific Reworking process added





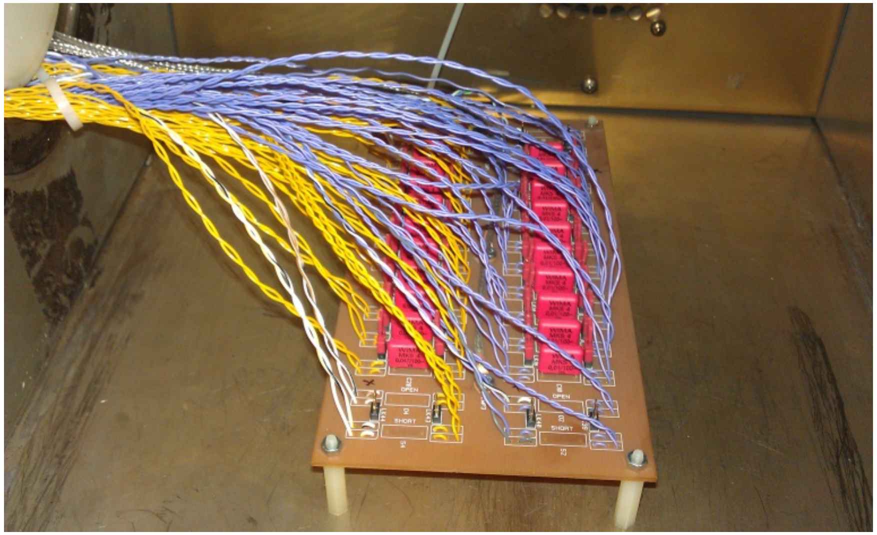


MAG instrument needed capacitors operating and surviving @ -150°C. MAG team had previous experience with commercial WIMA MSK type.

LOW TEMPERATURE APPLICATION

The objective:

- Evaluation of the capacitors and of the soldering method to withstand the low temperature range of the Solar Orbiter (MAG) in de-pointing scenarios.
- One board was provided soldered by Imperial College with 10 (10nF)+10 (47nF) capacitors



The test program:

1 cycle in parallel
1cycle in series
100 cycles unbiased
1 cycle in parallel
1 cycle in series

STEP	Temperature	RATE
1	25 ºC	40 ºC/min
2	-150 ºC	40 ºC/min

Results:

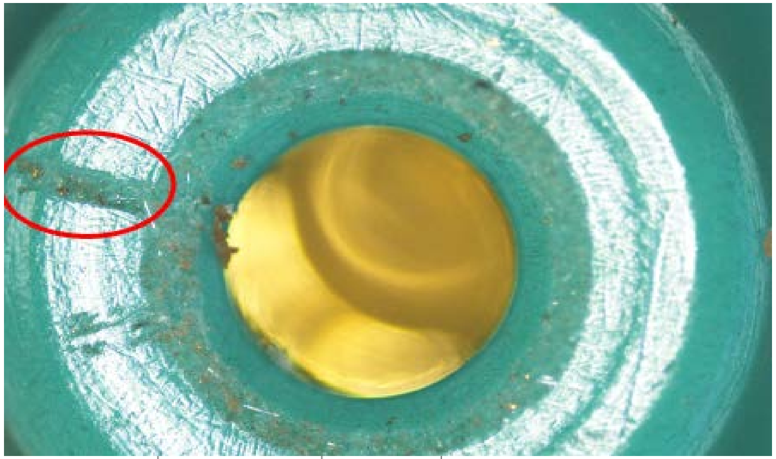
- Capacitors showed a decrease in capacitance of around 10% @ -150 °C
- After thermal cycles no permanent drift or degradations were observed

LACK OF KNOWLEDG PRODUCT CAPABILIT

HV cable assemblies requested by several users.

CPPA/ESA agreed on the test flow proposed by the manufacturer: test conditions and limit were the ones included in the manufacturer standard test flow for space product

- Many failures detected
  - HV test @ Tmax & corona test (results were significantly outside the claimed performance).
  - X-Ray anomalies detected during CSI (voids and lack of central contact alignment) – (100% for detecting manufacturing/assembly anomalies)
  - Receptacles showed contamination and particles (eliminated and cleaned during CSI)
  - Lack of knowledge about production yield (no overrun w.r.t. to quantities ordered in the PO- important impact in schedule)



Sub Assembly P/N	TRL MO	Quantity in Batch	Failure Details
260-0185-0508	MO00911553	8	S/N 5 failed corona (3.3.4) S/N 3 failed HV Tmax°C (3.4.2)
260-0185-1500	MO00911552	8	S/N 1 & 2 failed corona (3.3.4) S/N 2 failed HV Tmax°C (3.4.2)
260-0185-1600	MO00911551	7	All passed all tests (reported for info only)
260-0205-0600	MO00911550	22	S/N 4, 8, 12 & 17 failed corona (3.3.4)

Corona test at 7.5KV and 5KV at ambient temperature and pressure (100%) **reduced down to 3KV**

CONCLUSIONS

- JEDEC and IPC standard for delaminations not 100% adopted by commercial manufacturers
  - CSAM failures difficult to handle especially in case of lack of knowledge of the specific packaging technology used (is a delamination typical or is jeopardising the reliability of the component?)
  - Acceptance based on application criteria / useful to track evolution after stress test
- Technical visit (informal audit) to "unknown" manufacturer is recommended
- CA should include microsection of pins in order to determine composition and structure
- Solderability test followed by SEM inspection should be performed on screened samples as well
- Be prepared to get unusual results: do not give anything for granted, be prepared to adapt your evaluation plan: data sheet data as well as test plan and conditions should be carefully checked
- CPPA played a fundamental role in offering technical advisory, in minimizing not standard parts, and providing the necessary flexibility and expertise in evaluation campaign execution
- Direct ESA management of CPPA contract was a plus in this case because ensured the needed support in dealing with single use "exotic" technology that were however enabling the performance of a specific instrument