Qualification of Commercial Off-The-Shelf Supercapacitors for Space Applications

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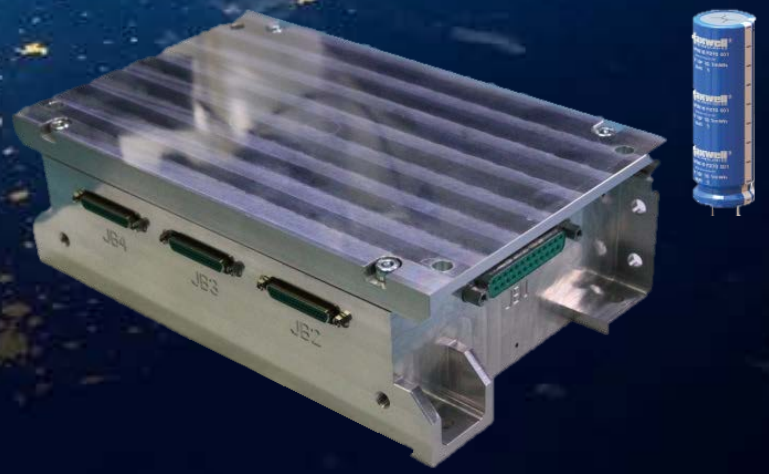

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Space Passive Components Days

12/10/18

Supercapacitors for Space Applications

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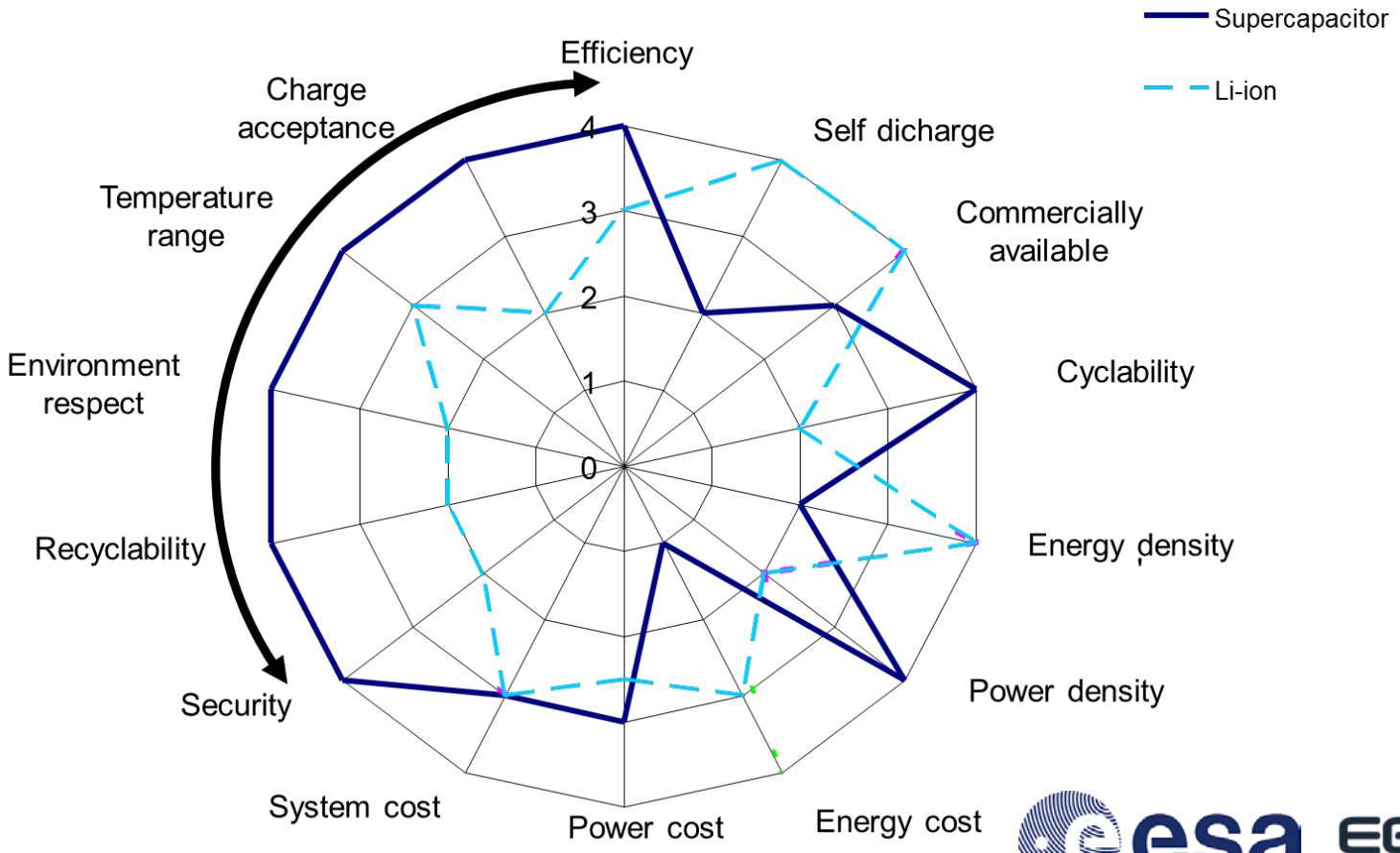
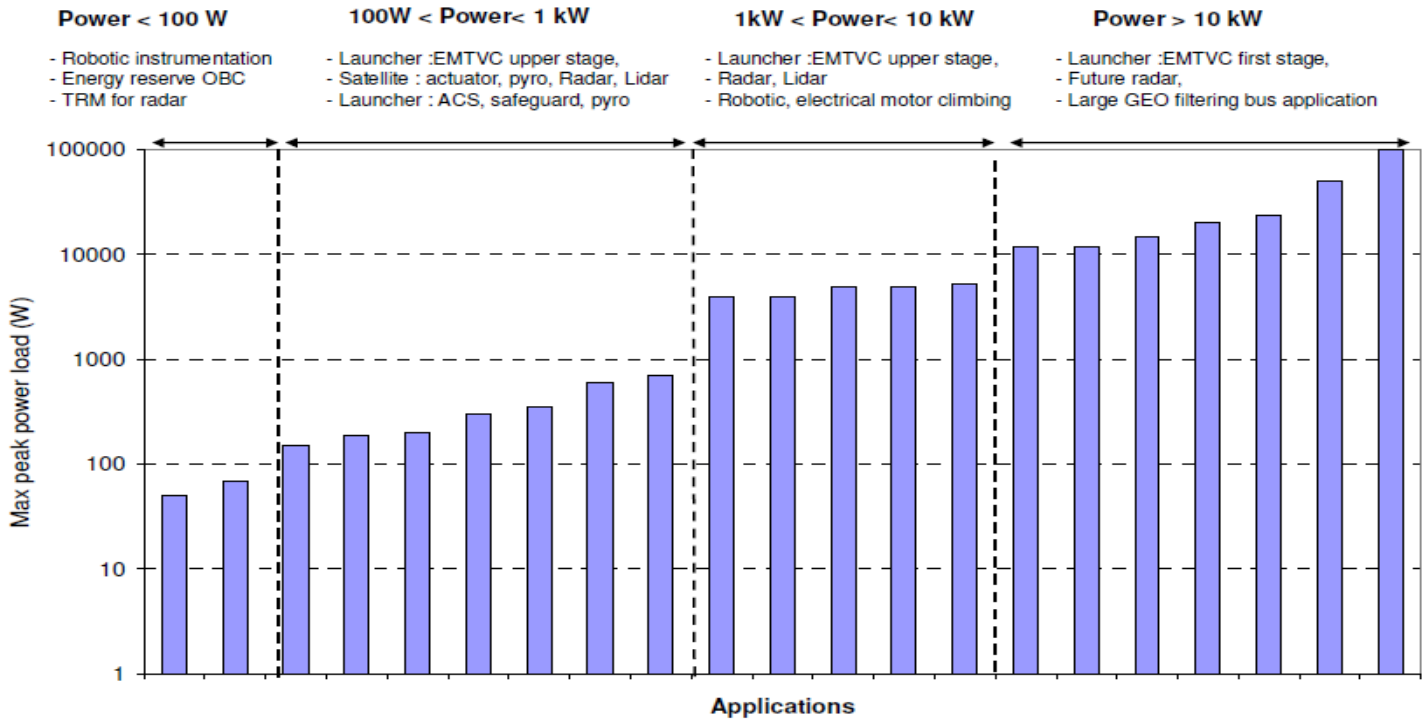
Supercapacitors for space applications

- Satellite and launchers power subsystems are based on batteries (State of the Art = Li-ion), source of energy.
- For some applications, oversizing of the battery on power peaks → embarked mass increase
- Supercapacitor fills the gap between batteries and capacitors, featuring very high power density (up to 100kW/kg) with lower stored energy than that of batteries (up to 7 Wh/kg).



Supercapacitors applications for space applications – Background

- ESA Study Contract No. 21814/08/NL/LvH entitled “High Power Battery Supercapacitor study” completed in 2010
- Potential applications for supercapacitors:



- Supercapacitors have the potential for hybridization with batteries (power peaks < 10s)
- Other applications such as memory back-up
- ESA funded activity under contract No. 4000105661/12/NL/NR “Evaluation of Supercapacitors and Impacts at System Level”

Supercapacitor qualification activities

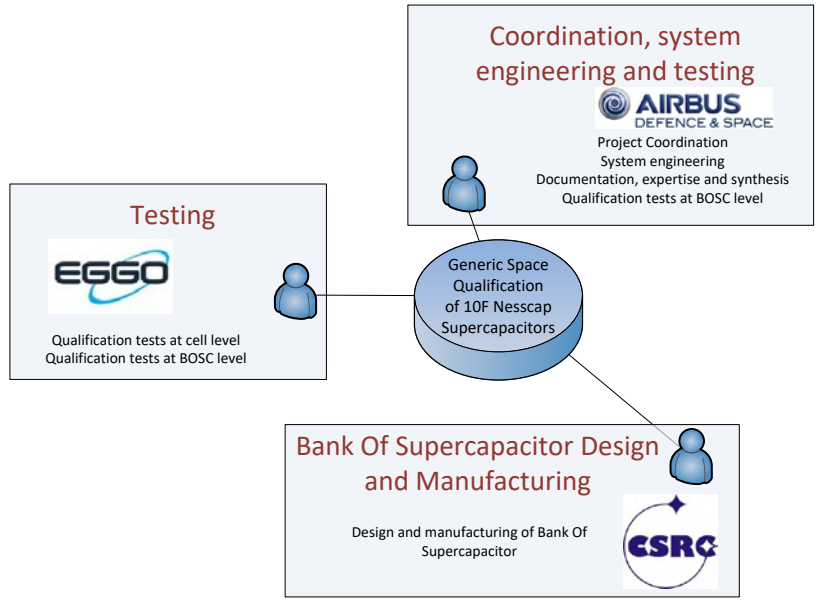
Objectives of the Project

ESA funded activity under contract No. 4000115278/15/NL/GLC/fk “Generic Space Qualification of 10F Nesscap Supercapacitors”.
The project has started in October 2015 and will be completed mid-2019.

Two main activities

- Official test campaign on Nesscap® ESHSR-0010C0-002R7UC in order to have the part introduced into ESA EPPL Part2.

- Development and qualification the associated Bank Of SuperCapacitor



Nesscap → Maxwell 10F supercapacitor

- 2015 : completion of the evaluation project under ESA contract No. 4000105661/12/NL/NR.
- Main outputs:
  - Interest and suitability of COTS supercapacitors for space
  - 10F components from Nesscap® : good candidate for future space qualification.

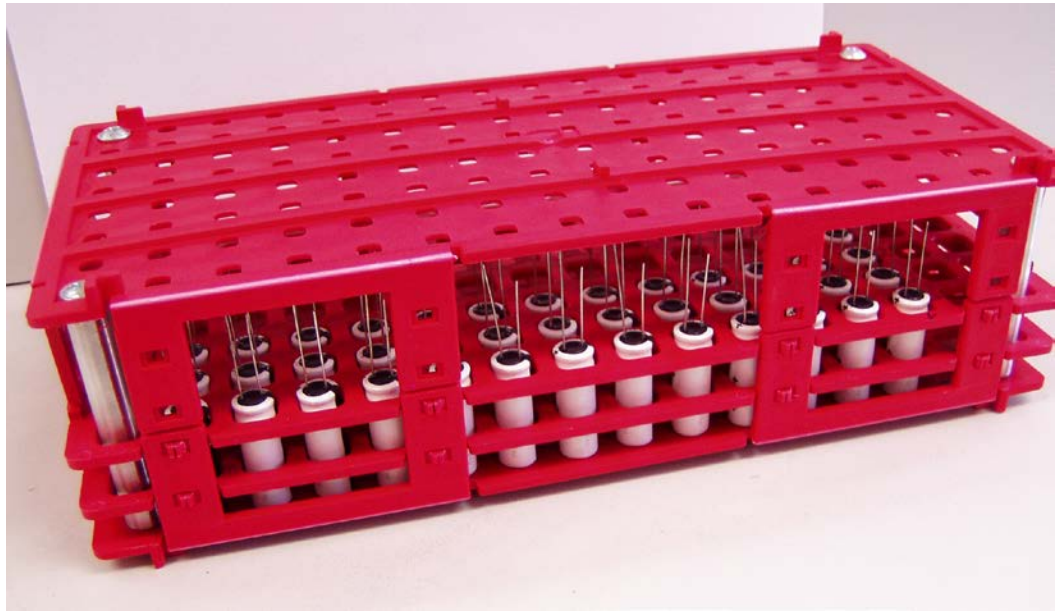
- In 2017 : Maxwell acquire Nesscap.
  - The 10F products will stay in production in the Korea facility, no design charge (only sleeve + reference change)

Manufacturer	NESSCAP → MAXWELL
Reference	ESHSR-0010C0-002R7UC → BCAP0010 P270 X01
Voltage V	2.7
Capacity F	10
AC ESR (average) Ohms	-
DC ESR (average) Ohms	0.0200
Weight (g)	3.2
Packaging	Cylindrical - PCB mount

- In the next slides, only the wording Nesscap 10F will be used

Components Qualification - Test campaign on Nesscap 10F

- Test campaign performed by EGGO Space
- Elaboration of qualification test plan
- Procurement of a 3000 parts batch
- Screening test facilities development / improvements for batches of 200 parts
  - Vacuum testing
  - Burn-in
  - Visual inspection
- Qualification tests campaign



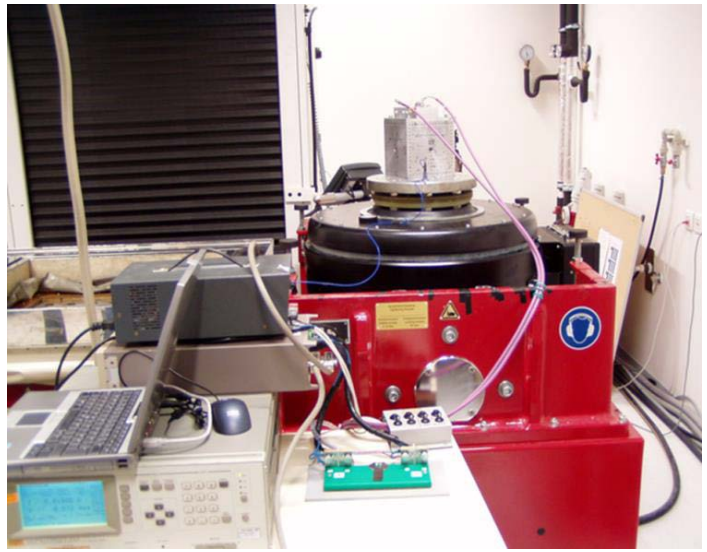
Components Qualification - Test campaign on Nesscap 10F

- The first step of the activity consists in parts screening.
  - Visual inspection
  - Initial characterization
  - Seal test : 3 days under vacuum glass bell (<50mbar) at 20°C
  - Burn-in : 96 hours / 50°C / Voltage: Vop
  - Final characterization

- Screening status
  - Screened 2400 pcs
  - Rejected Visual Inspection: 77 pcs
  - Rejected by screening : 3 pcs capacitance, 1pc ESR, 7 pcs mechanical defects

Components Qualification - Test campaign on Nesscap 10F

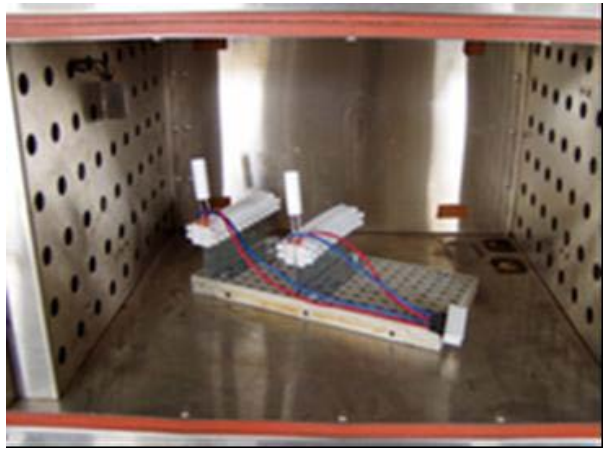
- Initial and final electrical characterization (80 parts)
  - Capacity
  - ESR (DC and AC impedance)
  - leakage current
- Technology analysis assessment (5 parts):
  - External inspection
  - X –Ray inspection
  - Solderability
  - Dimensions
  - Resistance of the terminals
  - Internal visual inspection
- Outgassing test (5 parts)
- Mechanical and Thermal tests (10 parts)
  - X-Ray inspection
  - Vibration
  - Shock
  - Fast temperature transients
  - Seal test
  - Technology analysis assessment

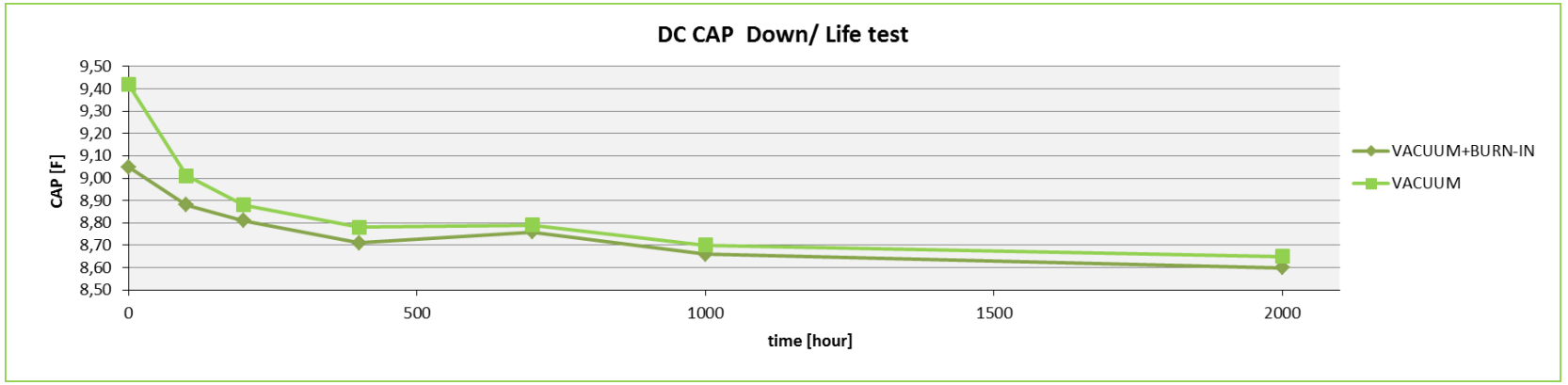


Components Qualification - Test campaign on Nesscap 10F

- Life test (60 parts)
- Floating life test (completed)
  – 20 parts at 0,9*Vop and @ 50°C (success criteria @ 2000h)
  – 20 parts at 0,9*Vop and @ 60°C (success criteria @ 2000h)

- Cycle life tests (completed)
  – 20 parts at continuous 100% energy cycling completed 240.000 cycles

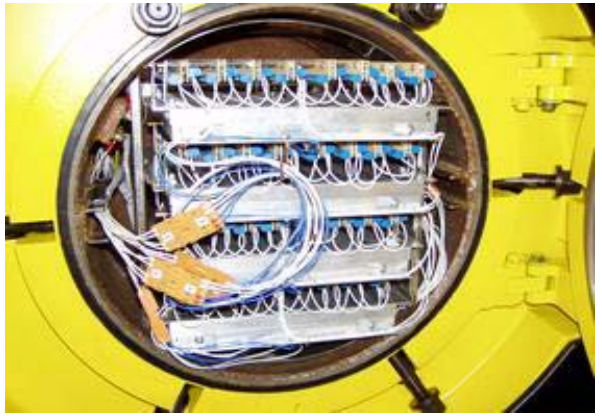




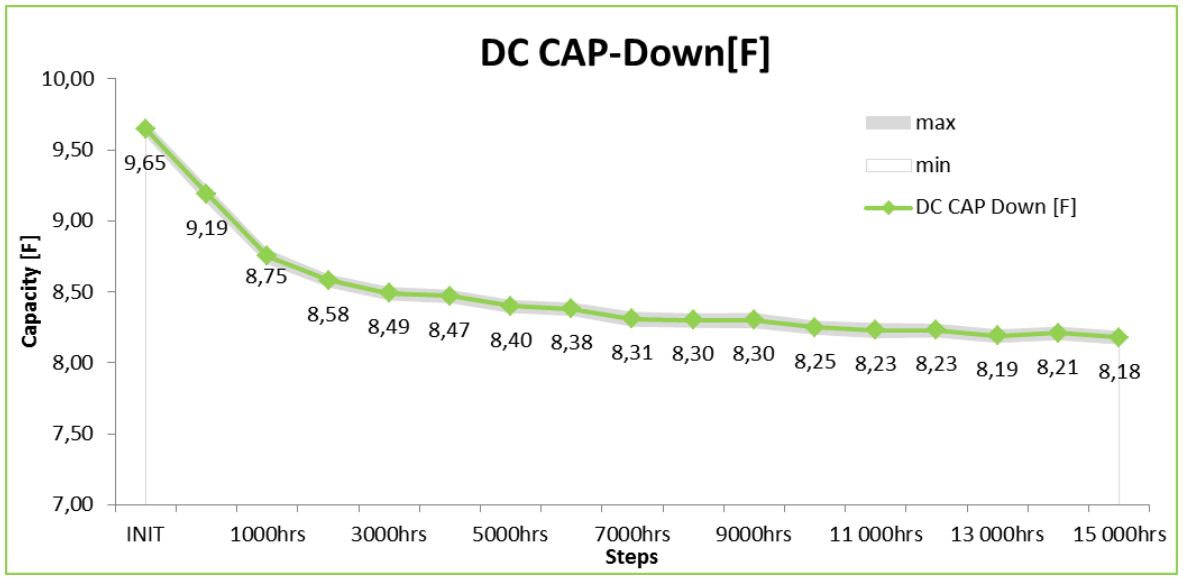
Capacitance degradation for 50°C 0,9 Vop calendar test condition

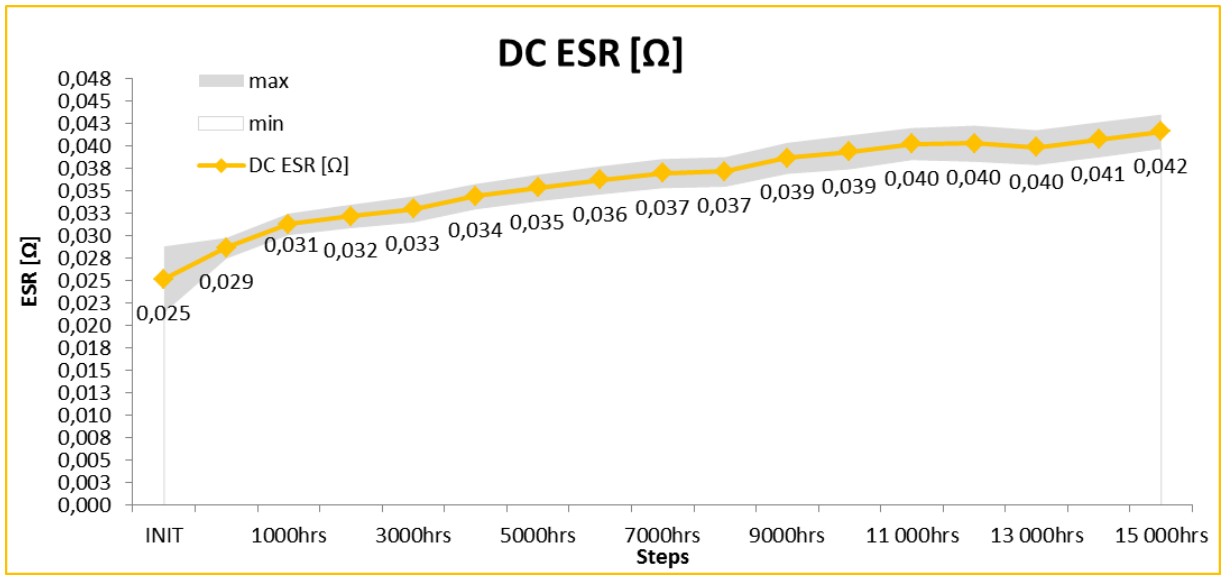
- After 2000h of life test, we can say that that the burn-in does not affect significantly the lifetime of components

Components Qualification - Test campaign on Nesscap 10F



- Vacuum life test (on-going – 15000h completed with no failure)
  - 800 parts to be tested up to 18000 h * in floating life test under vacuum at +55°C





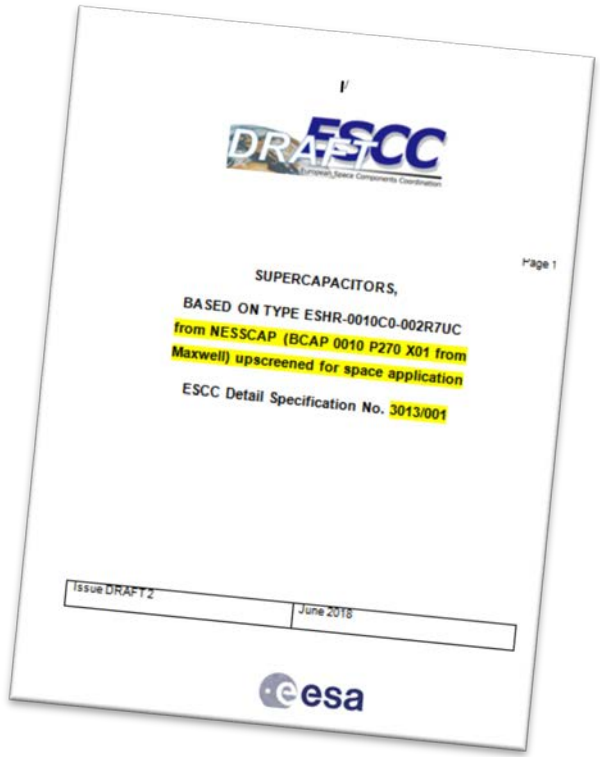
  - MTBF determination : after 15 000h of life test without failure, the reliability rate demonstrated is **24 FIT** for one supercapacitor

** Initially planned to stop at 9000h, extended to 18000h thanks to ESA CCN*

Next steps

- The vacuum testing for MTBF determination will continue up to 18000 hours.

- Two specifications are being currently written at ESCC template :
  - SUPERCAPACITORS, EDLC (Electric Double Layer Capacitor) - ESCC Generic Specification
  - SUPERCAPACITORS, BASED ON TYPE ESHR-0010C0-002R7UC from NESSCAP (BCAP 0010 P270 X01 from Maxwell) upscreened for space application - ESCC Detail Specification



BOSC Design and Qualification activities

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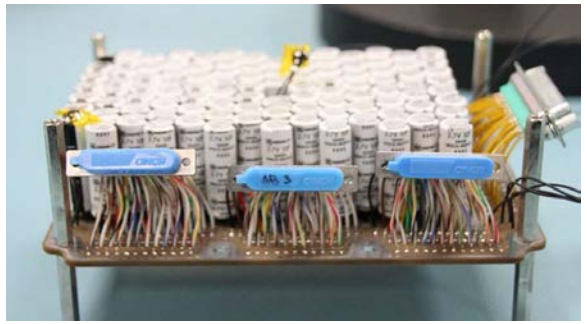
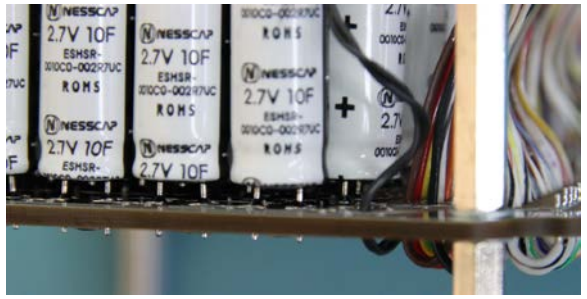
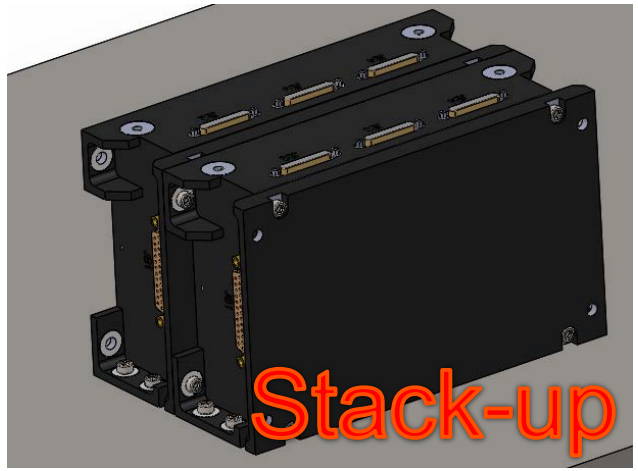
BOSC with Nesscap 10F – Design and Electrical Performances

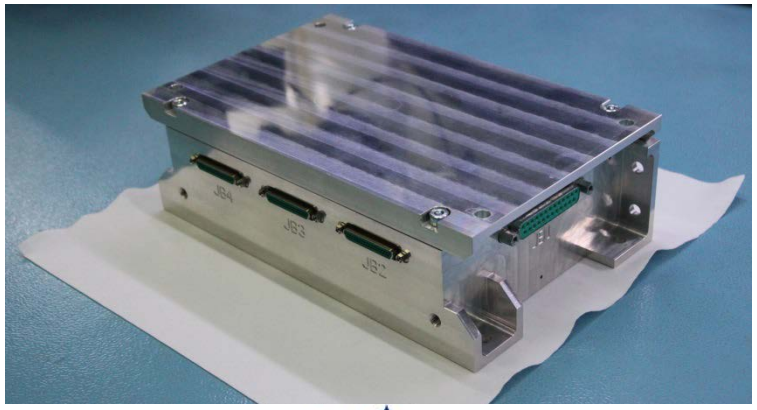




Parameter	Value
Max voltage	72V
Min EOL capacitance	0,62F
Max EOL resistance	0,7Ohms
Average current	+/- 2,4A
Peak current (non repetitive)	+/- 30A
Mass	1,43kg (TBC)
Dimensions	189mm x 116mm x 57mm

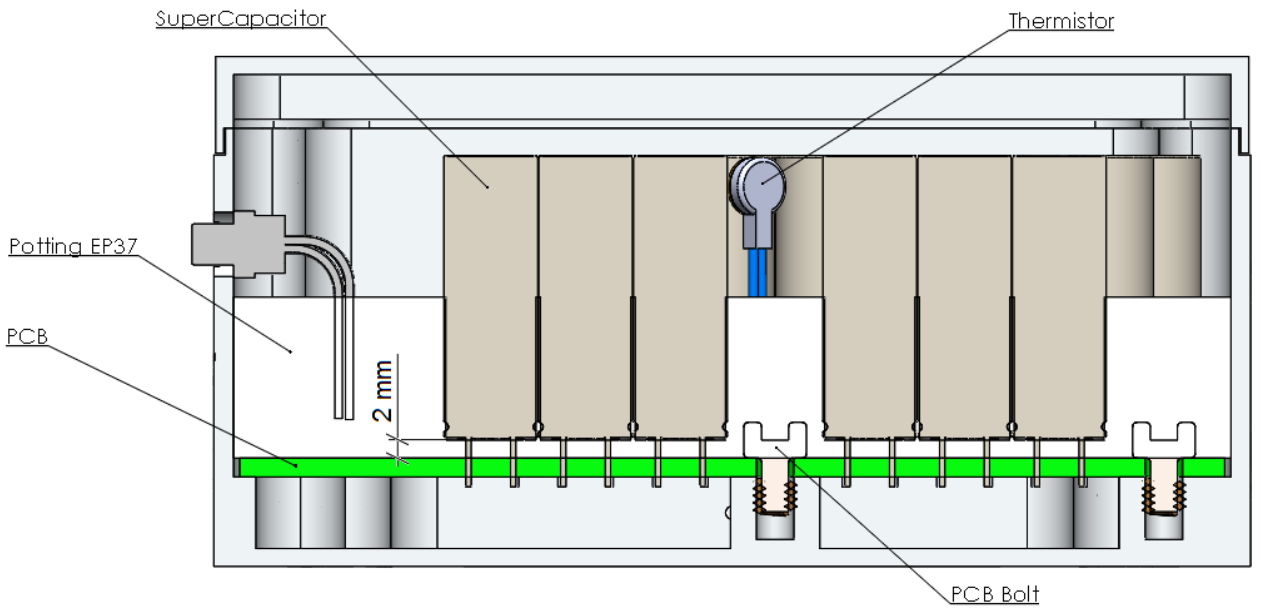


- BOSC design under BD Sensors / CSRC responsibility
- Design completed and CDR passed successfully
- EM1 BOSC manufactured and successfully electrically tested
  - Continuity and isolation : OK
  - Capacitance measured at room temperature (RT) : 0.878 F
  - Steady power consumption @ 72V and RT : 474,5mW
  - ESR at RT: 248 mΩ



BOSC with Nesscap 10F – Supercapacitor Assembly and Potting Need

- Supercapacitor assembly



- Need for potting ?
  The potting has three main functions : to hold the components mechanically, to conduct the heat flux from the components to the BOSC structure and to bring an additional hermeticity layer.

- Potting challenge ?
  Potting selection to meet technical requirements, manufacturability and repeatability of the assembly process, all in accordance with ECSS standards

BOSC with Nesscap 10F – Initial potting solution

- Initial potting choice : ECOBOND 285

- Several activities to define a manufacturing process in order to cope with the viscosity of the adhesive

- Potting qualification on EM1 BOSC (full scale)
  - Thermal cycling on the BOSC (100 cycles -10°C / +55°C).
  - After thermal cycling : tiny crack all around the perimeter of the housing
  - CT scan : reveal crack all long the housing of the potted layer
  - Reason for the crack was probably different coefficients of thermal expansion.
  - Lessons learned: elasticity of the adhesive should be also considered when selecting suitable candidate for potting as after the curing process, the adhesive becomes solid and not elastic at all.

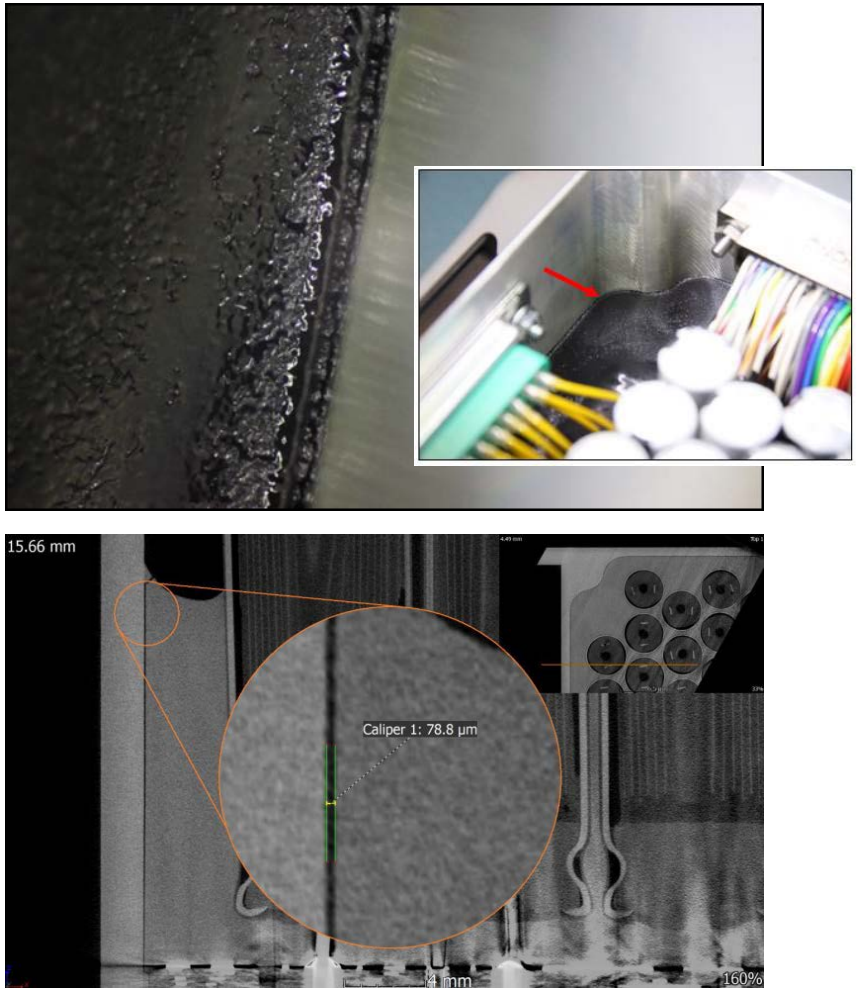


Figure 5- CT scan showing dark line (the crack) between the housing wall and the potting (top of the unit)

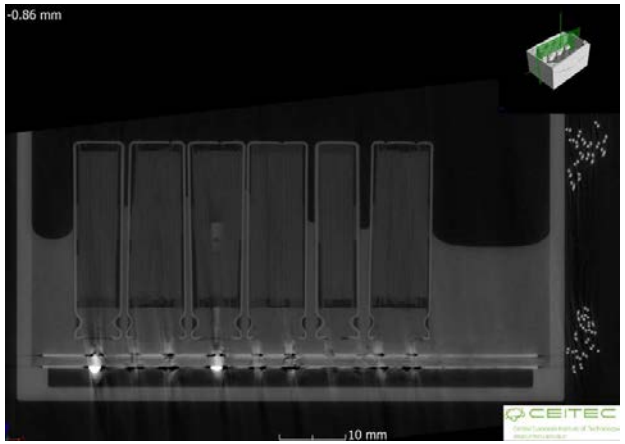
BOSC with Nesscap 10F – Potting investigation

- 6 potential new potting identified and 2 selected - QS1123, EP37 – for their suitable properties and their capabilities to be processed

- Validation of potting
  - Manufacturing of small mock-up samples for thermal cycling test with the 2 potting selected + EC285 as reference
  - Thermal Cycling performed (100 cycles)

	EC 285	QS1123	EP37
Visual inspections after thermal cycling	tiny cracks along the unit wall	No cracks or bubbles	No cracks were found in.
CT scan after thermal cycling	/	/	No major bubbles were present in the potting (<2mm).

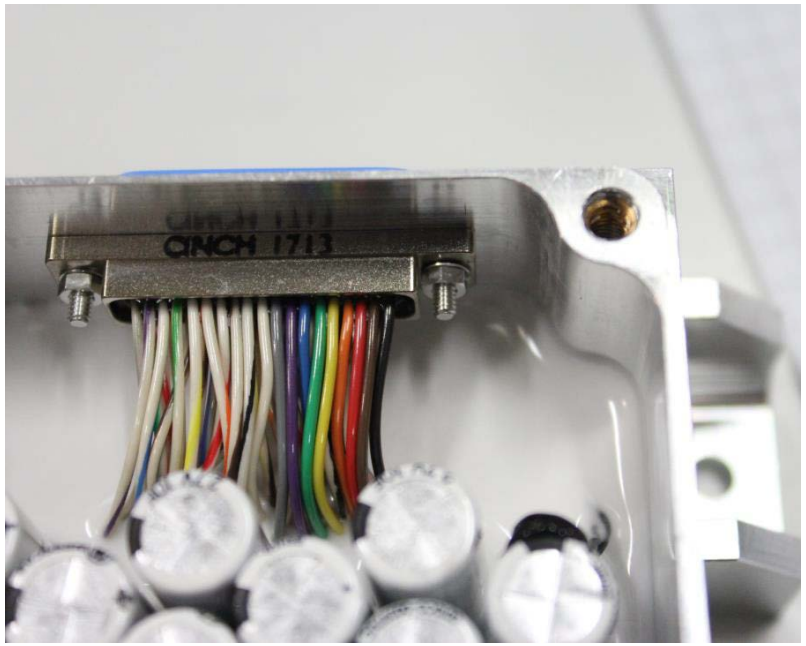
  - EP37 selected due to its higher thermal properties

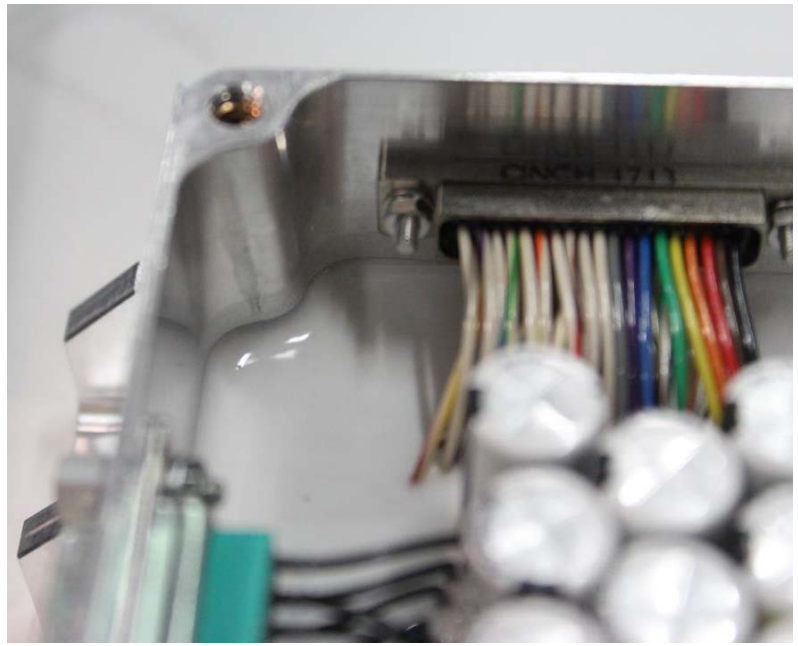


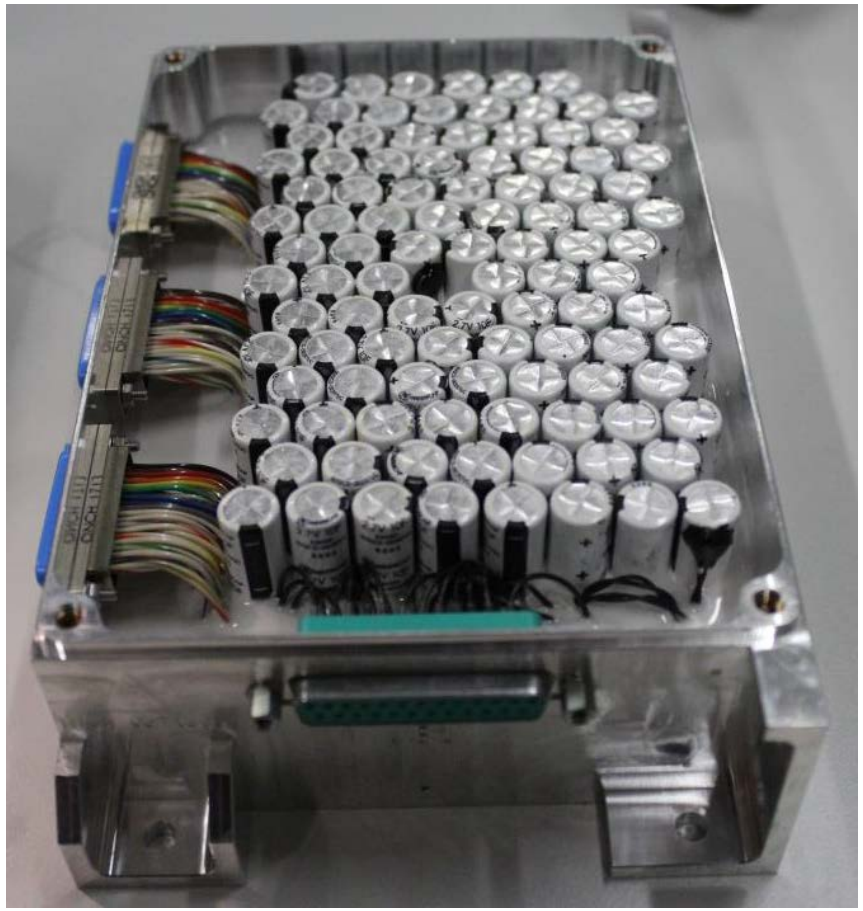
CT scan showing no cracks, no bubbles - EP37 (length side view)

BOSC with Nesscap 10F – Potting selected

- EP37 Potting qualification on EM2 BOSC (full scale)
- Test still on-going
- After 30 cycles of thermal cycling, no problems to report
- 100 cycles to be completed in October 2018





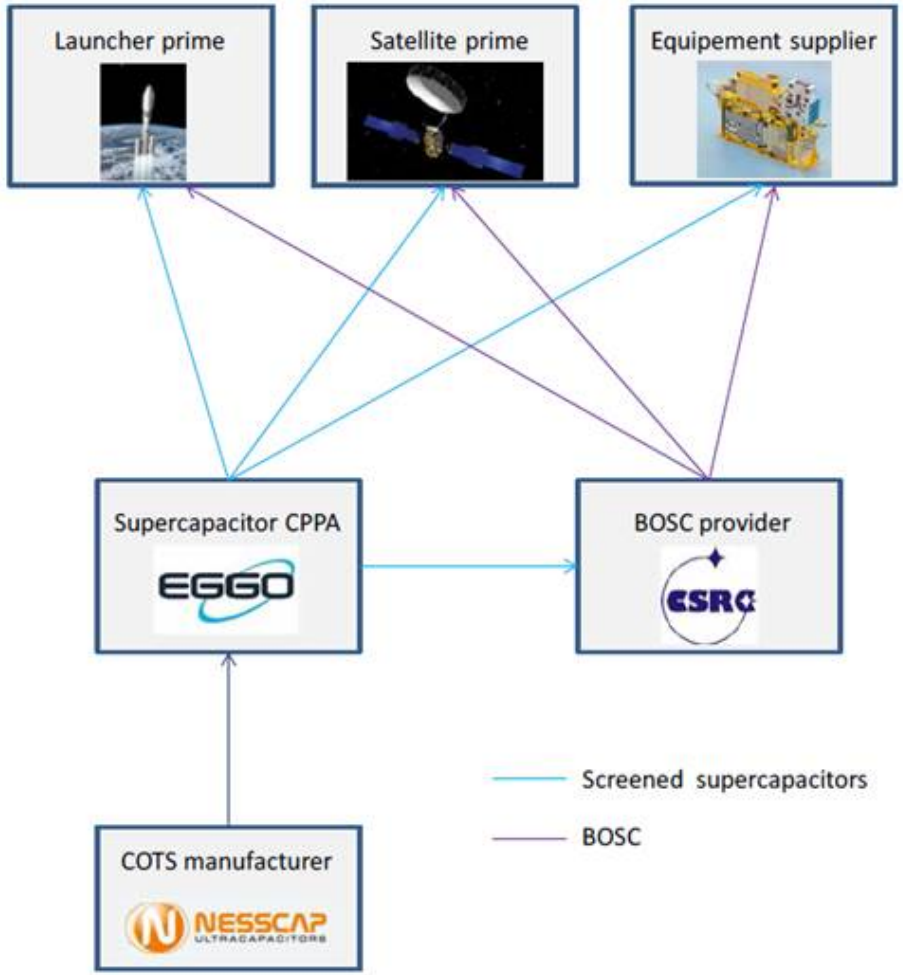


Conclusion and next steps

European Supply Chain for Supercapacitors and BOSC

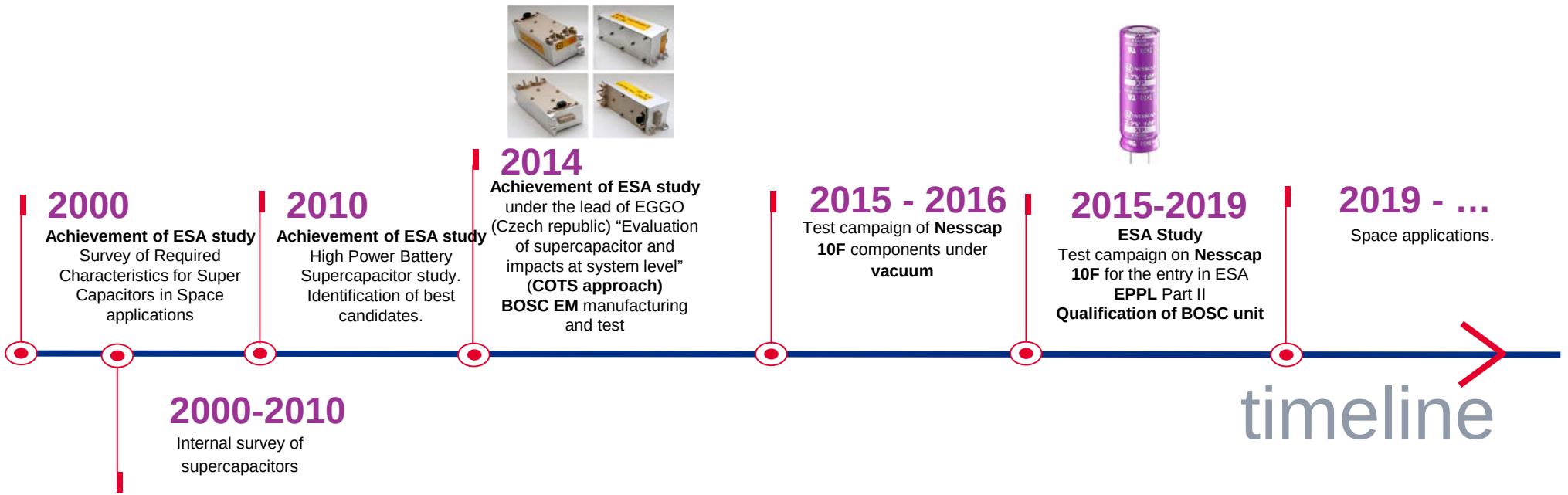
- Once the activity completed, EGGO Space company will take over CPPA in charge of :
  - Parts procurement
  - Screening / Lot Acceptance Tests
  - Sale of parts at space grade

- Once the activity completed, BD Sensors / CSRC will provide BOSC to users



Conclusion and next steps

- Timeline for COTS supercapacitors



- Next steps :
  - Completion of Nesscap® ESHSR-0010C0-002R7UC ageing test under vacuum
  - Completion of BOSC qualification by mid-2019
  - A procurement specification at ESCC format is being established
  - Ready for flight from 2019 !

Thank you
Any questions ?

The view expressed herein can in no way be taken to reflect the official opinion of the European Space Agency.