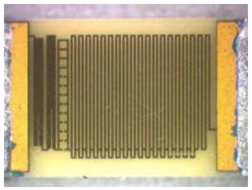
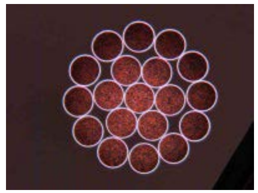
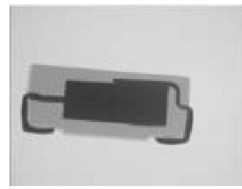
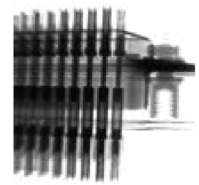
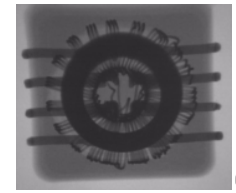
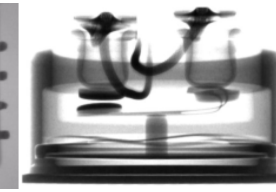
Overview on Passive Components for Space Applications

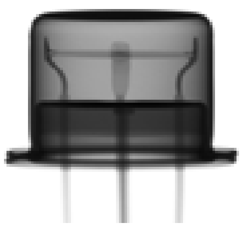
CNES/DLR/ESA
SPCDS - ESTEC
24/09/2013

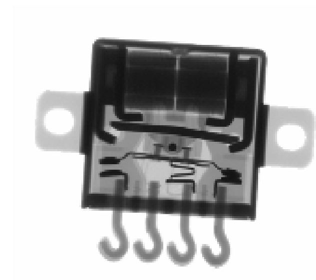
What is a passive component?

No power and no command

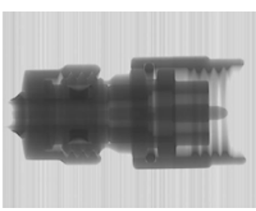
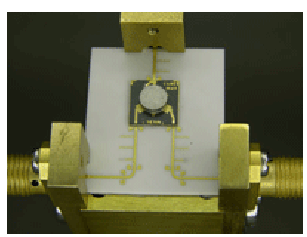







In addition : crystals, oscillators (XO) and relays





Including RF devices

Passive for space application

Passive are on all Projects :

- ~ 70%-80% of EEE parts - ~ 50% cost

⇒ Passive parts might bring far more risk to the system than the active parts

- Important number of PADs, RFD/RFW
- 25 ESA Alerts (20%) and 42 ESA IPN (13%)

Different components, functions, technologies, manufacturers

- Large technical perimeter (ESCC generic : 29, ESCC detail: 212)
- 90% ESCC qualified manufacturers are passive EEE manufacturers
- From small monolithic components (resistors, capacitors) to complex non-monolithic components (relays, transformers, RF devices)
- New families coming soon : XO oscillators, Cable Assemblies

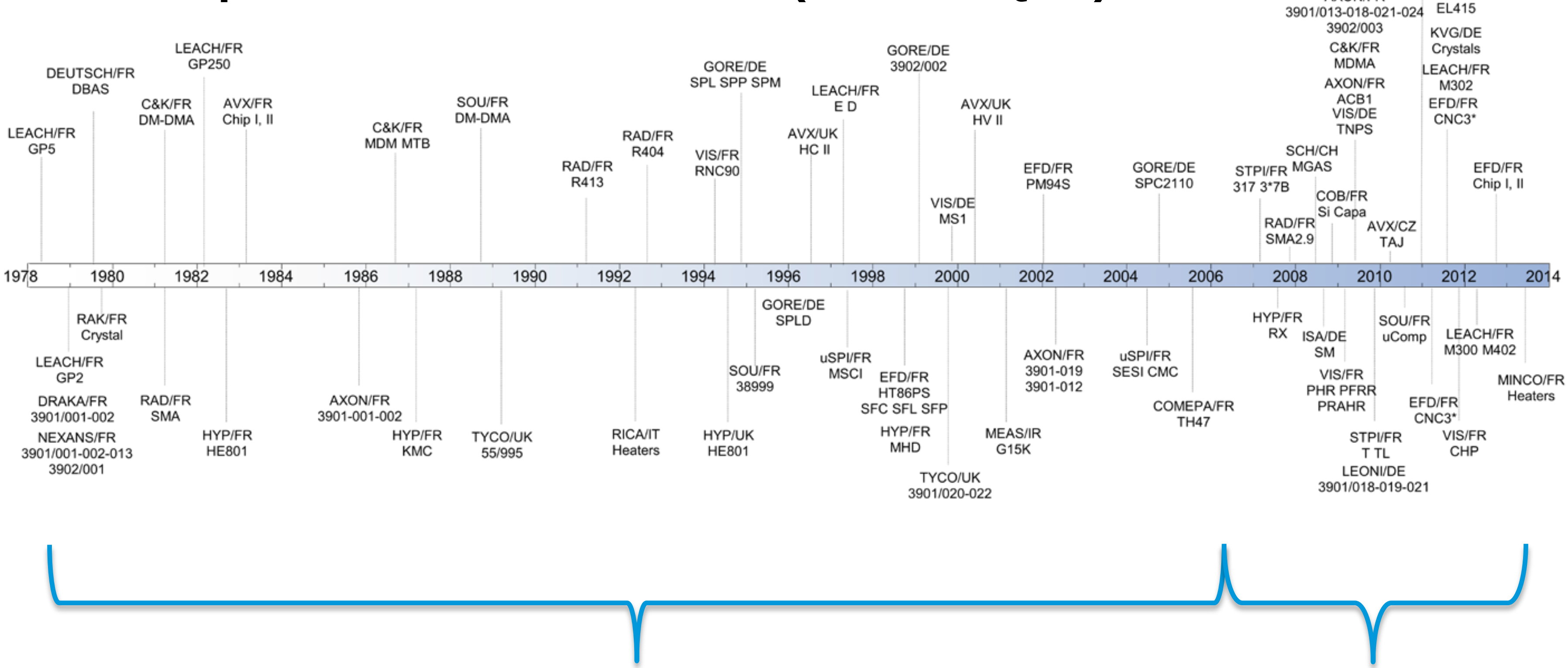
Content

1. European landscape
    a. Evolution of these last years
    b. Competitive market
    c. Manufacturer strategies

2. Issues, needs and solutions
    a. High reliability standard
    b. Lessons learnt
    c. Future trends & new technologies

ESCC Qualifications

31 ESCC qualified manufacturers (90% of QPL)
95 ESCC qualification certificates (80% of QPL)

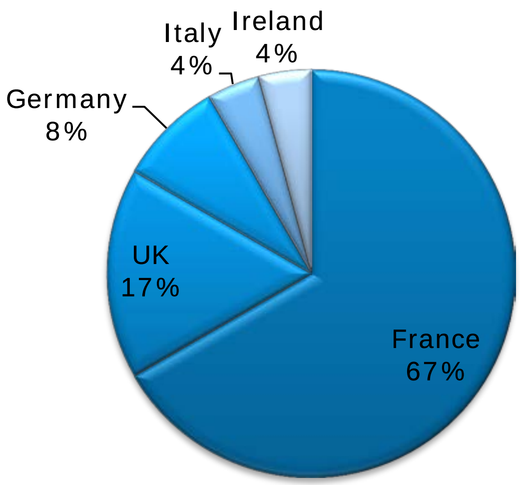


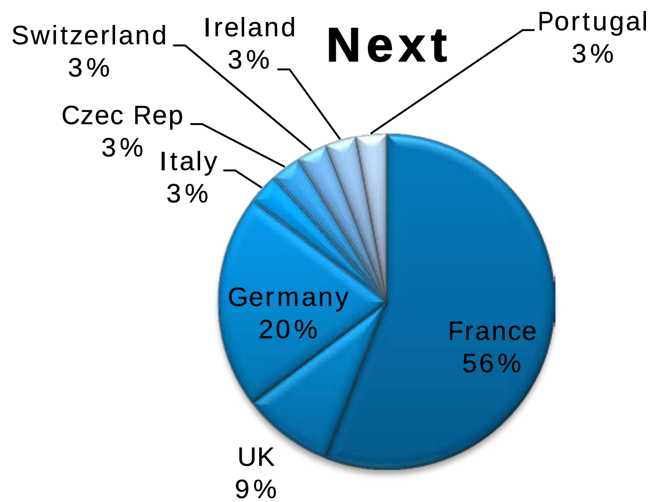
39 certifications
30 years

25 certifications
7 years

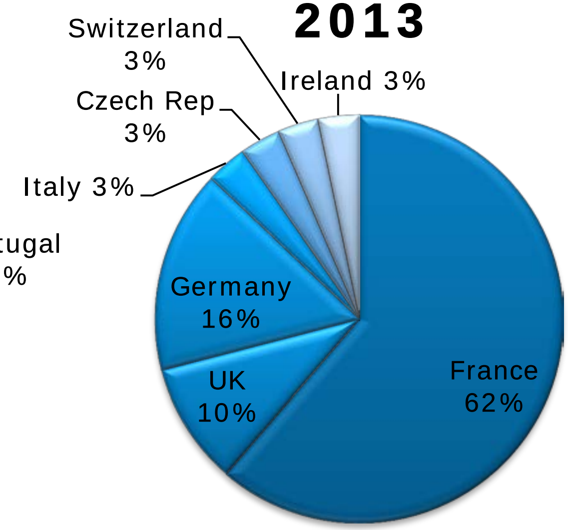
Evolution of QPL manufacturers

Manufacturer by country 2006





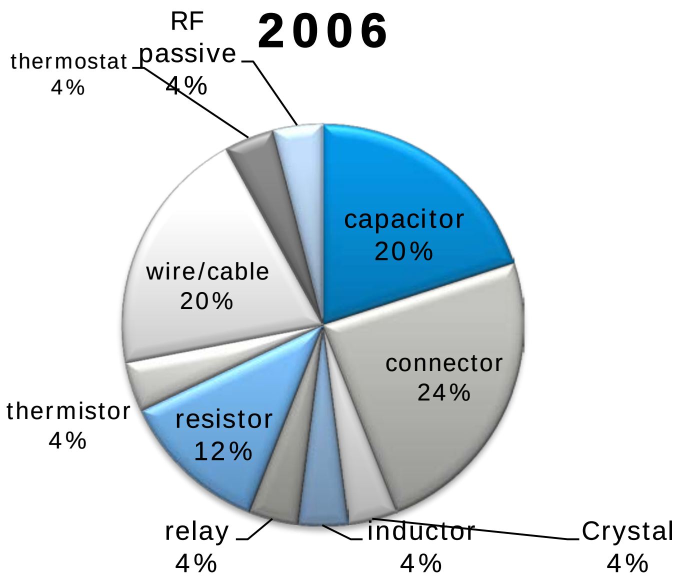
Manufacturer by country 2013



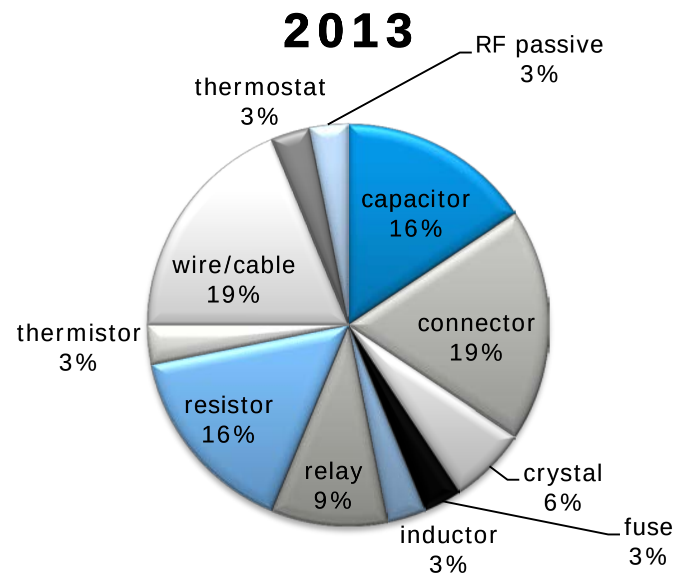
- Number of ESCC qualified manufacturer still increasing
- Since beginning strong activity in France
- Since 2005, strong activity in Germany
- New comers from Switzerland, Czech Republic, Portugal, etc.

Evolution of ESCC offer by type

2006



2013



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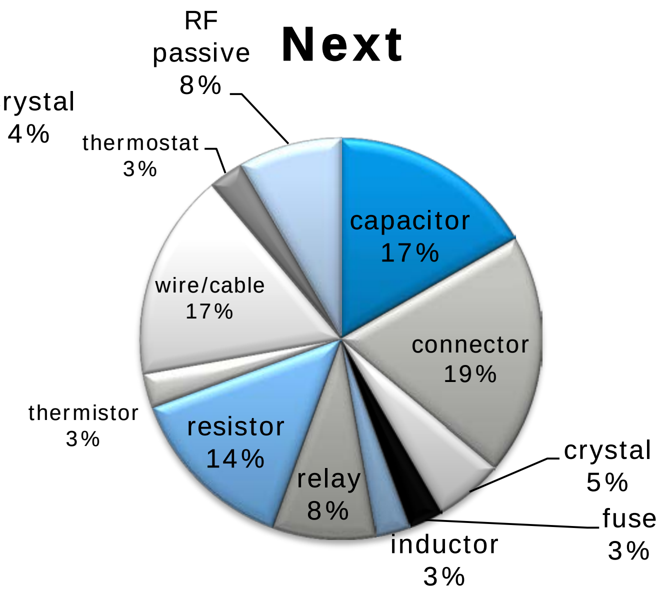


And :

- Oscillator
- Cable assembly
- Transformer

Competition outside Europe

1. Important Competition with US manufacturers
    a. Mainly on capacitors, resistors
    b. On parts not available in Europe : oscillators, RF passive, fuses

2. Market share estimated to be 50% - 50% between US/EU.

3. Explanation :
    a. Cost Impact ?
    b. Performances and Range ?
    c. Heritage ?
    d. Availability ?

Competition in Europe

1. Different situations for each types
   a. Connectors, cables, RF passive, ceramic capacitors: multi-sources
   b. Tantalum capacitors, resistors, relays, crystal, heater: no single source
   c. Film capacitors, inductors, thermo-switch: niche market, single source

2. ESCC Qualified vs not qualified
   a. Qualified : connectors, cables, relays, heater, thermo-switch, film capacitors, resistors, crystal, etc.
   b. Not qualified but EPPL : ceramic and tantalum capacitors, RF connectors
   c. Not qualified, not EPPL : RF passives, cable assemblies, XO oscillators

Competition from other market

1. In 2000 years, the telecom application took a big share of the R&D effort from manufacturers. Few interest for space market.

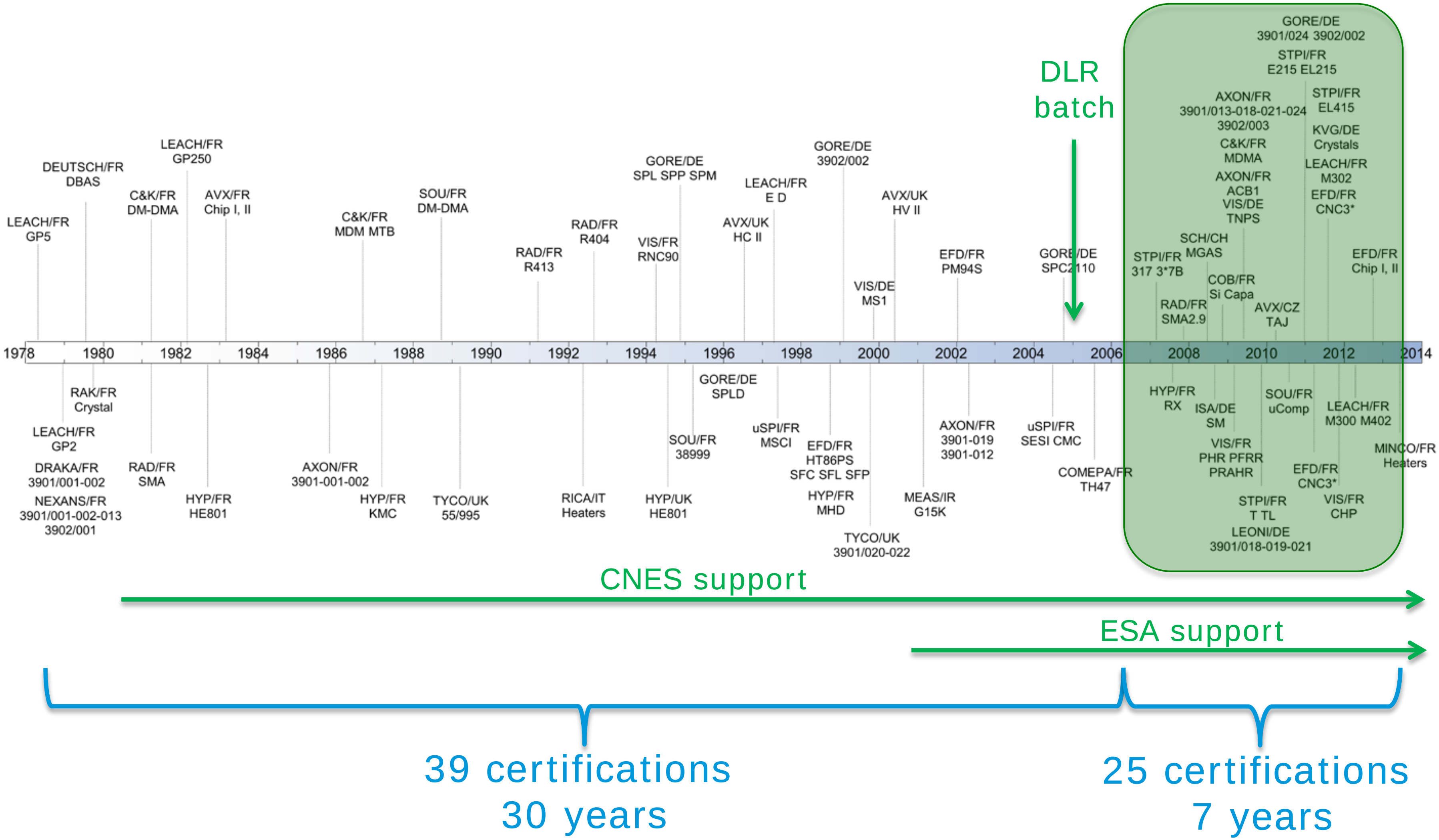
2. Today high reliability EEE parts development is lead by automotive and medical applications. Space applications are not driving the development.

   => Risk of obsolescence (pure tin) and challenging activities for technology adaptation to space use.

3. Space market is more and more considered (lesson learnt from telecom crisis).

4. Still need for support from agencies to convince ESCC qualified manufacturers and to attract new players to develop innovative technologies for space application.

Manufacturer strategies - ESCC certifications



ESA funding

TRL increasing →

TRP

ITI

GSTP

ECI

ARTES 5

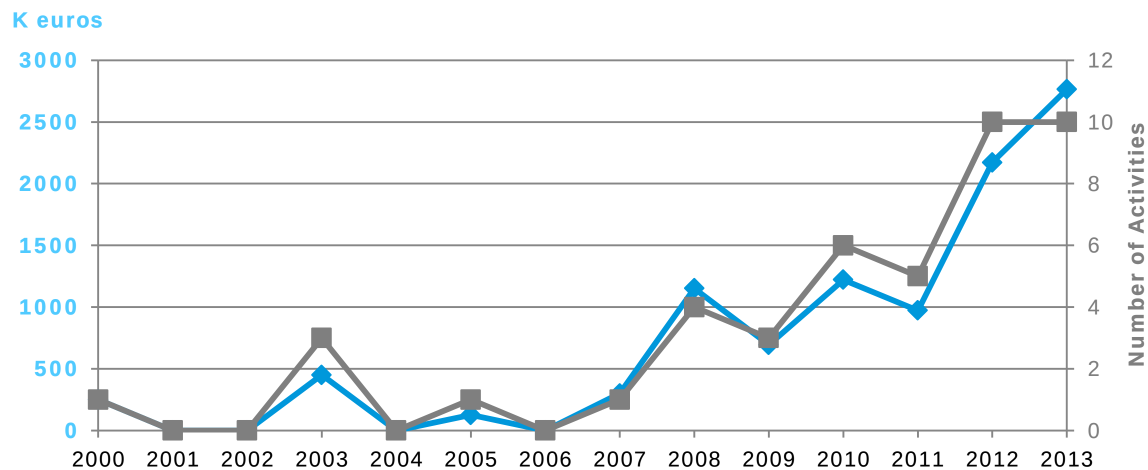
ARTES 3-4

http://www.esa.int/Our_Activities/Technology/
http://telecom.esa.int/
http://emits.sso.esa.int/emits/owa/emits.main?ul=Anonymous

More details on EMITS

ESA funding evolution

Funding and Number of ESA activities On Passives EEE parts



Manufacturer strategies – Global players

3 different examples of “global players”

1. Vishay (Sfernice): Thin and thick film resistors, “one stop shop”

   In progress for offering QPL/QML resistors from 0Ohm to 3MOhm

   ESCC tools: Technology Flow

2. Axon: Wires and cables, connectors and Cable Assembly manufacturer

   Large portfolio of product in all types

   Heritage in cable assembly (harness for bus 1553)

3. Excelia group: group of different manufacturers like Eurofarad, Microspire and Firadec

   Offer all the capacitor types + magnetics

Manufacturer strategies – Niche market

Specific products with low volume then high entry cost difficult to amortize

= protected market

Several examples:

- Thermostat from Comepa
- Fuse from Schurter
- Thermistor from Measurements Specialties
- Inductor from Microspire

These are single sources in Europe but second sources might exist in US (ITAR) or in Japan (EPPL)

Manufacturer strategies – Prices

When it is a concern?

- It is always a criteria for space projects even if it is not always the main one
- It is critical when there are competitors (outside Europe)

ESCC qualified parts more expensive than for example MIL qualified one because:

- ESCC requirements ? (qualification and/or screening)
- Lower volume compare to US market?

Possible improvement actions:

- ESCC Technology Flow
- Failure rate like for Vishay resistors
- Test facilities
- Review of ESCC requirements

Standards – ESCC specifications

1. More complex devices need to be considered under ESCC like XO oscillator and cable assembly:
   a. XO Oscillators: no European standard then no qualified sources. Today DLR has issued a specification (qualification of KVG) and ESA with Rakon are preparing a draft of what may be an ESCC standard. To be release in coming month for ESCC review.
   b. For several applications, the qualification of cables and connectors separately does not allow to fully address all the points. The followings applications were identified:
      – RF cable
      – Space wire / Space Fiber - High data rate
      – High voltage

   Since 2012 a specific working group is working to issue the basic and generic specifications needed. To be release in
2. Lack of qualified manufacturer for RF devices lead to the creation of a CTB working to define the needs and roadmap. A complete review of ESCC 3202 on isolator is almost achieved. Release schedule for the end of the year.

Standards – ESCC, NASA and JAXA

Recognition of the different systems is not completely done. Indeed, MIL standards are used almost by all space industry but JAXA and ESCC recognitions are not yet effective mainly in US.

1. Discussions are engaged between ESCC and JAXA with high level meetings leading to an increase of collaboration between the 2 agencies for EEE parts.
2. Some discussions were and are initiated by different actors with NASA but not at ESCC level with an official agenda.

ESCC standards with life test every 2 years may be a blocking point for recognition in US where MIL standards require it at least every year for most of the components.

Standards – ESCC - Complains

Time to market is too long.

Theoretically, an ESCC qualification may be done in 2 years. In reality, it takes 3 to 6 years. The qualified component may arrive too late on the market.

Why ? => ESCC evaluation

- ✓ It is a long process and we almost never know what we will find
- ✓ Often modification of design or process are necessary to obtain acceptable margin
- ✓ If no contract, it is based on the resources of the manufacturers and agencies

Do we have solutions? – Not complete ones but we may improve by:

- ✓ Reducing the evaluation flow duration by doing test in parallel
- ✓ Finding resources at manufacturers and agencies level

Standards – ESCC - Complains

User of EEE components usually procure directly from the QPL/QML manufacturers.

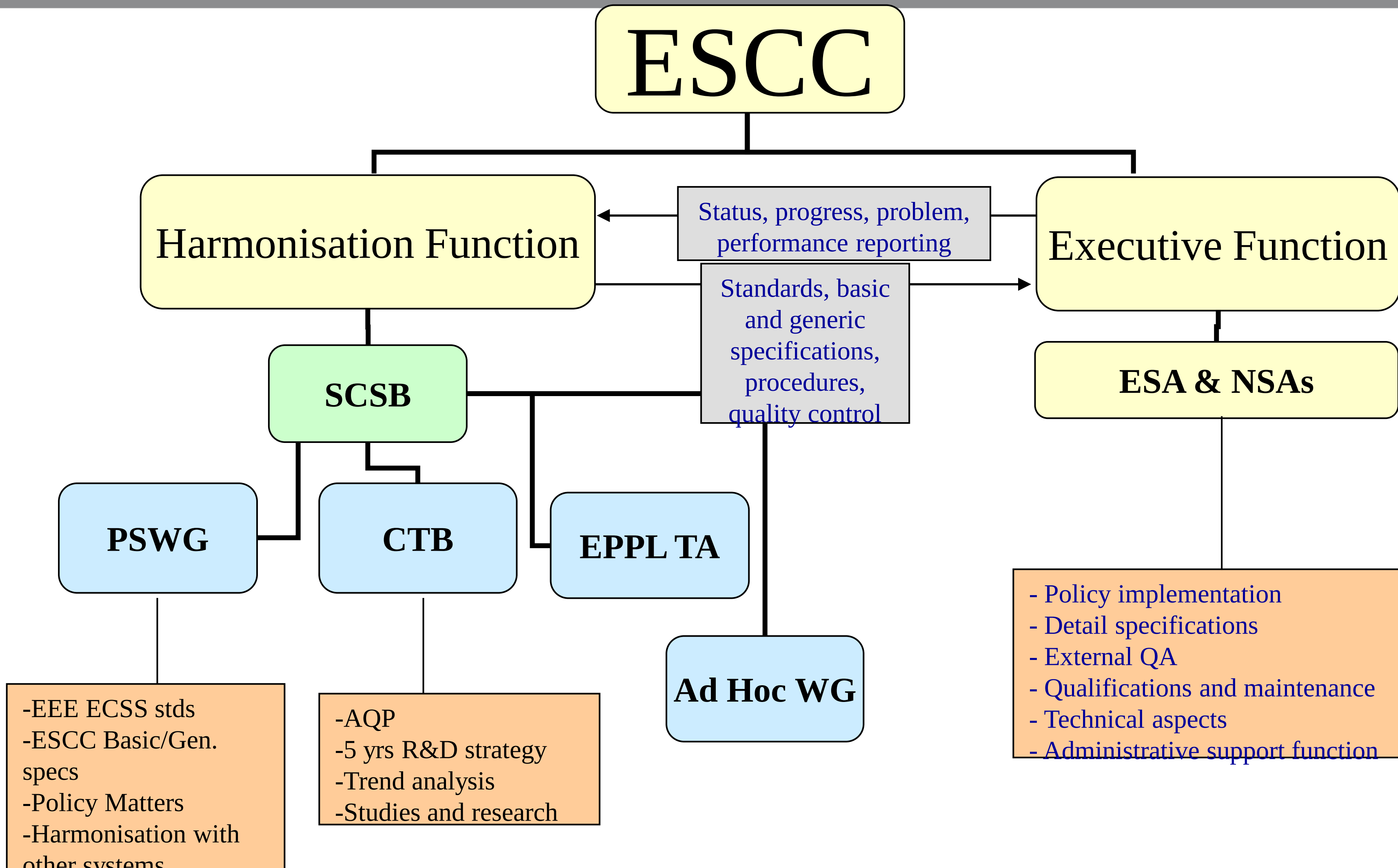
What is true in Europe may be different outside. European manufacturers have often dedicated distributors for their products in US or Asia.

It sometimes lead to confusing situations and several manufacturers would like to have ESCC qualified distributors (QDL).

This qualification status exist in MIL system for distributors of semiconductor and microcircuit:

Qualified Suppliers List of Distributors (QSLD)

ESCC bodies – passive manufacturers



Tantalum standards

KEMET

- Technique which allows the identification of capacitors with hidden defects in the dielectric, without any damage to the general population of the capacitors.
- The screening is based on the simulation of breakdown voltage (BDV) without actually damaging the capacitors.

ESCC

MIL

NASDA

AVX Q-process

- Combination of Reflow, Statistical screening at various temperatures and 125C burn-in
- AVX's maverick lot program is designed to identify any lot that is statistically different than previously supplied Lots
- Statistical screening (using AVX algorithm to determine sigma) both pre and post burn-in is effective in removing parts that may have long term reliability issues in the Field

Issues - ITAR

ITAR is a well know risk/challenge for procurement of US components

Passive despite their general use are also affected

European space industry needs to mitigate this risk and the best solution is to have European qualified components

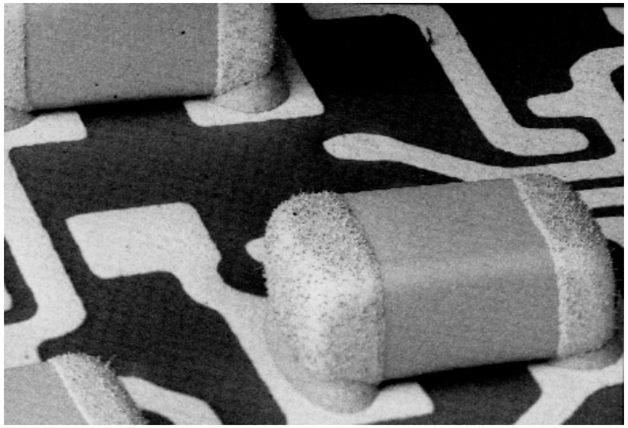
Examples:

- Thermistors: Fenwal thermistor became ITAR in 2003. Qualification of Betatherm (Measurement Specialities) thermistors for replacement

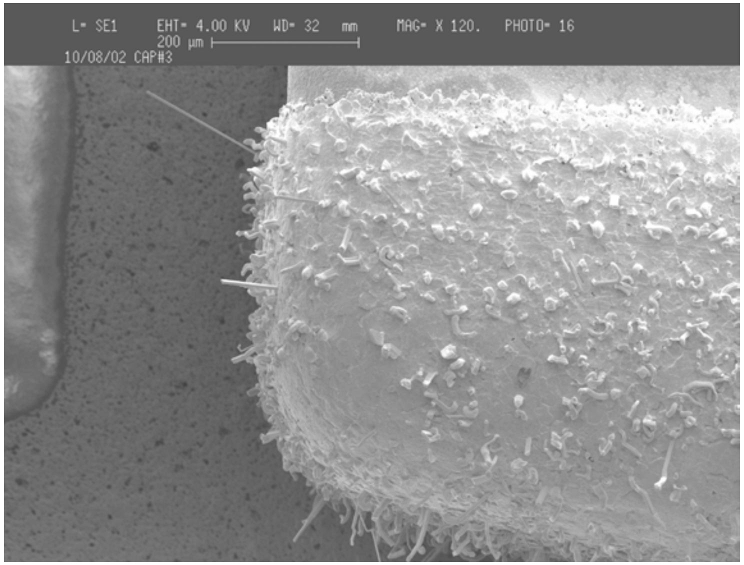
- Fuses: AEM fuses are under ITAR today. Activity started with Schurter to qualified MGAS. On-going activity to increase the range in current with the HCSF.

Issues – Pure Tin

Problem of whiskers



(pictures from NEPP, "tin whiskers")



- Outside always a risk of obsolescence but today still not
- Inside the parts: DPA, qualified parts (some design/process were changed to be compliant)

Issues – cracks in capacitors

Cracks in capacitor is a well documented problem.

- The main root cause types are all identified.
- Almost no failure observed these last years.

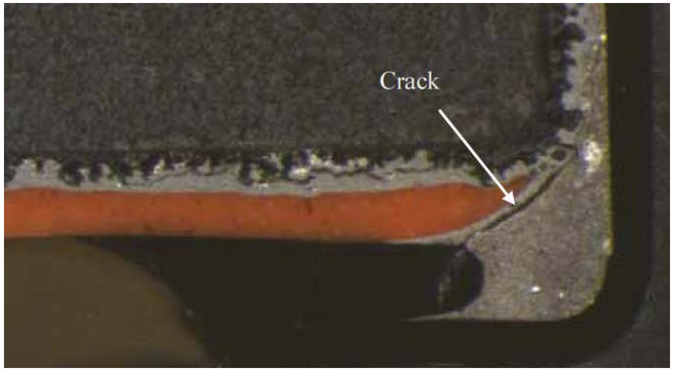
However, this is not acceptable for space flight unit.

Main issue today is assembly validation. If we observe a crack how can we:

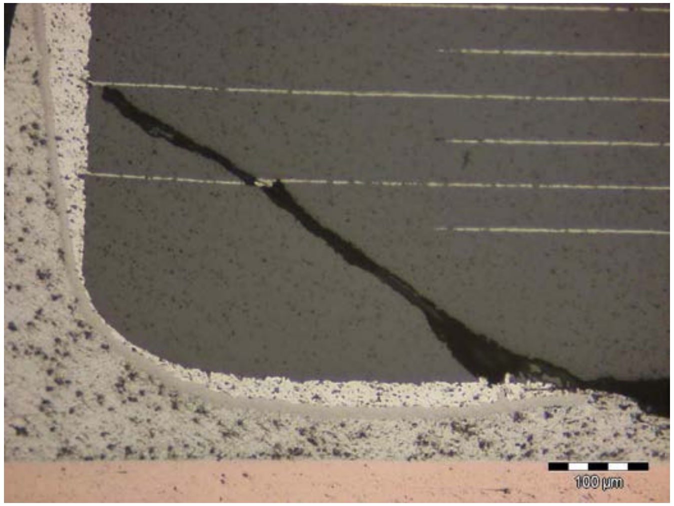
- Know the root causes
- Evaluate the risk

Mitigation by:

- Standard but ...
- DPA
- Electrical test during assembly validation
- Soft termination for ceramic capacitor and CWR11 design type for tantalum



CWR06 tantalum capacitor crack

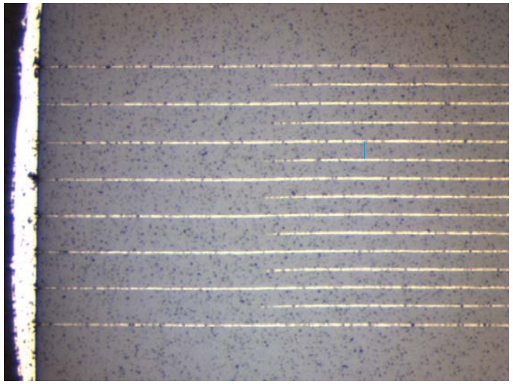


Ceramic capacitor crack

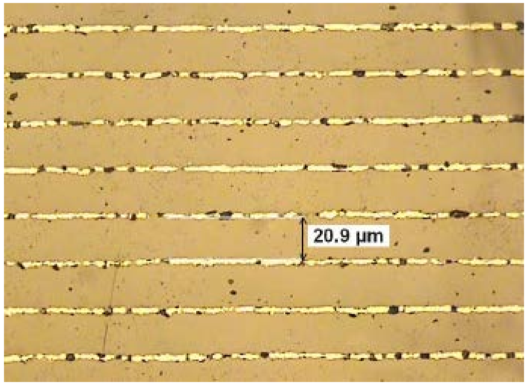
Issues – screening and rated voltage ceramic capacitors

Is a 16V ceramic capacitor a true 16V?

Usually, voltage rating is proportional to dielectric thickness. This may no more true with low voltage rating.



Dielectric thickness:35μm
Rated voltage 50V
Screening electrical field:2.8V/μm

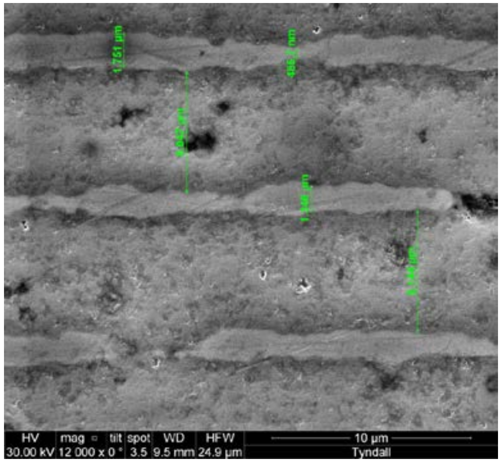


Dielectric thickness:20μm
Rated voltage 16V
Screening electrical field:1.5V/μm

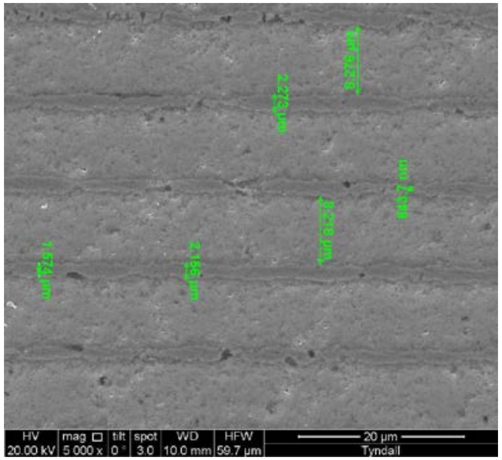
In this case the 16V is more a 30V, then do we perform the correct screening? Do we have to modify the voltage in screening and to set it proportional to dielectric thickness?

Issues – screening and rated voltage ceramic capacitors

Can I screen as usual all BME capacitor?



Dielectric thickness:6μm
Rated voltage 10V
Screening electrical field:3.3V/μm



Dielectric thickness:8μm
Rated voltage 100V
Screening electrical field:25V/μm

Number of grains seems more important than instead dielectric thickness for BME but today we don't know how to screen these capacitors when electrical field is too high.

Issues – humidity and capacitors

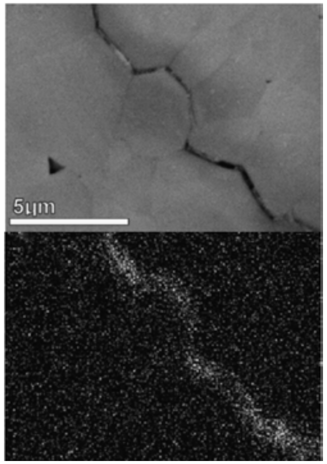
Low voltage failure in ceramic capacitor

- ➢ Usually detected by 85/85 test **by sampling**
- ➢ Difficult to detect as it may be intermittent

Recent presentations in CARTS 2011 propose:

- ➢ Remove this test as not efficient
- ➢ Do it at 100%

⇒ No more 85/85 test in NASA/NEPP, under discussion in ESCC

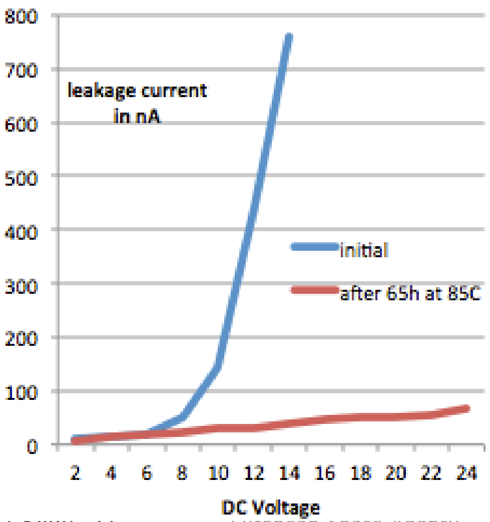


N. J. Donnelly and C. A. Randall

Tantalum failure due to humidity (EA-2009-EEE-7)

- ➢ No test perform
- ➢ Storage/transport condition and duration (clean room is not a dry environment)

=> Hermetic tantalum



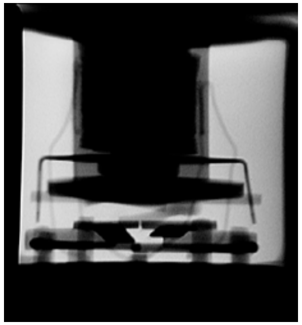
Needs –vibration and mechanical shock

Level of vibration and mechanical shock required for general purpose component like passive one are increasing due to launcher evolution.

The needed conditions are:

a. Mechanical shock : 2000g up to 3000g for some case (pyro)
b. Random vibration : 80grms to 100grms

Main issue with relays



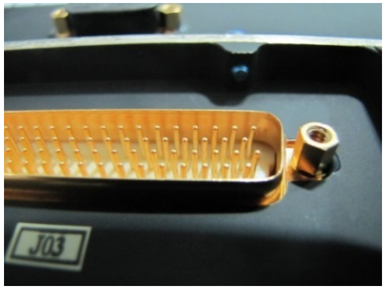
With the following requirements

- No change of position
- No micro opening or degradation of contact
- No evolution of electrical performances (command characteristic, contact resistance, insulation)
- As small as possible

Issues - connectors

- Usual issues mainly due to pollution or bending of pin, improper assembly of piece parts (at manufacturer level or user level).

Relevant workmanship standards are the best way to prevent such issue.



Qualified parts are inspected in this way. Deviation to “recognized” workmanship standard increase risk.

- Intermateability issue : connectors are interface components, often single point of failure. Intermateability can not be guaranteed and particular precaution shall be taken.

Issues - connectors

- Select the right connector for a given application. Some connectors have been designed for a dedicated space application (PYRO, Separable).

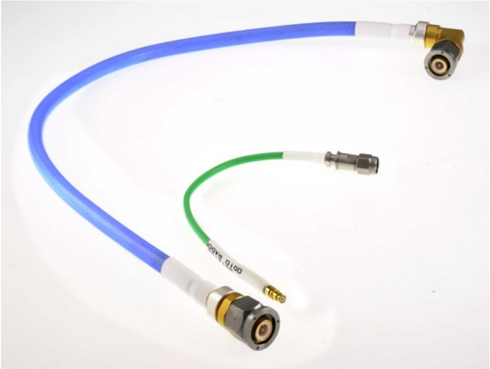
- Some connectors properties might have huge impact at system level (magnetism)

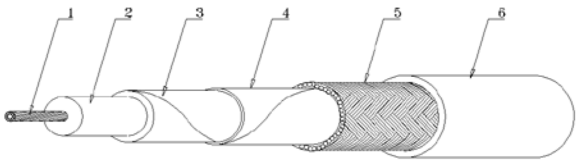
- Precaution shall be taken for the accessories selection (EMI/EMC backshell, cable clamp) and right cables.

Issues – connectors - Cable assembly

Problem to evaluate specific application: cable assembly

Example: RF cable assembly





Particular connector testing :
Mating/un-mating
Coupling proof torque
Contact retention
Contact resistance

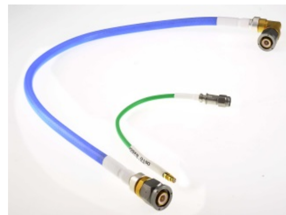
- Common Functional technical specifications :
Frequency range, Attenuation, VSWR, IL
- Common tests : IR, DWV, weight dimension, …

Particular cable testing :
Coating test
Conductor resistance
Bending, cold bend test
Resistance to fluid
radiation
Spark test
AB,

Issues – connectors - Cable assembly

Cable assembly qualification: end users needs

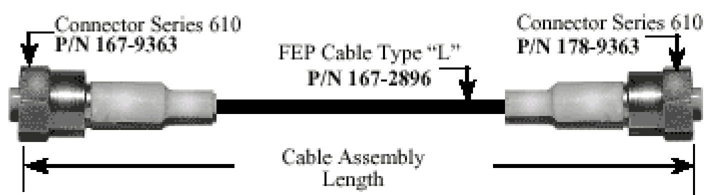
1. RF cable assembly



2. Space Wire assembly

3. High Data rate Assembly

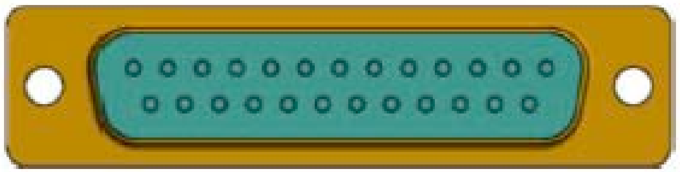
4. High Voltage assembly

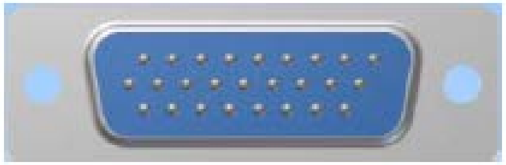


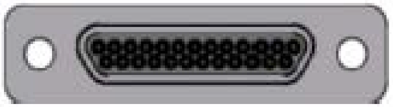
What we see for the future?

The different paths for miniaturisation

1. Connectors miniaturisation


D-SUB SD

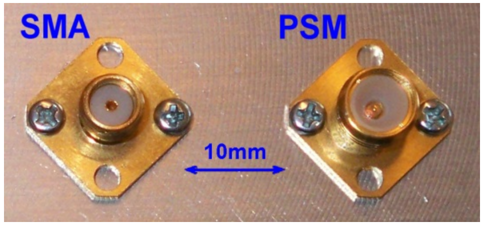

D-SUB HD


uD


nanoD

2. Flexibility with modular connector and new products (Combo uD)

3. Increase of performance : power RF connector, SpW/SpF connectors



What we see for the future?

Flexibility : for the users but also for the manufacturers

- Self-regulating cable
- cuttable heater
- Interposer
- Modular connectors

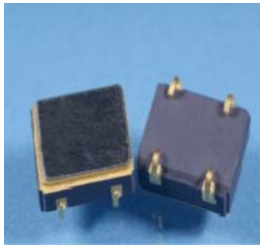
3 different but equivalent approaches are possible:

1. Component Qualification for one EEE component type or a family
2. Capability Approval customized or application specific components
3. Technology Flow Qual. stable and reliable manufacturing technology flows

What we see for the future?

The different paths for miniaturisation

- More and more SMD: crystal/oscillator, relays/switch



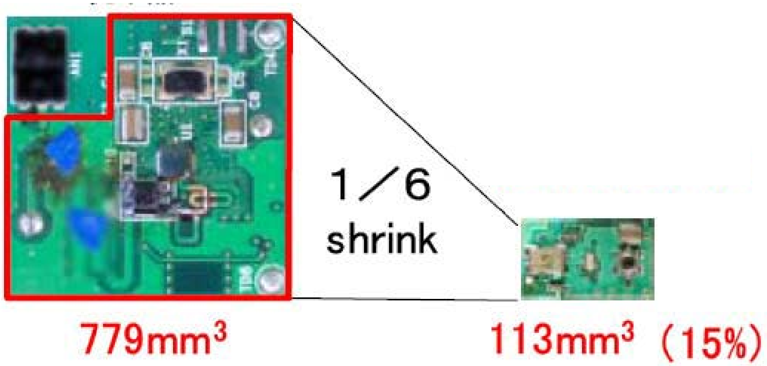
- Resistive and capacitive chips down to 0402 (0201?)

Problem of inspection and rework

The different paths for miniaturisation

- Replace current used parts by other with better performances:
  - ✓ BME capacitor
  - ✓ very low ESR tantalum (ESL)

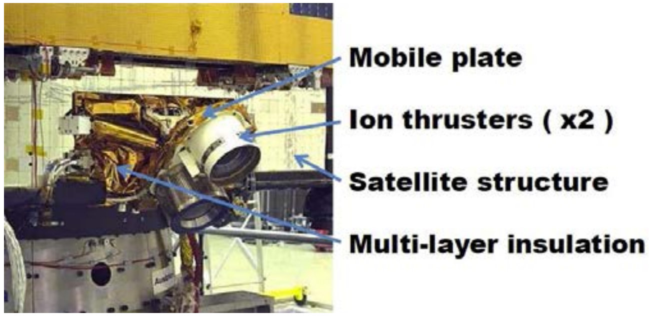
- Embedded passive component
  - ✓ Miniaturisation at board level
  - ✓ Improve performances

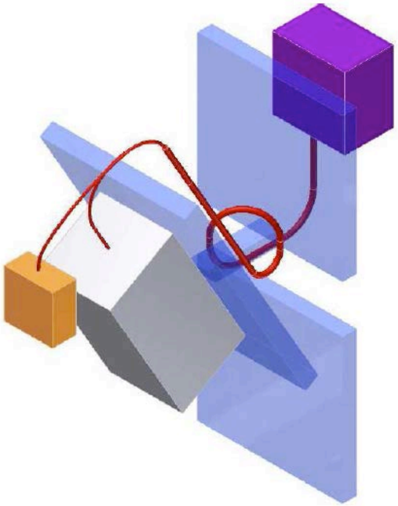


What we see for the future?

Electric propulsion need high voltage and high power (thermal dissipation then high temperature)

- Cable assembly
- Capacitor ceramic or Mica for high voltage
- Outside cable: flexible, radiation, ATOX, EV, ESD and temperature cycling

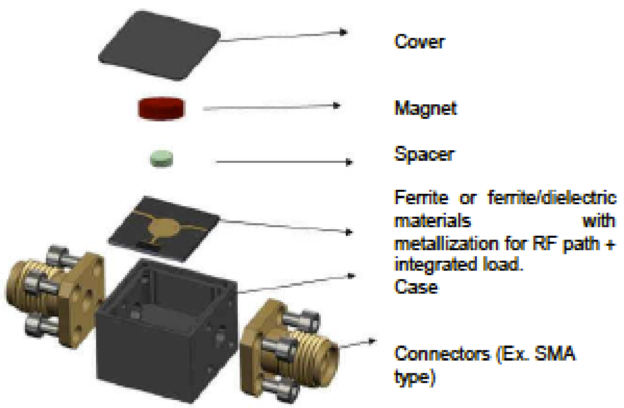


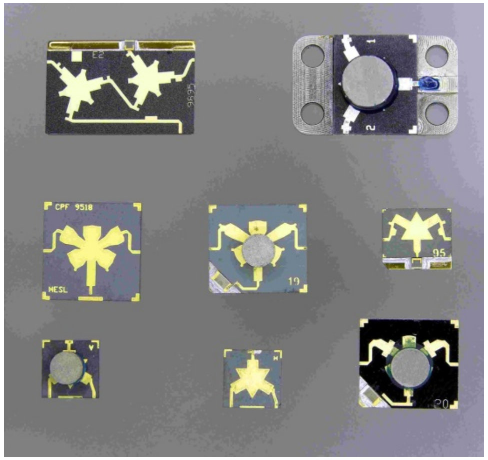


What we see for the future?

RF passive component: CTB RF passive working group, 2009)

- Qualified sources are today missing for the basic function like isolator. Several activities are on-going to cover the frequency and power range for isolator next we will have to consider divider and couplers
- New frequencies: Ka today then Q and V band
- Increasing power/miniaturisation





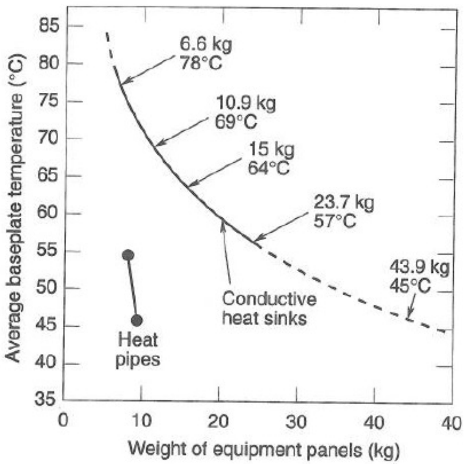
What we see for the future?

High temperature of base plate (90C to 110C)

- GaN may work up to 150C instead of today limitation
- High temperature is easiest to stabilise in space

Considering actual derating rules, we need reliable high temperature passive components:

- Capacitor and resistor
- Magnetic



We need to solve the issue that we may have for assembly

What we see for the future?

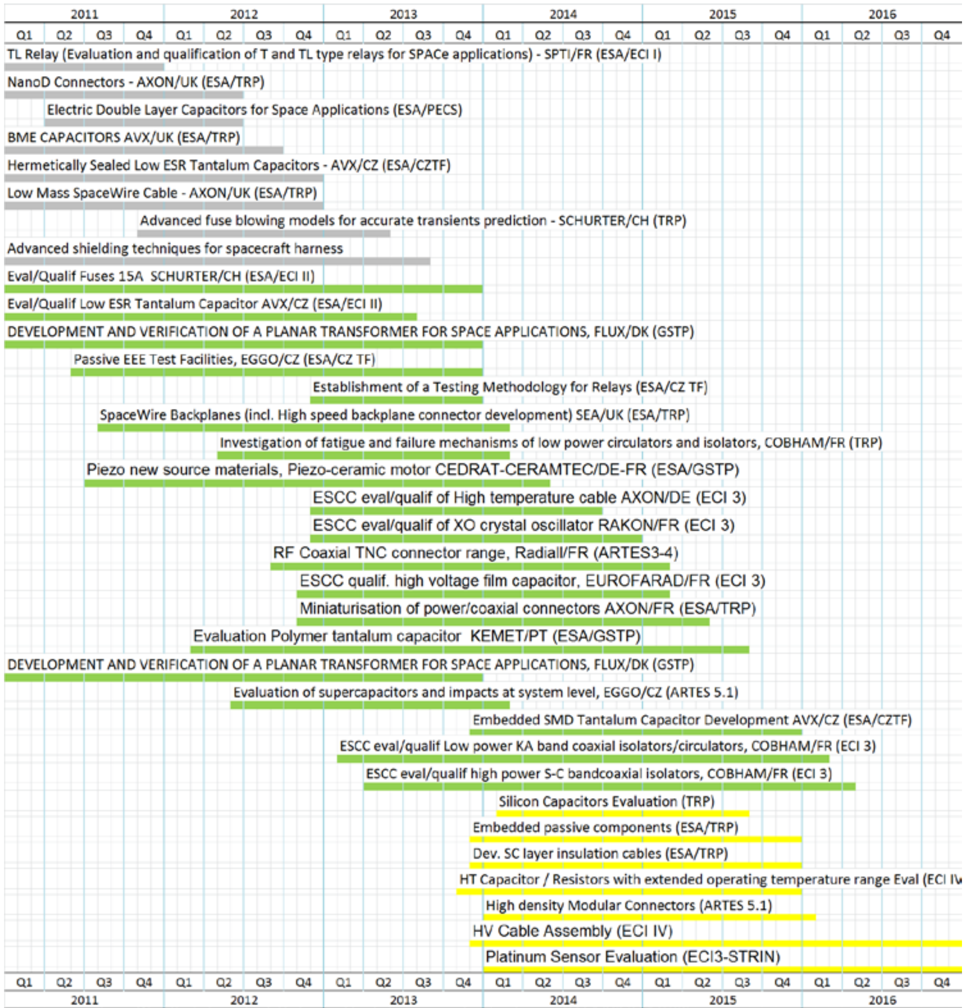
Space platform needs, two opposite trends:

- Voltage use on platform are mainly 50V but are evolving to 100V
- IC voltage is lower and lower

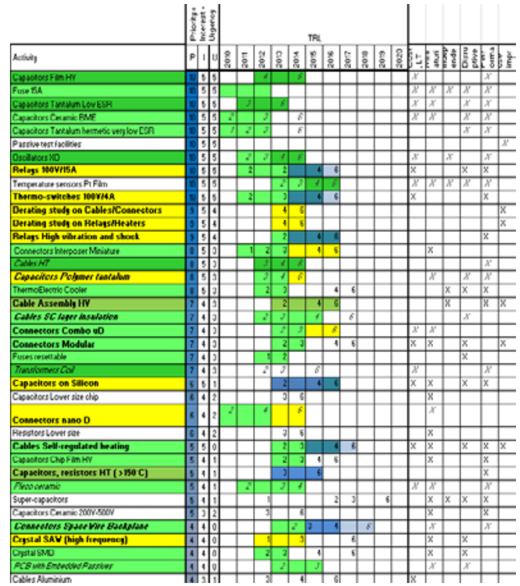
⇒ voltage range increasing at both end :

- Capacitor and resistor
- Relays and thermostat

Main Activities



27 Activities on going or to be initiated (TRP, ECI , ARTES, GSTP, etc.)



More than 30 topics identified in the Passive Component Roadmap defined by ESCC Passive Component Technological Board Working Group

Summary and Conclusions

- Large technical perimeter with unrelated technologies (relays, RF passives, capacitors, etc.) making challenging the standardisation.
- Hidden primary functions make difficult identification of needs and lower priority wrt active parts
- Used as interface components and safety functions
- Large quantities used increased failure risk
- Small market, with specialised manufacturers in competition with MIL products

- Large ESCC qualified range and EPPL offers cover the current needs
- Development, evaluation and ESCC qualification activities on going or defined for the future needs
- New proposals or new ideas are welcome