
ESA Passive Components: News, Activities and Trends
Dr. Léo Farhat & Mr. Joaquin Jimenez
ESA - European Space Agency
Failures
Activities
News &
Challenges
Trends


News &
Challenges
Long Lead
Time
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Long Lead Time

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Background & Data

Factors

Impact on ESA's Missions

Potential Improvements

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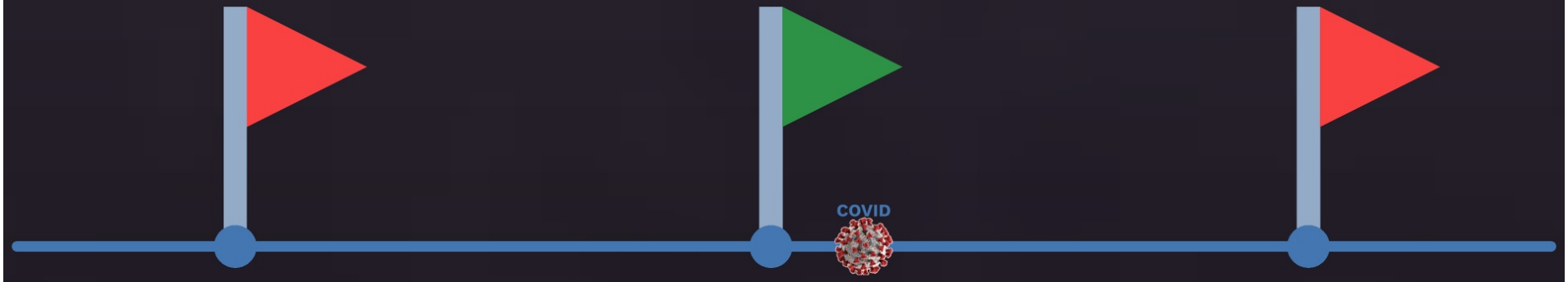

2018

Initially, there was a capacitor shortage at the beginning of 2018.

Resistors and transistors were badly needed, and suppliers were quoting 20-30 weeks.

2020

In 2019, demand balanced out, and for the first few months of 2020 demand and supply were perfectly balanced.

Then the COVID pandemic hit!

2022

Today, demand for passive components has never been higher!
On top of Semiconductors, the shortages rolled over to several Passive components!

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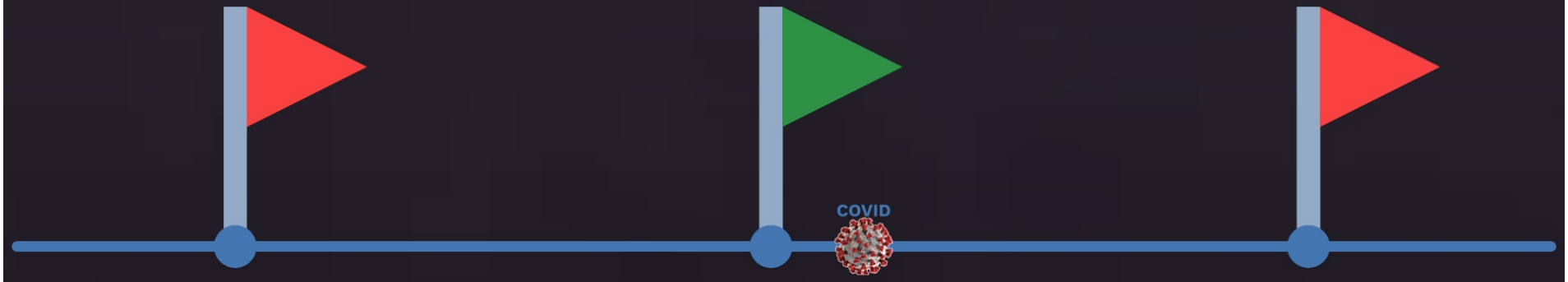

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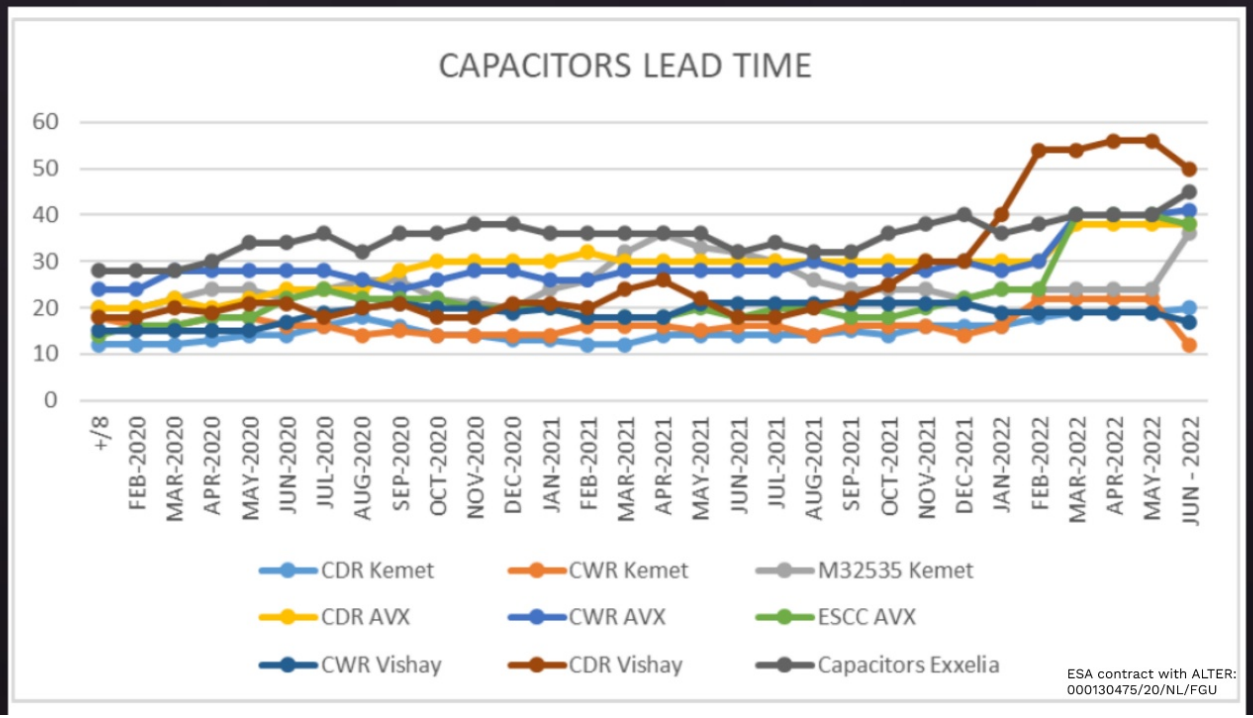
ESA signed a contract with Alter Technology in order to perform an analysis of critical functions required by multiple upcoming Science missions.

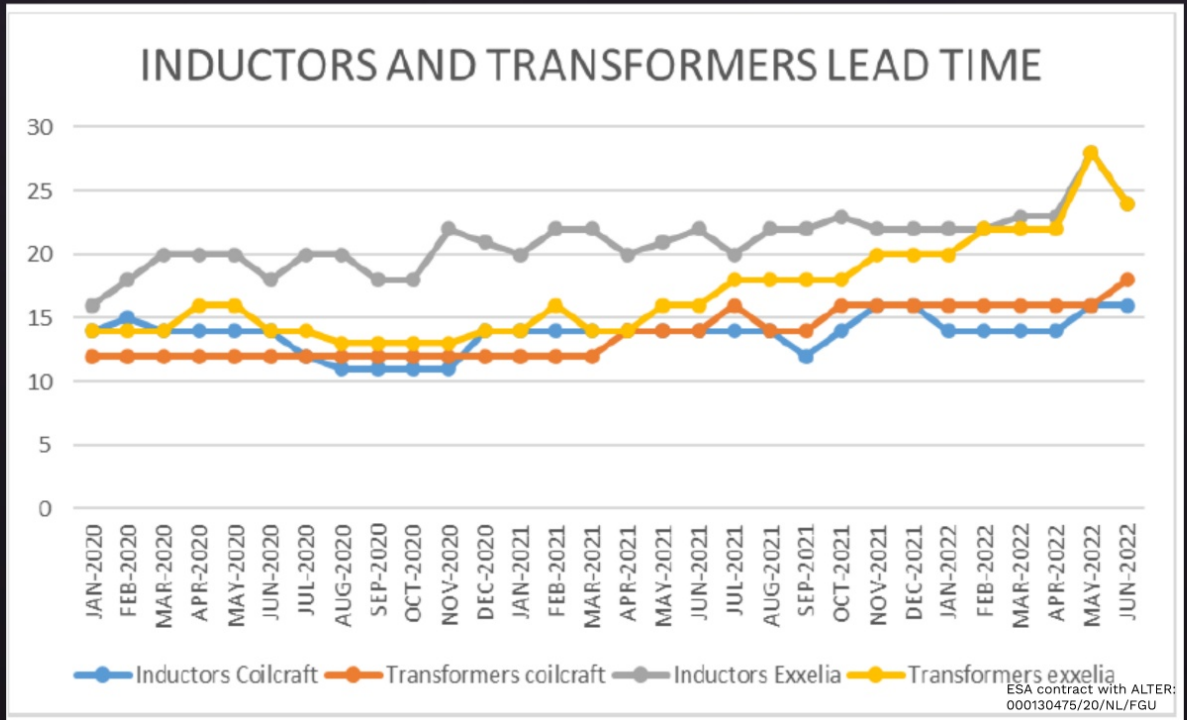
Capacitors

Lead Times (LT) have been increasing for capacitors during the last 2 years:
Typical LT was around 20 weeks and has now doubled! Today, CDR and CWR types are procured with an average around 40 weeks, and up to 48 weeks for some manufacturers!



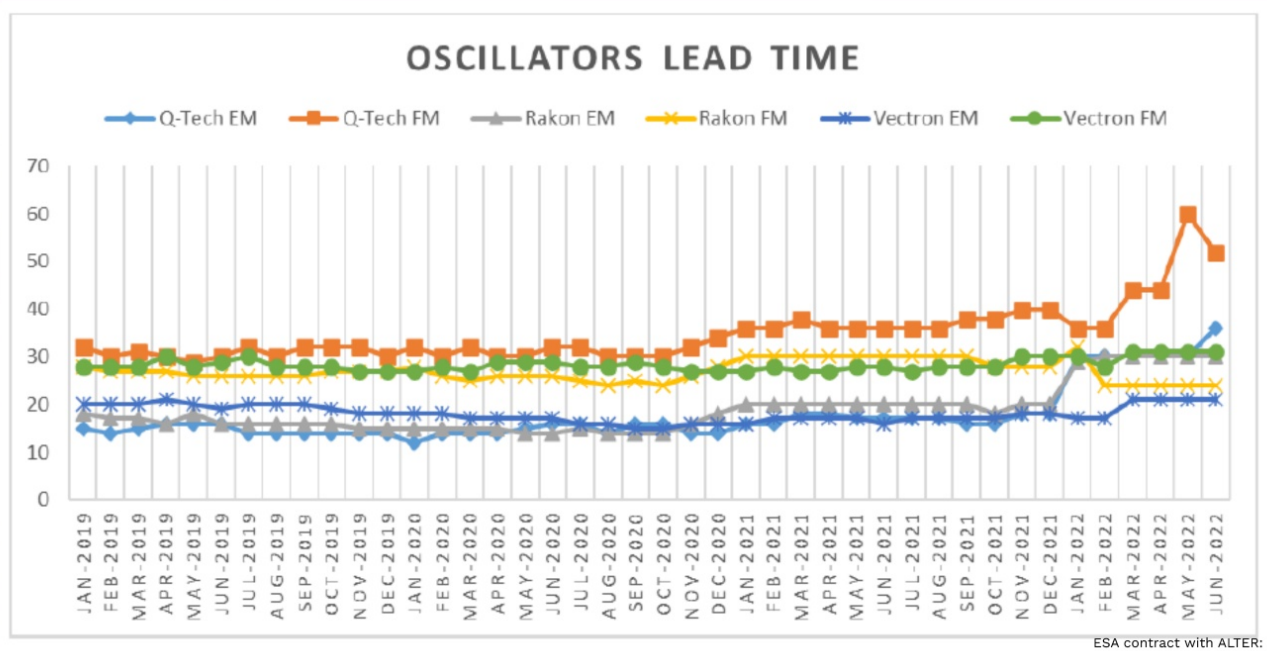
Magnetics

Inductors and transformers have, relatively, stable lead times. However, there is a slight rising tendency due to the shortage of some raw materials (e.g. ferrite cores).



Crystals and Oscillators

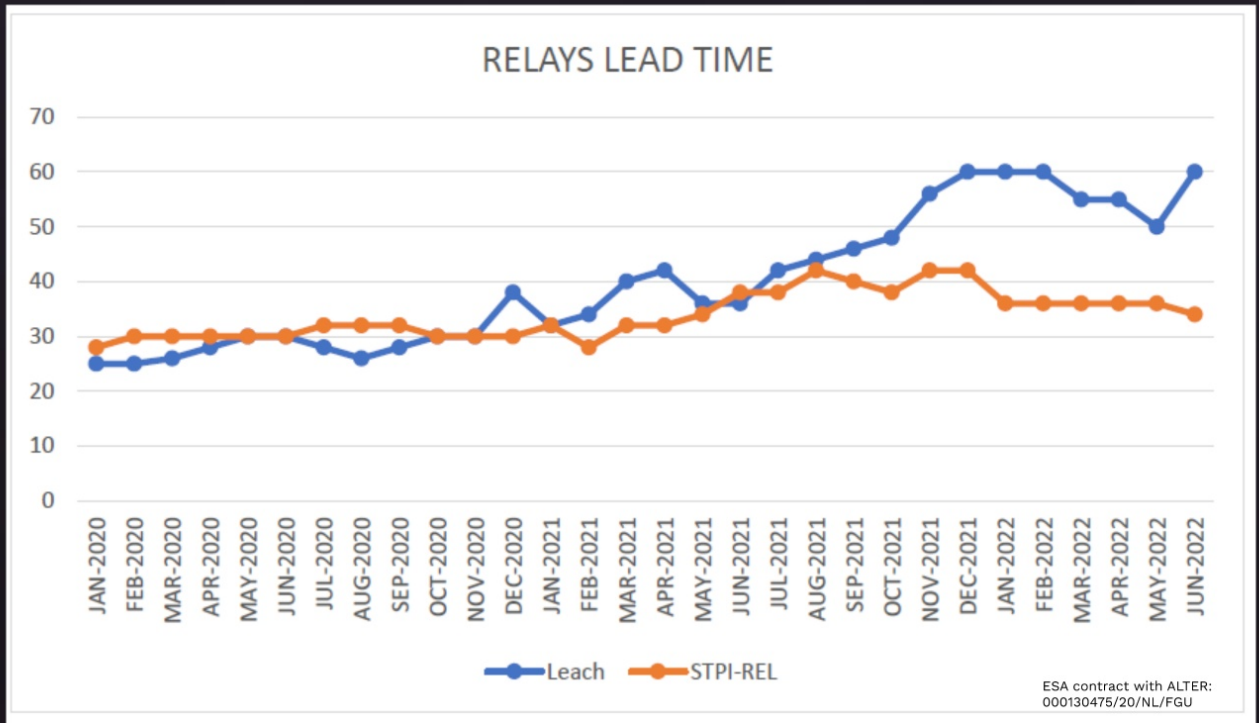
There is a light increase of the lead times for oscillators and crystals. However, consulted manufacturers are taking actions either by securing their supply chains or by developing innovative solutions (e.g. ESA contract with Rakon in order to develop re-programmable XO & VCXO and reduce LT from 30 to 4 weeks).



ESA contract with ALTER: 000130475/20/NL/FGU

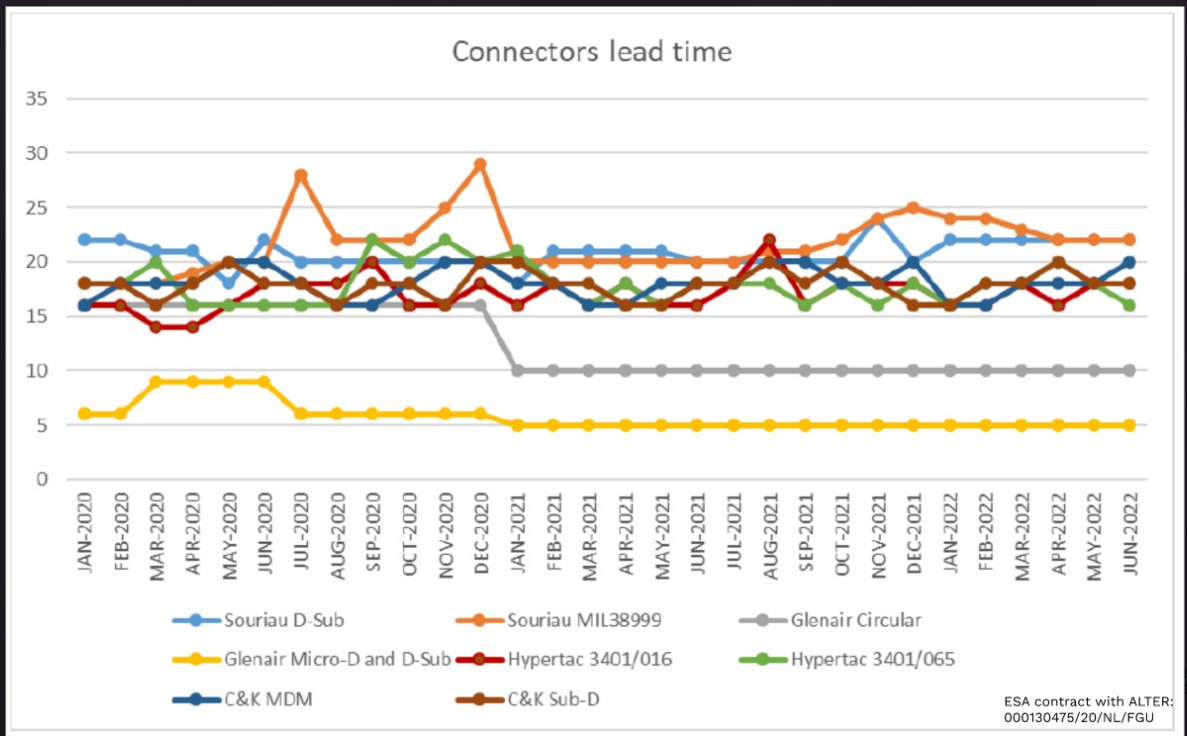
Relays

There is a fast increase in the lead times for the relays, mainly due to lack of raw materials (nickel, iron, etc.).



Connectors

The LT of connectors has been volatile in Q3 of 2020, it remained stable in the first half of 2021 before it increased slightly in 2022. The situation is still acceptable compared to other Passive parts, with an average of 18 weeks.



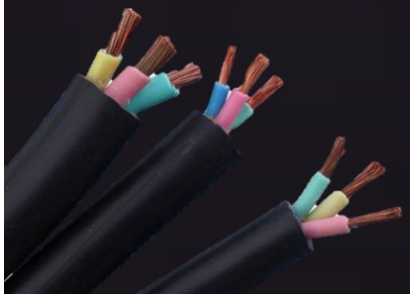
Other Passive Parts

IST provides QPL ESCC Platinum thermistors with a LT of 5-6 weeks.

The LT for the probe (thermistors+ extended wires) has increased from 8 weeks up to 15-20 weeks due to the dependency on the wires/cables suppliers.

TE connectivity provides Space standard probes with a typical LT of 12 weeks.
QTI have reported LT of 26 weeks for standard flight models and up to 40 weeks for custom parts including tests.

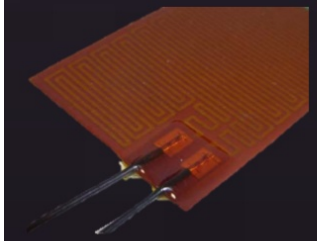
RF cables and RF cable assembly LT has increased from typical 10-12 weeks to 25 weeks!



LF cables' LT has also increased from 8-10 weeks to 20 weeks, due to delays of raw materials and non-conformance related to suppliers.

Other Passive Parts

Fuses (QPL ESCC MGA-S and HCSF, Schurter) are not affected by long lead time! Typical LT is 12-20 weeks depending on the volume.



Current LT for ESCC heaters (RICA/ZOPPAS and MINCO) is between 12 and 14 weeks. It can go up to 45 weeks (MINCO) only in the case of a custom heaters' design and unavailability of some materials (dependency on the wires/cables suppliers).

There is no impact on ESCC thermostats (COMEPA) as for the last 2 years, the LT for EM is 18 weeks and 24 weeks for FM. LT can be reduced if the customer justifies the emergency need.

Long Lead Time

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Factors

No single incident caused the EEE shortage. Instead, a confluence of events contributed to the situation the electronic industry now faces.

Several factors are impacting the lead time!

Pandemic Situation

The COVID-19 pandemic has brought unprecedented and abrupt changes into human society.
The world's economic activity slowed dramatically in March 2020, when the majority of the global population began to quarantine as the virus spread.

The pandemic shut down a lot of avenues for raw materials and bulk electronic components, leaving manufacturers with half-finished products and idle capacity.

Environmental Constraints

Environmental restrictions, e.g. due to energetic constrains, have led to temporary production shutdown of some manufacturers.

Plastics plants in Texas had to suspend production of the most widely used plastic polymers in the world (PE, PP and PVC), due to winter storms!

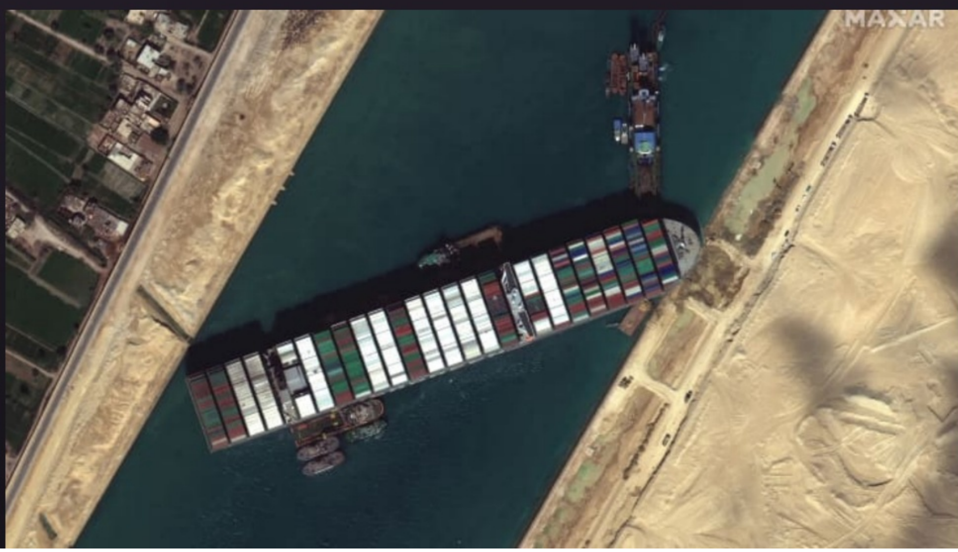
The growing power supply crunch in China is triggering blackouts for households and forcing factories to cut production, threatening to slow the country's vast economy and place even more strain on global supply chains.

Some manufacturers have stopped the production of non-sustainable materials, e.g Carcinogenic, Mutagenic, Reprotoxic, that do not respect human health and the environment.

Lack of Raw Materials

Lots of Manufacturers are issuing "Supply Issue Information" letters due to the lack of materials.

Suppliers of base materials are stopping the production of several raw materials (ferrite cores, nickel, iron, etc.) affecting several EEE Passive components (inductors, transformers, connectors, relays, etc.).



smiths interconnect

Supply Chain Challenge on MHD & MDD series

Dear Valued Customers & Distributors

This letter is to inform you that we have identified supply challenges to source components (058041-02EX & 058041-01EX) due to the on-going constraints from raw material suppliers.

This may affect our ability to source components, produce products and deliver within anticipated lead-times.

The affected products are the MHD & MDD series. We are currently reviewing open orders to assess the potential impact and will contact you directly if orders are affected.

Our Supply Chain team is working to address this issue, although the next delivery from our suppliers is estimated End Nov 2022 and hence delivery of these products will be extended.

For the avoidance of doubt, your order(s) shall remain subject to our standard terms and conditions (available at https://www.smithsinterconnect.com/company/terms-and-conditions-of-sale/) or such other terms expressly agreed between you and Smiths Interconnect setting out our respective rights and obligations.

We deeply value our relationship with you and want to assure you that we're taking appropriate steps to address this issue and minimize its impact on you.

We would like to take this opportunity to thank you for your continued support and trust with us. If you have any questions, please contact your usual Smiths Interconnect contact.

Best regards,

Rainer Daum
EMEA & Asia Business Development Director
Smiths Interconnect

US Sales | EMEA Sales | Asia Sales

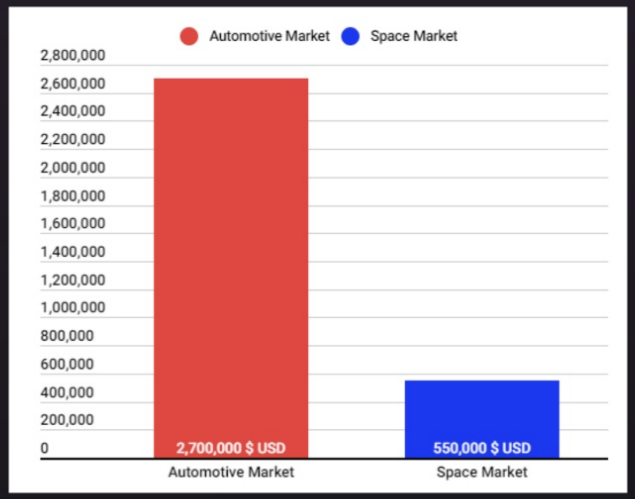
FLUX

Dear Valued Customer

Flux A/S

Manufacturers' Strategies

Manufacturers are dedicating most of their production efforts to those lines which provide higher margins!



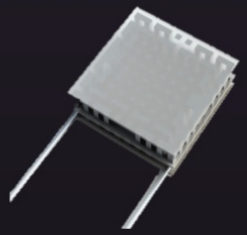
The current global automotive market is substantially larger at US $ 2.7 trillion than the worldwide Space market, which is at US $ 550 billion.

Geopolitical Situation

Armed conflicts and economic sanctions have an impact on the global supply chains. For instance, manufacturers may lack nickel, aluminium, copper, iron or gold. It should be Russia is the second world supplier of Palladium (44%).

TEC are crucial for the performance of Star Trackers. They have been identified as critical components by EDA, EC and ESA. Finding a European source is of very high interest for the European industry to ensure non-dependence.

An Invitation To Tender (ITT) will be issued in 2023 to develop, through a TDE activity: "European Thermo-Electric Cooler for Star Trackers".



TEC, also known as Peltier cooler, are needed in order to maintain detectors, in Star Trackers, at their optimal temperatures for performance.

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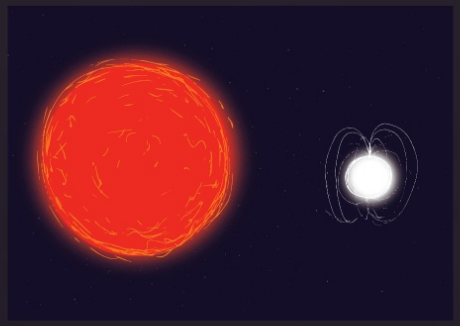

ARIEL, currently in the procurement phase, is an example of an affected ESA Science Mission.

ARIEL stands for the “Atmospheric Remote-sensing Infrared Exoplanet Large-Survey" mission.
It will be **the world’s first dedicated** exoplanet atmosphere **sniffer**!

It is a space telescope that will study more than 1000 extrasolar planets, simultaneously in visible and infrared wavelengths, in order to better understand their formation and evolution!

ARIEL will join previous ESA missions, CHEOPS and PLATO, in studying worlds beyond our own Sun.

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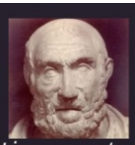


Hippocrates

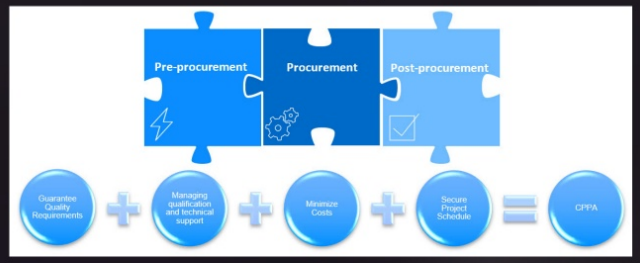
It is a matter of time before having a balance between the demand and supply of EEE parts. Meanwhile, some improvements can be done.

End user/prime/customers are taking, when possible, the following actions:

- Contracting the service of CPPAs (Centralized Parts Procurement Agency) in order to better coordinate the mission's needs, facilitate the procurement (including qualification testing) and issue grouped POs (Procurement Orders),

- Anticipating the needs and issuing POs in advance,

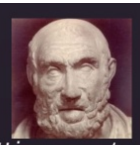
- Looking for alternative solutions and/or new opportunities (Automotive, new companies).



Unfortunately, this comes at the expense of an increased risk in terms of quality, design, etc.

Potential Improvements

"Healing is a matter of time, but it is sometimes also a matter of opportunity."



Hippocrates

It is a matter of time before having a balance between the demand and supply of EEE parts. Meanwhile, some improvements can be done.

Manufacturers are trying to do their best to cope with the increased lead time issue by:

- improving their procedures, optimizing their production lines and increasing their capacities,
- hiring and training engineers/operators in order to increase their production capacity,
- adding working shifts,
- Looking for and qualifying alternative suppliers,
- purchasing a larger stock of raw materials, to be able to keep their production running.

Unfortunately, this comes at the expense of an increase in component costs!

Do not miss the Interactive Panel Discussion on Thursday 13th @ 17:00h

"Long Lead Items: shortage, challenges and potential improvements"

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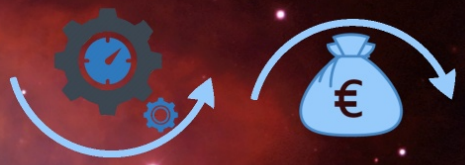
"New" Space Era

The Space market is opening up to a new commercial era called:
New Space.

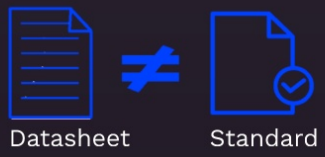
Space is becoming a more and more competitive sector, asking continuously for higher performances while reducing the overall cost!



COTS

Impact on ESA's missions

COTS: Commercial Off-The-Shelf



Definition of commercial parts is, as per ECSS-Q-ST-60:

"Parts neither designed, nor manufactured with reference to military or space standards defined in this document."

COTS components bring the following benefits:

Nevertheless there is a risk of:

COTS: Commercial Off-The-Shelf

- ESA has been procuring COTS for more than 20 years on several ESA missions!
- ECSS-Q-ST-60-13C “Commercial electrical, electronic and electromechanical (EEE) components” is the baseline standard to procure commercial parts.

ECSS-Q-ST-60-13C has been updated **recently (May 2021)** in order :
- to include provision for the procurement of commercial passive components,

- to consider specific evaluation and acceptance requirements for AEC-Q Automotive qualified components,

for the three different classes (Class 1, 2 and 3) of ESA missions.

The highest assurance and lowest risk is provided by class 1 and the lowest assurance and highest risk by class 3.
Procurement costs are typically highest for class 1 and lowest for class 3.

COTS: Commercial Off-The-Shelf

The ECSS-Q-ST-60-13 standard is now applicable to commercial parts from the following passive families:

- Ceramic chip capacitors
- Solid electrolyte tantalum chip capacitors
- Fuses
- Magnetic parts
- Resistors
- Thermistors

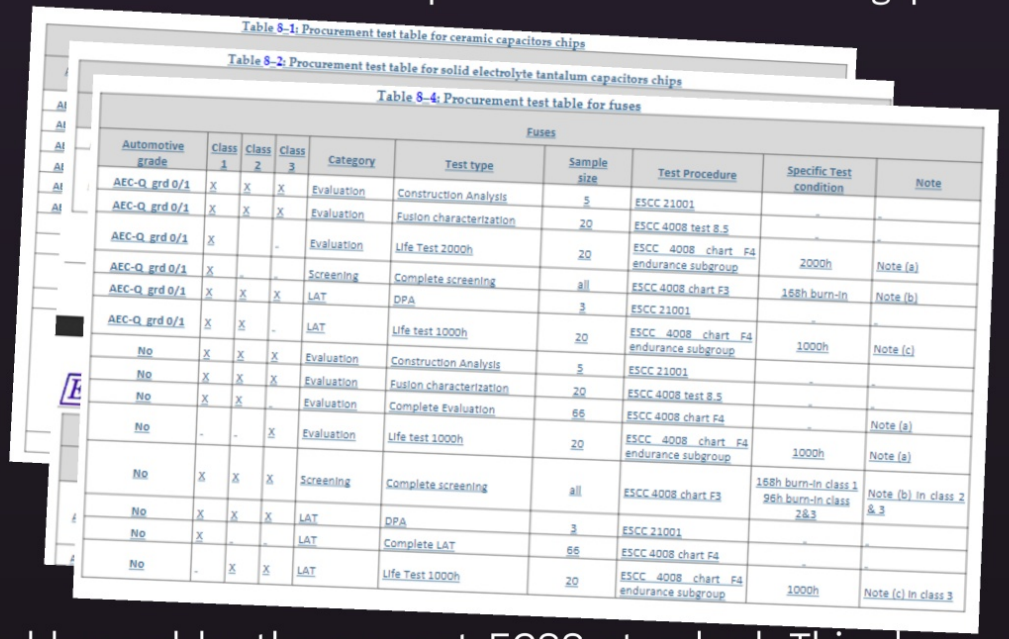


Table 8-1: Procurement test table for ceramic capacitors chips

Table 8-2: Procurement test table for solid electrolyte tantalum capacitors chips

Table 8-4: Procurement test table for fuses

Fuses									
Automotive grade	Class 1	Class 2	Class 3	Category	Test type	Sample size	Test Procedure	Specific Test condition	Note
AEC-Q grd 0/1	X	X	X	Evaluation	Construction Analysis	5	ESCC 21001	-	-
AEC-Q grd 0/1	X	X	X	Evaluation	Fusion characterization	20	ESCC 4008 test 8.5	-	-
AEC-Q grd 0/1	X		-	Evaluation	Life Test 2000h	20	ESCC 4008 chart F4 endurance subgroup	2000h	Note (a)
AEC-Q grd 0/1	X	-	-	Screening	Complete screening	all	ESCC 4008 chart F3	168h burn-in	Note (b)
AEC-Q grd 0/1	X	X	X	LAT	DPA	3	ESCC 21001	-	-
AEC-Q grd 0/1	X	X	-	LAT	Life test 1000h	20	ESCC 4008 chart F4 endurance subgroup	1000h	Note (c)
No	X	X	X	Evaluation	Construction Analysis	5	ESCC 21001	-	-
No	X	X	X	Evaluation	Fusion characterization	20	ESCC 4008 test 8.5	-	-
No	X	X	-	Evaluation	Complete Evaluation	66	ESCC 4008 chart F4	-	-
No	-	-	X	Evaluation	Life test 1000h	20	ESCC 4008 chart F4 endurance subgroup	1000h	Note (a)
No	X	X	X	Screening	Complete screening	all	ESCC 4008 chart F3	168h burn-in class 1 96h burn-in class 2&3	Note (b) in class 2 & 3
No	X	X	X	LAT	DPA	3	ESCC 21001	-	-
No	X		-	LAT	Complete LAT	66	ESCC 4008 chart F4	-	-
No	-	X	X	LAT	Life Test 1000h	20	ESCC 4008 chart F4 endurance subgroup	1000h	Note (c) in class 3

Other families of EEE components are not addressed by the present ECSS standard. This does not mean that they are forbidden!
For instance, other commercial technologies (e.g. connectors, cables, cable assemblies, RF passives, etc.) can be procured with the same approach.

COTS: Commercial Off-The-Shelf

However, these EEE commercial passive technologies are not allowed to be used :

- Hollow core resistors,
- Wet slug tantalum capacitors other than capacitor construction using double seals and a tantalum case,
- TO5 relays without double welding of the mechanism to the header or with any type of integrated diodes inside,
- Aluminum liquid electrolytic capacitors,
- Tin coated wires and cables,
- PVC insulated wires and cables,
- Electromechanical parts in commercial grade,
- Feed-through filter in commercial grade,
- Connectors without gold plating contact in commercial grade.

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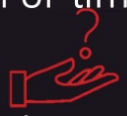
For limited life duration, known instability, safety hazards or reliability risks!



These requirements are based on Lessons-Learned and Data acquired through ESA missions and contracts.

"New" Space Era

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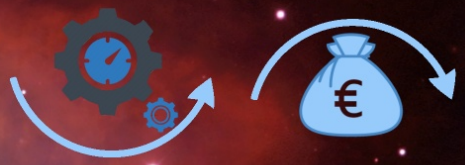


COTS

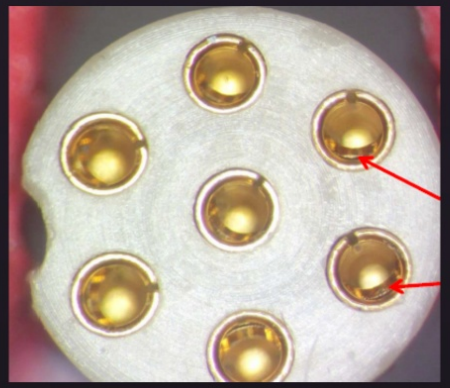
Impact on ESA's missions

Impact on ESA's missions

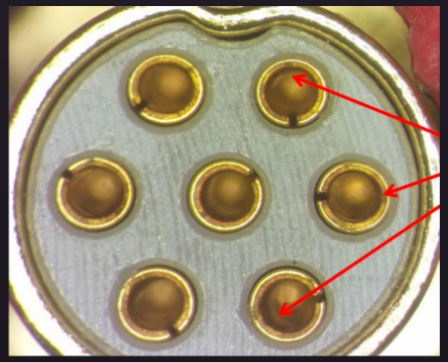
The procurement of COTS components has impacted some ESA's missions:

EXAMPLE 1: Commercial Connectors

When moving a harness with unconnected ends, an intermittent electrical resistance between the non-working supply line was detected.



Connector with good springs



Connector with small height spring

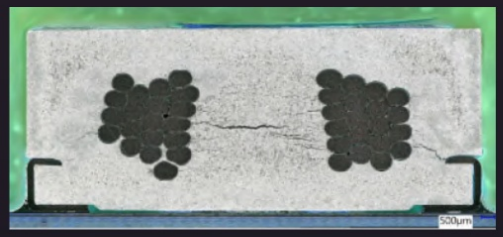
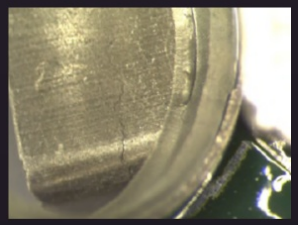
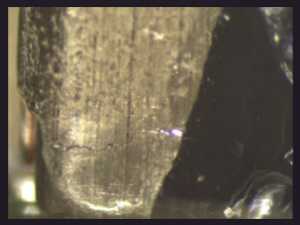
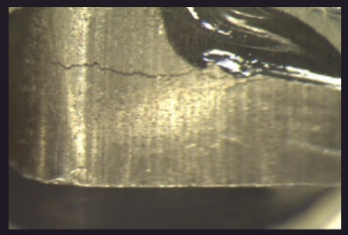
The root cause was identified at the connectors´ socket pins, where the spring was small in many cases, with low clamping forces.

The connectors were exchanged by new ones and the new harness is working properly.

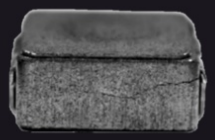
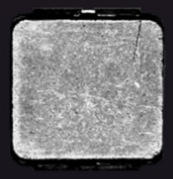
Impact on ESA's missions

EXAMPLE 2: Commercial Inductors

When using a new harmonized PCB cleaning agent, several external cracks were detected in already assembled commercial inductors, a drift in the inductance value was detected (before and after cleaning).

The drift in the inductance value was always lower than the component´s tolerance.
The manufacturer allowed for some level of cracks guaranteeing the nominal electrical parameters!
The root cause was identified as the new cleaning agent degrading the inductor´s ceramic composite.

The affected inductors were replaced and and an alternative cleaning agent was used.


News &
Challenges
Long Lead
Time
"New"
Space Era
Space
Standards
Resilience

Space Standards Resilience

ESCC (2) Resilience

(2) **E**uropean **S**pace **C**omponents **C**oordination

How are the European space industry and Agencies coping with the commercial era!?

ECSS (1) Updates

(1) **E**uropean **C**ooperation for **S**pace **S**tandardization

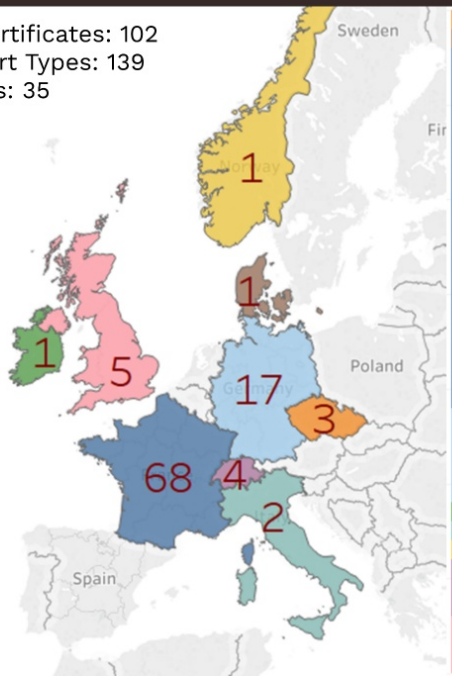
ESCC Resilience for Passive Components

2018

Number of Certificates: 98
Number of Part Types: 135
Manufacturers: 32

2022

Number of Certificates: 102
Number of Part Types: 139
Manufacturers: 35



Kyocera AVX Cz / 3 part types
Flux A/S / 1 part types
Axon / 17 part types
C&K / 18 part types
Cobham microwave / 2 part types
COMEPA / 2 part types
Deutsch / 4 part types
Draka Fileca / 2 part types
Exxelia SAS / 5 part types
Exxelia Technolgies / 19 part types
Exxelia Technologies / 4 part types
Hypertac / 4 part types
Kyocera AVX Fr / 10 part types
Leach Sarralbe / 4 part types
Minco / 1 part types
Nexans / 4 part types
Radiall / 13 part types
RAKON / 3 part types
REL STPI / 5 part types
Souriau / 25 part types
Vishay S.A. Sfernice / 2 part types
Bizlink / 6 part types
Isabellenhütte / 2 part types
Rosenberger / 12 part types
Vishay Draloric / 2 part types
W. L. Gore / 10 part types
TE Connectivity / 2 part types
IRCA - RICA / 2 part types
Kongsberg Norspace / 1 part types
Diamond SA / 1 part types
IST / 2 part types
SCHURTER AG / 2 part types
Kyocera AVX UK / 1 part types
Tyco Electronics / 3 part types
W.L Gore / 1 part types

Space Standards Resilience

ESCC (2) Resilience

(2) **E**uropean **S**pace **C**omponents **C**oordination

How are the European space industry and Agencies coping with the commercial era!?

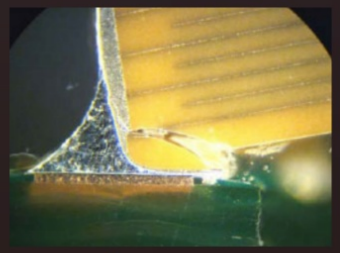
ECSS (1) Updates

(1) **E**uropean **C**ooperation for **S**pace **S**tandardization

ECSS Updates

On top of the update of ECSS-Q-ST-60-13, ESA - together with the European industry - have updated the standard ECSS-Q-ST-70-61C, High reliability assembly for surface mount and through hole connections, in order to better assess the cracks seen in ceramic (Type II) capacitors after the verification assembly.

The cracks in the ceramic observed at completion of assembly verification may be located either on the top terminations (CTE mismatch) or on the bottom terminations (Mechanical stress from bending the PCB, Thermal shock during soldering, etc.).



Bottom cracks are not accepted due to the different root causes.

A project specific request for deviation should be submitted including a risk analysis and impact study at system level!

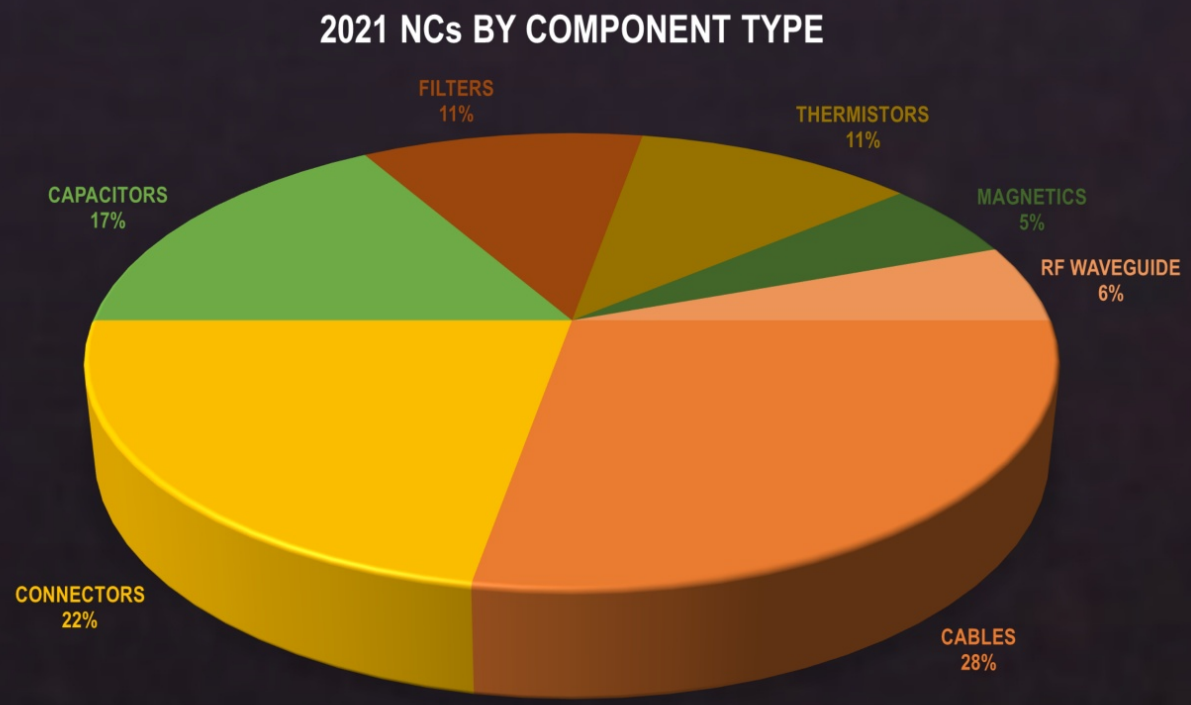
Recommendation to perform a "reduced temperature range" on the verification assembly of ceramic Type II capacitors, from the beginning!


ESA Passive Components: News, Activities and Trends
Dr. Léo Farhat & Mr. Joaquin Jimenez
ESA - European Space Agency
Failures
Activities
News &
Challenges
Trends


Failures
Component failures happen due to mechanical, thermal, environmental, electrical, mounting, aging factors, etc.
Non-Conformances
In-Orbit Failures

Non-Conformances: Some numbers

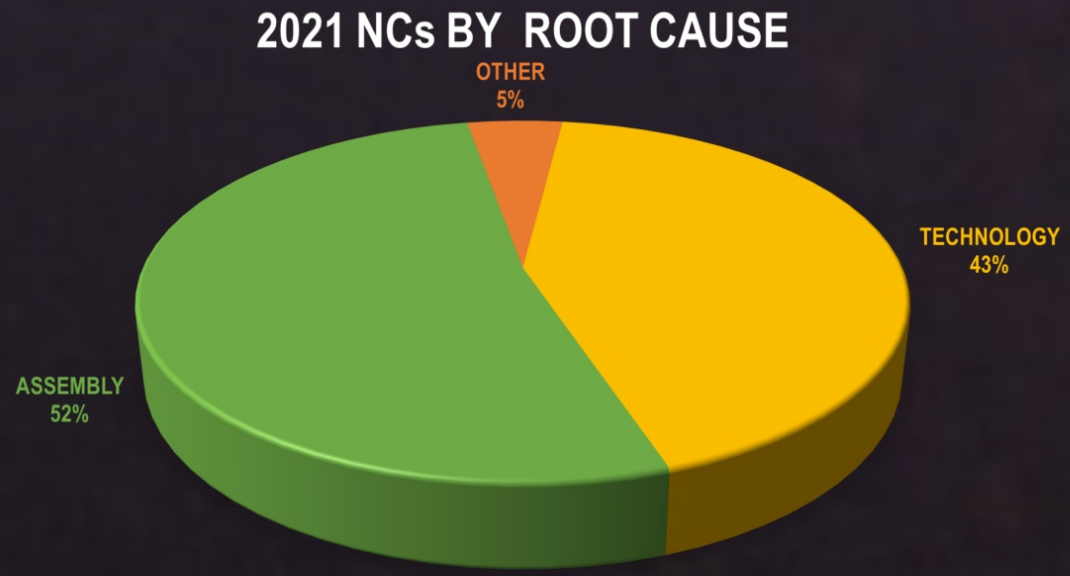
NCs are proportional to the number/amount of passive parts that are mounted in spacecrafts.



Non-Conformances: Some numbers

Most of the issues are related to the assembly processes.

Technology related issues were detected in the case of non-QPL parts: space-grade level, COTS or ESCC QPL used outside their qualification range.



Non Conformances: Mars Sample Return (MSR) example

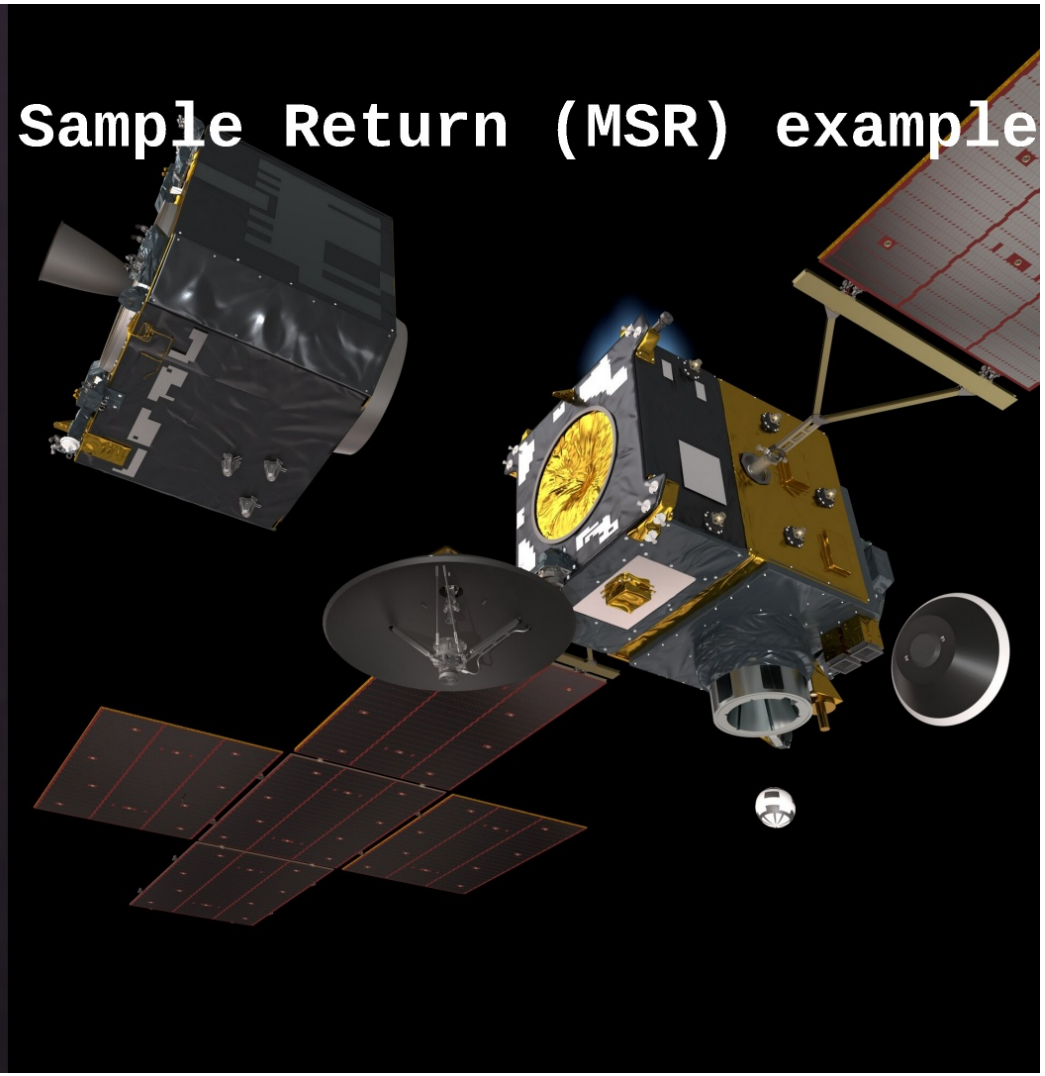
Bringing Mars to Earth is no simple undertaking!

It would require at least three missions from Earth and one **never-been-done-before** rocket launch from Mars.

Non Conformances: Mars Sample Return (MSR) example

ESA's Earth Return Orbiter, will have to capture the basketball-size Mars sample container orbiting Mars.
The samples are sealed. The spacecraft will then return to Earth, where it will release the entry capsule for the samples to end up in a specialized handling facility.

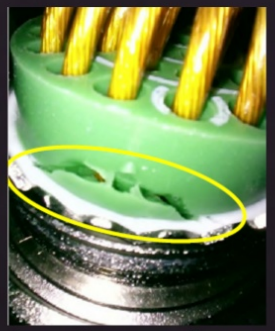
Around ~10 000 cycles are foreseen for the Earth Return Orbiter!
Therefore, **circular connectors** of the Solar Panels are expected to see extreme cold temperature (-170°C) far below their specified limits (-65°C) and qualified temperature as per ESCC specifications!

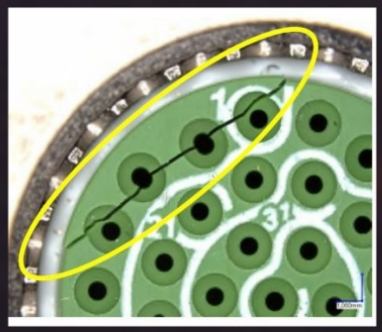


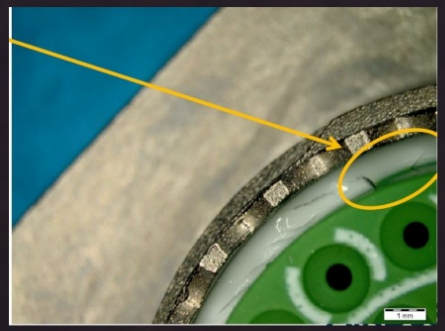
Non Conformances: Mars Sample Return (MSR) example

Cracks were seen in the plastic grommet of ESCC QPL circular connectors due to the extreme application conditions:
Connectors are being used far below their nominal temperature limits: -170°C instead of -65°C!

These connectors (plug and receptacle) are composed by a grommet (of plastic material), on top of a thermoplastic insert, that is adhered with a silicone filler to the connector´s housing.







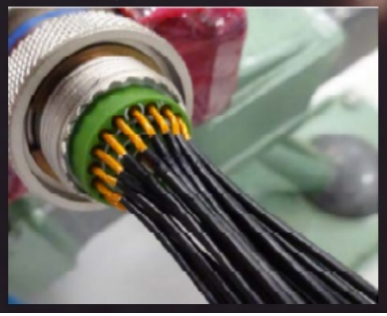
Several types of cracks have been detected on this grommet, only when tested below the minimum specified operating temperature and below the glass transition temperature of the plastic.

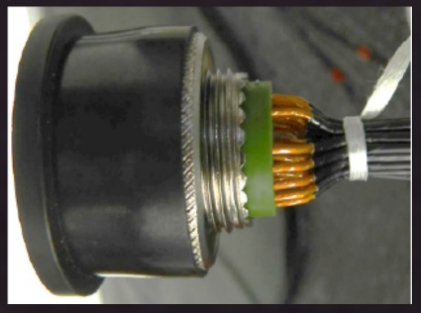
Non Conformances: Mars Sample Return (MSR) example

These cracks might potentially facilitate an electrical arc.
The risk of an electrical arc depends on the position of the connector (external/internal to the satellite), the voltage, current and distance between the pins, the insulation clearance between contacts and wire insulating jackets.

Root causes have been identified, on top of the use of the connectors beyond its specification:
- thermoelastic effects
- mechanical tension induced by the wires into the grommet.

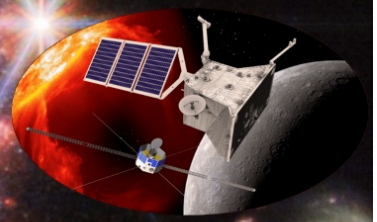
Several recommendations were proposed for ESA missions depending on the status of the procurement (New procurement, procured parts, already mounted parts):
- Dedicated TVAC Qualification Tests
- ESD Test and Analysis
- Improved Wire Routing
- Endoscopic Inspection





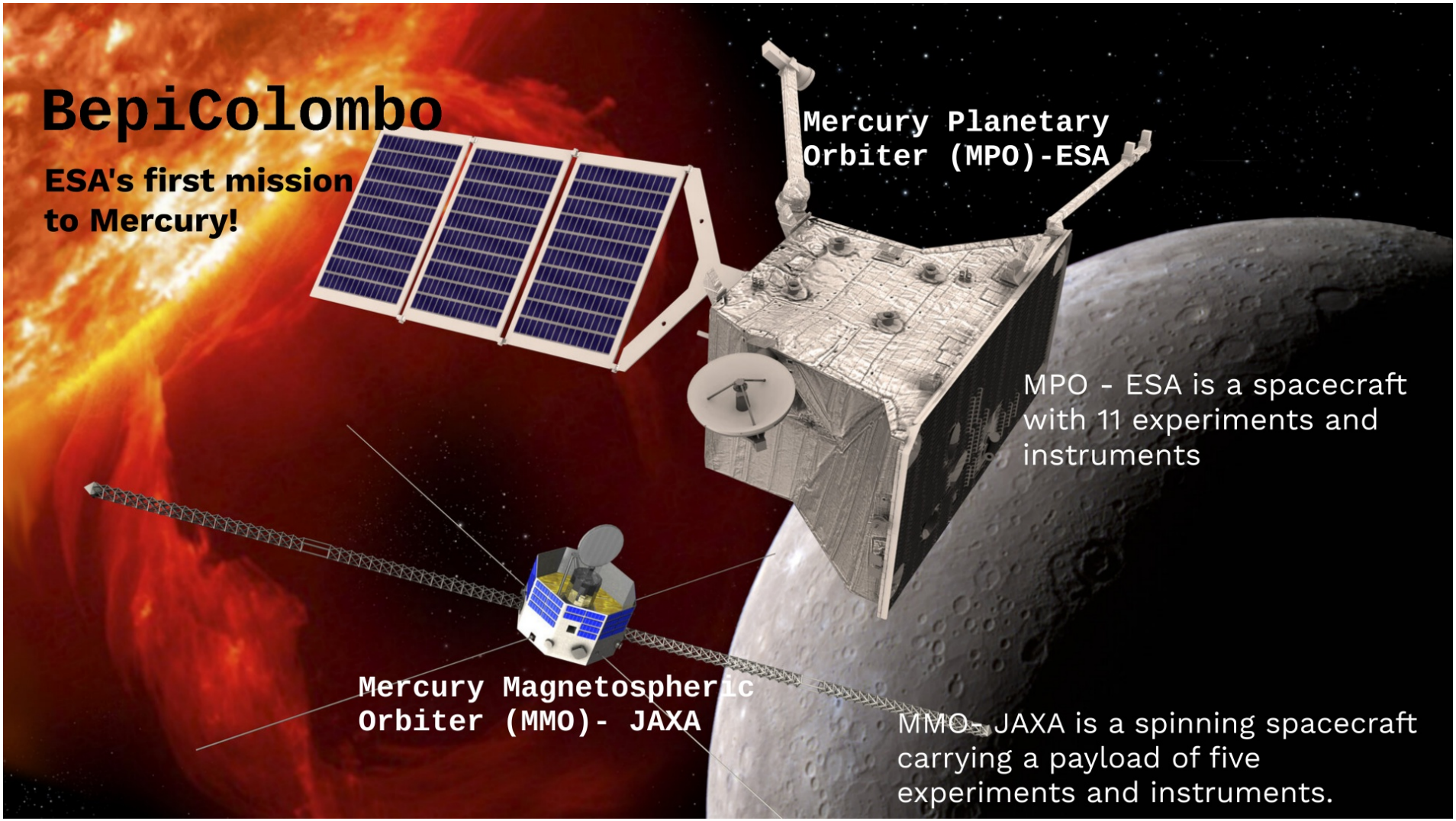
In-Orbit Failures

When a "simple" component causes Satellite in-orbit failures!



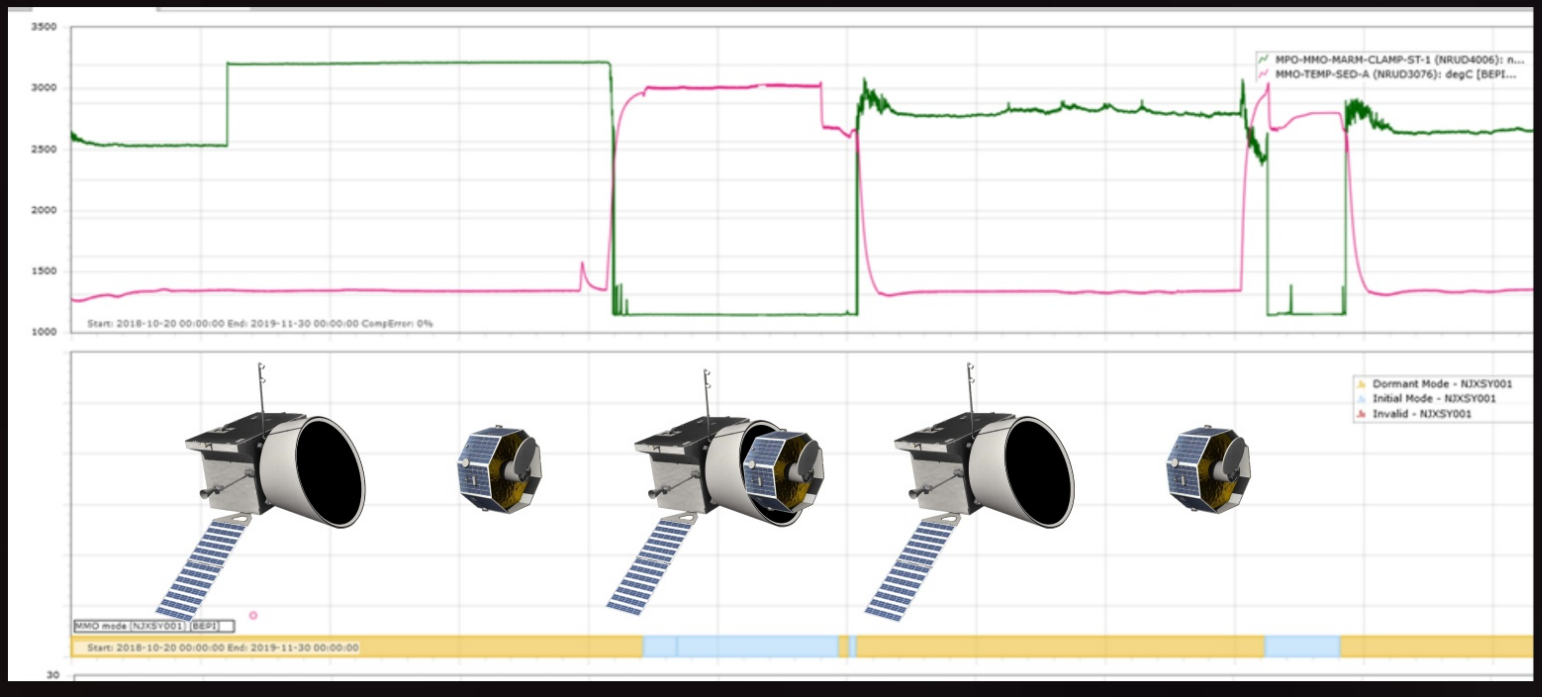
BepiColombo

Sentinel 1B


BepiColombo
ESA's first mission to Mercury!
Mercury Planetary Orbiter (MPO)-ESA
MPO - ESA is a spacecraft with 11 experiments and instruments
Mercury Magnetospheric Orbiter (MMO)- JAXA
MMO - JAXA is a spinning spacecraft carrying a payload of five experiments and instruments.

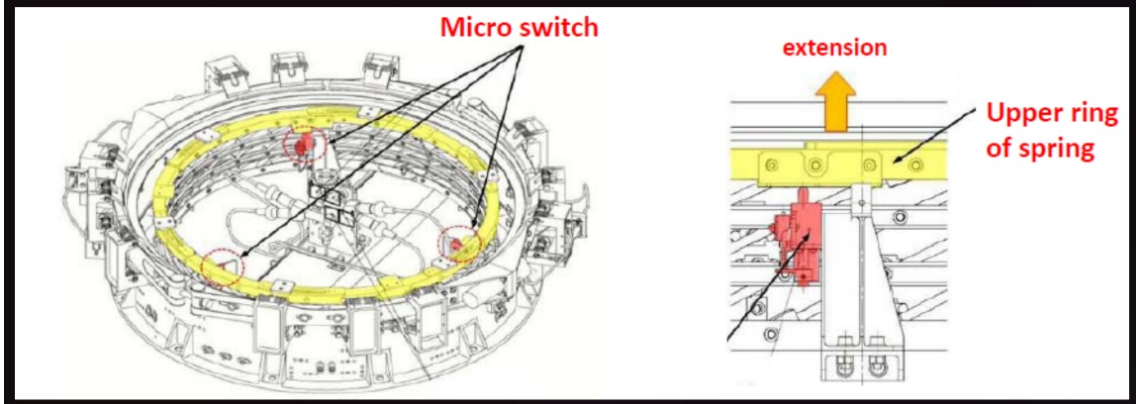
BepiColombo: In-orbit "minor" Anomaly

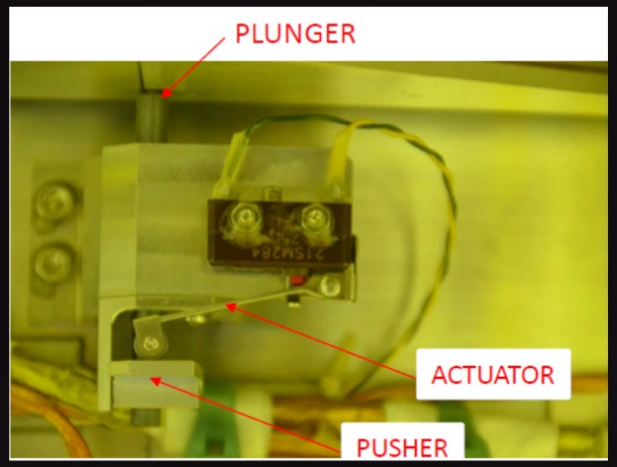
Telemetry data have - incorrectly - reported separation of the MMO orbiter, although no separation command of the MMO was sent!



BepiColombo: In-orbit "minor" Anomaly

Preliminary investigations show that the micro-switches may be incriminated, due to the toggling!





Plunger (and Pusher) is actually held in place by the clamp band spring, which is positioned right above the switch. Therefore, the Pusher can push the actuator only when the clamp band spring is released.

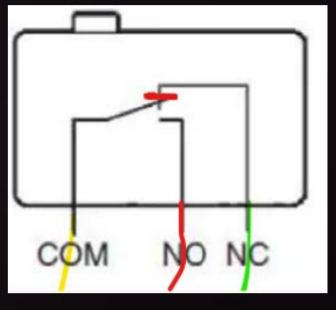
Several root causes have been investigated, with regards to the switch and its environment.

BepiColombo: In-orbit "minor" Anomaly

Several Lessons-Learned were collected:

1- Quality of the micro-switch:
High reliability micro-switches shall be procured in order to provide correctly (and reliably) the status information of S/C critical separation functions. This includes: hermetic technology, high temperature construction, better mechanical withstanding, bifurcated gold contacts for better reliability, space heritage, proper screening and LAT testing.

2- Wire connections to both NO (Normally Open) and NC (Normally Close):
The circuit design should have wire connections to both NC and NO in order to get all the necessary information about the separation status. This should help to discard the intermediate position (between NC and NO).



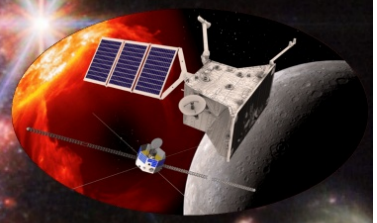
BepiColombo: In-orbit "minor" Anomaly

There is another way to monitor the separation of the MMO, by means of Sun Sensors that should detect the light/Sun in case of successful separation of the MMO orbiter!

BepiColombo meets Mercury!

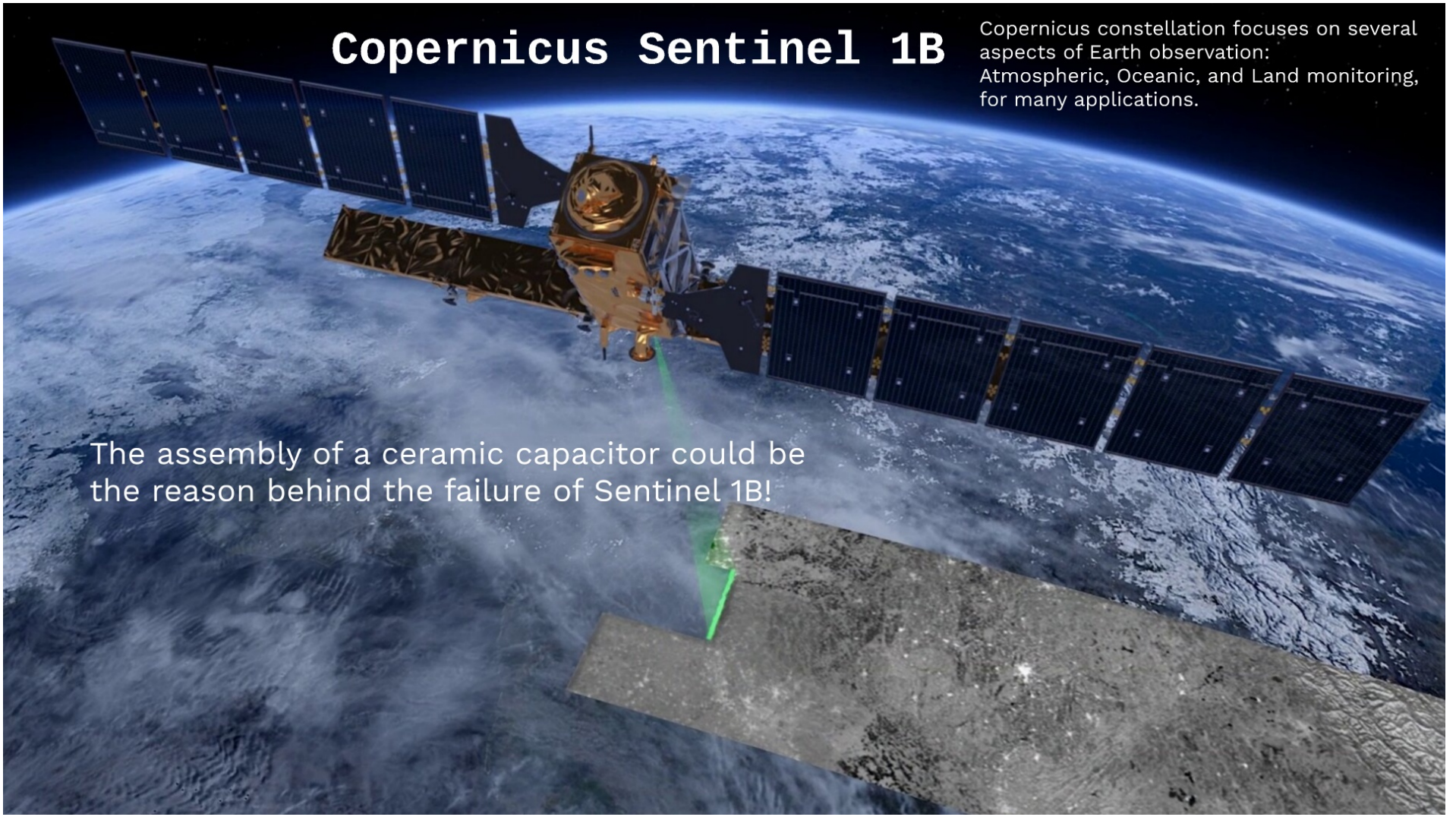
In-Orbit Failures

When a "simple" component causes Satellite in-orbit failures!



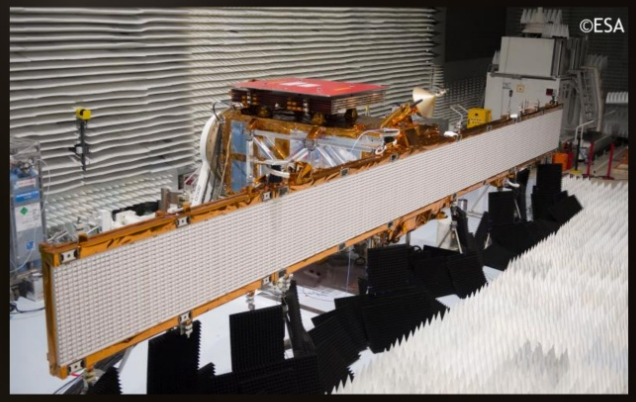
BepiColombo

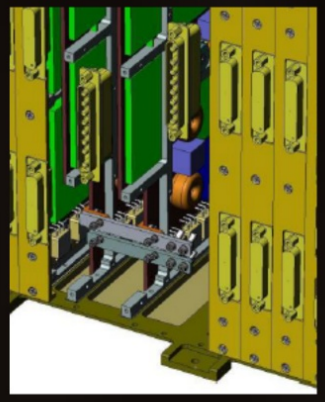
Sentinel 1B


Copernicus Sentinel 1B
Copernicus constellation focuses on several aspects of Earth observation:
Atmospheric, Oceanic, and Land monitoring, for many applications.
The assembly of a ceramic capacitor could be the reason behind the failure of Sentinel 1B!

Copernicus Sentinel S1B: The Failure

Sentinel-1B synthetic aperture radar (SAR) payload has malfunctioned and has ended the spacecraft's mission more than six years after its launch!





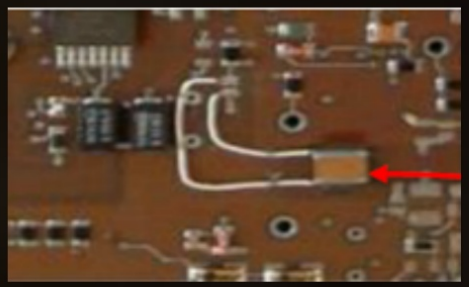
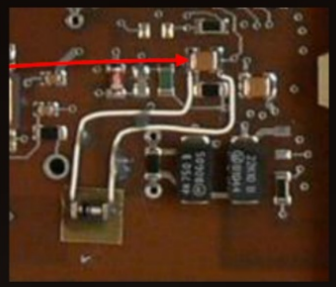
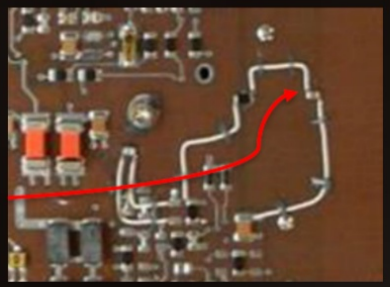
It was discovered that the main problem is related to the 28V regulated bus of the CAPS (C-SAR Antenna Power Supply), as it was observed that the main & redundant 28V power regulators were both unexpectedly OFF.

The CAPS is the unit –part of the electrical power sub-system of the platform –that provides power to SAR elements, including the SAR electronics.

Copernicus Sentinel S1B: The Root cause

Detailed investigations were performed, to understand the root cause of the CAPS anomaly, with the identification of 18 potential failure modes.
The soldering process used on this capacitor is considered the most probable root cause for the failure of the main and redundant regulators.

The possible Root cause is the rework (direct wiring) of ceramic (Type II) capacitors!

This capacitors had to be replaced as a result of a non-compliance detected during the manufacturing and testing phase. For the repair, the capacitors were soldered using a direct wiring soldering process.

Copernicus Sentinel S1B: The Root Cause

At the time of this rework, direct wiring on the capacitor was fulfilling applicable product assurance requirements. This repair process is no longer authorized following revision of applicable ECSS standard in 2017:

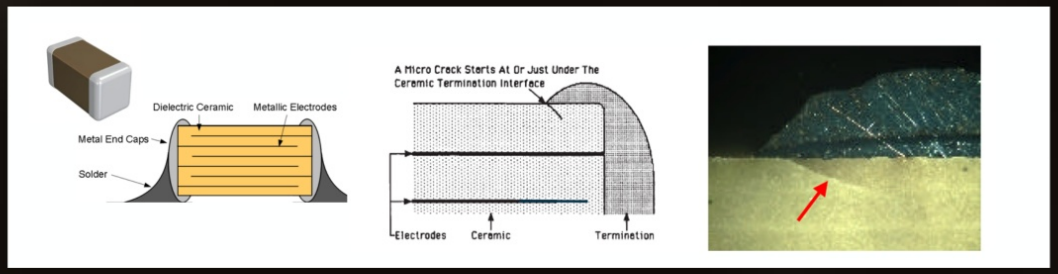
> Type II chip ceramic capacitors shall not be reworked.
>
> Reprocessing shall not damage the device.
>
> NOTE Reprocessing of ceramic chip capacitors is advised to be avoided due to potential crack formation.

Since 2019, Memo ESA-TECQTM-MO-1143 also forbids direct wiring of ceramic capacitors type II and recommends the use of dedicated patch boards.

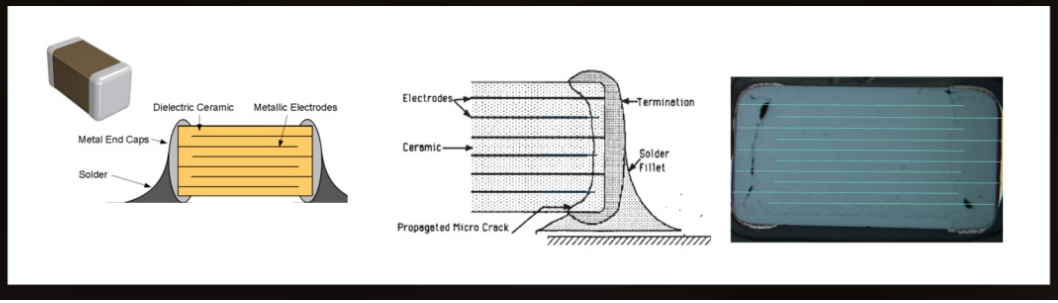
> Wiring directly on the component termination (eg. Component bonded on PCB and wiring connection made) and wiring made on the same PCB pad than the capacitor (modification after component assembly) shall not be performed due to possible damage within the component such as crack in the ceramic.
> It is recommended either to use a patch board with separate pads for the wiring (for addition of a capacitor) or to replace the capacitor during the wiring (modification applied after assembly)

Copernicus Sentinel S1B: The Failure Mechanism

During direct soldering of wire on chip ceramic capacitors, heat distortion occurs inside the chip capacitor.



A crack occur: It starts at the weakest point at the interface between the ceramic and the end point of the termination.
After several thermal cycles, the thermal shock crack propagates:



Copernicus Sentinel S1B: The Failure Mechanism

Diffusion and migration of Ag into dielectric layers from inner Ag or Ag/Pd electrodes might pose a problem for long-term reliability.

Silver is a material that is most susceptible to electromigration in the presence of moisture, and for this reason, cracking of PME (Precious Metal Electrode) capacitors creates a high risk of electrical failures.

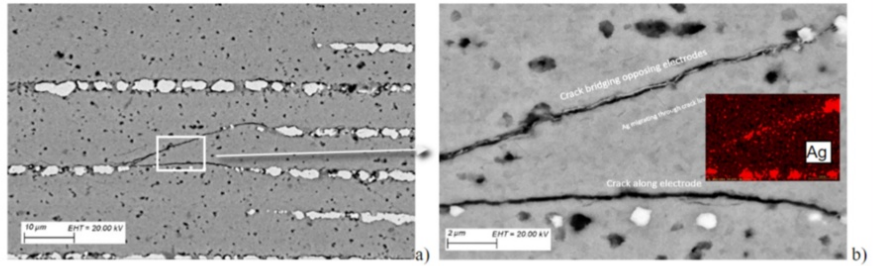


Figure 5. An overall (a) and close-up (b) views of a shorting crack in 0.1 µF 16 V PME capacitor. The part was tested at 6 V and started showing increased and unstable leakage currents after 110 hr at room temperature and then failed eventually short circuit due to silver electromigration after 50 hr at 60 °C. (Pictures courtesy of Ron Weachok, Jacobs Technology Inc.)

This results to excessive current leakage.

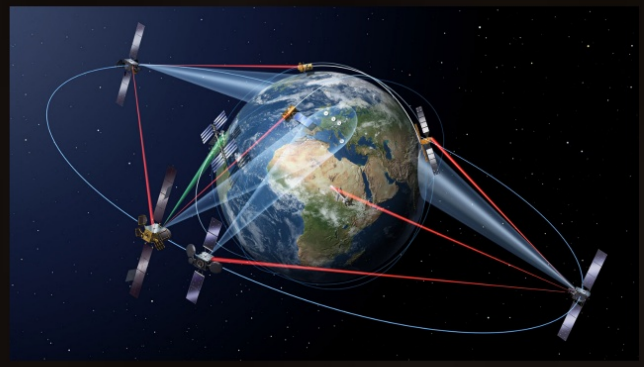
As the leakage current gradually increases, the heat generated by the capacitor continues to increase, which will eventually lead to dielectric thermal breakdown failure and a **short circuit.**

Copernicus Sentinel S1B: Conclusions and LL

Cracks were generated during the direct wiring soldering on the capacitors. Silver Electromigration has then caused a Short-Circuit.
The Satellite S1B has been retired and will be de-orbited according to space de-orbiting rules.

S1A has the same assembly process (Fingers crossed!).

S1C and S1D have been assembled according to the latest ECSS standard, that forbids direct wiring on the capacitors!



Micro-cracks in capacitors generated during assembly can be considered as a **“time bomb”.**

In order to avoid similar issues on Tantalum capacitors and Flexible ceramic capacitors, an internal ESA research will be conducted to perform reliability tests and gather enough data to forbid (or to authorize?) similar processes (direct wiring) on Tantalum SMD capacitors and flexible ceramic capacitors.


ESA Passive Components: News, Activities and Trends
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ESA - European Space Agency
Failures
Activities
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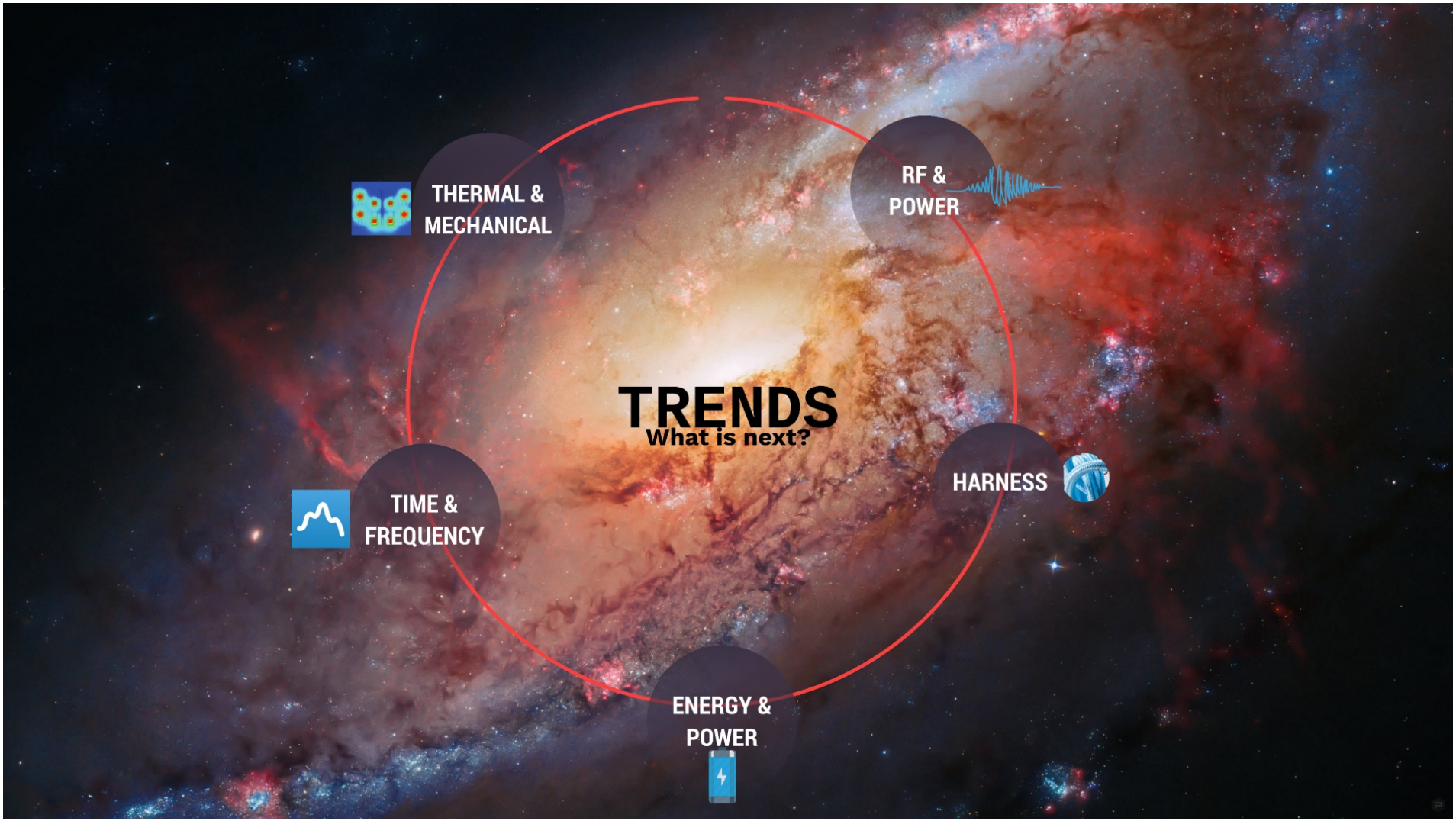
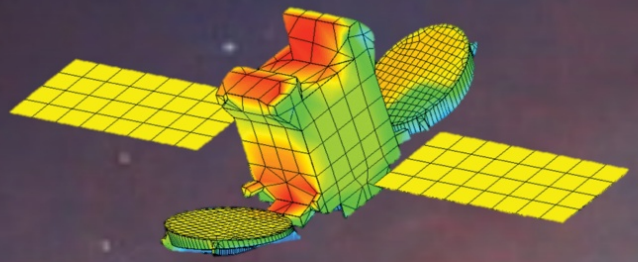
Trends


THERMAL &
MECHANICAL
RF &
POWER
TRENDS
What is next?
TIME &
FREQUENCY
HARNESS
ENERGY &
POWER

THERMAL & MECHANICAL

Spacecraft systems tend to be designed with increasingly complex architecture management (including cross-strap)



RELAYS

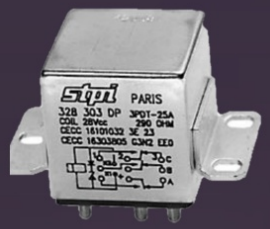
HEATERS

SENSORS

PELTIER MODULES

Relays



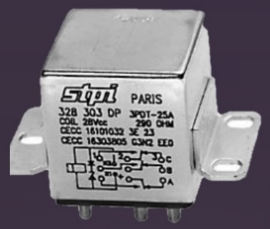



- **Need: High level vibration/shock relays for new systems**
  Improved design exceeding the current ESCC3602 levels for shocks and vibration.

		Mechanical Test ESCC3602
Vibration	Low Level Sine	30 g
	High Level Sine	40 g
		50 g
		60 g
		70 g
	Random	20.71 grms
		23.91 grms
		29.28 grms
Shock	Low Level	100g – 6ms
	High Level	500g – 1ms
		1000g – 0.5ms
		1500 g – 0.5 ms
	SRS (pyro-shock)	2 up to 1500 gsrs
		30 up to 4000 gSRS
		200 up to 20 000 gSRS

Relays



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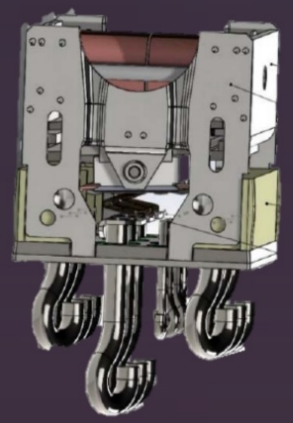
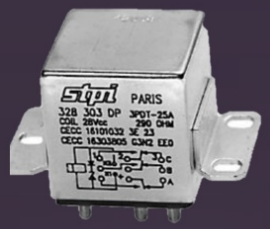
  Improved design exceeding the current ESCC3602 levels for shocks and vibration.

		Mechanical Test ESCC3602
Vibration	Low Level Sine	30 g
	High Level Sine	40 g
		50 g
		60 g
		70 g
	Random	20.71 grms
		23.91 grms
		29.28 grms
Shock	Low Level	100g – 6ms
	High Level	500g – 1ms
		1000g – 0.5ms
		1500 g – 0.5 ms
	SRS (pyro-shock)	2 up to 1500 gsrs
		30 up to 4000 gSRS
		200 up to 20 000 gSRS



Relays



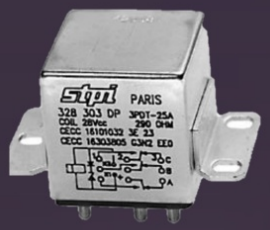



- **High level vibration/shock relays for new systems**
  Improved design exceeding the current ESCC3602 levels for shocks and vibration.

		Mechanical Test ESCC3602
Vibration	Low Level Sine	30 g
	High Level Sine	40 g
		50 g
		60 g
		70 g
	Random	20.71 grms
		23.91 grms
		29.28 grms
Shock	Low Level	100g – 6ms
	High Level	500g – 1ms
		1000g – 0.5ms
		1500 g – 0.5 ms
	SRS (pyro-shock)	2 up to 1500 gsrs
		30 up to 4000 gSRS
		200 up to 20 000 gSRS

Relays



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		Mechanical Test ESCC3602
Vibration	Low Level Sine	30 g
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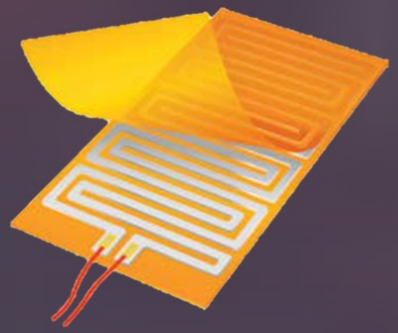
		23.91 grms
		29.28 grms
Shock	Low Level	100g – 6ms
	High Level	500g – 1ms
		1000g – 0.5ms
		1500 g – 0.5 ms
	SRS (pyro-shock)	2 up to 1500 gsrs
		30 up to 4000 gSRS
		200 up to 20 000 gSRS

- **Identified needs:**
  Electro-mechanical relays operating under high voltage (up to 5kV) for electric propulsion

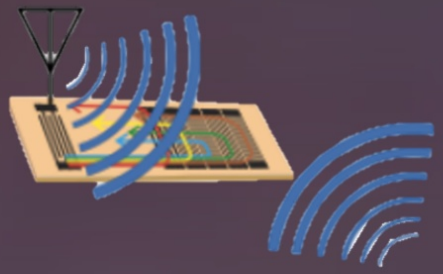
HEATERS



- **High Temperature (up to 270°C) and Flexible heaters:**

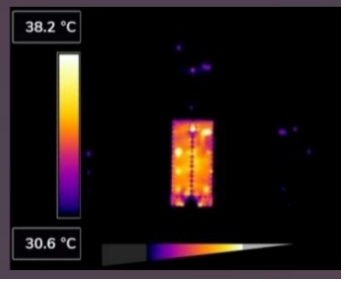
These heaters should be pre-assembled with wires and a fast-locking connector.
They should also be easily assembled (i.e. integarted glue) without applying any pressure (i.e. PSA).

- **Integrated heaters into flexible PCB Harness**



- **Wireless solutions for sensors and heaters**

Currently, ESA is investigating in a standardised **non-destructive test** method in the frame of a TDE activity "Foil Heater Hot Spot Characterisation" thanks to the use of IR cameras.
See ESA presentation on Friday 14/10 @12:00 for more information.



SENSORS

- **Pre-assembled Temperature sensors for extreme temperatures:**

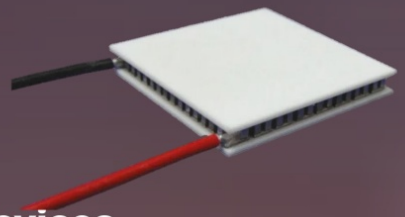
Currrently, space grade Platinum sensors (without pre-assembled wires) are qualified down to -200°C.
QPL Thermistors chips (pre-assembled with wires) are only given down to -65°C.
Applications are today requiring pre-assembeled (with wires) platinium sensors and down to -200°C.

- **European solutions for cryogenic temperature sensors:**

Science missions are requiring cryogenic temperature sensors down to 37K (-235°C).

These sensors should be able to withstand cryogenic temperatures and procured pre-assembeled with wires (and ideally integrated with fast-locking connectors).

PELTIER MODULES



- **Thermoelectric cooling (TEC) devices**

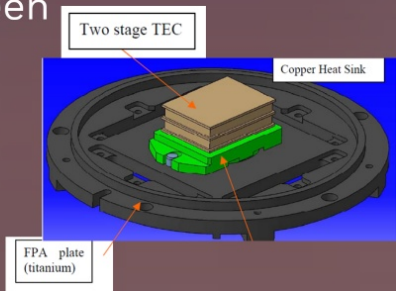
TECs are mainly used for star trackers and camera navigation space applications.

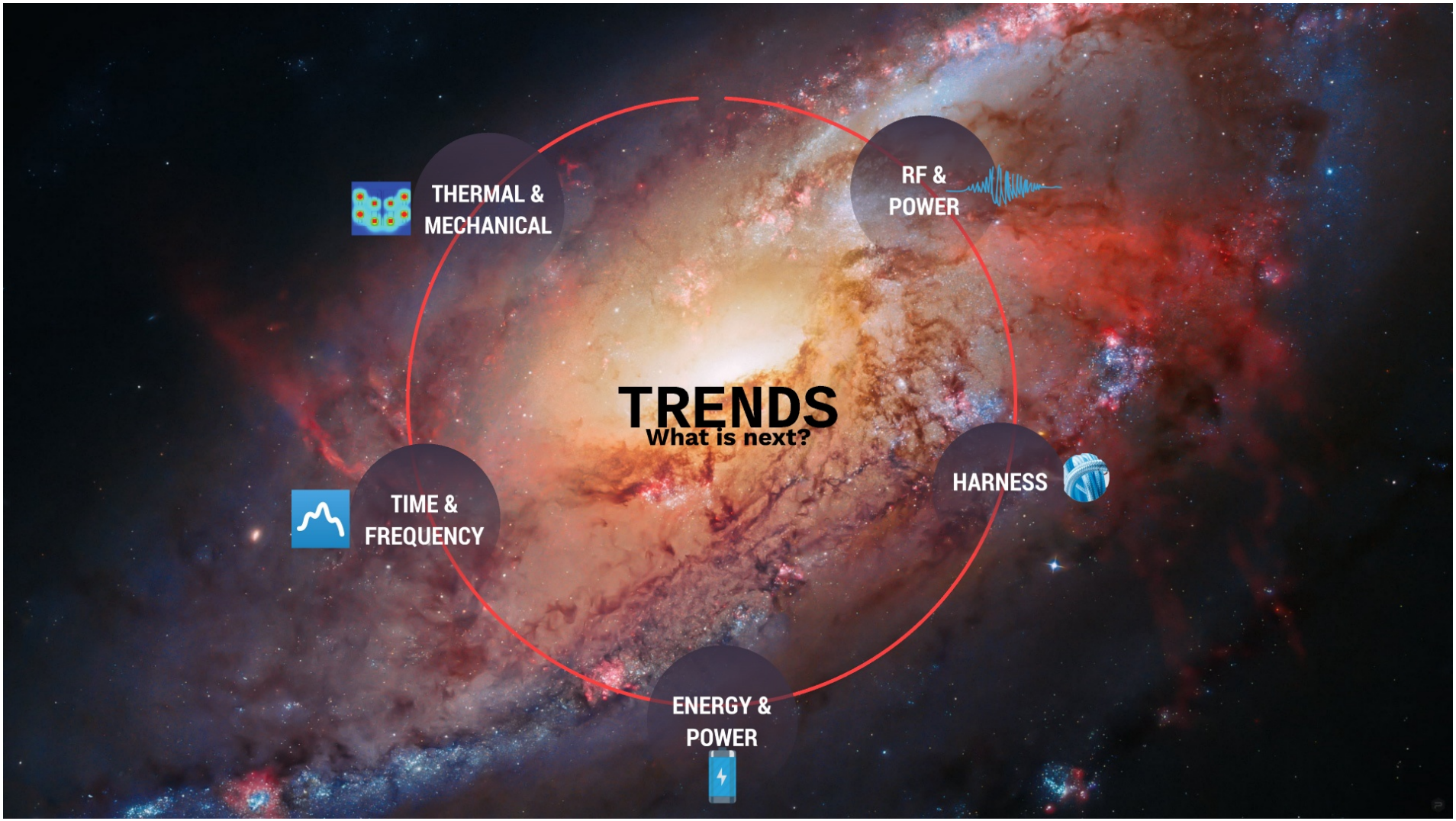
- **European non-dependence**

Up to now, the identified manufacturers for space come from Russia or Ukraine.
Apart from this, there are non-EU COTS solutions.

- **High Temperature gradient:**

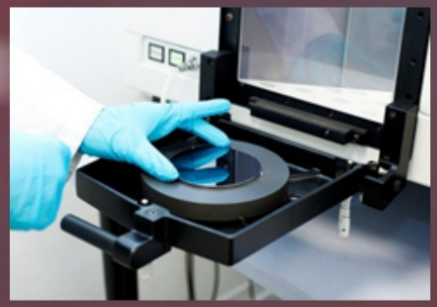
Thermoelectric coolers manufactured in Europe (with one or two stages), working up to 125°C, with delta-max T around 60°C (between hot and cold sides).




THERMAL &
MECHANICAL
RF &
POWER
TRENDS
What is next?
TIME &
FREQUENCY
HARNESS
ENERGY &
POWER

TIME & FREQUENCY

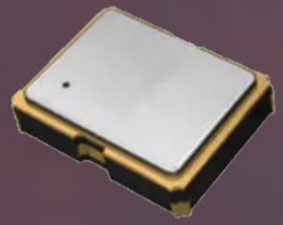
Low cost and rad-hard quartz oscillators are critical items for LEO mission applications like PNT (Positioning, Navigation and Timing), commercial telecommunication and any application requiring high spectral purity (e.g. Radar).



Quartz sweeping or pre-radiation are considered costly and time consuming processes. Those manufacturing processes are not compatible with low cost devices.

- Cost effective technologies for crystal growing and/or resonator process for reducing the sensitivity to radiation.

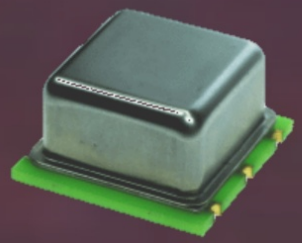
TIME & FREQUENCY



- **Frequency Flexible Oscillator:**

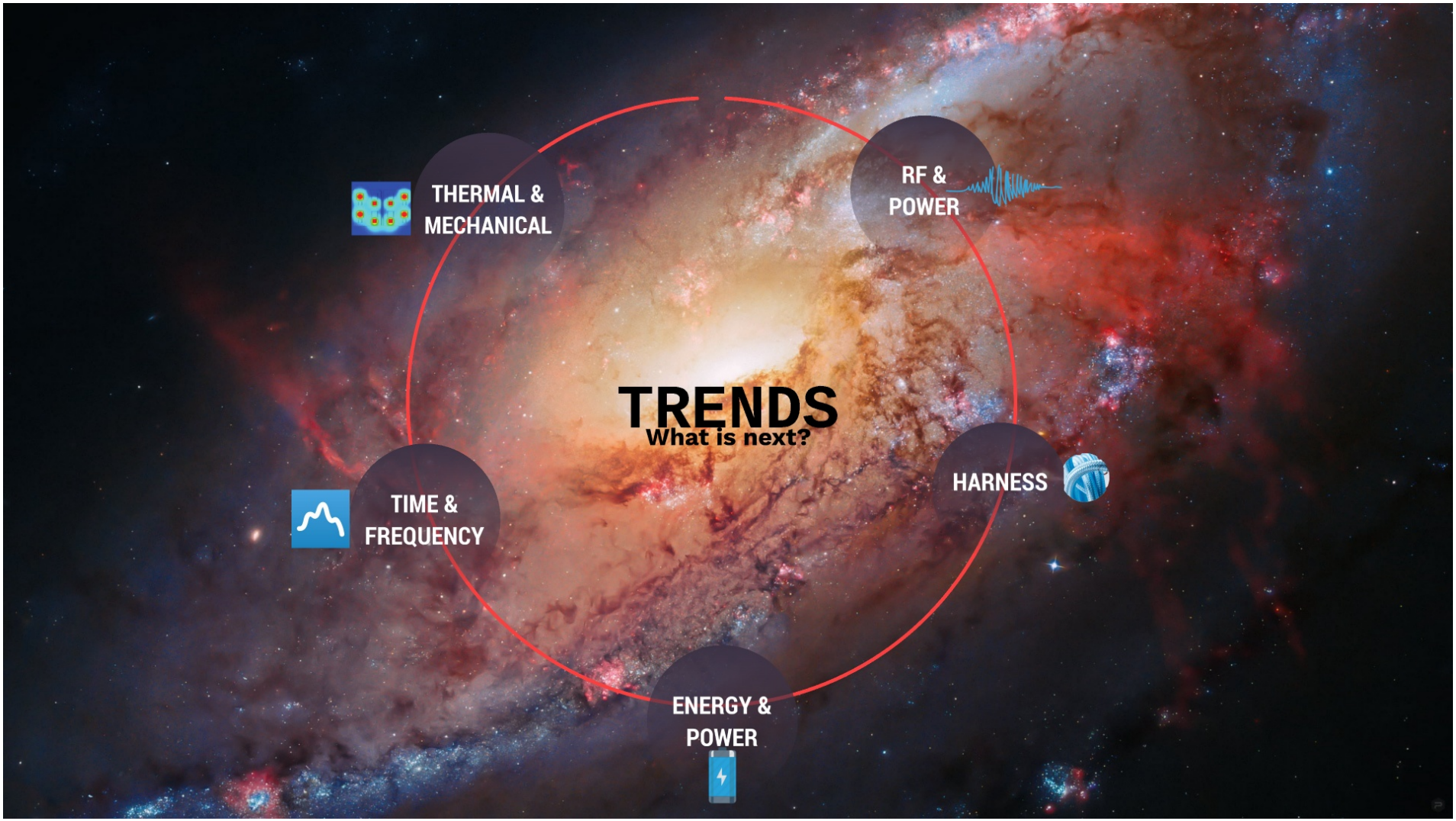
One of the drawback of hi-rel crystal oscillators is their long lead time, due to long-term stability test (i.e. frequency pre-ageing). ESA is supporting Rakon (FR) in order to develop a frequency-flexible oscillator.

This is possible by means of a one-time programmed (OTP) and an internal Phase-Locked Loop (PLL) frequency synthesizers. Pre-screened oscillators can be adjusted and delivered to the happy customer in few weeks!



- **SMT resonators :**

Resonators based on SMT (instead of through holes) are under development and are being space qualified in order to miniaturize and to ease the assembly.


THERMAL &
MECHANICAL
RF &
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TRENDS
What is next?
TIME &
FREQUENCY
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POWER

ENERGY & POWER

- **Global Trends**: Higher Power density & Better Integration.

High Capacitance and voltage in SMT packages for capacitors with lead-free.

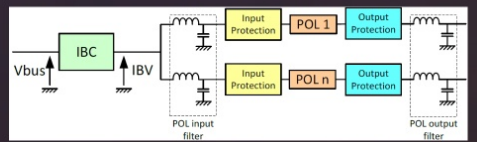
Planar transformers up to 8 kV for electronic power conditioning.

European solutions for ferrite beads for higher operating frequency in SMT packages.

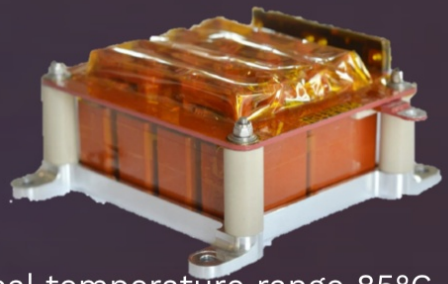
Wet Tantalum Capacitor for high power applications requiring high energy/voltage (i.e. RF GaN power transmitters) .

- **High current chip inductors:**

High current SMT chip inductors for FPGA for Telecommunication satellites, or to be used at the input/output filters of Point Of Load (POL), Distributed Power Architecture (DPA).
ITT to be published on "ESA-Star publication".



ENERGY & POWER



Supercapacitors' identified Applications:

There are specific supercapacitor applications identified for space:

- High power actuators, high power Lidar, High power radar:
  Supercapacitors with small capacitance (tens of F) and High operational temperature range 85°C.
  Number of cycles (> 3 millions) and Lifetime (15 years).

- Launchers (pyro, EMTVAS ElectroMechanical Thrust Vector Control, telemetry):
  Supercapacitors with **high specific Energy** (>15Wh/Kg) & **High operational temperature range** 80°C
  For pyro applications tens of A are needed.

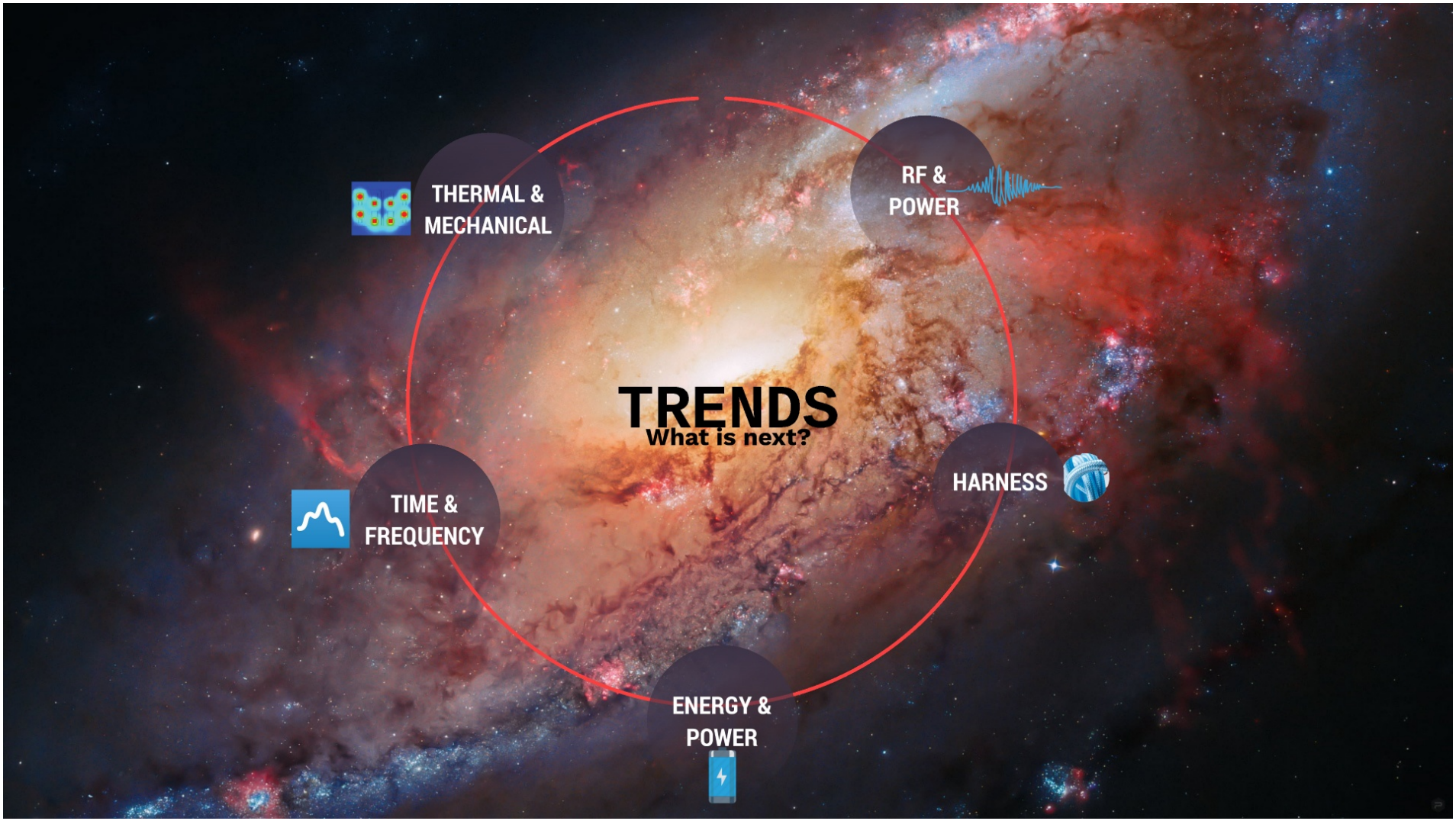
- Hybrid power system: supercapacitor cells assembled in BOSC (Banks Of SuperCapacitors), combined with battery pack.

- Small satellite (100-200kg) market: graphene supercapacitors as rechargeable energy storage medium as alternative to chemical batteries (for mass/volume constraints).

Identified Technologies:

Graphene, VACNT (Vertical Alligned Carbon NanoTubes), CDC (Carbide-Derived carbon)

For more information, please attend ESA's presentation: **"Supercapacitors for space applications: trends and opportunity"** on Wednesday 12/10 @ 11h30.


THERMAL &
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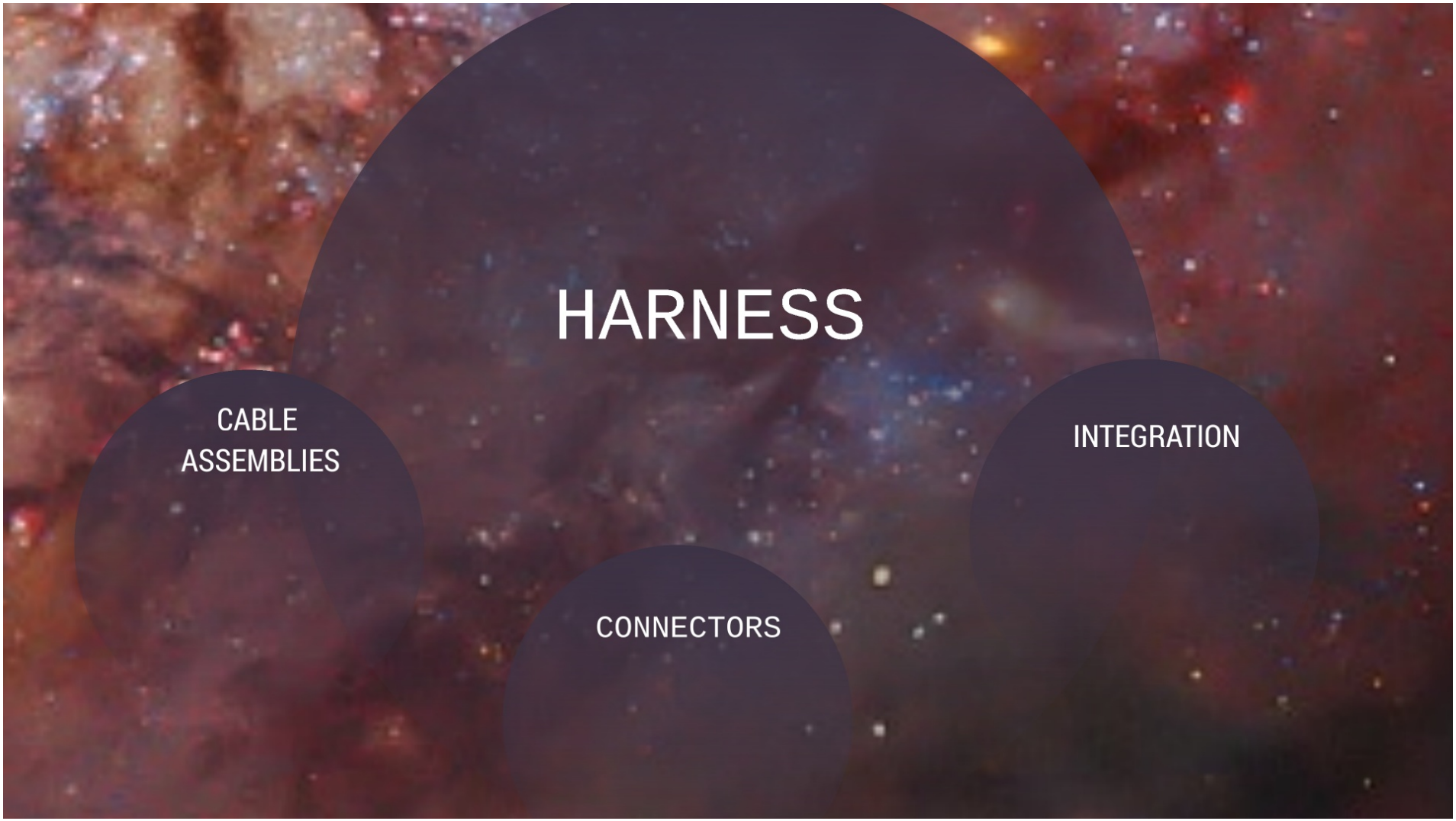

HARNESS
CABLE ASSEMBLIES
INTEGRATION
CONNECTORS

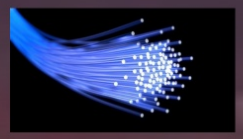
CABLE ASSEMBLIES

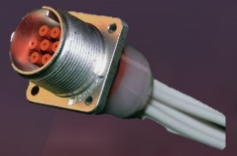
RF
ESCC 3408

Optical
ESCC 3420

High Data Rate
ESCC 3409

High Voltage
ESCC xxxx





RF Cable Assemblies

- **Today's Status:** ESCC QPL qualification of RF cable assemblies:

SMA 2.2 mm up to 22 GHz (Gore)
2.4 mm up to 45 GHz (Axon)
VHP RF cables (Radiall)

- **Ongoing:**

ESCC qualification 2.92 mm up to 32 GHz (AXOSAT, Axon)

Development of a RF interface for connectors and cable assemblies with a fast-locking mechanism, up to W band.

- **What is next?**

Development and Qualifaction of RF cable assemblies 1.85 mm (up to 65 GHz) and 1mm (up to ~110 GHz)!

SiO_2 based temperature phase-stable RF cable assemblies for phase sensitive equipment (e.g. SAR instruments, etc.)

CABLE ASSEMBLIES

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ESCC 3420

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ESCC 3409

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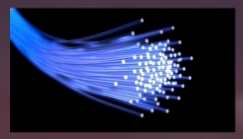
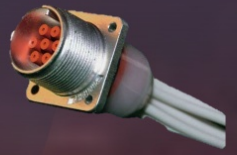
ESCC xxxx

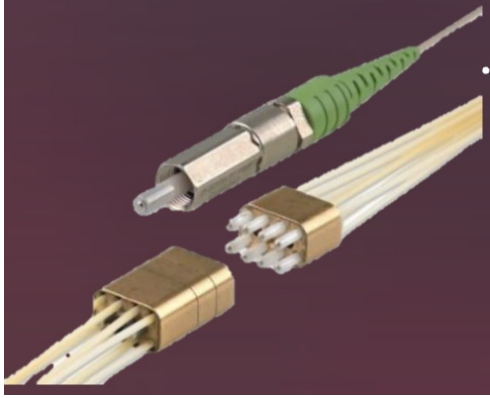




Optical Cable Assemblies

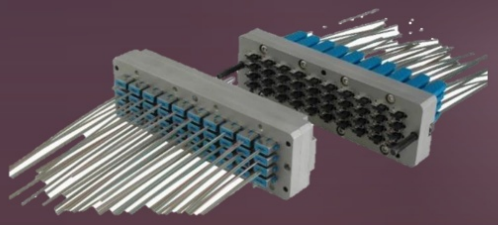
Solutions based on Fiber optic CA for very high speed flow of data:

- **Today:**
  - -ESCC QPL Diamond Mini AVIM 3420/001, for generic sensing and satellite external and internal communication applications.
  - -For single- and multimode fibers, PM technologies, multifiber ferrules and multicore fibers.
  - -IL: 0.2dB, RL<50dB, -40° to +85°C



- What is next?
  - -Miniature multichannel connector for high power PM applications

- What is next?
  - -Multiple MultiMode Mechanical Transfer based optical interconnects



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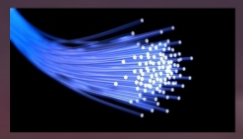
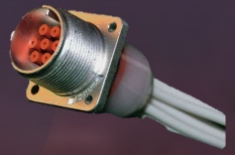
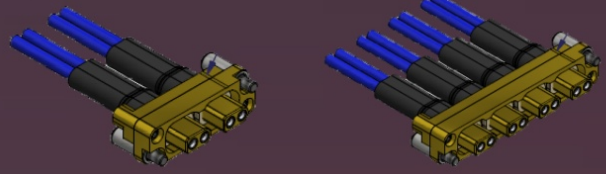


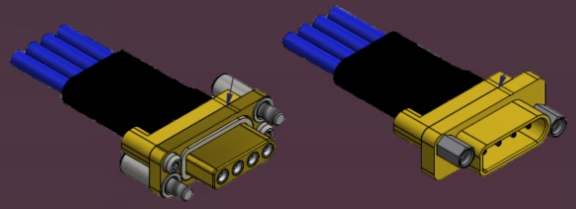


High Data Rate Cable Assemblies

Since ESCC3409 for HDR CA was published in September 2018, the following developments are available:

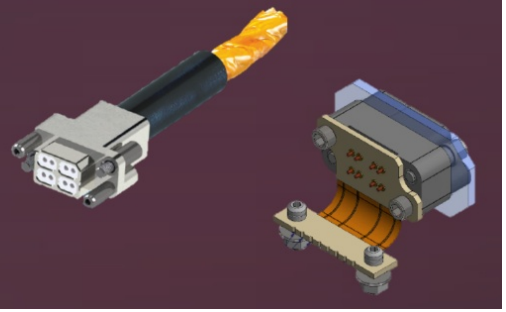
-AXON Cable **Axomach** and **Axomach Spacefibre** cable asssembly **up to 10Gbps.**





-AXON Cable **MicroMach** cable assembly **up to 3 Gbps**, with:

- Qualified Low Mass SpaceWire cables.
- EPPL-2 PCB MicroMach connectors



CABLE ASSEMBLIES

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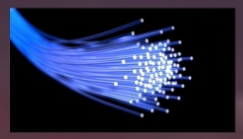
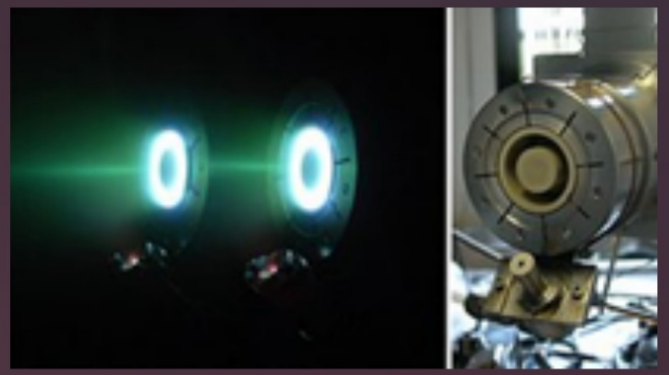


High Voltage Cable Assemblies

- **What´s next?**

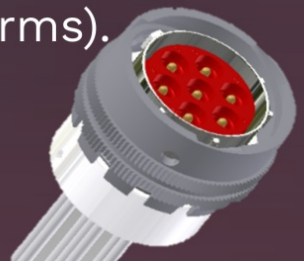
Evaluation and Qualification of High Voltage and High Temperature cable assemblies for electrical propulsion

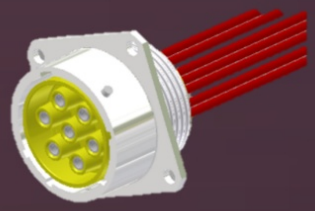
  - Operating voltage up to 15 kV DC
  - Operating temperature above 200°C

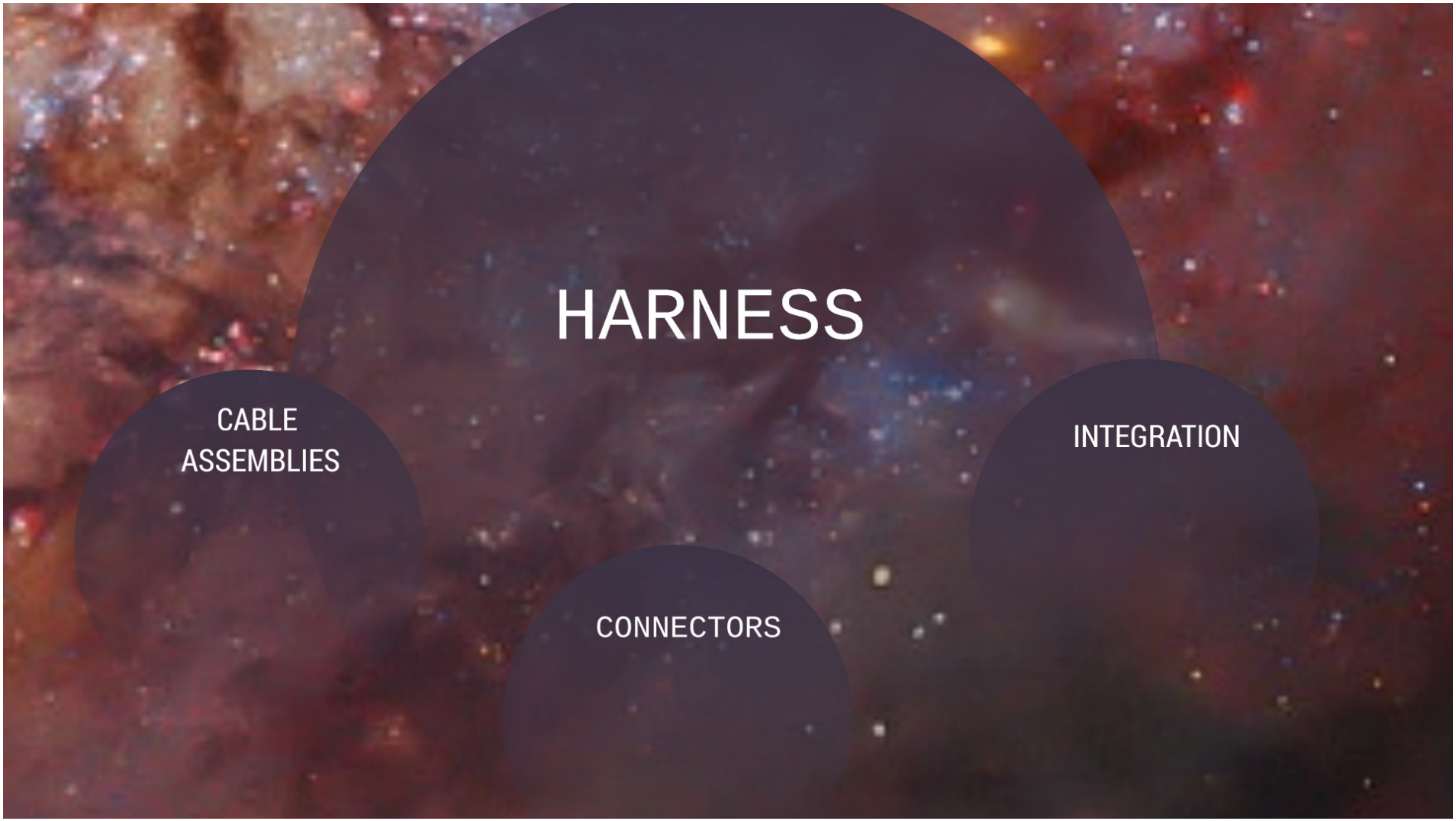


- Radiation resistance up to 200 Mrad.

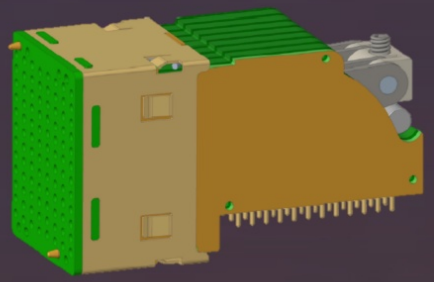
- Resistant to high temperatures:
  from min -55°C to max +170°C for dynamic applications (i.e. moving arms).






HARNESS
CABLE ASSEMBLIES
INTEGRATION
CONNECTORS

Connectors



- **Combo connectors:**

Versatys : Power + Signal + RF + **Optical**

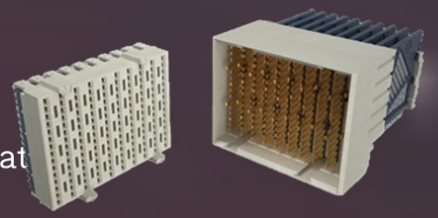
- **Solderless solutions** for High Data Rate compatible with cPCI SS:

ESA On-going activity to assess the reliability of the available COTS solution as well as Hyperbits solution of Performance Interconnect (France).

Future activities: **Speed up to 56Gb/s**

-ITT published (ARTES AT): Development of High Density Modular Electrical Interconnections for High Data Rate Applications.

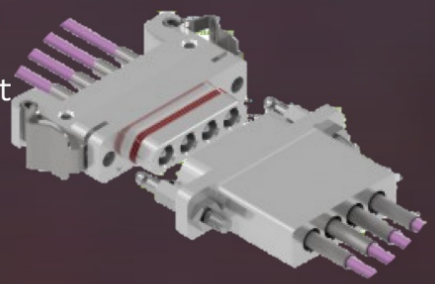
-ITT to be published (TDE): Board to board interconnections for high data rat applications.



- **Fast locking**

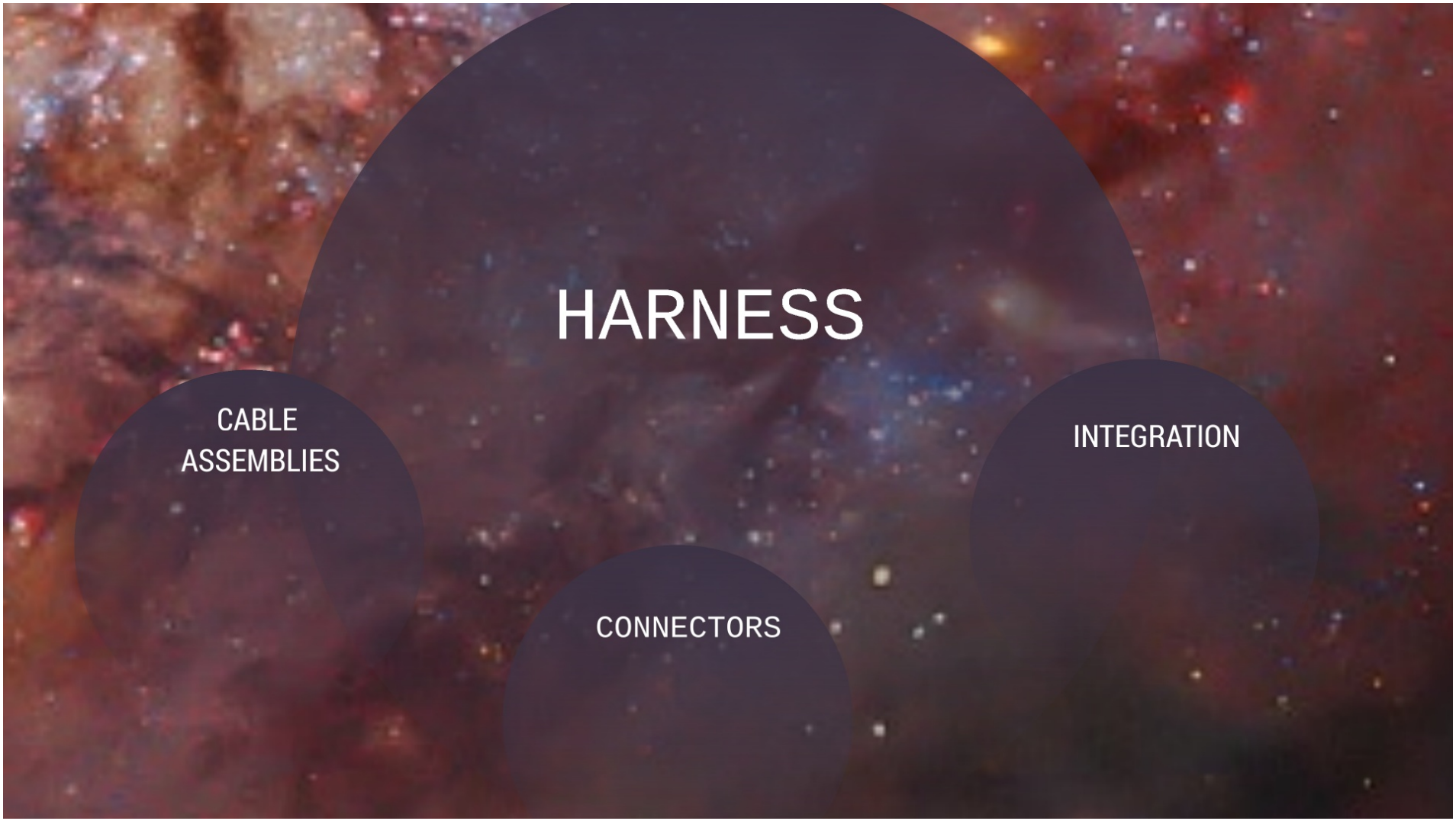
Development of SMT connectors with fast locking mechanism for connectorless flat cables.

-ITT published (ARTES AT) : Fast-lock interconnections and connectorless flat cables for satcoms.



- **What is next?**

Optical fiber microD connectors (with FT ferrule), IP68 sealed, standard or D-click, compatible with flat fiber optics!


HARNESS
CABLE ASSEMBLIES
INTEGRATION
CONNECTORS

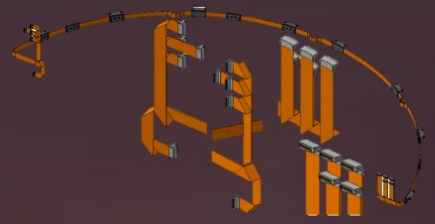
BETTER INTEGRATION & ROUTING

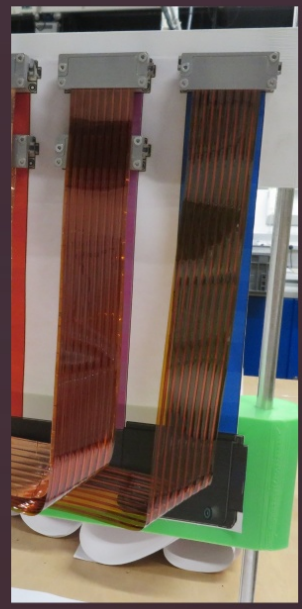
Upgrade of the rating and derating rules for wires and cables: ECSS-Q-ST-30-11C Rev. 2 (23 June 2021)
Expected mass savings: from 20% up to 50%

- Flexible PCB Harness:
  - -Mass savings target up to 30%
  - -Reduction of cost by reduction of the number of devices
  - -Better shielding and impedance characteristics
  - -Drastic reduction of AIT integration time

Harness

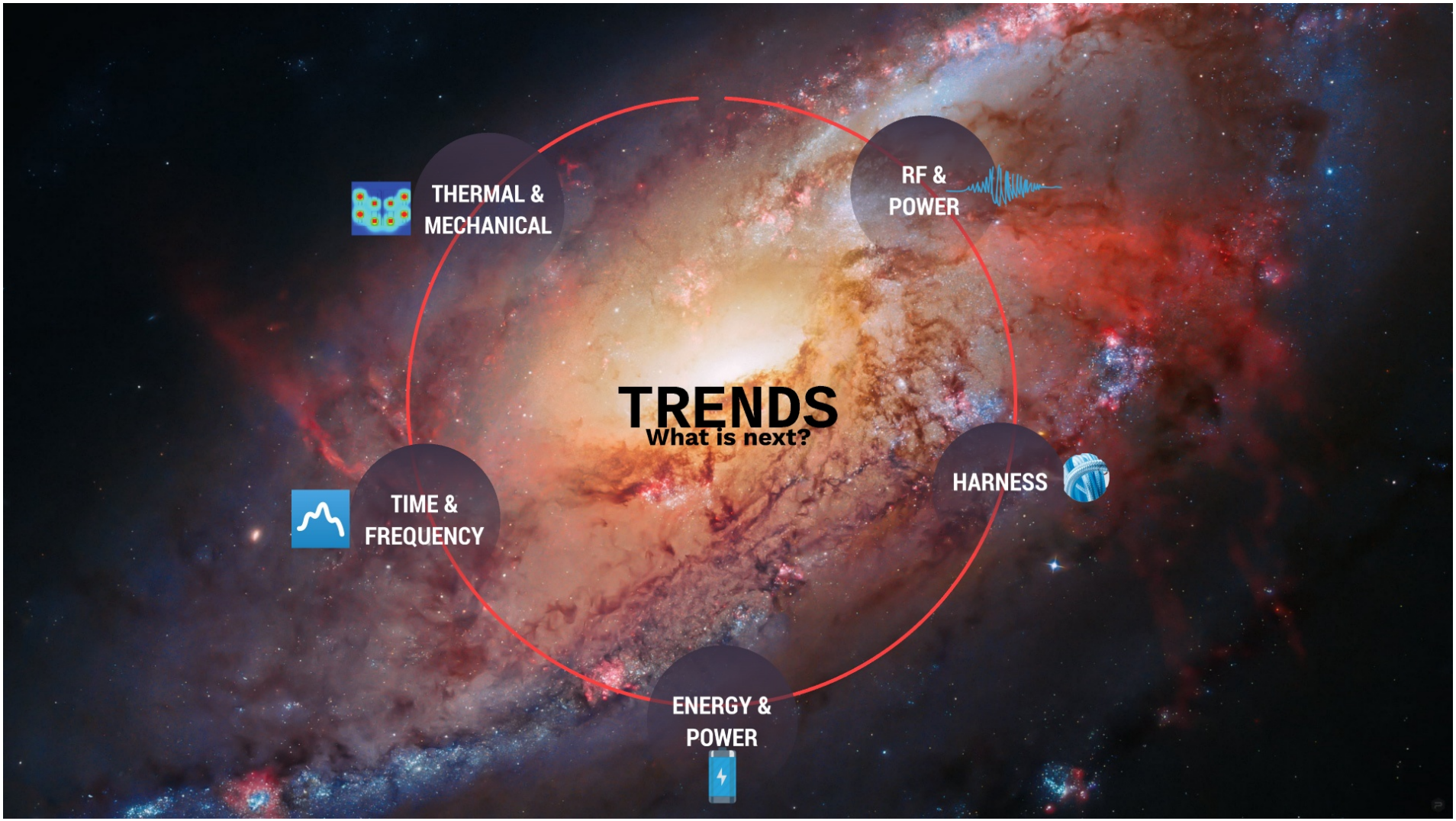
- **Improved design of harness for launchers:** ARIANE GROUP & AXON
  -Objective is to design, develop, manufacture and test an optimized harness: FCC (Flat Conductor Cable), fast-locking connectors, optimized harness support for Ariane 6 (bloc 2).
  - Mass savings expected at 30% (internal harness) and 75% (external raceways), overall volume saving of 90%!

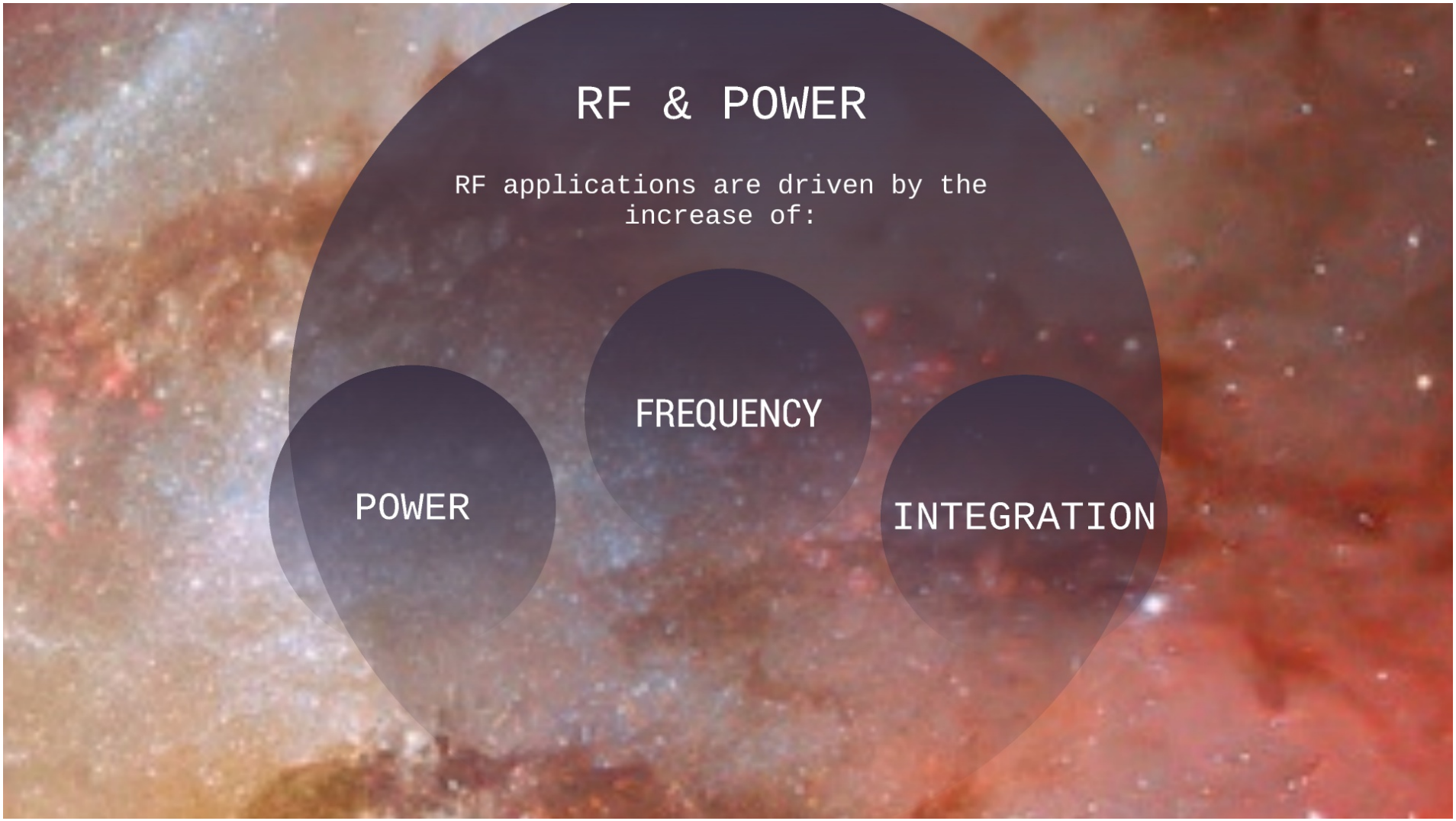




- **What is next:**

Published ITT : Fast-lock interconnections and connectorless flat cables for telecommunication satellites (ARTES AT).


THERMAL &
MECHANICAL
RF &
POWER
TRENDS
What is next?
TIME &
FREQUENCY
HARNESS
ENERGY &
POWER


RF & POWER
RF applications are driven by the increase of:
POWER
FREQUENCY
INTEGRATION

High Power Levels

- **Identified Super high power applications:**

Qualification of coaxial and waveguide RF Passives with:

- 360W for L band
- 360W for S band - ESA´s on-going activity with TKI-Ferrit
- 280W for C band

- **New Materials & Process** :

New materials and process for loads, gluying, etc. are needed for better dissipation at higher frequencies (Ku, Ka, Q, V & W bands)

- **European RF Diamond chip:**

Developement and Qualification of European solutions of RF Diamond chip and loads based on Chemical Vapor Deposition (CVD) in order to allow for better power dissipation and miniaturisation.

High Frequencies

- **Today:**

The frequencies needed for Telecom Satellites are: Q, V and W bands.

This requires different technologies for RF Passive components:

- **S**ubstrate **I**ntegrated **W**aveguide (SIW)
- Microstrip LTCC/Hexaferrite

- **What is next?**

Higher than W band frequencies (Up to 145GHz!?) and transition to optical fibre channels.

Faster & Better Integration

- **ESA Completed Activity:**

Ka-band isolators and circulators based on SMT, COBHAM (France), are now available for different applications (mainly low power and up to 10W).

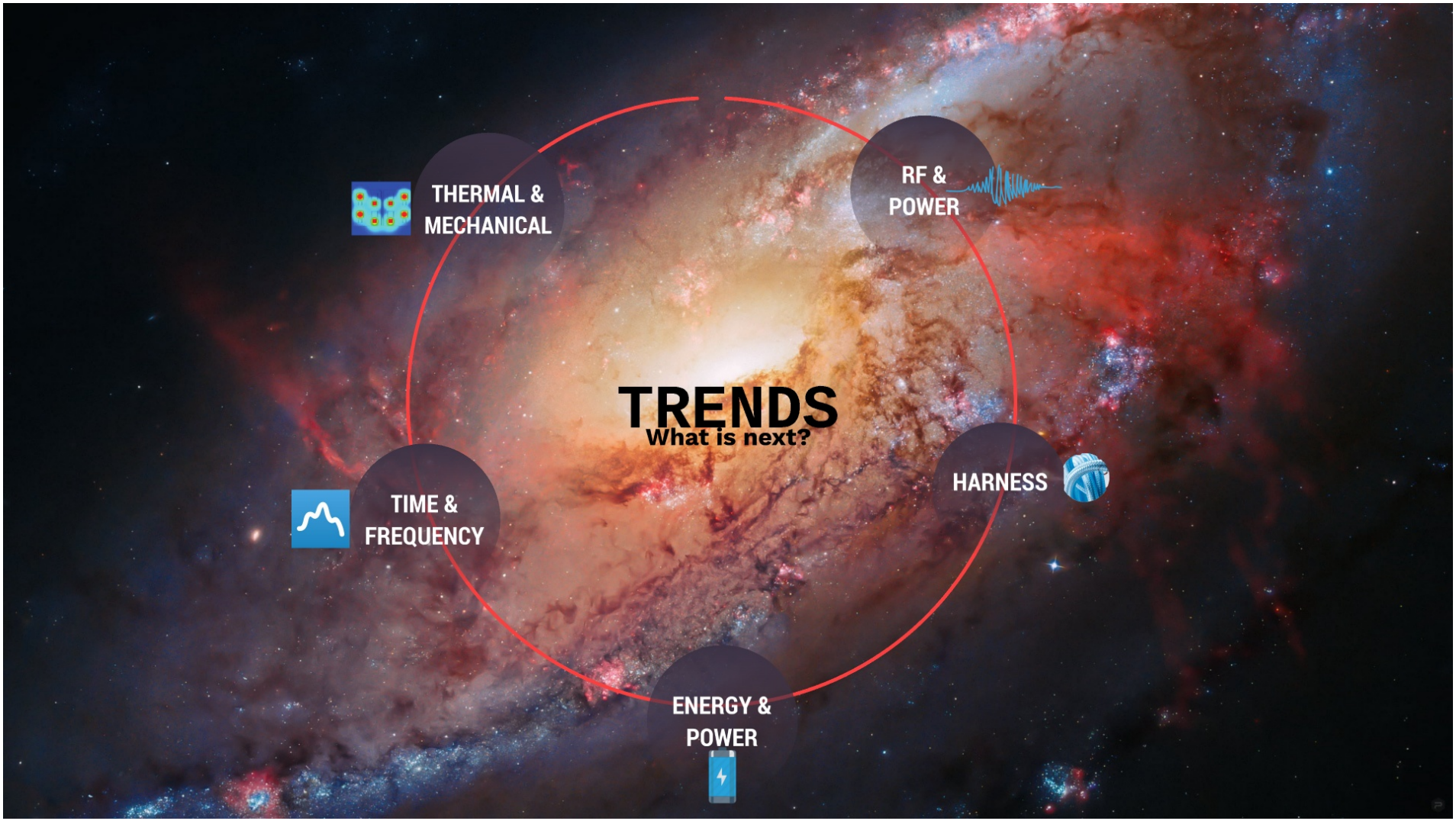
Several applications based on SIW have been identified, mainly for Telecom and New Space markets.
All RF chain parts will be increasingly based on SIW technology (no more connectors nor Waveguide adaptors are needed)!

- **ESA On-Going Development:**

Highly integrated SIW circulator and isolator for W band- HARP (Finland).
Integrated Ka band isolator and divider using SIW - Ecliptic DS (Cyrprus)
Ultra-low loss combiners using SIW at Ka band - Ecliptic DS (Cyrprus)

- **ESA Foreseen Activity:**

Intended ITT (TDE) about the development of Miniaturised self-biased (magnetless) circulators/isolators for GaN applications.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ESA Passive Components: News, Activities and Trends
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ESA - European Space Agency
Failures
Activities
News &
Challenges
Trends

Activities

How ESA is supporting the European **Passive** Industry?

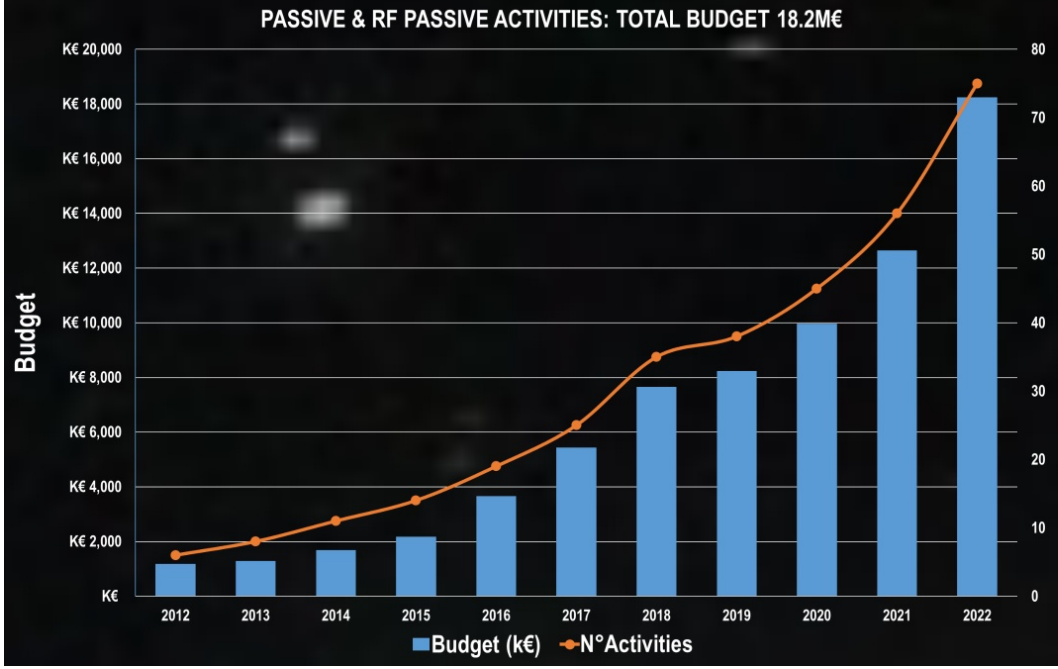
ESA R&D Passive & RF Passive Activities

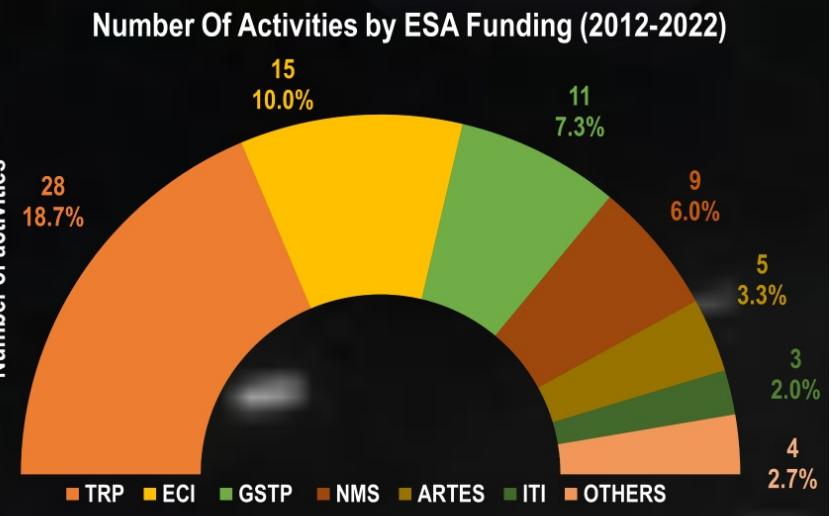
ESA has funded 75 activities for Passive & RF Passive components since 2012 with a total budget of 18.2 M€.

Total budget
18.2 M€

~7 new activities per year

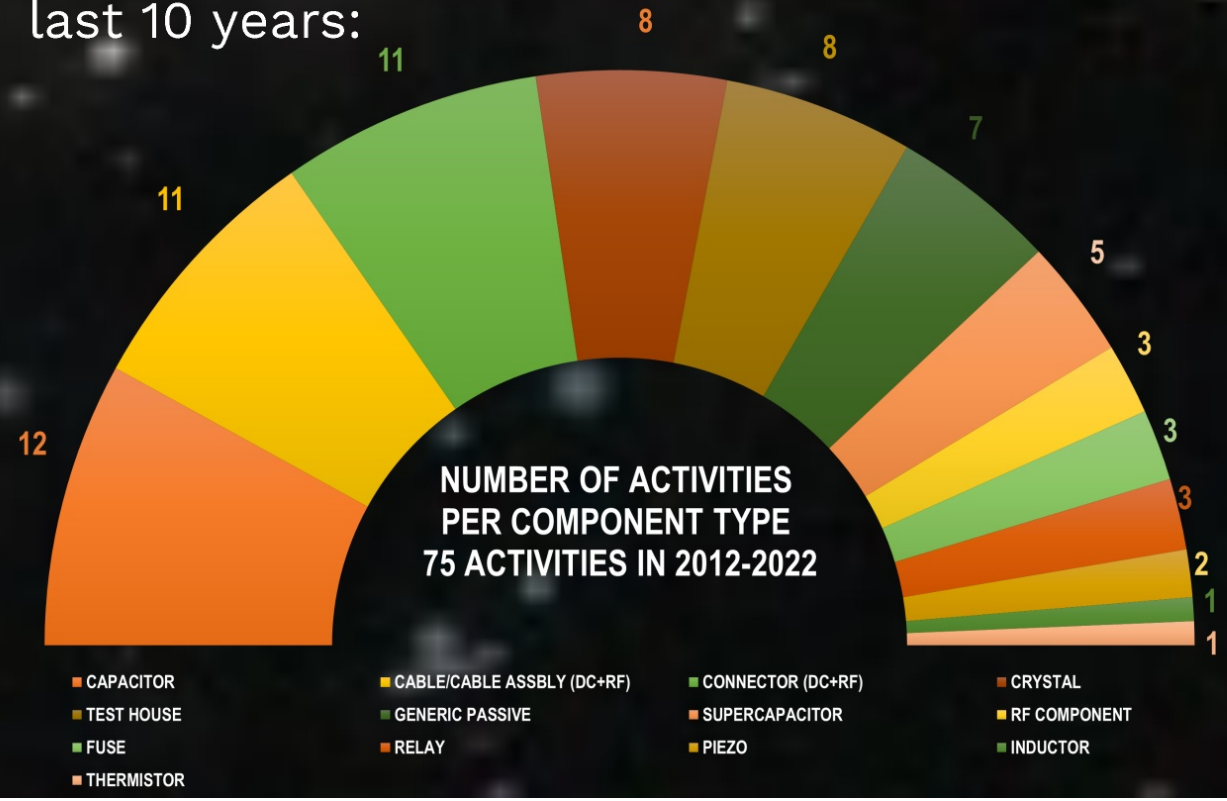
~244k€ per activity





ESA R&D Passive & RF Passive Activities

Developments are driven by space needs in the last 10 years:



Budget 2020/22
~4.7M€

19
new activities

~251k€ per activity

Application pull vs Technology push!

"A budget is more than just a series of numbers on a page; it is an embodiment of our values."
Barack Obama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Thank You For Your Attention!


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