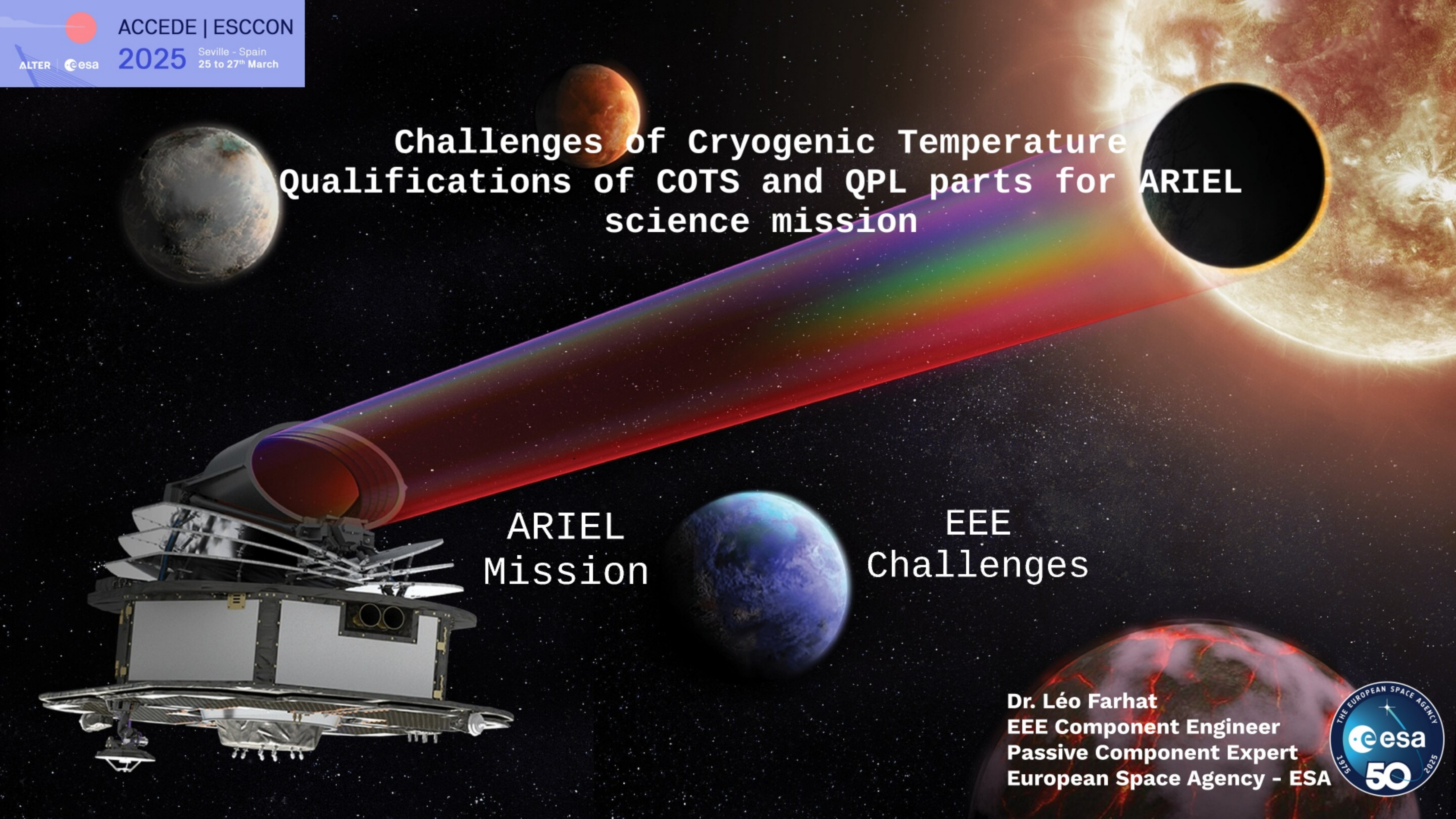
ACCEDE | ESCCON
2025 Seville - Spain
25 to 27th March
ALTER | esa



Challenges of Cryogenic Temperature Qualifications of COTS and QPL parts for ARIEL science mission

ARIEL Mission

EEE Challenges

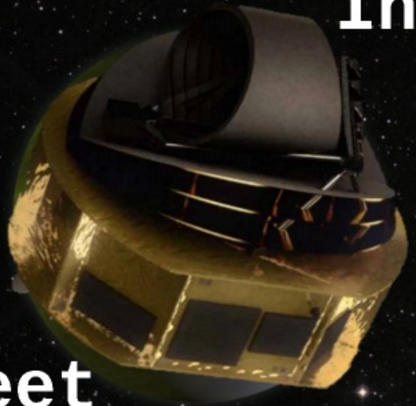
Dr. Léo Farhat
EEE Component Engineer
Passive Component Expert
European Space Agency - ESA

ARIEL Mission

Atmospheric **R**emote-sensing **I**nfrared **E**xoplanet **L**arge-survey

ESA's **World’s First** Exoplanet Sniffer

Instruments



Factsheet

FactSheet

Launch Date: Planned for 2029

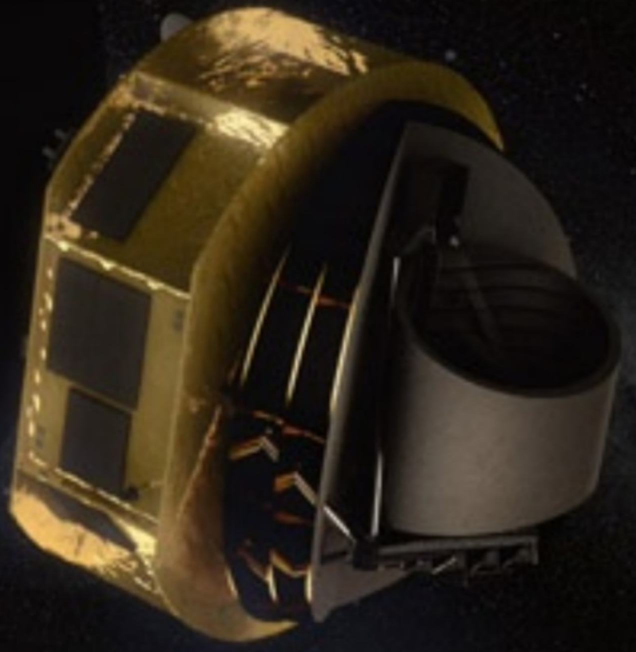
Launch Details: Ariane 6 - French Guiana

Orbit: halo orbit around Sun-Earth Lagrange point L2

1000 exoplanets

1400 KG Launch mass

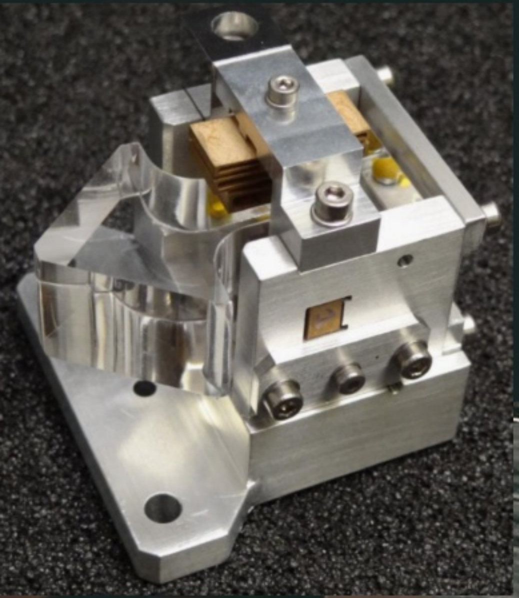
2 Instruments

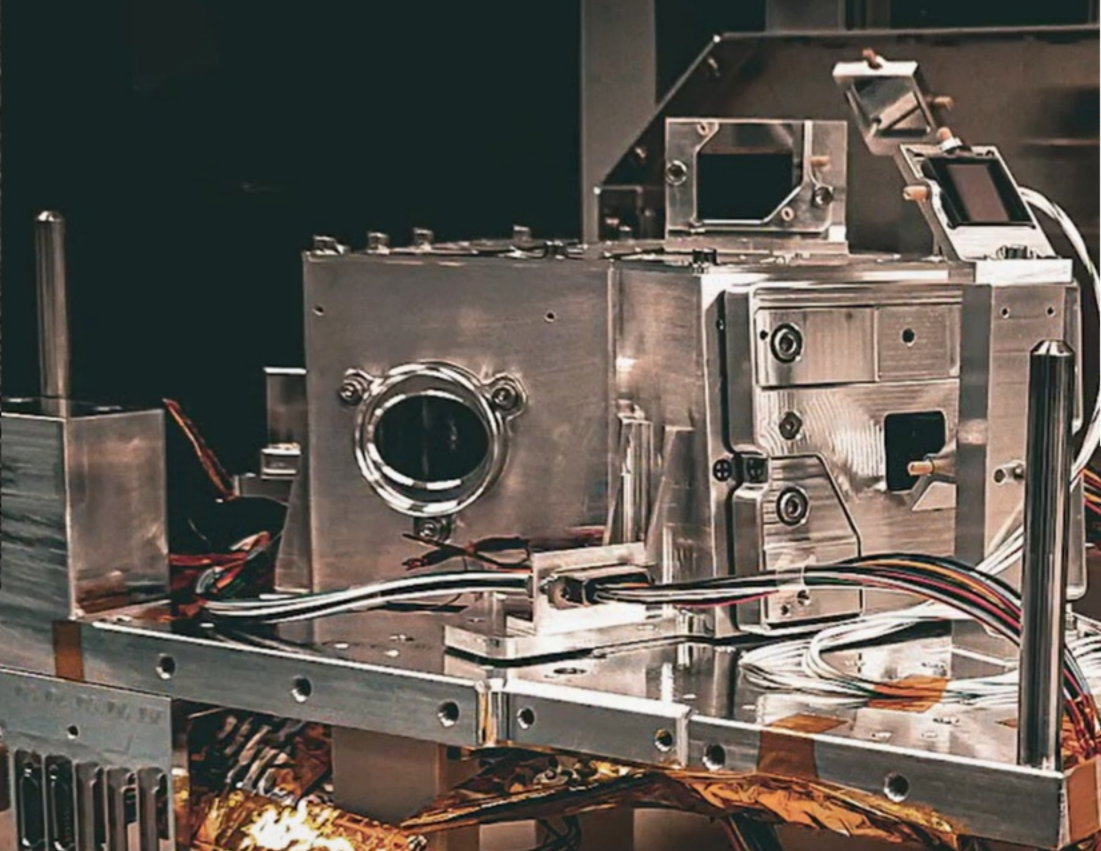


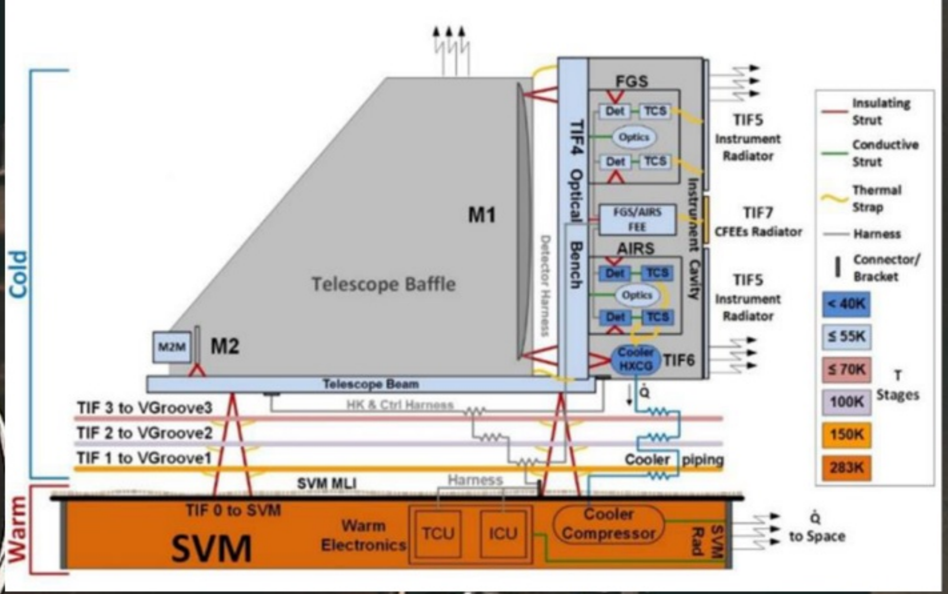
AIRBUS

UKRI Science and Technology Facilities Council | RAL Space

Ariel's Instruments







Two Instruments:

- Ariel medium-resolution InfraRed Spectrometer (AIRS) and the Fine Guidance System (FGS) + electronics subsystems (Cooler systems, Control units, Harness, Radiators, etc.)
- Cryogenic down to 29K
- A consortium involving over 50 institutes from 18 countries!

ALTER was selected as the **C**entralized **P**arts **P**rocurement **A**gency (CPPA).

ACCEDE | ESCCON
2025
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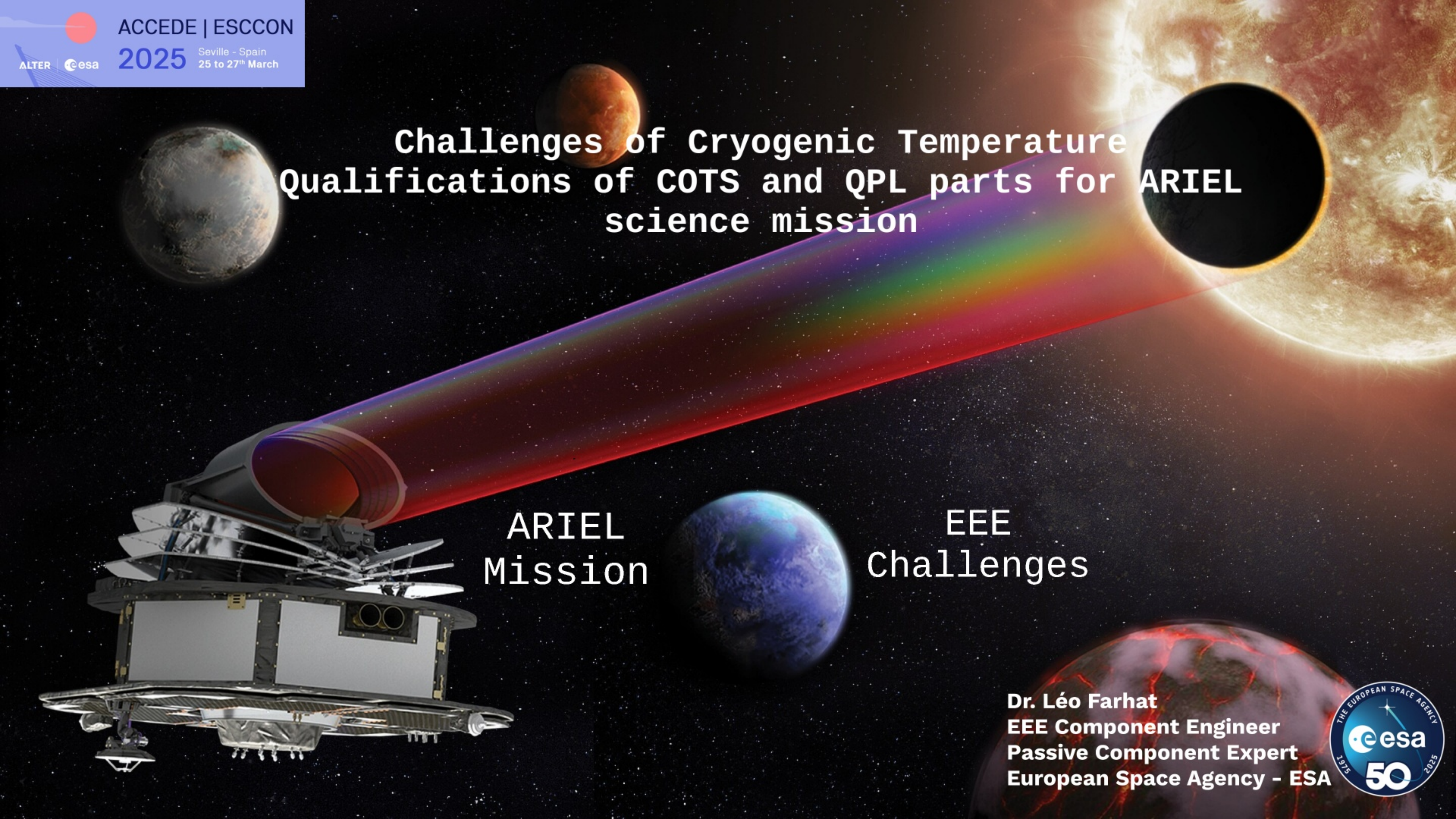

Challenges of Cryogenic Temperature Qualifications of COTS and QPL parts for ARIEL science mission

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EEE Components Breakdown

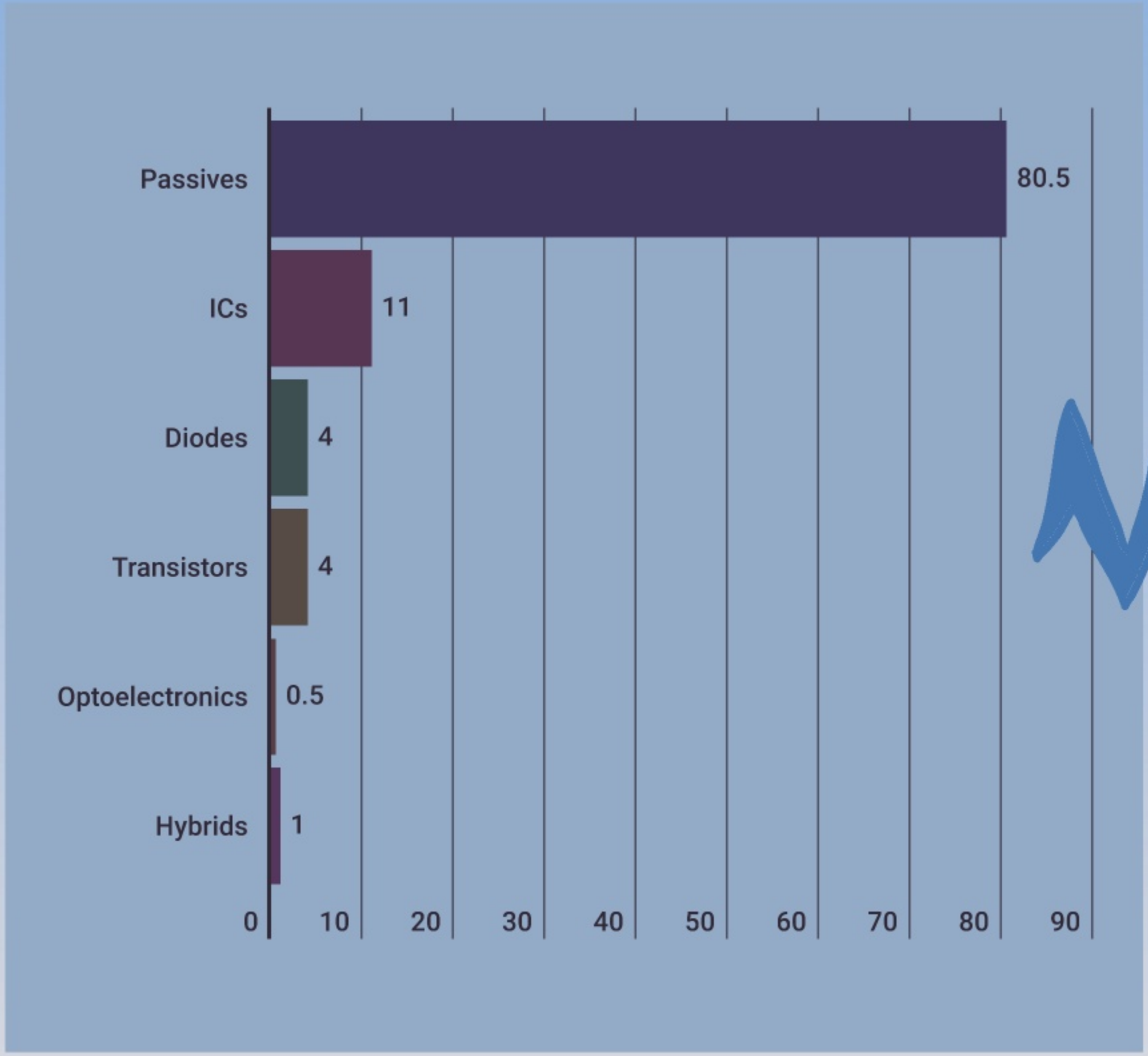
COTS Approach

Cryogenic Challenges

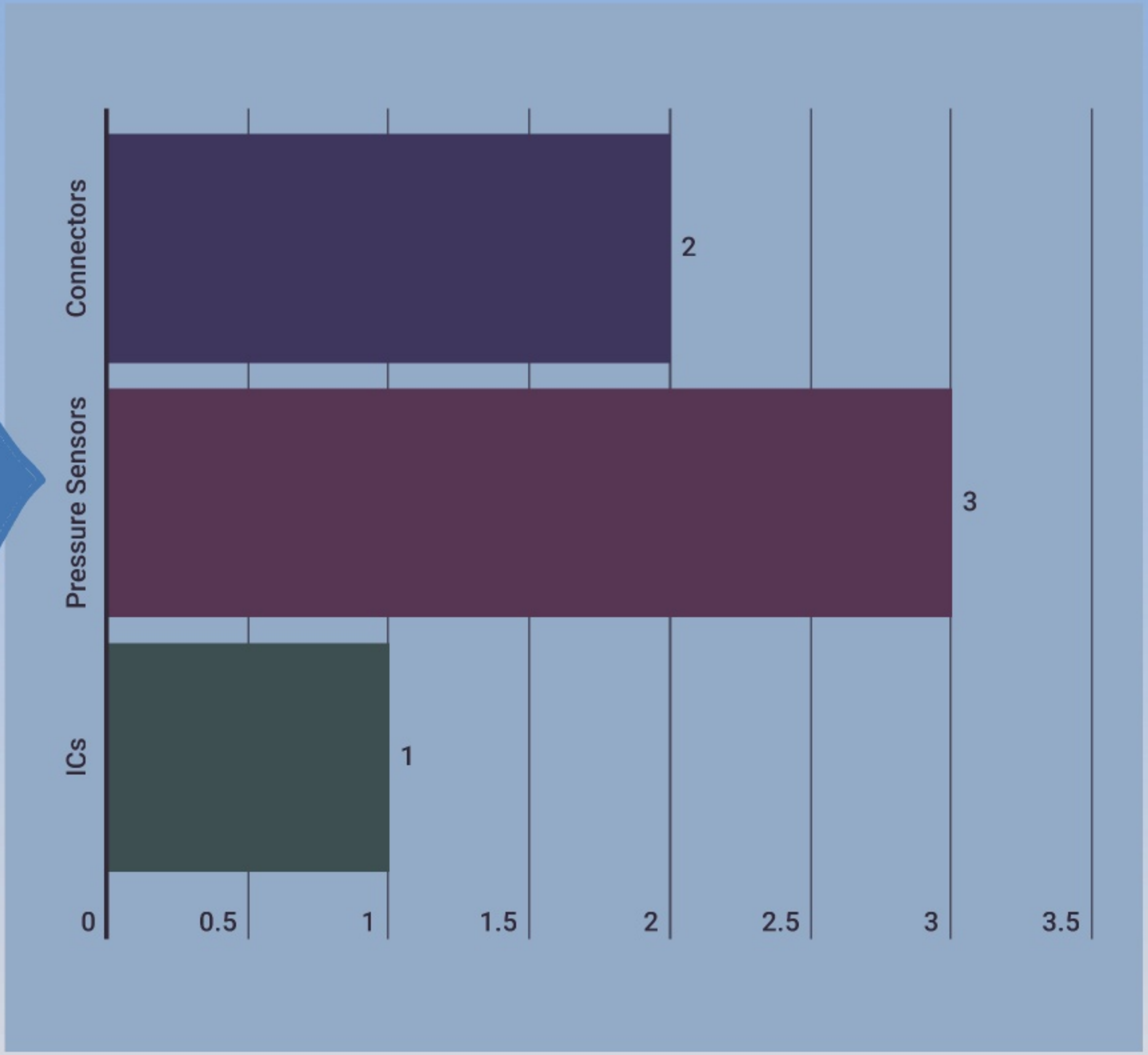
Conclusion

EEE Components Breakdown:

1521 space-grade level parts procured.

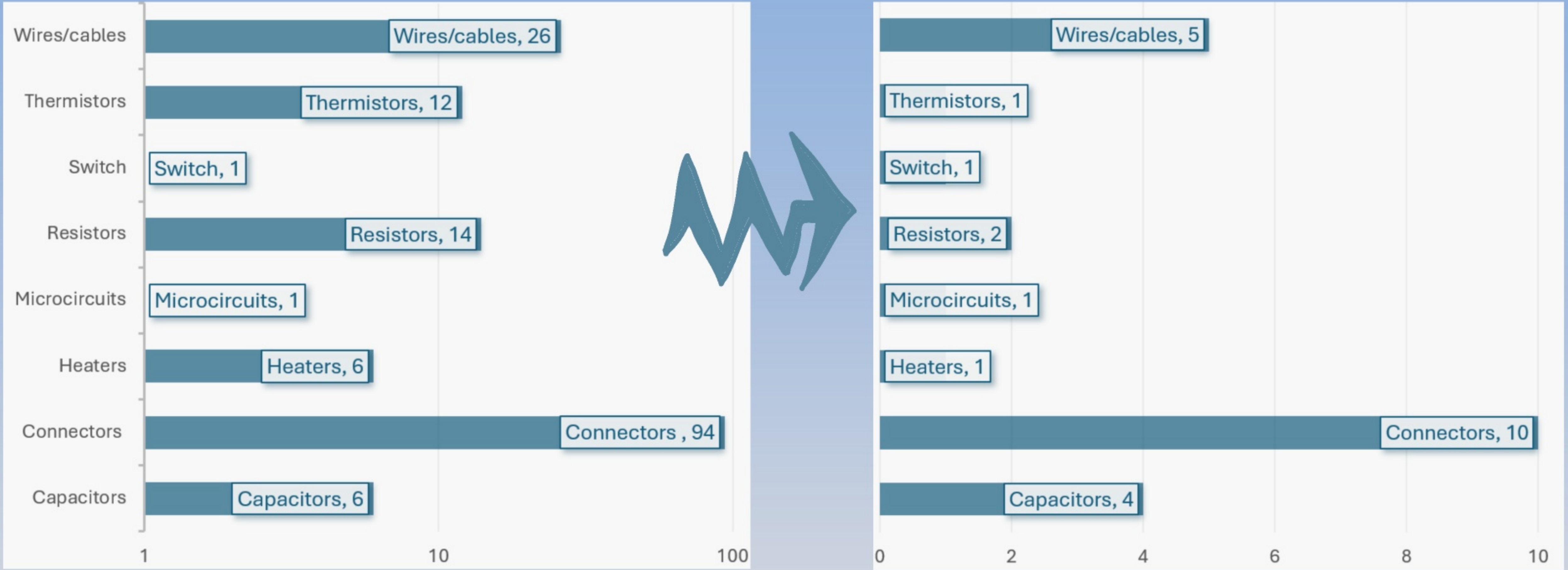


Except for 6 COTS parts!

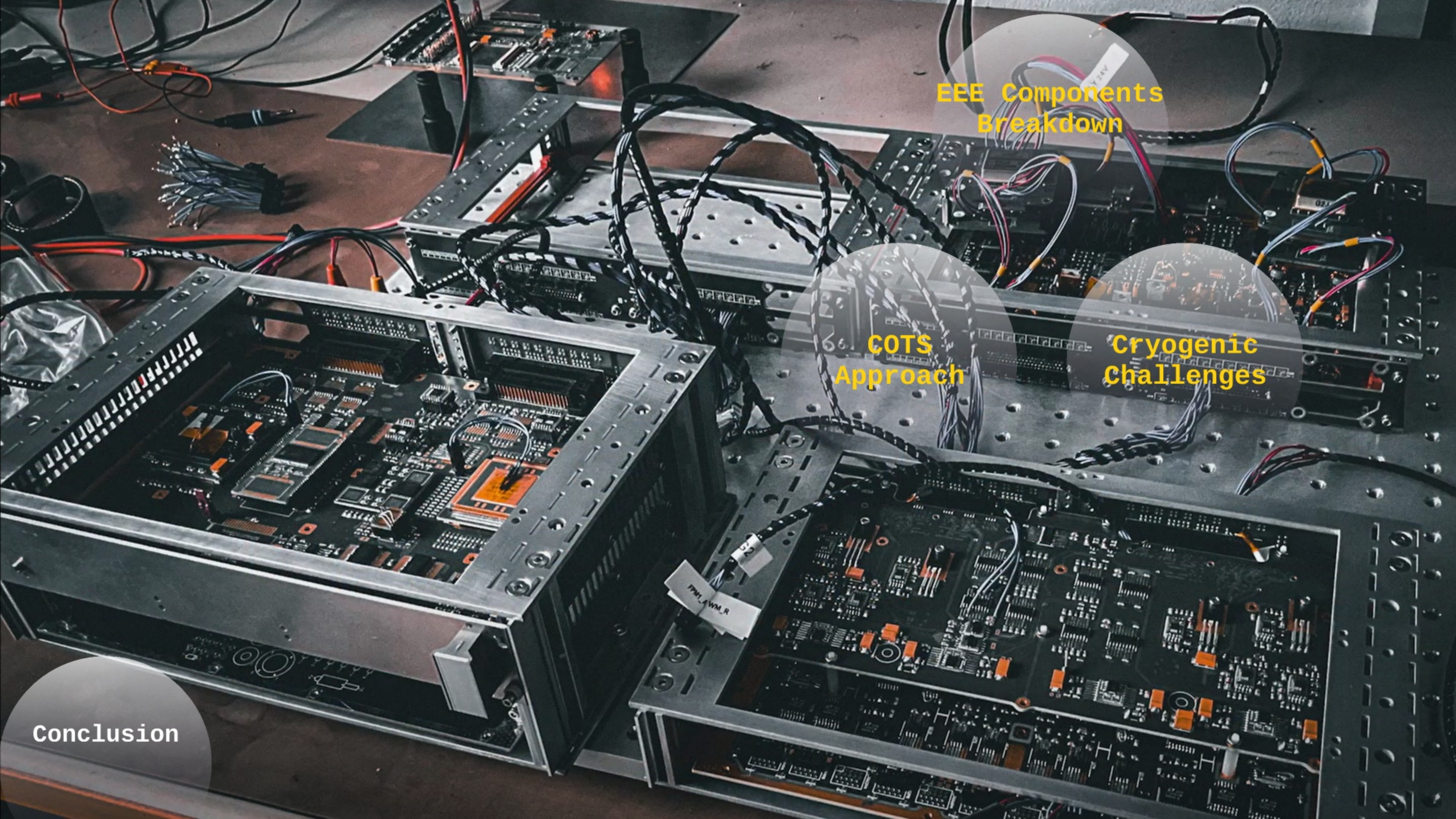


EEE Components Breakdown:

160 parts are used under Cryogenic conditions.
Of these, 25 parts (including 1 COTS) are tested under Cryogenic conditions



The downselection process is based on package sizes (AWG for wire, SMD size) and performance criteria (i.e. resistance, capacitance density, and other relevant factors).



EEE Components Breakdown

COTS Approach

Cryogenic Challenges

Conclusion

COTS Qualification

ECSS-Q-ST-60-13 standard has been applied, except for the connectors.

6 COTS parts were used due to the lack of equivalent Space Grade solutions.

1 **Absolute Pressure Sensor - Kistlers (CH)**

COTS

2 **Shear Force Sensor - Kistlers (CH)**

COTS

3 **Silicon Pressure Sensor - Omega (USA)**

COTS

4 **Feedthrough Connectors - Winschester (USA)**

COTS

5 **Plug Connector - Glenair (IT)**

COTS

6 **OpAmp - Texas Instrument (USA)**

COTS

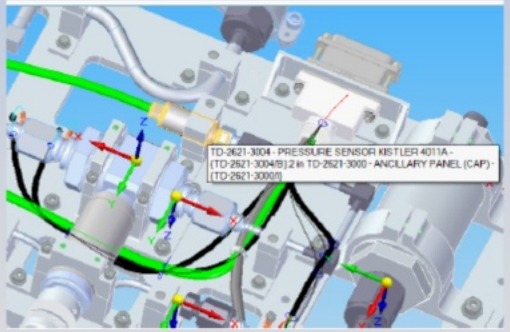
1 Absolute Pressure Sensor - Kistlers (CH)

Part-type:
4011A020DSL5

Objective:
The absolute pressure transducers will measure the high and low pressures achieved in the cooler.

Technology:
Piezoresistive

Qualification :
Upscreening, Radiation and Qualification acc. to ECSS-Q-ST-60-13 tailored with project's requirements (i.e. leak test, reduced temperature range + mechanical shock in tailored jig)



2 Shear Force Sensor - Kistlers (CH)

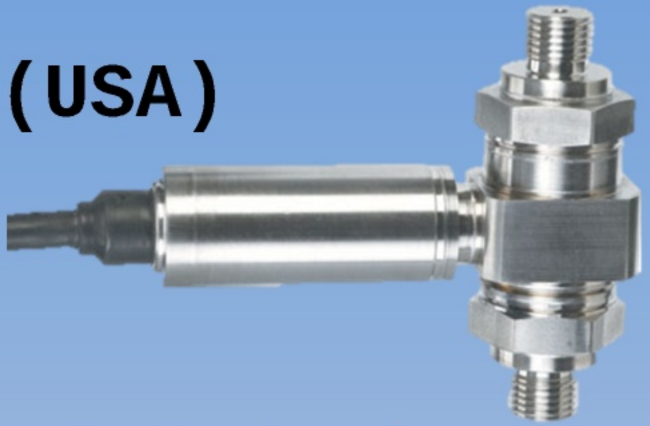
Part-type:
9021CQ12+1700A121

Objective:
The force washers will measure the exported micro-vibrations and the signals will be the input to the micro-vibration reduction control loop running in the Cooler Control Electronics (CCE) unit.

Technology:
Piezoresistive

Qualification :
Upscreening, Radiation and Qualification acc. to ECSS-Q-ST-60-13 tailored with project's requirements (i.e. reduced temperature range + mechanical shock in tailored jig)

3 Silicon Pressure Sensor - Omega (USA)

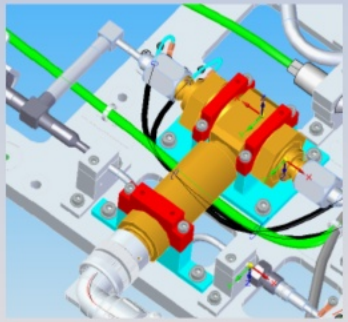


Part-type:
9021CQ12+1700A121

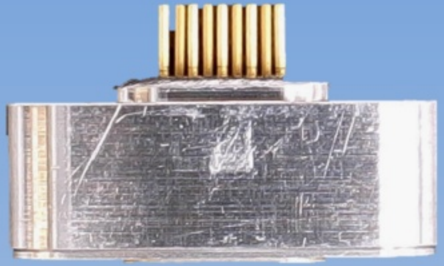
Objective:
The sensor is used to measure the pressure drops in the range 0–10 mbar that are produced by flowing gas in the high-pressure line through a restriction. The pressure drop will be post-processed by the CCE unit to calculate the flow rate.

Technology:
Piezoresistive

Qualification :
Upscreening, Radiation and Qualification acc. to ECSS-Q-ST-60-13 tailored with project's requirements (i.e. reduced temperature range + mechanical shock in tailored jig)

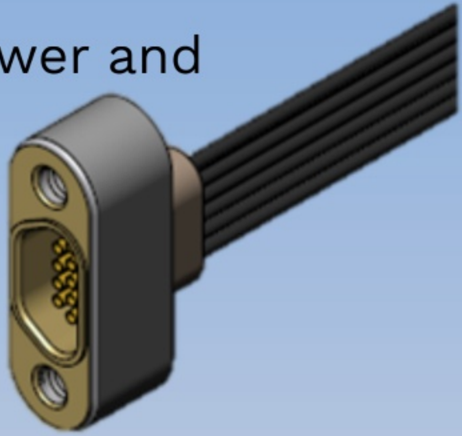


4 Feedthrough Connectors - Winschester (USA)



Part-type:
SRIMD604-09

Objective:
Hermetically sealed and weldable electrical feedthroughs are used to pass power and instrumentation signals into the internal gas volume of the unit.



Technology:
Hermetically sealed microD conenctor

Qualification :
Upscreening and Qualification acc. to ESCC3401 tailored with project's requirements (i.e. reduced temperature range)

Quality Issue:
Incoming Inspection at ALTER detected that the parts have not been subjected to the weld preparation required by the user, due to an "error" during manufacturing...

Parts were returned to the manufacturer for rework. Rework was not perfomed well enough!
In paralell, an alternative solution is discussed with another manufacturer Axon.

5 Plug Connectors - Glenair (IT)

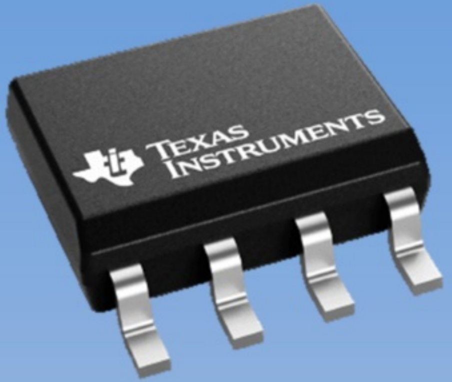
Part-type:
IPT-08-EM-10-6-S-F11

Objective:
Counterpart plug connector to link the the pressure sensors to the harness side.

Technology:
Plug Connector with 90º Backshell

Qualification :
Upscreening and Qualifiction acc. to EEE-INST-002 tailored with project's requirements (i.e. reduced temperature range)

6 OpAmp - Texas Instrument (USA



Part-type:
OP2350 replaced by OPA2192

Objective:
OpAmp is used as differential pre-amplifier to amplify the detector's output signals to the inputs of the Digital Control Unit of AIRs instrument through the long cryo-harnesses between the hot and cold parts of the instrument!

Technology:
Low Offset Voltage, Low Input Bias Current OpAmp

Qualification :
Upscreening, Radiation, and Qualification acc. to ECSS-Q-ST-60-13 and additional Cryogenic test.

Quality Issue:
Despite successful de-risking tests performed by the user during pre-development phase, some OPA2350 parts have shown misbehaviour at cold: unsuccessful power-on at cryo.
ESA (SCI) have endorsed alternative solution OPA2192 (higher ratings) after careful evaluation!

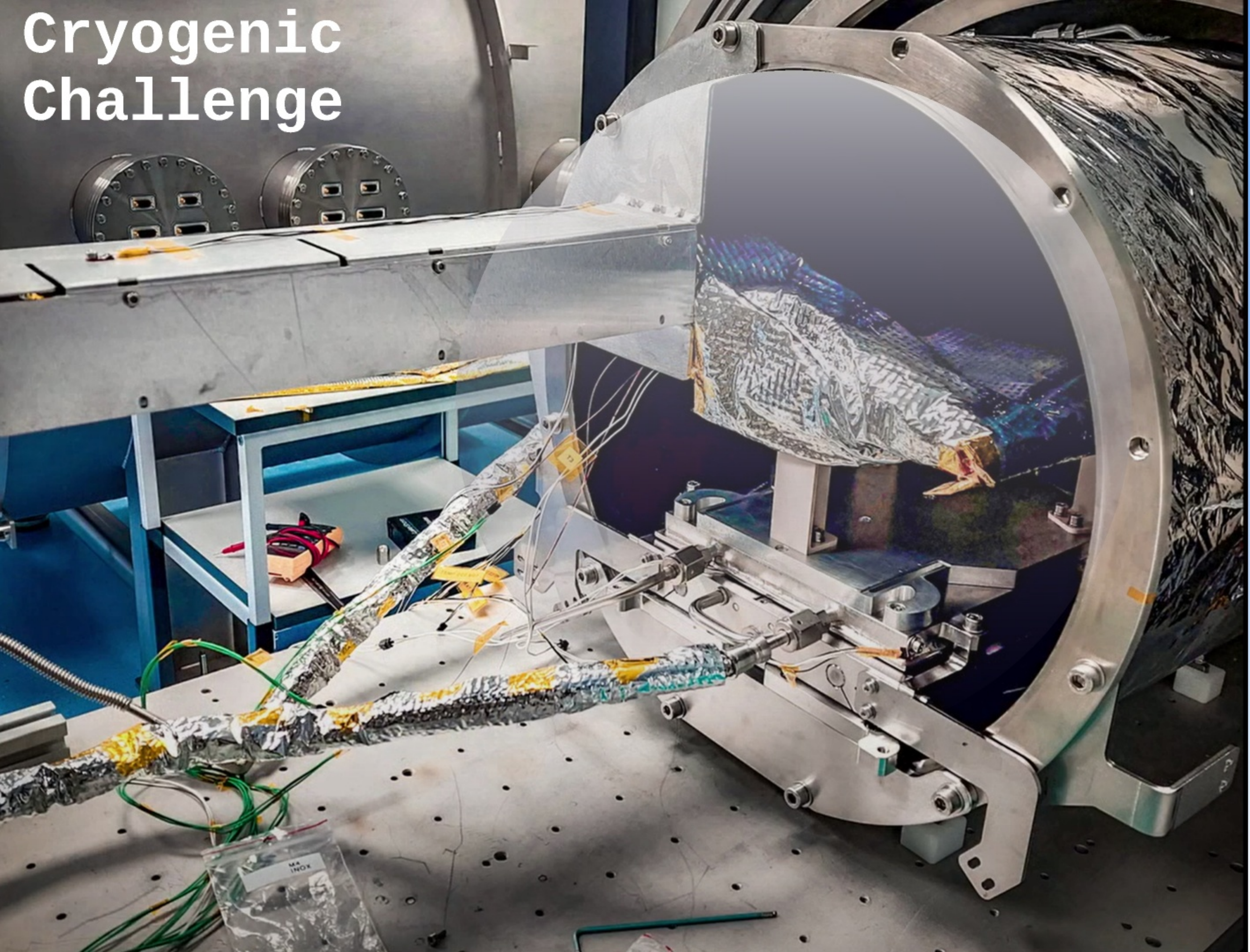
EEE Components Breakdown

COTS Approach

Cryogenic Challenges

Conclusion

Cryogenic Challenge



Thermal Sensors

Cryogenic Validation

Schedule Optimisation

On-Going Tests

Cryogenic Thermal Sensors

IST (CH) thermal PT sensors are limited to -200°C (73K) and are therefore incompatible with Ariel's instrument requirement of 29K.

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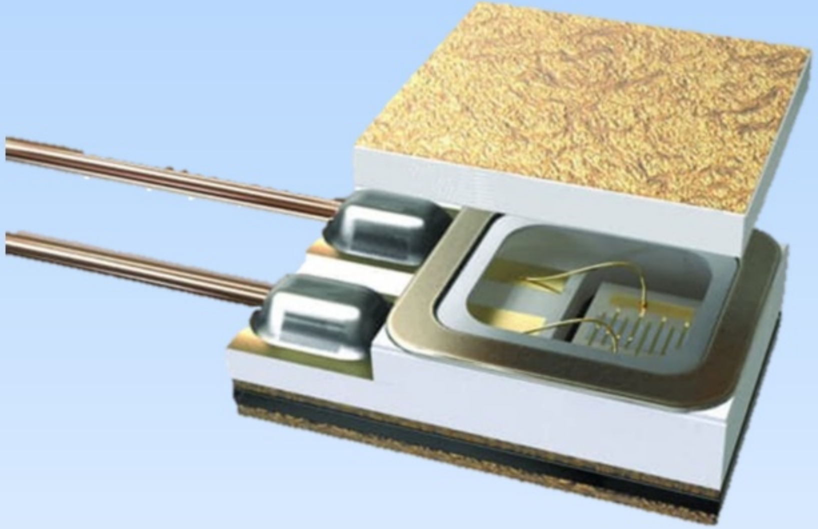
The **only** available **Hirel Quality solution for cryogenic** thermal sensors is the Cernox series, manufactured by Lakeshore (USA).



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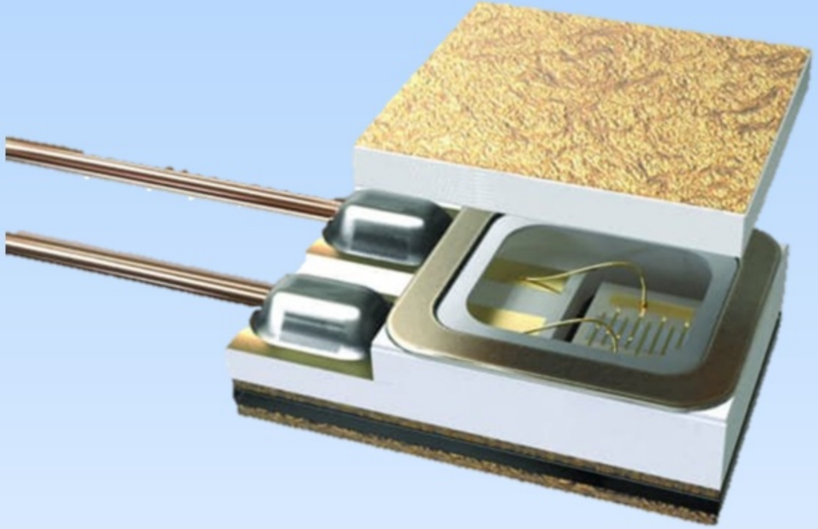


The starting price is $6,000 per part, plus an additional $4,000 per reference for the datapack.
Additional cost for specific requirements (+$3,000)!

Lead Time > 1 Year + Additional 6 months for LAT results!

Cryogenic Thermal Sensors

Total Required: 121 sensors for Ariel's instrument.

- **Design Standardization:**

Establish a consistent baseline for packages, wire gauge, and requirements.
Use two package types with the same PBr wire and identical AWG gauge (varying only in length).

- **Procurement Strategy:**

Consolidate all parts into a single PO to enable a unified qualification test flow on the same wafer.

- **Qaulification Optimization:**

Perform a single qualification on the same wafer.
Conduct an additional qualification of the fully assembled sensor (package + wire) at ALTER.
Avoid Verification Assembly per user.

Cryogenic Thermal Sensors

- **Cost Optimization:**

Instead of qualifying each unit separately, a standardized and combined purchase order (thanks to users' collaboration and ALTER's role as CPPA) significantly reduced qualification costs.

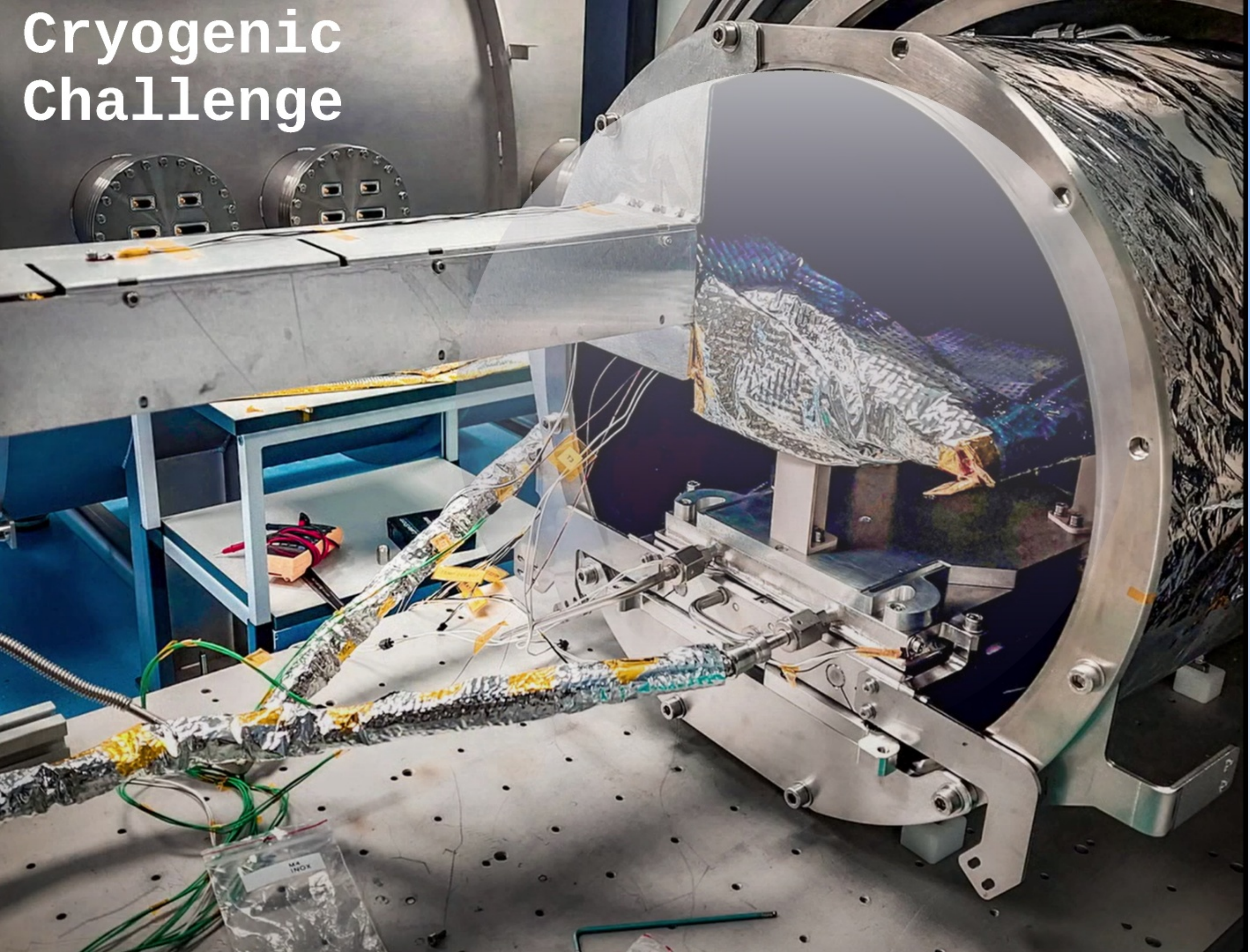
Cost Reduction: From €1M to approximately €200K.

Manufacturing Challenge:

After production began, Lakeshore reported that one specific part type (requiring additional resistance calibration at cryogenic temperatures) could not be met with the current wafer.

A new wafer had to be manufactured for this part, requiring additional life testing for the affected lot.
Additonal increased lead time of one year were communicated !

Cryogenic Challenge



Thermal Sensors

Cryogenic Validation

Schedule Optimisation

On-Going Tests

Cryogenic Validation - What to be tested?

25 Part types!

1 **MicroSwitch - Petercem (FR)**

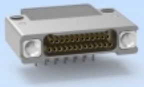
Space Grade Quality - 1x part-type

2 **Wires - AXON (FR)**

ESCC+ Space grade Quality - 4x part-types

3 **Heaters - RICA (IT)**

ESCC Space Quality - 1x part-type



4 **NanoD Connectors - Airborn (USA)**

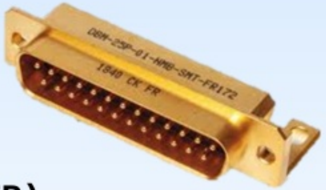
Space Grade Quality - 5x part-types

5 **Resistors & Capacitors Assembly - AVX (FR) +VISHAY (FR) +Presidio (USA)**

ESCC + Space Grade Quality - 5x part-types

6 **OPA - Texas Instrument (USA)**

COTS



7 **Sub-D Connecors - C&K (FR)**

ESCC - 4x part-types

8 **Micro-D Connectors - C&K (FR)**

ESCC - 3x part-types

9 **Thermistor - IST (CH)**

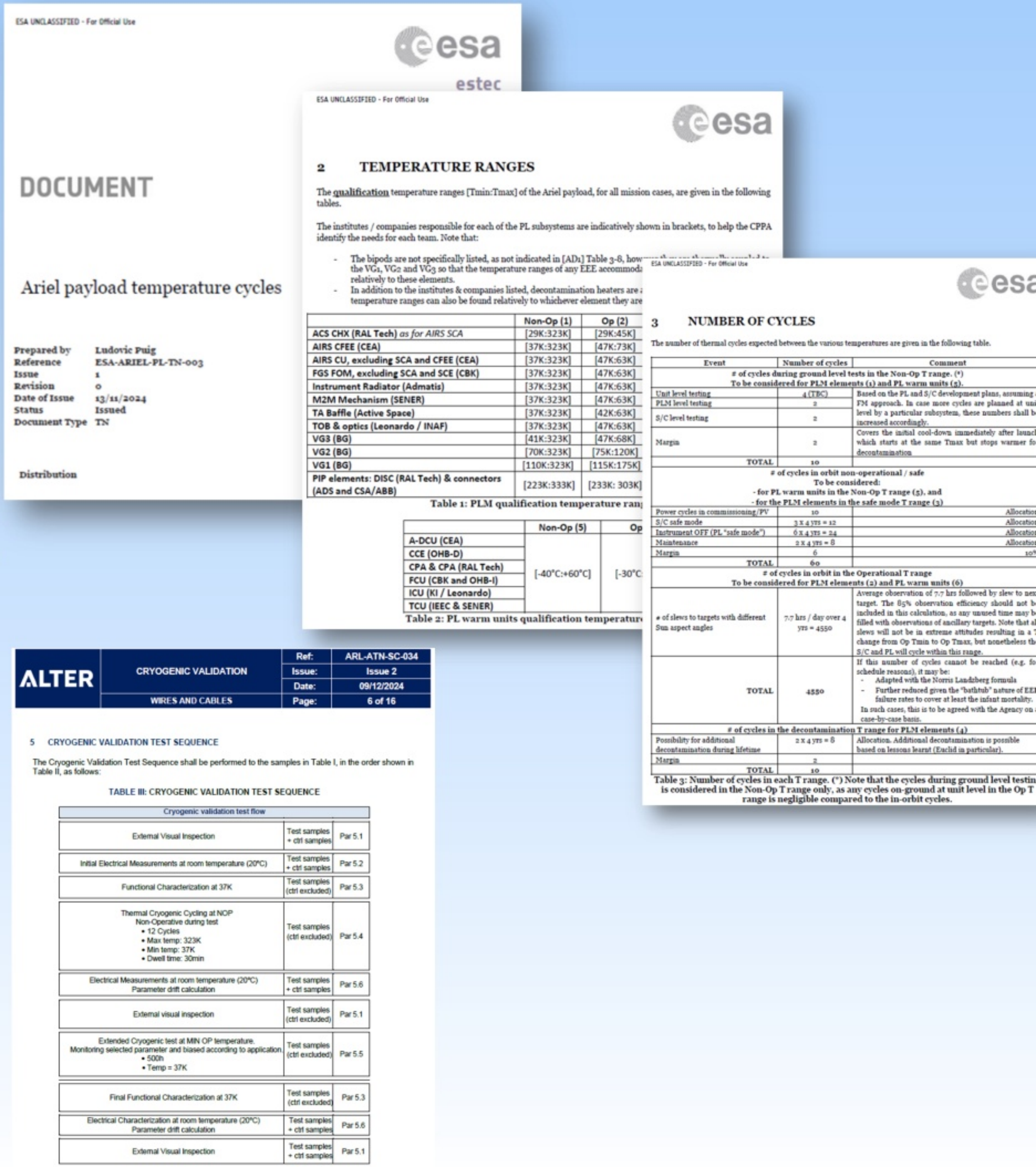
ESCC - 1x part-type

Cryogenic Validation - How to be tested?

Dedicated TN issued by ESA detailing :

- the operational (OP) and non-operational (NOP) temperatures (min. and max.),
- Number of thermal cycles including margins
- 8 different users/subsystems!

Standarised Test plans (9 per family type) were prepared together with ALTER and agreed by each user.



ESA UNCLASSIFIED - For Official Use

DOCUMENT

Ariel payload temperature cycles

Prepared by	Ludovic Puig
Reference	ESA-ARIEL-PL-TN-003
Issue	1
Revision	0
Date of Issue	13/11/2024
Status	Issued
Document Type	TN

Distribution

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2 TEMPERATURE RANGES

The qualification temperature ranges [Tmin:Tmax] of the Ariel payload, for all mission cases, are given in the following tables.

The institutes / companies responsible for each of the PL subsystems are indicatively shown in brackets, to help the CPPA identify the needs for each team. Note that:

- The bipods are not specifically listed, as not indicated in [AD1] Table 3-8, how the VG1, VG2 and VG3 so that the temperature ranges of any EEE accommoda relatively to these elements.
- In addition to the institutes & companies listed, decontamination heaters are temperature ranges can also be found relatively to whichever element they are

	Non-Op (1)	Op (2)
ACS CHX (RAL Tech) *as for AIRS SCA*	[29K:323K]	[29K:45K]
AIRS CFEE (CEA)	[37K:323K]	[47K:73K]
AIRS CU, excluding SCA and CFEE (CEA)	[37K:323K]	[47K:63K]
FGS FOM, excluding SCA and SCE (CBK)	[37K:323K]	[47K:63K]
Instrument Radiator (Admatis)	[37K:323K]	[47K:63K]
M2M Mechanism (SENER)	[37K:323K]	[47K:63K]
TA Baffle (Active Space)	[37K:323K]	[42K:63K]
TOB & optics (Leonardo / INAF)	[37K:323K]	[47K:63K]
VG3 (BG)	[41K:323K]	[47K:68K]
VG2 (BG)	[70K:323K]	[75K:120K]
VG1 (BG)	[110K:323K]	[115K:175K]
PIP elements: DISC (RAL Tech) & connectors (ADS and CSA/ABB)	[223K:333K]	[233K: 303K]

Table 1: PLM qualification temperature ran

	Non-Op (5)	Op
A-DCU (CEA)	[-40°C:+60°C]	[-30°C
CCE (OHB-D)		
CPA & CPA (RAL Tech)		
FCU (CBK and OHB-I)		
ICU (KI / Leonardo)		
TCU (IEEC & SENER)		

Table 2: PL warm units qualification temperatur

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3 NUMBER OF CYCLES

The number of thermal cycles expected between the various temperatures are given in the following table.

Event	Number of cycles	Comment
# of cycles during ground level tests in the Non-Op T range. (*) To be considered for PLM elements (1) and PL warm units (5).		
Unit level testing	4 (TBC)	Based on the PL and S/C development plans, assuming FM approach. In case more cycles are planned at uni level by a particular subsystem, these numbers shall b increased accordingly.
PLM level testing	2	
S/C level testing	2	
Margin	2	Covers the initial cool-down immediately after launc which starts at the same Tmax but stops warmer fo decontamination
TOTAL	10	
# of cycles in orbit non-operational / safe To be considered: - for PL warm units in the Non-Op T range (5), and - for the PLM elements in the safe mode T range (3)		
Power cycles in commissioning/PV	10	Allocatio
S/C safe mode	3 x 4 yrs = 12	Allocatio
Instrument OFF (PL "safe mode")	6 x 4 yrs = 24	Allocatio
Maintenance	2 x 4 yrs = 8	Allocatio
Margin	6	10
TOTAL	60	
# of cycles in orbit in the Operational T range To be considered for PLM elements (2) and PL warm units (6)		
# of slews to targets with different Sun aspect angles	7.7 hrs / day over 4 yrs = 4550	Average observation of 7.7 hrs followed by slew to nex target. The 85% observation efficiency should not b included in this calculation, as any unused time may b filled with observations of ancillary targets. Note that a slews will not be in extreme attitudes resulting in a change from Op Tmin to Op Tmax, but nonetheless th S/C and PL will cycle within this range.
TOTAL	4550	If this number of cycles cannot be reached (e.g. fo schedule reasons), it may be: - Adapted with the Norris Landzberg formula - Further reduced given the "bathtub" nature of EE failure rates to cover at least the infant mortality. In such cases, this is to be agreed with the Agency on case-by-case basis.
# of cycles in the decontamination T range for PLM elements (4)		
Possibility for additional decontamination during lifetime	2 x 4 yrs = 8	Allocation. Additional decontamination is possible based on lessons learnt (Euclid in particular).
Margin	2	
TOTAL	10	

Table 3: Number of cycles in each T range. (*) Note that the cycles during ground level testin is considered in the Non-Op T range only, as any cycles on-ground at unit level in the Op T range is negligible compared to the in-orbit cycles.

ALTER	CRYOGENIC VALIDATION	Ref:	ARL-ATN-SC-034
		Issue:	Issue 2
		Date:	09/12/2024
	WIRES AND CABLES	Page:	6 of 16

5 CRYOGENIC VALIDATION TEST SEQUENCE

The Cryogenic Validation Test Sequence shall be performed to the samples in Table I, in the order shown in Table II, as follows:

TABLE III: CRYOGENIC VALIDATION TEST SEQUENCE

Cryogenic validation test flow		
External Visual Inspection	Test samples + ctrl samples	Par 5.1
Initial Electrical Measurements at room temperature (20°C)	Test samples + ctrl samples	Par 5.2
Functional Characterization at 37K	Test samples (ctrl excluded)	Par 5.3
Thermal Cryogenic Cycling at NOP Non-Operative during test • 12 Cycles • Max temp: 323K • Min temp: 37K • Dwell time: 30min	Test samples (ctrl excluded)	Par 5.4
Electrical Measurements at room temperature (20°C) Parameter drift calculation	Test samples + ctrl samples	Par 5.6
External visual inspection	Test samples (ctrl excluded)	Par 5.1
Extended Cryogenic test at MIN OP temperature. Monitoring selected parameter and biased according to application. • 500h • Temp = 37K	Test samples (ctrl excluded)	Par 5.5
Final Functional Characterization at 37K	Test samples (ctrl excluded)	Par 5.3
Electrical Characterization at room temperature (20°C) Parameter drift calculation	Test samples + ctrl samples	Par 5.6
External Visual Inspection	Test samples + ctrl samples	Par 5.1

Cryogenic Validation - How to be tested?

1 EVI + Initial Measurments

@ Room Temperature

2 Functional Characterisation

@ Minimum Operational Temperature

3 12 Thermal Cycles

Between Minimum Non-Operational and Maximum Non-Operational Temperatures

4 EVI + Electrical Measurments

@ Room Temperature

5 Cryogenic Life test

@ Minimum Operational Temperature
500 hours (1000h for critical parts)

6 Functional Characterisation

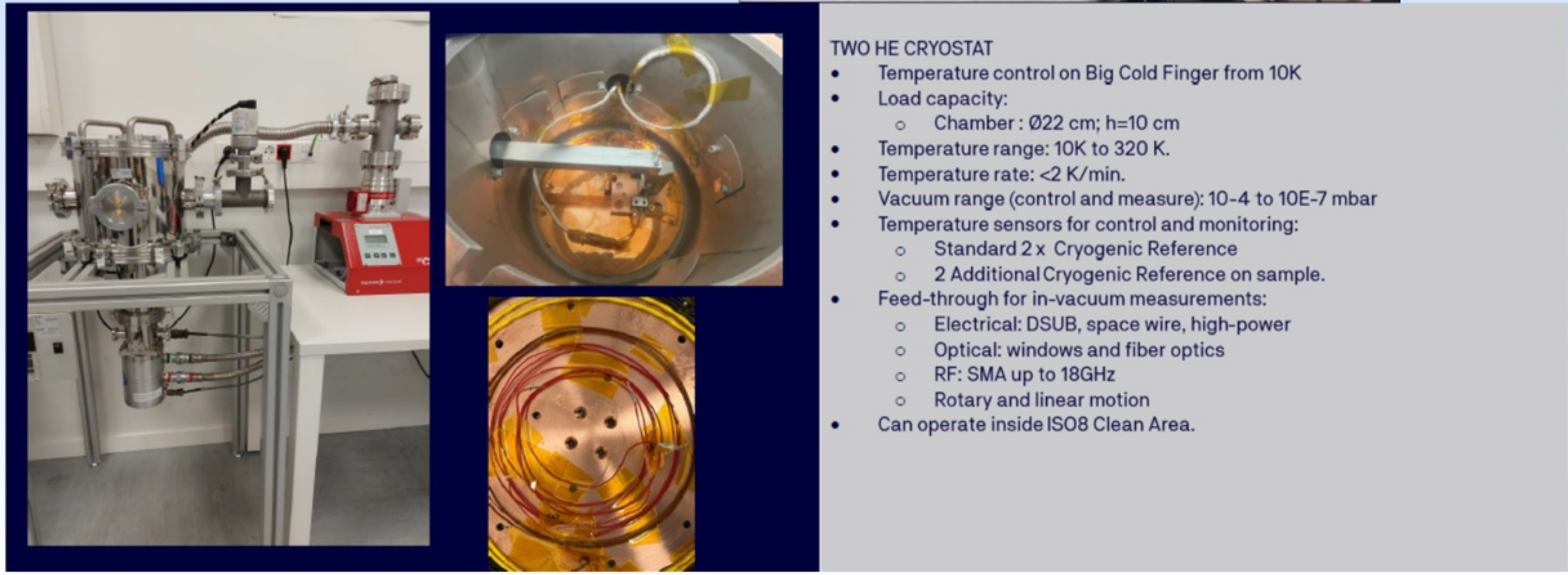
@ Minimum Operational Temperature

7 EVI + Final Measurments

@ Room Temperature

Cryogenic Validation - Where to be tested?

Alter Technology Madrid

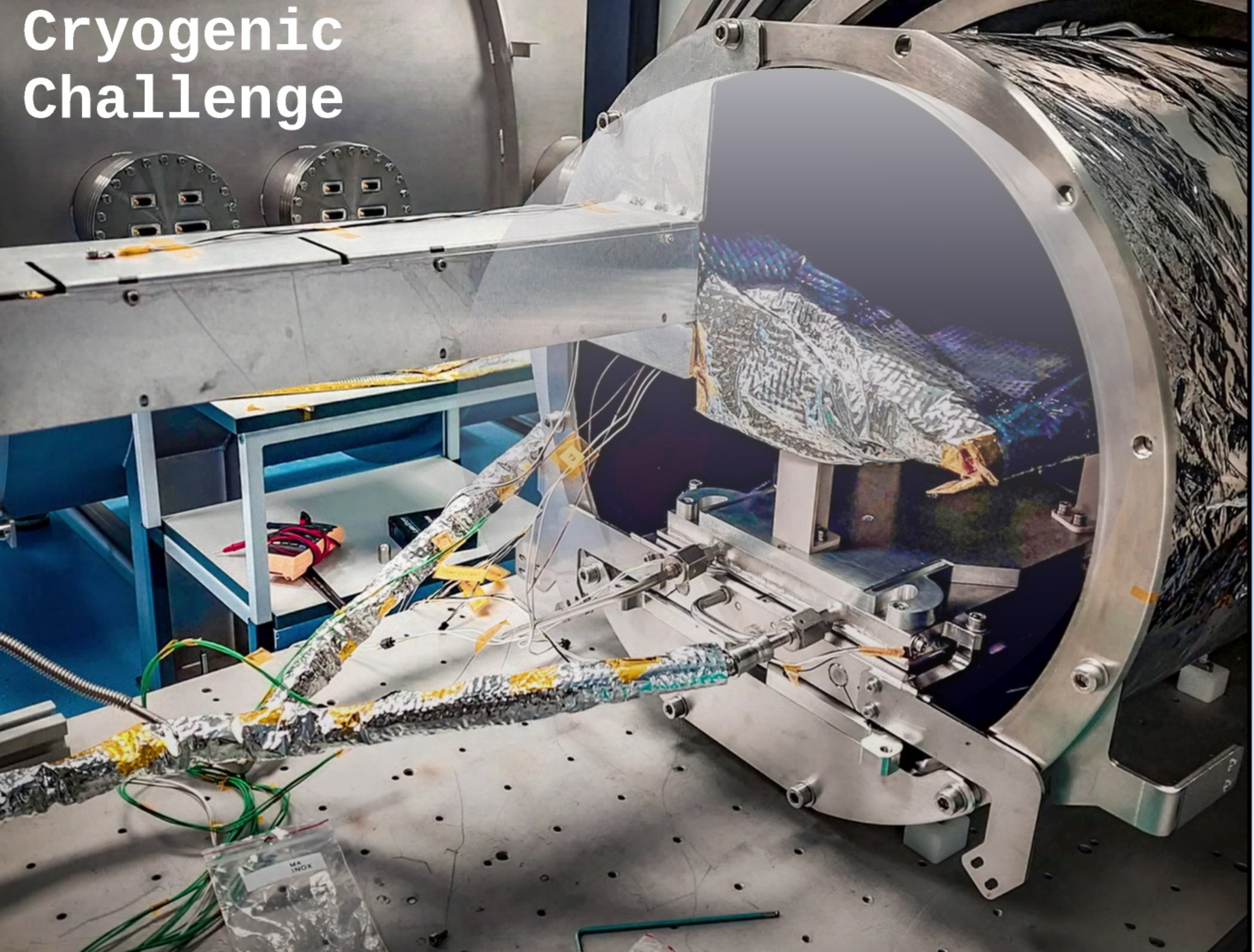


TWO HE CRYOSTAT

- Temperature control on Big Cold Finger from 10K
- Load capacity:
  - Chamber : Ø22 cm; h=10 cm
- Temperature range: 10K to 320 K.
- Temperature rate: <2 K/min.
- Vacuum range (control and measure): 10-4 to 10E-7 mbar
- Temperature sensors for control and monitoring:
  - Standard 2 x Cryogenic Reference
  - 2 Additional Cryogenic Reference on sample.
- Feed-through for in-vacuum measurements:
  - Electrical: DSUB, space wire, high-power
  - Optical: windows and fiber optics
  - RF: SMA up to 18GHz
  - Rotary and linear motion
- Can operate inside ISO8 Clean Area.

A Helium cryostat is required for Ariel instead of N_2 to achieve the extremely low temperatures (25-40K).

Cryogenic Challenge



Thermal Sensors

Cryogenic Validation

Schedule Optimisation

On-Going Tests

Schedule Optimisation

Exercice 1

One Cryogenic setup and testing of individual types (25):

✗ 25 runs x (setup, 1000h duration, reporting)-> Q4 2027

✗ 25 times x 25-35K€

Exercice 2

One Cryogenic setup and and reduction of number of runs:

✗ 18 runs x (setup, 500-1000h duration, reporting)-> Q2 2027

✗ 18 times x 25-35K€

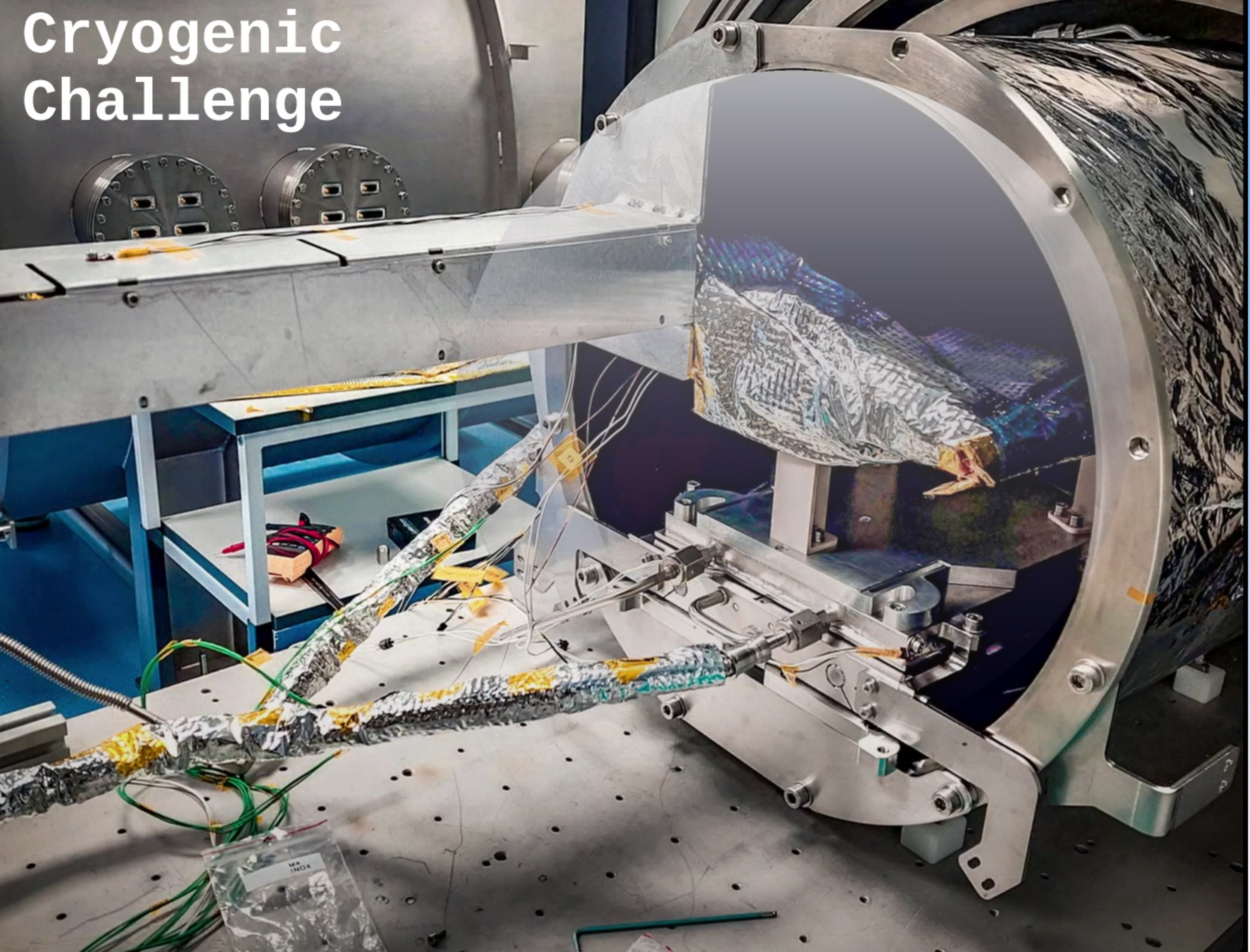
Exercice 3

Double capacity of Cryo setups and reduction of number of runs:

✓ 9 runs x (setup, 500-1000h duration, reporting)-> Q1 2026

✓ 9 x 25-35K€ + cost of additional cryostat funded by ESA (80K€)

Cryogenic Challenge



Thermal Sensors

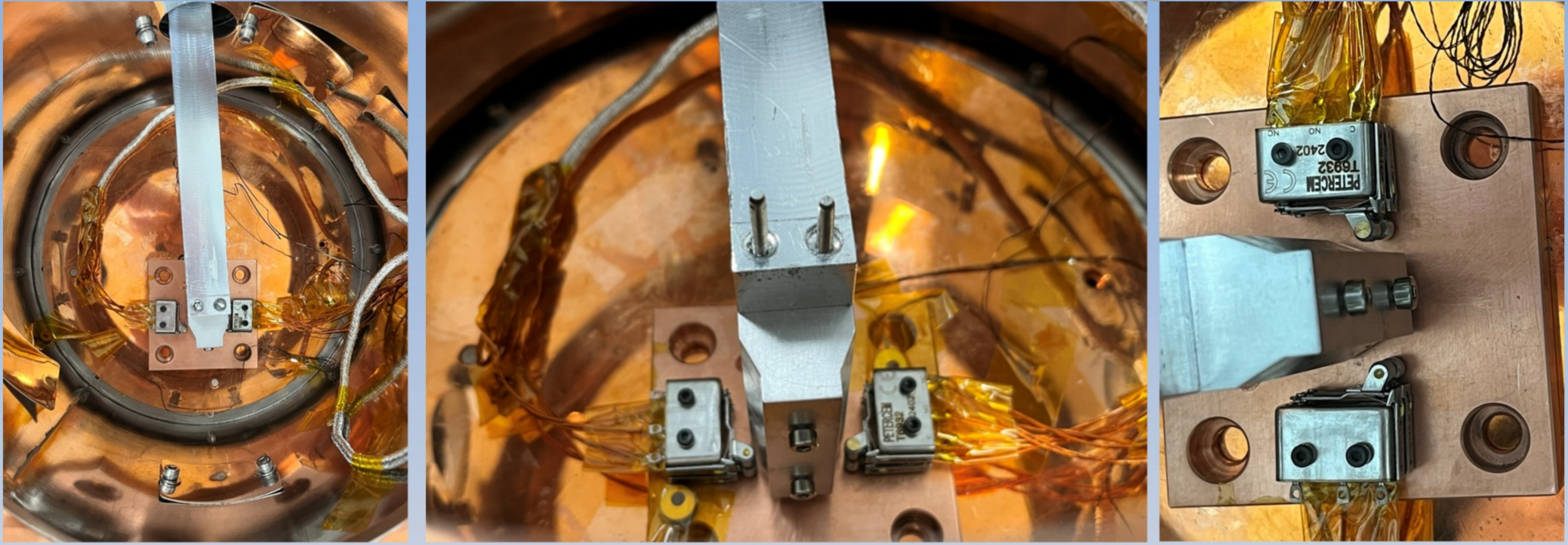
Cryogenic Validation

Schedule Optimisation

On-Going Tests

Cryogenic Tests

Switch T6932 - Petercem (FR) - Space Grade

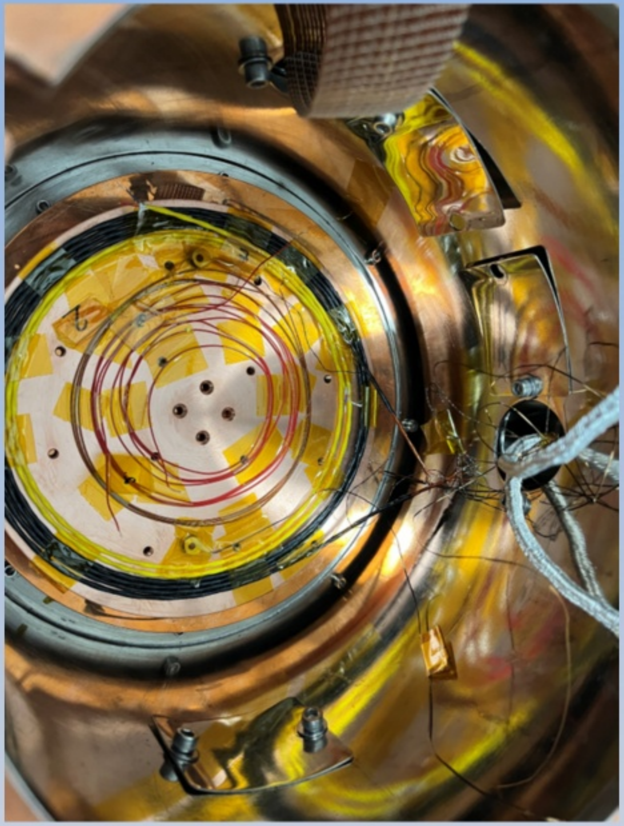


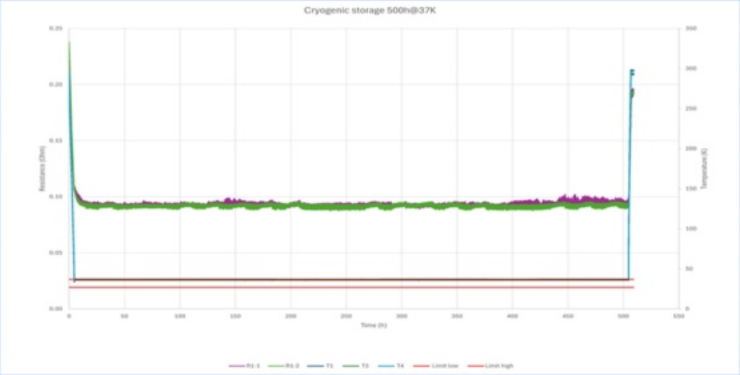
Special Conditions:

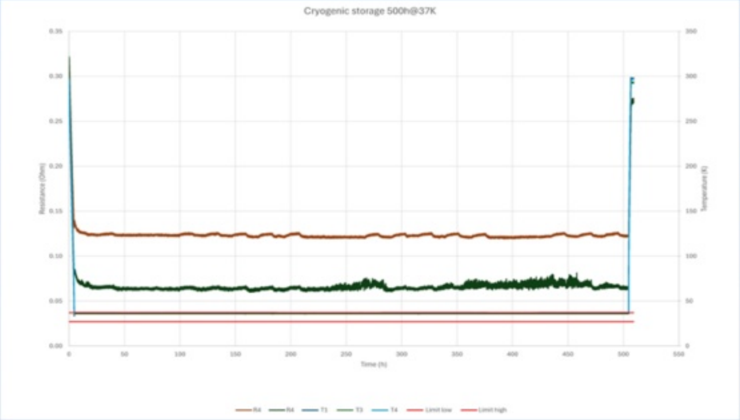
- 12TC (37-323K)
- 15000 run-in cycles under cryogenic conditions @37K

Cryogenic Tests

ESCC and Space Grade Stainless Steel Wires - AXON (FR)







Special Conditions:

- 4 different references (ESCC+ Stainless Steel)
- 12 Thermal cycles (37-323K)
- 500h cryogenic test (37K)

Cryogenic Tests - Upcoming Runs

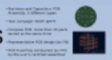
1 **MicroSwitch - Petercem (FR)** ✓
Space Grade Quality - 1x part-type

2 **Wires - AXON (FR)** ✓
ESCC+ Space grade Quality - 4x part-types

3 **Heaters - RICA (IT)** ▶
ESCC Space Quality - 1x part-type

4 **NanoD Connectors - Airborn (USA)** ⏭
Space Grade Quality - 5x part-types

5 **Resistors & Capacitors Assembly - AVX (FR) +VISHAY (FR) +Presidio (USA)**
ESCC + Space Grade Quality - 5x part-types



6 **OpAmp - Texas Instrument (USA)**
COTS

7 **Sub-D Connecors - C&K (FR)**
ESCC - 4x part-types

8 **Micro-D Connectors - C&K (FR)**
ESCC - 3x part-types

9 **Thermistor - IST (CH)**
ESCC - 1x part-type

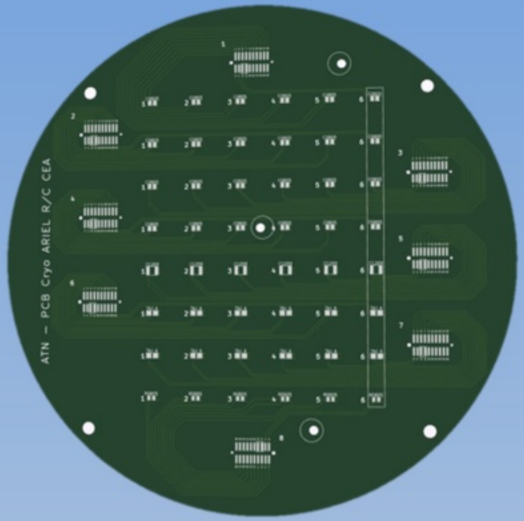
- Resistors and Capacitors PCB Assembly: 5 different types

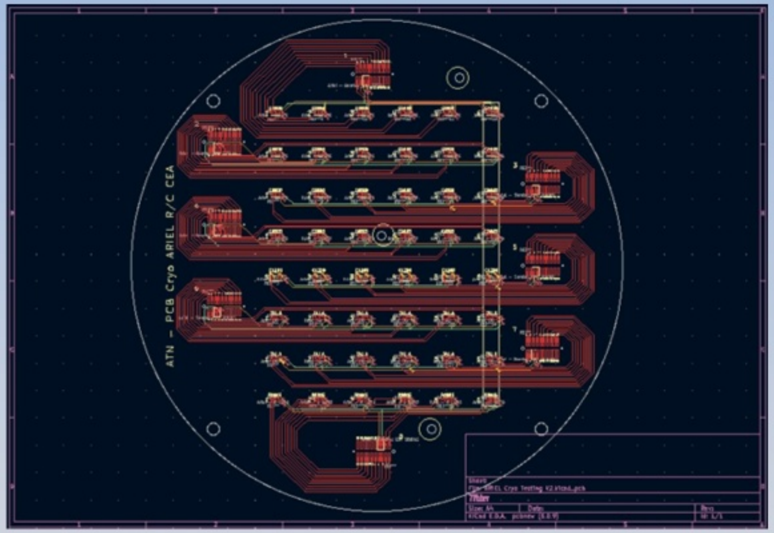
- Test campaign 1000h @47K

- Complex PCB: more than 40 parts tested at the same time!

- Representative PCB design (as FM)

- PCB Assembly conducted (as FM) by the user's certified assembler





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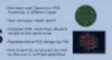

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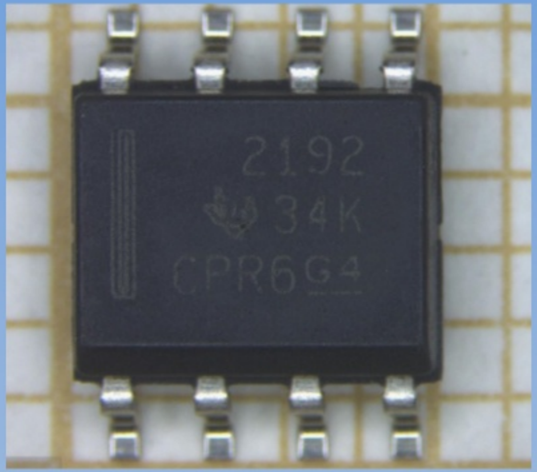
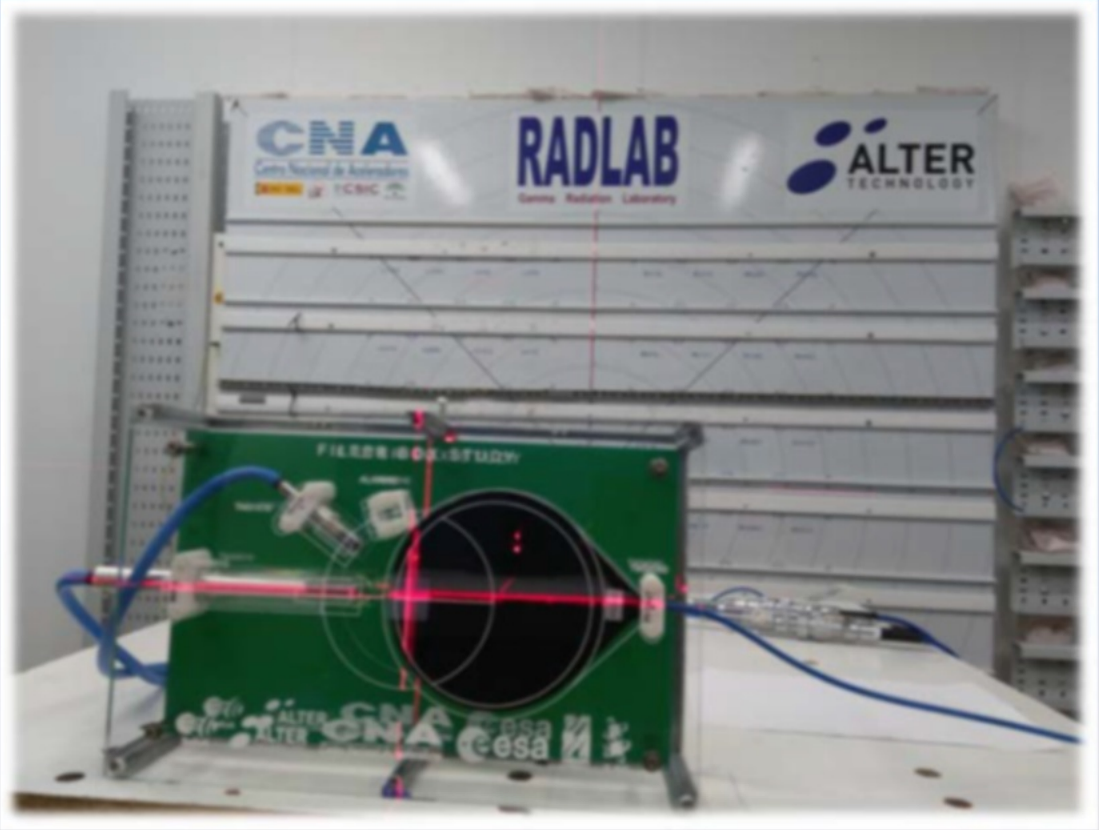
   ESCC - 1x part-type

- OPA2192, Low Offset Voltage, Low Input Bias Current Op Amp



- Test campaign 1000h @47K

- Radiation Test in Cryogenic conditions : Dedicated set-up with the new ESA cryostat!



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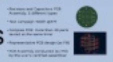

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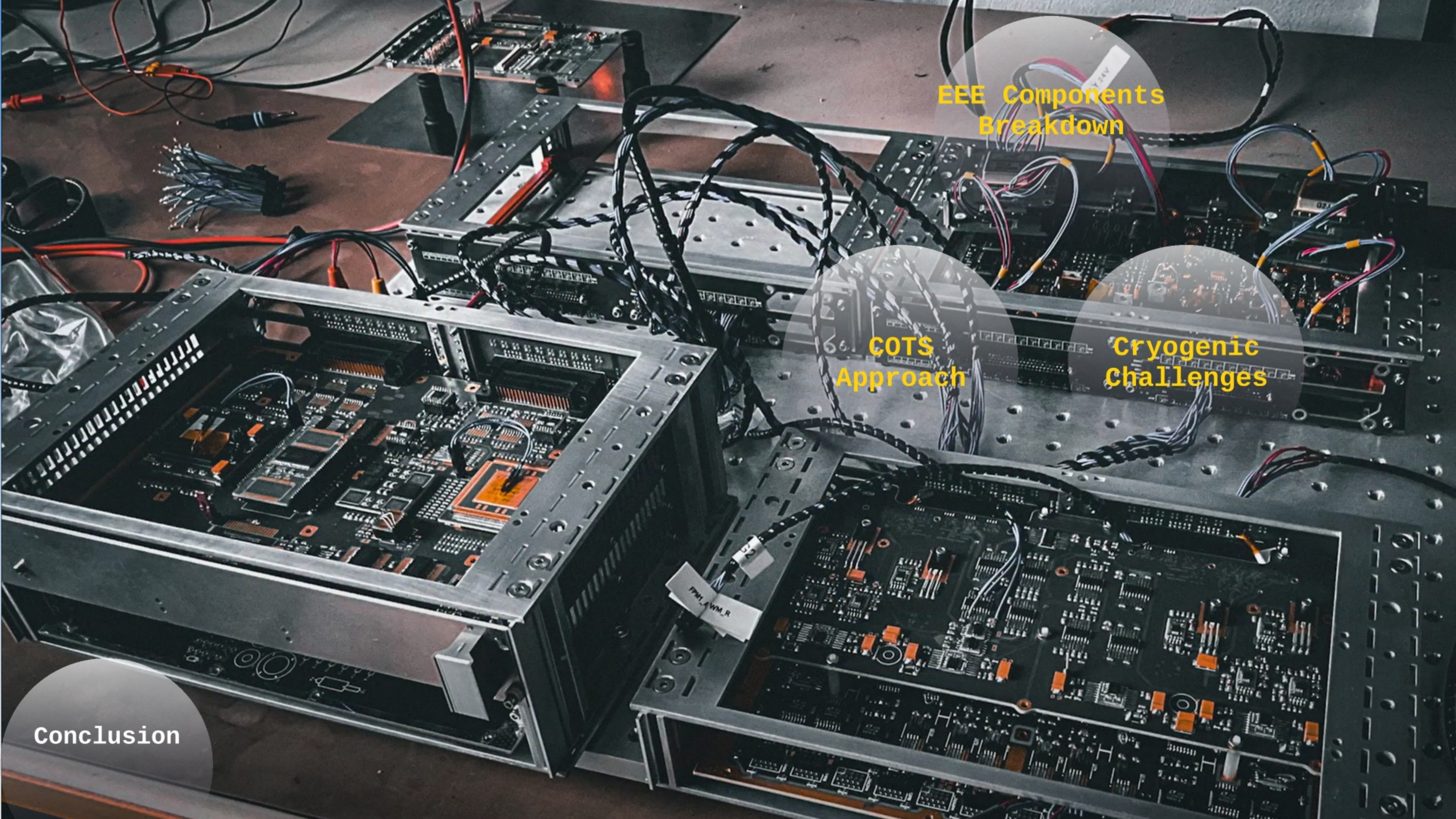


EEE Components Breakdown

COTS Approach

Cryogenic Challenges

Conclusion

Conclusion (1/2)

- **COTS Approach & Qualification:**

COTS selection follows ECSS-Q-ST-60-13 with mission-specific tailoring.

While de-risking is beneficial, it is not sufficient for critical applications (e.g., OPA);
Only representative tests can fully confirm reliability under real operational conditions.

- **Cryogenic Sensor Strategy:**

A standardized cryogenic approach ensures compatibility across users, by selecting representative part types, reducing the number of variations, and optimizing the number of parts to be tested.

ESA's financial support plays a crucial role in securing an additional cryostat, ensuring all instrument users meet their required timelines.

Conclusion (2/2)

- **Thermal Sensor Non-EU Dependency**

To reduce reliance on non-EU suppliers, it is critical to develop an EU-based solution for future Science and Exploration missions.

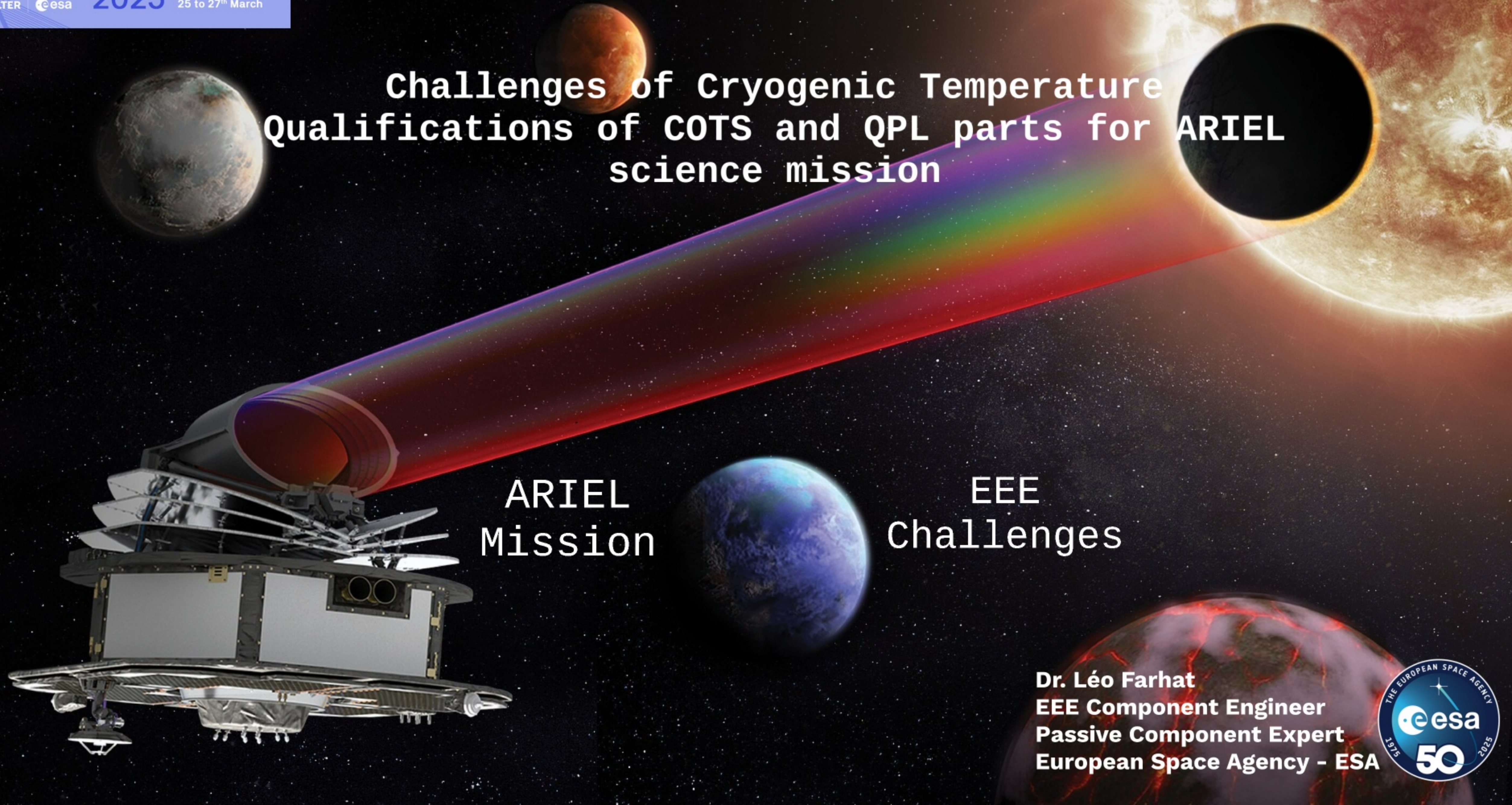
ESA is considering integrating these sensors into the upcoming GSTP Sovereignty funding program to drive European independence in this domain.

- **CPPA's Critical Role in Science Missions**

The CPPA plays a key role in ensuring mission success by identifying alternative space-grade solutions, consolidating procurement (POs), optimising stock management, negotiating lead times, overseeing manufacturers, and following closely quality issues.

Its involvement is **essential** for cost reduction, risk mitigation, and supply chain efficiency.

Challenges of Cryogenic Temperature Qualifications of COTS and QPL parts for ARIEL science mission



ARIEL
Mission

EEE
Challenges

Dr. Léo Farhat
EEE Component Engineer
Passive Component Expert
European Space Agency - ESA

Challenges of cryogenic temperature Qualifications of COTS and QPL parts for ARIEL science mission

Thank You For Your Attention!

Acknowledgement:
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ACCEDE | ESCCON
2025
Seville - Spain
25 to 27th March

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