Accelerated Testing for European Space Programs

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Speaker presentation

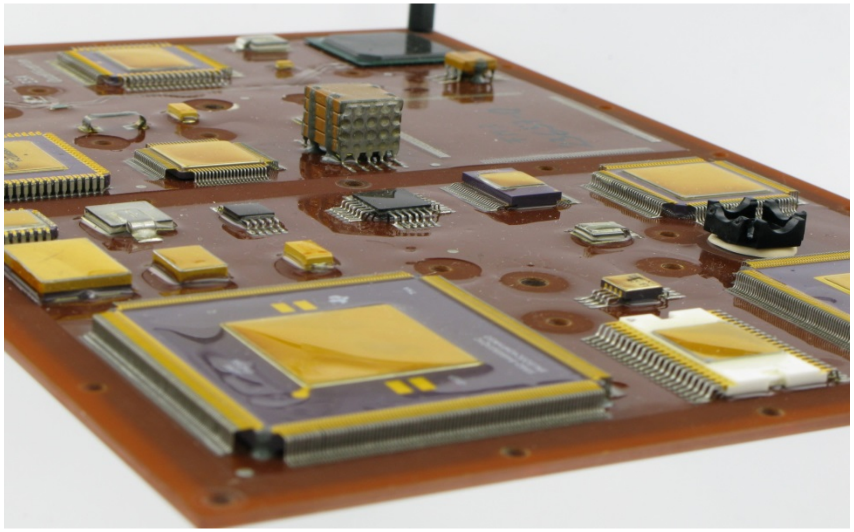
- Karin Lundmark
- Swedish, living in Netherlands
- Master of Science in Engineering Physics from Chalmers Technical University, Gothenburg, Sweden
- Component Engineer at European Space Agency, mainly supporting science programs in general EEE aspects. At ESA since 2009, previously also between 2002 and 2006.
- Have worked almost complete professional life with EEE component engineering for space, before ESA at Ruag Space Sweden and Swedish Space Corporation. Have done component analysis, procurement and technical as well as project related support.

General ESA presentation

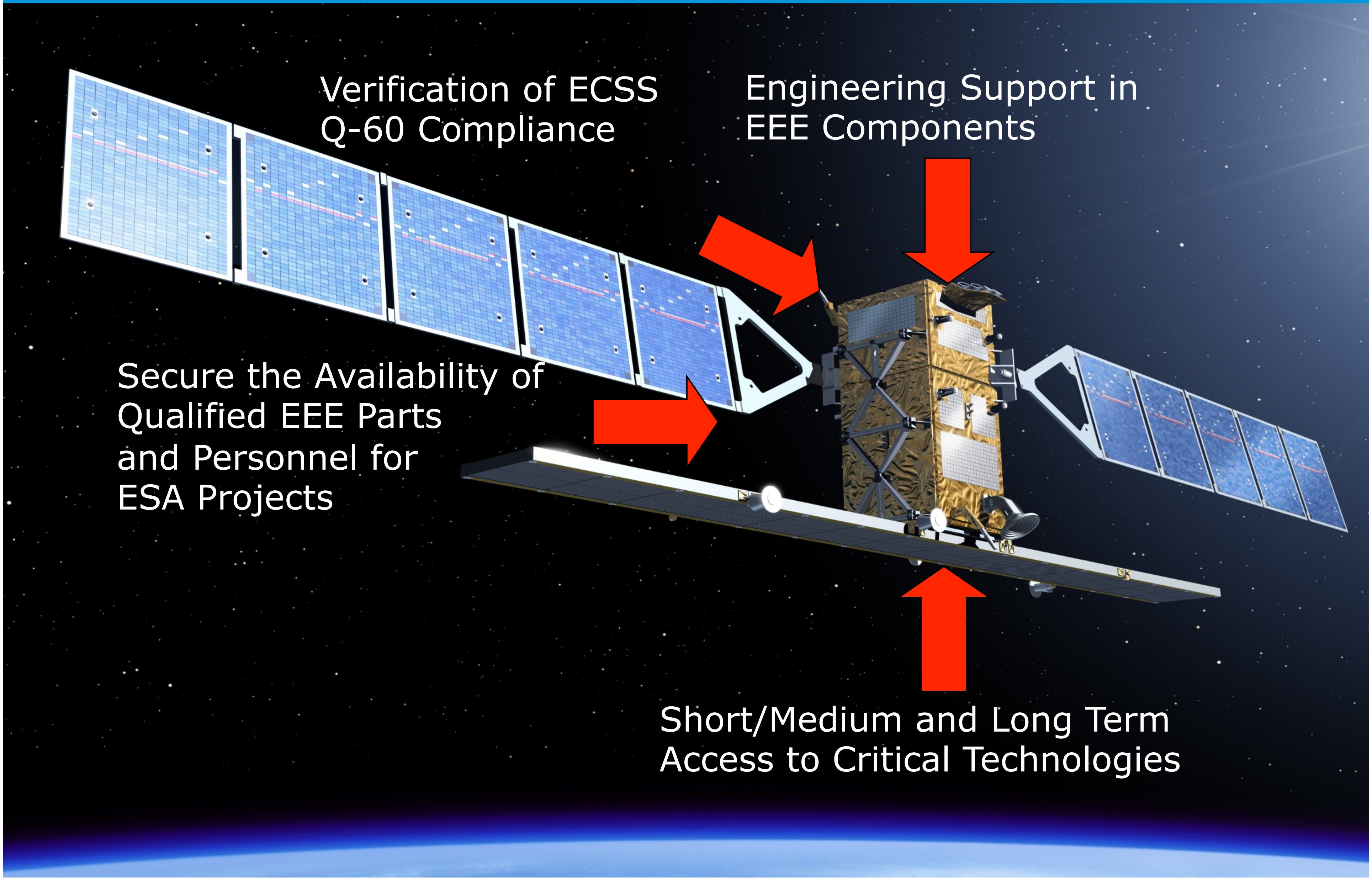
ESA_Presentation_EN.ppt

1. The ESA Component Technology Section

a. Our Mission
b. The Team
c. Responsibilities
d. Organisation



ESA Component Technology Section: Mission



ESA Component Technology Section: Organisation

- 16 Staffs
- 2 Contractors
- 1 Portuguese trainee (MEMS Pressure Sensors and Magnetometer)
- 1 German trainee (Power MOSFETs)
- 2 YGTs:1) Flip-Chip complex assembly
  2) Long term storage
- 1 Research Fellow: RF MEMS reliability (XLIM+TAS-F, France)
- 1 Co-shared Post-Doc: MEMS Simulation and Packaging (Aalto, Finland)
- 3 Co-shared PhDs: RF MEMS prototyping and testing (Cambridge UK), GaN reliability (Tyndall Ireland), SiGe MMIC Process (IHP, Germany)
- 1 Trainee: Section communication tool development

In addition,

- In charge of the ESA Component Database development
- Technical management of European Components Initiative

ESA Component Technology Section: Responsibilities

Technologies:

- Silicon: Discrete components & VLSI including power
- Microwave, mm and submm-wave, WBG (GaN, SiC)
- Photonics: Components and Detectors
- Passive components including wire/cables; RF and standard
- Hybrid circuits
- Packaging
- Micro-Nano Technologies

Two major responsibilities:

EEE support for ESA projects: formulation of EEE requirements, parts selection, project specific EEE qualification, technical management of NCRs and associated NRBs

EEE Component Engineering: support to EEE fabrication process development, prototyping, reliability assessment, transfer to volume production, technical management of ESCC evaluation and qualification. Support to In-Orbit Demonstration

ESA Component Technology Section:
EEE support for ESA projects

1. **Definition** of adequate **quality, control and procurement requirements** for components

2. Support the **selection**, application and approval of appropriate technologies and components

3. **Control** of the **procurement** approach, progress and results

4. Participation in **project reviews** where component matters are discussed (NRBs, designs reviews, parts control boards, PADs (Part Approval Document) reviews, etc.) and in project reviews

5. Identification and coordination of necessary functional support in parts engineering, analysis, testing and radiation effects

ESA Component Technology Section:
EEE support for ESA projects cont.

6. Monitoring of components quality and support in component **problem resolution and non conformances**

7. Evaluation and review of tenders and procurement documentation for ESA programmes

8. Provision of inputs to the section components development activities and in particular ECI (European Component Initiative)

9. Support to market surveys and corporate component data and information databases, in charge of TEC-Q Declared Component List (DCL Tool) development

10. Promotion of corporate programmes for increasing availability of components for space projects and maximising European EEE parts usage in ESA programmes.

ESA Component Technology Section:
EEE Component Engineering

1. Provision of **expert technical support to ESA programmes**, National Space Agencies and European Space Industry concerning the selection, characterization, evaluation, qualification and application of components for space applications.

2. **Technical management of ESA ESCC evaluation and qualification activities**

3. Technical assessment of parts **non-conformances and participation in manufacturer NRBs**.

4. Technical assessment and monitoring of European component space manufacturers as well as the various Assembly and Test Houses (ATH) used by European component manufacturers.

5. **Determination of technology needs of ESA projects**, **defining technology study** activities and the preparation and evaluation of R&D proposals for ESA Technology Programmes

ESA Component Technology Section: EEE Component Engineering cont.

6. **Formulation and management of technology activities** addressing the Agency's foreseen requirements for space components.

7. **Formulation, implementation and management** of activities under the **European Component Initiative.**

8. **Participation and leadership in appropriate ESCC and ECSS working groups** for the coordination of components development activities; including the definition, **review and maintenance of component engineering standards and specifications.**

9. **Leadership of CTB (Component Technology Board) WGs**: Microwave, Silicon & VLSI, Passive Components, Photonics, MNT, Hybrid and Micropackaging.

10. Definition and monitoring of work to be performed by the Components Laboratory

The ESCC System for component specifications and qualification

EEE components play an essential role in the functional performance, quality, life cycle and costs of space systems.

Project qualification testing is often built using ESCC specification as baseline documents and that the ESCC Specification system that is a self-standing system of specifications dedicated to EEE parts for space applications:

- Detail specifications of EEE parts to be used for procurement
- Methodologies for component evaluation and qualification
- Outline of necessary test methods
- Quality Assurance requirements
- ESCC system operational procedures

All the ESCC Specifications are **FREE** and available in the **public domain** of the ESCIES web site. The web address is **https://escies.org**

Example of evaluation testing from ESCC 2265000, discrete semiconductors

CHART I – EVALUATION TEST PROGRAMME

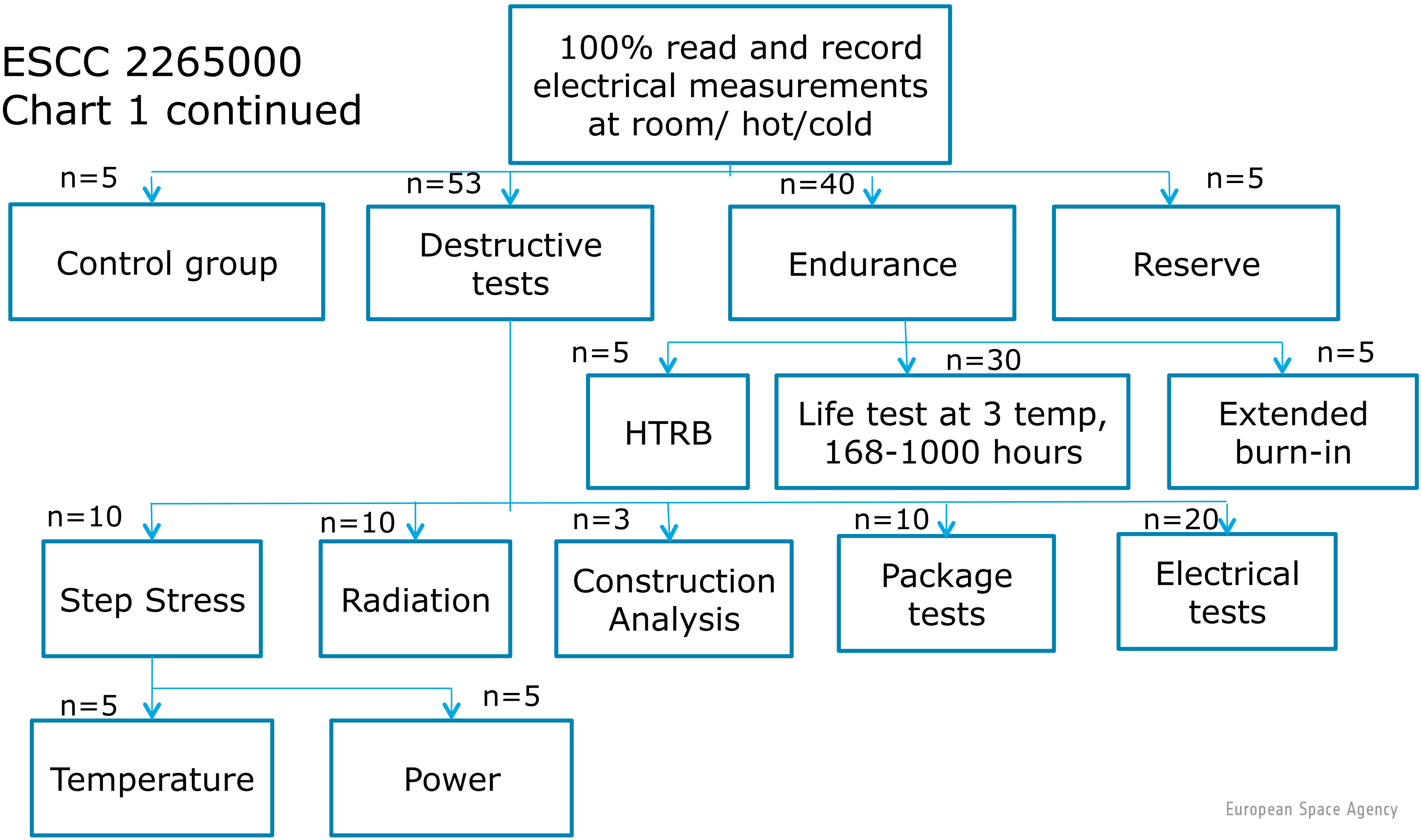
n = 103

INSPECTION Para. 5	
Dimensions go-no-go	100%
Mass	100%
Electrical Parameters go-no-go	100%
External Visual Inspection	100%
PIND	100%
Radiographic Inspection	100%
Hermeticity	100%
Marking and Serialisation	100%

The ESCC Specification System

Concept of the ESCC system – evaluation always precedes qualification

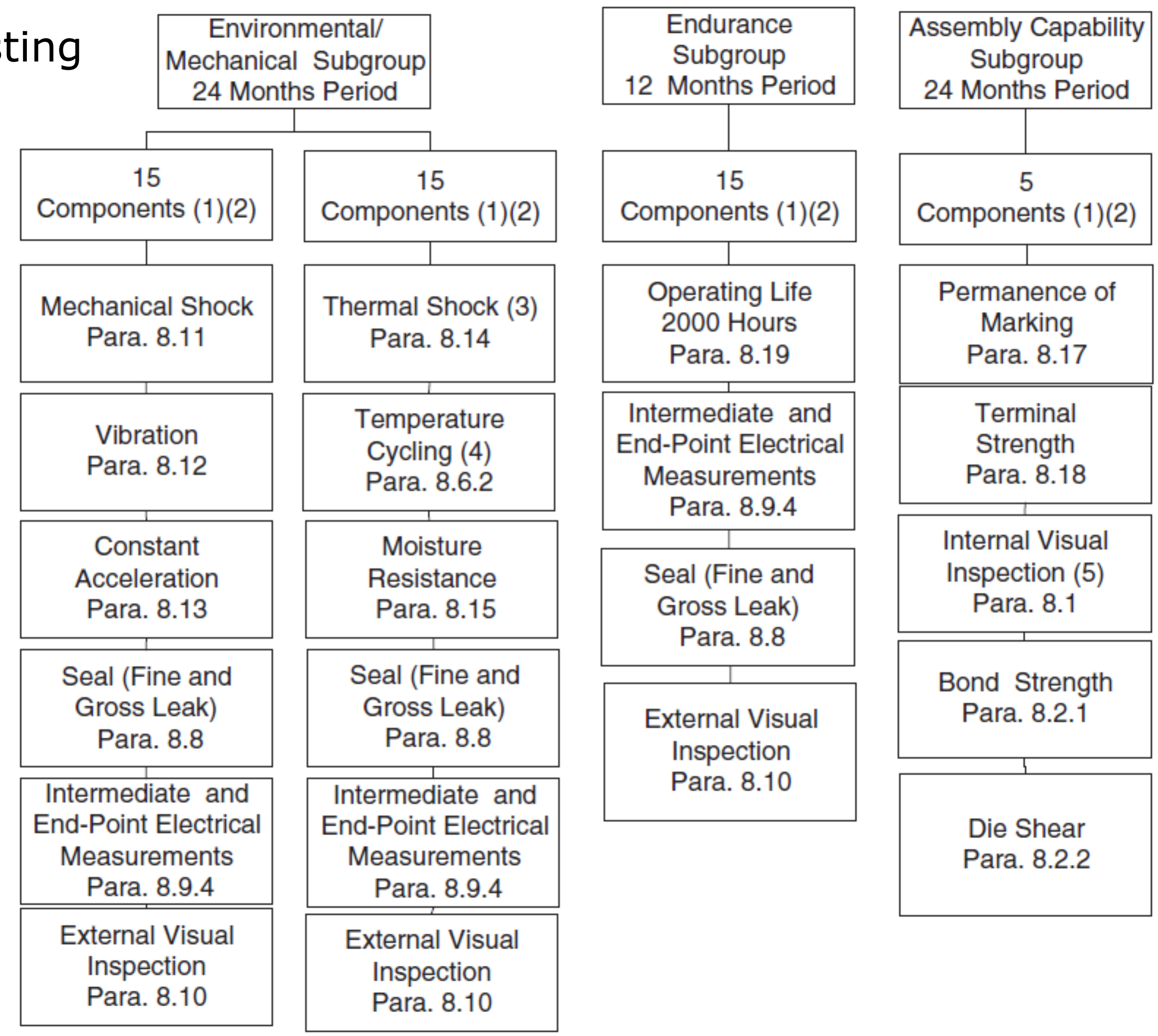
ESCC 2265000
Chart 1 continued



The ESCC Specification System

Concept of the ESCC system – evaluation always precedes qualification.

Example of qualification testing from ESCC 5000, discrete semiconductors



Why do we test so much?
What is specific for space?

- No repair or maintenance possible (few exceptions)
- Large financial investments
- Small or no series production
- High mechanical loads
- Vacuum
- Irradiation, cosmic and from the sun
- Other space specific environmental issues; micro meteorites, atomic oxygen, zero gravity…

Estec test centre

[ESA Test Centre presentation April 2014 short.pptm]

Bepi Colombo

Bepi Presentation.ppt

Bepi Colombo Solar Array blocking diodes

Solar panels requires blocking and shunt diodes. The thermal environment is normally demanding but on this mission even more so due to the high temperatures reaching way above 200°C. Minus temperatures are also low, down to around -170°C and number of thermal cycles high.

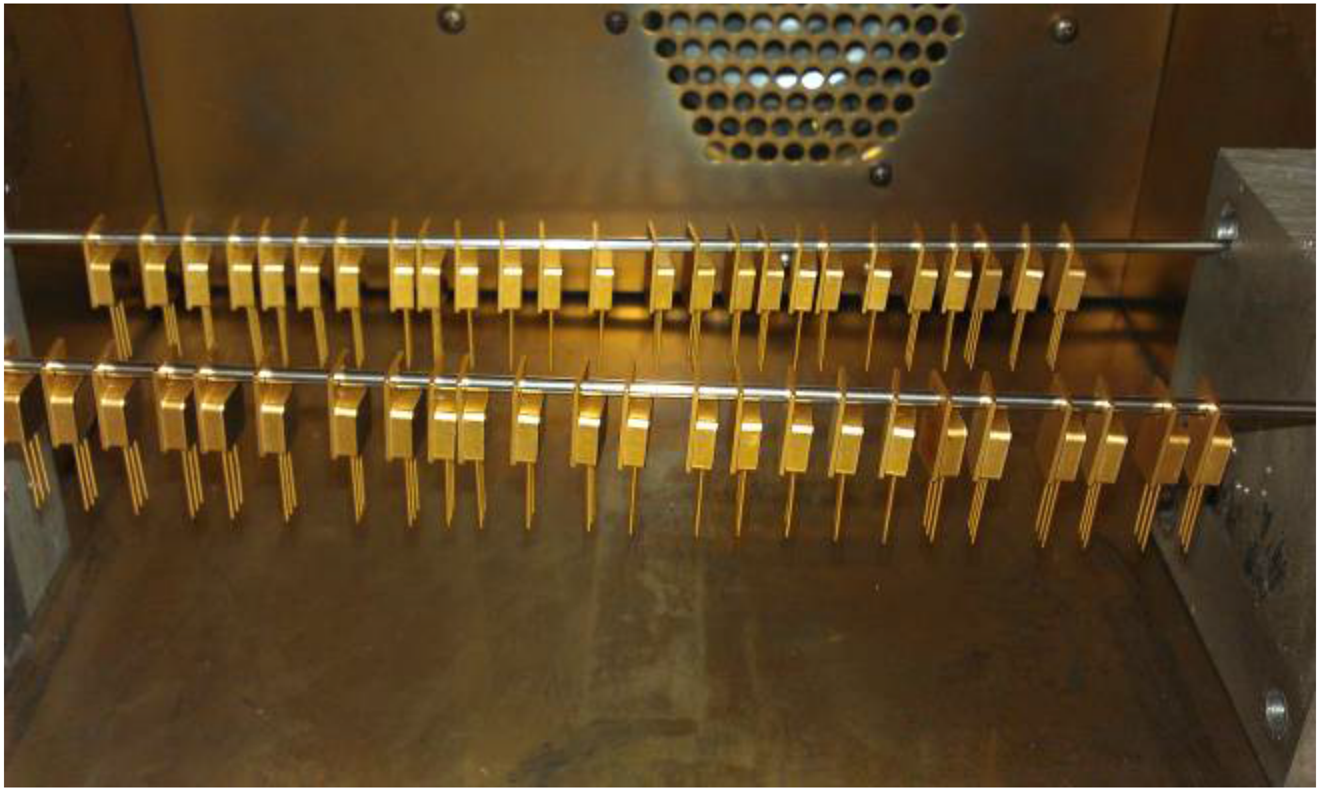
For the blocking diodes a separate development and evaluation of silicon carbide blocking diodes was initiated many years in advance. This has been successful and flight diodes have now been qualified between -170°C and +270°C and with a reverse voltage of 250V.

Bepi Colombo Solar Array blocking diodes
Summary of tests from evaluation

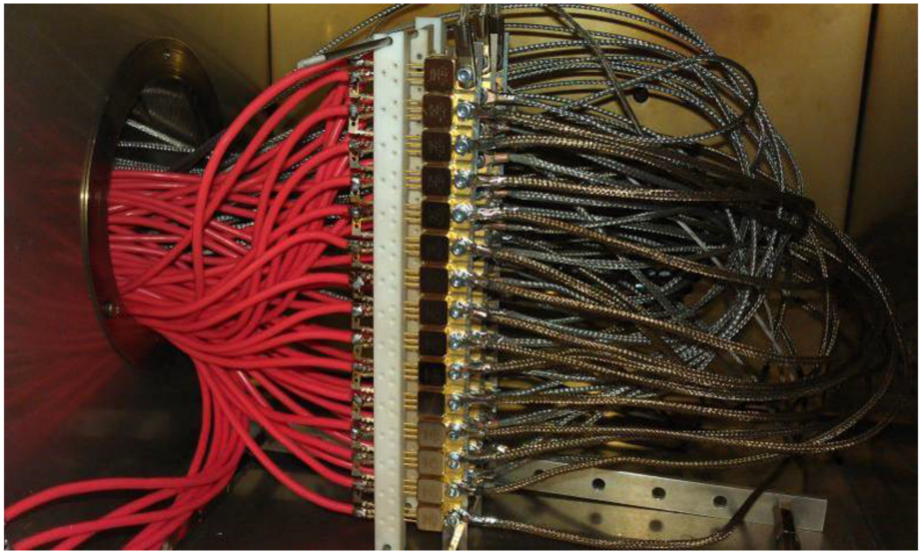
- Power step stress test @ 230°C
- Temperature step stress from 230 to 370°C
- Accelerated life tests with power and reverse bias at temperatures up to 310°C
- Thermal shocks, 200 between -180 and 280°C
- Radiation tests (gamma and proton)
- Constructional analysis
- 4000 thermal cycles from -150 to +250°C with forward bias in warm phase
- Constant acceleration 20000g
- Shock, sine and random vibration in accordance with system requirements

Bepi Colombo Solar Array blocking diodes
Summary of tests from qualification

- 4000 hours accelerated life tests with power and reverse bias at 270°C
- 100 thermal cycles from -170 to +270°C in agreement with standard ESCC approach



Bepi Colombo Solar Array blocking diodes
Summary of tests from qualification



- Additionally >5000 thermal cycles in smaller temp range and with forward bias applied in warm phase

- Constant acceleration 20000g, one direction
- Shock and sine vibration in accordance with ESCC requirements;
    - 1500g. 0.5ms, 5 shocks in each plane
    - 20 g, 10-2000Hz
- Moisture resistance

Bepi Colombo Solar Array blocking diodes
Acknowledgements

- CNM, Centro Nacional Microelectronica (Barcelona, Spain), manufacturer
- TAS I, Thales Alenia Space Italy (Turin), development and evaluation
- Airbus Defence and Space Munich (Germany), solar array subcontractor
- Airbus Defence and Space Friedrichshafen (Germany), Bepi Colombo prime contractor

- More detailed presentation from development and evaluation, see Silvia Massetti (ESA) "*Development and Evaluation of a SiC Schottky Diode for Harsh Environment Space Applications*" at ESPC2011.

Bepi Colombo Solar Panel wires

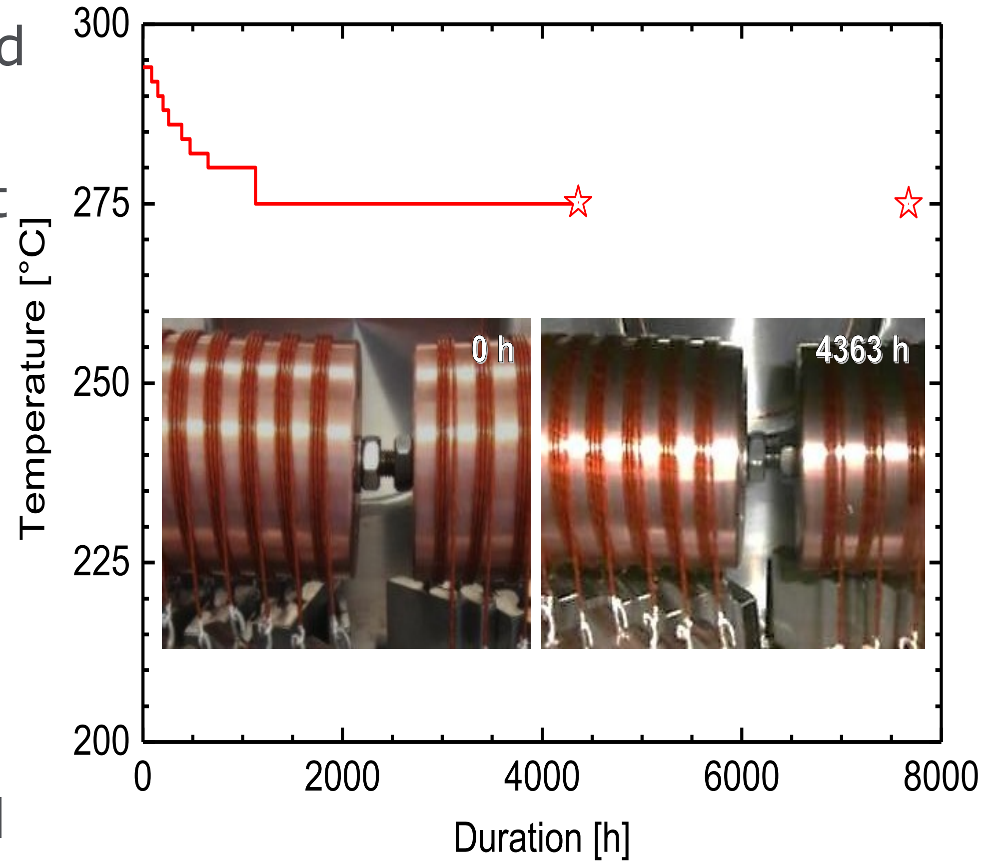
- As an additional example of high temperature testing for components for the solar panels next slides will focus on the wires.
- The presentation from Thomas Andreev (Airbus Defence and Space) at ESPC 2014 "*Qualifying Solar Array Components for High Intensity, High Temperature Environments. The test approach for the BepiColombo Solar Arrays*" contains information about the wires and also presents solar cells, shunt diodes and OSRs.
- Test campaign performed by Gore (Germany) and AAC (Austria), last tests still pending
- Also in this case TAS I run a pre-study to identify the most suitable candidates

Bepi Colombo Solar Panel wires

- Standard wires qualified up to 200°C, in this case application temperature will be maximum around 300°C.
- For Bepi two type of GORE high temperature wires have been selected and tested, pure silver and silver plated copper respectively. ePTFE and polyimide used for insulation. AWG sizes 20-24.
- The qualification test program has been set-up based on ESCC requirements but heavily tailored with respect to temperatures and duration of life test.
- Wires are baked/outgassed prior to use and also qualification testing due to the high temperatures

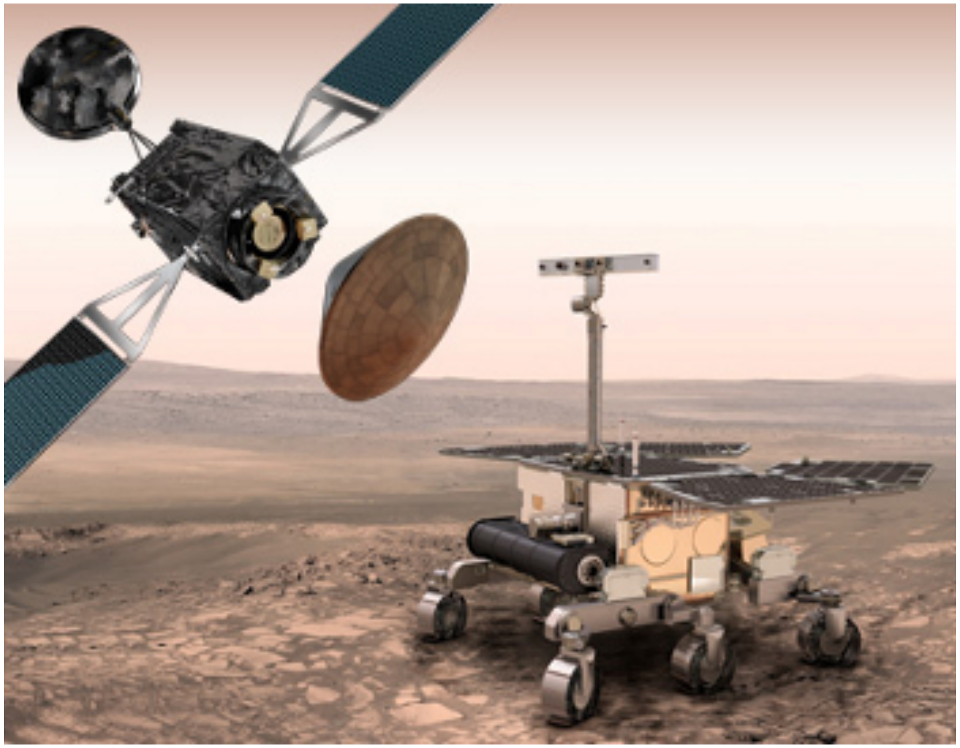
Bepi Colombo Solar Panel wires Summary of qualification tests

- Life test in vacuum (expected to give better results), approximately 8000 hours at 275°C and higher temperatures. Wires are mechanically loaded during life test and also needs to pass wrap test followed by 2.5kV voltage test afterwards.
- Also a number of mechanical and environmental tests.



Exomars

- 2016 - Trace Gas Orbiter and Entry, Decent and Landing Demonstrator Module
- 2018 – Rover



- Challenge – exposure to low temperature during Martian nights in non-heated compartments.

Exomars
Low temperature testing

- Temperature can drop to -120°C during Martian nights.
- Most electronics are in temperature controlled areas some though need to survive around 200 cycles down to Martian night environment, very few also need to operate at very low temperature.
- Space components are typically qualified down to -55 or -65°C.
- To cover the most critical parts Tesat-Spacecom performed an evaluation test campaign under TAS I contract.
- Presentation of this see Anita Weinschrott-Schaaf (Tesat-Spacecom) “*Evaluation of Parts for a Low Temperature Environment on Mars*” ESCCON 2013

Exomars
Low temperature evaluation testing

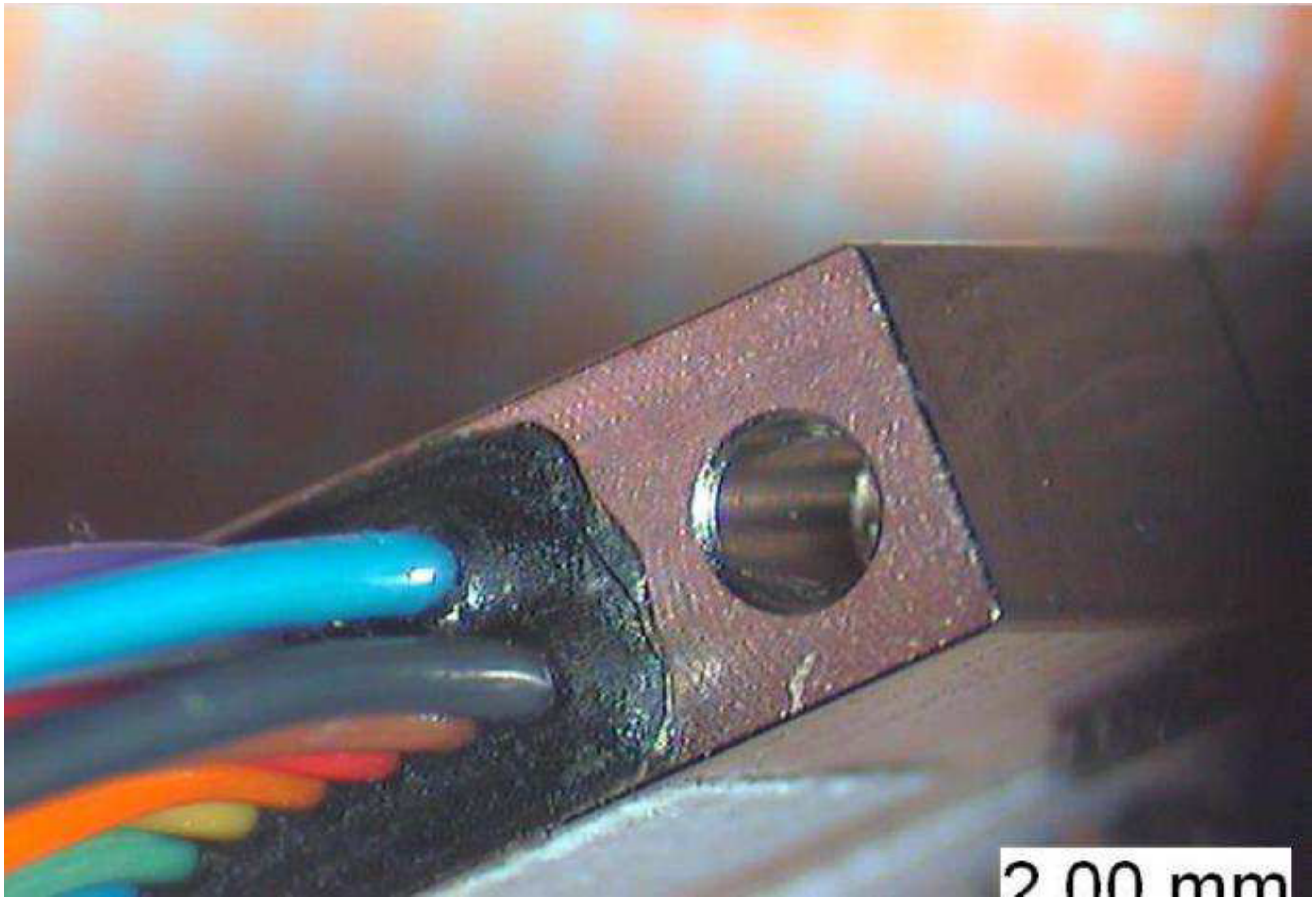
- 240 cycles from +70 to -130°C, temperature change rate 40K/min
- Dwell time 30 minutes at each extreme
- Parts tested stand alone
- Test chamber especially developed. Cooled by liquid Nitrogen.
- Electrical measurements, when applicable also seal and PIND tests performed. Parts deemed extra critical where also exposed to destructive physical analysis

Exomars
Low temperature evaluation testing

Part family	Number of types	Summary of results
Capacitors	14	All OK
Connectors	4	One failed visual inspection
Oscillators	4	One failed
Diodes	2	One acceptable finding
Inductors	6	All failed visual inspection
Microcircuits	11	All OK
Relays	2	All OK
Resistors	16	All OK
Transistors	3	One acceptable finding
Optocouplers	5	Three failed, none can be recommended.

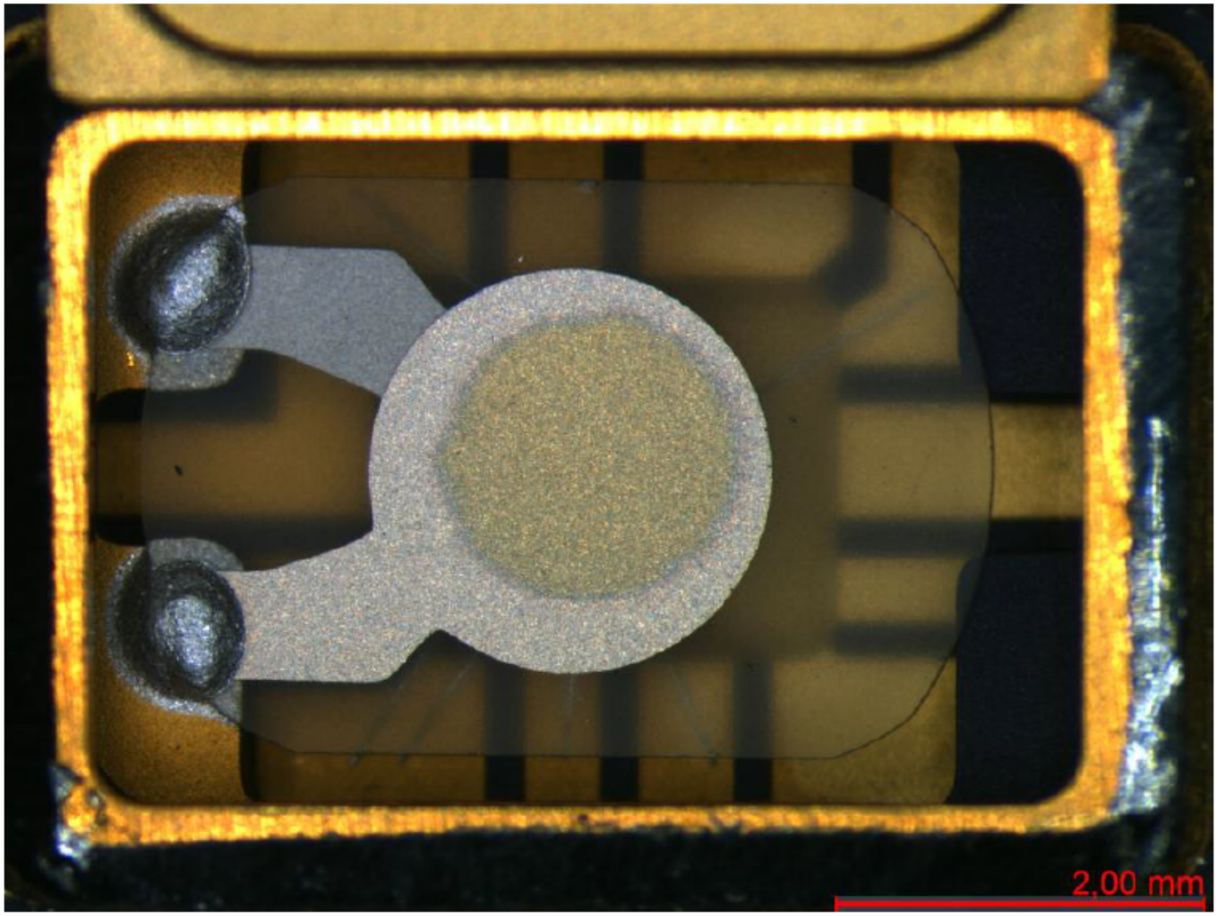
Exomars Low Temperature Evaluation Testing – Nano Connector Failure

Cracks in potting



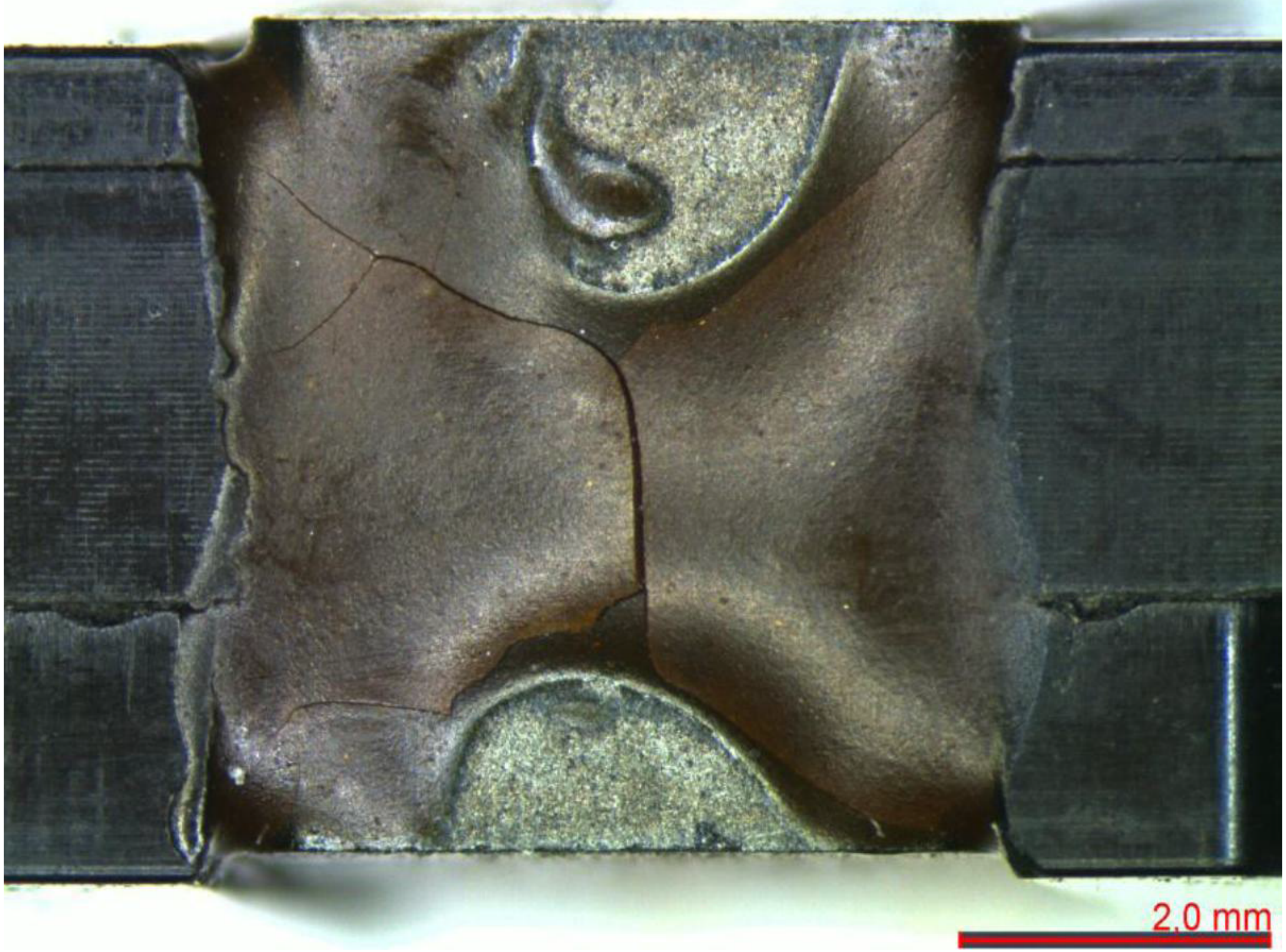
Exomars Low Temperature Evaluation Testing – Oscillator Failure

- One component of one part type failed electrical measurements, frequency at low temperature.
- Believed that this is due to stress settling in crystal.



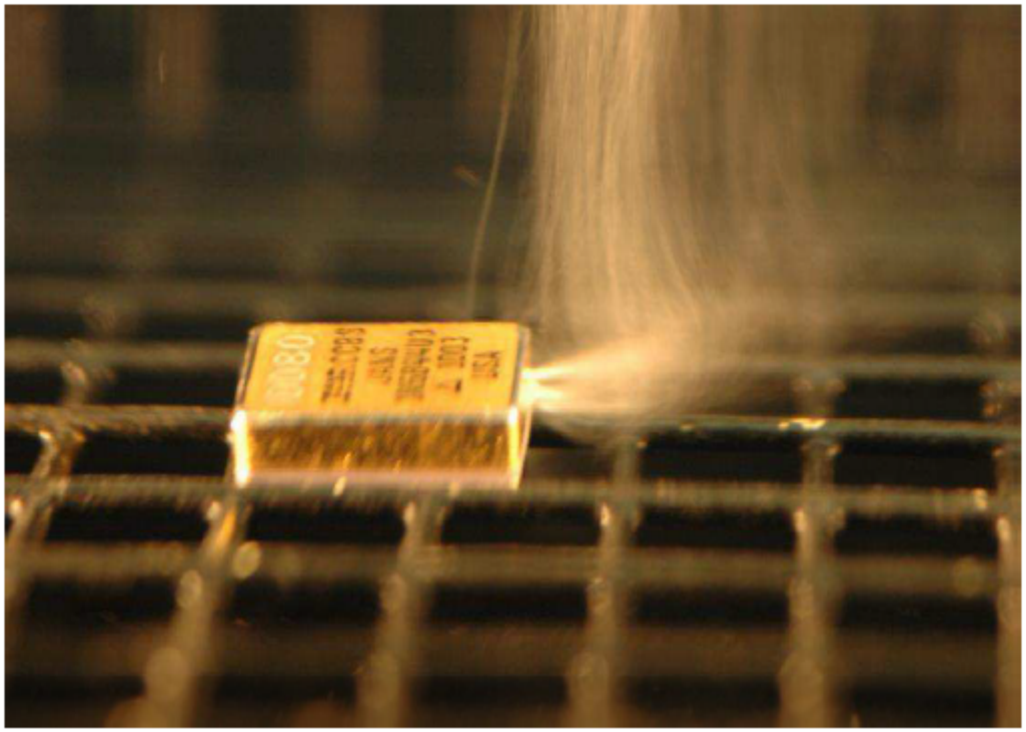
Exomars Low Temperature Evaluation Testing – Inductor Failure

All parts exhibited major cracks in glue



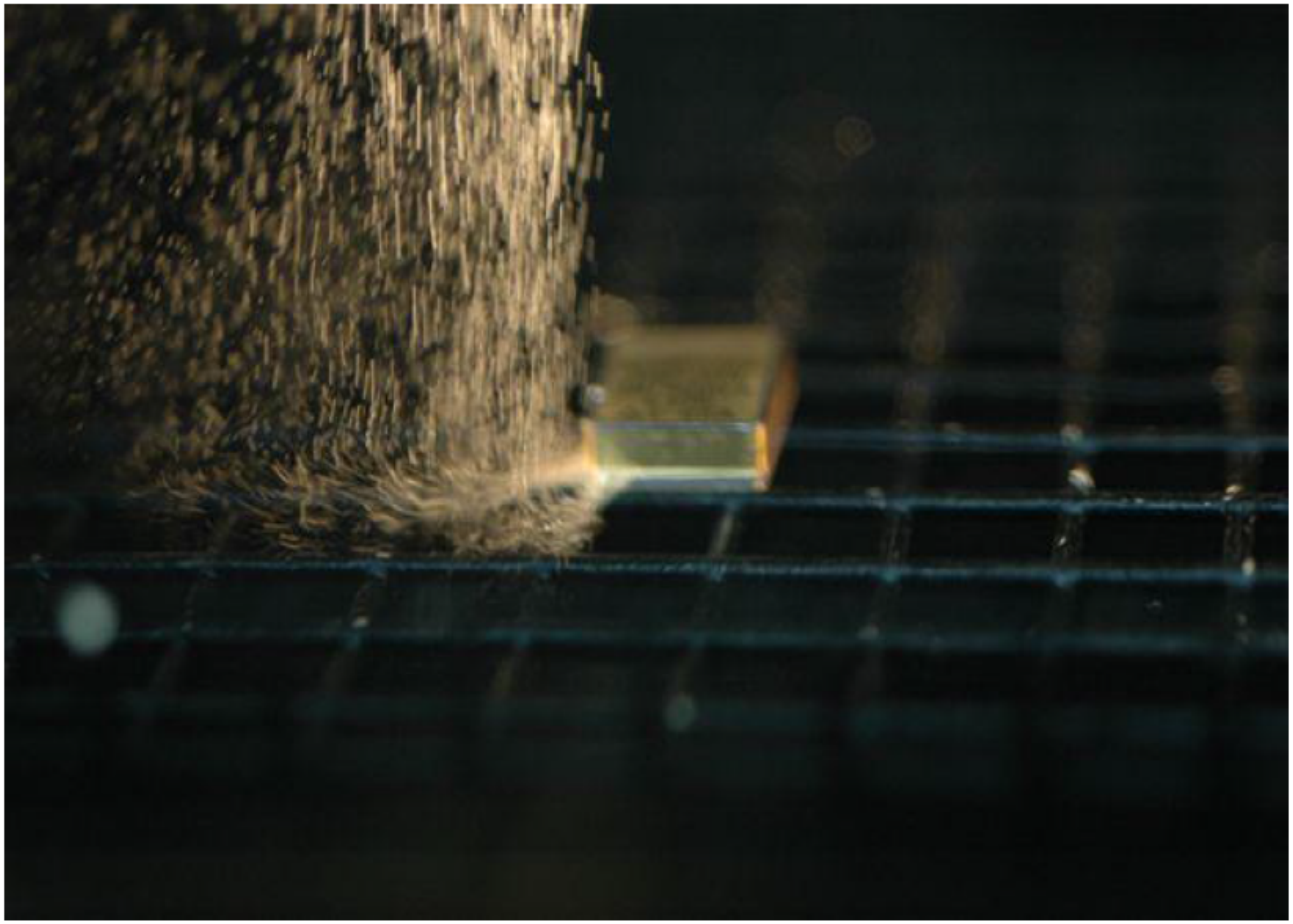
Exomars Low Temperature Evaluation Testing – Diode Finding

One gross leak failure – not critical



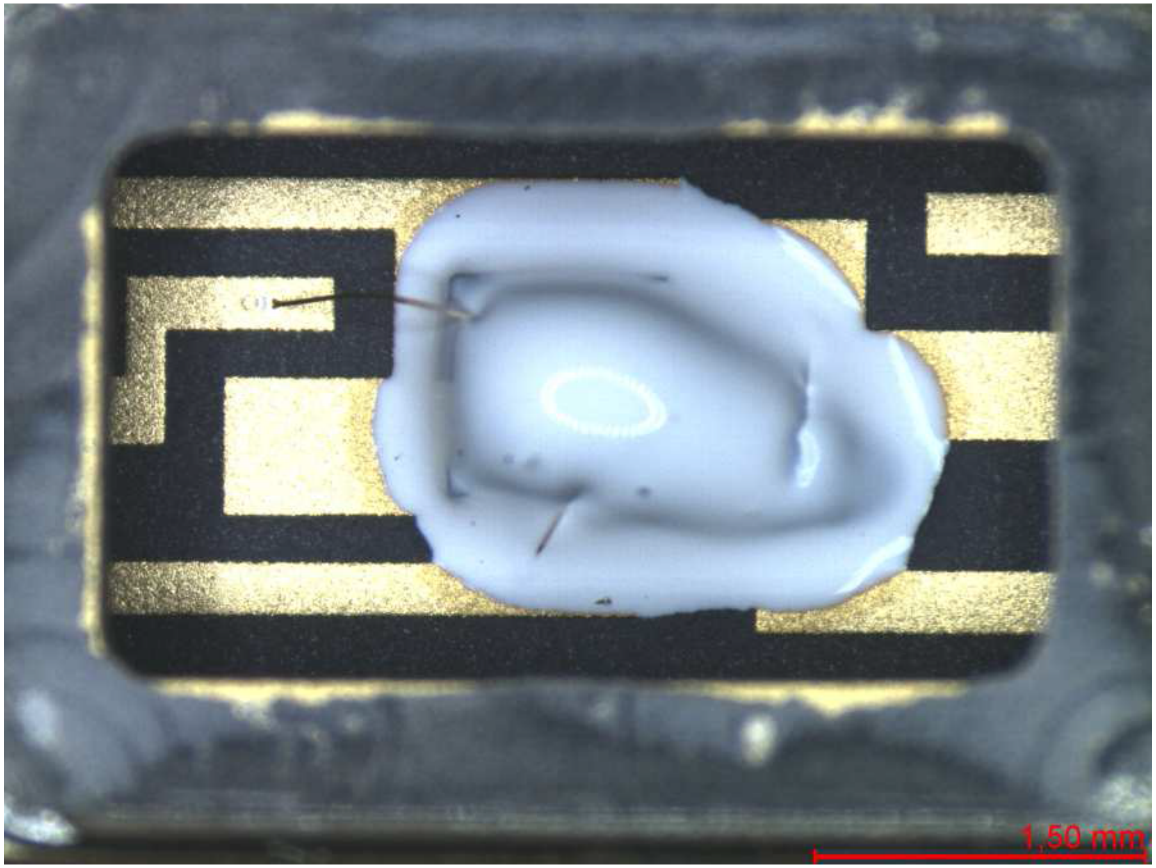
Exomars Low Temperature Evaluation Testing – Transistor Finding

Two gross leak failures – not critical



Exomars Low Temperature Evaluation Testing – Optocoupler Failures

- Optocouplers are typically manufactured with an optical gel covering chips and part of the cavity. This is known to be sensitive to thermal cycling.
- The low temperature evaluation confirmed that these parts are indeed critical. Three out of five part types failed catastrophically and due to similarity in construction none can be recommended.



Exomars Low Temperature Evaluation Testing – Optocoupler Failures

- Failure modes were bond lifts or broken wires.
- Parts with thicker bond wires are more robust, parts with less silicon gel are also expected to be more robust. Glass transition temperature of the gel is about -110°C.