axon'
cable & interconnect

SPACE

Space Passive Component Days
24-26 September 2013

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Development of a high temperature flexible thruster cable

ESA ITT A01 5245 07 NL SFe

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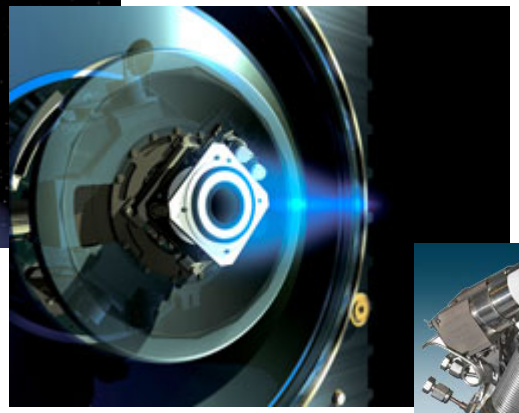
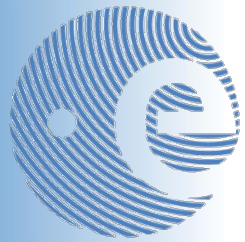
Electric propulsion





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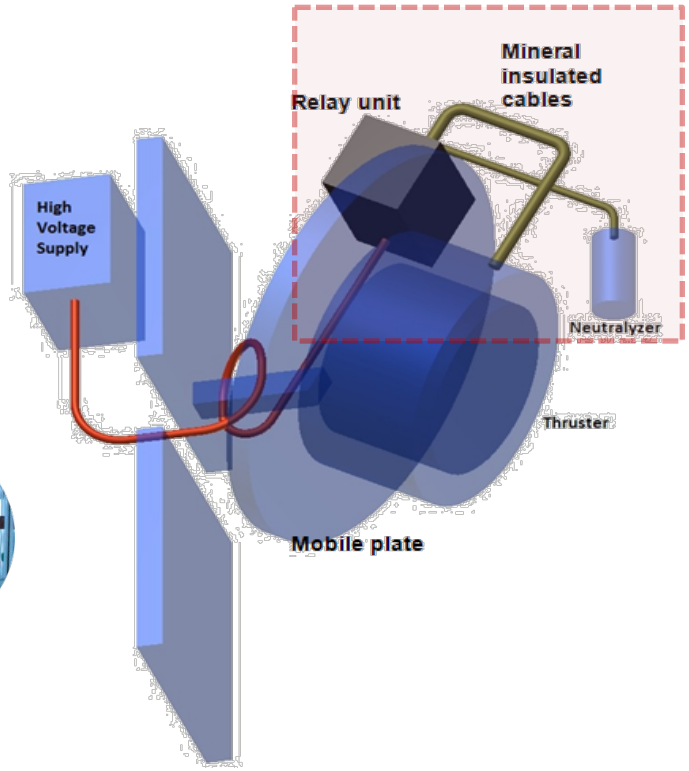
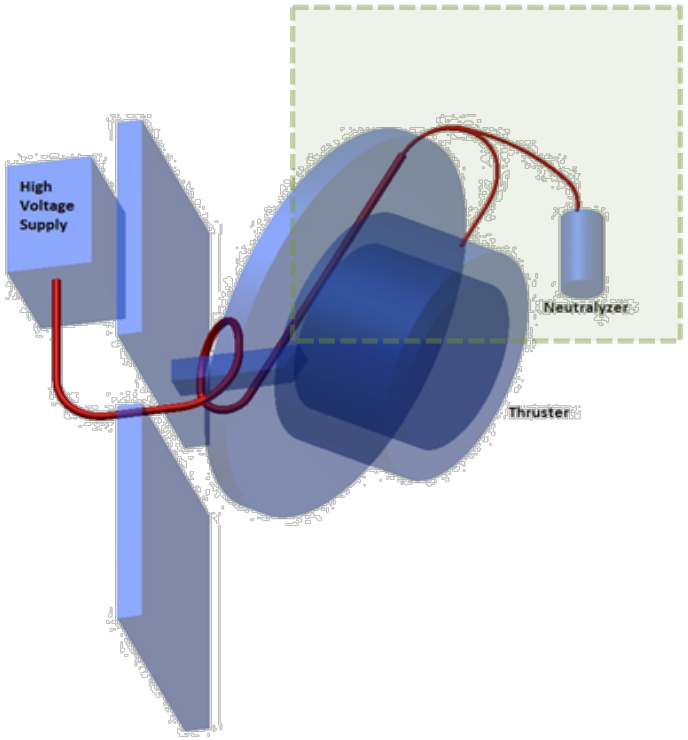
Description of the problematic





Current technology

- Complex & heavy design
- Rigid metallic wiring
- Vibration

Expected technology

- Light design
- Flexible
- Simple

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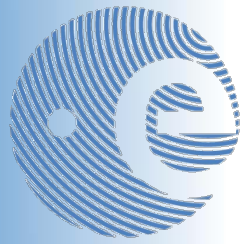
Thrusters technologies

Thruster technologies considered

Thruster	Technology	Nom. Power (W)	Nom. Voltage (V)
FEEP	Field emission electric propulsion	50	10000
T6	Gridded ion thruster	5000	1850
ROS 2000	Hall effect thruster	200	350
HET	Hall effect thruster	5000	550
HT100	Hall effect thruster	150	300
DS HET	Hall effect thruster	5000	550
			100
HEMP-T	Plasma thruster	1500	1000
PPS 1350	Hall effect thruster	2500	350

Design drivers

- ELECTRIC REQUIREMENTS
  - Voltage, amperage
- THERMAL REQUIREMENTS
  - High, low temperatures
- ENVIRONMENTAL REQUIREMENTS
  - Radiation, pressure, UV…
- MECHANICAL REQUIREMENTS
  - Bending radius, torque, angles…
- LIFETIME, CYCLE REQUIREMENTS
  - High amplitude, low amplitude cycles



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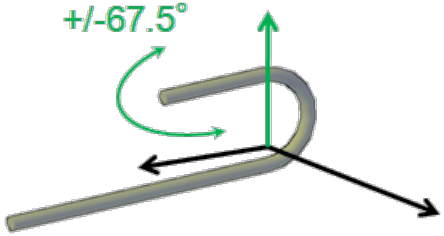
Requirements

Brief summary

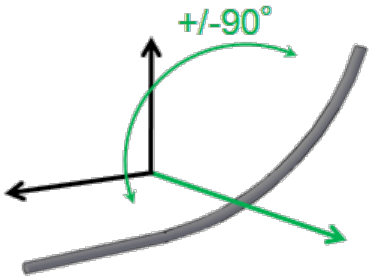
Requirement	Value
Voltage	5 kV DC
Amperage	Up to 30 A
Temperature	From -100°C to up to 280°C
Radiation TID	200 MRad

Dynamic application

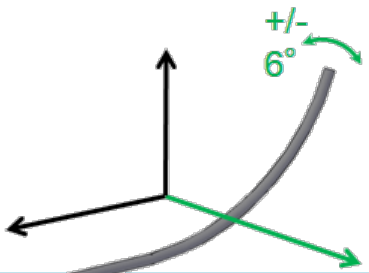
non-operating modus +/-67.5°

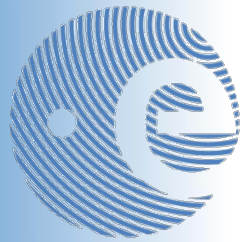


+/- 90°



daily operation +/- 6° range





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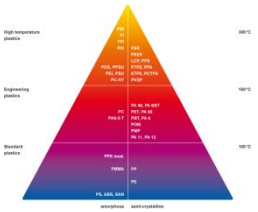
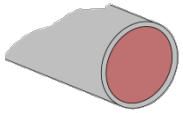
Study approach

Material survey
Technologies survey

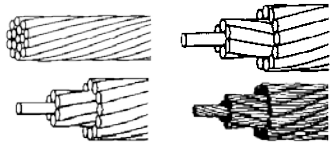


Conductor assessement

-New alloys



-Most adapted construction



Insulation assessment

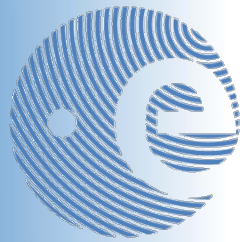
-New engineering polymers

-Aging tests, partial discharges…

Final construction assessment

-Combined aging tests

-Radiation, partial discharges…



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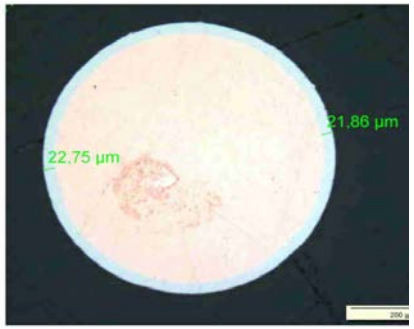
Conductor assessment

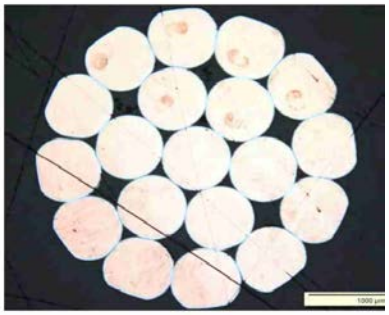
Extensive testing of conductors

- 5 single strands

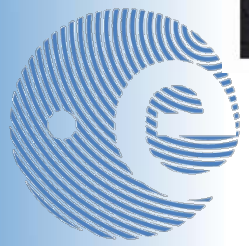


AWG	Material	Plating
2401	Nickel plated copper alloy	27% Ni
2401	Nickel plated copper alloy	10% Ni
2401	Nickel plated copper alloy	7 % Ni
2401	Nickel plated copper	27% NI
2401	Nickel plated copper	1.5% NI

- 4 conductor constructions



AWG	Material	Plating	Construction
19 x 0.511 (24)	NPCA	10% Ni	Unilay
19 x 0.511 (24)	NPCA	10% Ni	Concentric
7 x 7 x 0.320 (28)	NPCA	10% Ni	Ropelay
37 x 0.361 (27)	NPCA	10% Ni	Concentric



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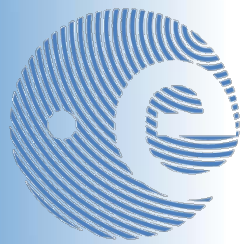
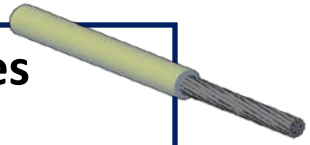
Insulation assessment

Test plan to select the best from 4 selected materials



Test series
Mechanical
Electrical



Thermal ageing tests
- Thermal Shocks
- 280°C Thermal ageing

No voltage

Test series
Mechanical
Electrical

Selection of the appropriate material

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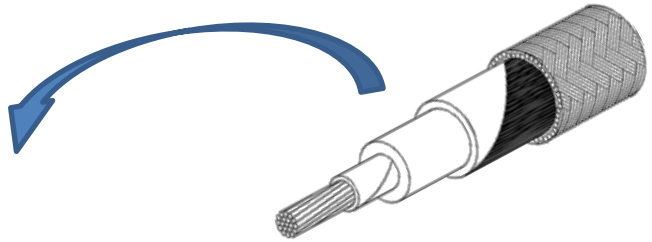
Final construction assessment



Test series

Temperature cycling under 5 kV

200 hours at 280°C Voltage: 5 kV

100 hours at 300°C Voltage: 5 kV

200MRad Radiation test

Tests serie

Test series

Test series

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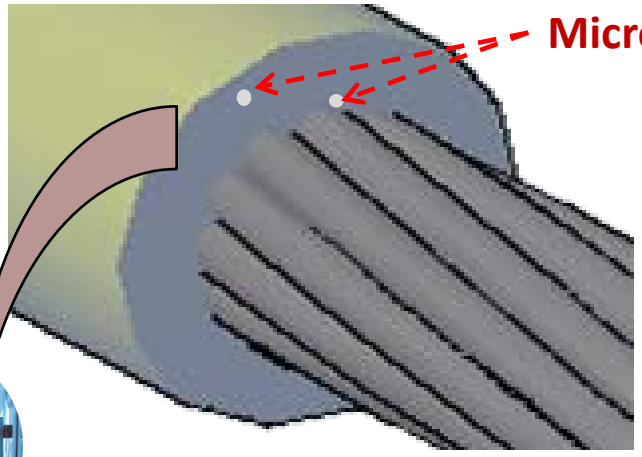
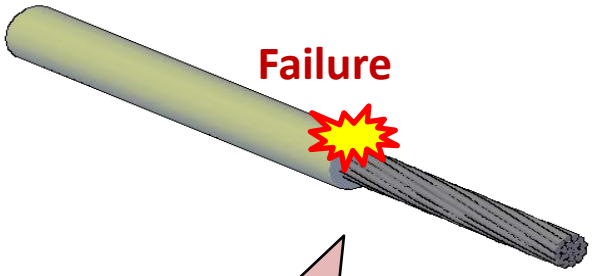
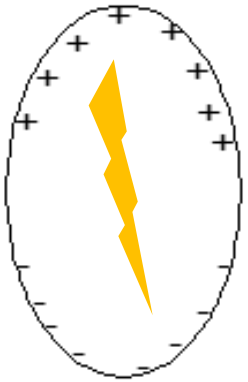
Partial Discharge in cables



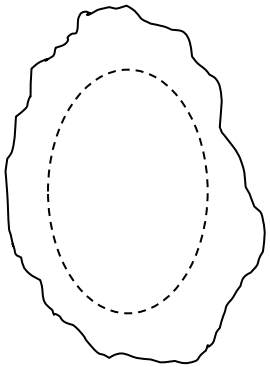
Micro defects



Failure



Cavity after discharge



Cavity after several weeks, months or years…

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Partial Discharge detection

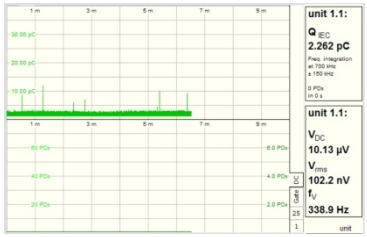
Purpose

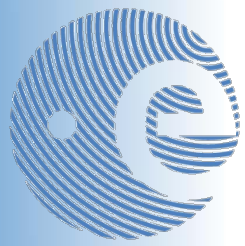
Partial discharge testing is a PREDICTIVE qualitative analysis tool that can warn of a potential UPCOMING system failure.

Specific high voltage equipment

Detection Device

Dedicated software





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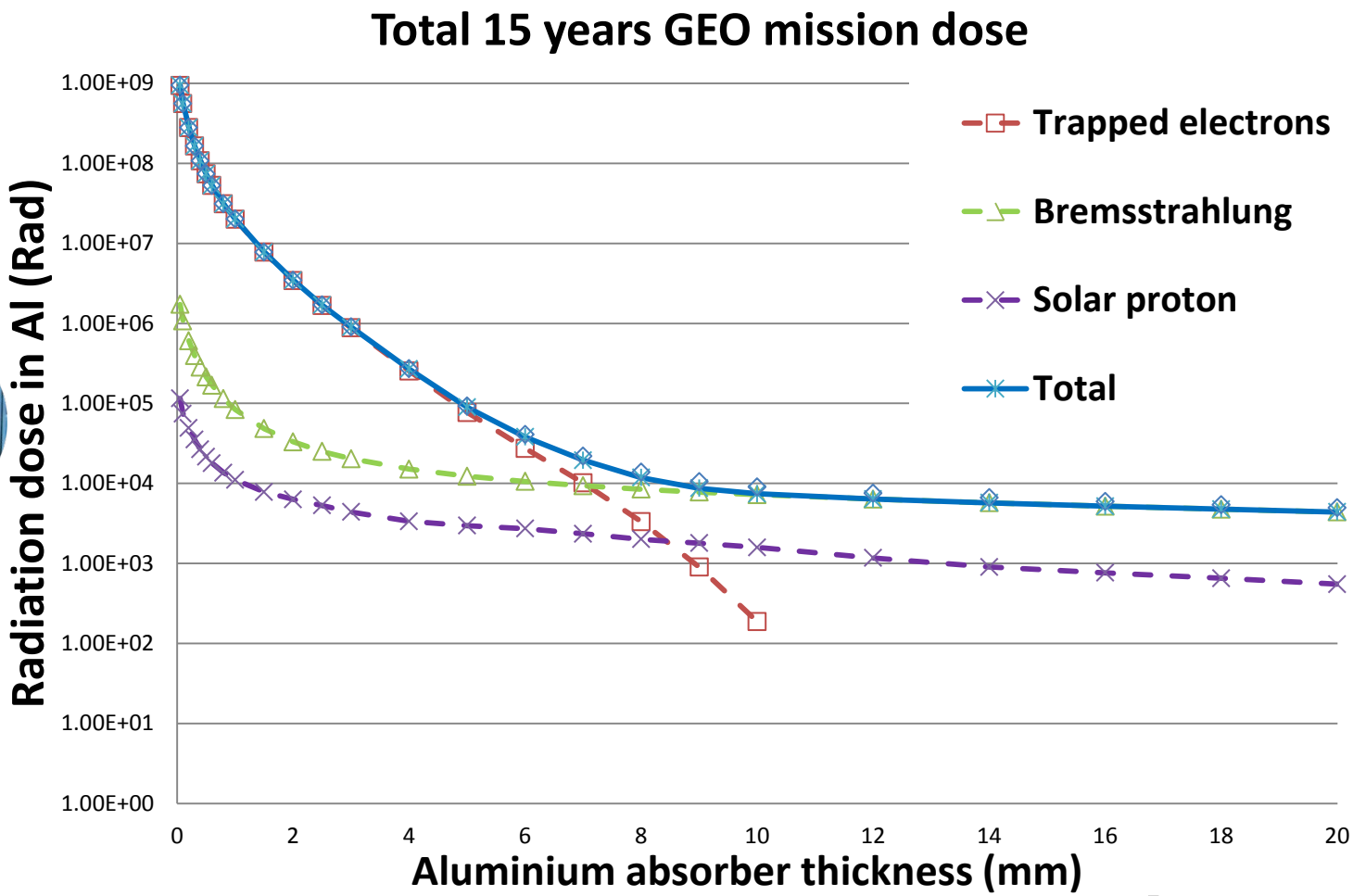
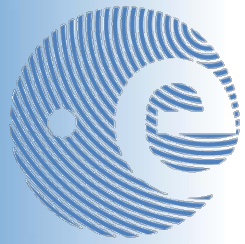
Radiation test profile

High radiation dose application





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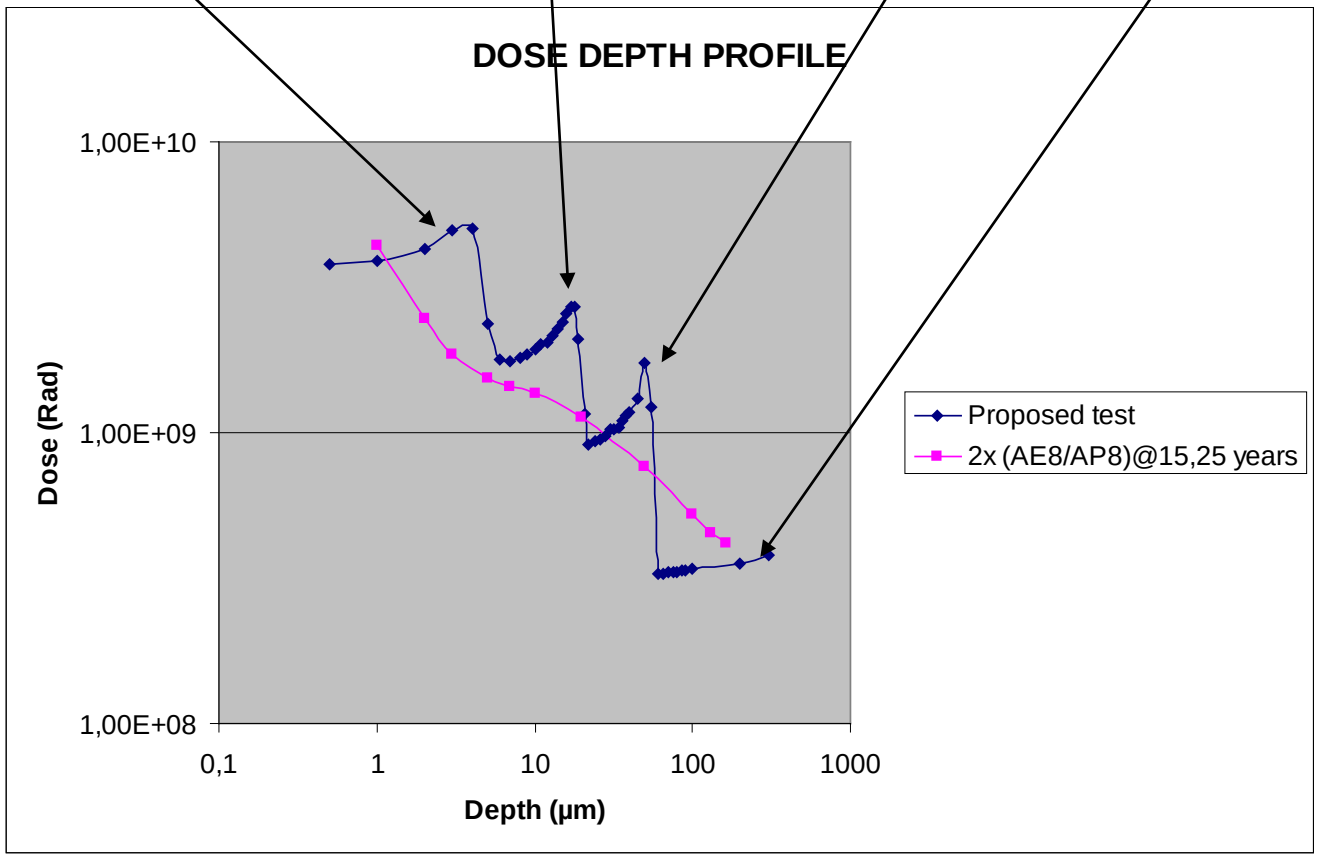
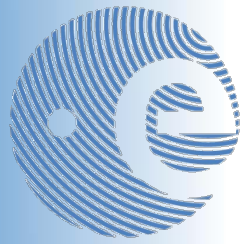
Radiation test profile

200 MRad TID requirement





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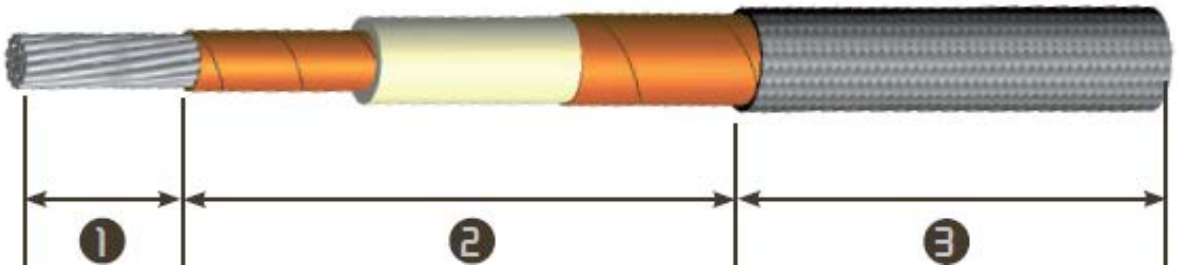
Cable solution



The thruster cable is able to withstand harsh space conditions that characterize electric propulsion environment :

- **High temperature up to 280°C**
- **High voltage up to 5 kV DC**
- **High radiation with TID of 200 Mrad**
- **Mechanical stresses due to thruster motion**

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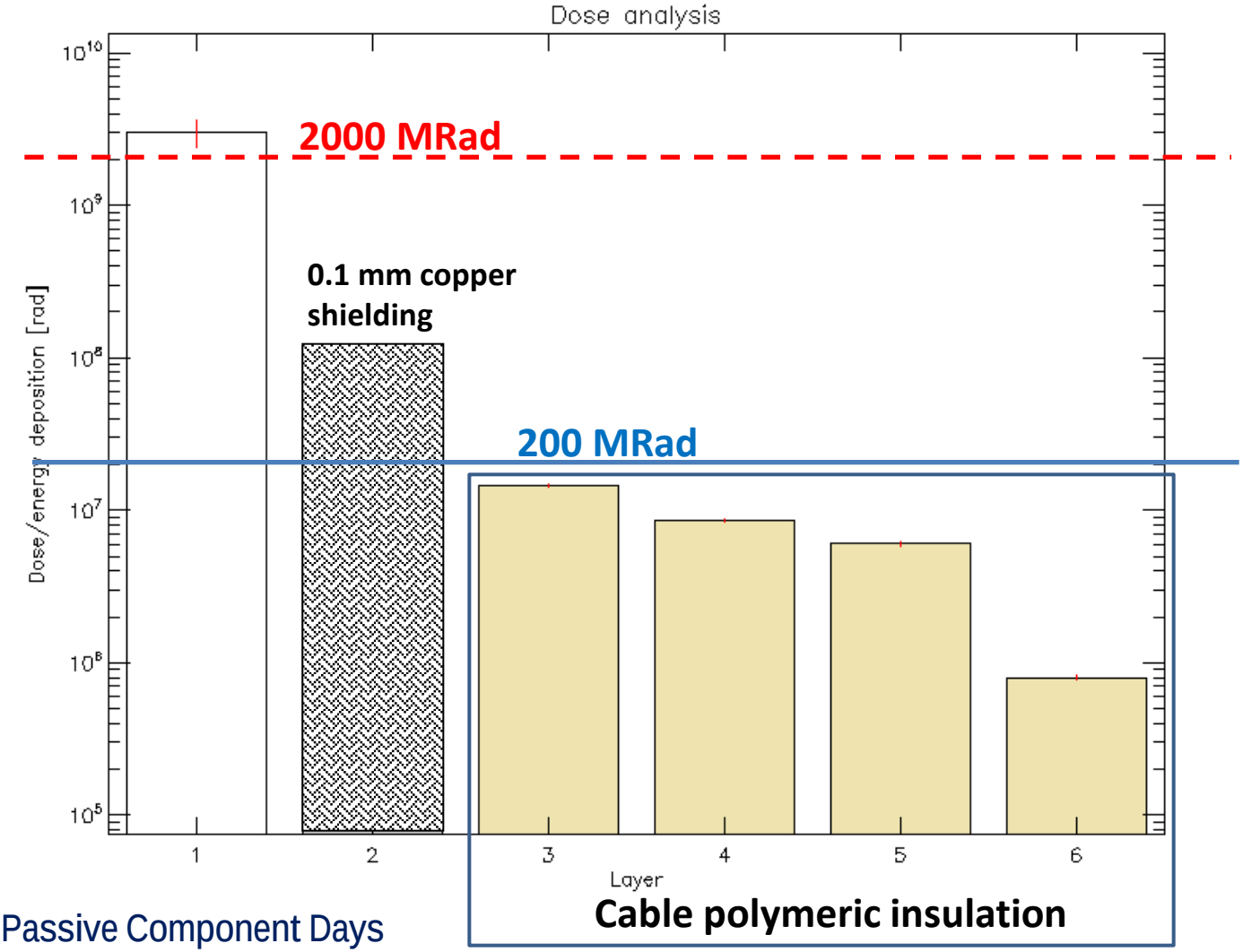
2000 MRad Cable application

Radiation dose with Mulassis



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Development of a new high temperature wires range

ESA ITT A01 683911EM EEE10

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24-26 September 2013

Context

Context

Current ESA qualified rating is up to +200°C.
Application of derating rules reduces significantly maximum amperage.
High engineering materials should allow operating temperature up to 250°C!

Objectives

- **QUALIFY** a new wire **family** for continuous use at high temperature – up to 250°C.
- **DEFINE** the appropriate derating rules

Benefits

- **Significant Reduction** of weight and size of the harnesses.

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Evaluation axis

- Processability
- Definition of appropriate materials
- Evaluation tests campaign
  - Accelerated testing – SSALT&ALT
  - Amperage characterization
  - Harness configuration characterization

- Qualification tests campaign

→ New ESCC 3901 wire family

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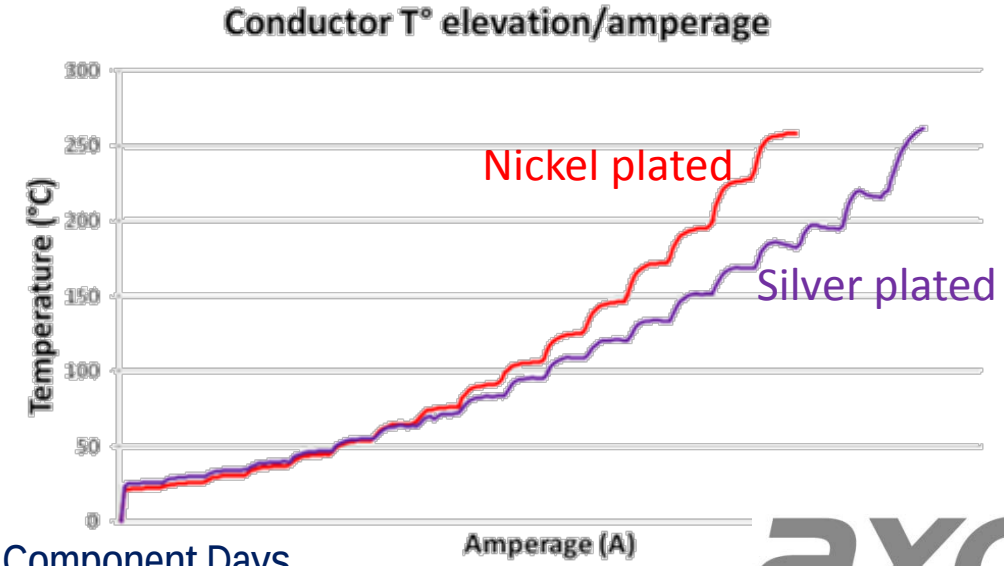
Amperage rating

	SILVER plated conductor	Conductivity (%IACS)	Conductivity (%IACS)	NICKEL plated Conductor
Copper Alloy	AWG 3007	92	83	AWG 3007
	AWG 2419	92	86	AWG 2419
Copper	AWG2219	101	94	AWG2219
	AWG1237	101	94	AWG1237



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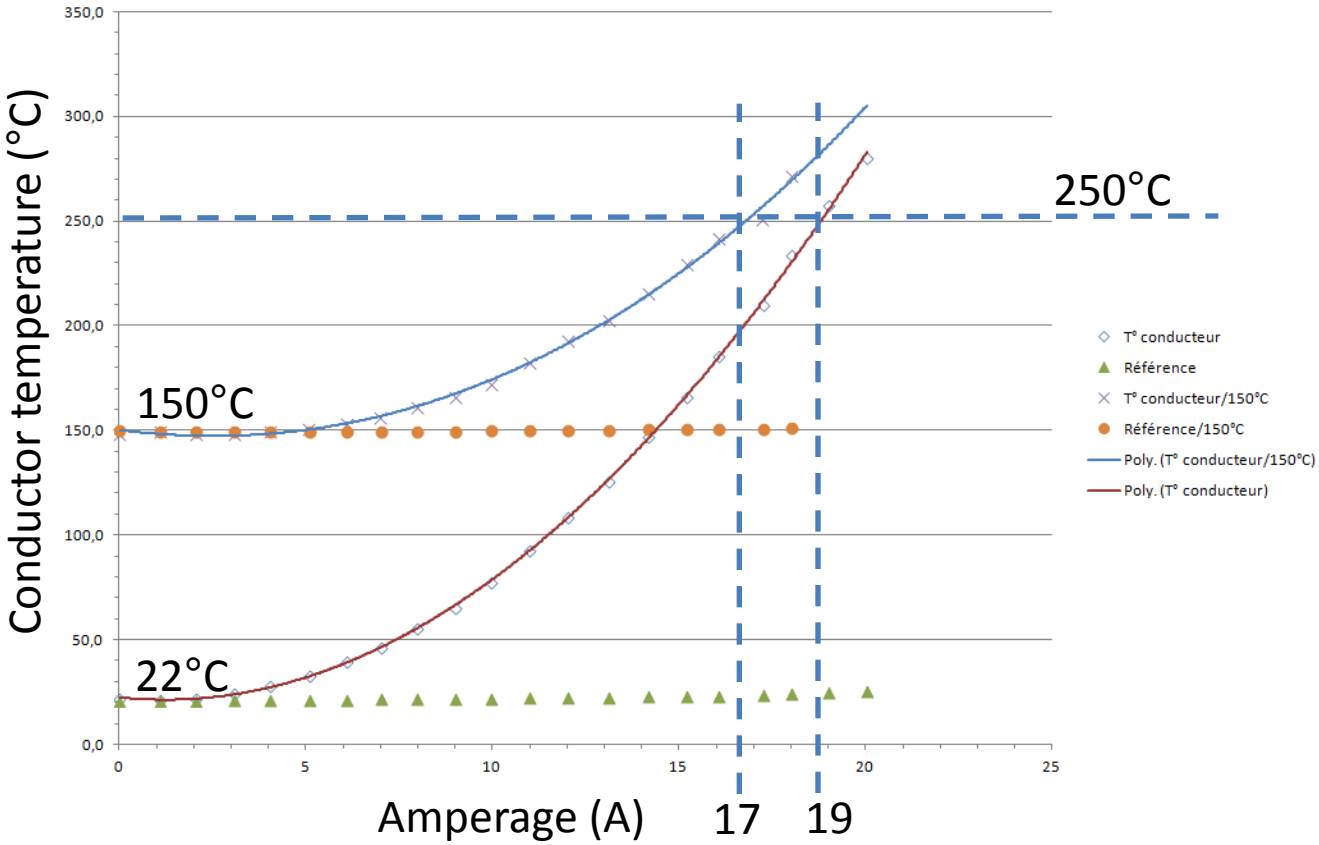
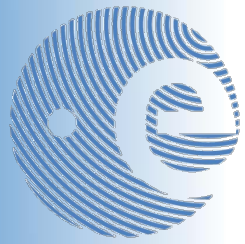
Amperage rating

Temperature rise at ambient temp. and at 150°C





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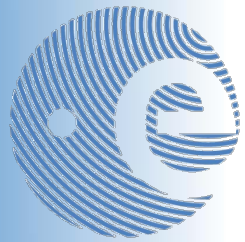
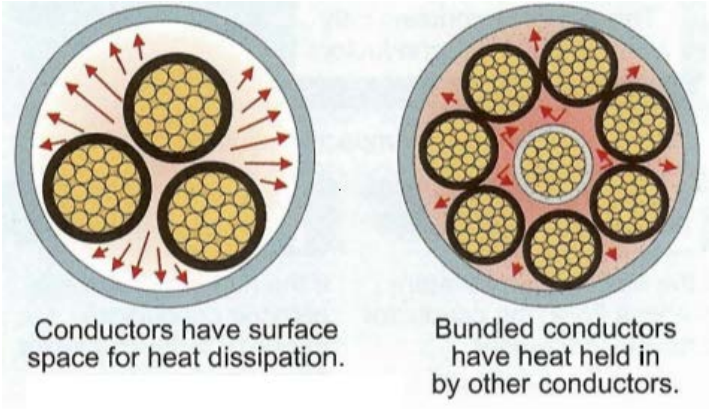
Harness configuration

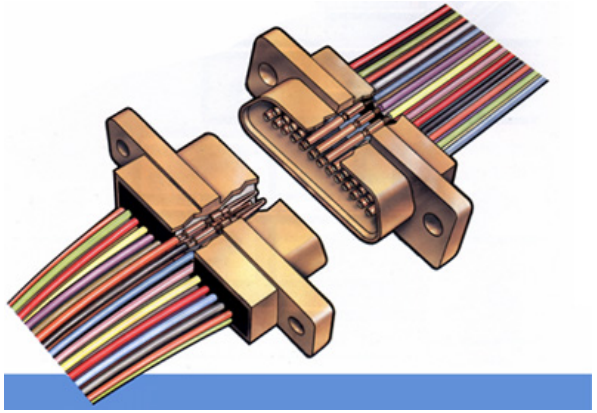
Requirement related to harness configuration



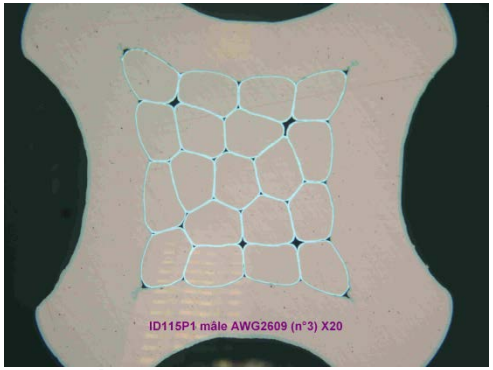
Bundle configuration



Contact surface resistance



Crimping behavior



Harness behavior

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Global chart of the test plan

Preliminary tests	Preliminary test series	
Mechanical and electrical test series	Test series	
Ageing tests – SSALT & ALT	Step Stress Accelerated ageing tests	Long term ageing test
Temperature elevation under high intensity tests in normal atmosphère environnement		
Tests to define the derating rules for single wire,a ssemblies and bundles		
High intensity tests on the assemblies and harness configuration (bundles, high temperature sub-d connectors)		

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For any information please contact

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THANK YOU FOR YOUR ATTENTION