

Electric Propulsion Cables for milli-Newton Thrusters



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CABLE & INTERCONNECT

Axon's Electrical interconnection solutions across a satellite

Communications Module

One to three floors

Propulsion

Chemical only or
Chemical + Electric (Plasma)

Several CPS tank capacities

Solar array

3 to 5 panels per wing
2 panel sizes

Scalable power supply

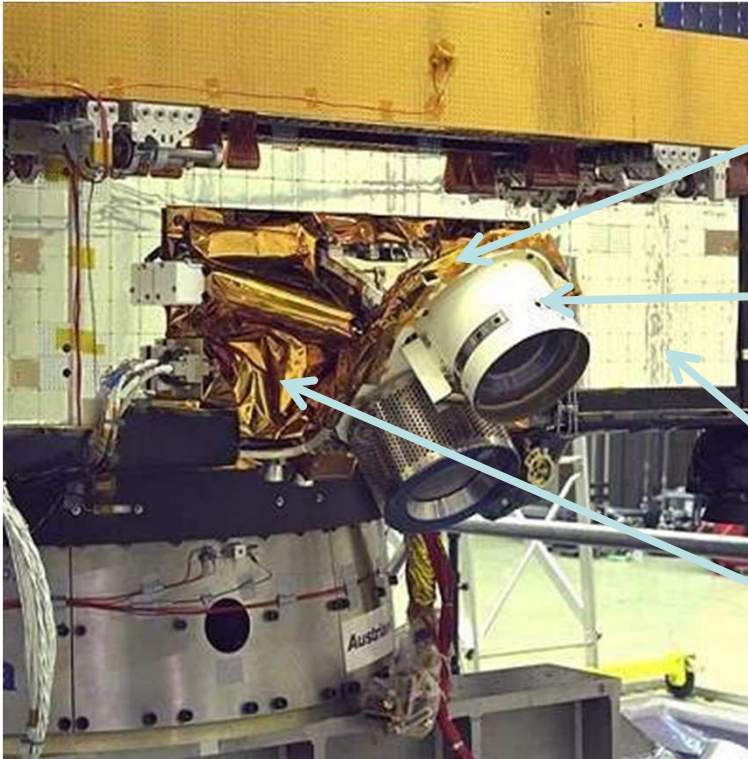
Modular PSR concept
Range of 9 to 26 power
modules

Batteries

Li-Ion cells

9/5/2011

Initial Situation



Mobile plate

Ion thrusters (x2)

Satellite structure

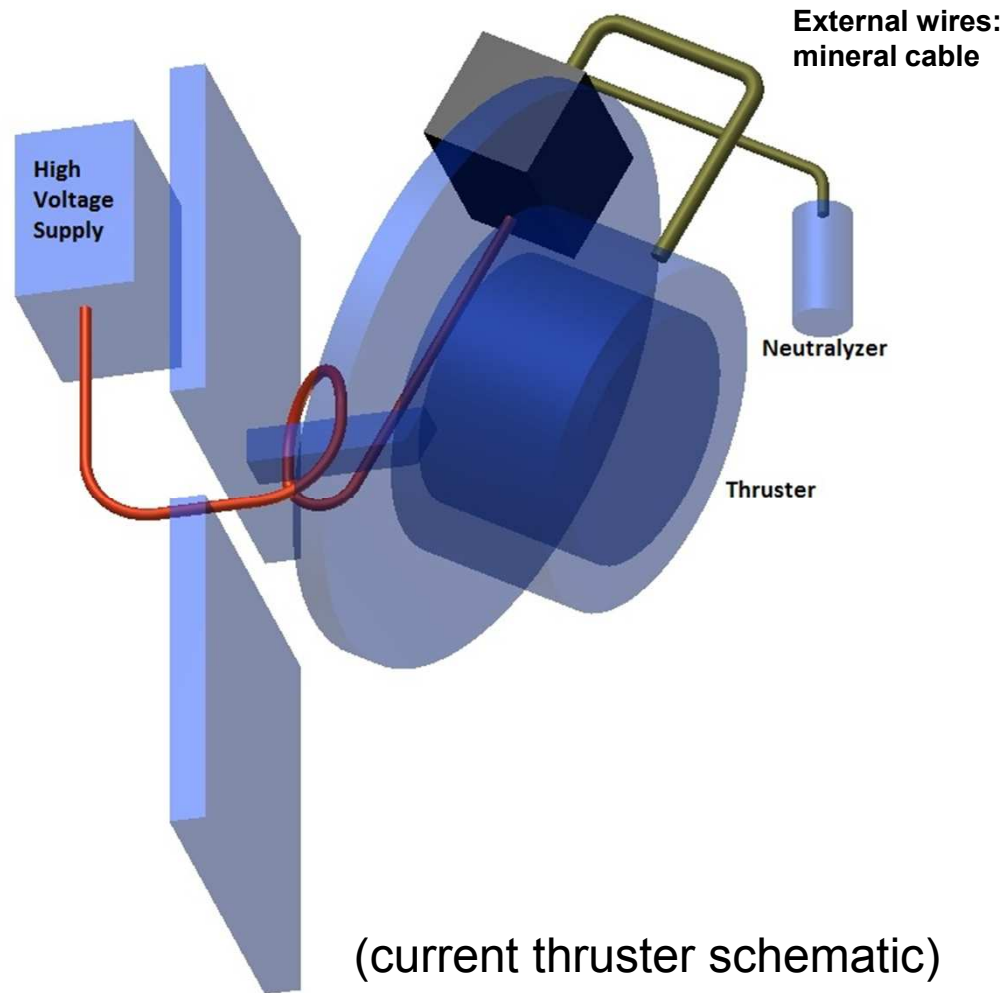
Multi-layer insulation

- Thrusters are mounted outside satellite, exposed to
 - Extreme temperatures (high and low)
 - Vacuum (no convective cooling)
 - Ionizing radiation
 - High energetic particles (heavy ions, protons)

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Initial Situation (cont.)



Actual technology

- not suitable for future missions in temperature requirement
- the Relay Box create vibrations.
- Mineral rigid type cable (heavy too).
- not enough performant.

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Requirement Specification

Electric Requirements

max. continuous operating voltage (derating included)	5kV
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max. operating current	12A
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conductor gauges	AWG 16 - AWG 4
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immunisation	against ESD
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Requirement Specification

Temperature requirements

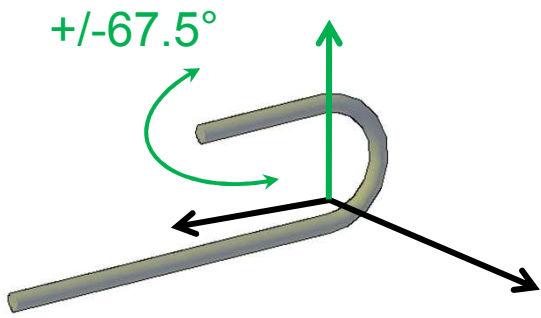
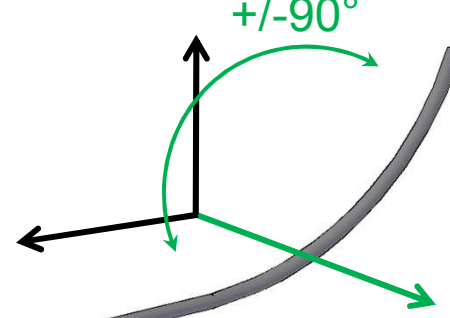
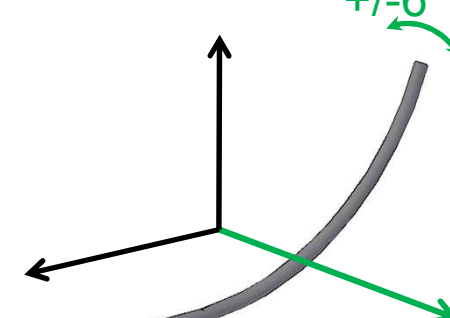
		Static application	Dynamic application
Operating temperature	min °C	-50	-20
	max °C	280	120
Non operating temperature	min °C	-100	-50
	max °C	200	120

Radiation levels

The cable shall be designed to withstand a radiation level of 200MRad.

Requirement Specification

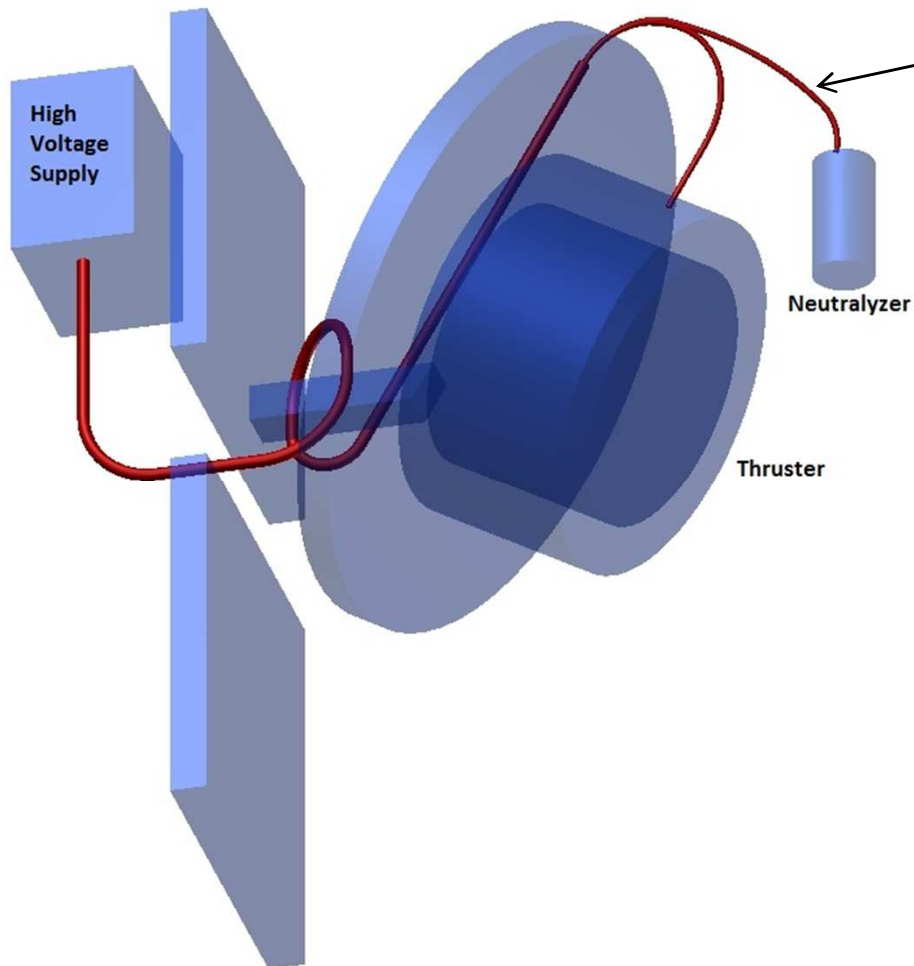
Geometrical Requirements

non-operating modus		daily operation
$\pm 67.5^\circ$ on a first axis	$\pm 90^\circ$ on a second axis	Max $\pm 45^\circ$ within an overall $\pm 6^\circ$ range
		
<p>Linear displacement of the cable, due to rotation movement : 40mm.</p>		
<p>Minimum bending radius shall be a ratio of 5 between bend radius and cable diameter.</p>		

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Proposed technology



flexible, one
piece solution

Advantages included

- environmentally improved
- Weight gain
- Less vibrations
- Simplified integration

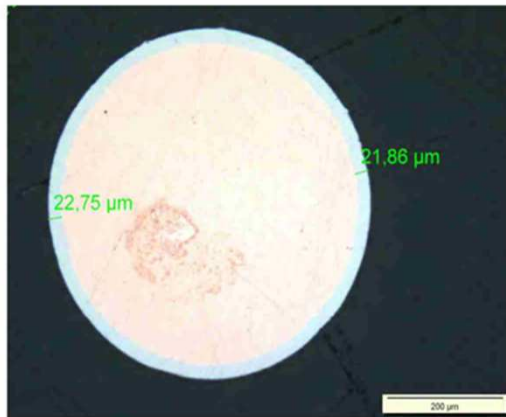
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Potential solutions

1. CONDUCTOR



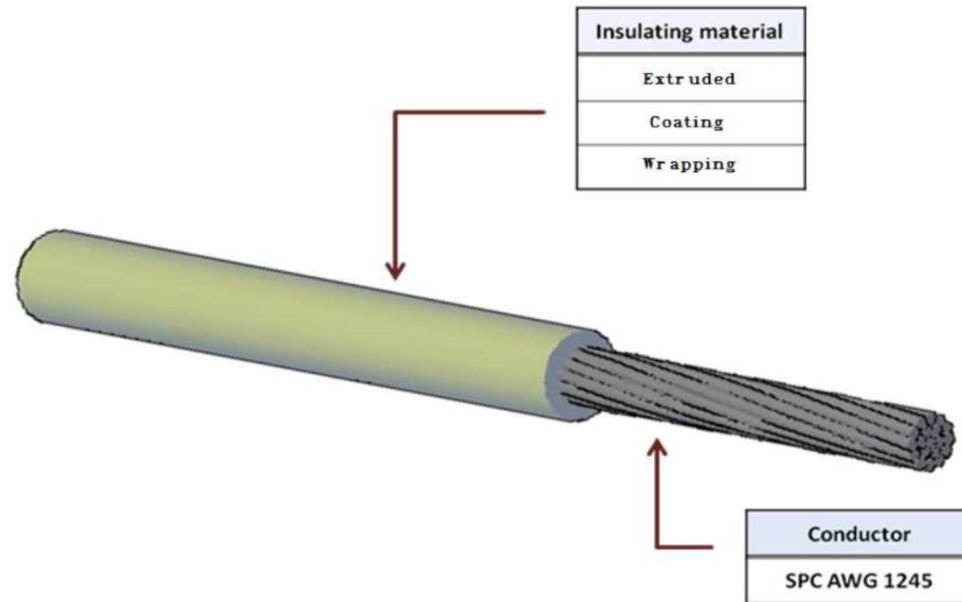
- Selected conductor
 - 19x0.511 Unilay

- Specific alloy
- Specific construction
- Specific coating
- **Results statement**
 - ✓ Good mechanical stability when exposed to very high temperature (short exposition)
 - ✓ Good mechanical and electrical stability when exposed for long time to high temperature
 - ✓ Design suitable for High voltage application
 - ✓ Good flex life



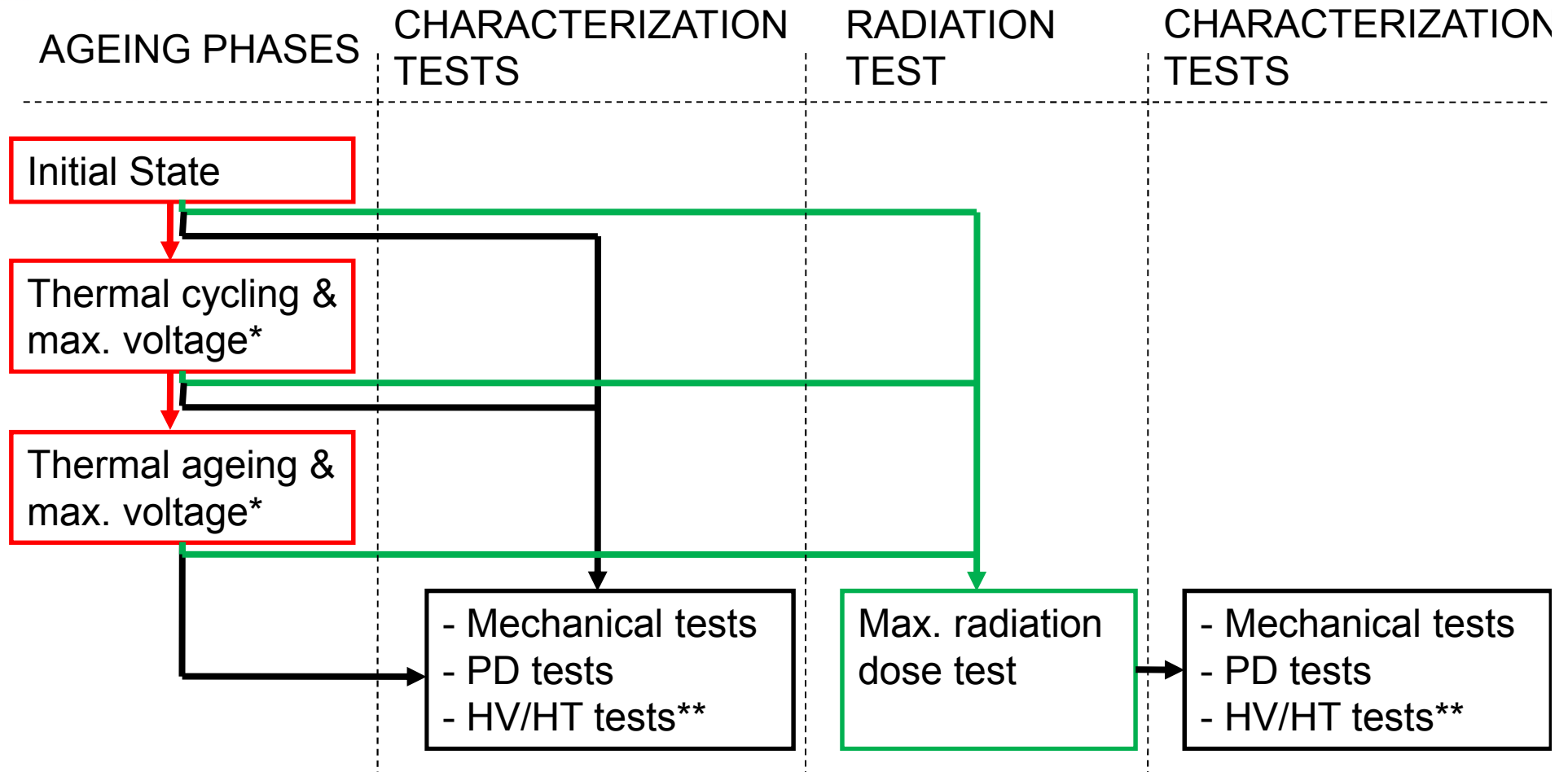
Potential solutions

2. INSULATION



Many special tests have been performed during evaluation

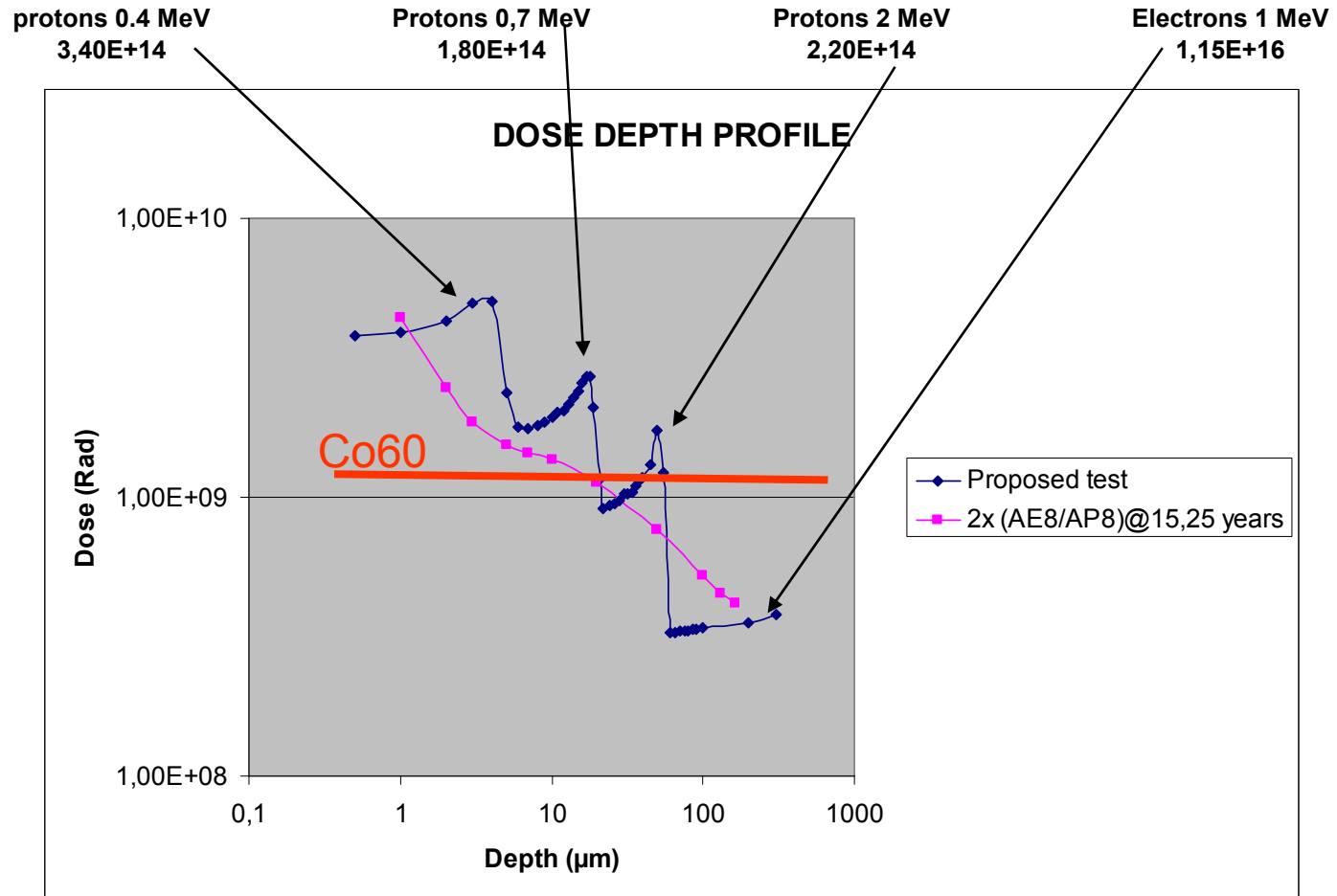
Critical test plan



* Ageing phases were combined to high voltage.

** HV/HT tests: high voltage breakdown at high temperature.

Radiation dose profile

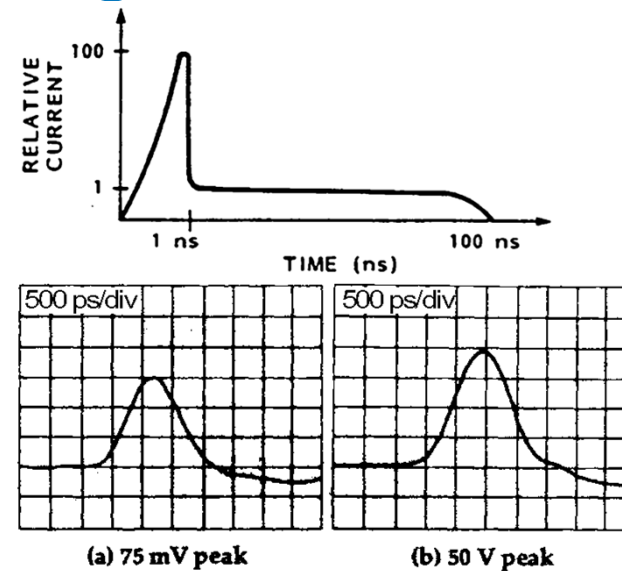
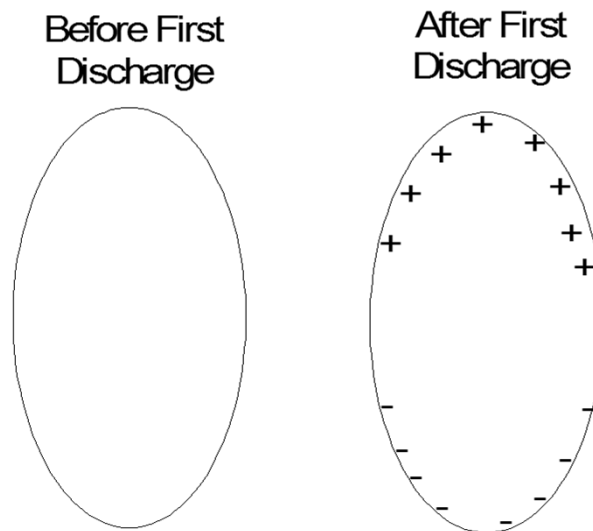


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What is a partial discharge ?

- **A gas discharge which does not bridge the system electrodes**
 - Discharge in a cavity
 - Corona off an electrode
 - Tracking discharge along an interface
- **Cavity before and after discharge**



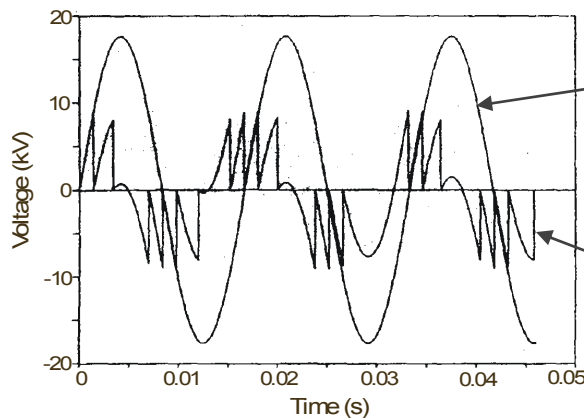
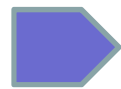
PD testing

- **Partial discharge testing can detect:**

- Insulation defects that may have occurred during cable system installation or the manufacturing process
- Insulation deterioration due to normal service operating conditions

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

Typical Discharge Pattern



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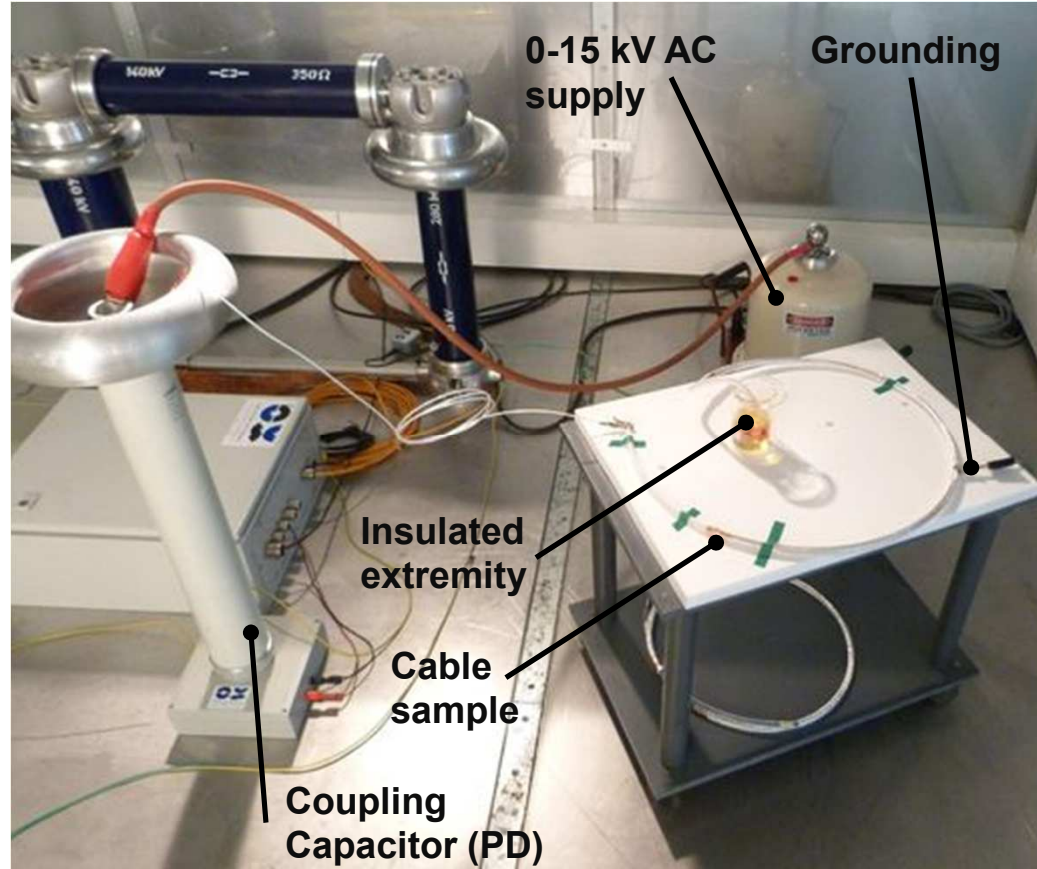
PD & HV testing equipment



High Voltage AC/DC generator



Partial discharge detection & measurement system



Example of a cable sample partial discharge testing set up.



partial discharge displaying



955/200/03/2011

Selection of insulation

Complete evaluation with different ultra polymers :

- **PTFE (PolyTetraFluorEthylen) and family range (PFA, MFA, FEP..)**
- **PEEK (PolyEtherEtherKetone) and family range (PEK , PEKK, ...)**
- **PI (PolyImide) family range (PI , TPI , PBI ..)**

Selection of insulation summary

- **Only one material and one reference** fulfill the requested combined criteria's :
 - Temperature range : -100 °C / 280°C
 - Operating voltage of 5KVDC
 - Radiation resistance : 200Mrads
 - Dynamic application (as shown before)

Potential solutions

3. SPECIFIC SEMICONDUCTIVE LAYER



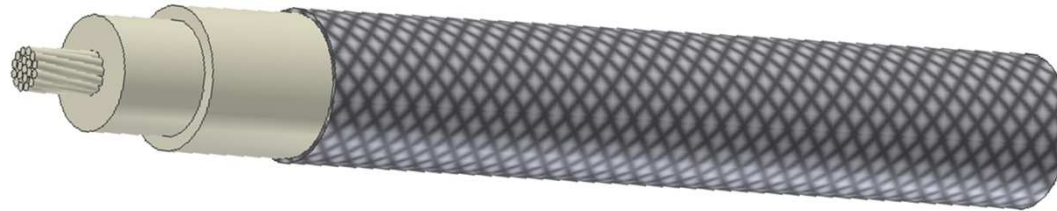
- ESD protection by evacuation of the discharges
- thermal protection screen
- helps to prevent against radiation as well (...to some extent)

The evaluation is done with an equivalent tape than the „original“ one due to ITAR reasons and the reason that there will be a CNES & ESA evaluation on an european carbon nanotube tape starting in Sept. 2011.



Potential solutions

4. SHIELDING



Test criteria of shielding

<i>subject</i>	<i>result / conclusion</i>
material selected	same alloy as for conductor
test targets for construction	flexibility performance of cable almost not to be reduced
make of shielding	braid with coverage >90%
	different conductor sizes have been tested
results	ageing & radiation tests showed acceptable results with evaluated braid



Final status

The target of this study as presented was to develop & validate the use of this product for space.

This had been shown through all tests done during the project.

Now, the product is available on request.

Points of contact

- www.axon-cable.com
- m.jakob@axon-cable.de

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