JOHNS HOPKINS
APPLIED PHYSICS LABORATORY

Radiation Shielding Qualification of PTFE Cable Insulation Exposed to Extreme Thermal and Radiation Environments

Authors: Ryan Tillman, Sarah Katz

Ryan Tillman
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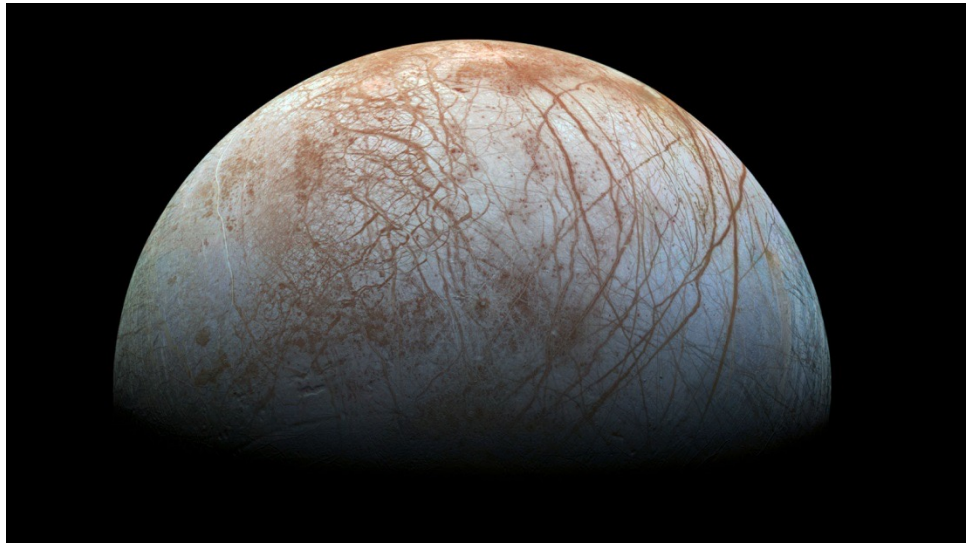
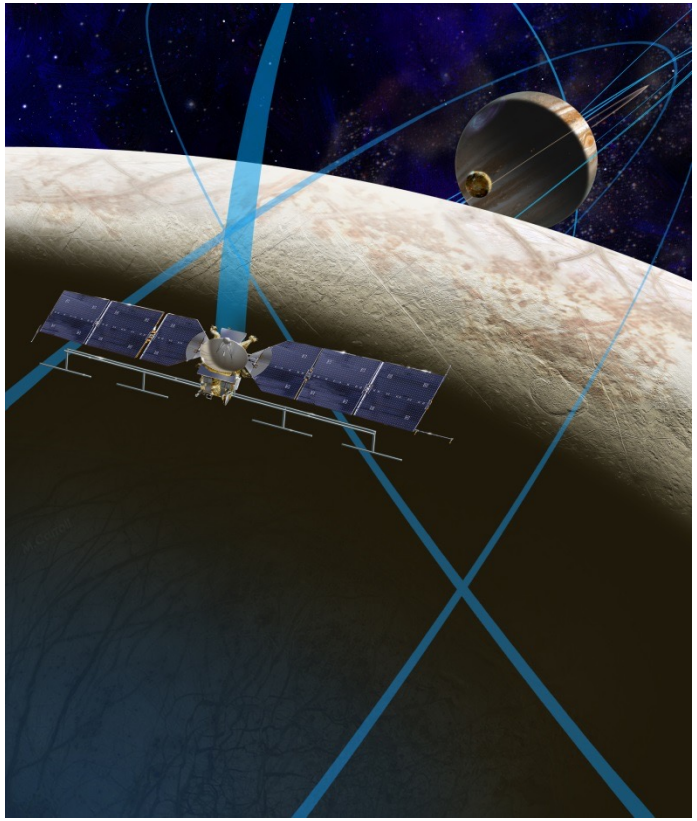
NASA Europa Clipper Project

- NASA planned mission to Jupiter's moon Europa will perform scientific investigation to understand Europa's potential to harbor life
- Mission duration
  - 45 flybys around Europa
- Jovian environment
  - High radiation levels on the order of GigaRads
  - Extreme thermal range -200 C to +200 C (in cases)



Credits: NASA/JPL-Caltech/SETI Institute



Credits: NASA/JPL-Caltech

Radiation Tolerance of Insulation Materials

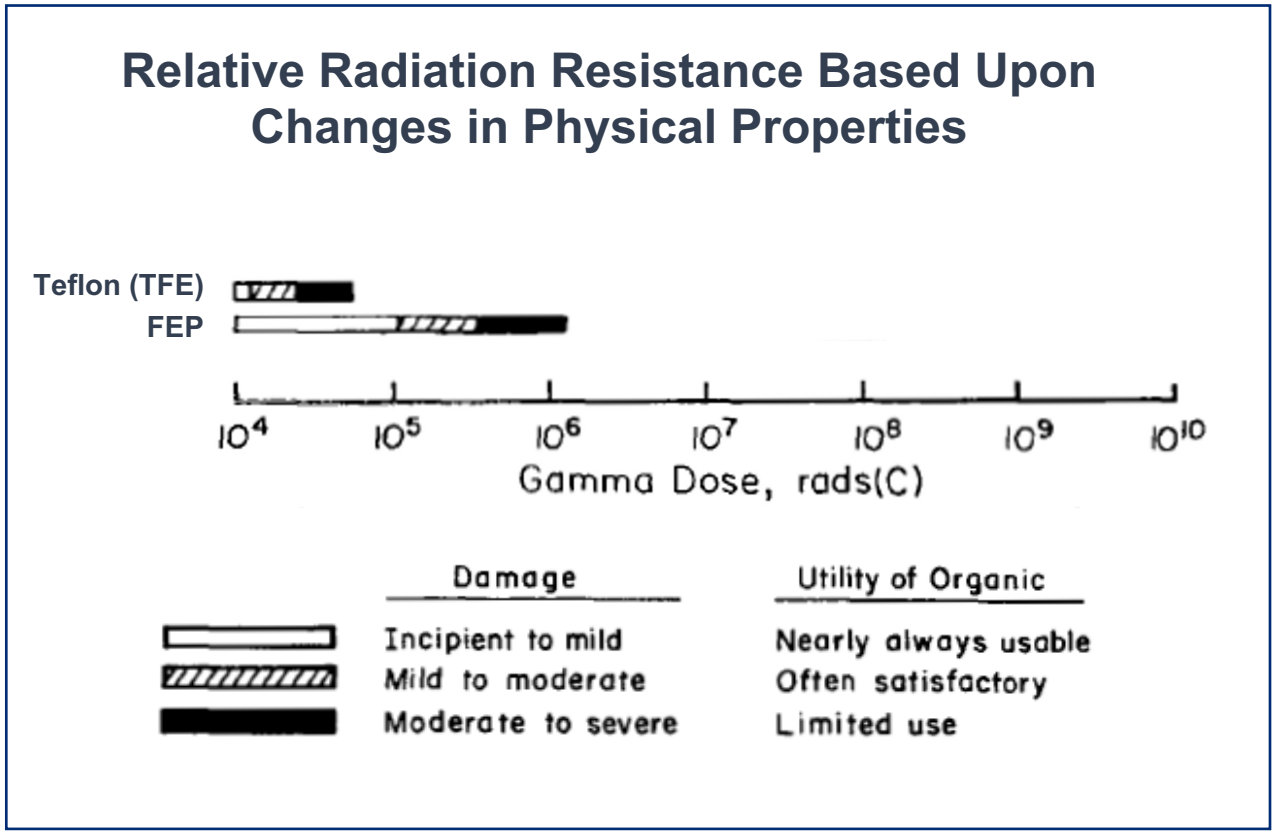


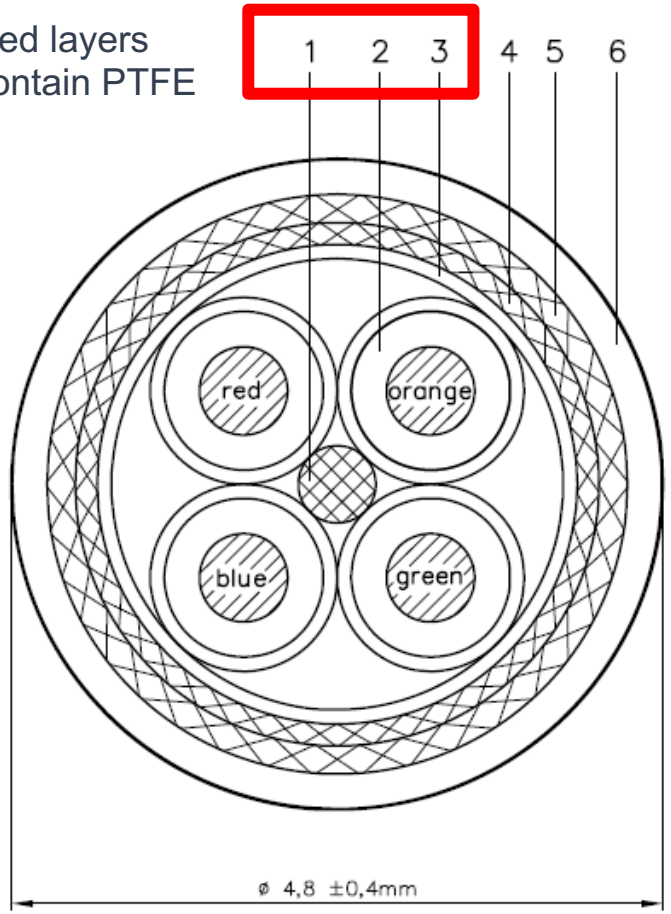
Table Image Modified from the Radiation Effects Design Handbook Section 3, page 9. NASA CR-1787

- Polytetrafluoroethylene (PTFE, Teflon) has a limiting total ionizing dose (TID) of 100 kRad!
- Clipper hardware under MLI blankets will be seeing ~40 Mrad RDF = 2
  - RDF = Radiation Design Factor
- Need PTFE wire/cable to survive and meet performance requirements to the Clipper radiation TID and thermal environment with appropriate shielding wrap

PTFE Wire/cable Products Tested

Gore 100 Ohm Double Shielded Quad Cable GSC-05-84513-00

Red layers contain PTFE



inner conductors per Gore GSC-05-81305

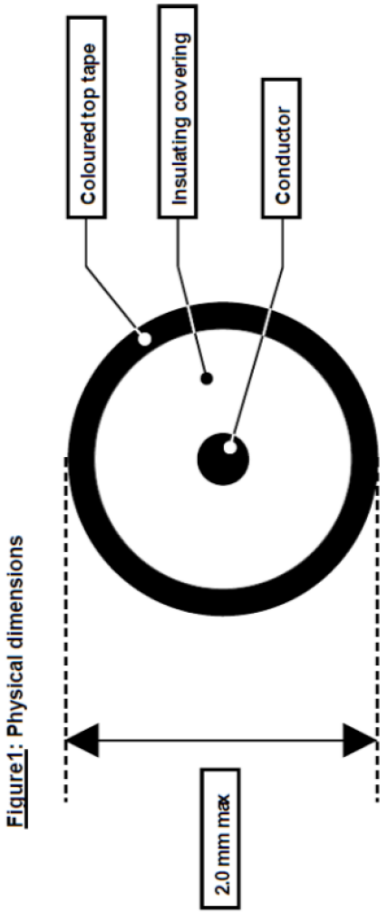
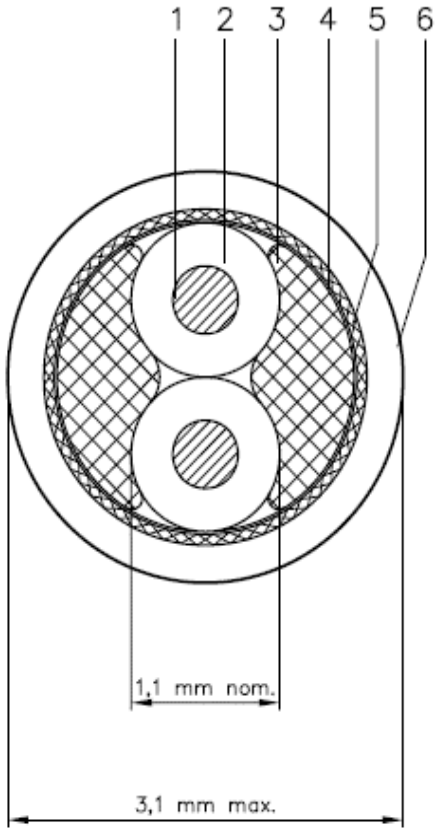
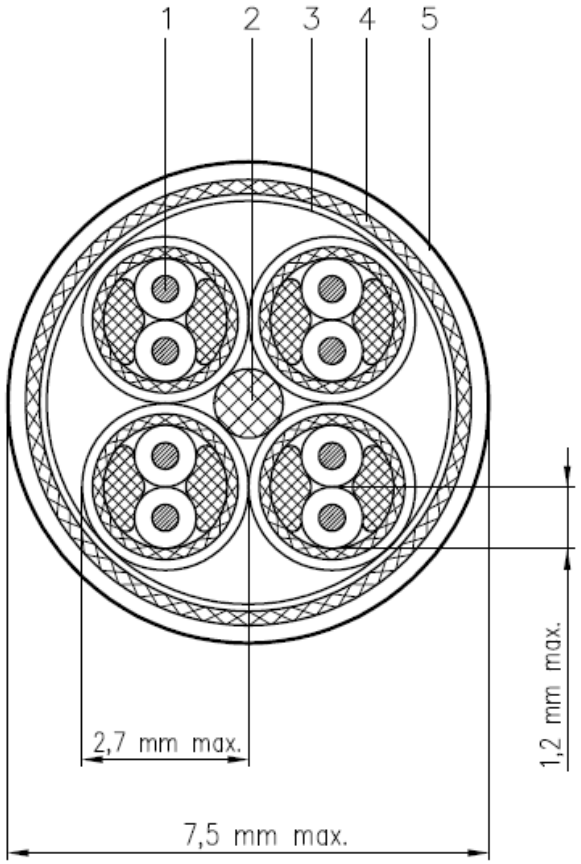


Figure1: Physical dimensions

GSC-05-81973 balanced shielded line



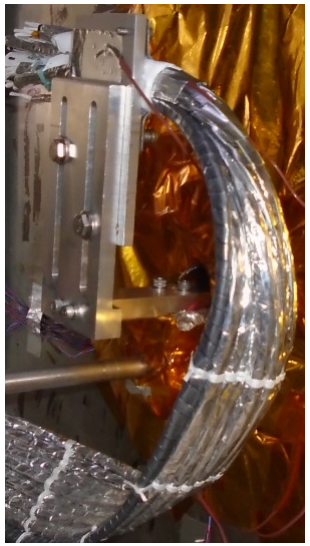
GSC-05-81757 Space wire cable



Shielding Options

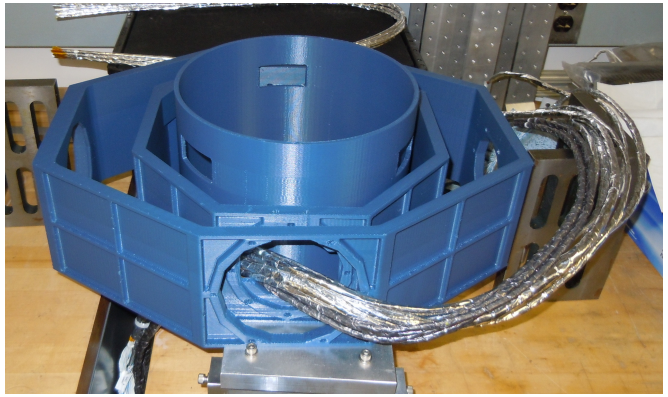
3M 1181

- 1.4 mil copper
- 9 g/cc
- Electrically conductive acrylic



Nuclead lead tape

- 5 mil lead
- 11 g/cc
- Electrically conductive PSA



Neptape 1526

- Vapor deposited aluminum on polyimide
- 9 g/cc
- No adhesive

CCJ Parker Chomerics tape

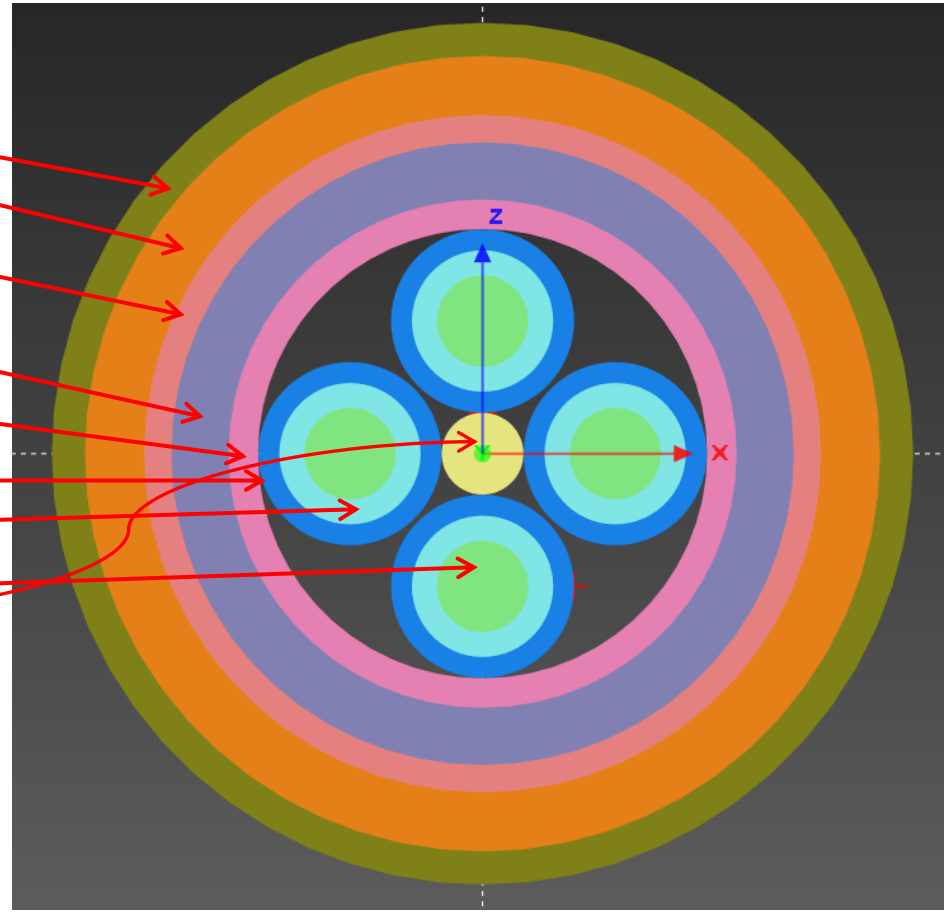
- 2 mil aluminum
- 2 g/cc
- Electrically conductive acrylic

Cable Radiation Modelling Method

- Detectors were placed 0.0005 mm in from the surface and directly in center of the material
- Novice code with external environment

Gore 100 Ohm Double Shielded Quad Cable GSC-05-84513-00

1.) MLI – 7.3 mils AL (2.7 g/cm3)
2.) Leadtape – 6.5 mils Lead (x 2 for double wrapping) (11.35 g/cm3)
3.) Tefzel jacket – 6 mils (1.7 g/cm3)
4.) Silver Copper Braids – 6.28 mil (x2) modeled as Copper 8.96 g/cm3)
5.) Binder – 6.5mil (0.5 g/cm3)
6.) Wires:
Outside Insulator – 4.6 mil (2.16 g/cm3)
Inside Insulator – 5.5mils (0.5 g/cm3)
Copper Conductor – 20.1mils (8.96 g/cm3)
7.) Filler – 18mils (2.16 g/cm3)

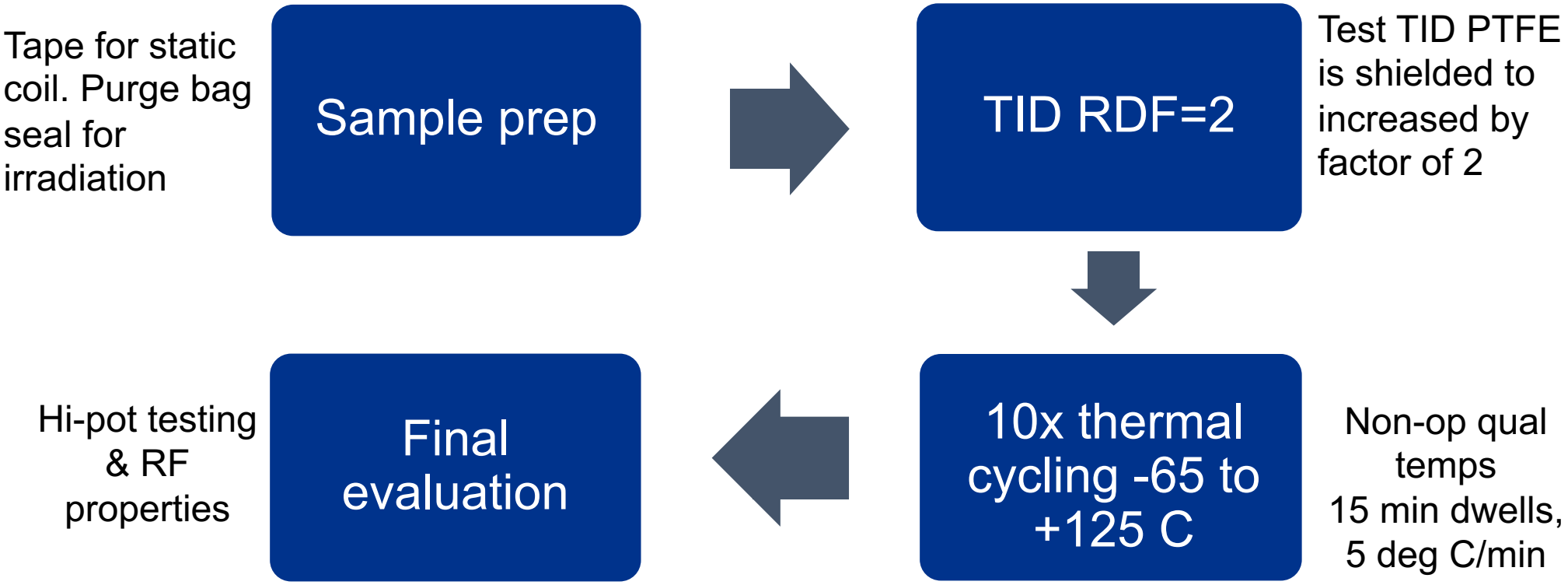


Novice radiation model results – RDM 1x

Detector Name	Neptape Wrap (Mrad-Si)	Cu-Tape Wrap (Mrad-Si)	Pb-Tape Wrap (Mrad-Si)
Wire Copper Center	2.5	2.5	1.5
Wire Copper Edge	3	3	1.5
Inside Insulator Center	3	3	1.5
Inside Insulator Edge	3	3	1.5
Outside Insulator Center	3	3	1.5
Outside Insulator Edge	3	3	1.5
Binder Center	3	3	1.5
Binder Edge	3	3	1.5
Silver1 Center	4	4	1.5
Silver1 Edge	5	5	1.5
Silver2 Center	7	7	2
Silver2 Edge	13.5	13.5	2
Tefzel Jacket Center	14.5	14.5	2
Tefzel Jacket Edge	16	16	2.5

- External environment (with RDM 2x) is 44 Grad
- Novice results predict insulation edges of Pb-tape wrapped SerDes would experience 1.5 Mrad
- Unwrapped cable exposure; use equivalent TID on wrapped cable with RDM factors
- Test cases of 1.5 Mrad, 3 Mrad, 10 Mrad, and 15 Mrad (for PTFE insulation RDM = 1, 2, 6, 10)

Test Overview



Visual inspection before and after each exposure, and after evaluation tests to confirm no cracking/failing of insulation.

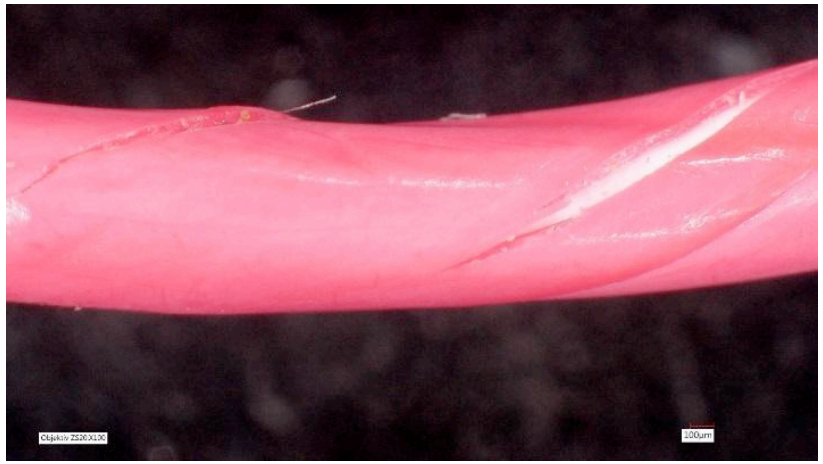
Radiation and Thermal Exposure

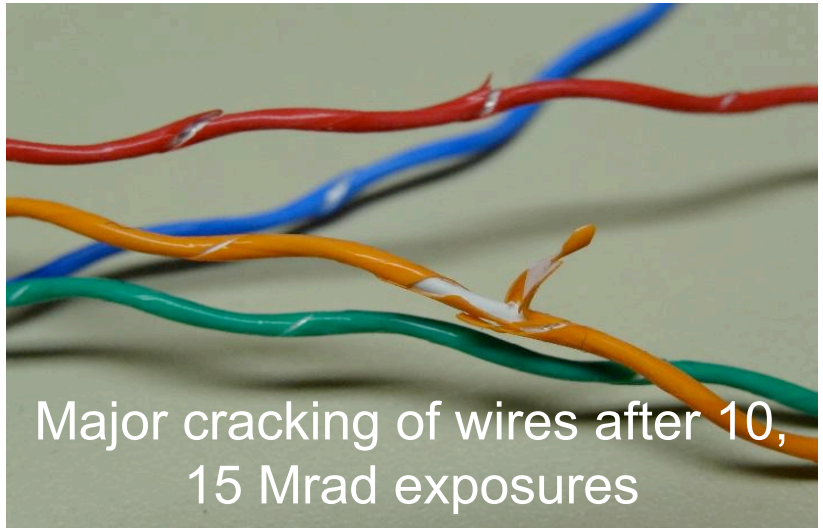
- Seal adhesive samples in Kenlam bagging material through APL purge vacuum sealing system
  - Remove oxygen and moisture
- Irradiate in APL Space Department Cobalt-60 gamma radiation chamber

Co60 fixture with sample wire bag sealed

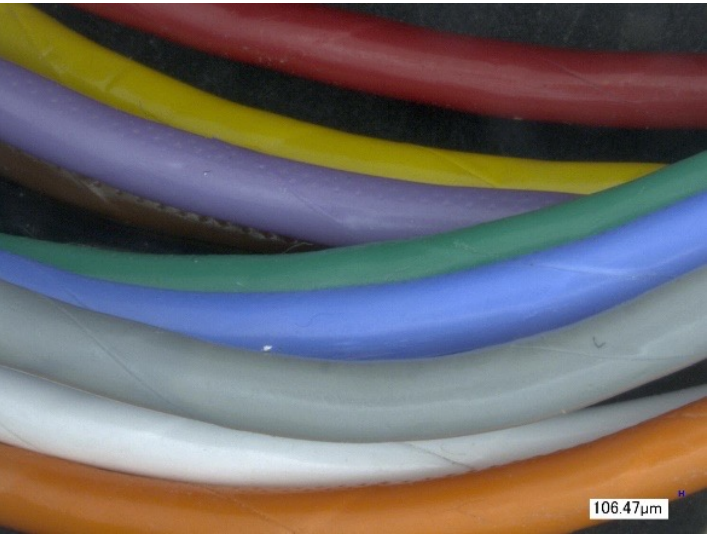
Wire samples prior to thermal cycling

Gore 100 Ohm Double Shielded Quad Cable GSC-05-84513-00

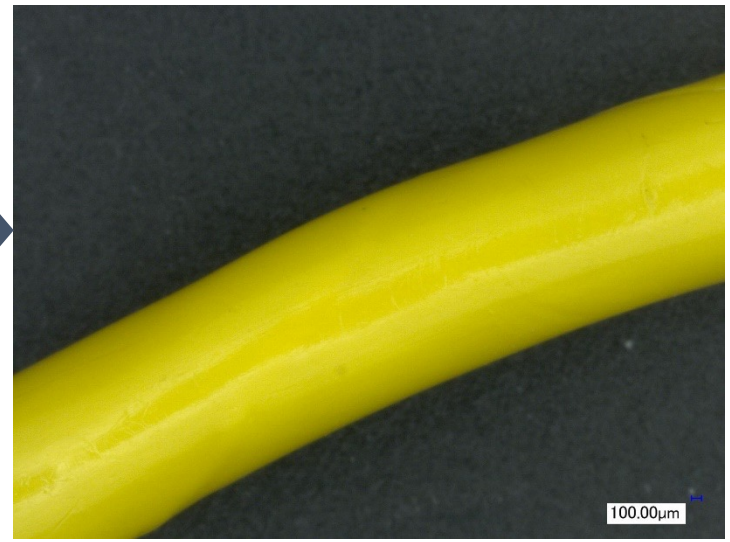




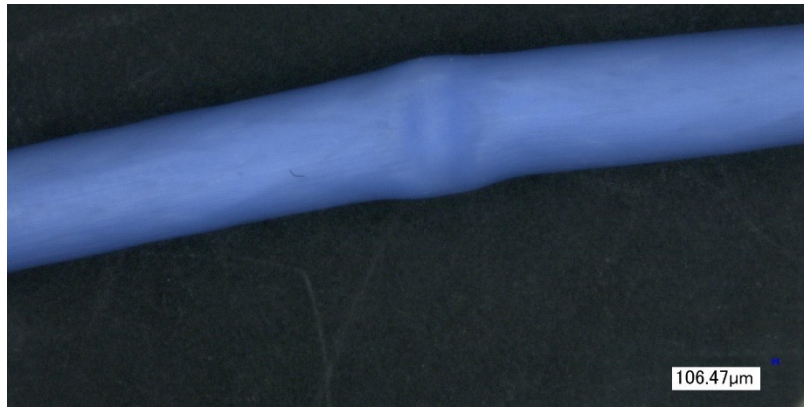
Cables after 2 Mrad exposures, bends



20x mag



10x tight bend to assure success



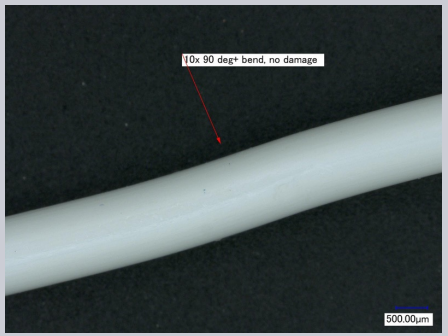
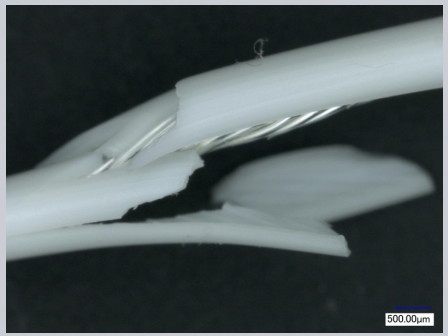
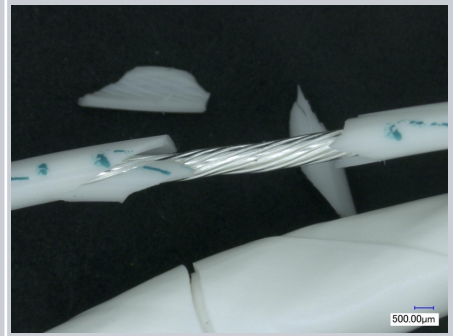
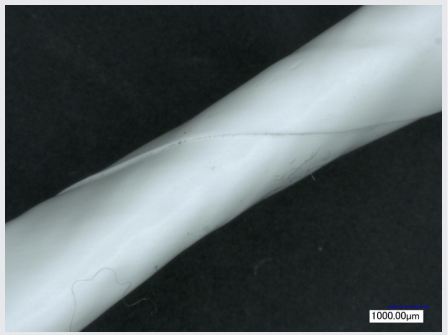
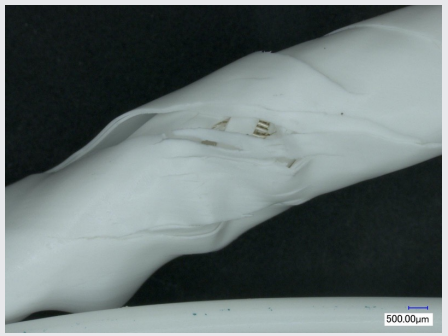
Bent wire outer insulation “crumpled” but did not fail

20x mag

Cables passed visual inspection (no cracking) and hi-pot insulation testing

Sample prep effects

- 6 Mrad wire results after -65C/+125C thermal cycling

	Before	After: Vac seal	After: N_2 purge	After: Air purge
M22759/11 PTFE insulated wire				
M27500 PTFE insulated cable				

Presence of oxygen and/or ozone effects reduce radiation tolerance. Vac seal samples passed hi-pot testing, purge samples did not

Conclusion

- Various wire/cable have all been qualified to the Europa Clipper environment of ~ 2 Mrad and -65 C to +125 C with the use of lead tape shielding wrap
  - Aiming for 1-2 Mrad with shielding is manageable
- Physical movement and mechanical stress after 10+ Mrad can induce insulation cracking and failure
- Purge bagging remains ideal for radiation exposure sample prep

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