Qualifying Photonics for the Space Environment

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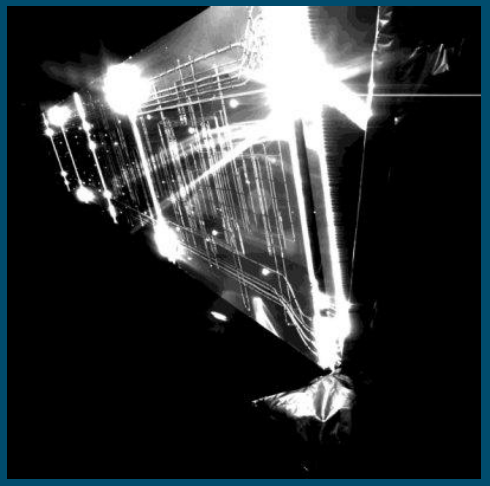
Qualifying Microphotonic Devices for Space

Mechanical
- vibration
- Pyro-shock

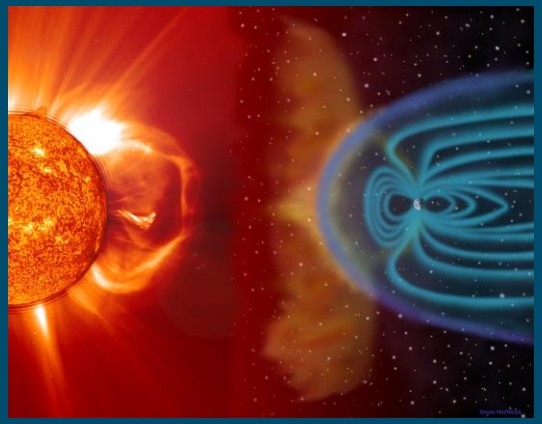
Thermal
- Large temperature variations

15 years service life
- No maintenance
- Guarantee of end of life performance



Vacuum
- Outgassing
- Contamination
- Packaging

Space radiation
- Displacement damage
- TID
- Charging due to interaction with charged particles



NASA vs. Telcordia Test Requirements

- Due to the usage of MIL-STD-883 in Telcordia specifications, the random vibration environmental parameters and duration are of greater intensity than is required for space flight launch vehicles.

	NASA Requirements		Telcordia Requirements
Vibration Testing	Vibration conducted on each of three areas	3 minutes / axis	20-2,000 Hz min / cycle
	Frequency (Hz)	Protoflight Level	
	20	0.052 g^2 / Hz	
	20-50	+6 dB / Octave	
	50-800	0.32 g^2 / Hz	
	800-2000	-6 dB / Octave	
	2000	0.52 g^2 / Hz	20G 4 cycles / axis
	Overall	20.0 grms	
Thermal Cycling Testing	-20°C / +85°C, 30 cycles for pass / fail, 42 cycles for info		-40°C / + 70°C, 100 cycles for pass / fail, 500 cycles for info

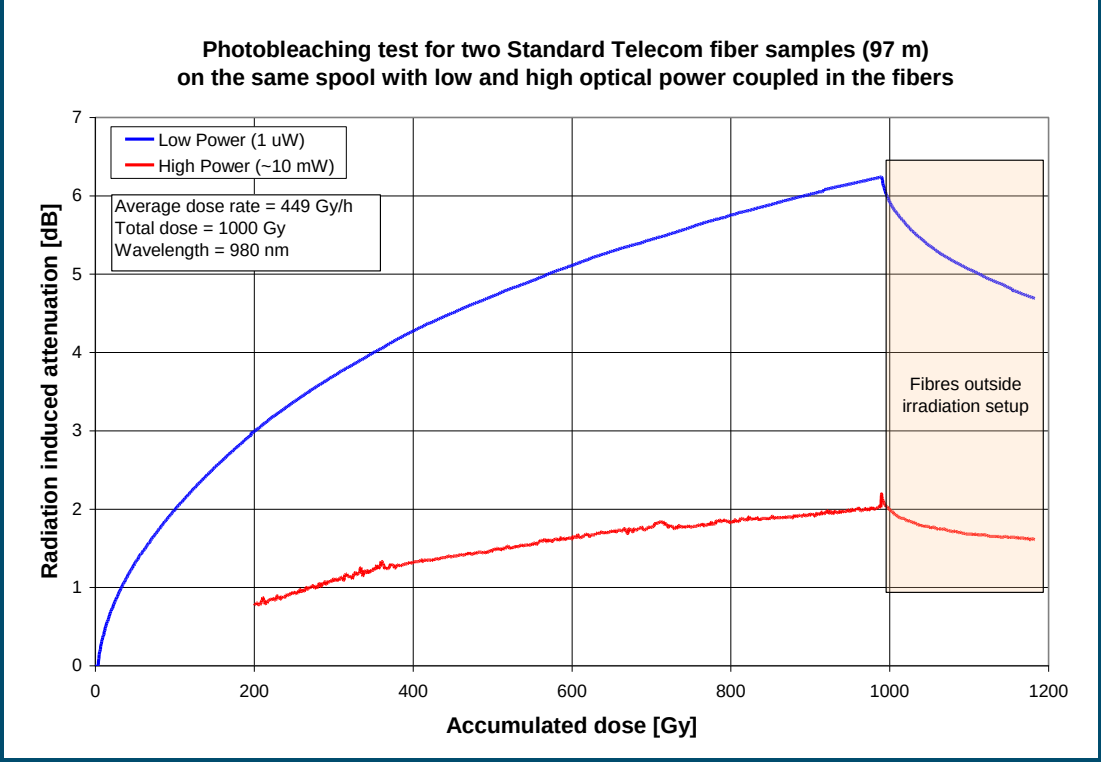
Reliability of Optical Fiber Modulators for Space Flight Environments, M. Ott, et al, NASA Parts and Packaging Program Report, Electronic Parts Project, IPPAQ Task Report, October 2002.

Radiation Effects on Fibre Optic Sensor Hardware

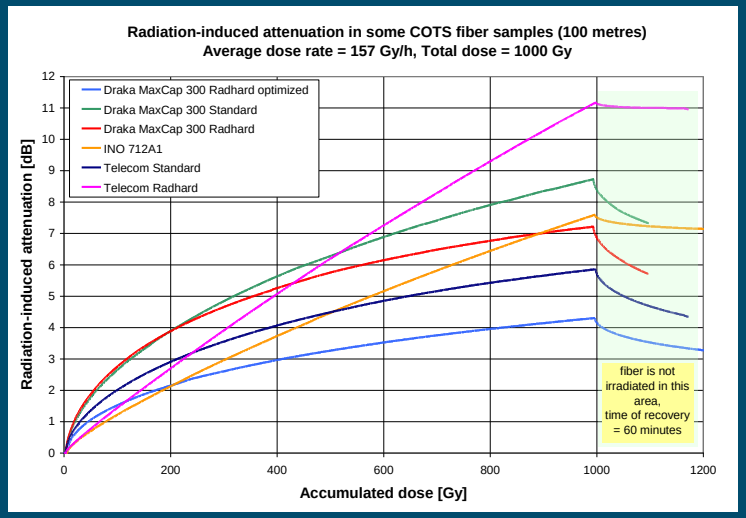
- Induced attenuation in optical fibres
- Refractive index change in glass （FBG shift）
- Impact on fibre optic coating （FBG shift）
- Displacement damage semiconductor laser （increased laser threshold, decreased slope efficiency）
- Displacement damage in detector （increased dark current, reduced efficiency）
- SEE – laser driver sensitivity

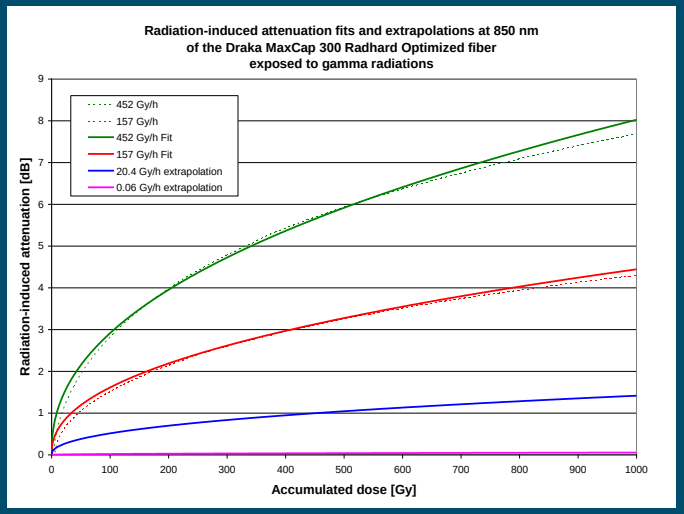
Other Parameters that Effect Darkening

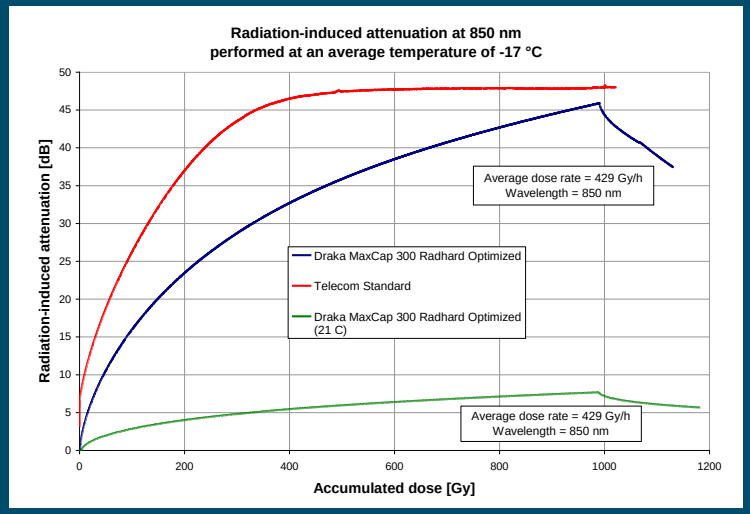
- Stress in the fibre
- Photo bleaching



Radiation Darkening of Optical Fibers



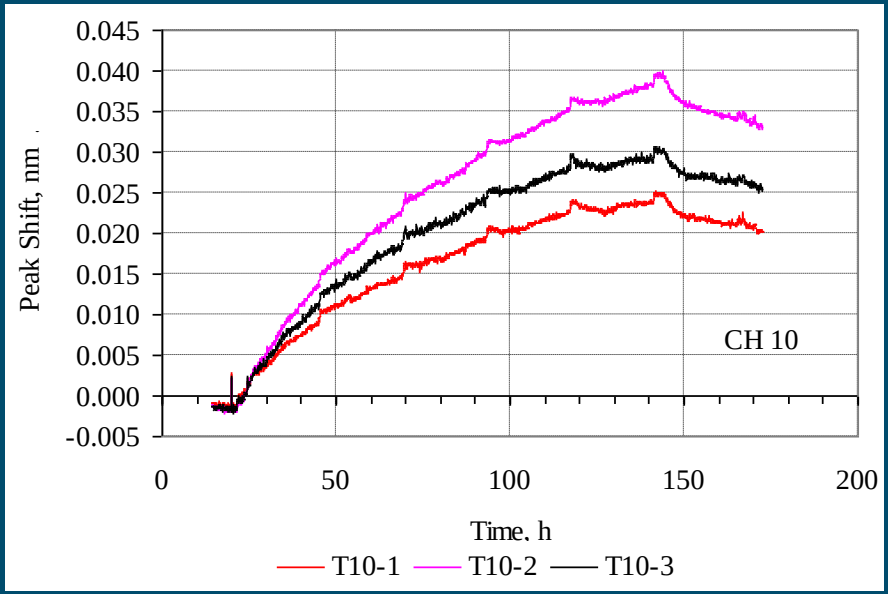




Courtesy of INO And SpaceFibre Project

FBG Wavelength Shift Due to Radiation

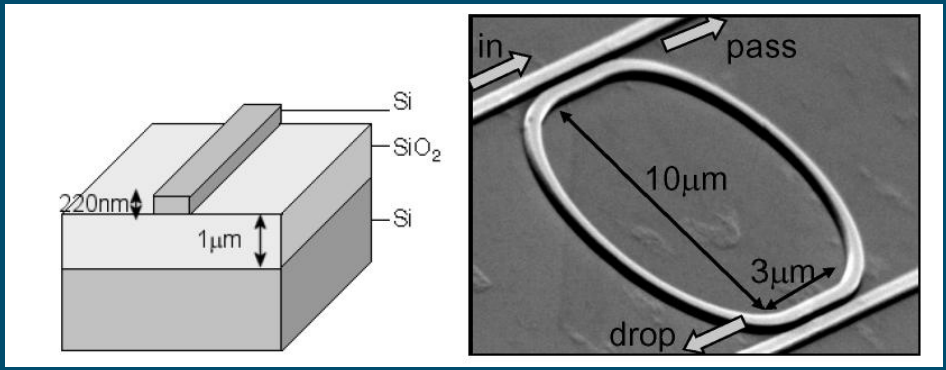
- Applications include laser wavelength stabilisation, filtering, and sensing
- FBGs show a shift in peak wavelength with radiation due partly to change in n
- Changes for 1Mrad are on the order of some 10s pm
- Radiation hardness improves with good selection of fibre, FBG writing approach, annealing process (thermal and UV), even coating type.
- Femto second laser writing approaches so better radiation hardness

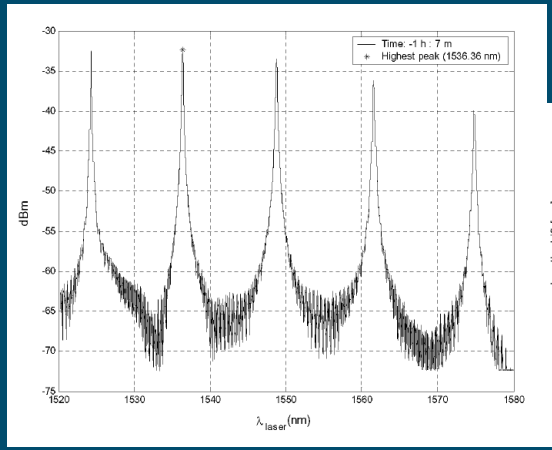


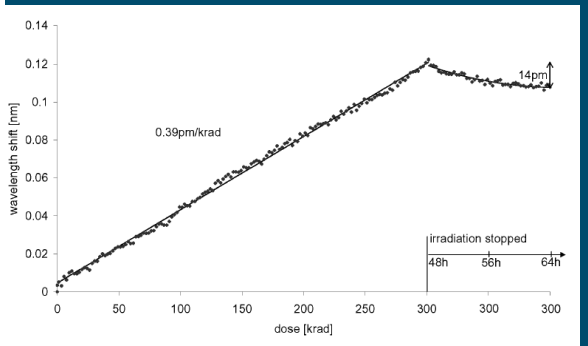
Results courtesy of SCK-CEN ESA contract.

Radiation Testing of SOI Devices

- Co-60 TID testing of SOI ring resonator devices
- Total dose 300kRad
- 0.39 pm/kRad shift of resonance peaks
- Important to note that ~100pm/K is expected due to thermally induced refractive index changes.







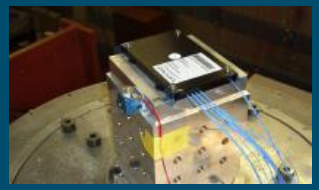
Vacuum

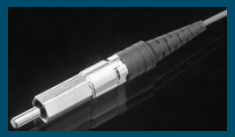
- Material Selection – Outgassing
- Contamination （hermetic sealing）
- Packaging and Mounting
- Hermetic Sealing required for active optoelectronic components （lasers and detectors） – problems with moisture in package.

SMOS Qualification Program

SMOS Mission (Soil Moisture and Ocean Salinity) Payload Module: Microwave Imaging Radiometer with Aperture Synthesis (MIRAS)

- COTS components used:
  - Modulight AlGaInAs 1300nm FP laser diodes,
  - Hamamatsu InGaAs PIN photodiodes,
  - Gooch and Housego Fiber Splitters
  - Gore FO Cable
  - Diamond AVIM connectors





Qualification Approach

- **Highest quality level for commercial off-the-shelf opto-electronic components is according to Telcordia standard or similar.**
- **Subsea is a good starting point – very high reliability requirements – 20 year life expectancy**
- **Space qualified components usually not existing**
- **A full qualification exercise as per ESCC specification not feasible due to**
  - **time and cost constraints**
  - **industry is too fast moving**

What to do?

Qualification Approach

- **Partial evaluation of 2 alternatives**
- **Full qualification of 1 FL plus samples**

- **+ costs are moderate (only one qualification)**
- **+ risk of qualification failure low**
- **– impact on overall schedule is high as procurement has to be performed for the samples and after successful evaluation for the FL again**

- **In order to reduce risk:**

Evaluation phase with two possible COTS candidates for each component (subjected to most critical tests, constructional analysis, manufacturer assessment)

Evaluation Process

- Procurement from two different suppliers
- Detailed constructional analysis
- Critical selection and performance tests – Standard evaluation tests should be designed to stress components and reveal failure mechanisms. Depending on schedule and budget this may not be possible.
- Visit and make assessment of supplier's manufacturing procedures
- Based on final assessment procure flight lot

Flight Lot Acceptance Testing (LAT)

Selection testing (Evaluation phase):

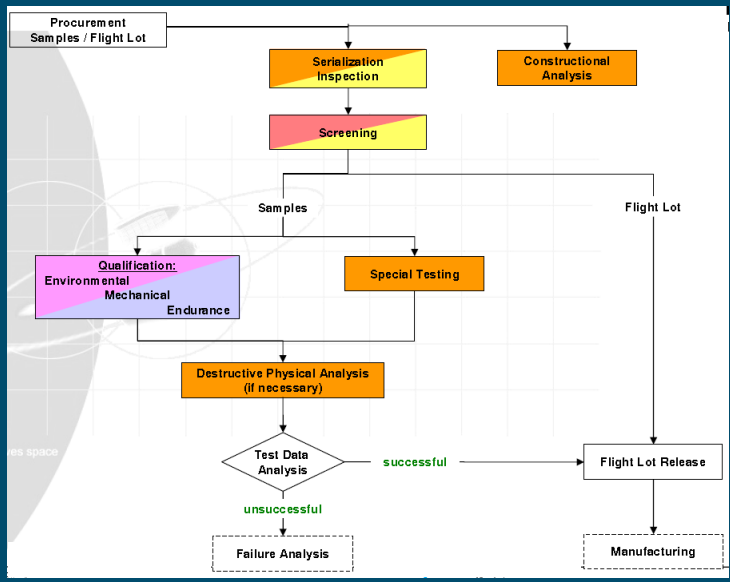
1. - vibration, shock
2. - thermal vacuum cycling
3. - radiation (gamma & proton)
4. - constructional analysis & manufacturer assessment

Flight lot screening / qualification

1. - extended burn-in
2. - acceptance thermal cycling
3. - measurement at high and low temperature

Flight lot acceptance testing

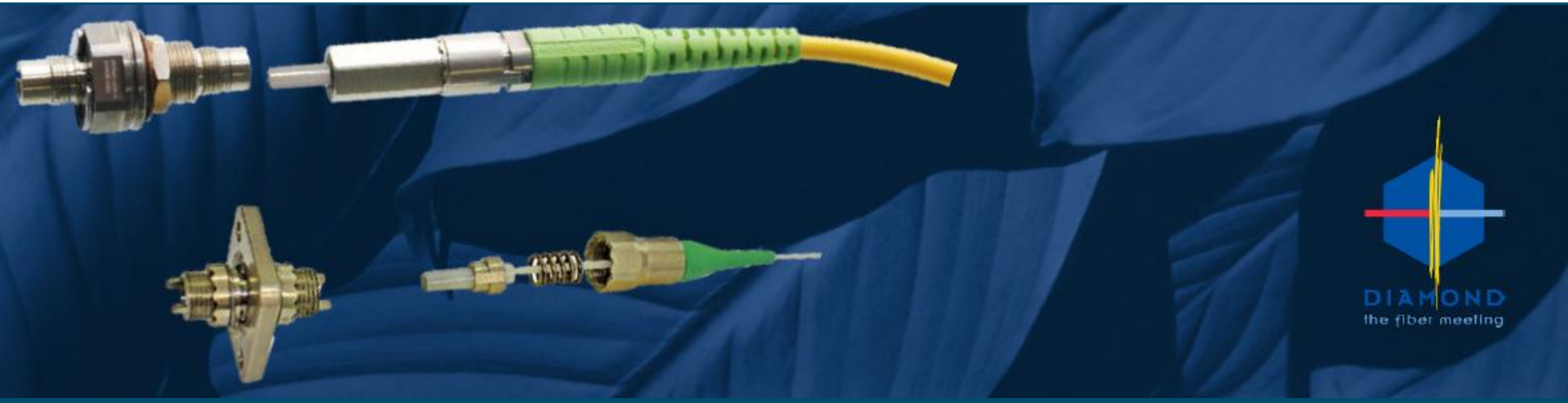
1. - thermal cycling, vibration, shock and radiation
2. - life test
3. - bending, fibre pull, mating, DPA



Lessons Learnt from SMOS Qual.

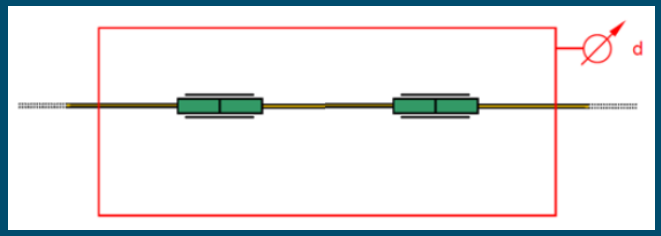
- Most manufacturers are not willing to customise their process for a small volume order.
- Be fast, products change fast – telecom market.
- Smaller manufacturers show greater interest and higher flexibility to customise their manufacturing and/or disclose the exact processing
- Be very accurate in manufacturer assessment (which activities are outsourced, how is the visibility)

Evaluation and Qualification of AVIM FO Connector



Project Scope:

- Evaluate and qualify connector set AVIM
- Document and write specifications for connector sets and assemblies
- Qualify a patchcord patchcord=fiber+cable+connectors-set+assembly-process



Evaluation Test Plan (ETP)

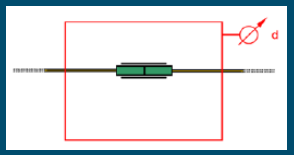
Purpose of an ETP is to *test resistance limits to understand safety factors and define Qualification values*

Scope: Break things and doing FA look why and when Find the extreme temperature and define Tmin and Tmax for the long term tests and cycles.

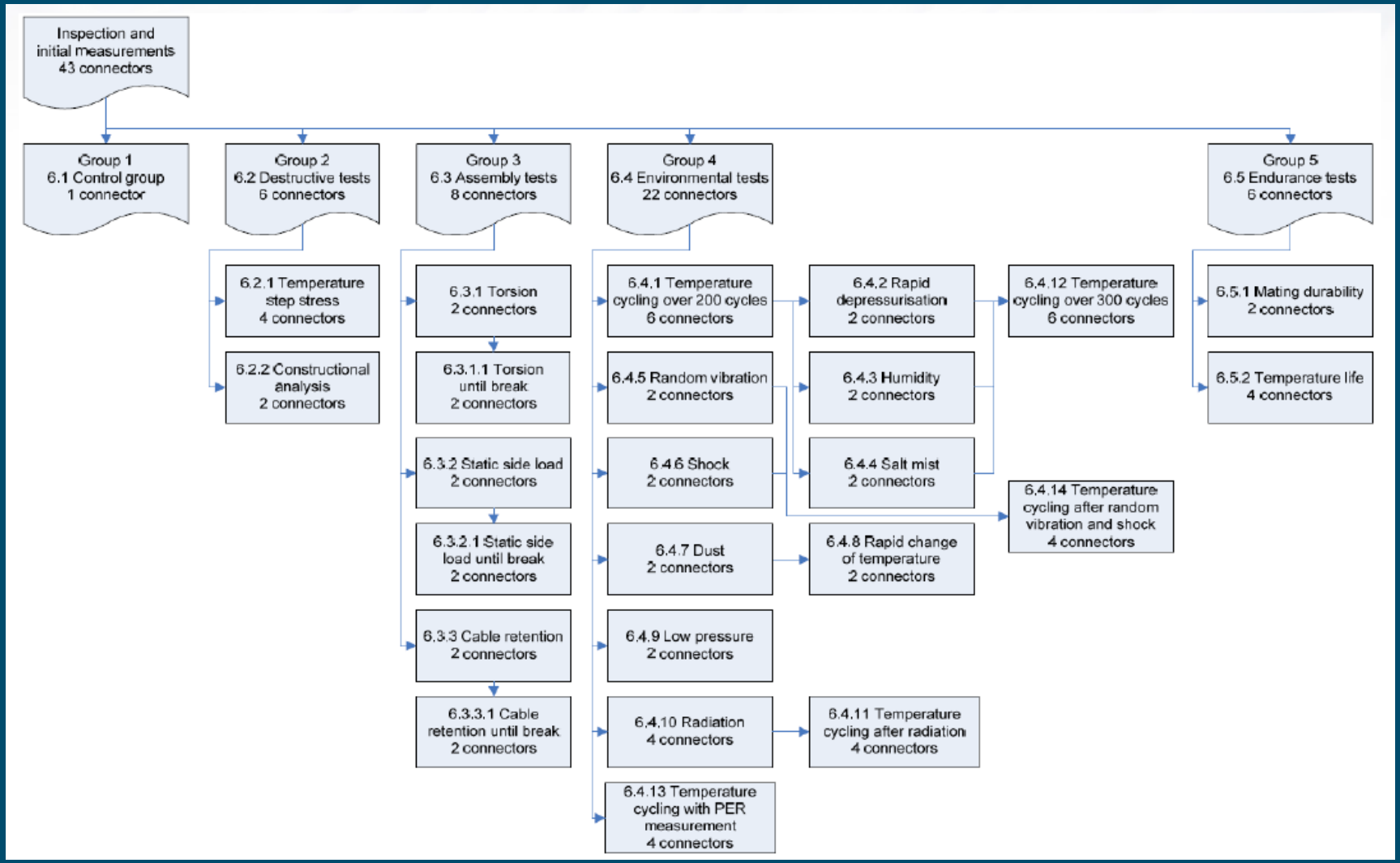
- Evaluate limit in vibration and shock
- Evaluate survivability to special condition (dust, salt mist,..)

Configuration Tested:

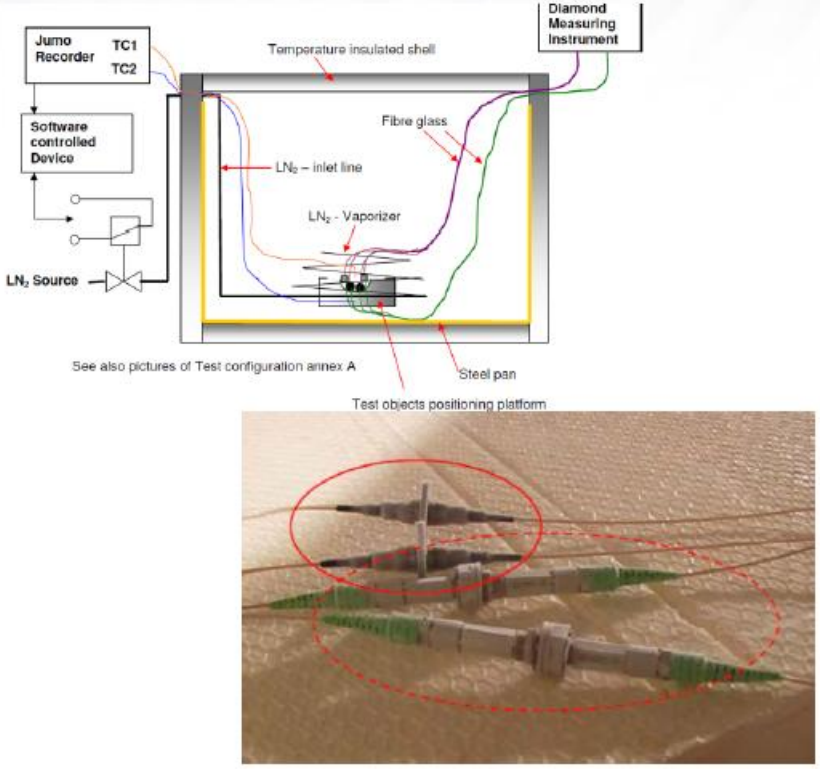
- PM fiber Fujikura SM.15-P-8/125-UV/UV-400 1550nm, acrylate coating
- Loose tube OD=1mm PEEK Victrex 450G
- Pigtails configuration (two connectors assembled when tested)



Evaluation Test Plan



Temperature Step Stress



Temp -190°C to +190°C

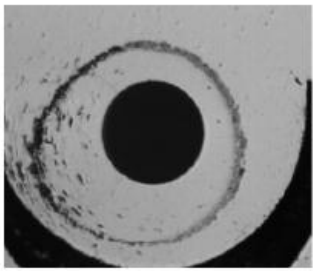
AVIM: -190°C to +180°C

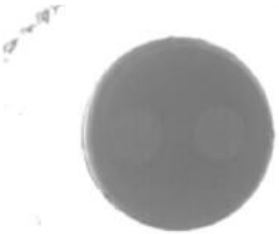
Mini-AVIM: -190°C to +125°C

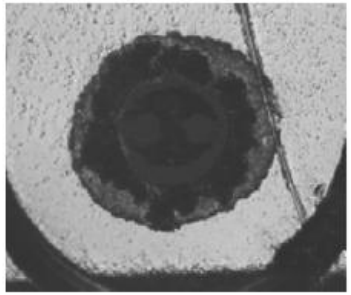
Limitation attributed to cable

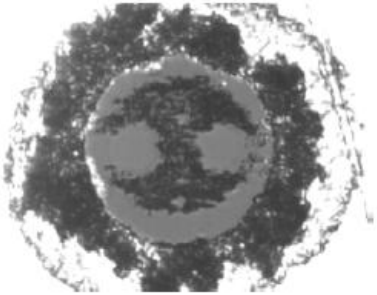
Random Vibration Step Stress

25gRMS 20-2000Hz
50gRMS 20-2000Hz
75gRMS 20-2000Hz
90gRMS 20-2000Hz



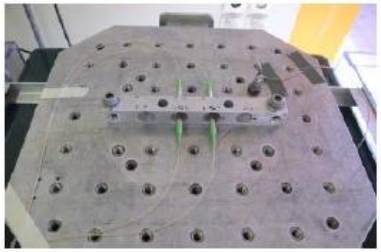


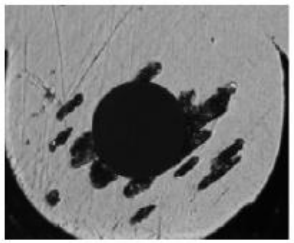


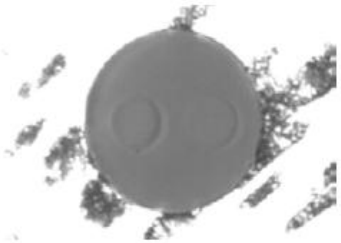


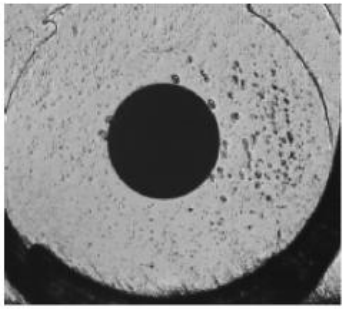
- AVIM marks starting at 50gRMS
- Mini-AVIM marks starting at 90gRMS

Shock Step Stress







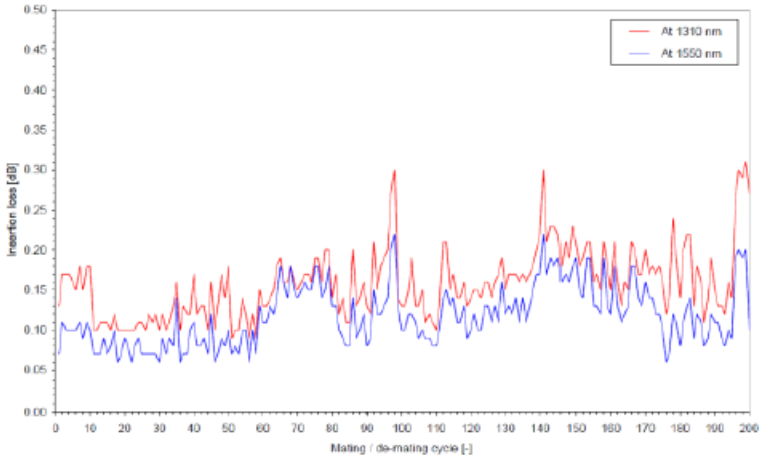


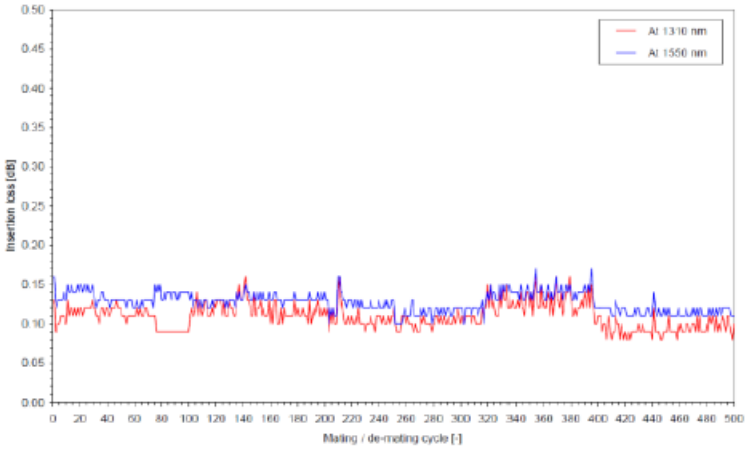
500g to 3000g

Longitudinal and transversal

- Spring loaded ferrule loose contact at ca. 2000g
- Transversal shock limited at 2500g on AVIM
- Transversal shock no influence on Mini-AVIM up to 3000g

Mating – Demating Test





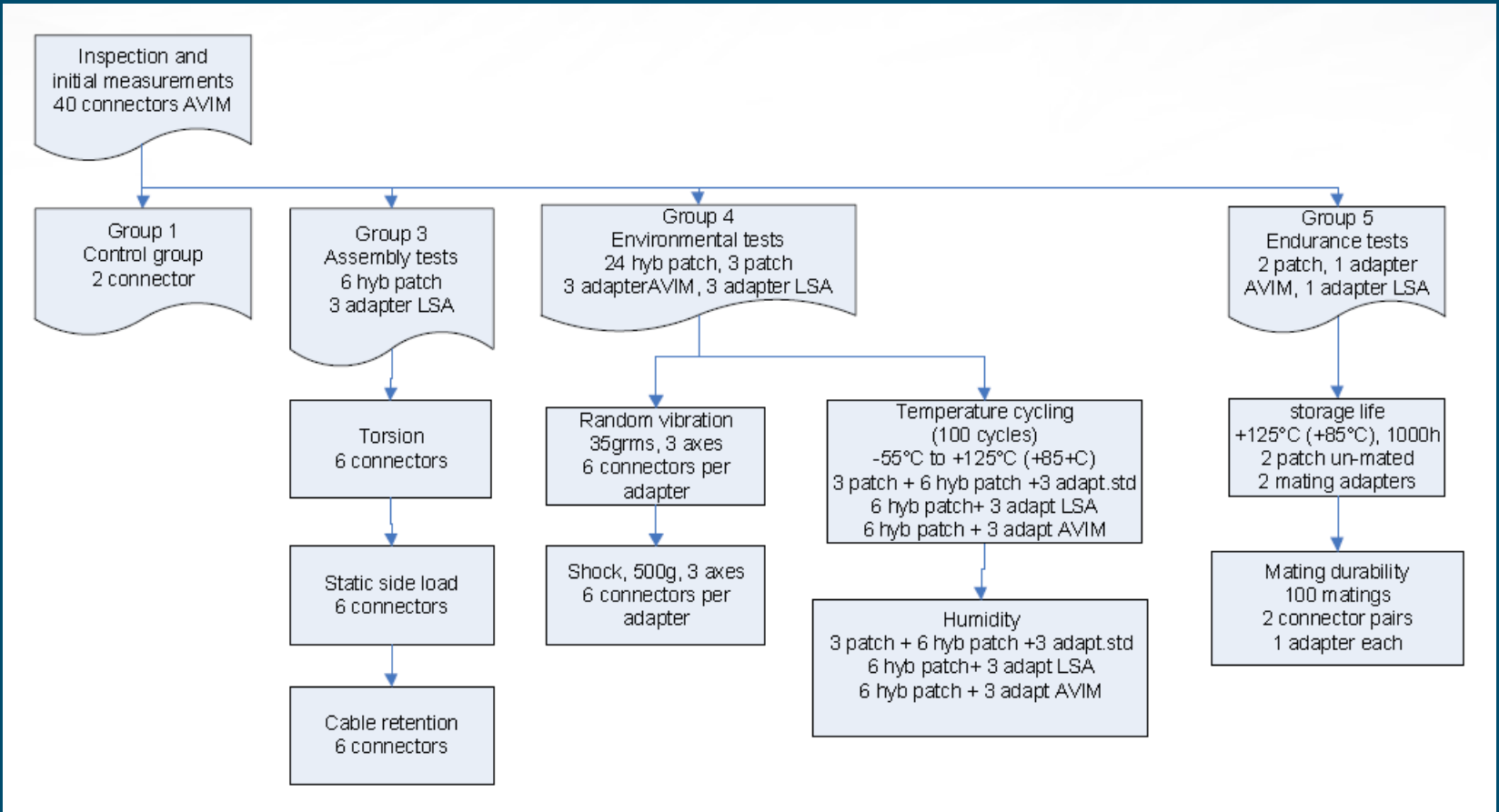
- AVIM shows wear of thread and key (due to DIN LSA original standard design)
- 200 mating demating

- Mini-AVIM Titanium on titanium shows little or no thread wear
- Better repeatability, up to at least 500 mating demating

Qualification Values

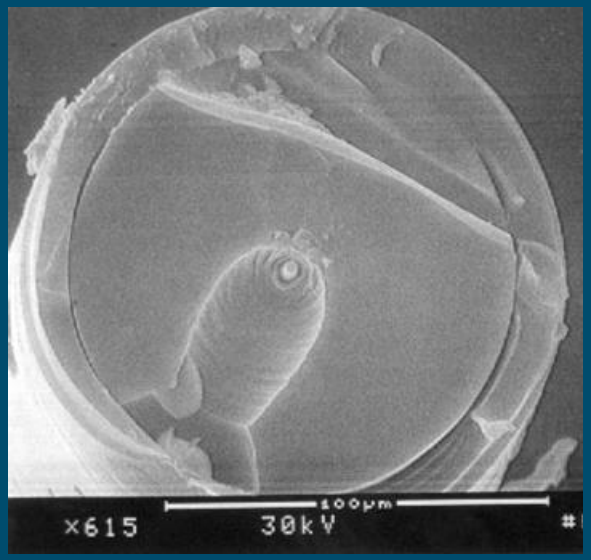
- Temperature cycles 100 cycles
  - AVIM -55°C to +125°C
  - Mini-AVIM -55°C to +85°C
- Vibration 35gRMS, 20..2000Hz
- Shock 500g
- Endurance 1000h at Tmax
- Mating durability 100 mating-demating
- Torsion 3N
- Static side load 0.2 N
- Cable retention 5N

Qualification Test Plan



Rocked Defect Investigation

Strange failure mode on ISS fibers observed in 1999



Night lights from space

Thank you for your attention.