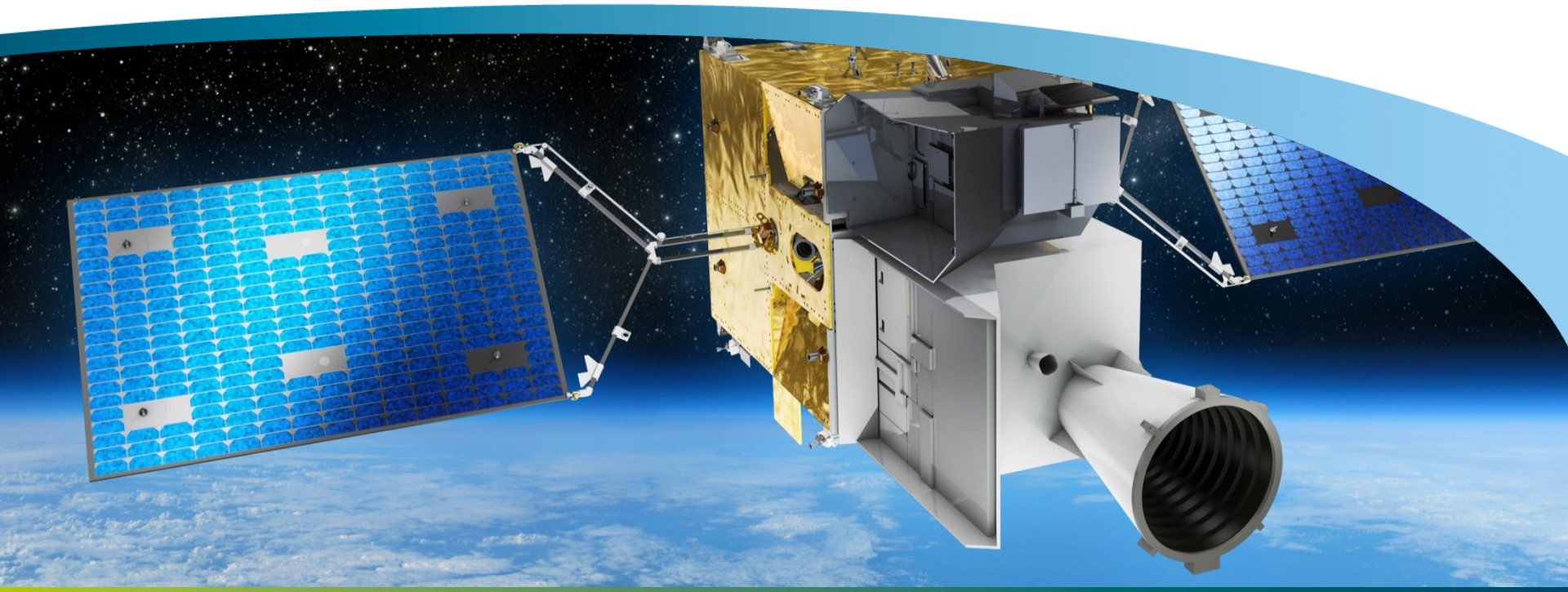
OHB System AG
Andreas Hurni
2015-12-11, ESTEC



SPACE SYSTEMS

Intra-satellite Fibre Optic Links Workshop

Photonically Wired Spacecraft Panels

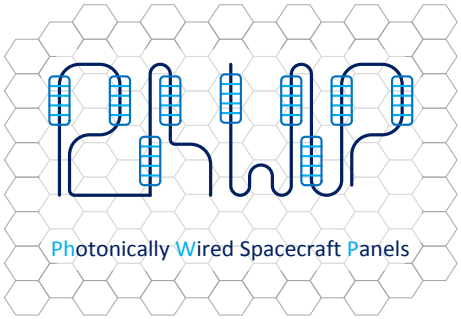
We. Create. Space.

Introduction

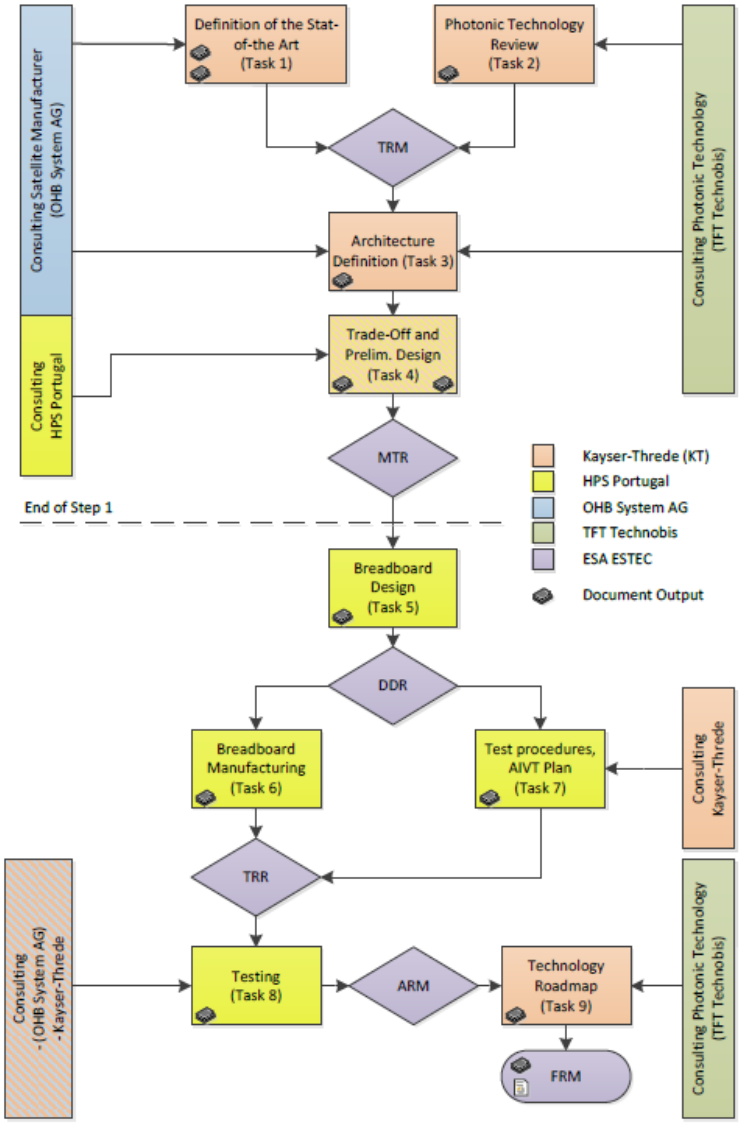
- Techno-economical study investigating fiber embedding in spacecraft panels → smart panels
- Definition of the sensors in a telecom satellite which can be replaced by embedded sensors
- Design of satellite panels (breadboard) with integrated sockets, fibers and sensors for monitoring
- Definition of the temperature sensing technique including sensors, their performance in space and the interrogation techniques of them
- Implementation of a data transmission link into the panels
- Manufacturing of the designed panels including creation of detailed AIT procedures and analysis of cost saving aspects
- Testing of the panels in terms of their temperature sensing functionality and data transmission capability
- Preparing a Road-Map at the end of the project how to further proceed with smart panels

HPS
High Performance Structures
Gestão e Engenharia Lda.
PORTUGAL

Technobis
tft-fos

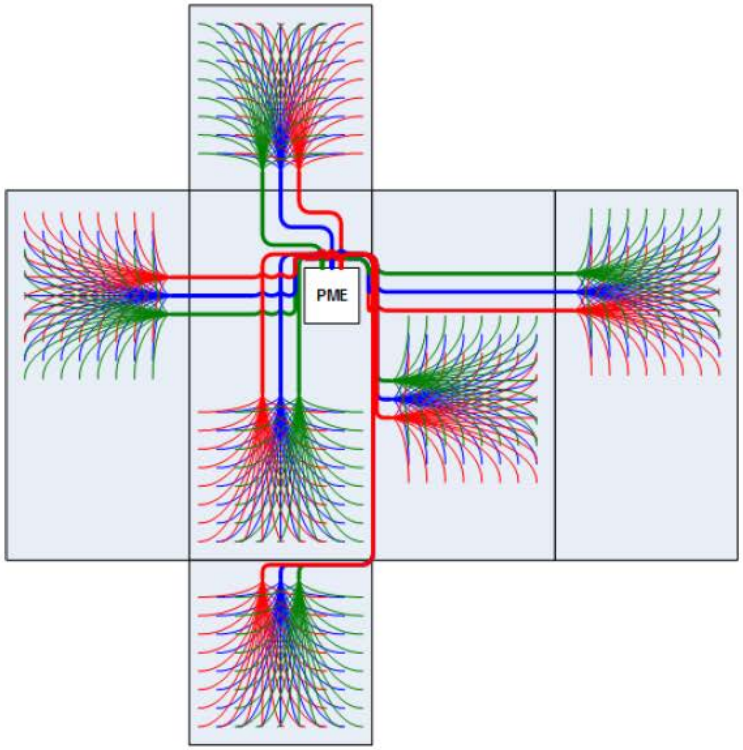


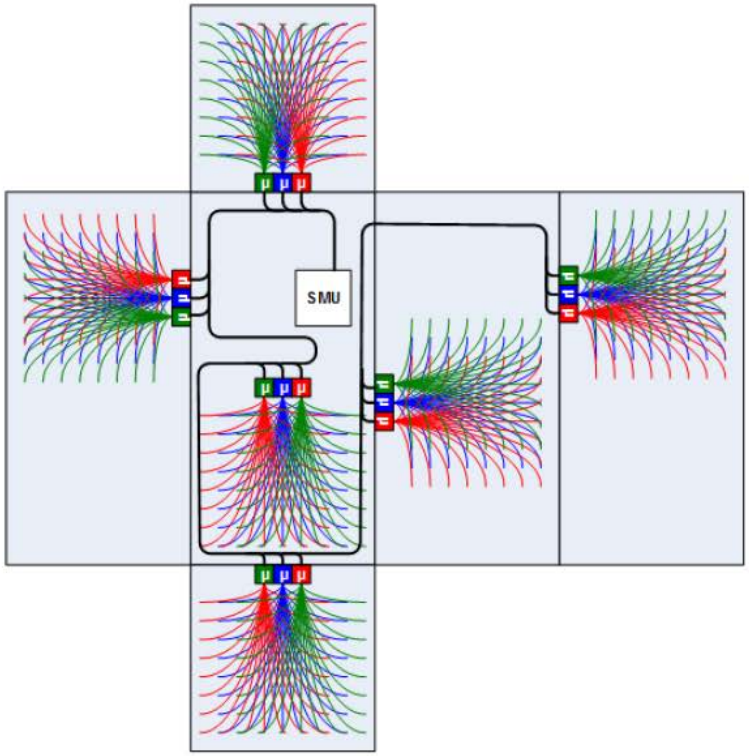
Work Logic


Consulting Satellite Manufacturer (OHB System AG)
Consulting HPS Portugal
Consulting Photonic Technology (TFT Technobis)
Definition of the Stat-of-the Art (Task 1)
Photonic Technology Review (Task 2)
TRM
Architecture Definition (Task 3)
Trade-Off and Prelim. Design (Task 4)
MTR
End of Step 1
Breadboard Design (Task 5)
DDR
Breadboard Manufacturing (Task 6)
Test procedures, AIVT Plan (Task 7)
Consulting Kayser-Thredе
TRR
Consulting - (OHB System AG) - Kayser-Thredе
Testing (Task 8)
ARM
Technology Roadmap (Task 9)
FRM
Consulting Photonic Technology (TFT Technobis)
Kayser-Thredе (KT)
HPS Portugal
OHB System AG
TFT Technobis
ESA ESTEC
Document Output

Definition of the State of-the Art

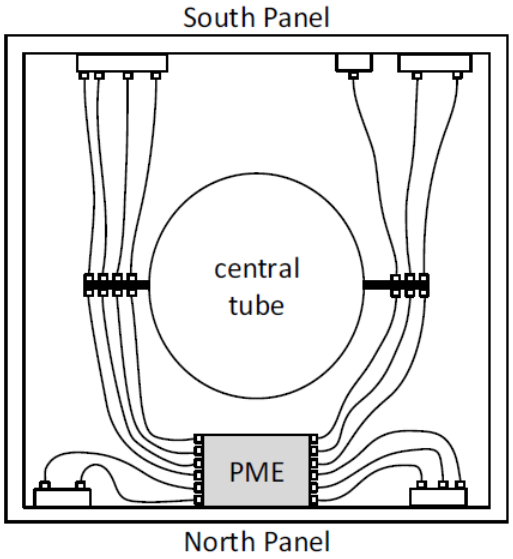
- SGEO Platform from OHB as baseline for sensor replacement analysis
- Centralized PME vs. De-centralized PME → Remote Terminal Unit (RTU)



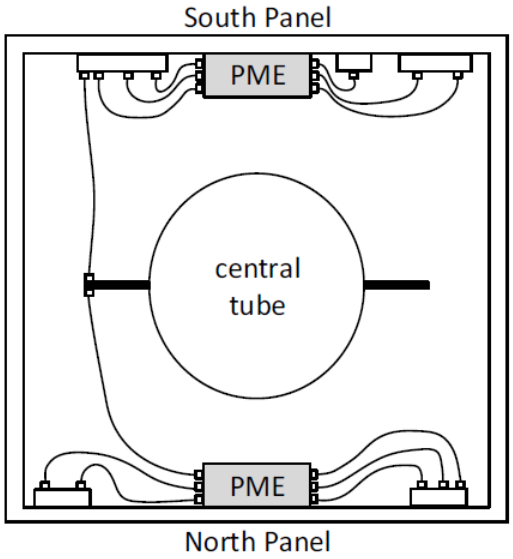


Definition of the State of-the Art

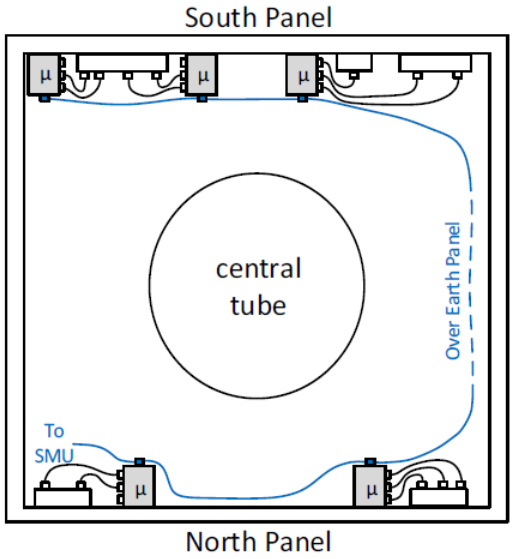
- Thermistors are the sensors with by far the highest quantity on the satellite
- The typical thermistor is provided with two flying leads and a shielding
- The effort estimated for integrating each thermistor is assessed as follows:
  - 25 min for electrical integration, 45 min for mechanical integration → 70 min / thermistor



(Sat C.A)



(Sat C.A)



(Sat D.A)

Definition of the State of-the Art

- Rough indication of the harness mass associated with thermistor
  - 1 Connector with backshell for every 6 thermistors, 1 tie base + 1 tie rap for every thermistor

North Panel Thermistor Harness Mass Assessment

	Qty.	Avg. Length in m	Total Length in m	Mass per unit	Mass per twisted line in g / m	Total Mass in g
Thermistor Lines	118	1.36	161	-	6.9 (AWG26 incl. shielding)	1111
Connectors with Backshell	20	-	-	40	-	800
Tie Bases (every 10cm, 15 cables)	118	-	-	0.9	-	106
Tie Raps	118			2		236
TOTAL						2253

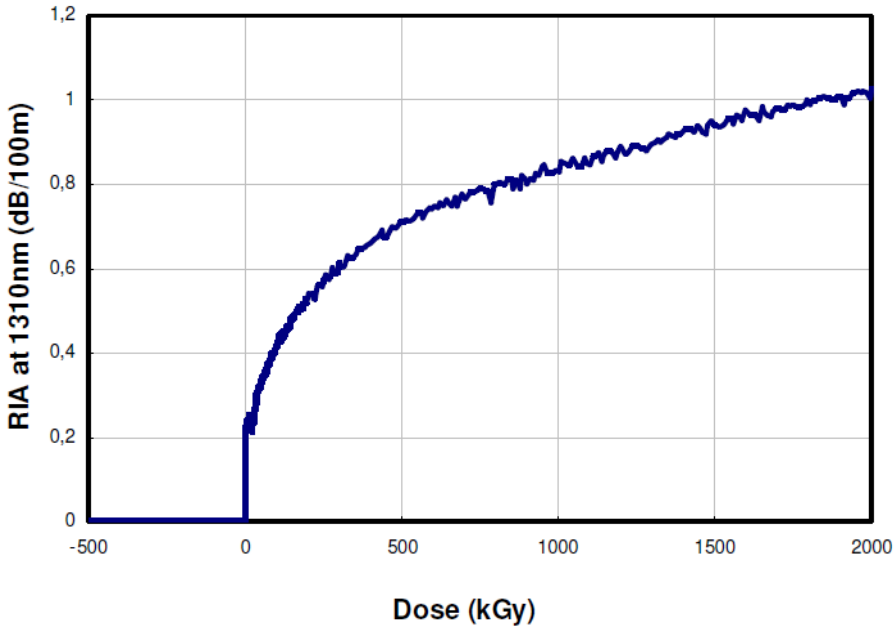
- The total number of thermistors in satellite: ca. 426 → 8.4 kg overall TSM mass
- Including TMTC harness ca. 106 kg → to be replaced by fiber-optics

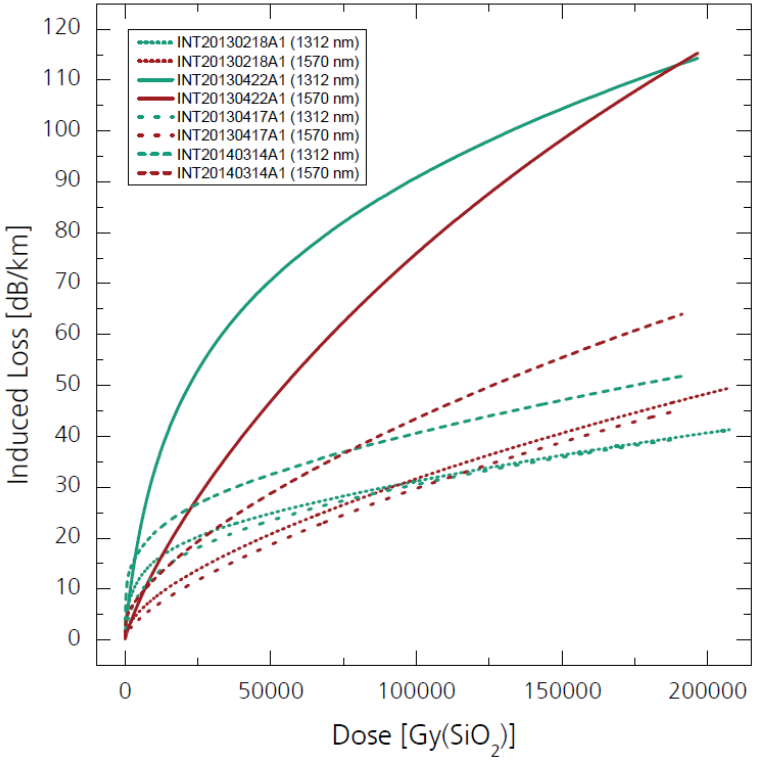
Photonic Technology Review

- Optical Fibers
- Optical Cables
- Optical Connectors
- Fiber Bragg Gratings (FBGs)
- Communication and Fiber Routing Architecture
- Interconnection of Panels

  → Trade-offs

Optical Fiber – Radiation Effects





Fluor-doped Fiber

- Very low RIA, < 1dB / 100 m for 200 Mrad
- FBGs written in f-doped fibers unstable (!!!)

Pure Silica Core Fiber

- Loss of 40 dB/km = 0.04 dB/m
- FBGs can be written and are stable (low BWS)

Optical Fiber – Component Identification

- Optical Fiber for Communication
  - Linden Photonics fiber-optical cable

Parameter	Value
Fiber type	DrakaElite Radiation Hardened Singlemode
Operating wavelength	1310 nm, 1550 nm
Outer diameter	2.0 ±0.13 mm
Attenuation	< 0.6 dB/km @ 1310 nm < 0.4 dB/km @ 1550 nm
Tensile strength	50 lbs (≈ 23 kg)
Costs	≈ 10 USD / m
Weight	3.7 g/m
Temperature range	-55 °C to +125 °C
Minimum bend radius	5 mm to 10 mm

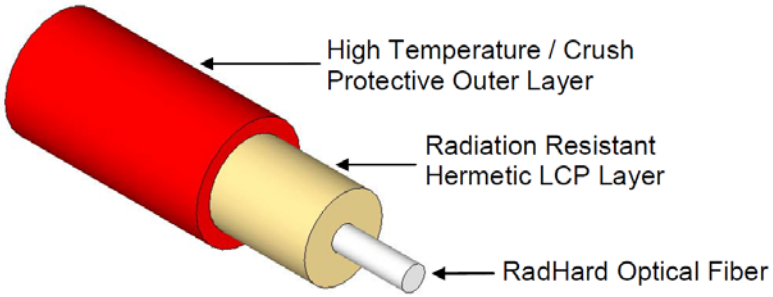
- Optical Fiber for Sensing
  - Fujikura RRSMFB single mode fiber

Parameter	Value
Fiber type	Pure SiO_2 core with F-doped SiO_2 cladding
Operating wavelength	1310 nm, 1550 nm
Coating diameter	245 ±5 µm
Attenuation	< 0.4 dB/km @ 1310 nm < 0.3 dB/km @ 1550 nm
Tensile strength	4 GPa (≈ 49 kg)
Costs	≈ 17.7 €/ m
Temperature range	-55 °C to +125 °C
Coefficient of thermal expansion	$0.51 \cdot 10^{-6}$ (0 °C to 100 °C)

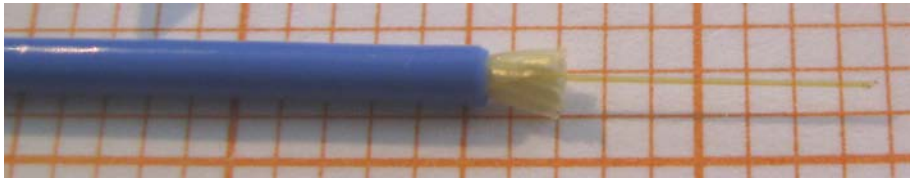
  - GEOSIL-SM Single-Mode Fibers from OFS

Optical Cable – Component Identification

- Linden Photonics Fiber Cable
  - Single mode fiber (DrakaElite Radiation Hardened Singlemode), outer diameter (OD) of 1.2 mm, 1.4 mm, 1.65 mm, 2.0 mm, 2.2 mm
  - Multi-mode fiber (Verrillon 50/125/155 Polyimide or DrakaElite Radiation Hardened 62.5/125 Multimode), outer diameter (OD) of 1.2 mm, 1.4 mm, 1.65 mm, 2.0 mm, 2.2 mm



- Gore Simplex Fiber Cable
  - Diameter of 1.8 mm
  - Mass of 4 g/m
  - Temperature range from -55 °C to +125 °C
  - Custom mode fiber possible
  - Preshrinking required



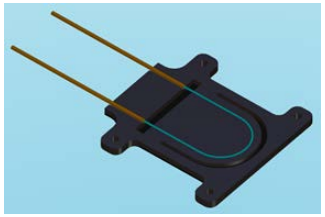
Connector – Component Identification

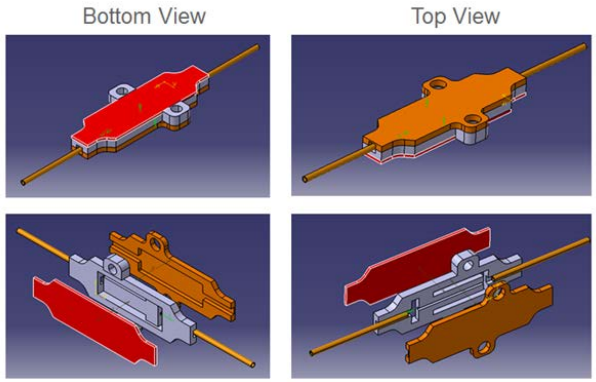
- Glenair Multi Fiber Connector
  - D-Subminiature GFR Fiber Optic Connector
  - Micro-D GFR Fiber Optic Connector

Parameter	Value	Remark
Number of FO connections	1, 2, 3, 4, 5, 8	For D-Subminiature variant up to 12
Total connector mass	16 g	For connector with 4 FO pins
Connector mass per FO connection	4 g	For connector with 4 FO pins Mass per FO connection decreases for higher number of FO connections
Insertion Loss	< 0.5 dB	
Operation Temperature	-65 °C to +150 °C	
Costs	782 €	Connector with 4 FO pins: 652 € 4 FO pins: 130 €
Connector costs per FO connection	196 €	
Space qualification	Military grade	MIL-PRF-28876

Fiber-optical Sensor – Component Identification

- Pure grating glued to the panel
- Feedthrough based transducer
- Single-ended transducer
- Capillary based transducer

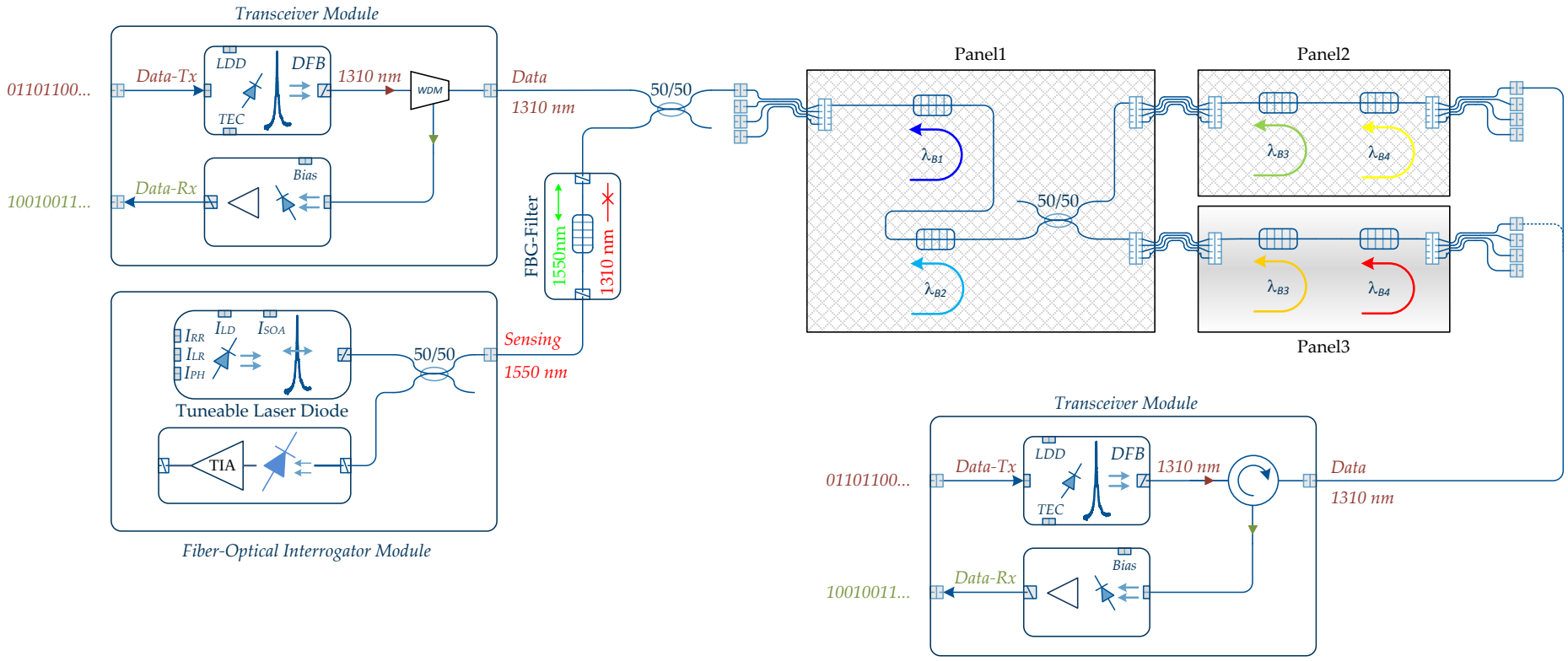




No.	Configuration	Decoupling	Weight	AIT Effort	Cost
1	Pure grating	Poor	0.1 g	Low	Low
2	Feedthrough transducer	Good	3.5 g (Steel) 1.2 g (Alu)	High	High
3	Single-ended transducer	Good	15.65 g (Steel) 5.37 g (Alu)	High	High
4	Capillary based transducer	Poor	< 2 g	Low	Medium

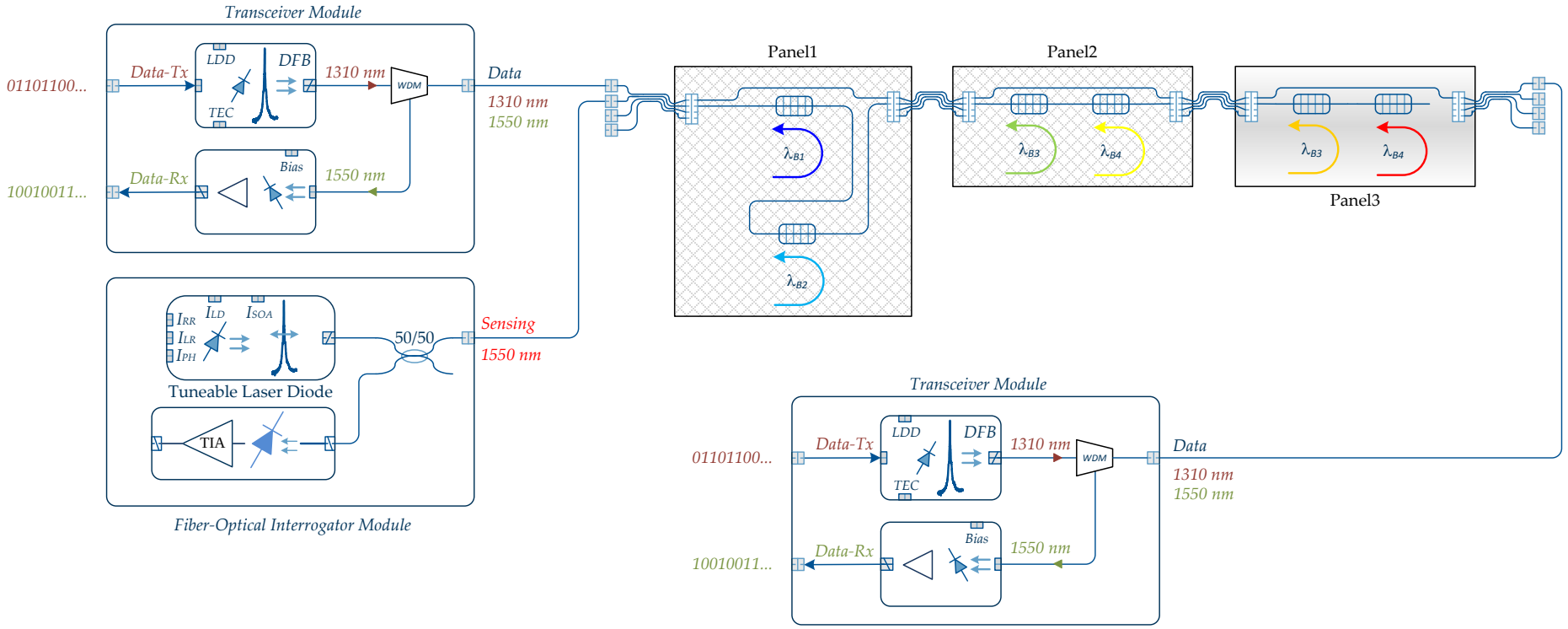
Architecture – Combined Sensing and Data Transmission

- Bi-directional data transmission in parallel panel configuration



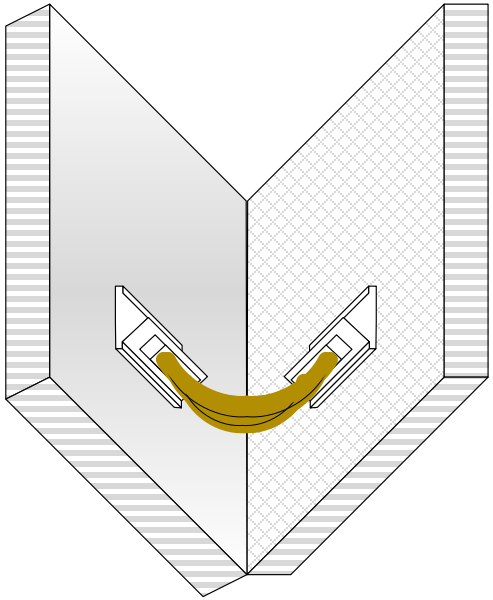
Architecture – Separated Sensing and Data Transmission

- Bi-directional data transmission in serial panel configuration

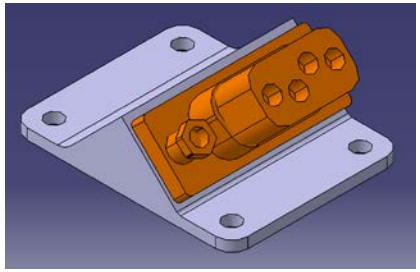


Panel Interconnection

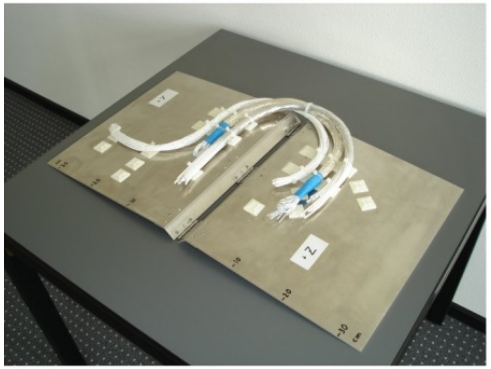
Patch cord

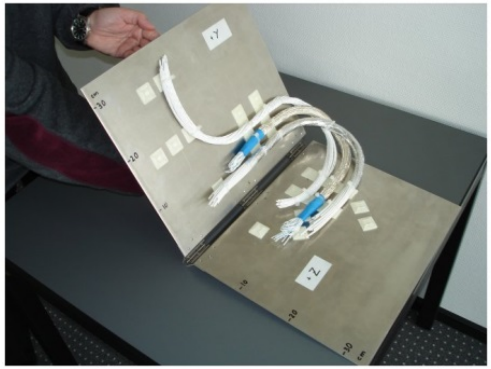


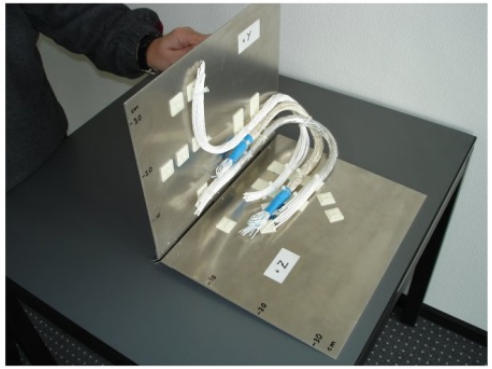
45 ° Bracket



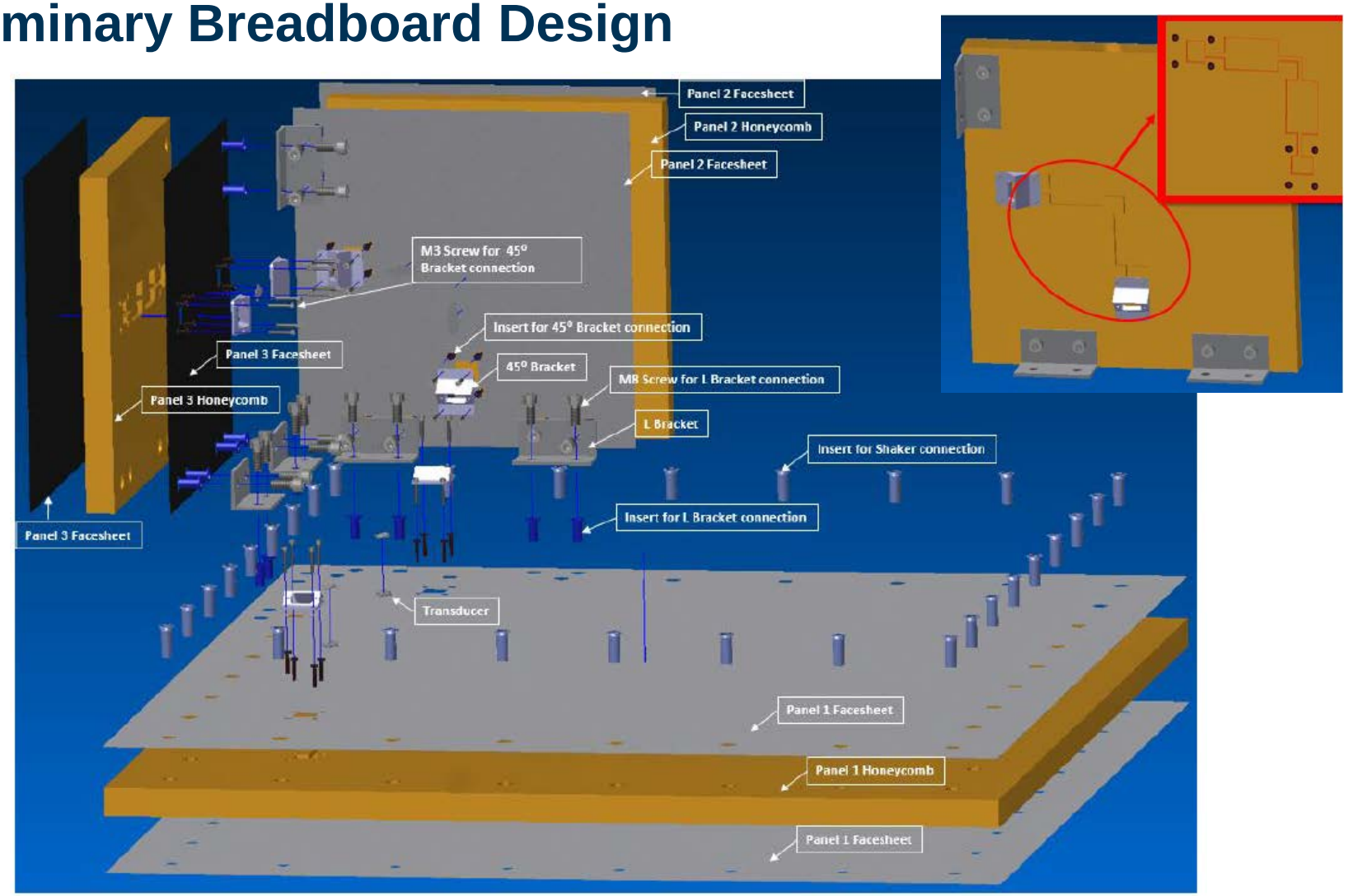
Hinge solution (Galileo)







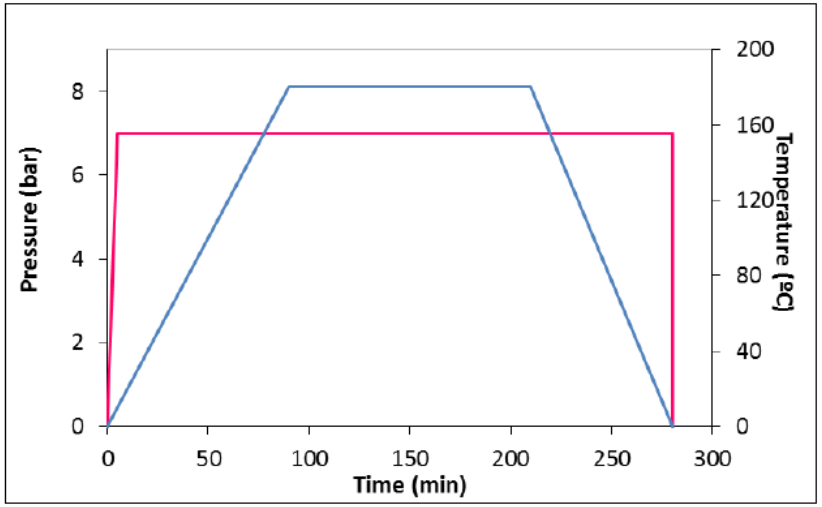
Perliminary Breadboard Design



CFRP Facesheet Manufacturing

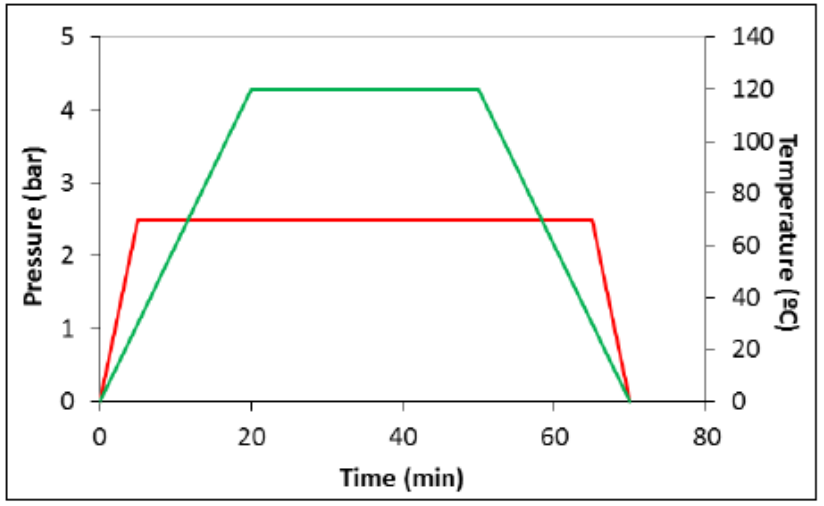
CFRP prepreg curing

→ no fiber-optics!



Adhesive curing

→ fiber-optics embedded!



Future Tasks

- Breadboard Manufacturing at HPS Portugal
  - 1x big panel (Al facesheets), 1x small panel (CFRP facesheets) and 1x small (Al facesheets)

- Test procedures, AIVT Plan to create

  → Q1 2016

- Breadboard Testing at HPS Portugal
  - Distributed integrated temperature sensing and hot spot detection
  - Connection capability to neighboring structural components
  - Vibration tests

- Technology Roadmap to create together with TFT

  → Q2 2016

Acknowledgements

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- Thanks to the subcontractors
  - HPS Portugal (Portugal)
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- Special thanks to Iain McKenzie, Xavier Geneste and Nikos Karafolas from ESA