TECHNOLOGIE IST UNSERE LEIDENSCHAFT

ESA Clean Space Industry Days

Design, Analysis and Testing of a Deployable Membrane for a passive De-Orbiting System

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Agenda

- Background and Objectives
- Deployable Membrane Development
  - Requirements
  - Design
  - Simulation & Analyses
  - Demonstrator Manufacturing
  - Test Campaign
- Conclusion and Next Steps

Project Objectives

- ESA has initiated two activities to advance the technology required for passive means of de-orbiting

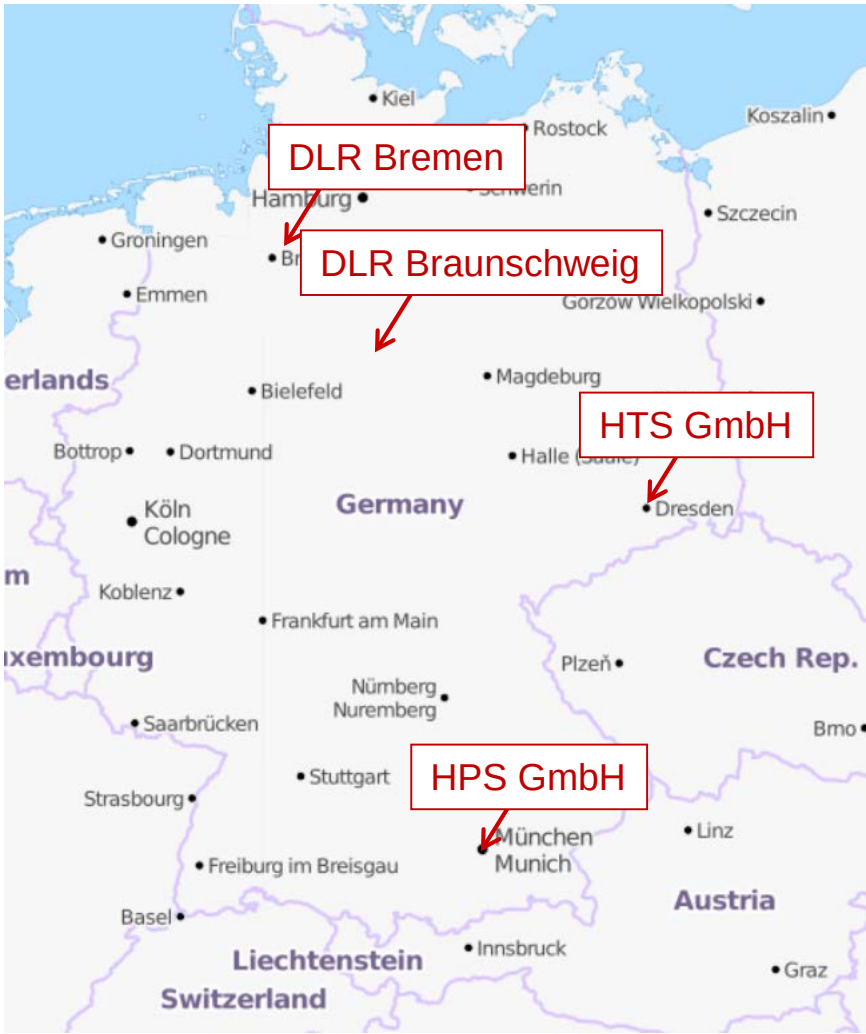
- The ultimate goal of this project:
  Develop a lightweight, robust and reliable membrane which can be used as a drag sail for passive de-orbiting, along with:

  - Membrane Material selection and coating definition
  - Definition of folding and deployment approach
  - Design of drag sail and interfaces
  - Material tests (impact tests, a geing tests)
  - Full scale Breadboard (deployment tests)

The activity is carried out under ESA contract No. 4000112241 within the Clean Space Programme (GSTP 6-1 CS)

Project Team

- Hoch Technologie Systeme HTS GmbH
  - Prime
- High Performance Space Structures HPS GmbH
  - Detailed Analyses
  - Impact tests and assessments
- DLR Bremen
  - Packaging, deployment, aging
- DLR Braunschweig
  - Boom to Sail Interfaces



The idea of passive deorbiting:

- Advantages
  - No energy or propellant required
  - Simple plug-and-play system (no major implications to satellite design)
  - Optimal solution of small and medium sized satellites

- Drawbacks
  - Comparably long descent time
  - No controll during descent
  - Only applicable for LEO spacecraft

  → Complex effects of environmental conditons due to long storage and operational period, any by such demanding design requirements

Major Requirements to a Deployable Membrane for Drag Sails

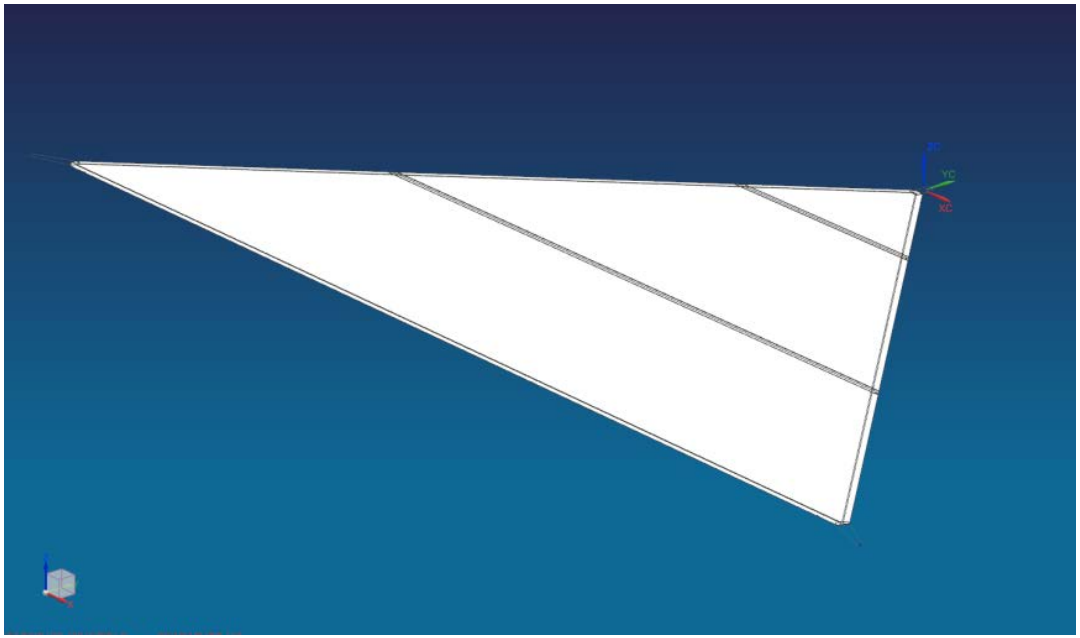
- Low specific weight to allow for sufficiently large, yet lightweight sails
- Small storage volume
- Long lifetime (resistance to solar and cosmic radiation, particle radiation, etc.) – up to 25 years
- Tolerance to long storage time under difficult environmental conditions – up to 15 years
- Resistance to wide temperature range during storage and operation
- Mechanical robustness and damage tolerance

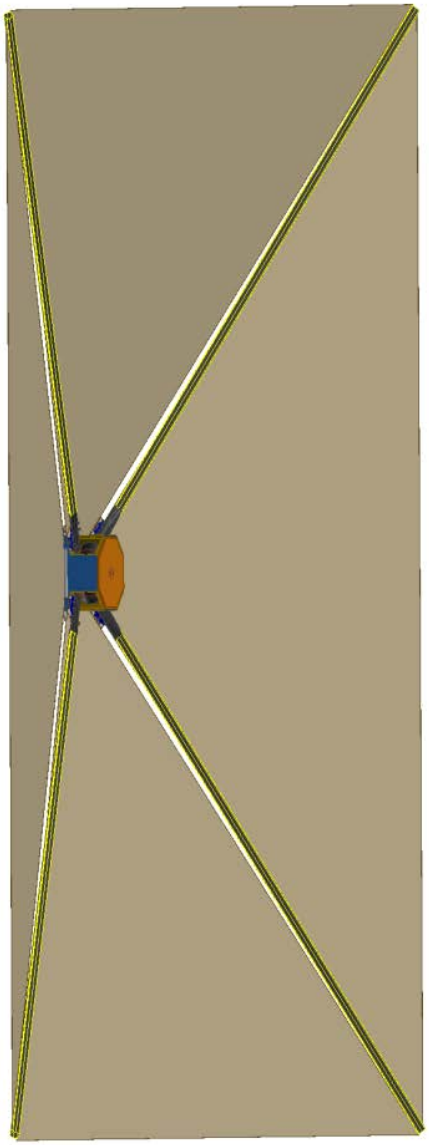
Deployable Membrane Design

- Overall Design

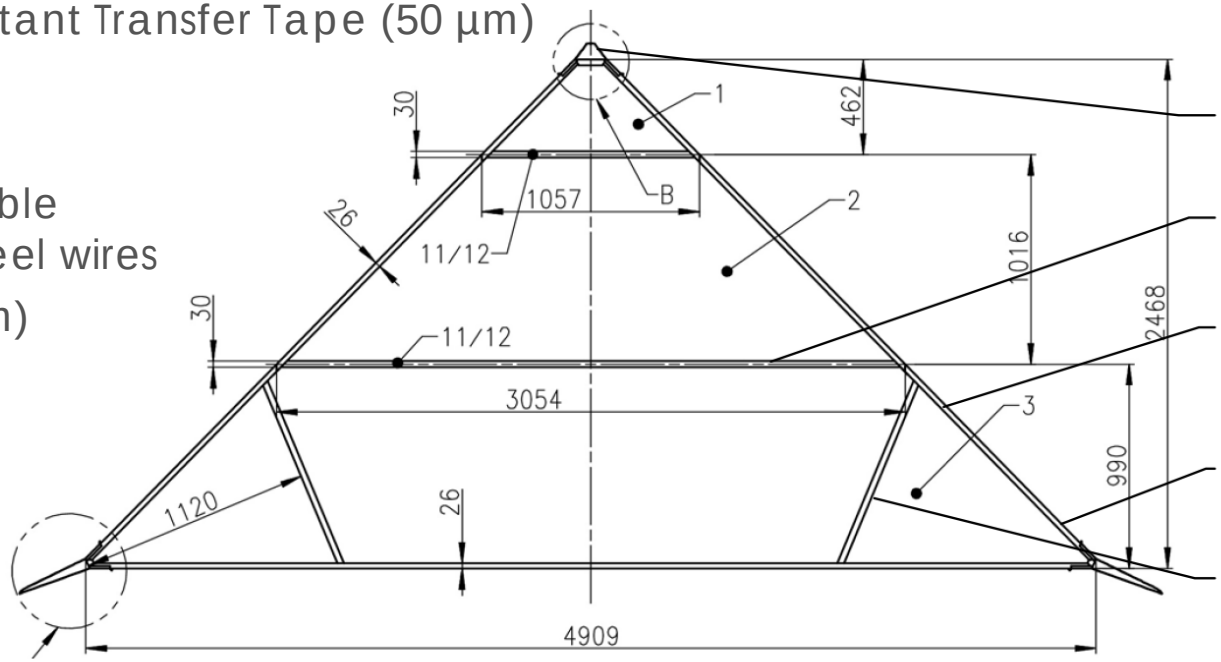
- 4x triangular sail (4.9 x 2.5 m²)
- 25 m² Drag Area

  → sufficient to de-orbit 1000 kg S/C from 650 – 700 km in 25 years
- Pyramidal arrangement to ensure stability





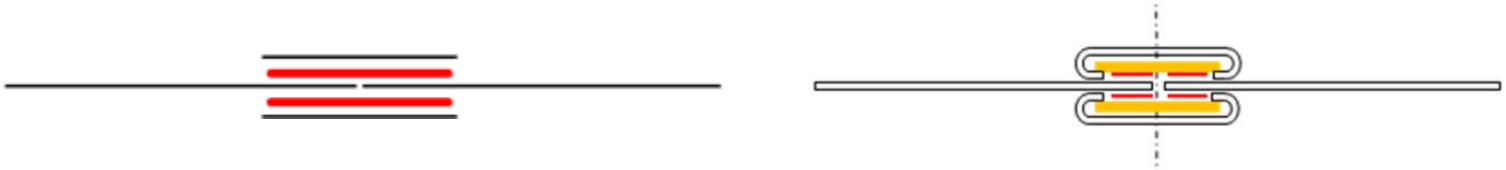
- Membrane Design
- Membrane Basic Material
  - Al coated PI Foil (12,5 µm)
  - 2 configurations possible: 100 nm AL and 500 nm Al coating
- Joints and Crack Stoppers
  - Al coated PI Foil (12,5 µm)
  - Temp. resistant Transfer Tape (50 µm)
- Interfaces
  - Highly flexible stainless steel wires (Ø 0,45 mm)



- Joints and Interfaces Design

  - Edge design

  - Joint Design

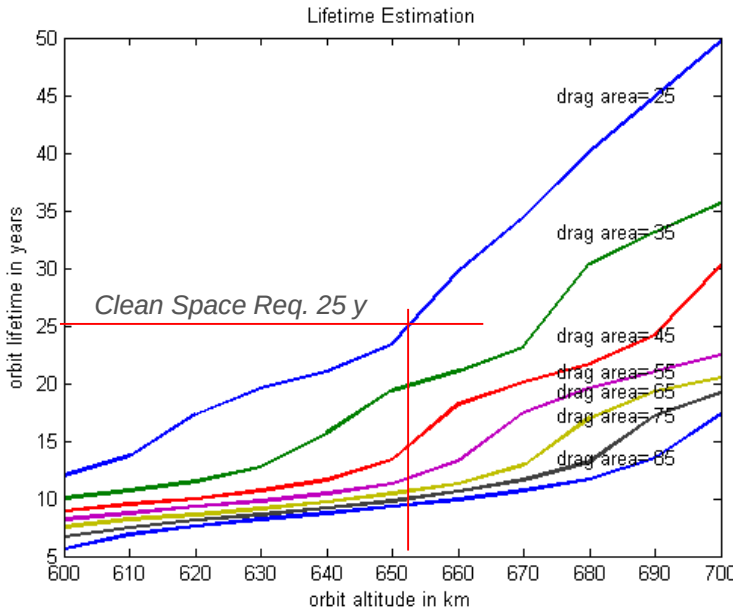


Standard Double Lap Joint

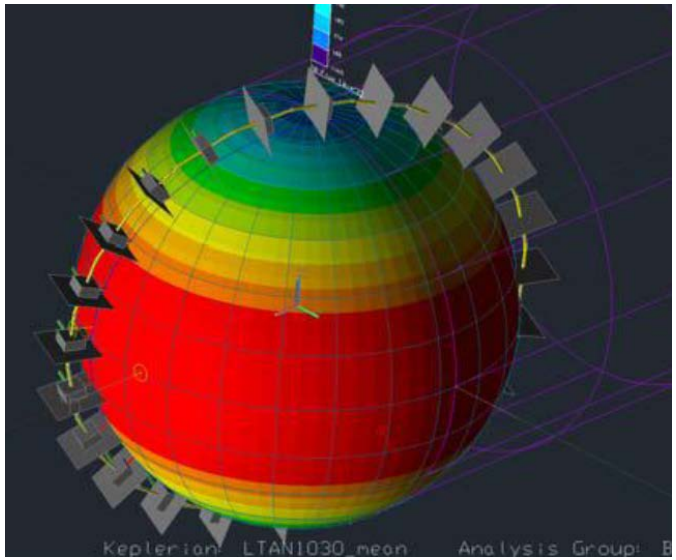
Design Optimized for AO Resistance

Simulations and Analyses of Deployable Membrane

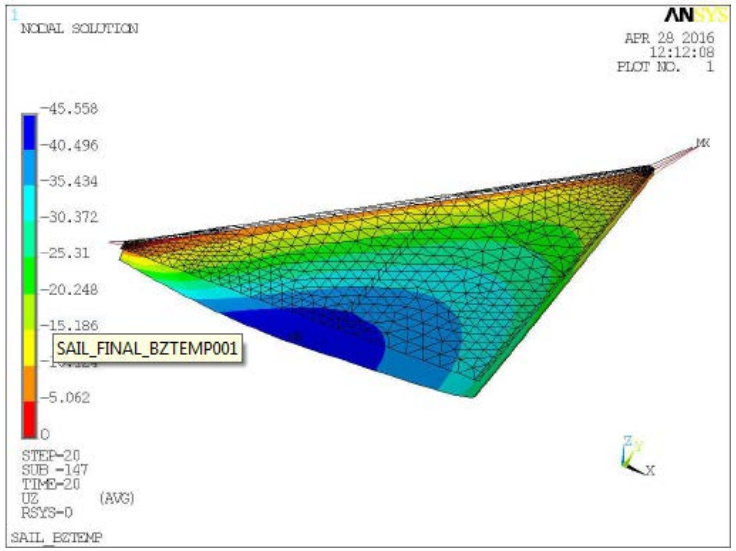
- Deorbiting Analysis
  - 25 m² Drag Area
  - 25 y descent duration
  - Starting from 650 km
  - Evaluation of maximum drag force



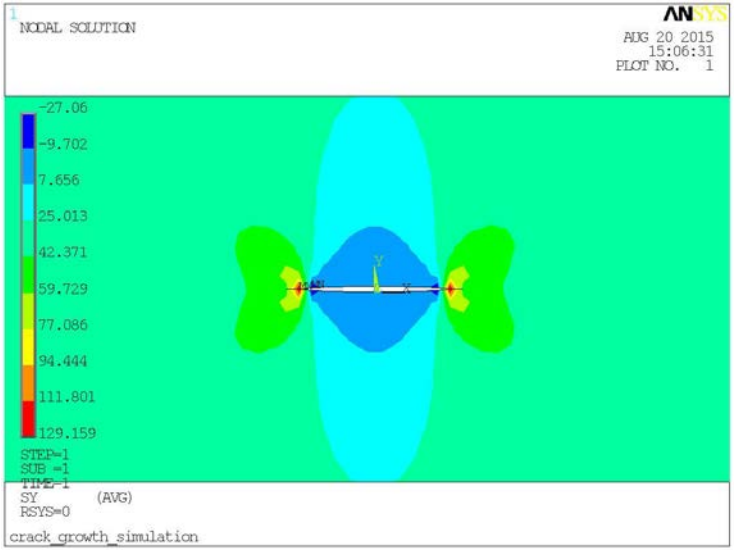
- Thermal Analysis
  - Orbit Analysis (LEO)
  - Sail Temperatures: - 100 °C … 220 °C
  - Thermo-optical properties are driving → coating selection



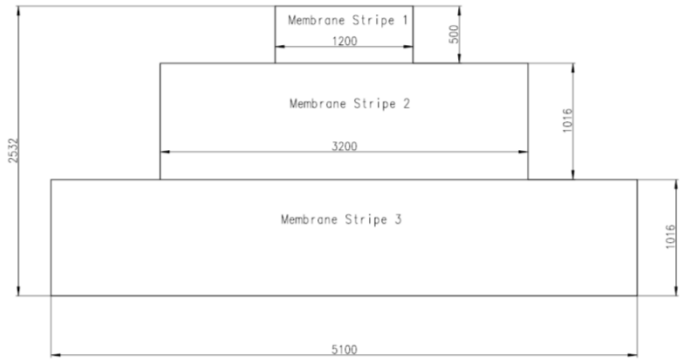
- Quasistatic Analysis
  - Quasi-static drag force
  - Negligible slack due to small drag forces
  - Reaction forces in I/F
  - Stresses
  - At room temp and low temp

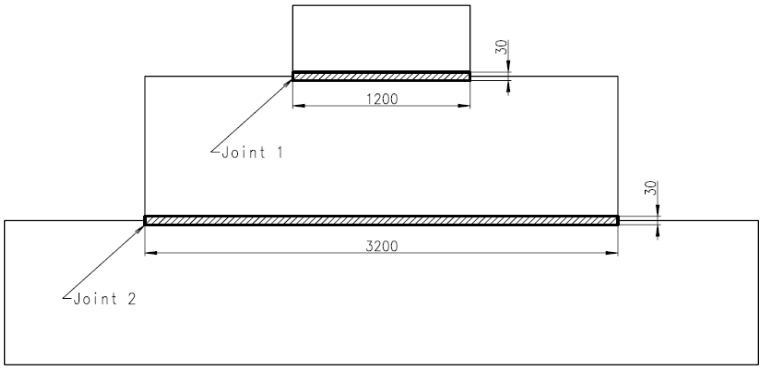


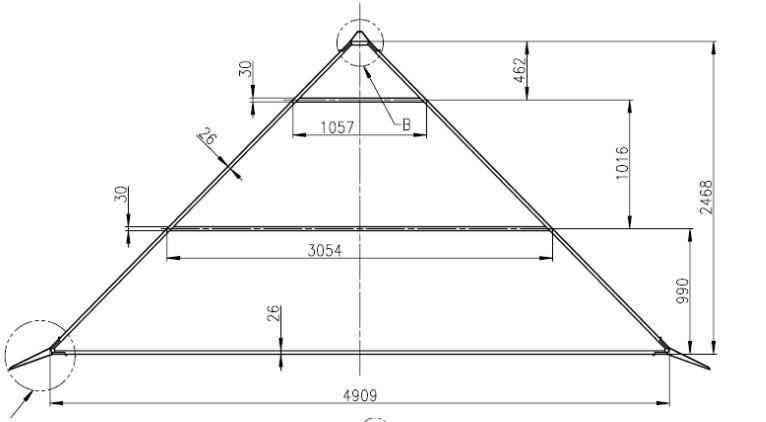
- Crack Propagation Analysis
  - Sample level done
  - Sail level analysis ongoing
  - Based on different matieral properties
  - Correlation with tests ongoing

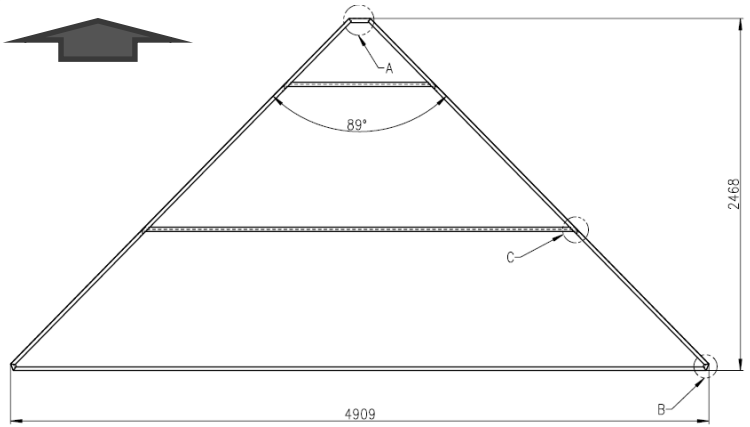


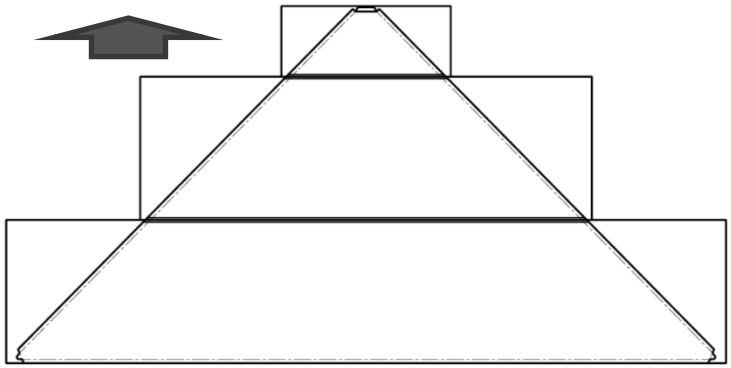
- Manufacturing of 1:1 demonstrator











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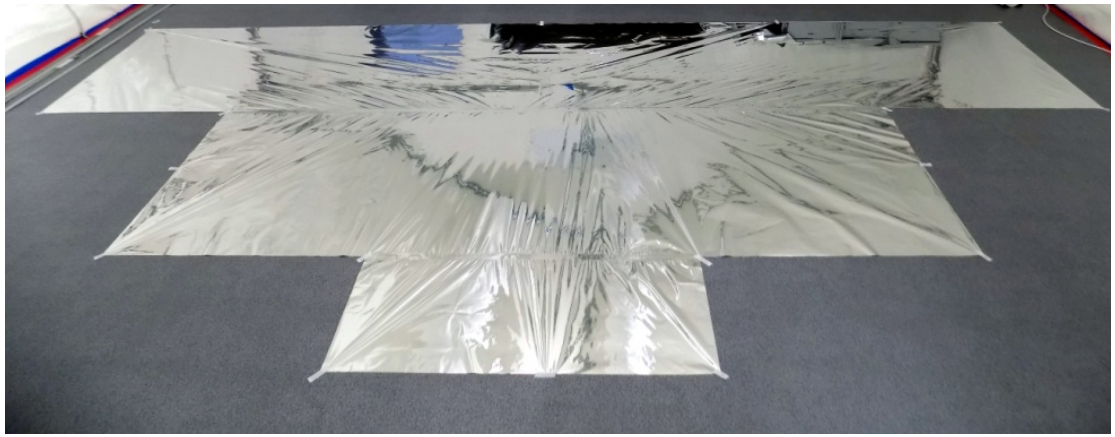
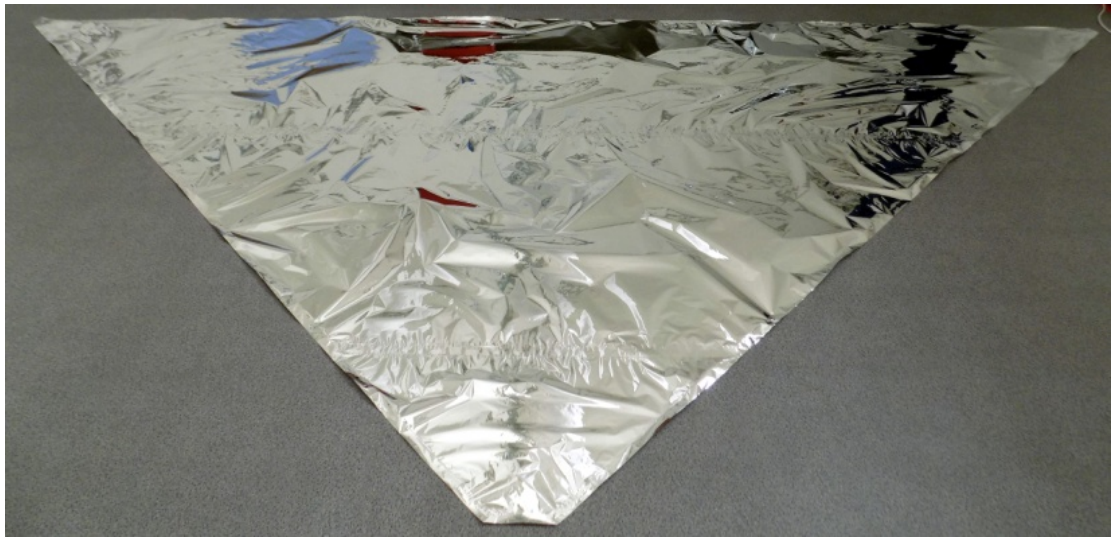
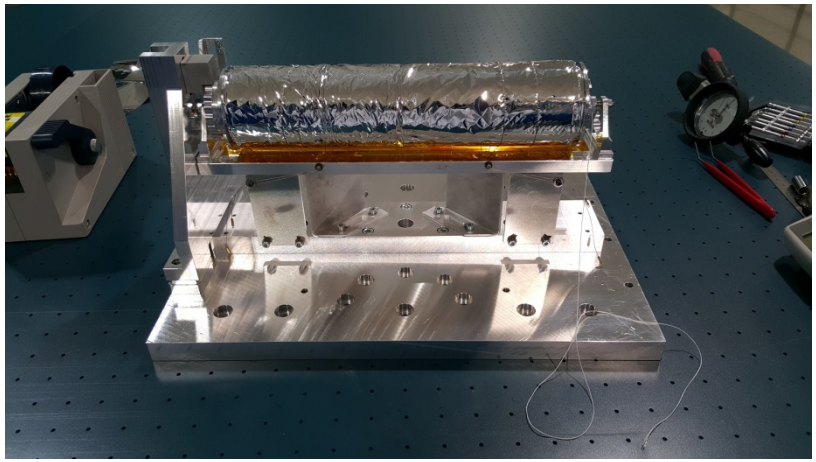
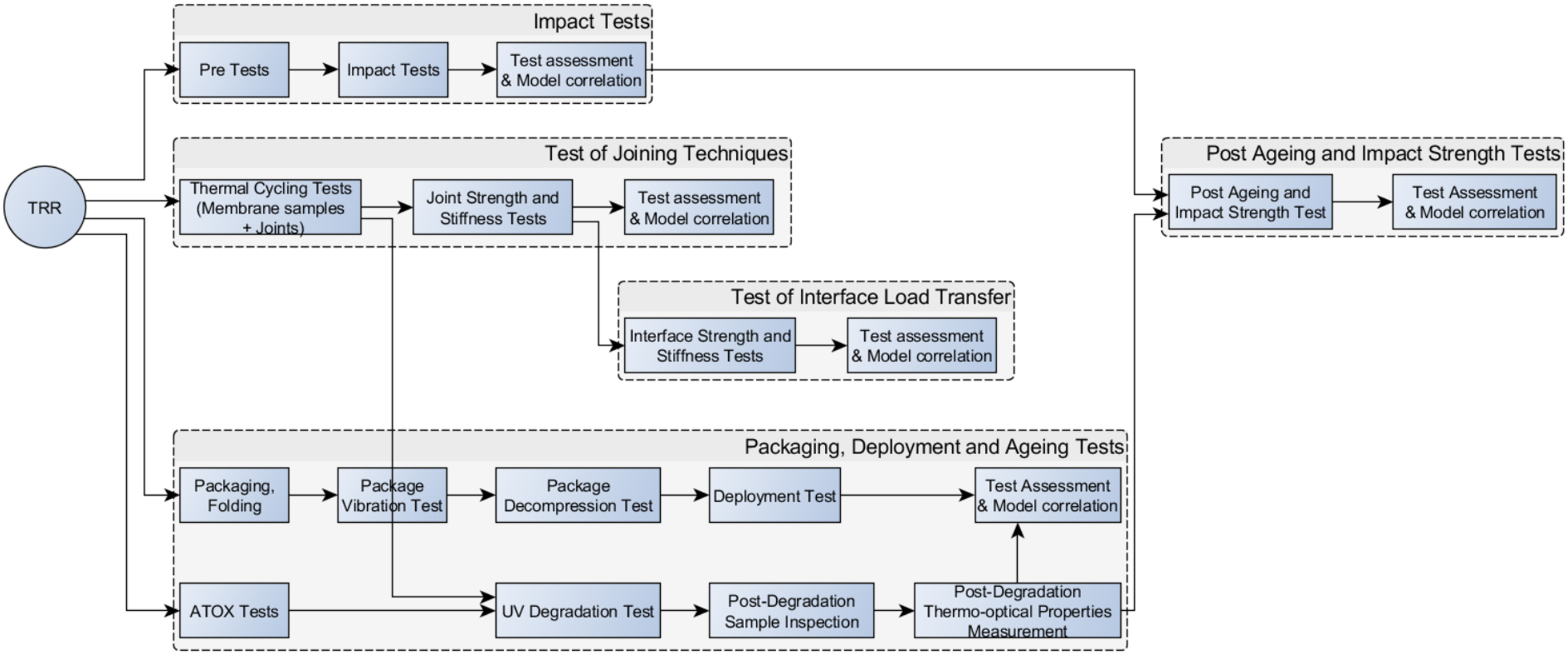




- Demonstator folding and stowing



Test Plan

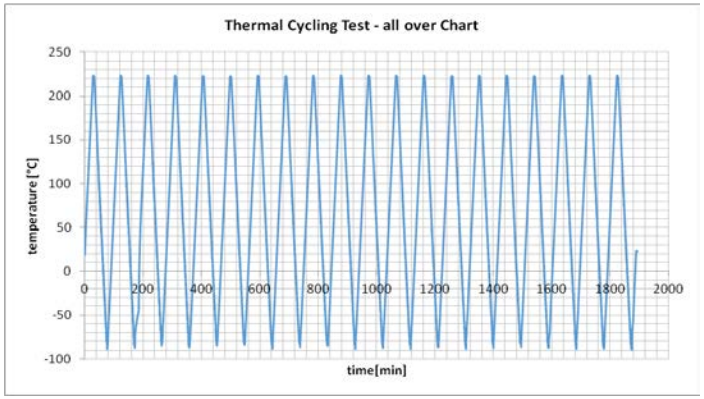

Impact Tests
Pre Tests
Impact Tests
Test assessment & Model correlation
Test of Joining Techniques
TRR
Thermal Cycling Tests (Membrane samples + Joints)
Joint Strength and Stiffness Tests
Test assessment & Model correlation
Test of Interface Load Transfer
Interface Strength and Stiffness Tests
Test assessment & Model correlation
Post Ageing and Impact Strength Tests
Post Ageing and Impact Strength Test
Test Assessment & Model correlation
Packaging, Deployment and Ageing Tests
Packaging, Folding
Package Vibration Test
Package Decompression Test
Deployment Test
Test Assessment & Model correlation
ATOX Tests
UV Degradation Test
Post-Degradation Sample Inspection
Post-Degradation Thermo-optical Properties Measurement

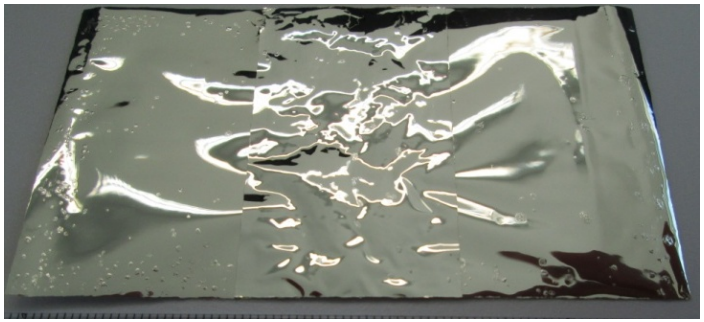
Demonstrator Tests

- Preliminary results

- High velocity impact Tests
  - Projectile diameter 4 mm
  - Projectile velocity > 3 km/s
  - Done

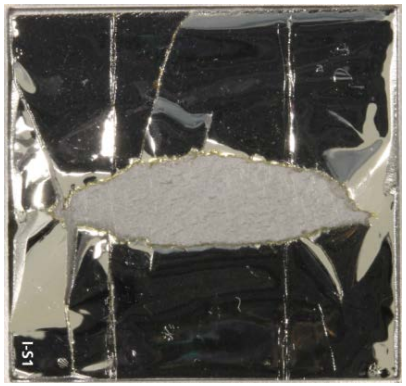
- Thermal cycling
  - 20 cycles
  - Tested temp -80°C … 220 °C
  - 100 nm (Off-the-shelf) samples are in good shape
  - 500 nm (customized coating) samples show bubbles

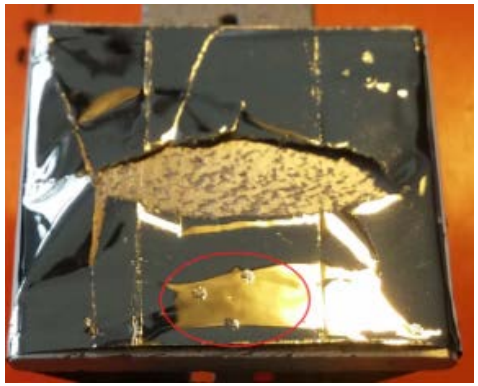




Demonstrator Tests

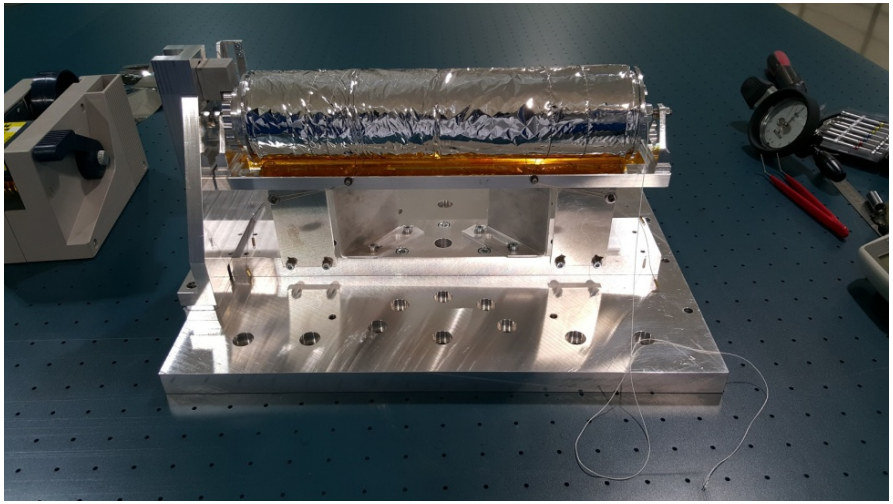
- Preliminary results





- AO Tests
  - AO test done
  - No defect on intact coating
  - No major defects on edges
  - Assessment of results ongoing

- Vibration Test
  - Pattern 1 done
  - Successfully passed



- Fast Decompression
  - Pattern 1 done
  - Successfully passed

- Deployment Tests
  - ongoing

Conclusion and next steps

- Up to know:
  - Comprehensive design phase
  - Detailed simulations
  - Manufacturing of 1:1 demonstrators
- Demonstrator Tests are ongoing
  - First vibration and decompression tests are passed
  - First Deployment test ongoing
- Next test stage: VUV testing (>7400 equivalent sun hours)
- More mechanical tests to be performed
- Finalization of project in Q3 / 2016

Thank you very much!

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