BGA CADM RELEASED

Efficient MLI Mounting Final Presentation

Efficient concepts for mounting of thermal MLI blankets

08 10 2024 | Klaus Reitterer

Efficient MLI Mounting
Presentation Outline

- Motivation for Development
- Development Flow
- Key Requirements for Development
- Pre-Selection – Trade-off
- Selection of mounting techniques
- Test Samples
- Testing
- Conceptual Demonstration Mock-Up (CDM)
- Assessment of Duration and Cost
- Conclusion
- Outlook

Efficient MLI Mounting
Motivation for Development

- State-of-the-art method for MLI fixation is time-consuming
  - Current method: Stand-offs glued to the spacecraft structure, clip washers fix blankets on the stand-offs
  - For a typical satellite more than 1000 stand-offs with several different geometries
  - Considerable design effort: Exact stand-off positions included in 3D CAD model and transferred to 2D template drawings
  - In case of clashes between stand-offs and other items such as harness, lengthy clarification between AIT teams is necessary
  - Current stand-offs are rigid items and nominal position might deviate from actual position; therefore, holes can only be punched in the blankets during integration after fit-check of the blankets

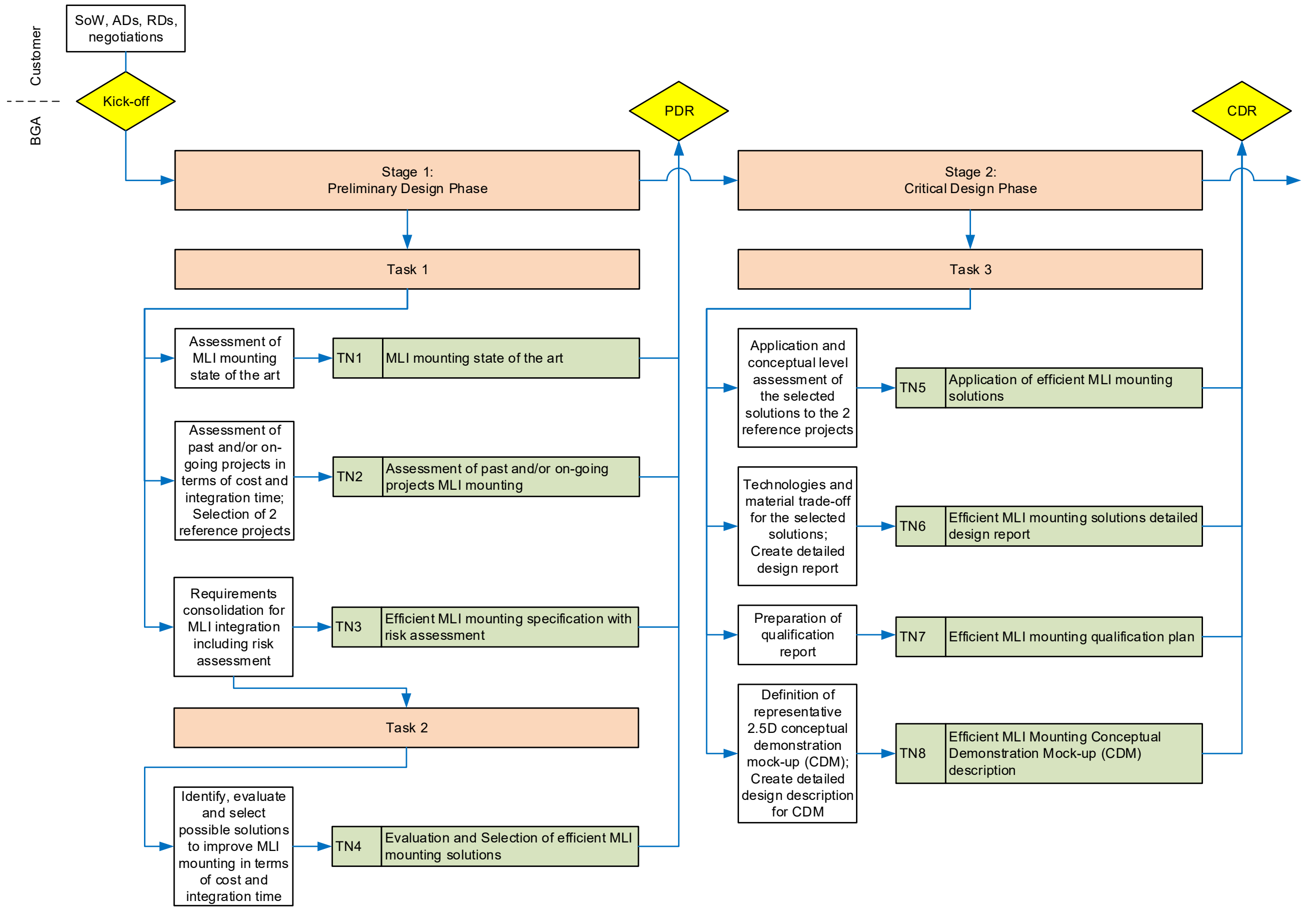
Efficient MLI Mounting
Motivation for Development

beyond gravity

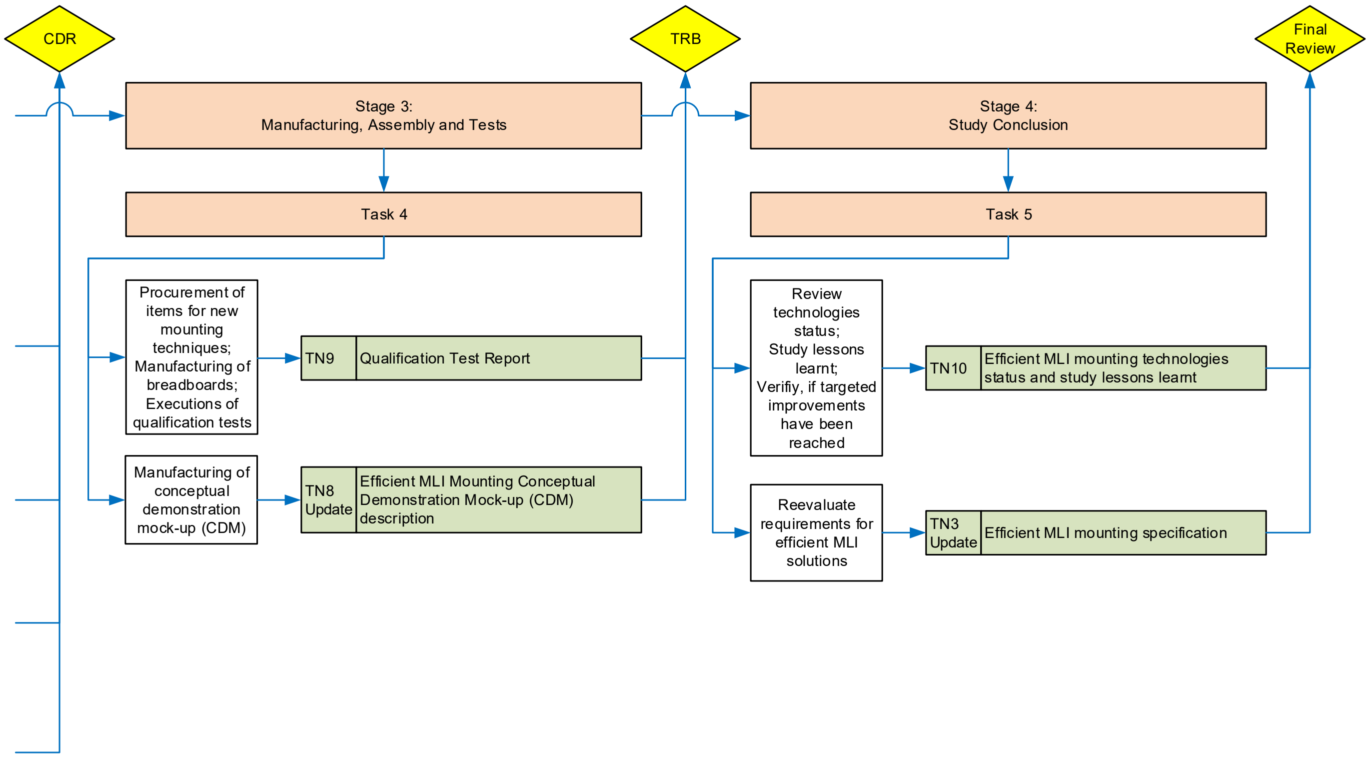
- Development of alternative MLI mounting systems
  - Reduce the time effort and overall cost for MLI integration
  - Consider commercial aspects and typical, technical requirements, e.g. electrical grounding, thermal performance, mass, cleanliness, outgassing, removability, overlapping and interfaces, environmental conditions
  - Improve flexibility of attachment elements
  - Standardize MLI blanket design and attachment to the structure
  - Improve attachment method, e.g. anchoring
  - Reduce number of small items, which have to be handled during the integration
  - Simplify blanket fit-check and punch majority of stand-off holes already during manufacturing

Efficient MLI Mounting

Development Flow – TRL 5



Efficient MLI Mounting
Development Flow – TRL 5



Efficient MLI Mounting
Key Requirements for Development

beyond gravity

- Concepts
  - The solutions shall be generic and flexible so that they fit to a large number of future projects.
- Thermal insulation efficiency
  - same or better as for the state-of-the-art fixation method
- Cost reduction
- MLI integration time reduction
- Mass
  - less than 10% increase

- Typical MLI and structural temperature ranges
- Vibrations: Typical launcher vibration levels enveloping all common launchers
- Electrical grounding: <10 Ω between MLI bonding point and structure, <100 Ω between MLI bonding point and aluminized MLI layer
- Cleanliness: Particulate contamination < 300 ppm (visibly clean)
- Outgassing: RML < 1%, CVCM < 0.1%
- Design constraints: Geometry envelops such as for state-of-the-art fixation method
- Overlapping, interfaces and removability: Comparable to state-of-the-art fixation methods

Efficient MLI Mounting
Pre-Selection – Trade-off

- Trade-off – Technical Criteria
  - Adaptation for variable structure design
    - Ability to cover various S/C shapes and dimensions without redesign of used parts
  - Area coverage
    - Potential for large area coverage on a S/C
  - Compatibility with S/C I/F
    - Standalone concept vs. impact on existing structural design
  - Thermal performance
    - thermal impact when compared to state-of-the-art standoff
  - Mass
    - mass impact when compared to the state-of-the-art method
  - Cleanliness
    - cleanliness impact when compared to the state-of-the-art method

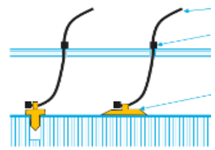
- Trade-off – Development Costs and Risk
  - Complexity
    - Number and complexity of parts
  - Reliability
    - Impact on reliability when compared to the state-of-the-art method
  - Development costs
    - Is concept based on parts/materials already used at BGA or available on the market?
  - Qualification need
    - Development gap to reach flightworthy status

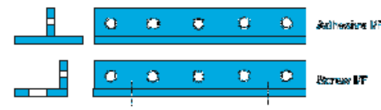
- Trade-off – Commercial Potential
  - Installation effort
  - Recurring cost

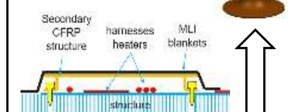
Efficient MLI Mounting

Pre-Selection – Trade-off

- Rating
  - 5: perfect solution
  - 1: bad solution
- Weighting
  - 5: important criterion
  - 1: less important criterion





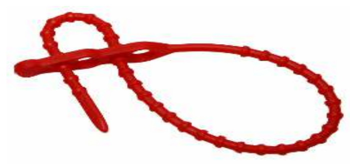


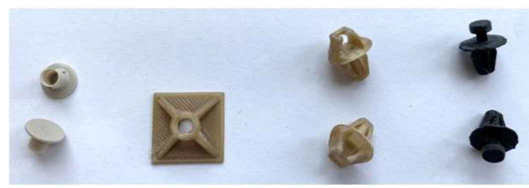
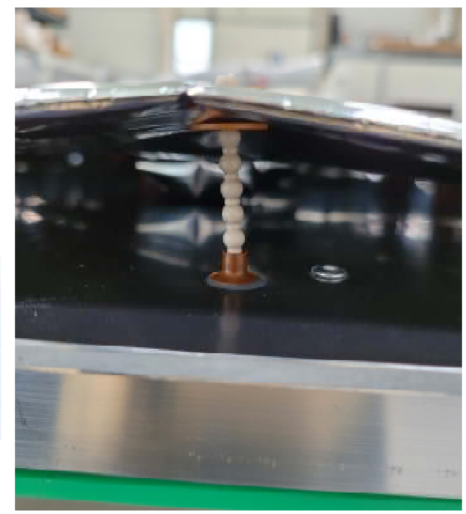
Criteria	Weighting	Flexible Blanket Fixation				Attachment to Structure (fixation techniques from other markets)					
		para.3.1.1 Ty wrap		para.3.1.2 Fixation - Lace		para.3.2.1 Adhesive I/F		para.3.2.1 Anchor I/F		para.3.2.1 Screw I/F	
		rating	weighted	rating	weighted	rating	weighted	rating	weighted	rating	weighted
4.3.1 Technical											
Adaptation for variable structure design	4	4	17	4	16	4	17	3	13	3	10
Area coverage	3	4	13	4	13	4	12	3	10	3	10
Compatibility with S/C I/F	4	4	17	4	17	4	16	3	10	2	8
Thermal perfofrmance	4	4	15	4	15	4	14	4	15	4	14
Mass	3	4	12	4	12	4	12	4	12	3	10
Cleanliness	3	4	13	3	10	4	12	4	12	4	13
average	3,7	4,1	14,2	3,9	13,6	4,0	13,8	3,5	11,9	3,2	10,8
4.3.2 Development costs / risks											
Complexity	4	4	14	4	15	4	15	4	14	3	12
Reliability	4	4	17	4	15	4	16	4	15	5	19
Development costs	3	4	11	3	9	4	11	4	11	4	12
Qualification need	3	4	9	3	7	2	5	3	8	4	11
average	3,3	3,9	12,7	3,4	11,4	3,5	11,9	3,6	11,8	4,2	13,7
4.3.3 Commercial potential											
Installation effort	5	4	19	4	19	3	15	5	22	3	16
Recurring costs	4	4	18	4	16	4	15	4	16	3	11
average	4,4	4,2	18,5	4,0	17,7	3,5	15,3	4,3	18,9	3,1	13,7
Sum			45,3		42,6		41,0		42,5		38,1
Rank Total			2		5		8		6		9

Criteria	Weighting	Attachment to Structure fixation cleat				Ancor S/O		Self-Adhering MLI Blankets		Secondary Structure Elements		Modular Standoff	
		para.3.2.2 Cleat bonded		para.3.2.2 Cleat screwed		para.3.2.3 Ancor I/F		para.3.3 Velcro Fixation		para.3.4 CFRP structure		para.3.5 Bonded and screwed I/F	
		rating	weighted	rating	weighted	rating	weighted	rating	weighted	rating	weighted	rating	weighted
4.3.1 Technical													
Adaptation for variable structure design	4	3	12	2	9	4	16	4	15	4	16	5	20
Area coverage	3	3	10	3	9	4	13	4	14	4	13	4	13
Compatibility with S/C I/F	4	3	12	2	8	4	15	4	15	4	15	5	19
Thermal perfofrmance	4	4	13	4	14	4	14	4	14	4	16	4	14
Mass	3	3	8	2	7	4	13	4	11	3	10	4	13
Cleanliness	3	4	13	4	13	4	12	2	6	5	14	4	12
average	3,7	3,3	11,3	2,9	9,9	4,0	13,8	3,6	12,4	4,0	13,9	4,3	15,2
4.3.2 Development costs / risks													
Complexity	4	3	12	3	12	4	15	5	17	4	15	4	15
Reliability	4	4	15	4	16	4	16	3	12	4	17	5	20
Development costs	3	3	8	3	8	5	14	4	10	3	8	3	8
Qualification need	3	3	9	3	8	5	13	4	9	2	5	4	10
average	3,3	3,4	11,0	3,3	11,1	4,5	14,4	3,7	12,0	3,3	11,2	4,0	13,4
4.3.3 Commercial potential													
Installation effort	5	3	15	4	17	4	19	4	21	5	24	3	15
Recurring costs	4	4	14	3	11	4	16	4	17	3	12	3	12
average	4,4	3,4	14,9	3,2	14,1	4,0	17,7	4,3	18,9	4,0	18,1	3,0	13,3
Sum			37,2		35,1		45,9		43,3		43,2		41,8
Rank Total			10		11		1		3		4		7

Efficient MLI Mounting
Selection of “local” mounting techniques

- Flexible, modular stand-off concept consisting of
  - Different shafts
    - Ball rod (Aluminium, PEEK, Vespel, Vespel Alternative)
    - Commercial ball ty-wrap (Polyethylene)
  - Different bases
    - Base type RD (PEEK, PET) – for ball rod
    - Base type SQ (PEEK) – for ball rod
    - Clip-in type F (PEEK, PET) – for ball rod
    - Clip-in type M (PET) – for commercial ball ty-wrap
  - Different washers
    - Clip hat (Vespel, Vespel Alternative) – for ball rod
    - Cover cap clip (PEEK, PET) – for ball rod
    - Cover cap washer (PEEK) – for commercial ball ty-wrap
    - Cover cap (Vespel, Vespel Alternative) – for cover cap clip and cover cap washer
    - State-of-the-art clip washers – for ball rod
  - Novel type of self-adhering, reclosable fastener



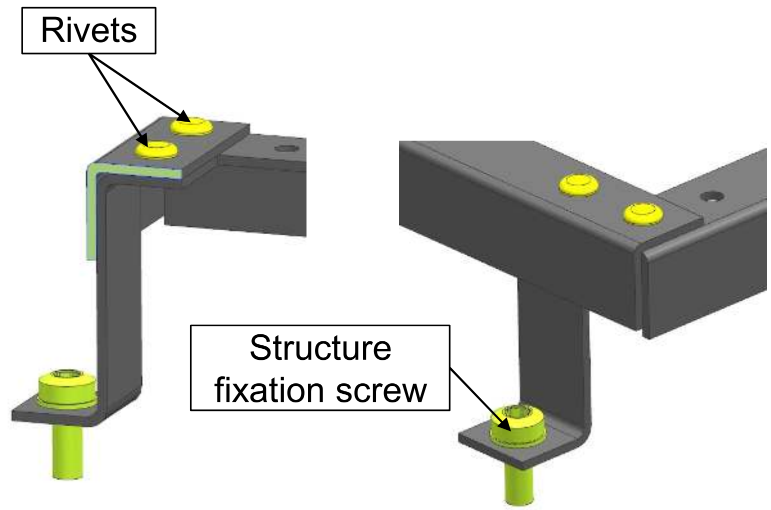



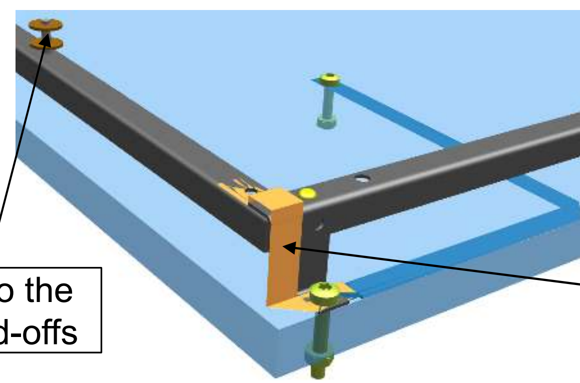


Efficient MLI Mounting

Selection of "global" mounting technique

- Standardized, lightweight secondary structure frame
  - with pre-mounted and pre-grounded MLI blanket



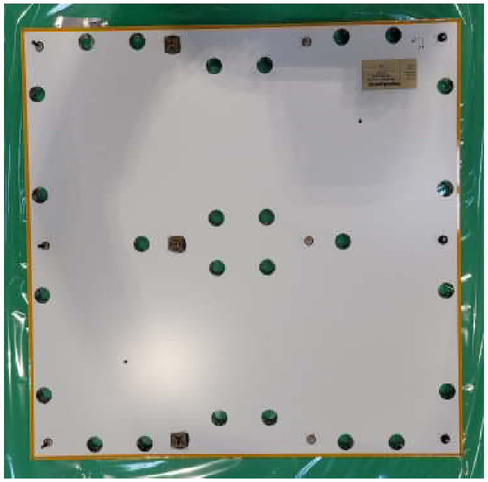


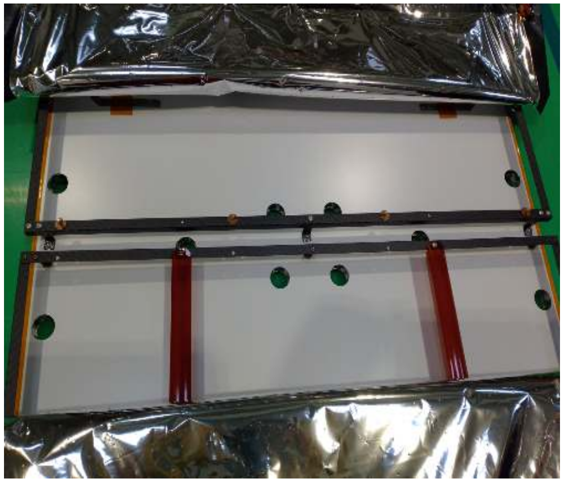
Pre-mounting of MLI blankets to the frame with state-of-the-art stand-offs

Grounding of the frame/MLI assembly via incorporated aluminium grounding straps

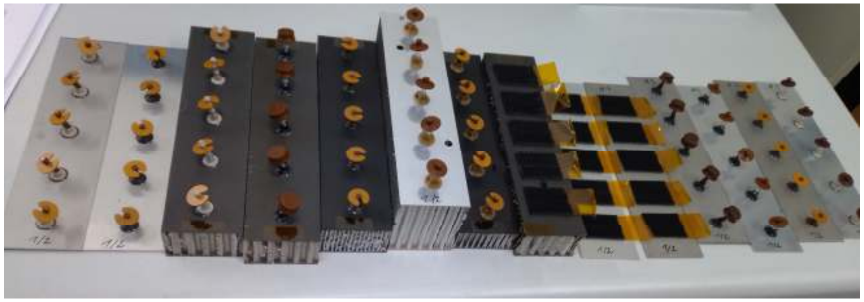
Efficient MLI Mounting
Test Samples

- Breadboards:
  - 4 breadboards
  - 1 reference breadboard
  - 600 x 600 mm each
  - thermal cycling, mechanical vibration
  - visual inspection
  - electrical resistance measurements
  - mass measurements
  - particulate contamination test

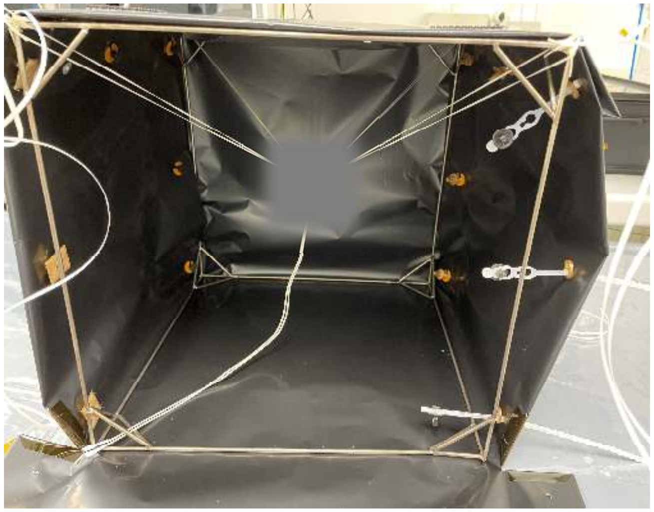




- Attachment test samples:
  - 11 different material combinations
  - 3 different substrates (aluminium, CFRP, titanium)
  - 200 x 50 mm each
  - thermal cycling, mechanical pull-off test
  - visual inspection



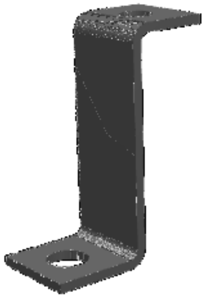
Efficient MLI Mounting
Test Samples



- 3D cube test sample:
  - 300 x 300 x 300 mm
  - thermal performance test
  - 5 different, novel attachment elements incorporated

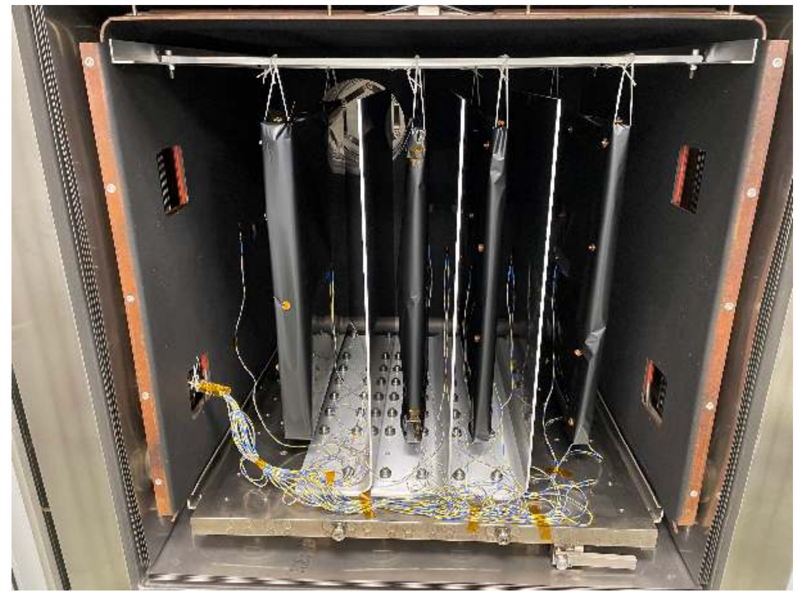
- Outgassing test samples:
  - standard outgassing test at 125°C
  - 4 novel materials tested (PET, PEEK, Vespel Alternative, CFRP profile)

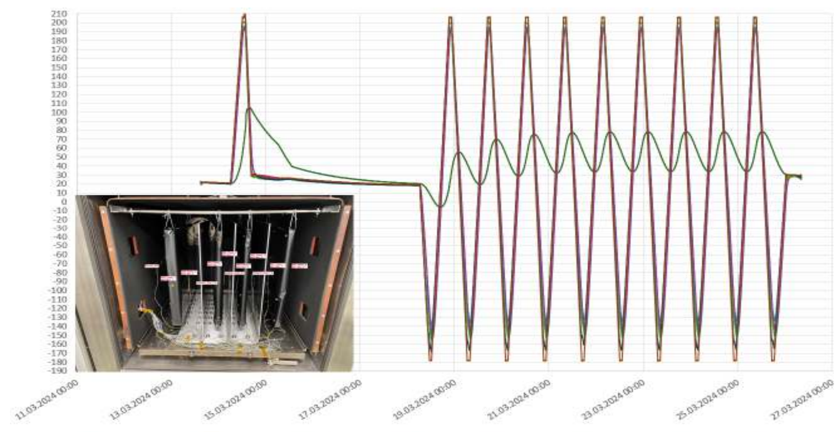


Efficient MLI Mounting
Breadboard Testing

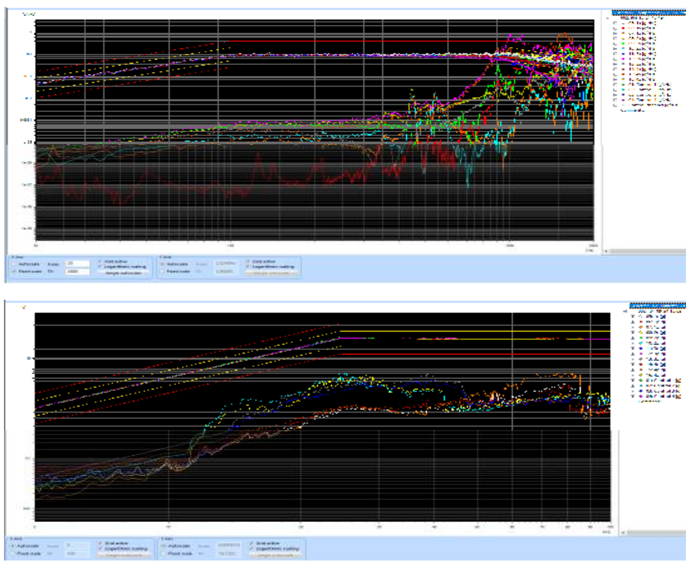
- Breadboard thermal cycling test
  - -130°C to +200°C on the outermost black Kapton layers specified for pilot thermocouples
  - Down to ≈ [-140°C ÷ -150°C] and up to ≈ +196°C actual temperatures on outermost black Kapton layers
  - On breadboard panels underneath the MLI blankets: Between ≈ [+35°C ÷ +45°C] and ≈ [+80°C ÷ +85°C] for BB1, BB2 and BB4, up to ≈ +110°C for BB3
  - Pressure < 1 x 10^{-5} mbar
  - 10 cycles

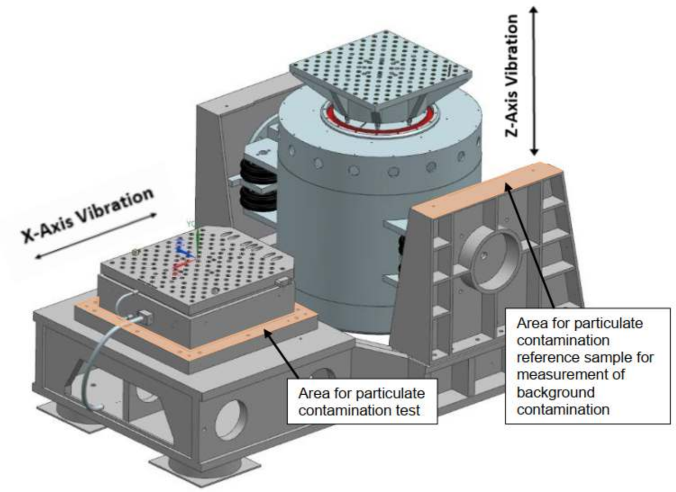


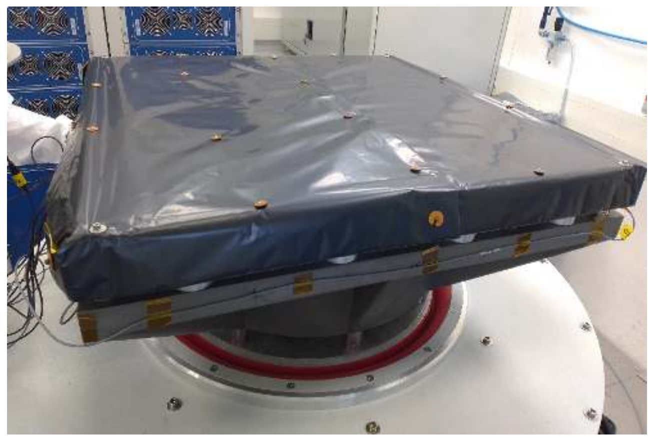


Efficient MLI Mounting
Breadboard Testing

- Breadboard mechanical vibration test
  - Typical launcher vibration levels enveloping all common launchers
  - Random and sine mechanical environment tested
  - In plane and out of plane tested

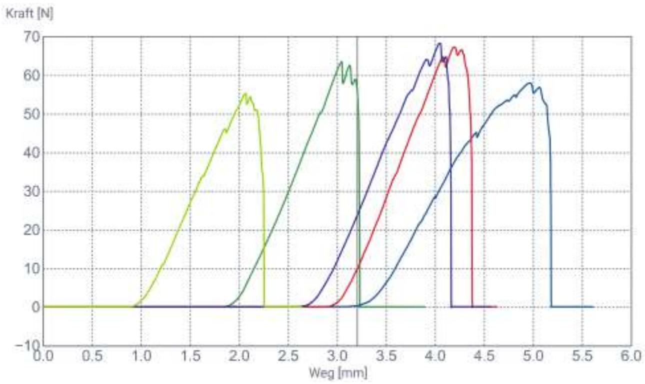






Efficient MLI Mounting
Attachment Testing

- Attachment thermal cycling test
  - Thermal cycling -100°C to +70°C
  - Pressure < 1 x 10^{-5} mbar
  - 100 cycles
- Pull-off test
  - At room temperature
  - Cycled and uncycled reference samples tested and compared



Efficient MLI Mounting
3D Cube Testing

- 3D Cube test
  - 7 test cases
  - Pressure < 1.3 x 10^{-5} mbar

Test case	Avg. Temp. Outermost Layer [°C]	Avg. Temp. Innermost Layer [°C]	Avg. Specimen Temp. [°C]
1	-141	-79	-108
2	-141	-37	-84
3	-139	48	-34
4	-81	56	-7
5	0	73	38
6	39	84	62
7	39	112	77

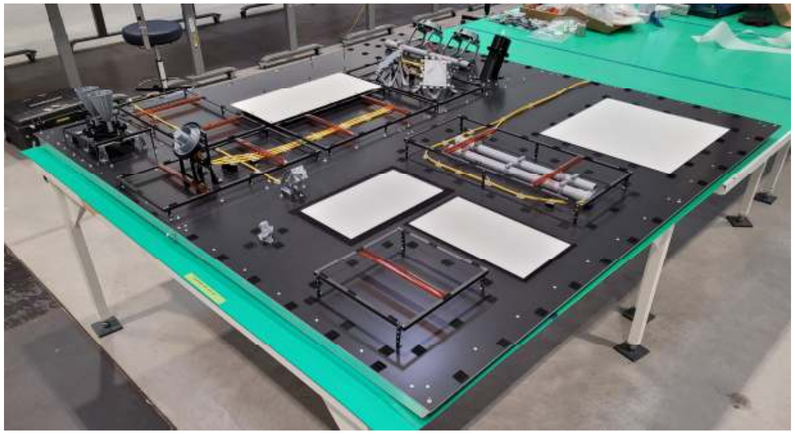
Efficient MLI Mounting
Outgassing Testing

- Outgassing test
  - Acc. ECSS-Q-ST-70-02C
  - At nominal temperature of 125°C

Efficient MLI Mounting

Conceptual Demonstration Mock-Up (CDM)

- Demonstration of integration feasibility of novel attachment concepts
- 2m x 2m mock-up representing a full-scale satellite panel
- Including typical items:
  - 3D printed polyester brackets from FLEX THW and JUICE SSTS
  - Harness made of commercially available harness
  - Radiators made of simple aluminium plates
  - Pipes made of simple plastic tubes
- MLI blankets made of polyester layup with 10 layers
- Attachments consisting of:
  - State-of-the-art stand-offs
  - Different types of new, local attachment elements (bases, ball rods, clips), implemented as bonded and floating stand-offs
  - New type of self-adhering, reclosable fastener
  - Secondary structure CFRP frames



Efficient MLI Mounting
Assessment of Duration and Cost

beyond gravity

- Local mounting techniques

Used main elements	**LC compared to state-of-the-art (MLI integration time)**	**NLC compared to state-of-the-art (cost)**	**Total cost compared to state-of-the-art (LC and NLC)**
Aluminium ball rod, self-adhering reclosable fastener	≈ -16%	≈ -25% (ball rods) ≈ -84% (reclosable fasteners)	≈ -17% (ball rods) ≈ -18% (reclosable fasteners)
Vespel ball rod	≈ -16%	≈ +14% (due to use of expensive Vespel ball rods)	≈ -15%
Commercial ball ty-wrap	≈ -16%	> +200% (due to use of expensive Vespel clip hats and cover caps)	≈ -7%
Conclusion for local mounting techniques	Substantial cost and effort reduction achieved with new techniques, extent depending on the selected material solutions		

- Overall, all local concepts lead to a reduction of the total cost (LC and NLC).

Efficient MLI Mounting

Assessment of Duration and Cost

- Global mounting technique

Used main elements	LC compared to state-of-the-art (MLI integration time)	NLC compared to state-of-the-art (cost)	Total cost compared to state-of-the-art (LC and NLC)
Secondary structure frame - assessment for complex, scientific program	≈ -9%	≈ +18%	≈ +10%
Secondary structure frame - assessment for constellation program	≈ -50% (due to use of a high number of standardized frames)	≈ +18%	≈ -2%
Conclusion for global mounting technique	Solutions yield similar or higher cost		

- Overall, the global concept leads to a small cost reduction only for constellation programs.
- The justification for the global concept is to provide technical solutions for complex areas on scientific satellites, even though they are slightly more expensive than the state-of-the-art concept.
- For constellation programs several risks of the state-of-the-art concept can be mitigated with the new global concept, therefore, the global concept leads overall to an improvement of the MLI integration process for constellation programs.

Efficient MLI Mounting
Conclusion

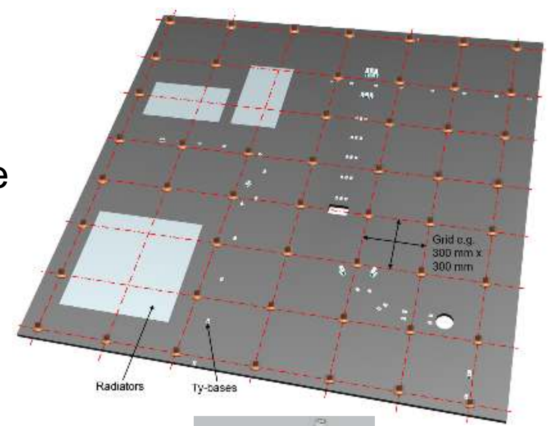
- **All tests successfully conducted**
  – Thermal, mechanical, electrical, mass, cleanliness, performance, outgassing, overlapping/interfaces/removability/geometry envelops

- **Assessments performed**
  – MLI integration time
  – Cost

- **Thermal, mechanical:** All concepts passed, <u>except for</u>:
  – Commercial ball ty-wrap (melted during breadboard thermal cycling)
  – Small parts made of PET (parts were deformed or broke)
  – Self-adhering, reclosable fastener (melted during breadboard thermal cycling, low fracture forces during pull-off testing)

Efficient MLI Mounting
Outlook

- Introduce new concepts to the market as of now
- Include concepts in upcoming MLI projects, e.g. with the following scenario for the local mounting technique:
  - Bond stand-off bases on the panels in a certain grid at an early stage, i.e. when the S/C panels are still almost empty, at the same time when e.g. harness ty-bases or radiators bonding takes place.
  - Punch stand-off holes in the MLI blankets already during manufacturing.
  - During MLI integration the ball rods are clicked in the bases. The lengths of the ball rods can be chosen during integration by cutting the ball rods to length as needed.
  - Integrate MLI blankets by using the rotational flexibility of the ball rods.
- Obtain flight heritage in 2025-2026



Efficient MLI Mounting
Acknowledgements

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  - K. Reitterer – Beyond Gravity
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- BEYOND GRAVITY
  - Development, Manufacturing & Testing

Thank you for your attention

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