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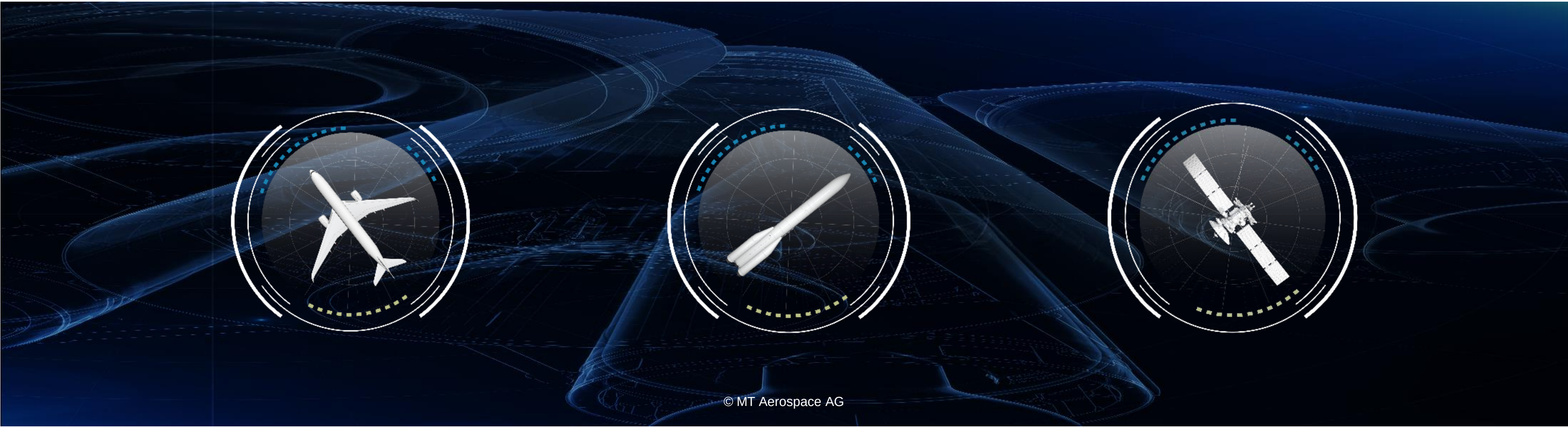

COMPOSITE LANDING STRUCTURES FOR REUSABLE LAUNCH VEHICLES

M. JEVONS, C. THIES, D. DIŠLIJESKI AND P. STARKE

MT AEROSPACE – WHO WE ARE

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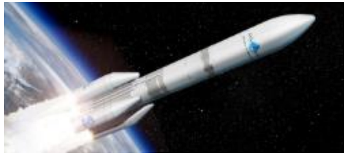
OHB

OHB Systems



Aerospace & Industrial Products

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- **OHB SE** one of the largest European space companies
  - Revenue 1 BN€
  - ~2500 employees
- **MT Aerospace AG** is the launcher division of OHB
  - Established in 1969 as MAN New Technologies
  - ~500 employees
  - Revenue 122 M€ (2021)

Space

- Launcher
- Spacecraft
- Satellite Components
- Structures & Tanks
- Development & Manufacturing

Aeronautics & Defence

- Water Tanks & Structures
- Development & Manufacturing

Infrastructure & Ground Services

- Ground Infrastructure
- Launch Site Operations

MT AEROSPACE WORKSHARE IN ARIANE 6

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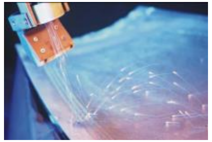
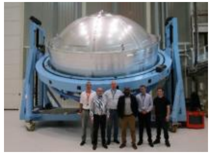
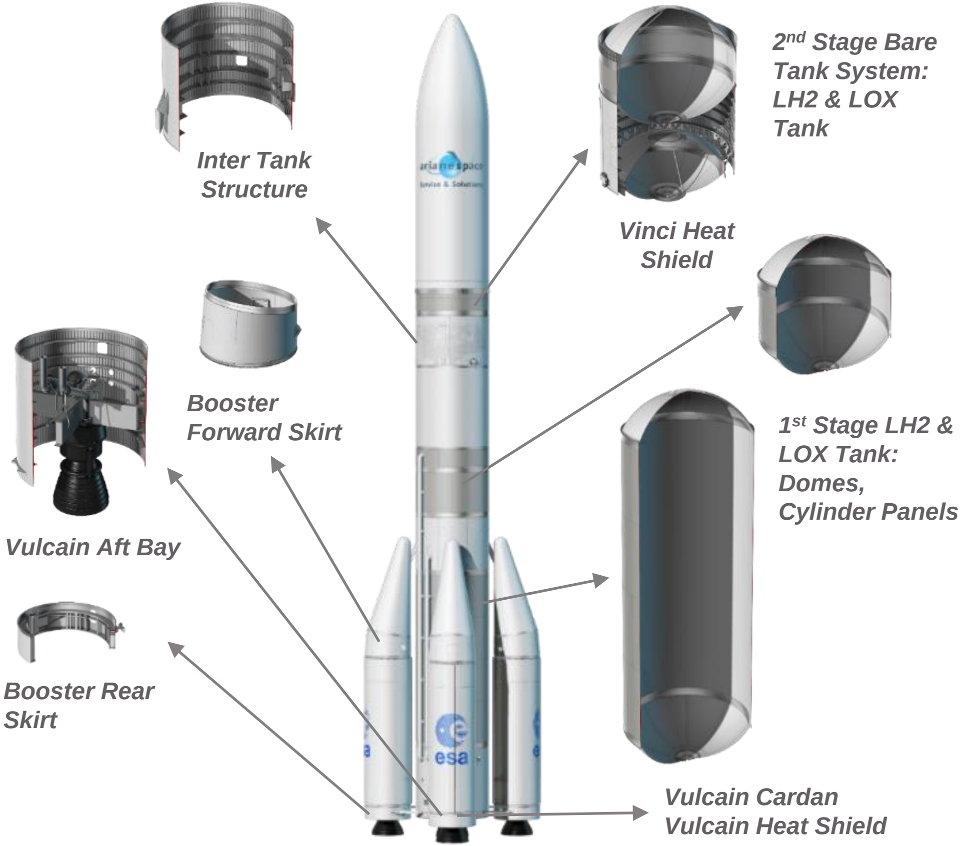
- MT Aerospace holds about 10% workshare in Ariane 6
- Design definition authority for metallic aero structures
- Design and development responsibility for core manufacturing processes/facilities







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Focus: **Reusability**

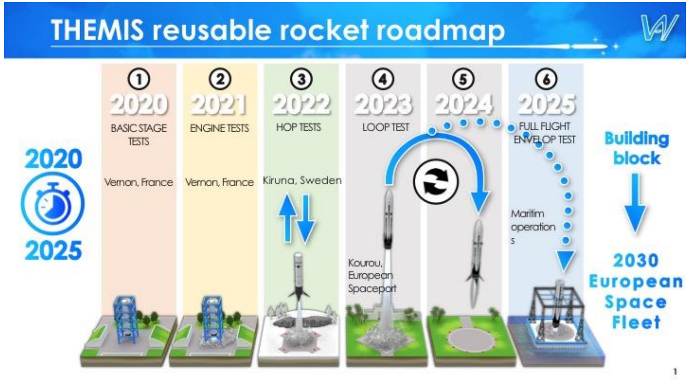
Source

MT Aerospace Activities:

- RETALT[1]
  - Landing structures
  - Control Surfaces
- THEMIS[2]
  - Propellant tank for T1H launcher
- SALTO[3]
  - Propellant tank for THEMIS T3 launcher
  - Landing structures demonstrator for THEMIS T3 launcher
  - Ground operations

RETALT
RETro propulsion Assisted Landing Technologies

This project has received funding from the European Union's Horizon 2020 Research and Innovation Framework Programme under Grant Agreement No. 821890



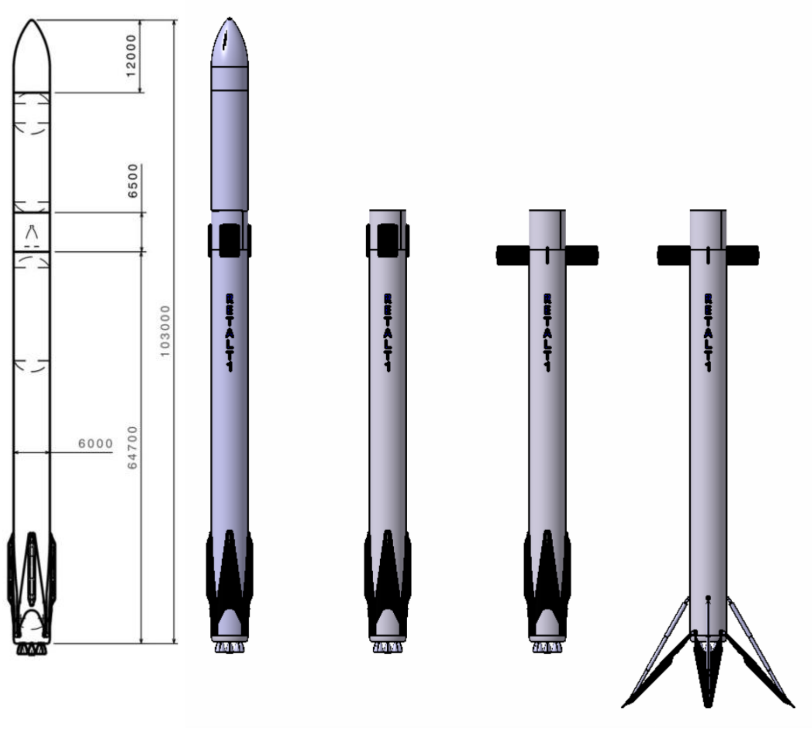
Source

This project is receiving funding from the European Union's Horizon Europe Research and Innovation Framework Programme under Grant Agreement No. 101082007

[1]European Union fundend RETALT project, Grant Agreement number 821890
[2]ESA THEMIS programme
[3]Ariane Group press release , Grant Agreement number 101082007

THE RETALT LAUNCHER

Key Charachteristics	
Payload	14t
Orbit	GTO
Reusability	1st Stage only
Oxydator/Propellant	LOX/LH2
Overall length	103m
First stage length	64.7m
Diameter	6m
Return control mechanism	Deployable supersonic aerofoil
Landing mechanism	Deployable landing legs
Mass budget for landing mechanism	4000kg



Marwege, A., et al., “RETALT: review of technologies and overview of design changes”, CEAS Space Journal 2022.

LANDING LEG CONFIGURATIONS

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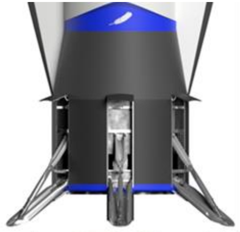
Characteristics	Concept 1	Concept 2	Concept 3	Concept 4
Style	1	1	2	3
Number of legs	4	8	6	6
Structure mass [kg]	536	186	356	139
Mechanism mass [kg]	464	314	311	528
Total mass per leg	1000	500	667	667

Selection criteria	Concept 1	Concept 2	Concept 3	Concept 4
Performance	4.8	4.8	3.6	4.3
D&D Risk	2.0	2.0	1.9	2.1
Cost	4.2	3.8	3.2	3.8
Integration	3.0	3.0	3.0	3.4
Life & Reliability	4.2	4.7	3.7	4.0
Final score	**3.64**	**3.65**	**3.09**	**3.52**

Final selection: **Concept 1**

Note: although Concept 2 had a slightly higher score, the reduced number of active components was deemed preferable.

Configuration concept styles:

1


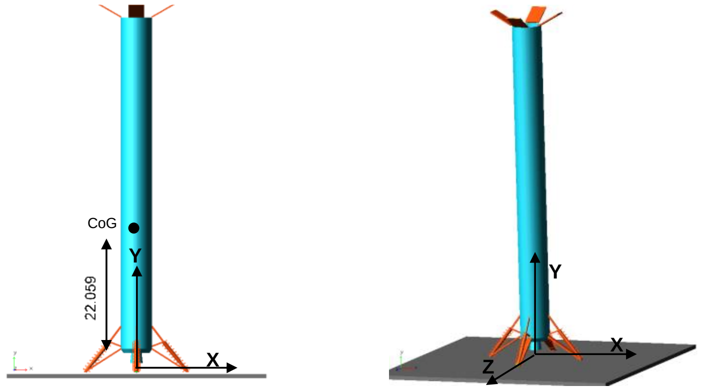
2

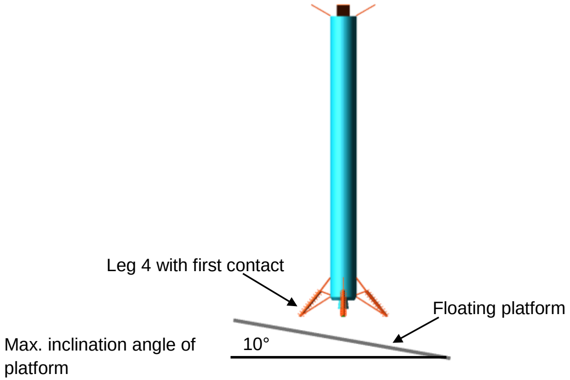

3


[2]https://www.blueorigin.com/new-shepard/
[1,3]https://www.blueorigin.com/new-glenn/

LOAD CASES

Mass core stage [t]	Total mass [t]	Velocity v_0 axial [m/s]	Velocity v_0 lateral [m/s]	Friction [Stick]	Friction [Slip]	Inclination Angle [°]	Reach parking position		
							yes	no	comment
59.3	61.3	-15.0	0.0	0.5	0.1	10.0	-	x	sliding from Pad
		-5.0		0.5			x	-	less sliding no drop off from pad
				0.3			-	x	sliding from Pad
				0.4			-	x	sliding from Pad
	66.3	-5.0		0.5			x	-	less sliding **no** drop off from pad
	61.3	-15.0		0.5		5.0	x	-	less sliding **no** drop off from pad
				0.3			x	-	less sliding **no** drop off from pad
				0.1			x	-	less sliding **no** drop off from pad
		-4.3	-5	0.5		10	x	-	less sliding **no** drop off from pad
		-5.5	5				-	x	sliding from Pad
		-5.5	4				-	x	sliding from Pad
		-4.5	3				-	x	sliding from Pad
		-4.5	0.5				x	-	less sliding **no** drop off from pad
		-15	5	0.1		5	-	x	sliding from Pad
			3	0.5			-	x	sliding from Pad
			1	0.1			-	x	sliding from Pad
				0.5			x		large sliding no drop off from pad
			5		0.5		-	x	launcher is tipping
					0.2		x	-	large sliding no drop off from pad





For full details of the load cases investigated, see:
Thies C. "Investigation of the landing dynamics of a reusable launch vehicle and derivation of dimension loading for the landing leg", CEAS Space Journal, 2022.

DESIGN OVERVIEW AND PRINCIPAL FUNCTIONS

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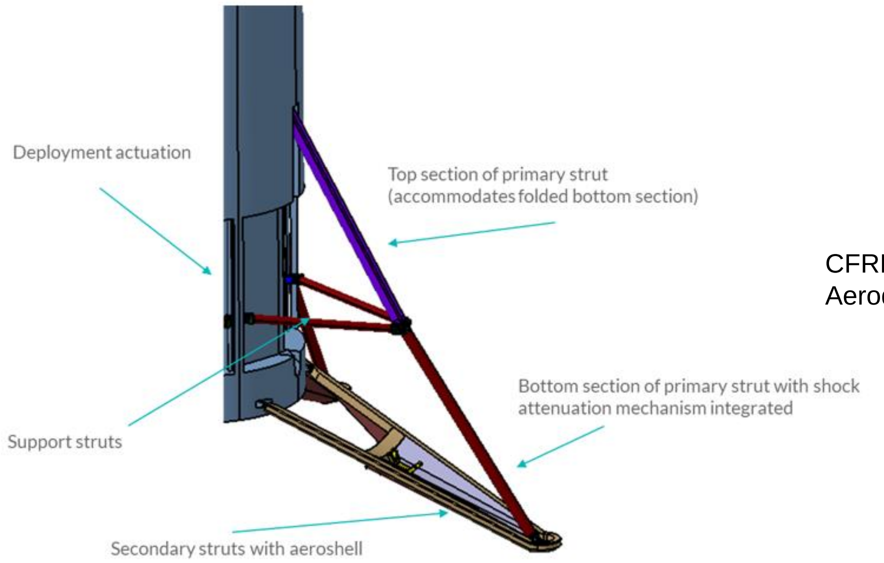
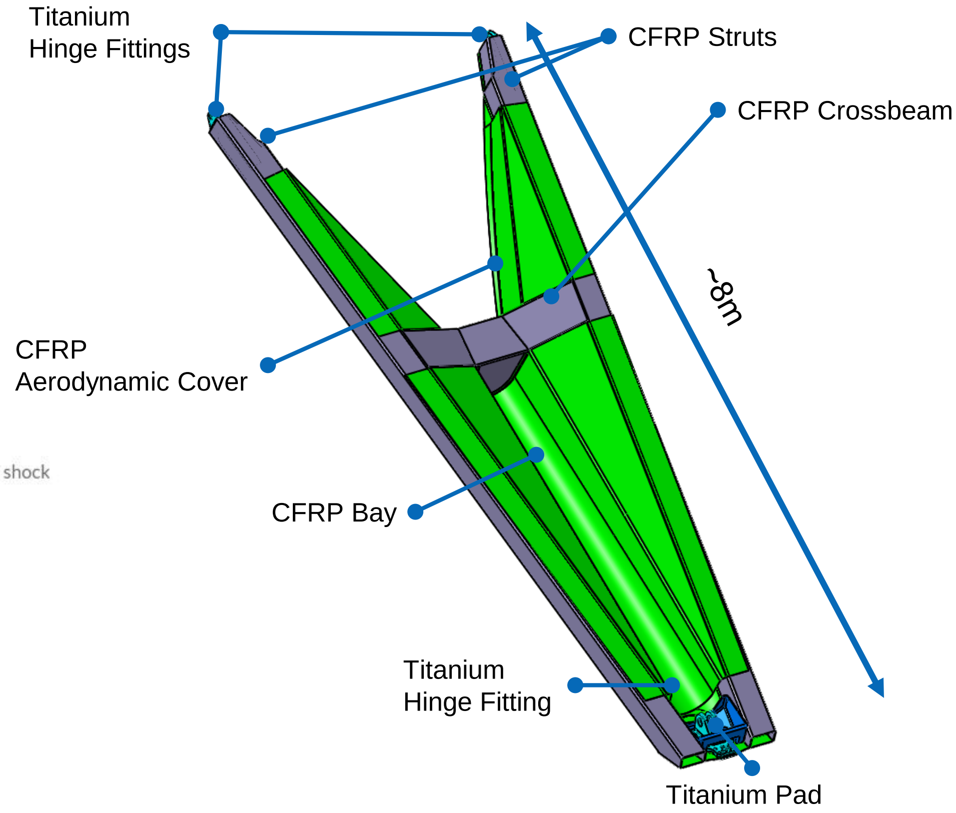
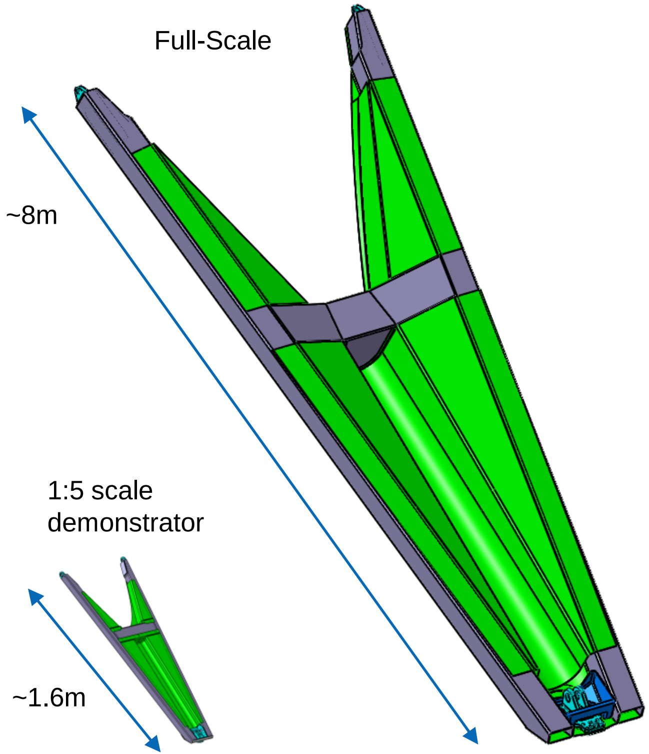




BUILD OF DEMONSTRATORS

1:2 scale manufacturing demonstrator of the landing pad region

1:5 scale test demonstrator for testing landing performance



Approximate scale comparison

TEST OF DEMONSTRATOR – SETUP

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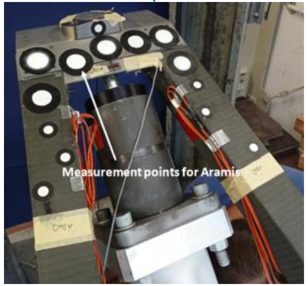
Test type: Drop tower

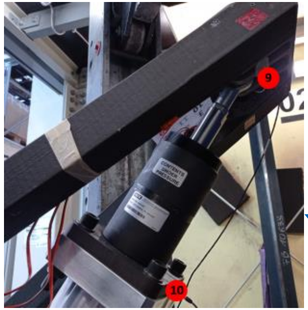
Test partner:

Leichbau Zentrum Sachsen (LZS), Dresden

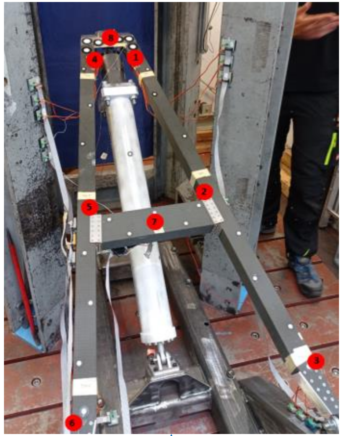
No.	Descript.	Drop height [m]	Drop mass [kg]	Drop vel. [m/s]
1	Static load (I)	-	365.5	-
2			488.5	
3			608.5	
4			365.5	
5	Shock test (II)	0.03	365.5	0.77
6	Impact test (III) (nominal friction)	0.1	365.5	1.4
7		0.3		2.43
8		0.5		3.13
9		0.3		2.43
10	Impact test (high friction)	0.1	365.5	1.4
11	Impact test (IV) (nominal friction)	0.1	365.5	1.4
12		0.5		3.13
13		0.7		3.71
14		0.9		4.2
15		0.5		3.13
16		0.9		4.2

Measurement points for video tracking

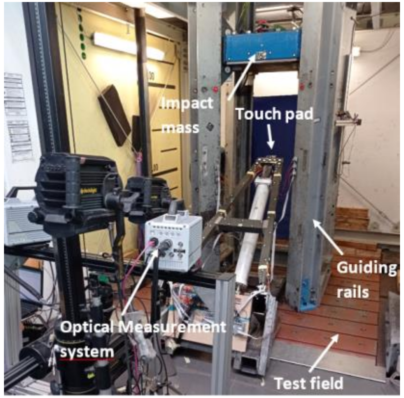




Accelerometer locations



Strain gauge locations



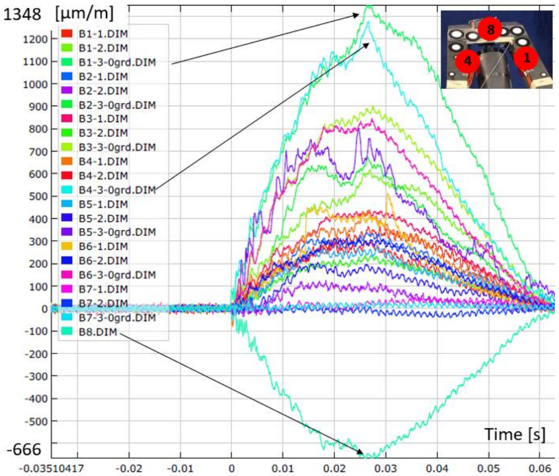
Test setup

Demonstrator in test rig

For further details of the test campaign, see:
Thies, C. "Drop Test Description and Evaluation of a Landing Leg for a Re-usable Future Launch Vehicle", FAR2022 , Heilbronn, 2022.

Results shown for test #5 – Shock test

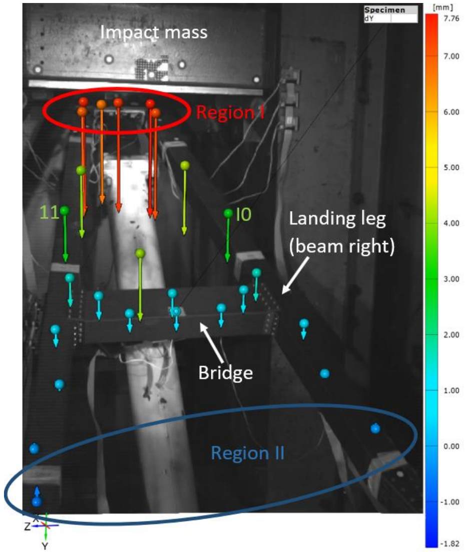
Note: Test data was captured for tests.

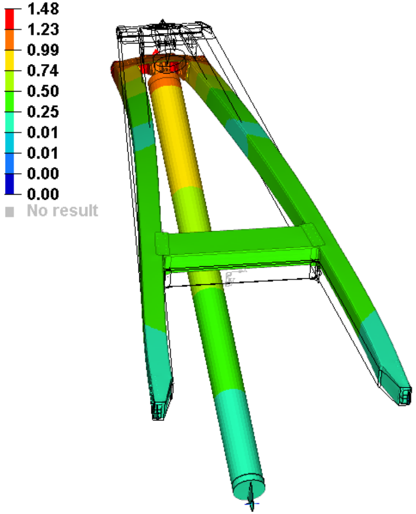


Strains measured at critical locations

All strain gauges have functioned correctly

Maximum strain is 0.13% in fibre direction





Displacement as tracked by digital image correlation matches well with pre-test prediction

For further details of the test campaign, see:
Thies, C. "Drop Test Description and Evaluation of a Landing Leg for a Re-usable Future Launch Vehicle", FAR2022 , Heilbronn, 2022.

CONCLUSIONS AND OUTLOOK

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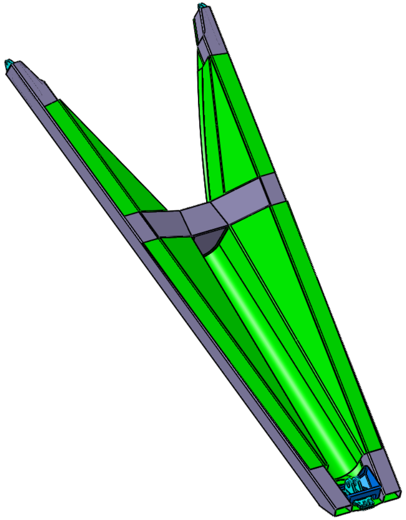
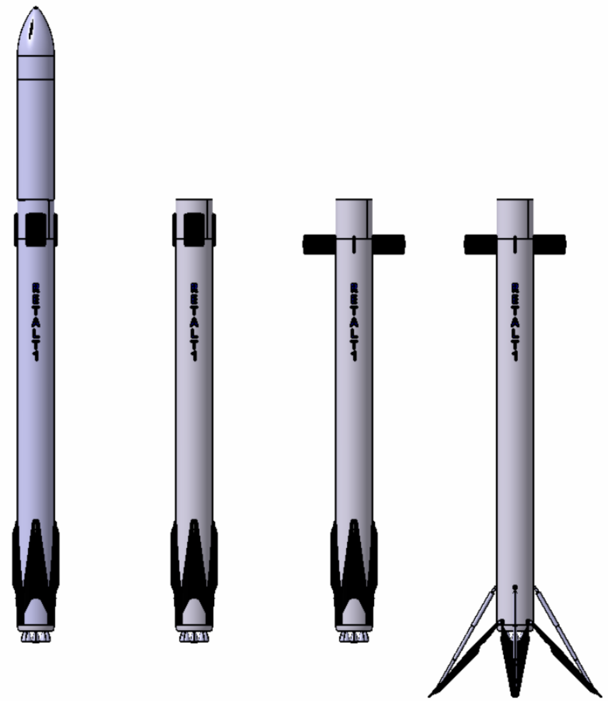
- Experiences gained during the RETALT programme form a sound basis to be applied in the SALTO programme
  - Load cases and landing characteristics
  - Suitable mechanisms
  - Structural concepts for landing legs
  - Sizing methods of landing legs
  - Test data validates prediction methods
  - Manufacturing experience
  - Assembly, mounting and handling



SUMMARY

- Recap
  - Landing leg design for future European launchers
  - Manufacture and test of scaled demonstrators
- Next steps
  - Transfer experience into SALTO programme
  - Desing and build a full-scale landing leg in the SALTO programme



- **Thank you for listening**
- **Questions?**

ACKNOWLEDGEMENTS AND REFERENCES

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- RETALT
  This project has received funding from the **European Union's Horizon 2020 Research and Innovation Framework Programme** under **Grant Agreement No. 821890**
- SALTO
  This project is receiving funding from the **European Union's Horizon Europe Research and Innovation Framework Programme** under **Grant Agreement No. 101082007**
- The authors would like to acknowledge the excellent collaboration with our project partners **Almatech** who collaborated in defining the landing leg mechanism and provided the shock absorber for the test as well as the **Leichtbau Zentrum Sachsen** for providing the test facilities

- **Referenced Literature**:

Marwege, A., et al., "RETALT: review of technologies and overview of design changes", CEAS Space Journal 2022.

Thies C. "Investigation of the landing dynamics of a reusable launch vehicle and derivation of dimension loading for the landing leg", CEAS Space Journal, 2022.

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Jevons, M., Krammer A., Starke P., Lichtenberger M., Structural Concept Report, RETALT Project, 2019.

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