Investigation of a Low Cost Concept for Landing Impact Attenuation

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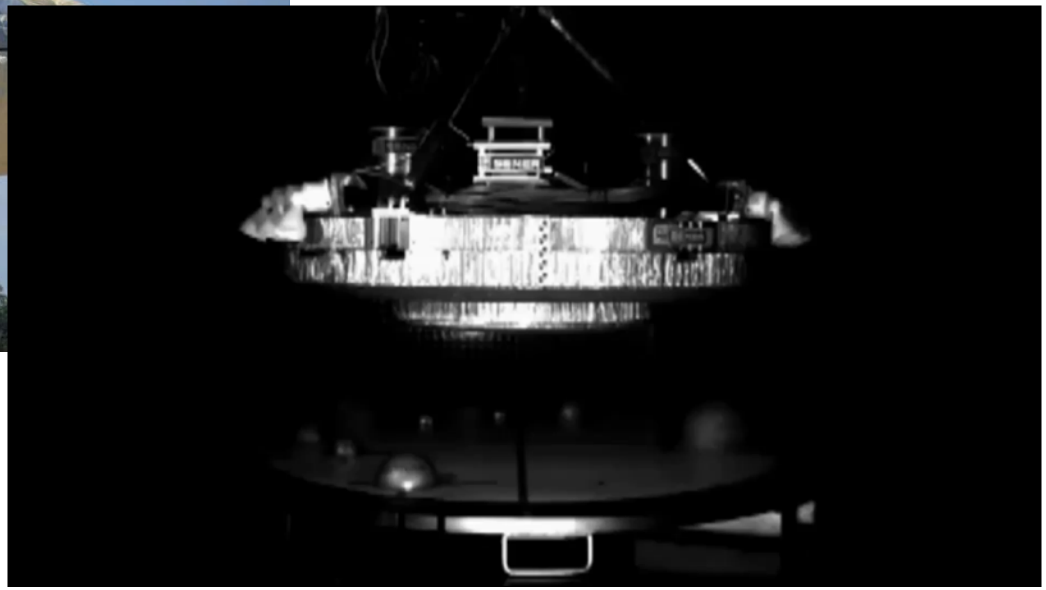
Roadmap

- Background: Evolution of the ExoMars EDM
- Layout of *Marslander* TDM
- Virtual Test Lab
- Physical Tests
- Conclusions

Background ExoMars: Evolution from early Phases to EDM

ExoMars LM in early phases (A… adv. C/D)



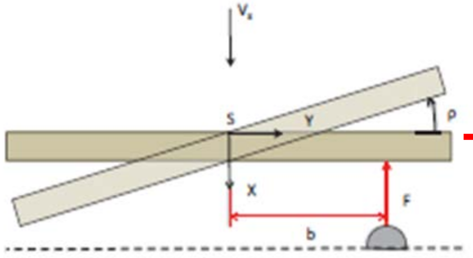
Entry, Descent and Landing Demonstrator Module (EDM) of ExoMars Mission 2016

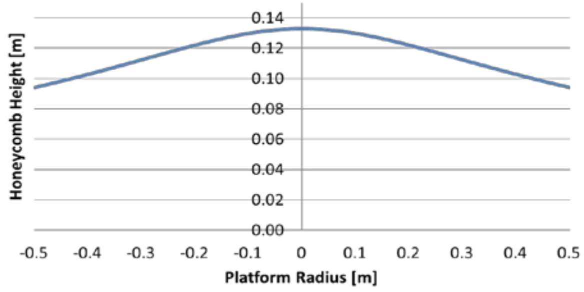
Credits: ESA, TAS-I, Aero Sekur, SENER…. and Airbus DS (former Astrium)

Guidelines for the *Marslander* TDM - Layout and Physical Tests

1. Limitation of platform diameter to <1.25m
   → Fits typical automotive crash test barrier size
   → Cheap procurement, already cut into pieces

2. Continuously curved shape based on reduced mass



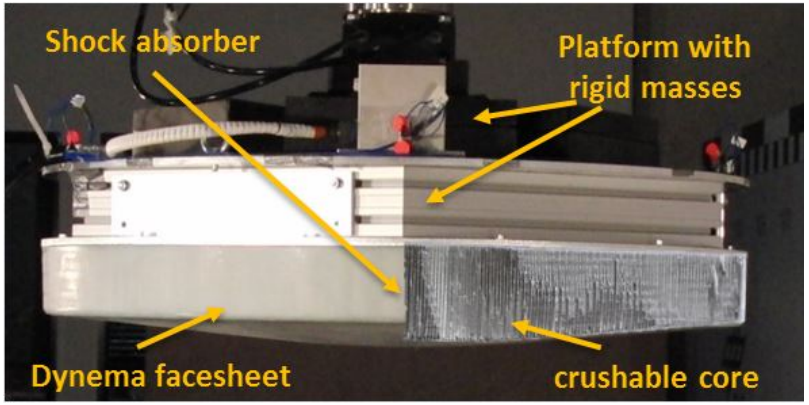


   → Easy to manufacture on a CNC molding cutter
   → Smoothly increasing force instead of plateau
   → Crushable contributes to the spacecraft stiffness
   → Slightly higher layer thickness in the center

3. Rigid test platform with exchangeable crushable
   → No instrumentation on crushable
   → Short changeover times

Summary of TDM layout

Mass:	290kg
Moment of Inertia:	I_1= 64kgm²
	I_2= 40kgm²
	I_3= 40kgm²
Center of Mass:	91mm above crash material
Diameter:	1000 mm
Core Material:	3/16 - 5056 – 0.0007 – 1.0 perforated (Plascore)



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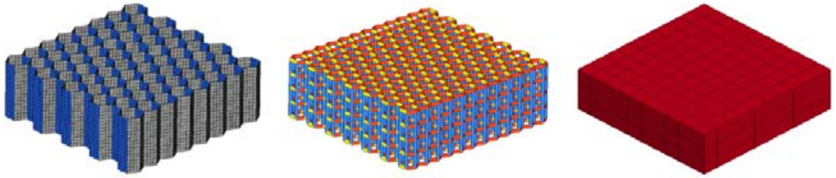
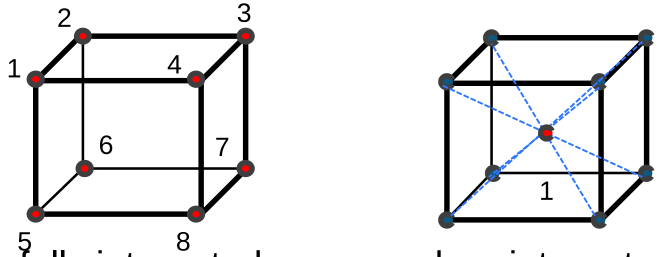
Guidelines for the *Marslander* TDM cont. - Virtual Test Lab

4. Focus on homogenized models (solid elements)



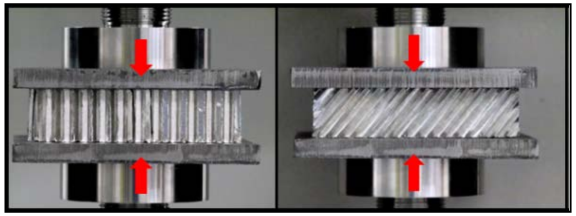
Shells Beams Solids

5. Use under-integrated elements (where appropriate)



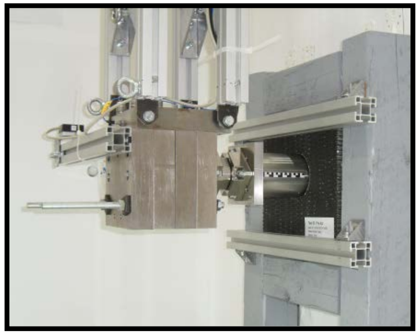
fully integrated under - integrated

6. Perform early model correlation tests on low level of integration



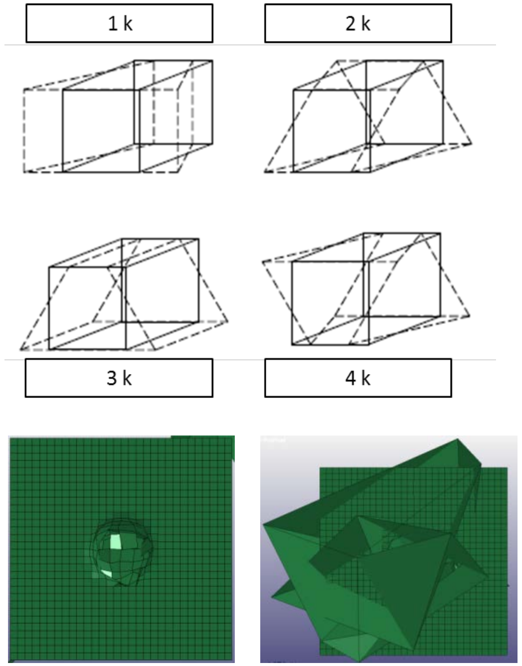
Core

Facesheet



Sandwich

Risk of occurrence of hourglass modes



Solution: Introduction of Hourglass control forces

Target: Hourglass energy <10%

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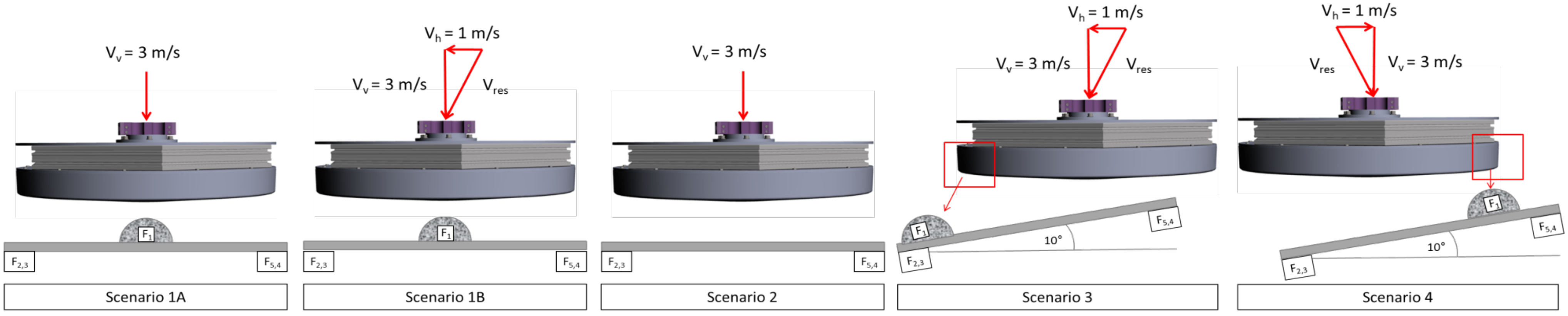
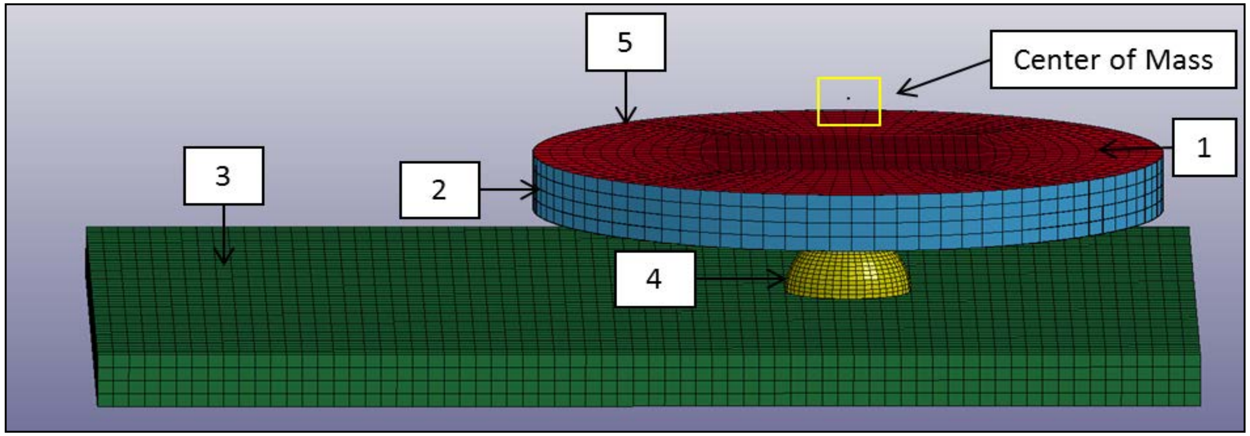
Virtual Test Lab - Test Cases

- Touchdown scenarios:



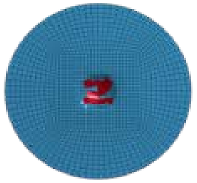
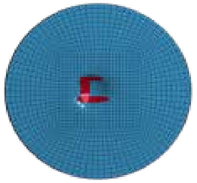
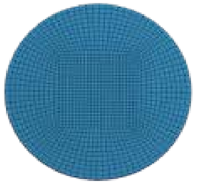
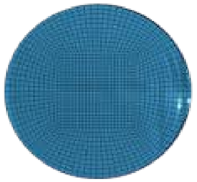
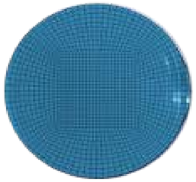
- Numerical Model:



1. Aluminum honeycomb core
2. Dyneema facesheet
3. Rigid ground
4. Rigid stone
5. Rigid plate (virtual)

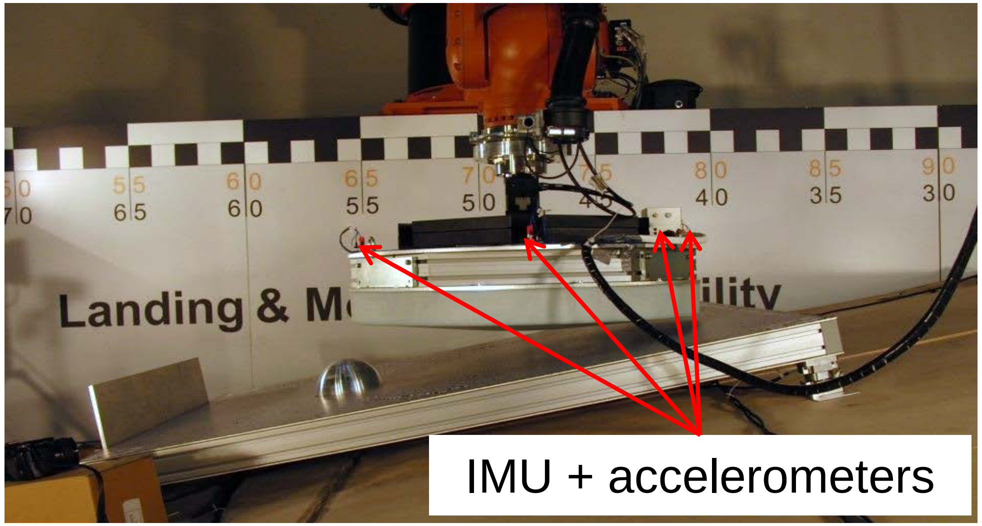
Virtual Test Lab - Summary of Test Predictions

Summary of prediction

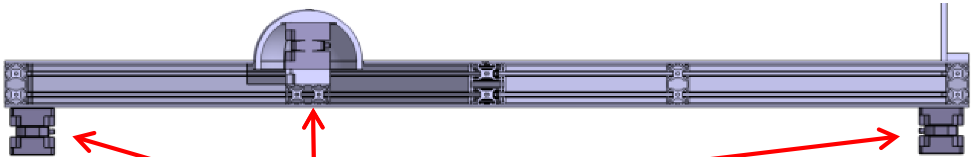
	Deformation	Penetration Depth	Maximal Crash Force	Maximal Acceleration	Hourglass Energy	Total CPU Time
Scenario 1A **v_v= 3m/s**		74.4mm 	27.8 kN	81.8 m/s²	4.04 %	6628 s (1h 50min 28s)
Scenario 1B **v_v= 3m/s** **v_h= 1m/s**		68.4 mm 	49.9 kN	151 m/s²	2.76 %	5865 s (1h 37min 45s)
Scenario 2 **v_v= 3m/s**		18.1 mm 	166 kN	543 m/s²	0.18 %	5536 s (1h 32min 16s)
Scenario 3 **v_v= 3m/s** **v_h= 1m/s**			73.7 kN	214 m/s²	3.75 %	5014 s (1h 23min 34s)
Scenario 4 **v_v= 3m/s** **v_h= 1m/s**			129 kN	415 m/s²	3.03 %	3794 s (1h 3min 14s)

Physical Test Lab - “the real Test Cases”

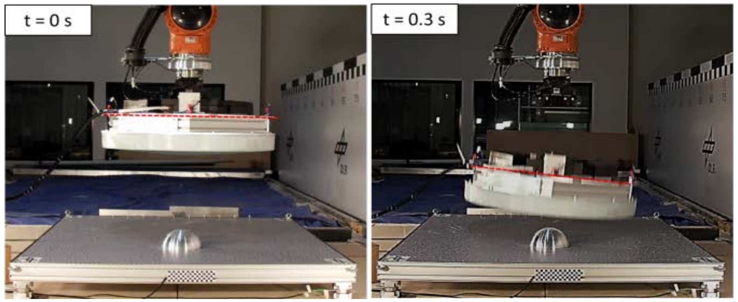
Test Set-Up on DLR’s Landing and Mobility Test Facility (LAMA)

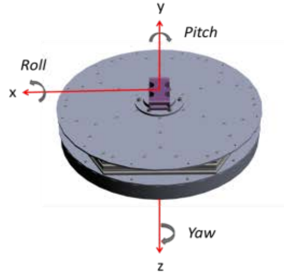


Instrumentation of ground plate



3-axial force sensors





Scenario	Orientation Angle and Angular Velocity at Time of Impact		
1A (Test 2)	Roll: 7.83 deg Pitch: 0.99 deg Yaw: 0.19 deg	ω(x)= -0.141 deg/s ω(y)= 19.64 deg/s ω(z)= -1.203 deg/s	
1B (Test 6)	Roll: 7.34 deg Pitch: 2.36 deg Yaw: 0.12 deg	ω(x)= 20.5 deg/s ω(y)= 0.714 deg/s ω(z)= -1.041 deg/s	
2 (Test 4)	Roll: 6.67 deg Pitch: 1.19 deg Yaw: 0.16 deg	ω(x)= 16.32 deg/s ω(y)= -0.225 deg/s ω(z)= -1.14 deg/s	
3 (Test 7+8)	Test failed due to unhitching of stone		
4 (Test 10)	Roll: 7.22 deg Pitch: 1.7 deg Yaw: -0.55 deg	ω(x)= 16.65 deg/s ω(y)= -0.039 deg/s ω(z)= -1.026 deg/s	

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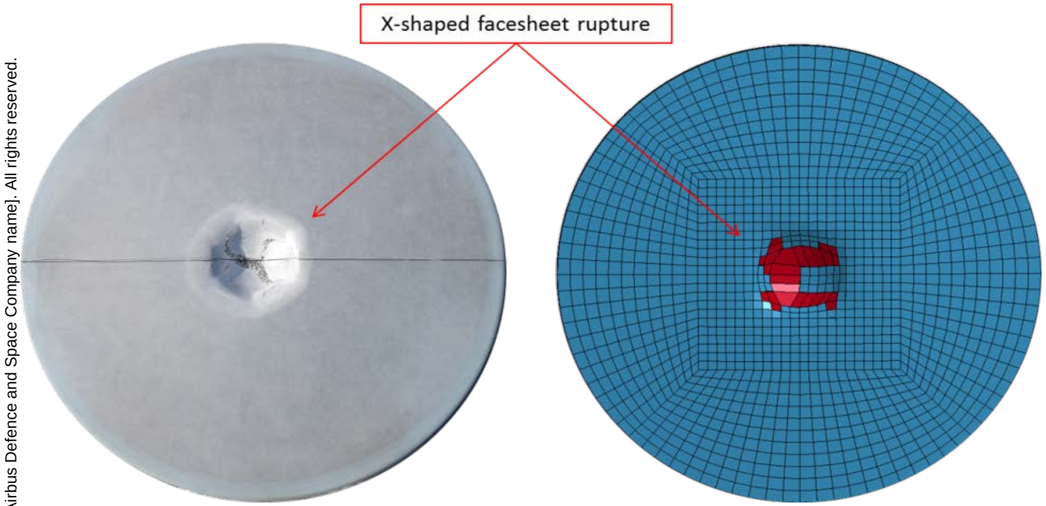
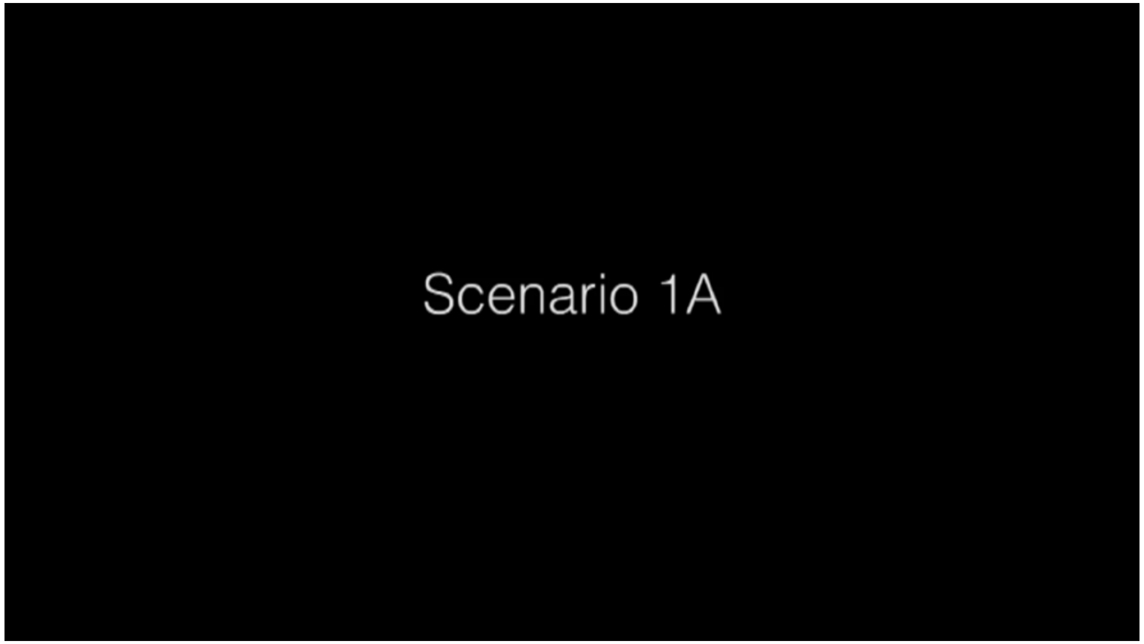
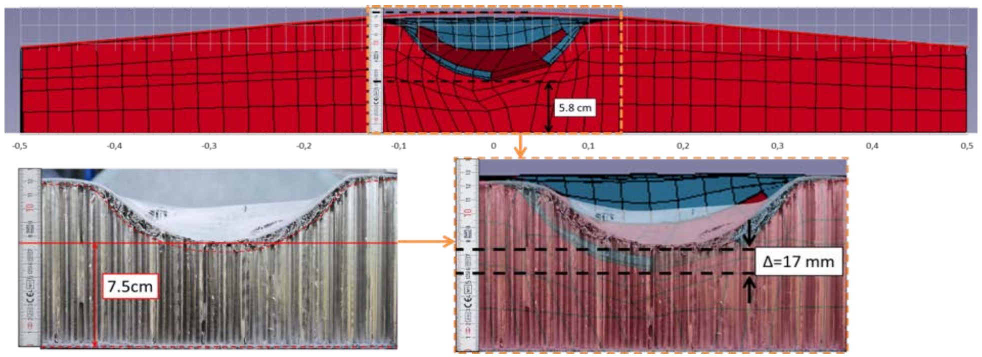
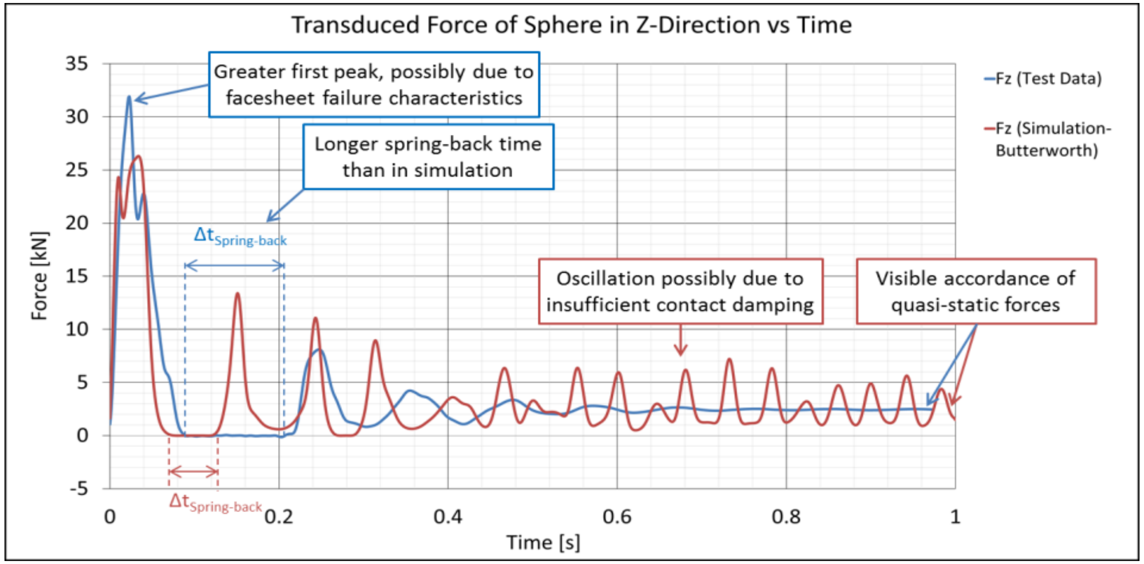
Validation - Scenario 1A



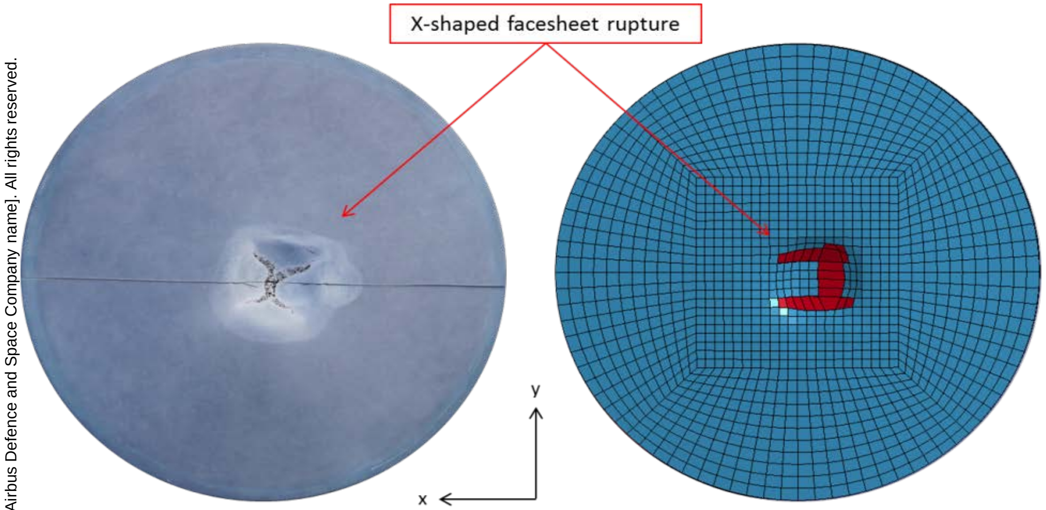


Penetration Depth: Δ=17mm	
Test: 59.2 mm	Simulation: 76.2 mm

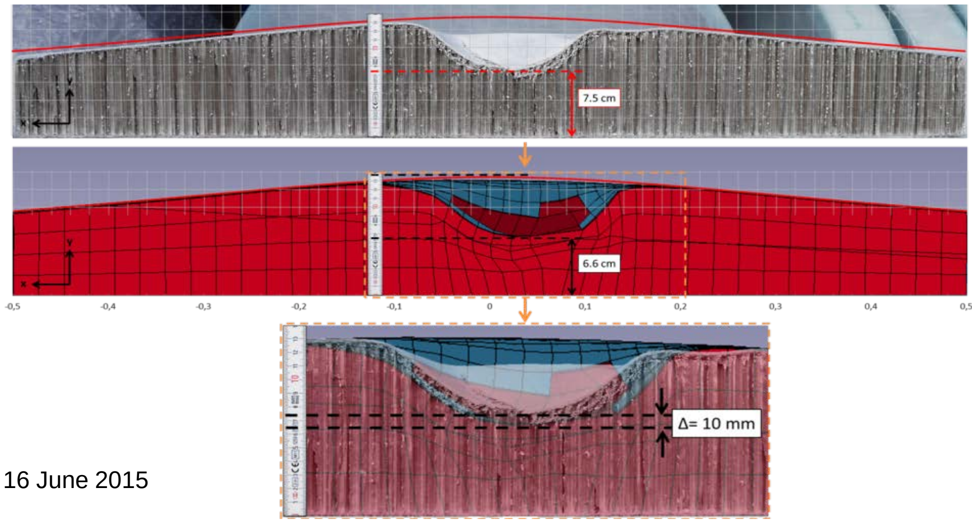


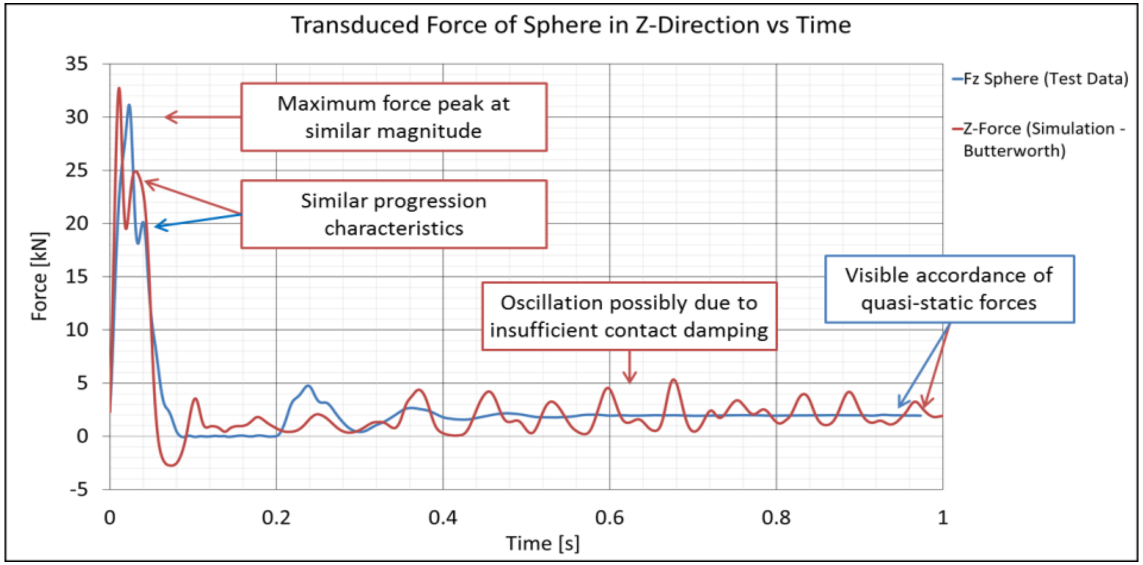


Validation - Scenario 1B

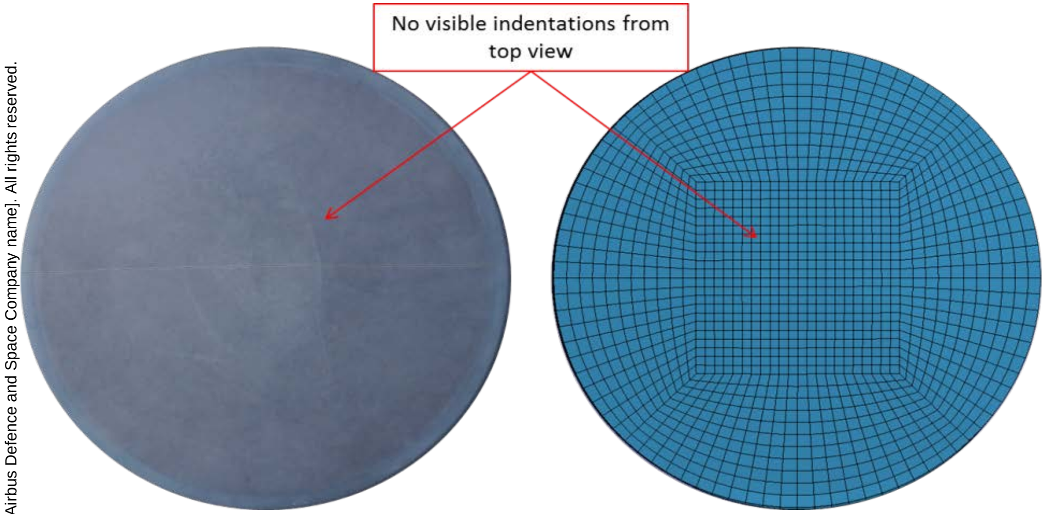


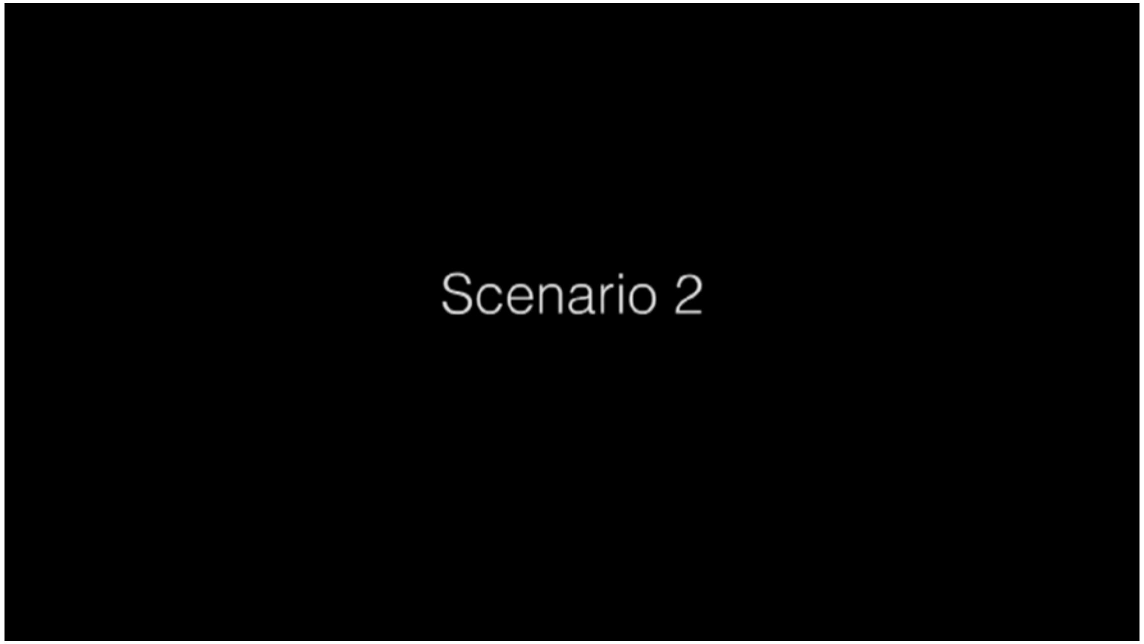
Penetration Depth: Δ=10mm	
Test: 59.2 mm	Simulation: 68.2 mm

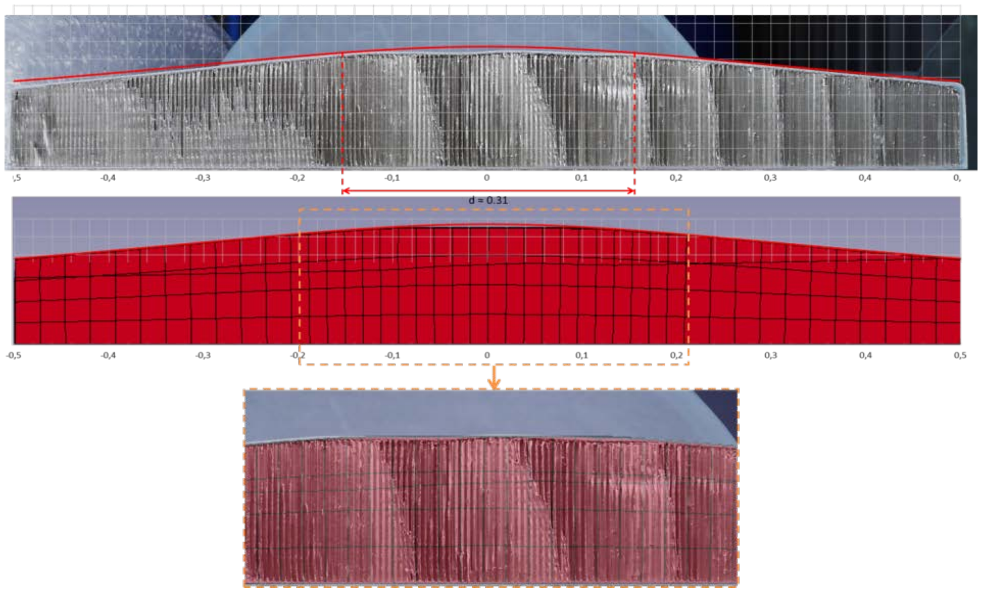


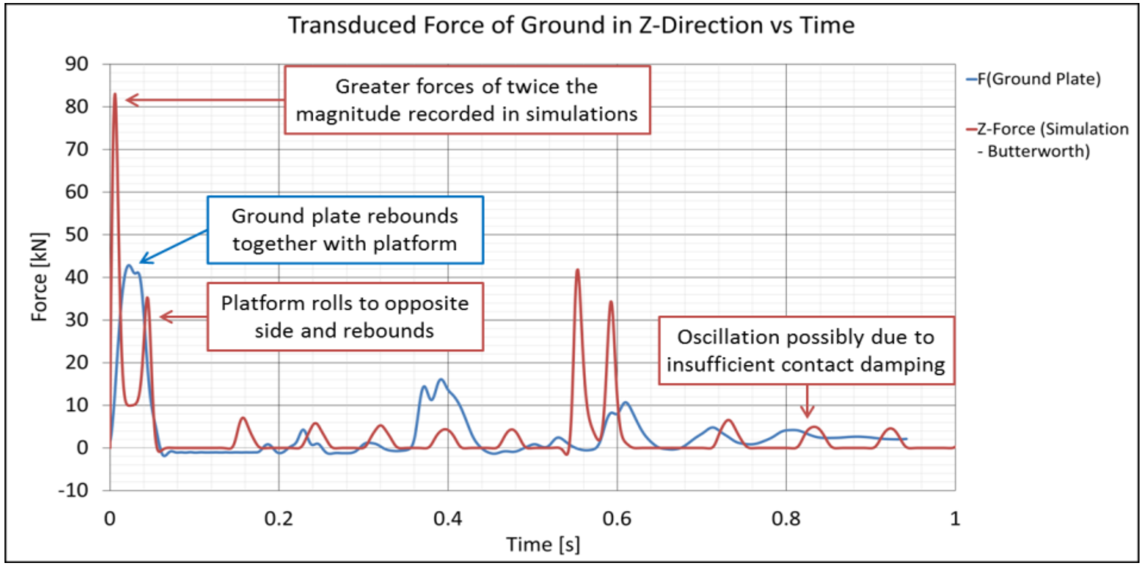


Validation - Scenario 2









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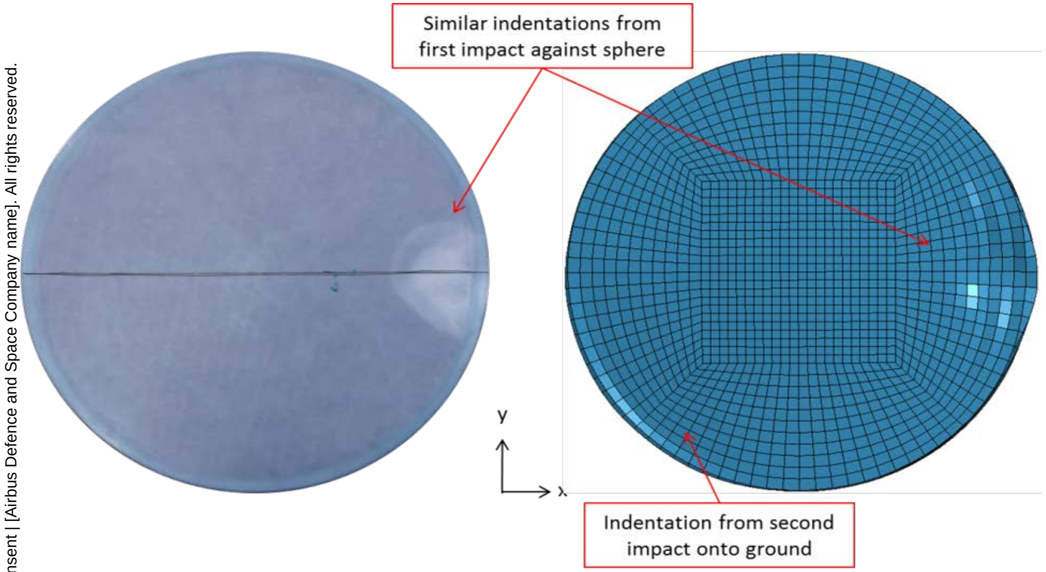
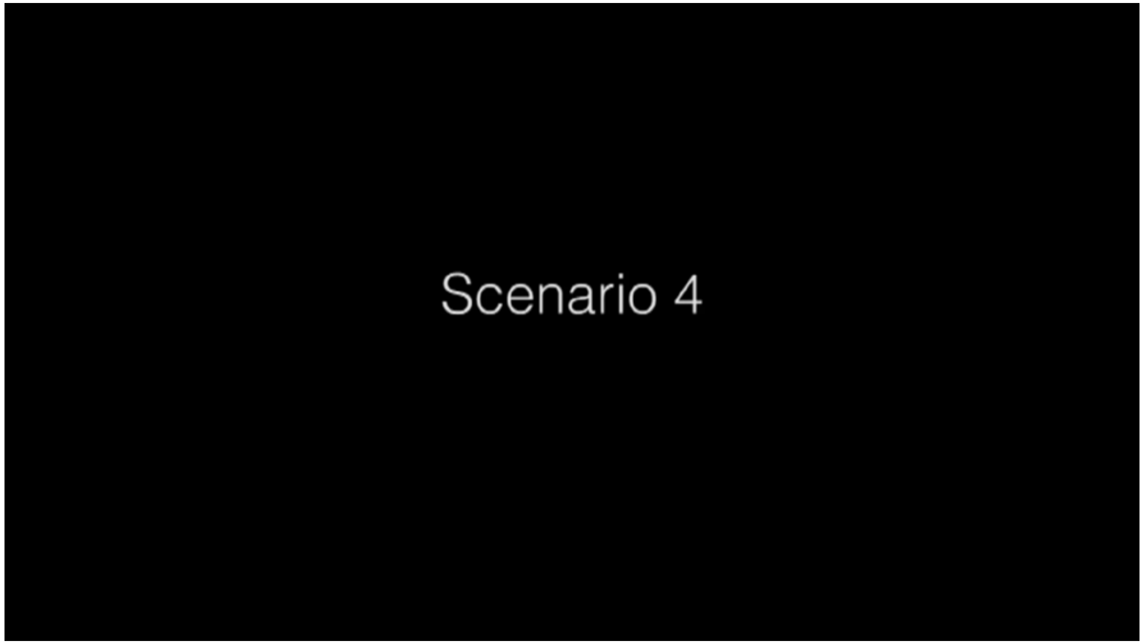
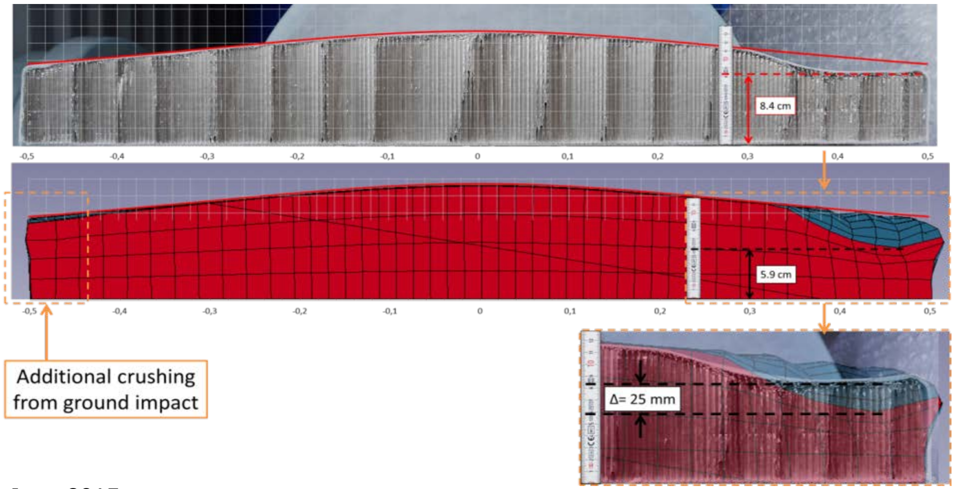
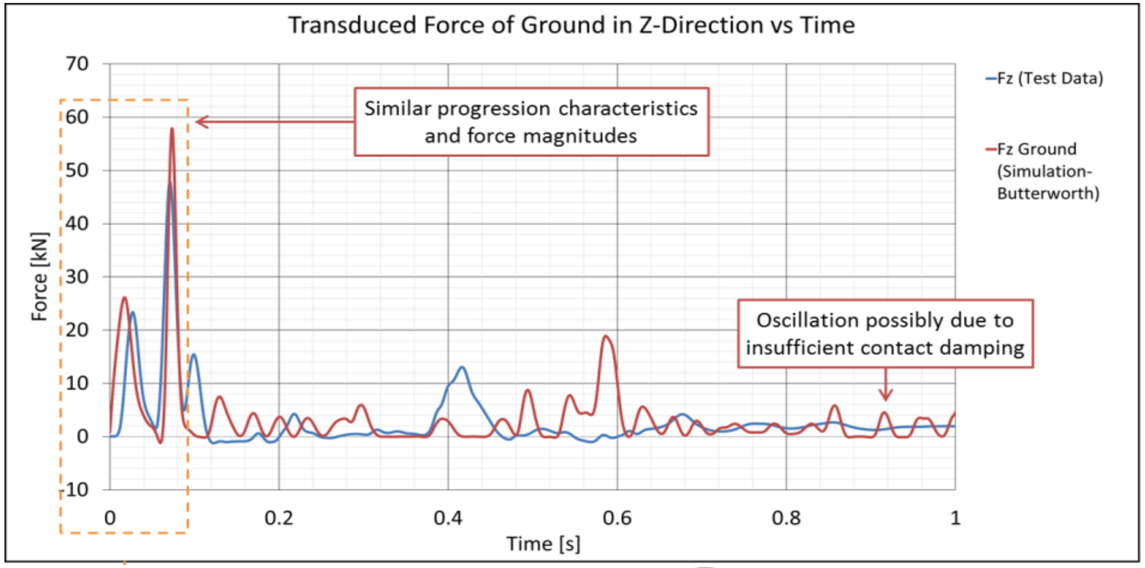
Validation - Scenario 4





Penetration Depth: Δ=25mm	
Test: 16 mm	Simulation: 41 mm





Summary and Conclusions

- A cost optimized shock absorber for a landing platform based on a single crushable layer of Aluminum honeycomb has been developed
  → Continuously curved shape
  → Layer thickness based on reduced mass
  → Potentially interesting for missions with several small landers

- 12 specimen have been manufactured and tested under typical touchdown conditions (slopes, rocks, soft soil etc.) at DLR's Landing and Mobility Test Facility (LAMA)
  → Excellent performance under all conditions

- A virtual test lab using homogenized FE models has been established, correlated with material tests (facesheet, core and sandwich) and validated regarding the performed touchdown tests
  → Use of under integrated elements for core material only
  → Simulator over predicts penetration depth and rebound for cases without facesheet failure
  → Correlation based on simple tests led already to surprisingly accurate results at 1.5h CPU time per load case

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100% R&D

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