Initial Results of Shell Lander Impact Tests for the Exploration of Medium-Size Airless Bodies

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Christian D. Grimm,
Silvio Scröder,
Lars Witte

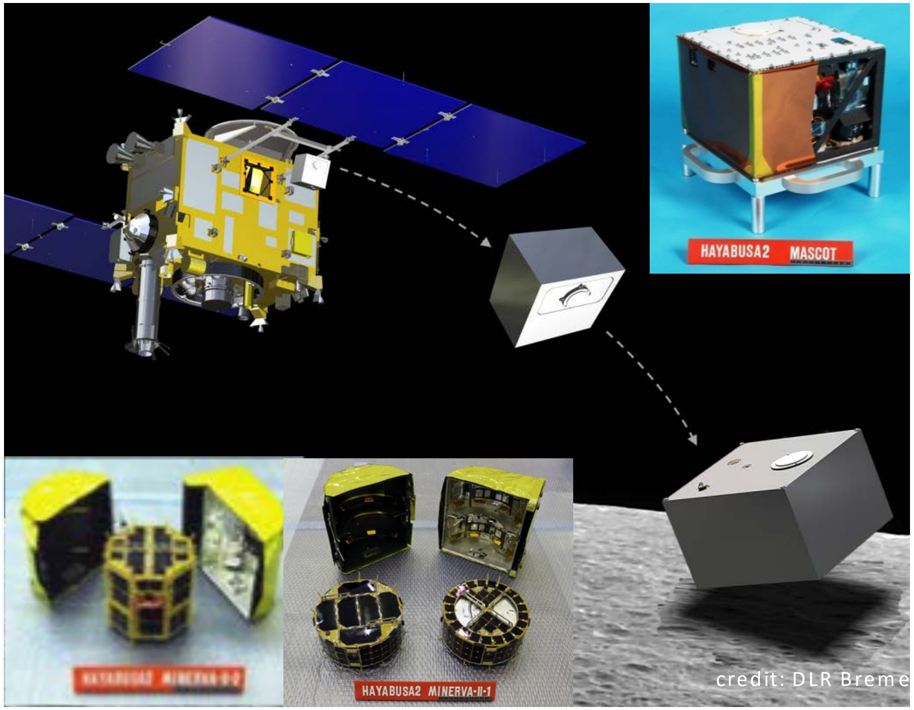
Institute of Space Systems,
German Aerospace Center (DLR),
Bremen, Germany;

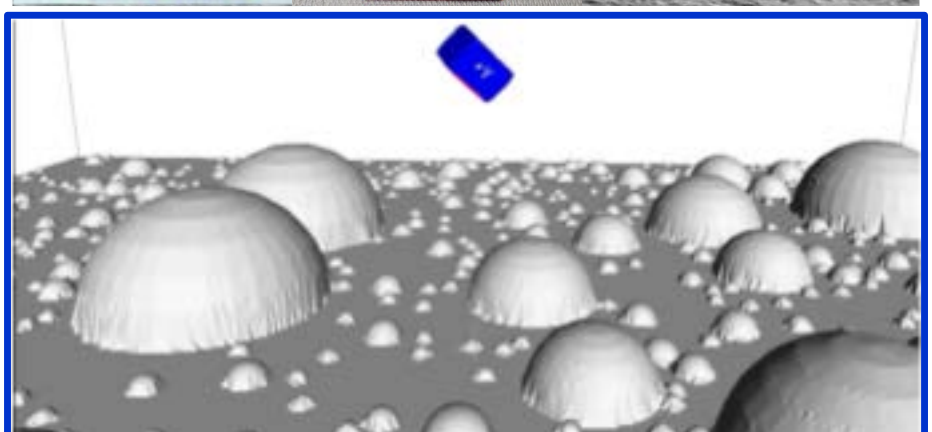
Teaser: MASCOT Landing on Asteroid Ryugu
(October 2018)

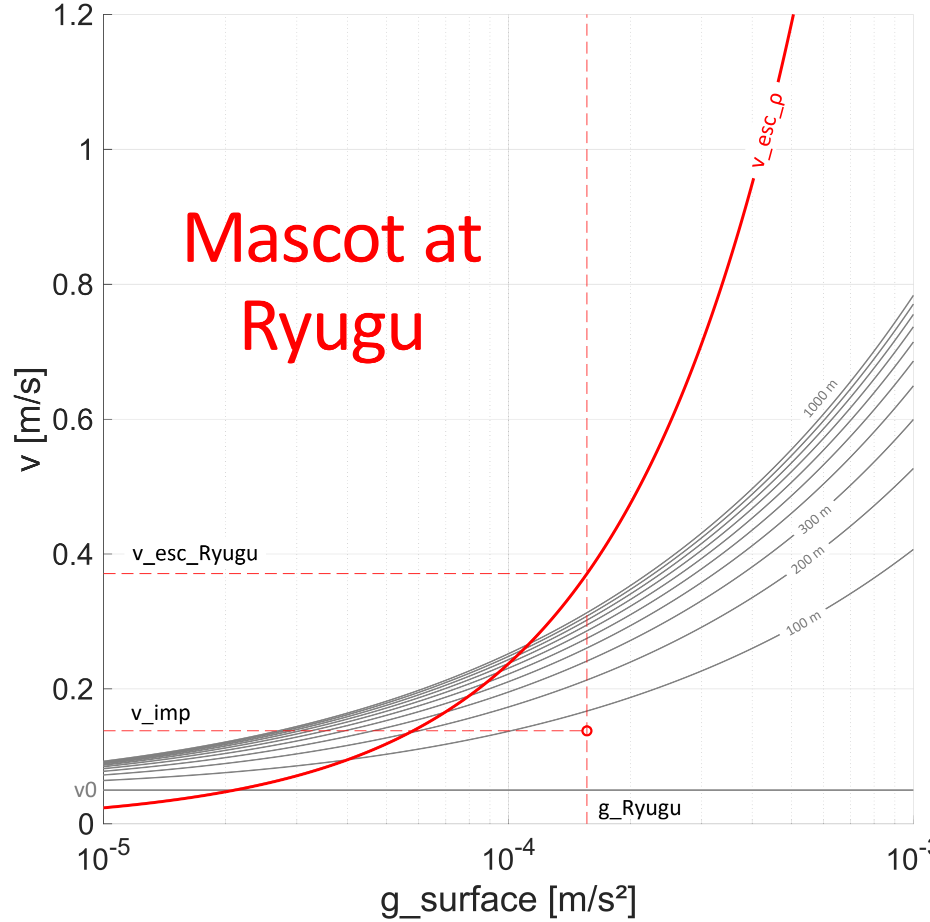
“Landing” Missions to Small Bodies – up to date

Mission	Target	Lander	Carry-on	Launch	Landing	TD Vel. [m/s]
Fobos 1	Phobos	Fobos 1 DAS	yes	07.07.88	-	<1
Fobos 2 (CCCP)	Phobos	Fobos 2 DAS	yes	12.07.88	-	<1
		Fobos 2 PrOP-F	yes		-	<1
NEAR (NASA)	Eros	orbiter	-	17.02.96	12.02.01	~1.6
Hayabusa (JAXA)	Itokawa	orbiter	-	19.11.05	19.11.05	~0.03
		MINERVA	yes		-	~0.1
Rosetta (ESA)	Chury-G.	orbiter	-	02.03.04	30.09.16	~1
		Philae	yes		12.11.14	~1
Fobos-Grunt (Russia)	Phobos	lander stage	-	08.11.11	-	
Hayabusa2 (JAXA)	Ryugu	orbiter	-	14.12.14	10.2018 (TBD)	~0.03
		MINERVA-II-1	yes			~0.2
		MINERVA-II-2	Yes			~0.2
		MASCOT	Yes			~0.2
OSIRIS-REx (NASA)	Bennu	orbiter	-	08.09.16	2019 (TBD)	

Body dependent Gravity Acceleration





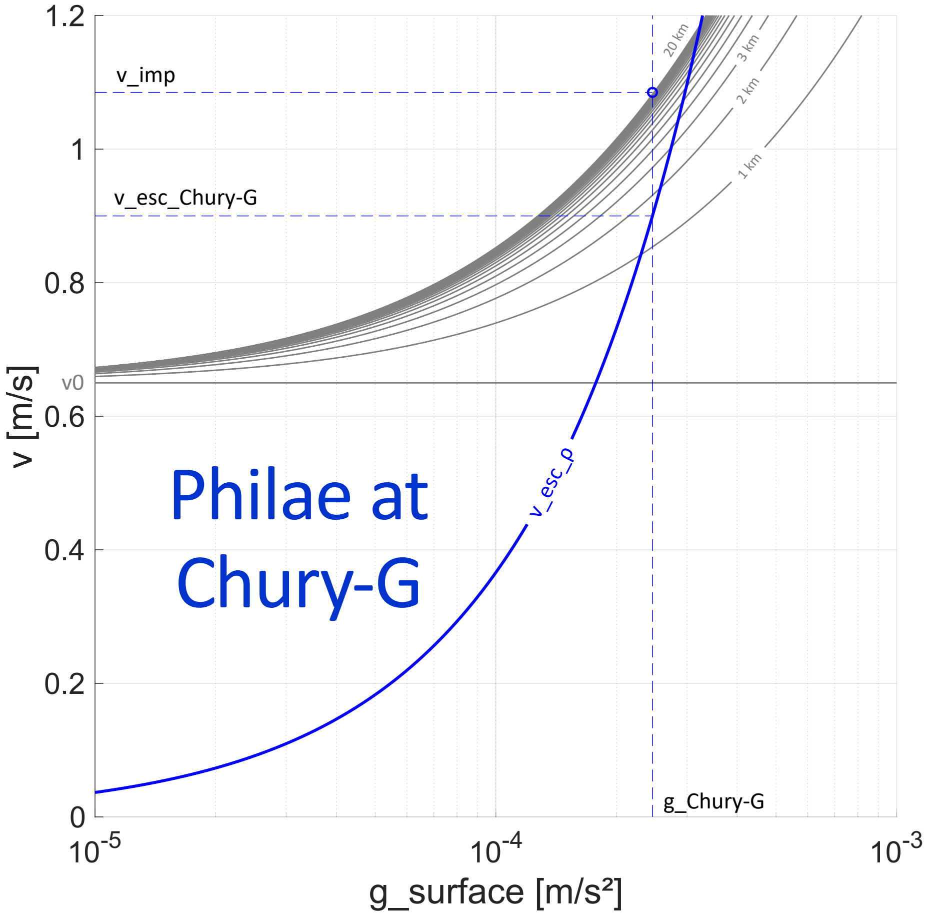


d_mean	ρ_bulk	g_surface	v_esc
0.88 km	1.27 g/cm³	1.56*E-4 m/s²	0.37 m/s
h_sep	v0	v_imp	
60 m	0.05 m/s	0.138 m/s	

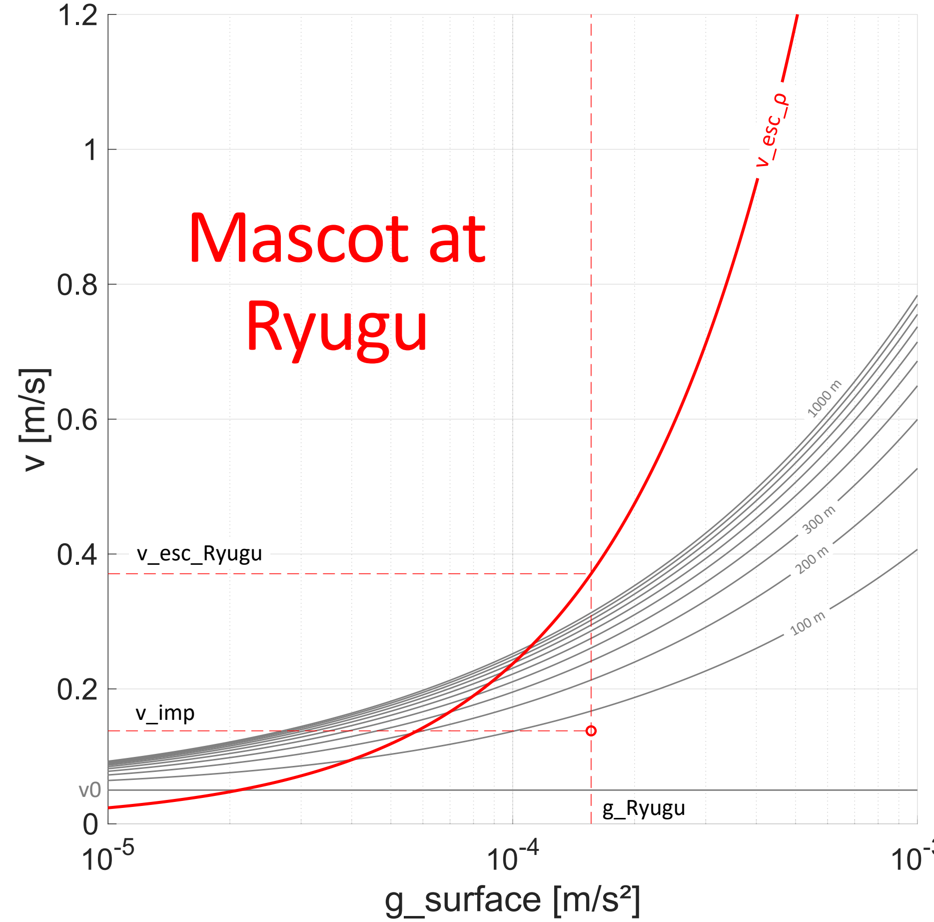
Mascot landing (MBS)
(realistic time scale)

DLR

Body dependent Gravity Acceleration

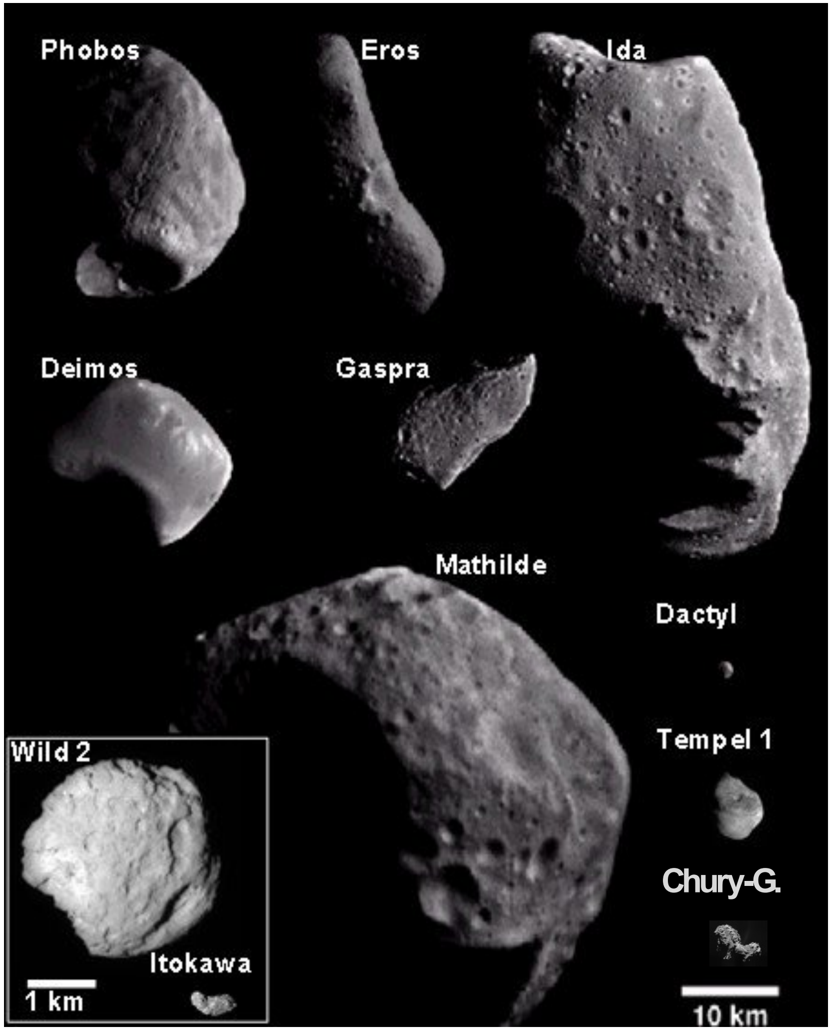


d_mean	P_bulk	g_surface	v_esc
3.3 km	0.53 g/cm³	2.46*E-4 m/s²	0.9 m/s
h_sep	v0	v_imp	
22.5 km	0.65 m/s	1.085 m/s	

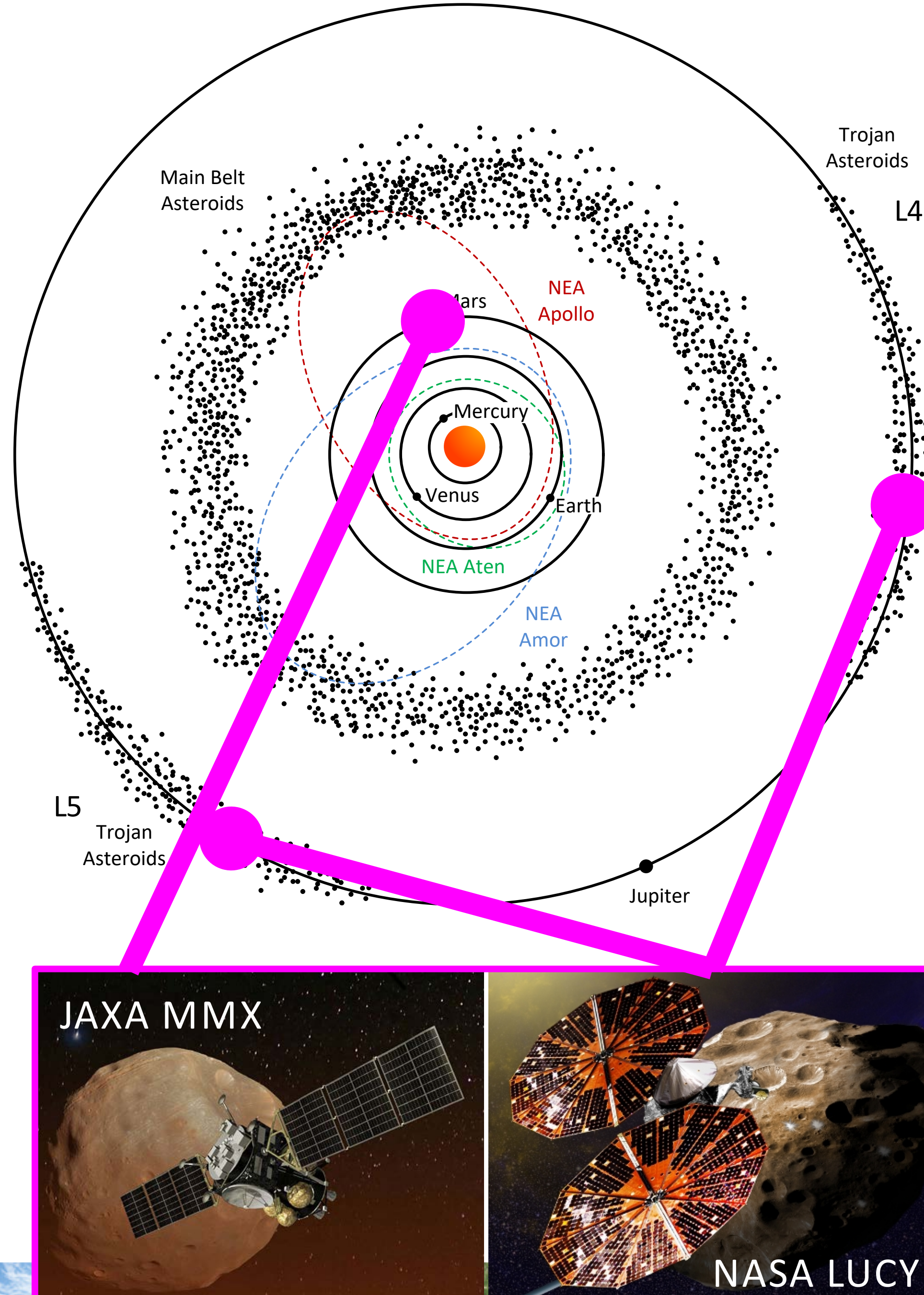


d_mean	ρ_bulk	g_surface	v_esc
0.88 km	1.27 g/cm³	1.56*E-4 m/s²	0.37 m/s
h_sep	v0	v_imp	
60 m	0.05 m/s	0.138 m/s	

Other Targets

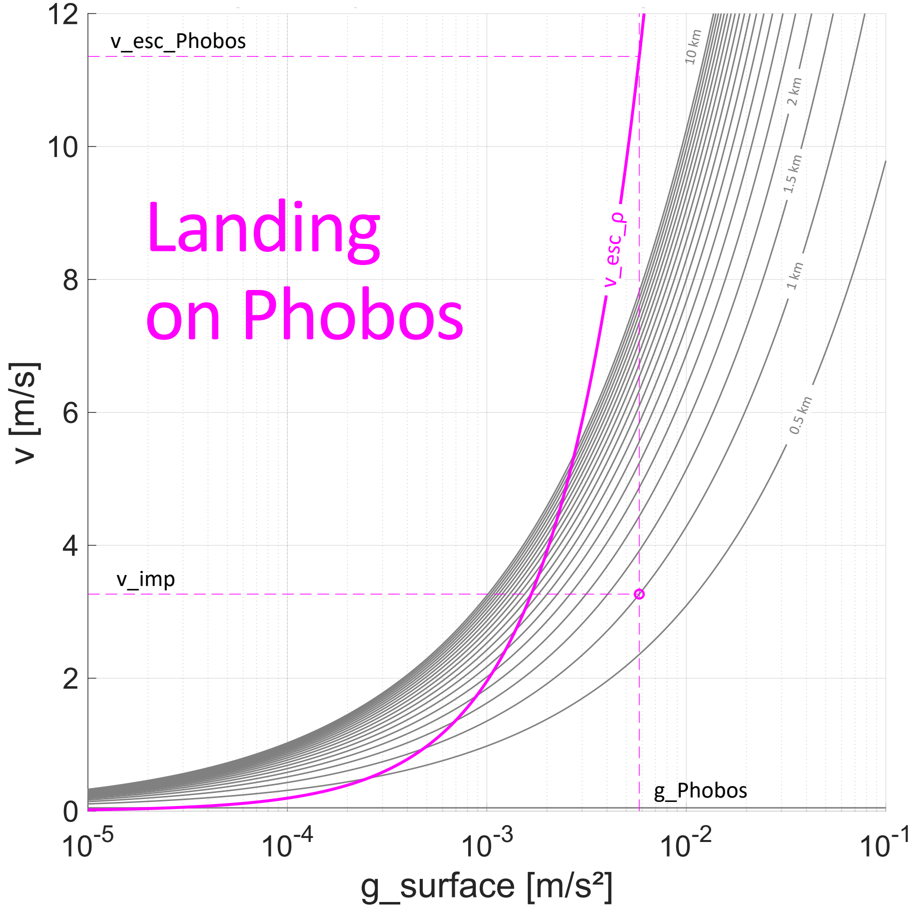


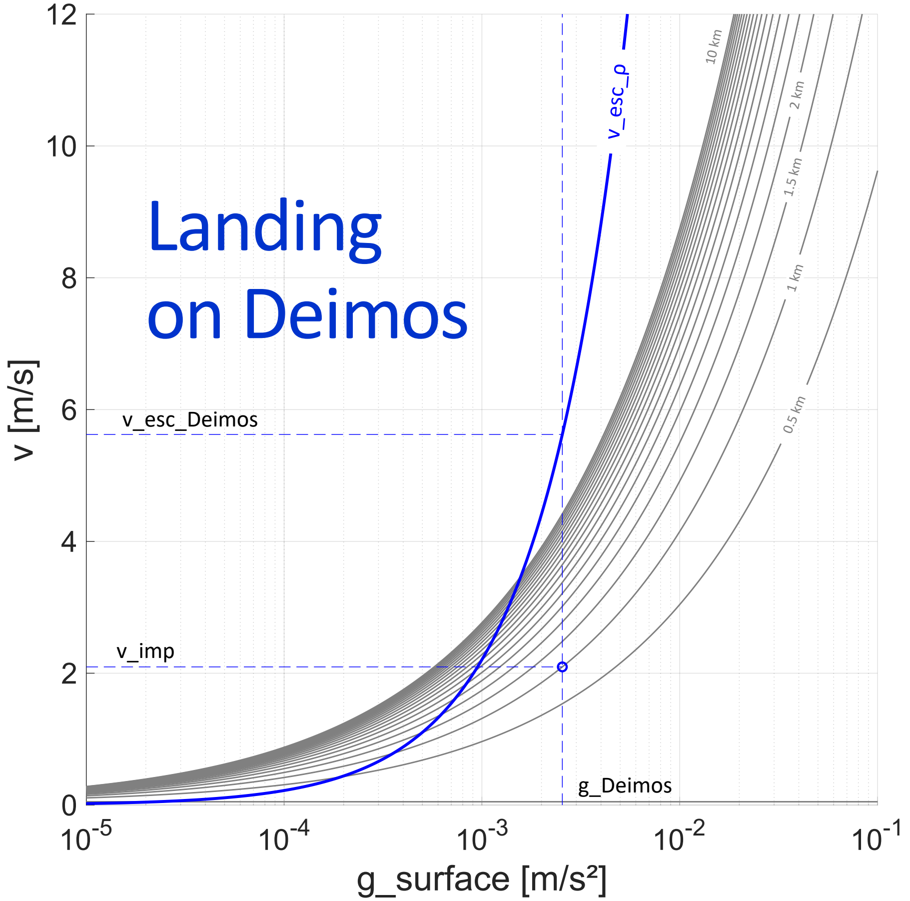
Source (www.lpl.arizona.edu)



Reference Misisons:

Landing on larger Bodies (e.g. Martian Moons)



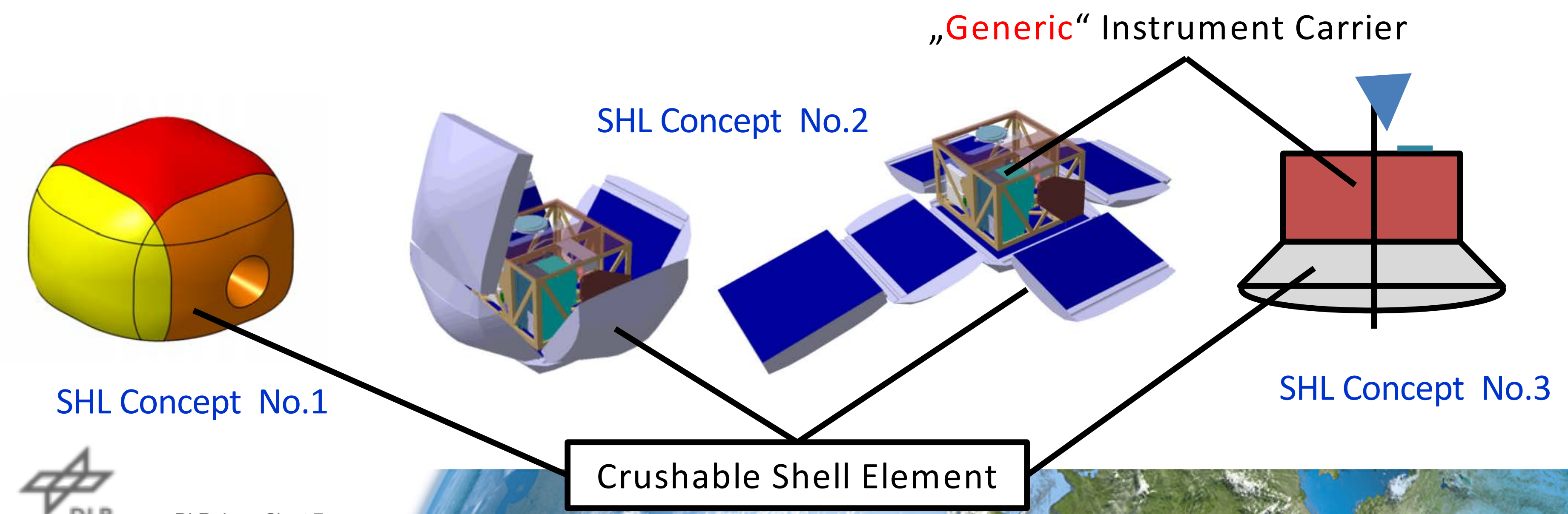


d_mean	ρ_bulk	g_surface	v_esc
22.2 km	1.87 g/cm³	5.81*E-3 m/s²	11.35 m/s
h_sep	**v0**	**v_imp**	
1 km	0.05 m/s	3.27 m/s	

d_mean	ρ_bulk	g_surface	v_esc
12.4 km	1.47 g/cm³	2.55*E-3 m/s²	5.62 m/s
h_sep	**v0**	**v_imp**	
1 km	0.05 m/s	2.1 m/s	

Shell-Lander (SHL) – Concepts

- Carry-on Surface Science Package (e.g. Mascot) with a mass of 10-15 kg, with a protective shell structure to sustain higher impact loads during landing resulting from touchdown velocities of 1-4 m/s.
  - Concept No.1: full-shell, no Propulsion, no attitude control, no electric actuators (motors), fixed shell with cut-outs for optical sensors.
  - Concept No.2: full-shell, no propulsion, no attitude control, no electric actuators (motors), unfold or eject shell after landing with spring mechanism, posibility of additional solar generators.
  - Concept No.3: half-shell, no propulsion, vertical attitude control with fly-wheel or spin stabilzed at separation, ejection of shell after first impact.



Hardware Tests - Pendulum Testbed

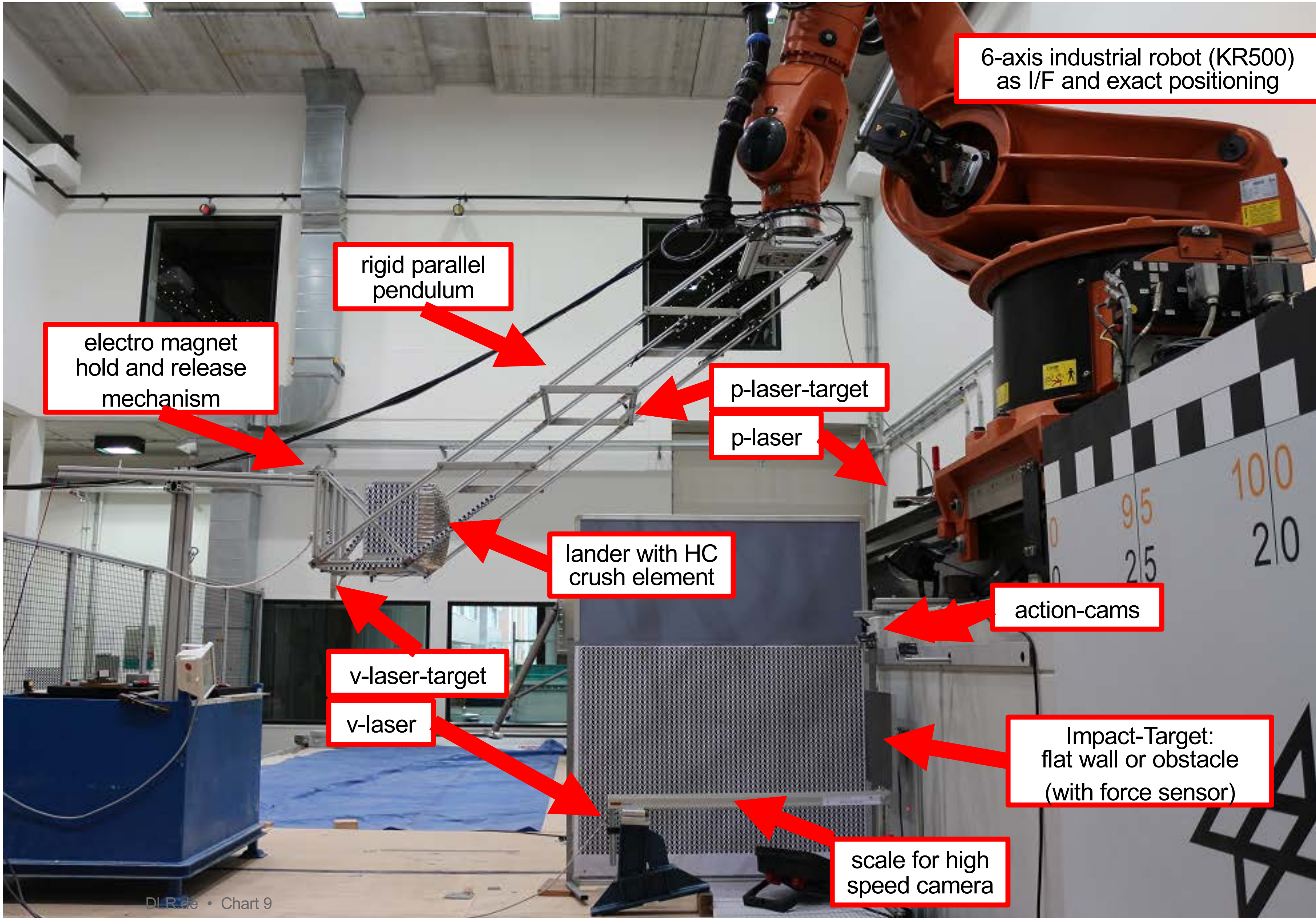
d

mg

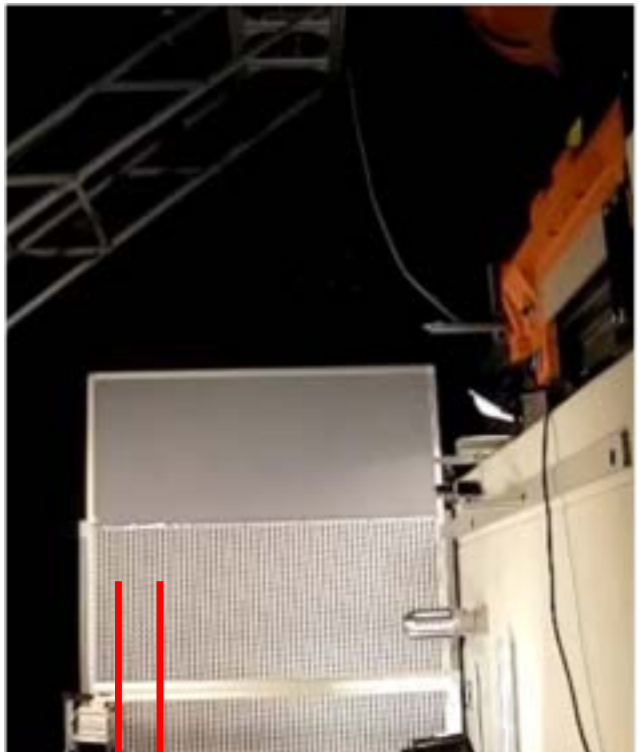
Target:
flat wall or hemisperical obstacle

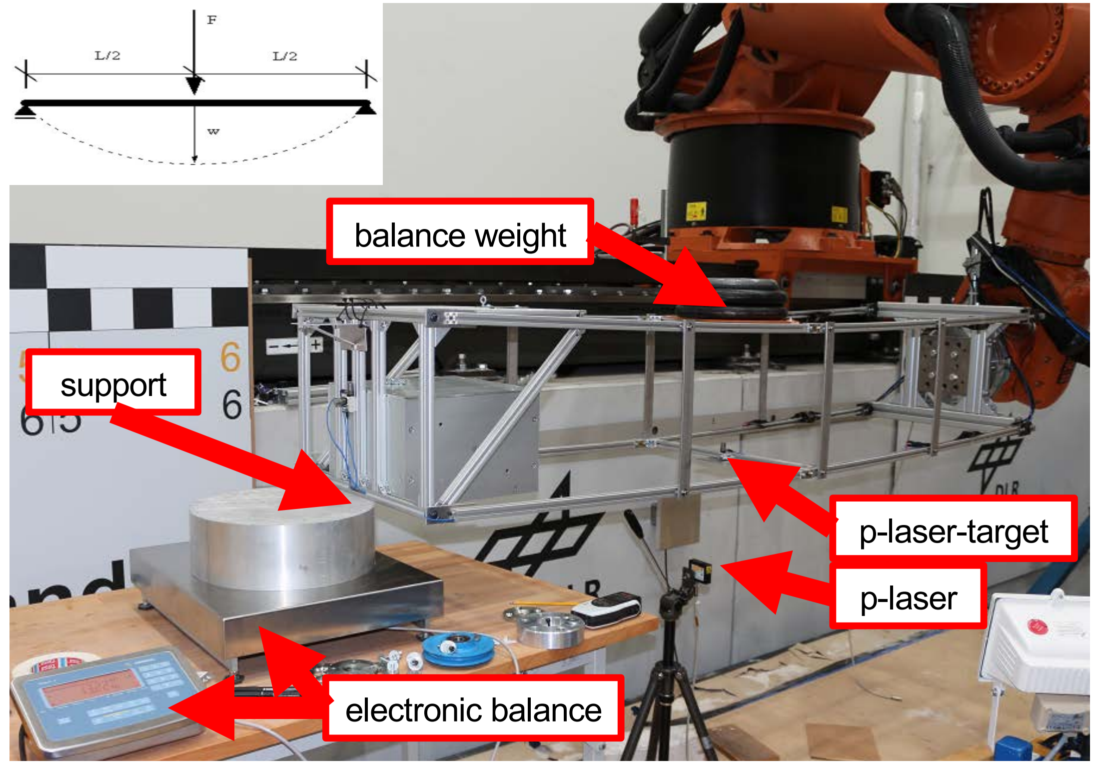
Lander
demonstrator

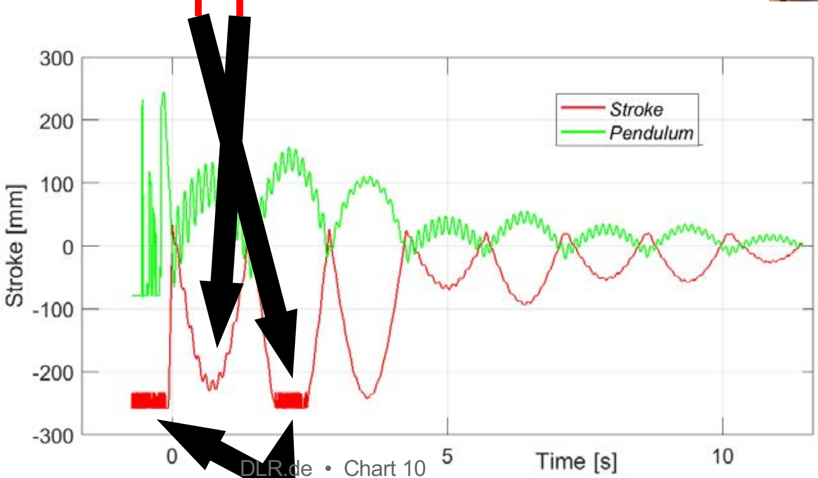
Test Setup @ DLR Landing and Mobility Test Facility (LAMA)

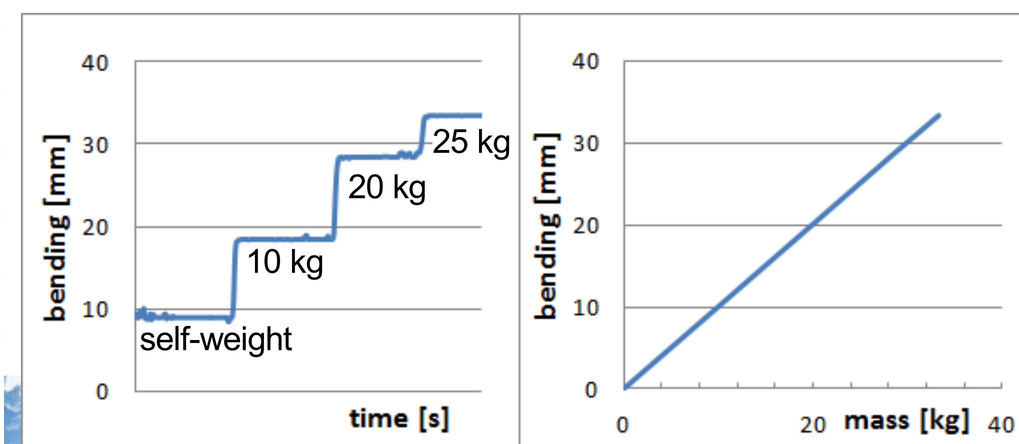


Pendulum Characterisation „Bending Beam Oscillation“









Testplan

Fixed core and face sheet material:

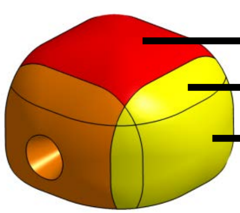
- core: AL-Honeycomb
- FaceSheet: Dyneema fabric

Tests performed for worst case scenarios:

- hard flat (boulder >> lander)
- hard obstacle (boulder << lander)

Objectives:

1) Difference between flat and obstacle impact
2) Difference between top side and edge elements

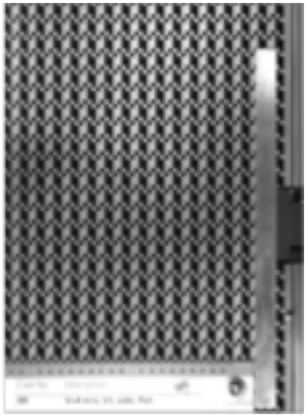


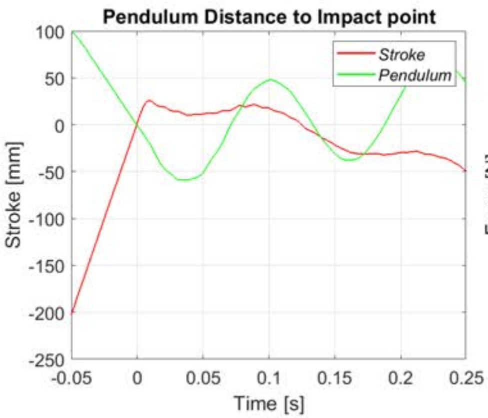
3) Influence of face sheet and number of laminates (specifies stiffness)
4) Influence of impact speed

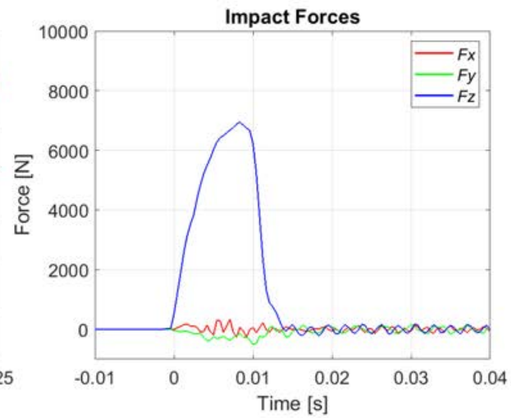
Test No.	Part No.	No.of Laminates	Impact Velocity [m/s]	Impact element	Impactor type
1	T4	2	4	top	flat
2	T5	2	4	top	penetrator
3	T1	1	4	top	penetrator
4	T2	1	4	top	penetrator
5	T3	1	4	top	flat
6	T8	0	4	top	flat
7	T7	0	3	top	flat
8	T6	0	2	top	flat
9	S1	1	4	side	flat
10	S2	1	4	side	penetrator
11	S9	0	4	side	penetrator
12	S8	0	3	side	penetrator
13	S7	0	2	side	penetrator
14	S6	2	2	side	penetrator
15	S5	2	4	side	penetrator
16	S4	2	4	side	flat
17	E1	1	3	short edge	penetrator
18	S6/T4	2/2	4	long edge	penetrator
19	T4/S6	2/2	4	long edge	penetrator
20	T5/S5	2/2	4	long edge	flat
21	S5/T5	2/2	4	connection T5/S5	flat

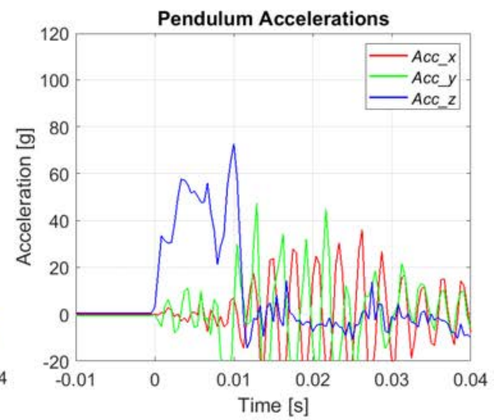
Parts/Elements: T: Top/Bottom, S: Side, E: Edge

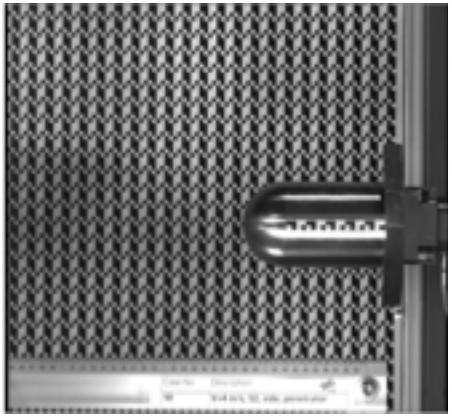
Exemplary Results – Side Elements

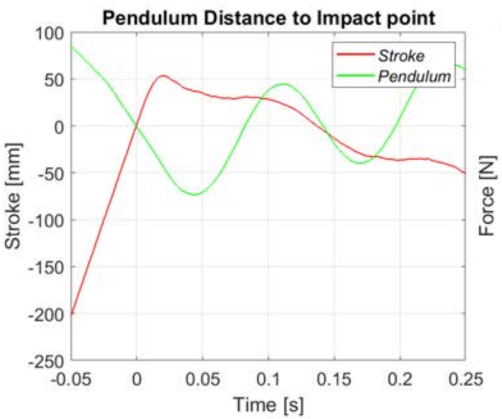


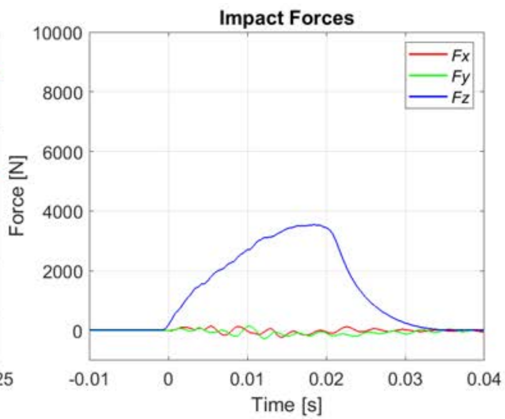


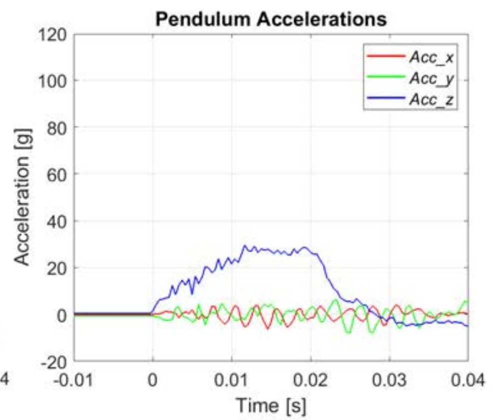








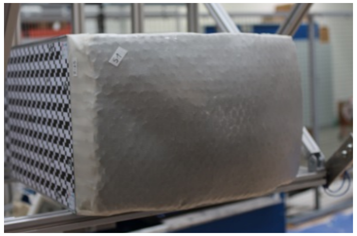


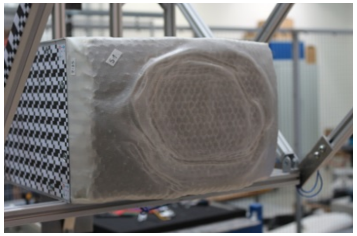


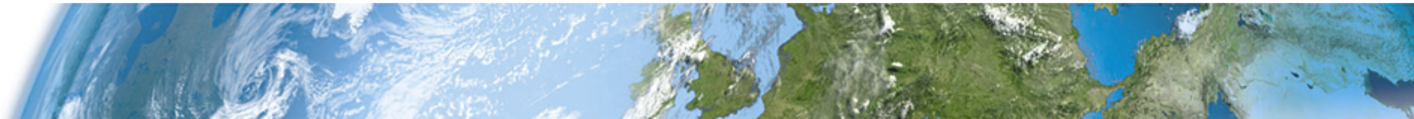
shell dimension:

side shell: 30x20x10cm; mass: 350g

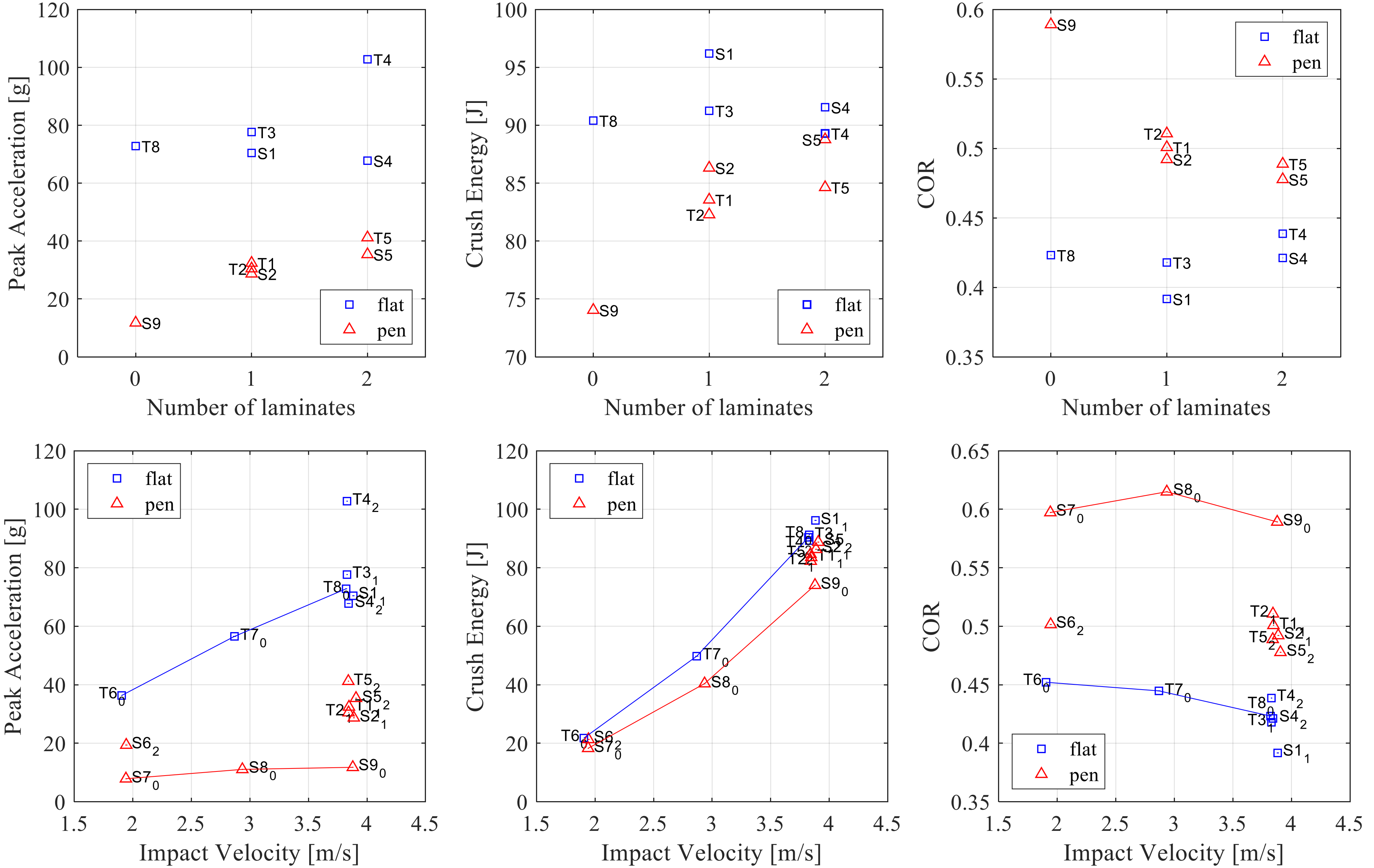
top/bottom: 30x30x10cm; mass: 500g





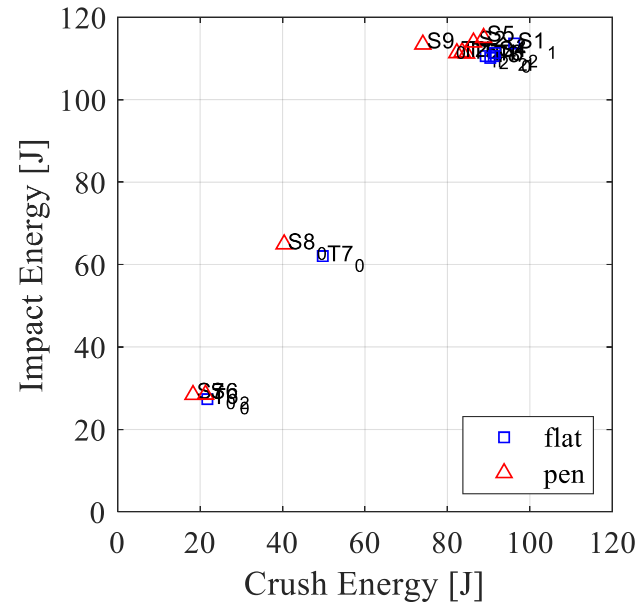


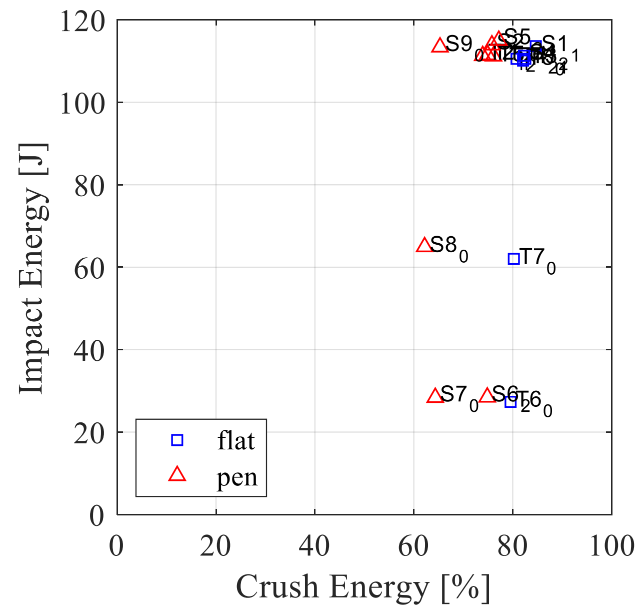
Comparision of Crush-Elements



Conclusion

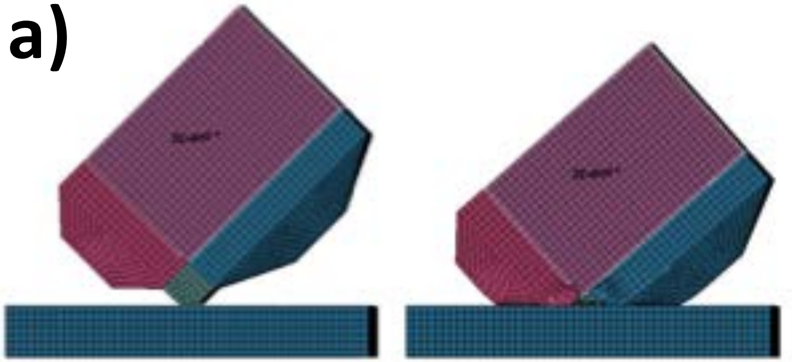
- Shell Lander Concept to support „generic“ surface science pacakges for heigher landing velocities on small bodies (e.g. missions to the Martian moons or Trojan asteroids with diamters of 10 – 50 km),
- Current design includes full- and half shell concepts, dedicated trade-offs on-going,
- Tests performed for shell-elements in lab environment => TRL-4 achieved,
- The combination of a hard shell with a soft core, yields to high enery absorbtion and lower peak acceleration,
- Absorbed Energie and COR independ of impact speed, here: ~80%





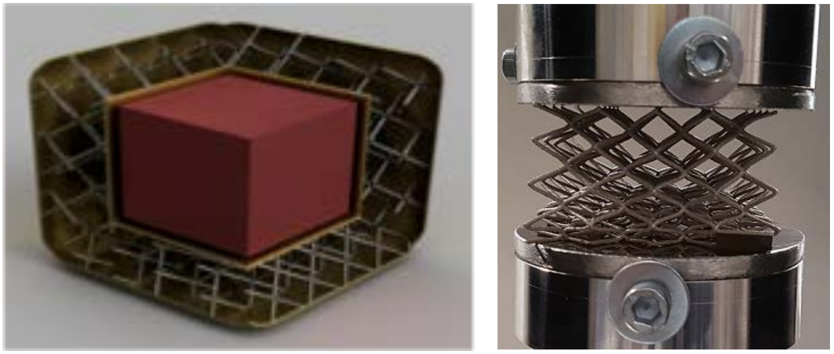
Outlook and Ongoing Work

a)



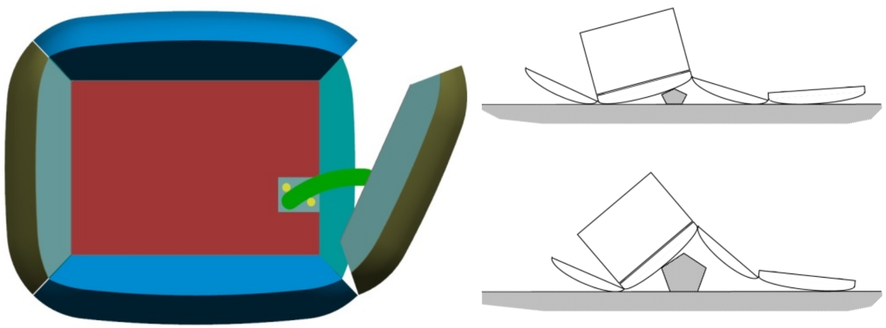
Numerical Simulation and Test Correlation

c)



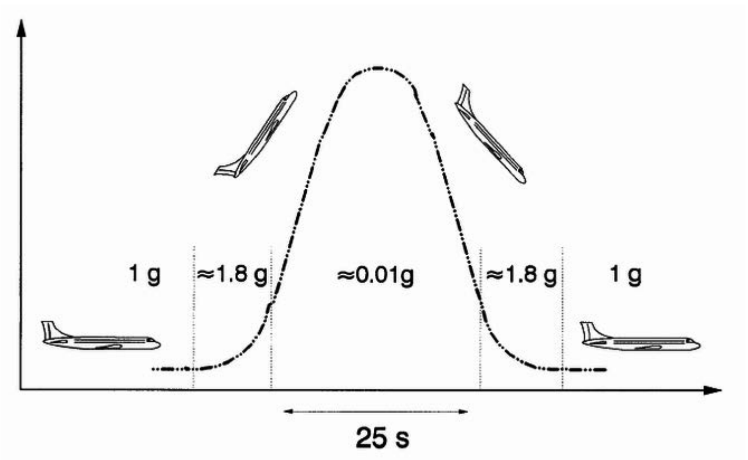
Test of different materials
(e.g. 3D-printed metal structures)

b)



Design and test of unfolding mechanism

d)



Bouncing Tests in Zero-G