Abstract #1640

English

Lunar regolith sampling using PACKMOON device and its potential application for Moon exploration and utilization

Surface sampling and excavation processes on planetary bodies significantly differ from their Earth equivalents due to spacecraft constraints and nontrivial influence of lower gravity. In some cases, new devices or their subsystems need to be invented to get feasible operations. In this paper the prototype of a new type of sampling device, called PACKMOON, dedicated for low gravity bodies space environment, is presented. The principle of operation of the PACKMOON device is based on two key elements: insertion of the spherical jaws into regolith by rotary hammering actions and minimization of interaction with the lander by taking advantage of doubling mechanical subsystems, which operate in the same angular direction but in opposite sense. Results of the tests that were conducted with highly compacted lunar regolith (Chenobi and AGK2010) have shown its reliable operation. The tests conducted on harder materials have shown its proper operation if the regolith bearing capacity do not exceed 5-7 MPa. The tests on air bearing table with lander mock-up shown its negligible influence on lander stability. In addition, the analysis of PACKMOON re-scaling was done to estimate its potential usage for more industry oriented excavation processes needed for both the early phase of Lunar base development as well as its further nominal operation.

French

No abstract title in French

No French resume

Author(s) and Co-Author(s)

Dr. Karol Seweryn
(UnknownTitle)
Space Research Centre of the Polish Academy of Sciences (CBK PAN)

Mr. Pawel Pasko
(UnknownTitle)
Space Research Centre of the Polish Academy of Sciences (CBK PAN)

Dr. Gianfranco Visentin
(UnknownTitle)
European Space Agency (ESA/ESTEC)

Profile of Dr. Karol Seweryn

General

Email(s): ksewery n@cbk.waw.pl
Position:

Preferred Language: [Language not defined]

Addresses

Business

Home

Biographies

Biography submitted with the abstract

Karol Seweryn is an assistant professor at the Space Research Centre of the Polish Academy of Sciences in Warsaw, Poland. He obtained his Ph.D. from Warsaw University of Technology in the field of Control System and Robotics. His principal research interests lie in the field of dynamics of elastic and rigid multibody systems working in space environments, and planetary surface/subsurface exploration in low gravity environments. He is involved in future ESA robotic and exploratory missions such as Phootprint or eDeorbit.

Biography in the user profile

Collaborators

Author(s) and Presenter(s)

Author(s):

Dr. Karol Seweryn

[Unknown Title]
Space Research Centre of the Polish Academy of Sciences (CBK PAN)

Mr. Pawel Pasko
[Unknown Title]
Space Research Centre of the Polish Academy of Sciences (CBK PAN)

Dr. Gianfranco Visentin
[Unknown Title]
European Space Agency (ESA/ESTEC)

Presenter(s):

Dr. Karol Seweryn
[Unknown Title]
Space Research Centre of the Polish Academy of Sciences (CBK PAN)

Lunar regolith sampling using PACKMOON device and its potential application for Moon exploration and utilization

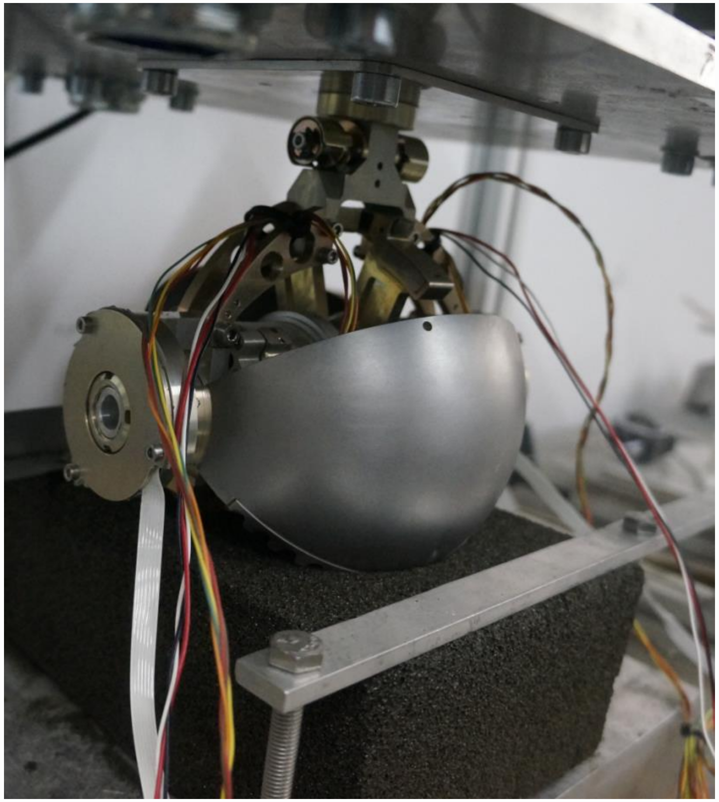
K. Seweryn[1], P. Paśko[1], G. Visentin[2]

[1]Space Research Centre PAS (CBK PAN), Warsaw, Poland (kseweryn@cbk.waw.pl).
[2]European Space Agency (ESA/ESTEC), Noordwijk, The Nederlands.

Planetary and Terrestrial Mining Sciences Symposium,
Montréal, Canada, 2017.

Outline

1. CBK previous experience with planetary subsurface investigations and gravity impact on its design
2. PACKMOON device: concept, breadboards, final prototype, tests results
3. Conclusions
4. Future plans

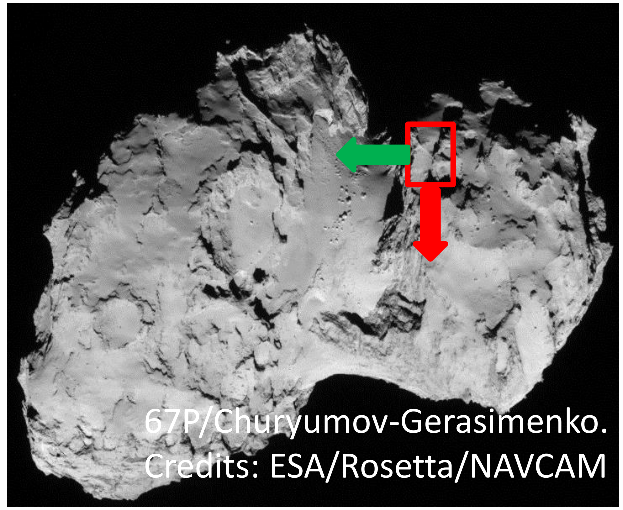


Low and near zero gravity

Regolith processing is different in low or near zero gravity environments

Sampling processes should not impact on lander stability

Source: J. Grygorczuk, CBK PAN



67P/Churyumov-Gerasimenko.
Credits: ESA/Rosetta/NAVCAM

Small bodies posses not spherical gravity field

Angle between local vertical and gravity vector may significantly differ

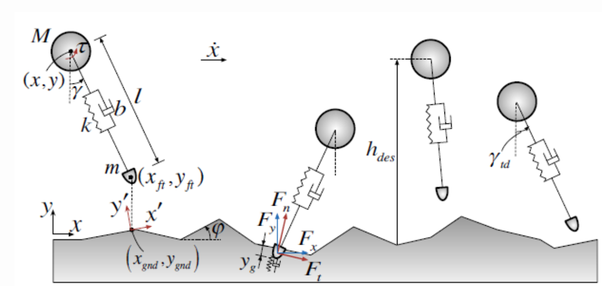
It caused a need to investigate from scratch principles of many devices and processes

Source: thespacereview.com

Mobility:

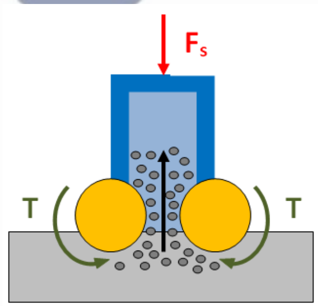
The rovers may not be the best option for axampe to investigate Moon caves

Jumping might be much more efficient

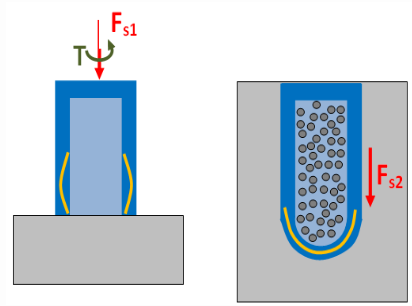


Source: Vasilopoulos et al. ASTRA, 2015

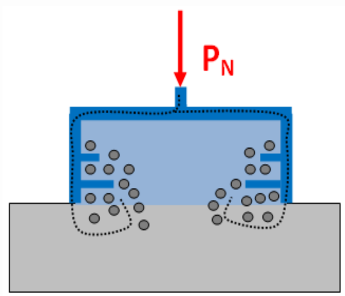
Possible Sampling devices



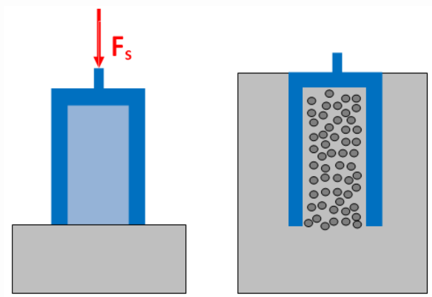
Brush sampling tool



Corer sampling tool



pressure sampling tool

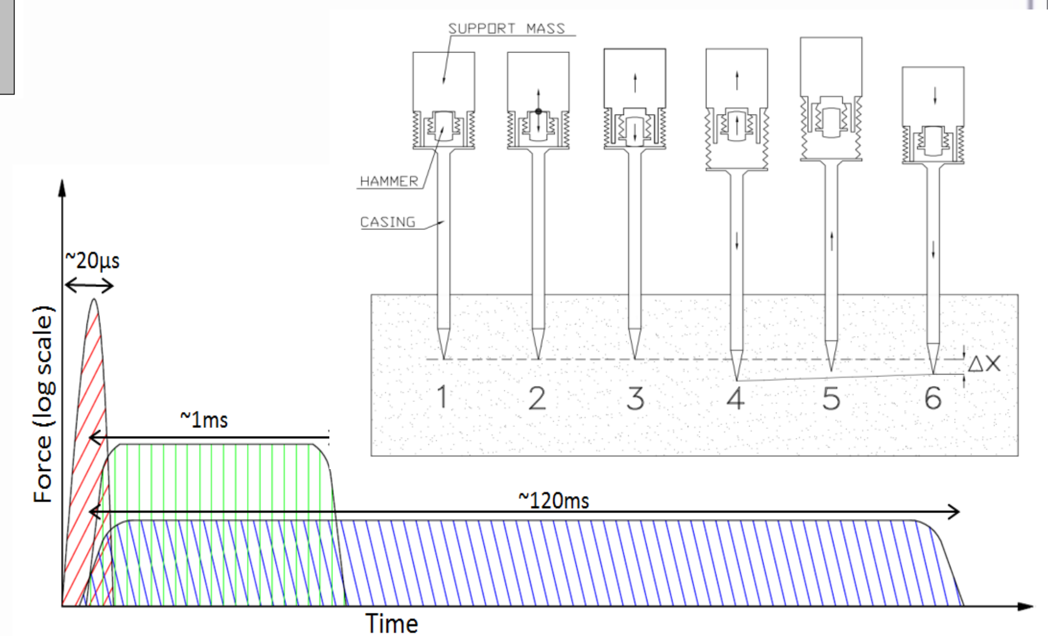


static sampling tool

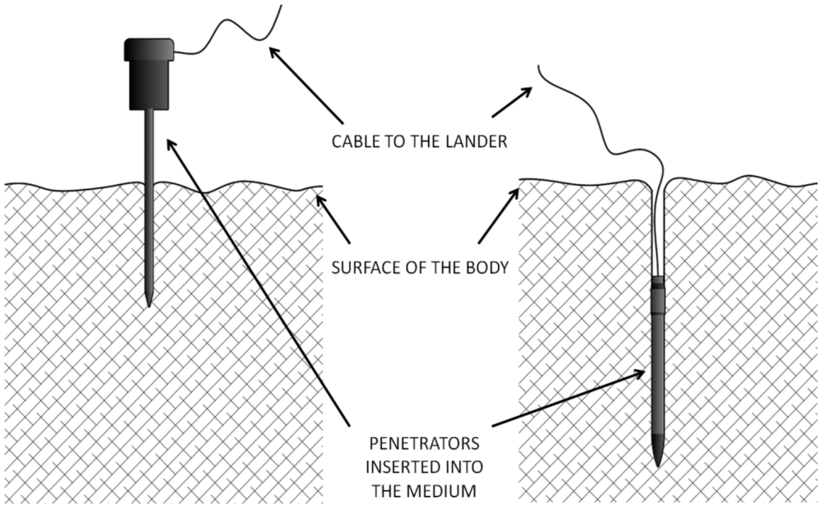
- If not anchor the gravity is needed for proper hammering operation
- LVP was invented (Gromov et al., Grygorczuk et al.) to overcome lack of gravity

Still two problems remains

- Reaction (blue part) in some specific cases are able to stop foreword motion
- Sample breaking require lander support



Past expirience



Theoretical description is provided in Seweryn et al., Acta Astronautica 99, 2014

CBK PAN / Astronika contribution to HP3 on NASA Insight mission

Low Velocity Penetrators

MUPUS

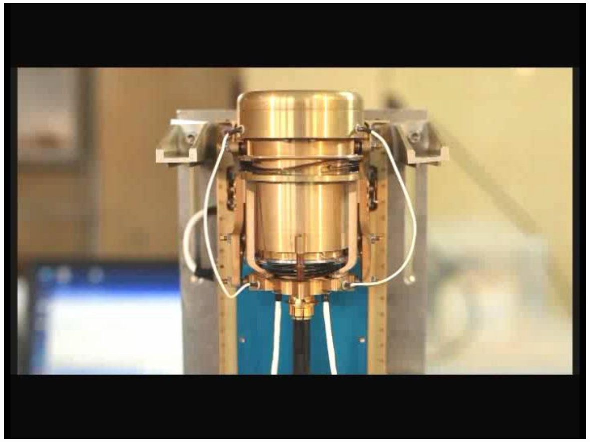
KRET

CHOMIK

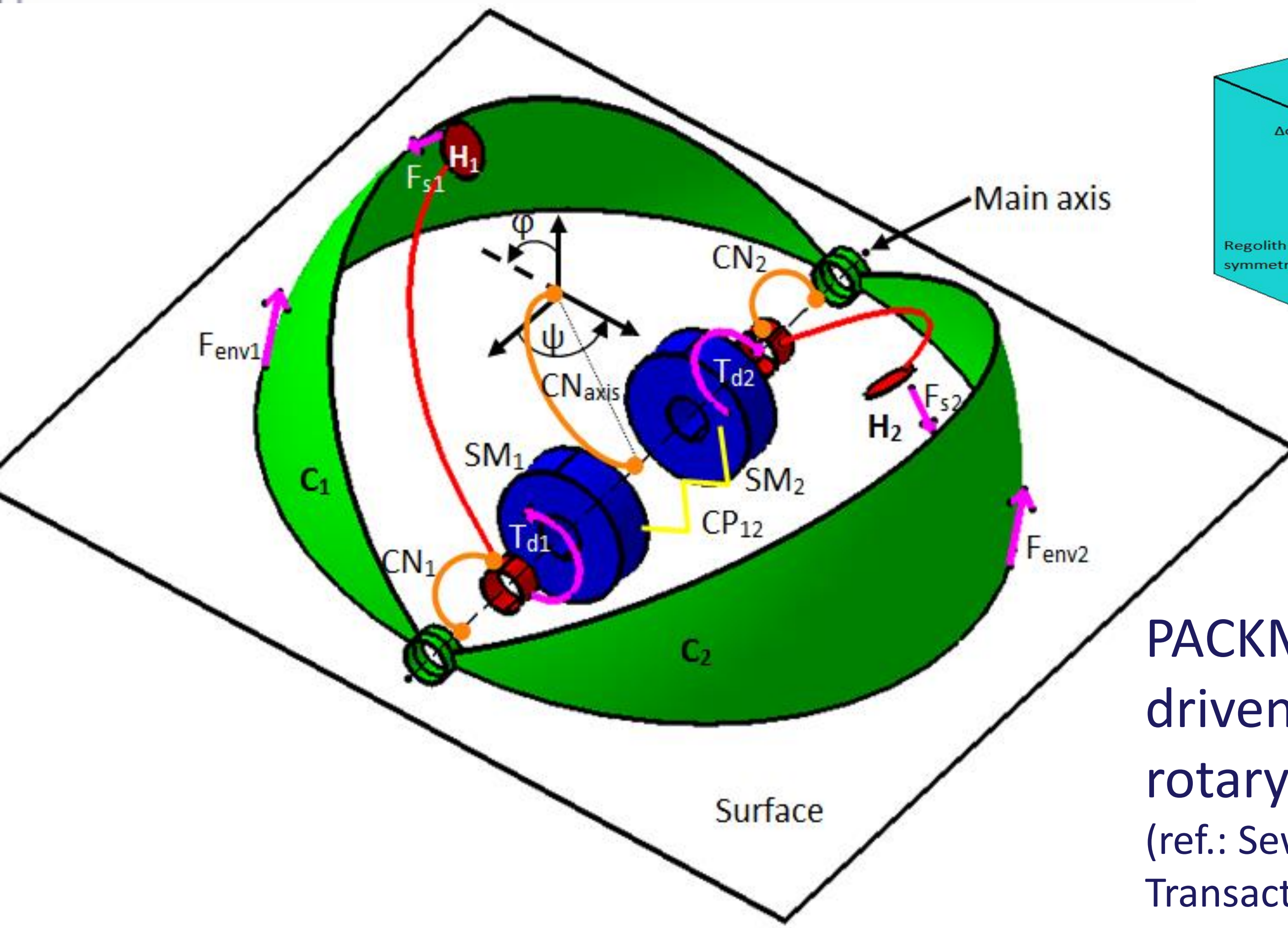
PACKMOON concept

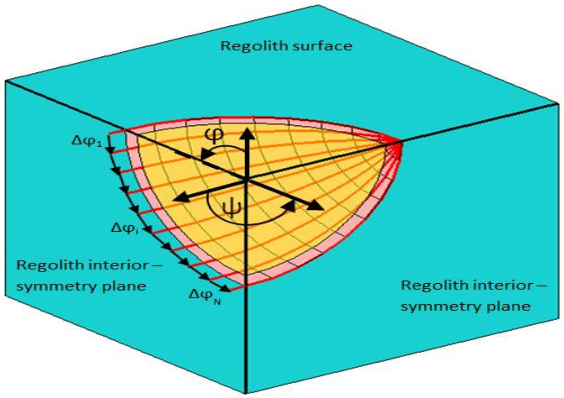
Main drivers for a PACKMOON sampling tool development

- High amplitude dynamic force is the effective way to pump energy into the end of crack and in that sense it seems to be well applicable for sampling process in a priori unknown space environment.
- For safety reasons, the sampling tool must not anchor the lander.
- The sampling tool must not disturb the sample interior structure.
- The sample tool should allow for multiple use



PACKMOON concept





PACKMOON device driven by hammering rotary action

(ref.: Seweryn K., ASME/IEEE Transactions on Mechatronics; Vol. 21, No. 5, 2016)

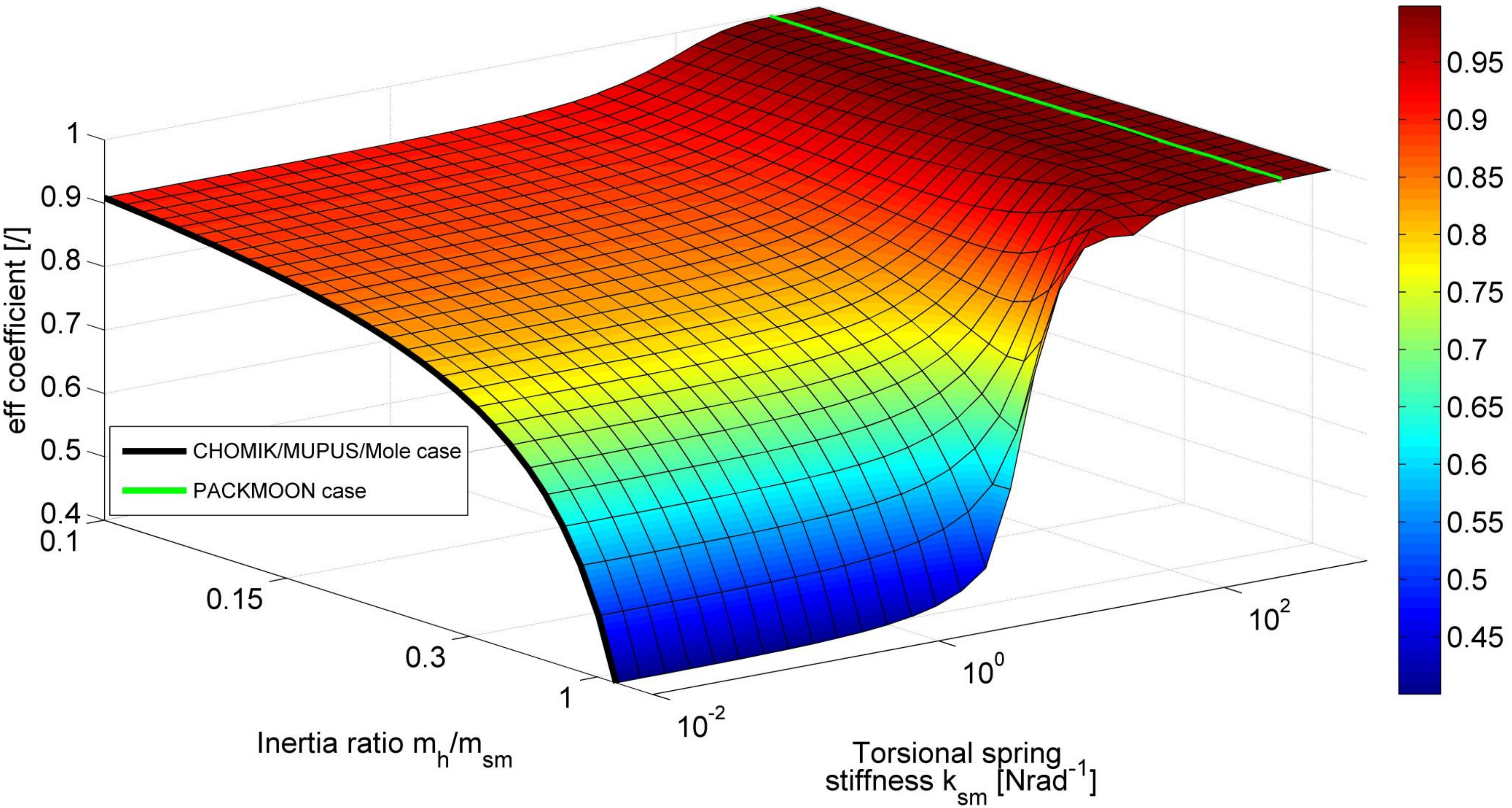
PACKMOON concept

- Phase 1: Accumulation of the potential energy in capacitors
- Phase 2: Exchange of the potential energy for the kinetic energy of the respective hammer through generation of torques (T_{d1} and T_{d2})

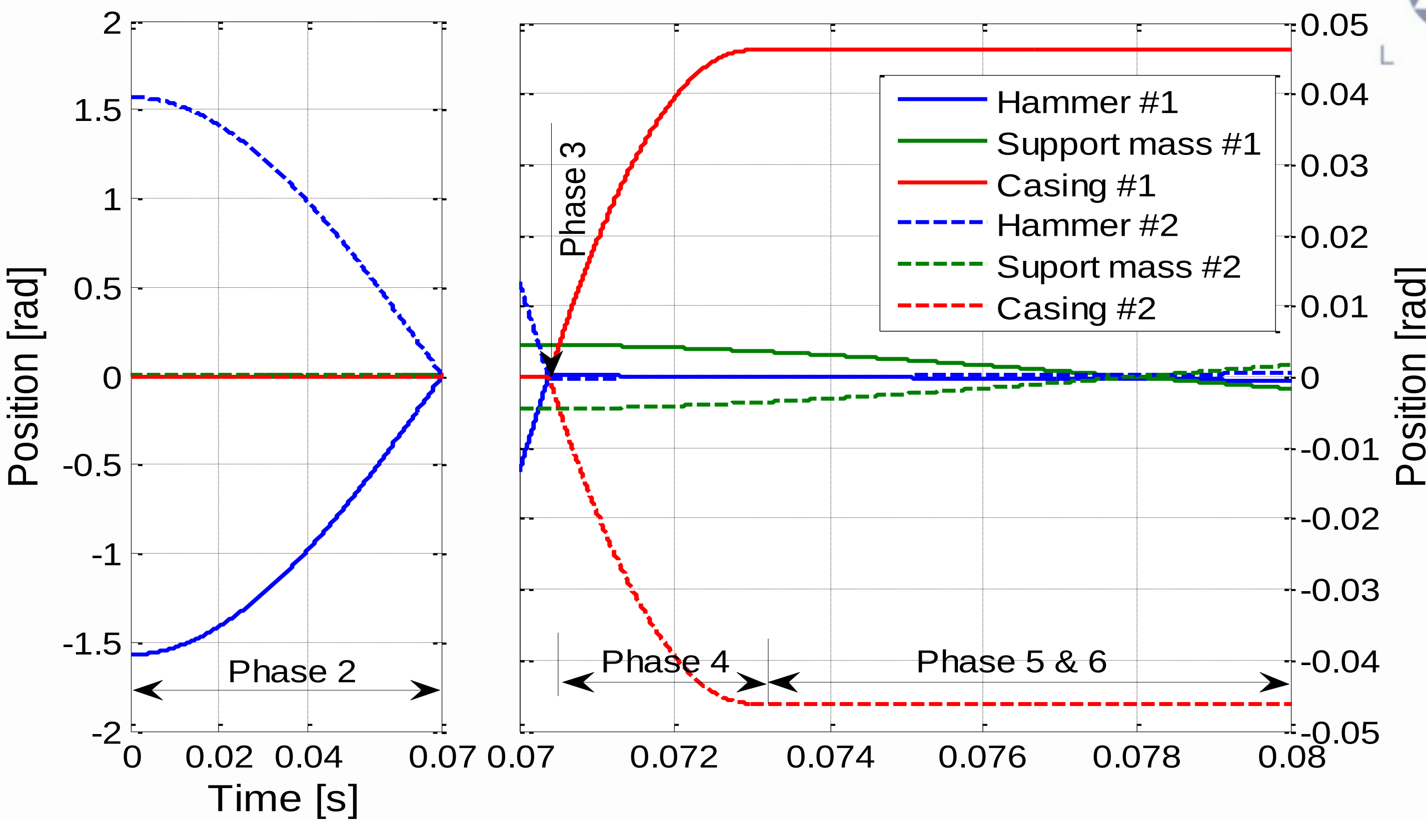
$$E_h(t_3) = \frac{1}{2} I_h \omega_h^2 = E_{pot} - \left(\frac{1}{2} I_{sm} \omega_{sm}^2 + \frac{1}{2} k_{sm} \varphi_{sm}^2 \right) = eff \cdot E_{pot}$$

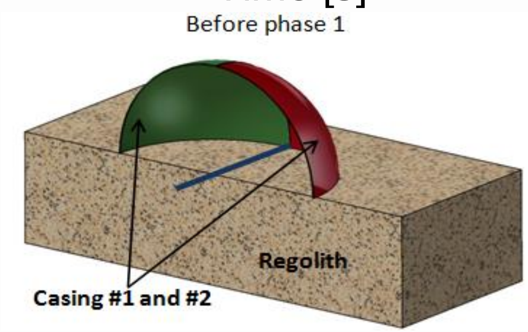
- Phase 3: Exchange of the kinetic energy between the hammer and the casing by impact.
- Phase 4 Damping of the casing motion due to interactions with surrounding materials
- Phase 5 In this phase, the support mass moves in the opposite sense to the respective hammer and casing

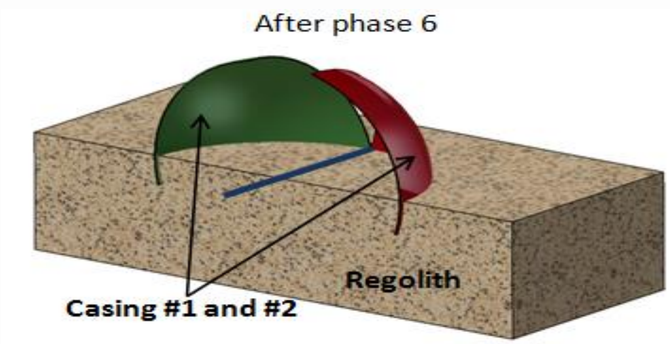
PACKMOON concept



PACKMOON math model

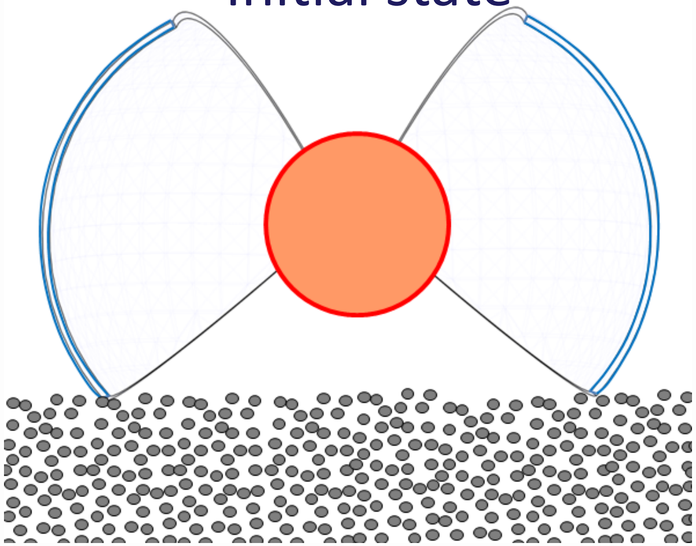




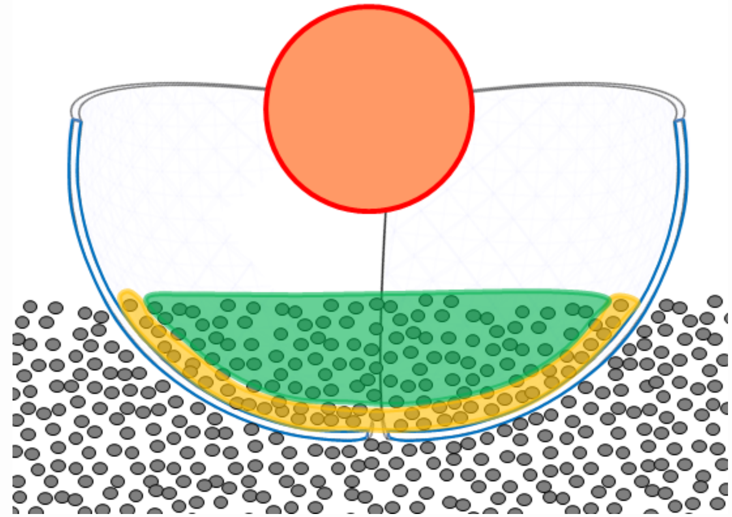


Impact on sample

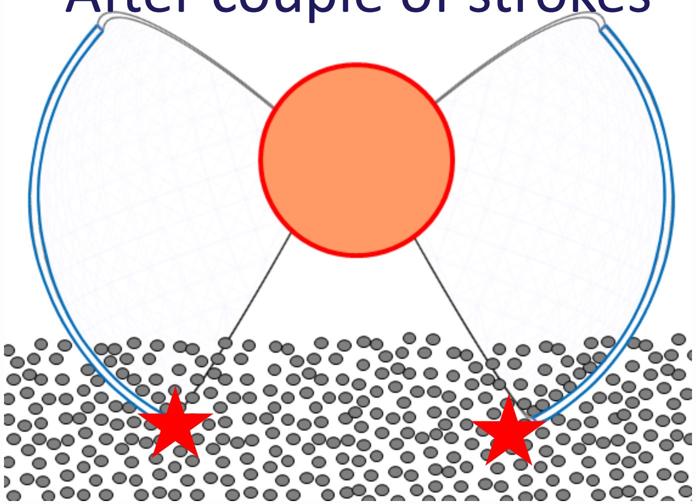
Initial state



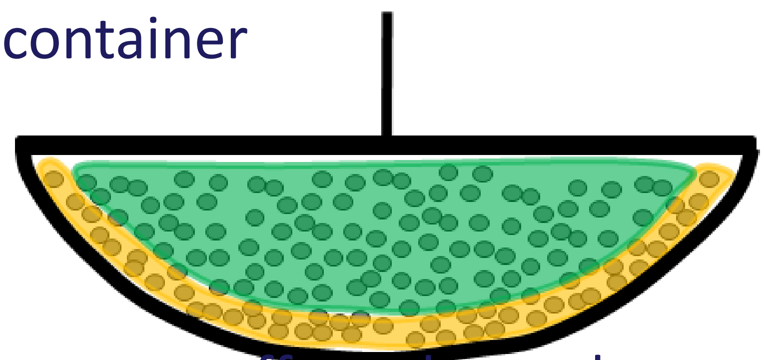
Final state



After couple of strokes



Sample delivery to container



Green – not affected sample

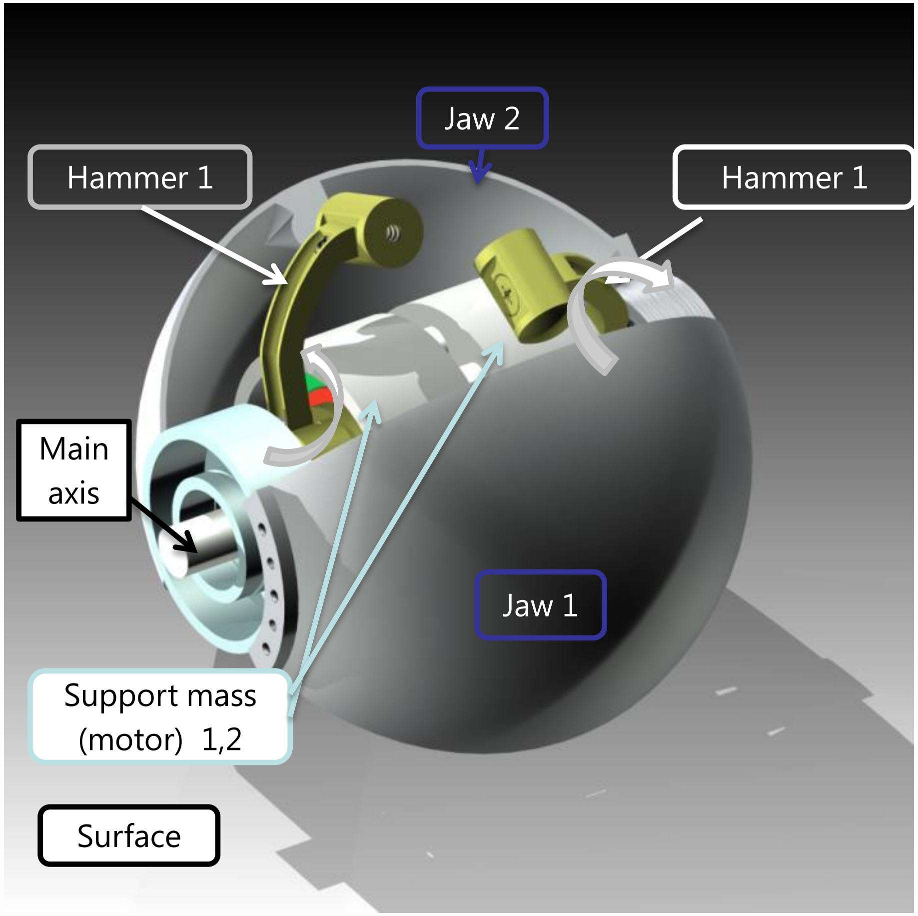
Yellow – partially affected sample

Breadboards

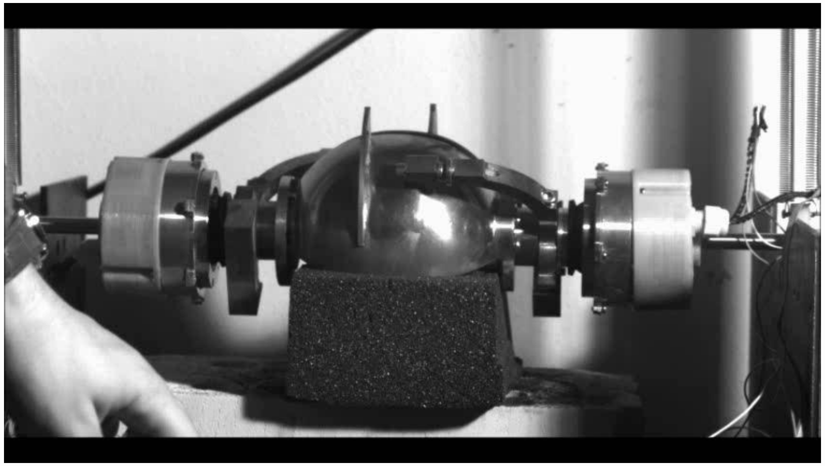
PACKMOON sampling design

Project founded by ESA 4000112603/12/NL/CBi

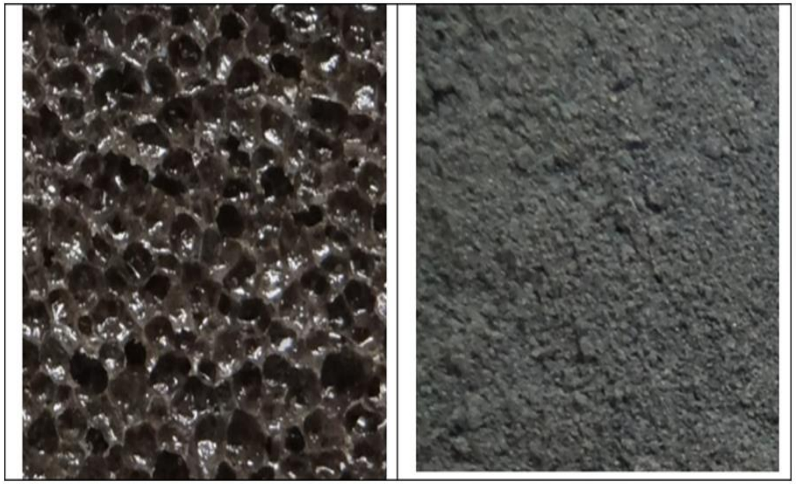
- PACKMOON are able to collect a large regelith sample in near zero g planetary environment
- PACKMOON not generate reactions force to lander
- PACKMOON is safe for collected sample
- PACKMOON is one of third European sampling device considered for future Phobos Sample Return mission (MREP optional program)



First and second breadboard



Materials sampled during tests ref. Seweryn K., et al., PSS, 2014



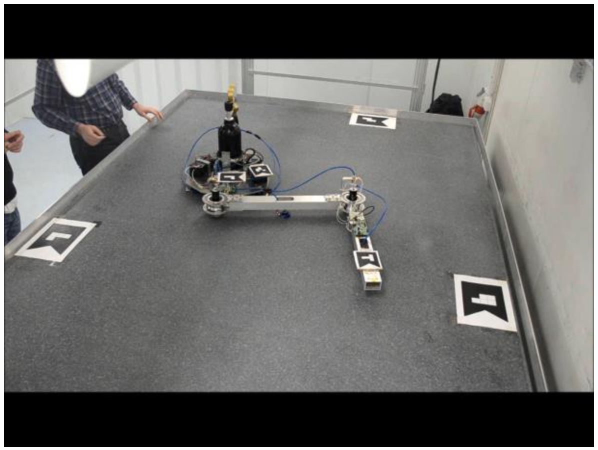
Test results

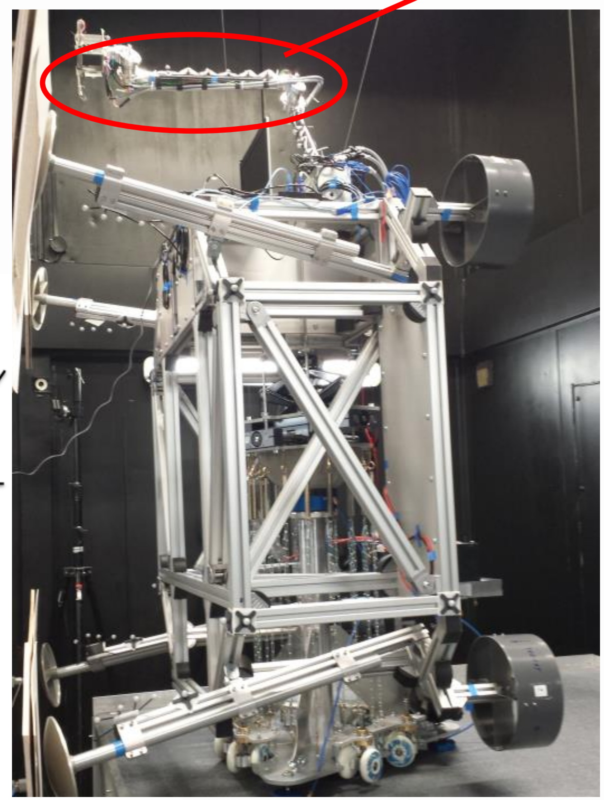
Material	Regolith		
Lander Support force	5N	13N	20N
Number of hammering actions	1	2-3	9
Avarage stroke energy	0,6J	0,2-0,7J	0,24J
Mass/volume of acquired sample	120 g/85 cm^3	300 g/ 212 cm^3	450g/ 318cm^3

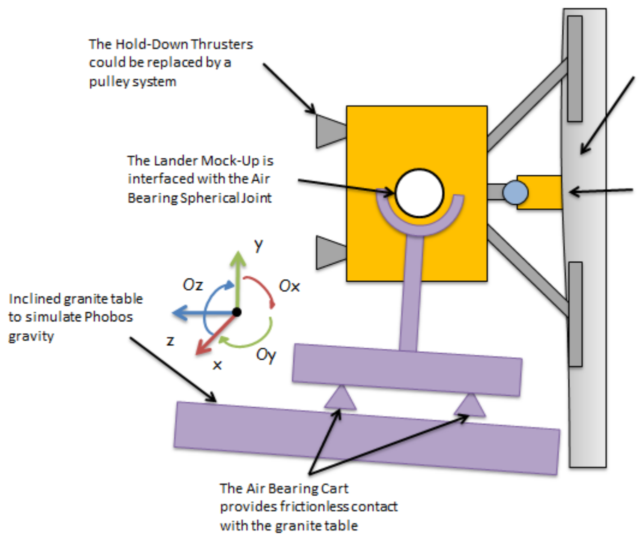
Material	"Soft" foamglass	"Firm" foamglass	"Firm" foamglass
Lander Support force	11N	11N	20N
Number of hammering actions	19	51	105
Avarage stroke energy	0,3J	0,31-0,43J	0,24J
Mass/volume of acquired sample	17,2 g/100 cm^3	16,5 g/135 cm^3	35,6 g/292 cm^3

Fourth breadboard

Activity funded by ESA SAMPLER project led by Airbus UK with AVS, Selex, Open univ and Frentech involvment



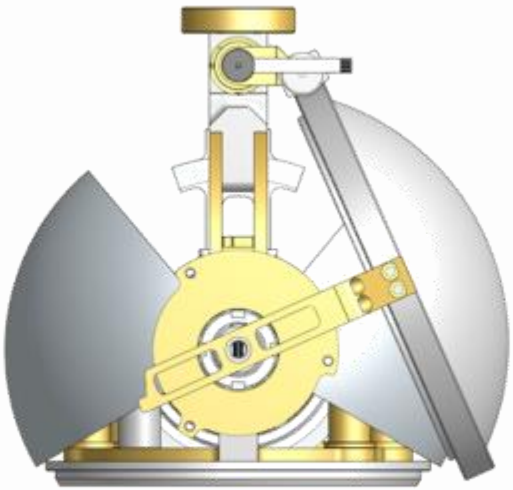




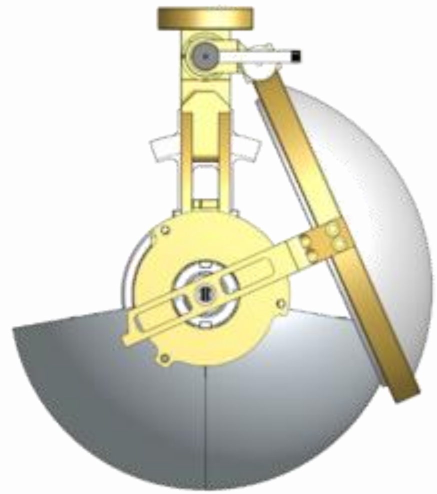
Final Prototype

Operation Scenario

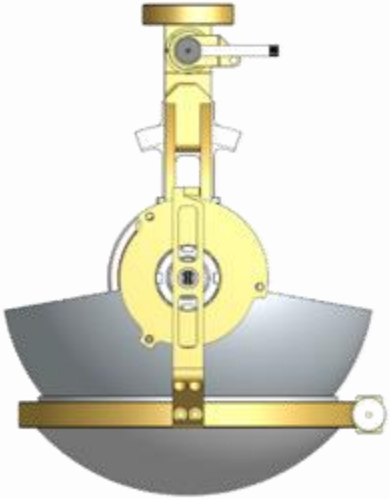
1. Initial position



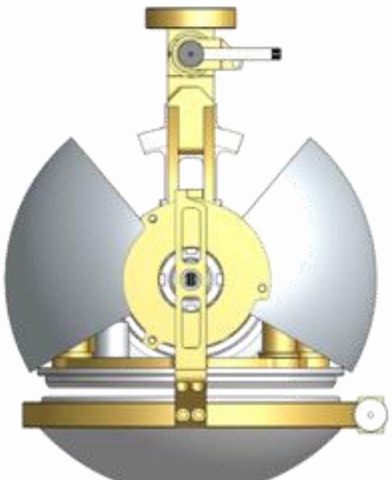
2. Hammering and jaws closure



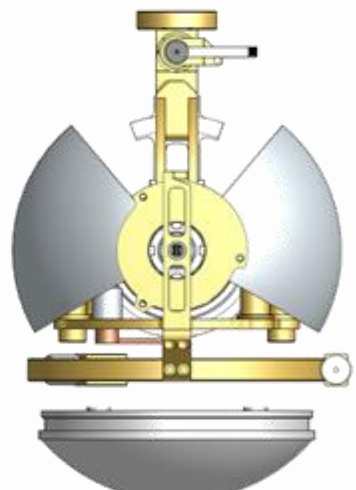
3. Container deployment



4. Jaws opening and sample removal

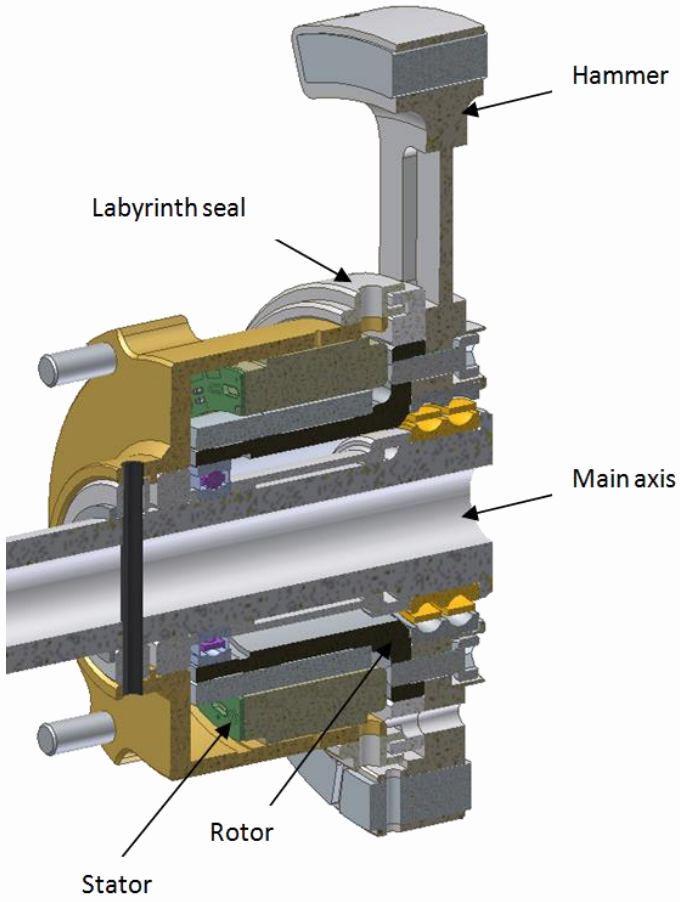


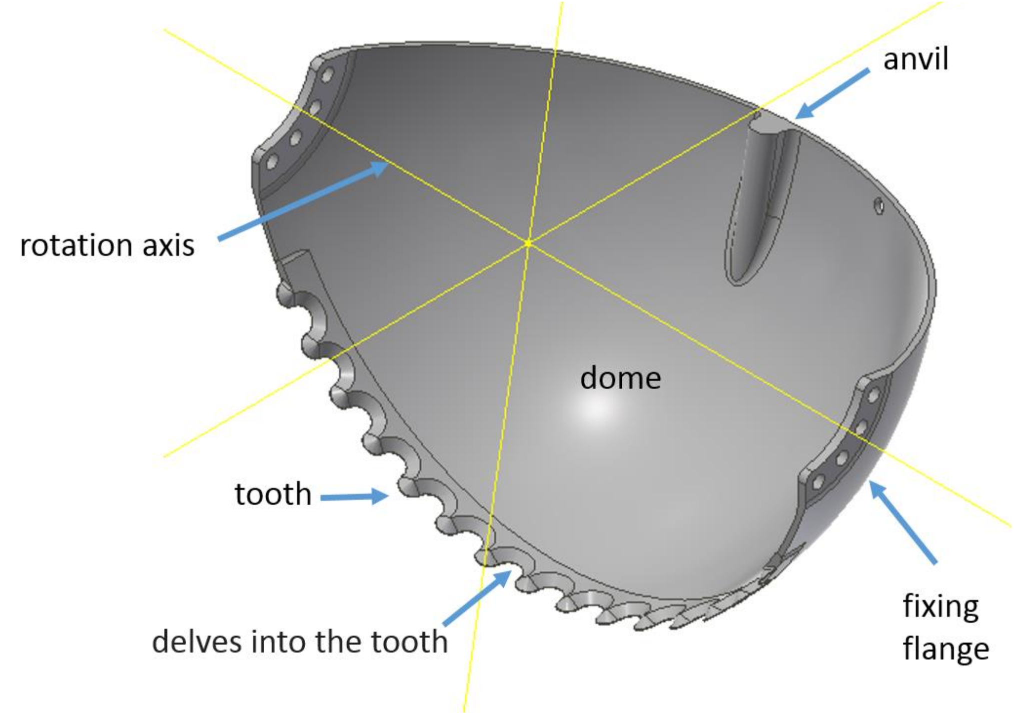
5. Container release



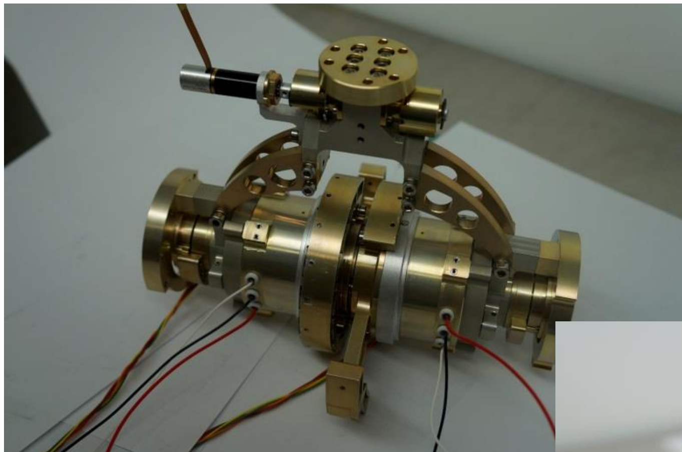
Hammers and spherical jaws

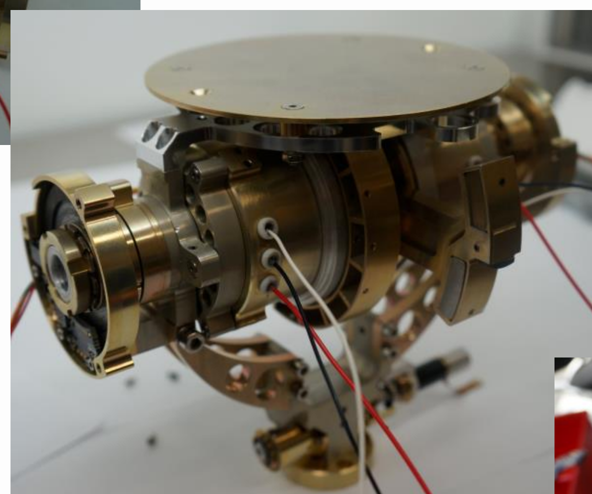
Element	Mass	Moment of Intertia	COG distance
Hammer with rotor	395g	535 Kg*mm^2	X: -0,31 mm Y: 11,1 mm Z: 0,19 mm

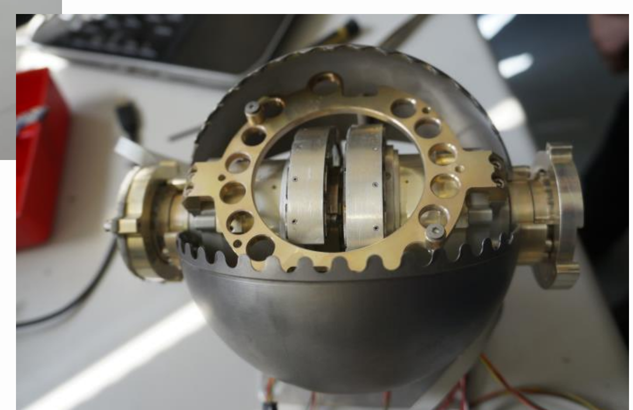




Assembly and Integration

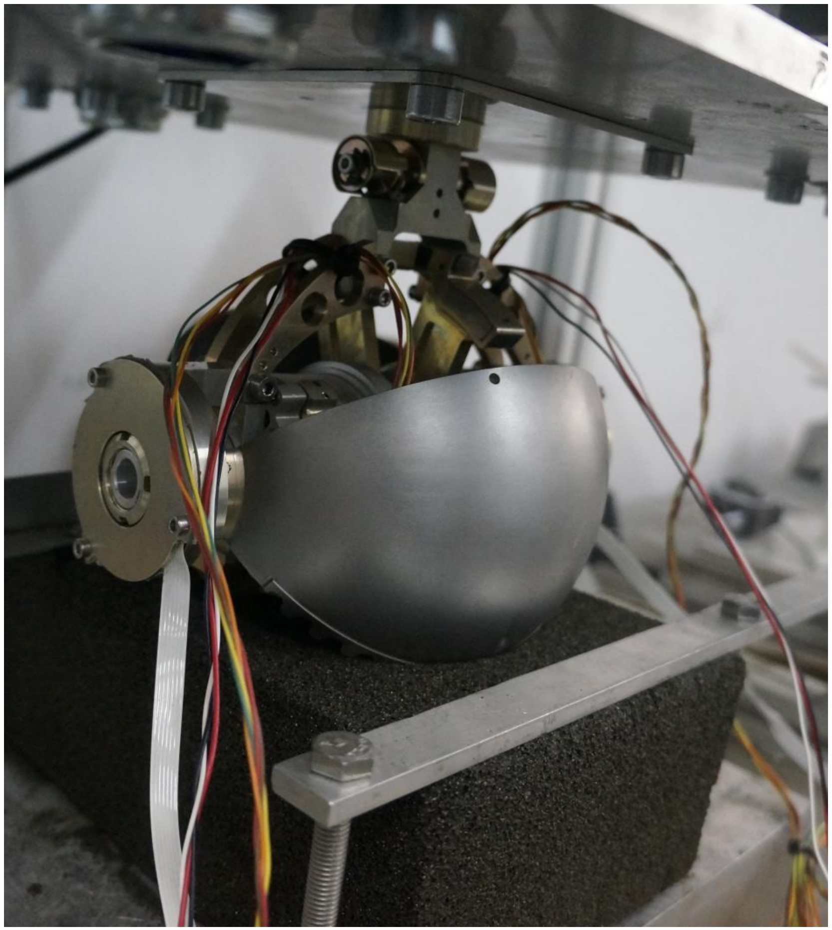






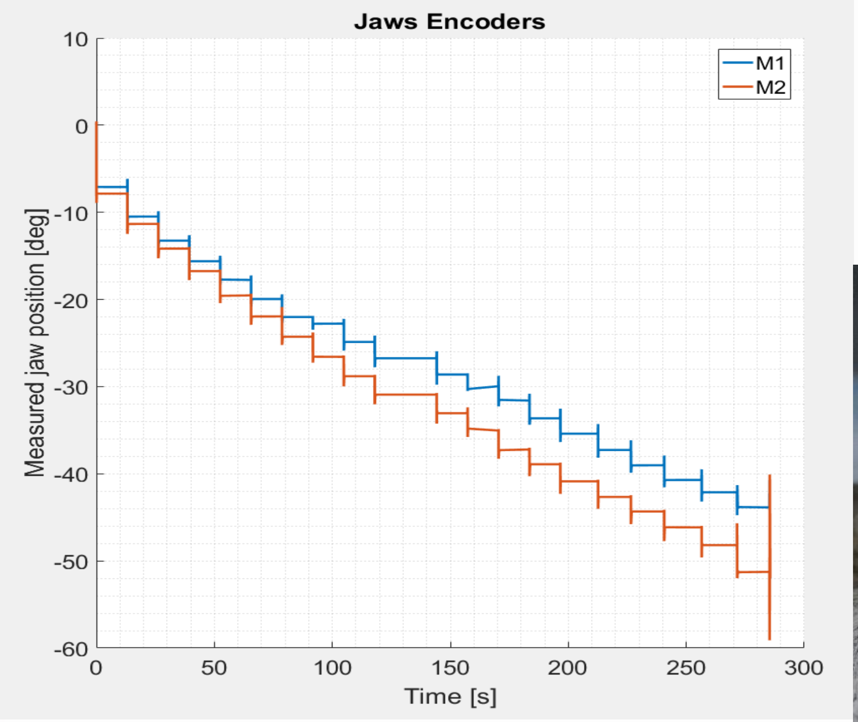
Testing campaign

Tests done in Lunar regolith and foamglass



Tests Results

- Jaw progres recorded by the encoders



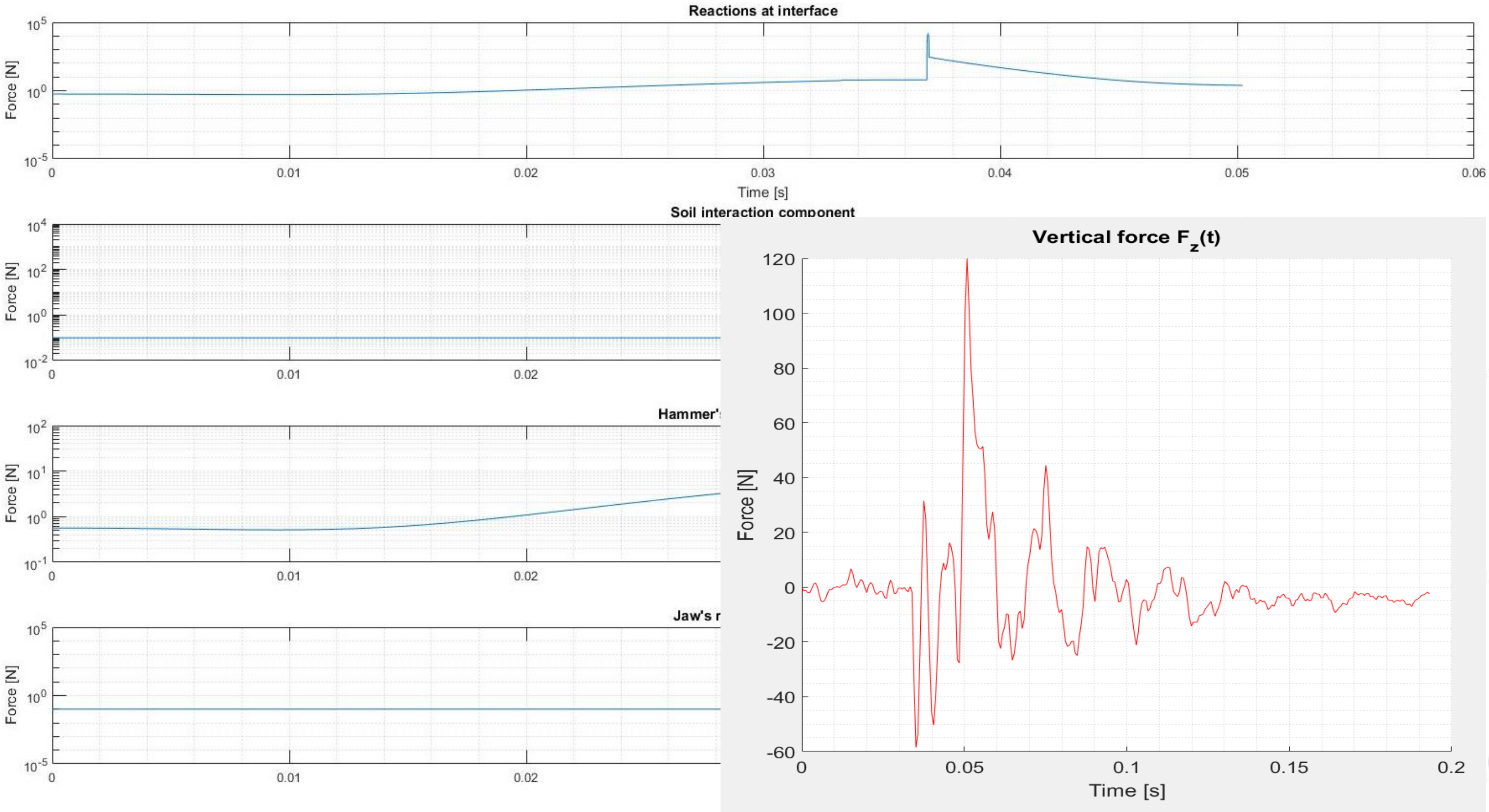
- PACKMOON is capable to collect sufficient amount of the sample even when the jaws are not fully closed (eg. stuck pebble)

Tests Results

Material	Strikes	Time [s]	Mass [g]	Strikes (mean)	Time [s] (mean)	Mass [g] (mean)
Foamglass 2.1 Mpa	22	176	19.3			
Foamglass 2.1 Mpa	20	160	25.5			
Foamglass 2.1 Mpa	23	184	19.3	21.5	182.5	21.1
Foamglass 4.4 Mpa	47	376	25.3			
Foamglass 4.4 Mpa	50	420	27.2			
Foamglass 4.4 MPa	47	376	27.1	49.8	403.0	28.0
AGK2010 (Lunar regolith anloague)	3	24	218			
AGK2010	3	24	267.9			
AGK2010	4	32	276.5	3.3	26.7	254.1
OU Soil Simulant (Phobos analogue)	20	160	294.9			
OU Soil Simulant	26	208	233.1			
OU Soil Simulant	29	232	243.7	23.6	188.8	251.5

Reactions from simulator and tests

- Horizontal reaction at interface and its components.
- Impulse lasts for 8.0x10−5 [s]



Conclusions

1. The PACKMOON device has several specific features
- Relatively large sample can be collected (100 – 300 cm^3) which is structurally and thermally not impacted by sampling process
- The device is small and compact (<3kg, 15x15x18cm size)
- Low power consumption (<10W) with high energy impact
- Sample is secured to be not cross contaminated
2. The device is considered by ESA for future exploratory missions (e.g. Phootprint – Phobos Sample Return)
3. The first fully working prototype is ready and first testing campaign was done – currently we are testing sample securing in container
4. The device is scalable –> with bigger version excavation is possible -> and in my opinion could be a solution for Moon

PACKMOON on Moon … or other low gravity body