The Penetrating Mole of the InSight Mars Mission

ROBEX Sensorworkshop

Marco Scharringhausen, Lars Witte

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InSight

„Interior exploration using Seismic Investigations, Geodesy and Heat Transport“

Source: NASA/JPL

InSight: Science goals and objectives:

1. **Understand the formation and evolution of terrestrial planets through investigation of the interior structure and processes of Mars by:**

   - Determining the size, composition and physical state (liquid/solid) of the core
   - Determining the thickness and structure of the crust
   - Determining the domposition and structure of the mantle
   - Determining the thermal state of the interior

2. **Determine the present level of tectonic activity and meteroid impact rate on Mars.**

   - Measure the magnitude, rate and geographical distribution of internal seismic activity
   - Measure the rate of meteroite impacts on the surface

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P/L: ***HP3*** **(by DLR)**
SEIS **(by CNES)**

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P/L: ***SEIS*** **(by CNES)**

DLR

Heat Flow and Physical Properties Probe (HP3) : Science bckgrnd

Innovative, self-penetrating mole penetrates to a depth of 3–5 meters

Heat Flow

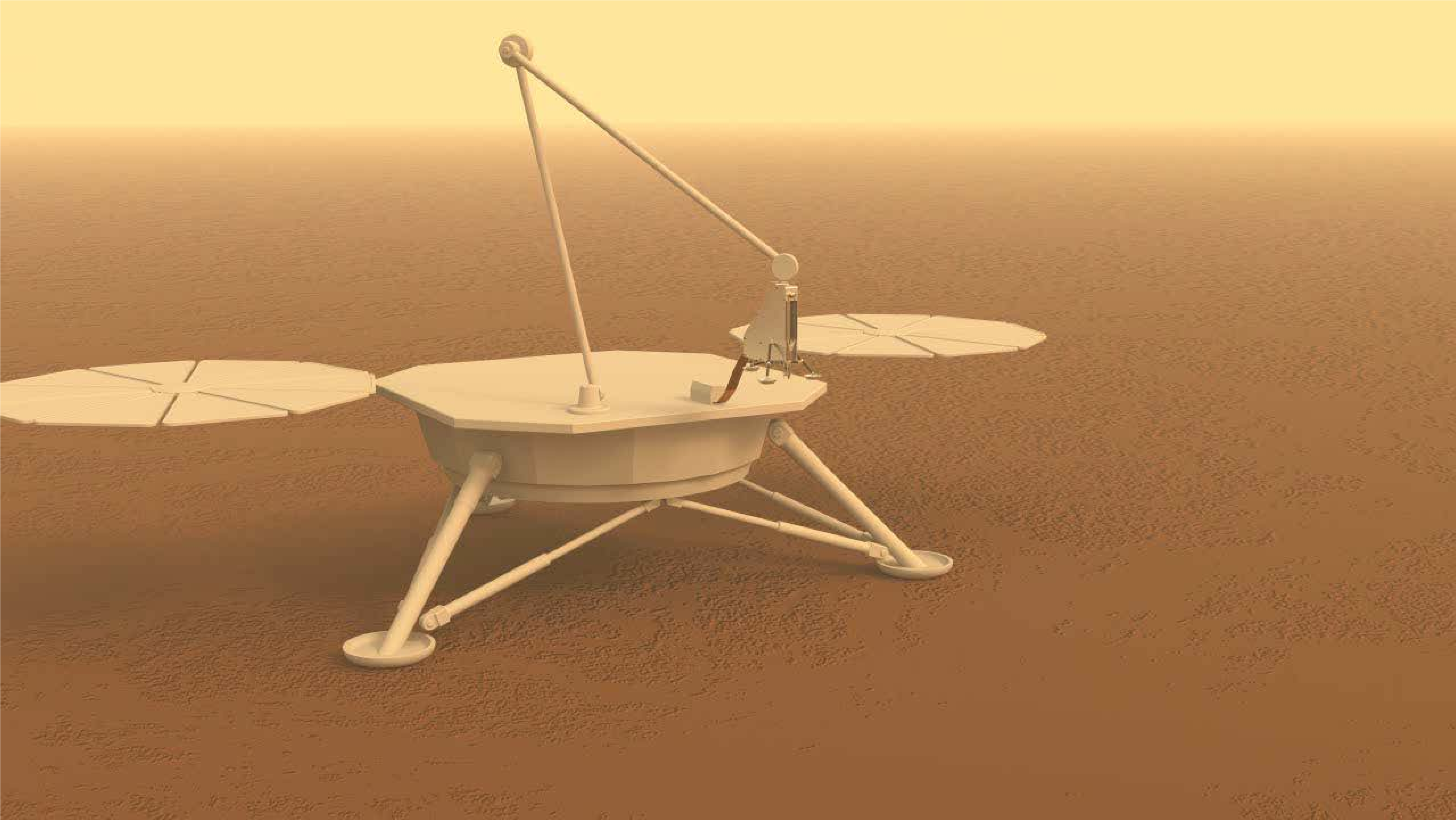
- Heat flow provides ***InSight*** into the thermal and chemical evolution of the planet by constraining the concentration of radiogenic elements, the thermal history of the planet and the level of its geologic activity
- Surface heat flow is measured by determining the regolith thermal conductivity, *k*, and the thermal gradient *dT/dz:*

$$F = k\frac{dT}{dz}$$

- **Key challenges:**
  - Measuring the thermal gradient undisturbed by the annual thermal wave
  - Accurately measuring the thermal conductivity in an extremely low conductivity environment

DLR

HP³: Operational Concept



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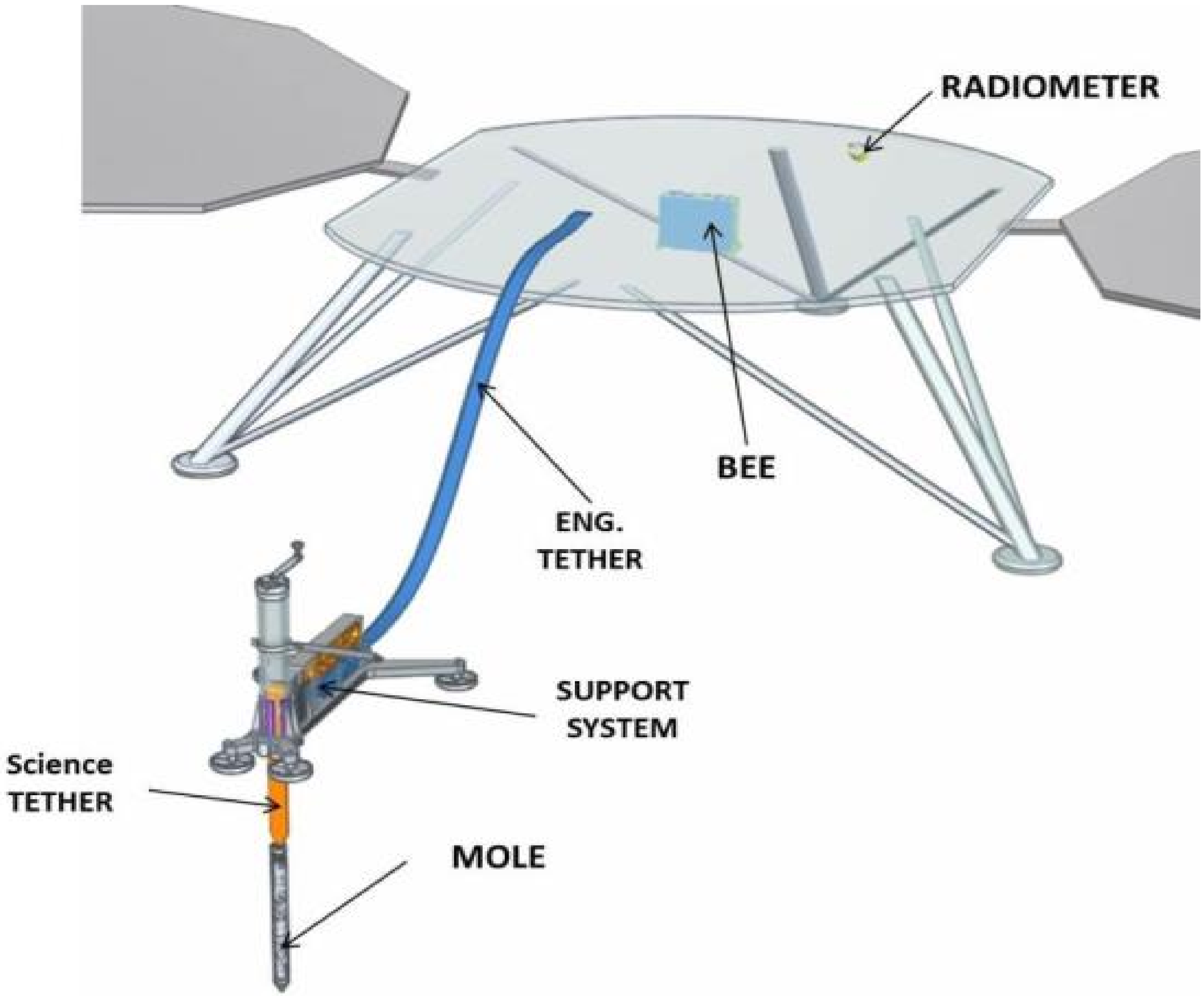
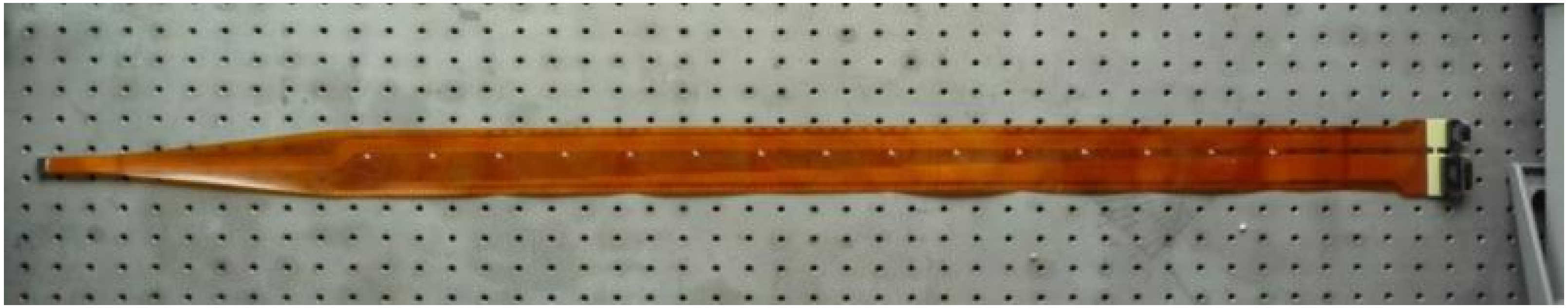
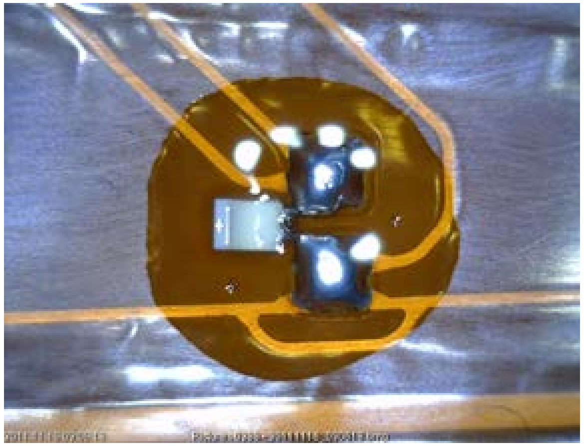
HP³: Operational Concept (BACKUP)



HP³: System Assembly Overview

HP³: Science Tether



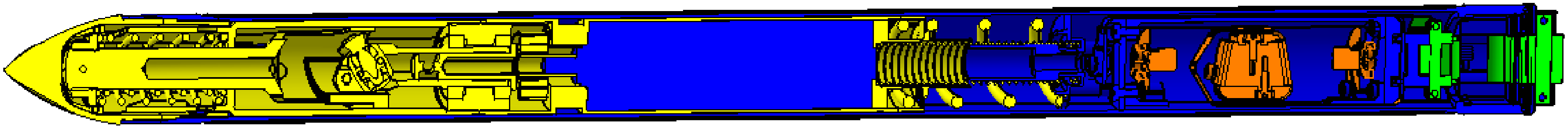


- Kapton based flex cable including PT100 sensors to determine thermal gradient
- Potted for mechanical protection

HP³: Mole Subsystems

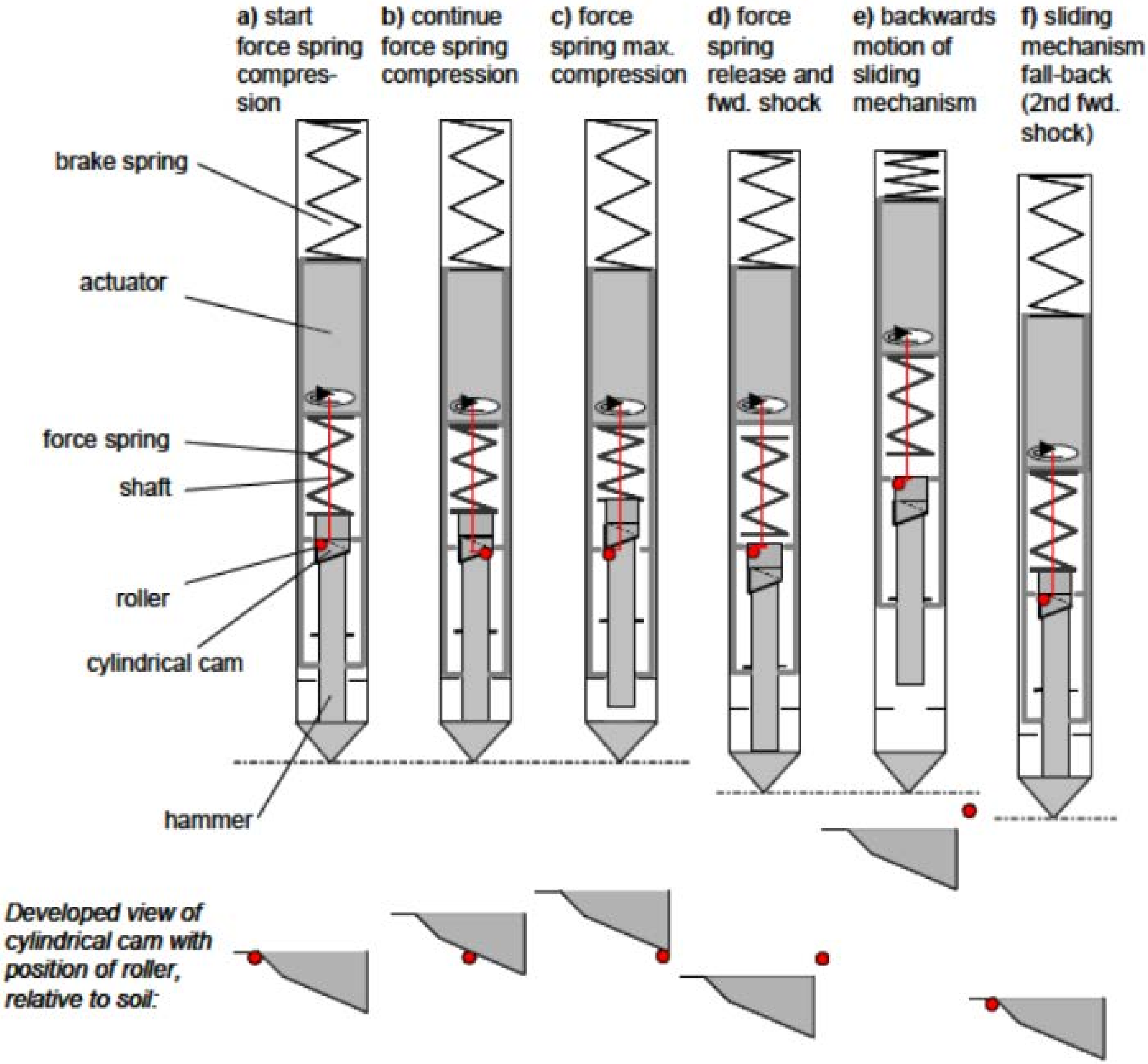
- Development started in late 2012 from ~TRL 3-4
- No sampling/retraction capability (as had PLUTO@Beagle 2)

- **DLR Bremen**
  - Outer Hull, Back Cap, Motor, Payload Compartment
- **CBK Warsaw**
  - Hammering mechanism, tip, locking mechanism
- **DLR Cologne**
  - STATIL (tilt/inclination meter)
- **DLR Berlin**
  - TEM-A, TEM-P (thermal measurement suite)

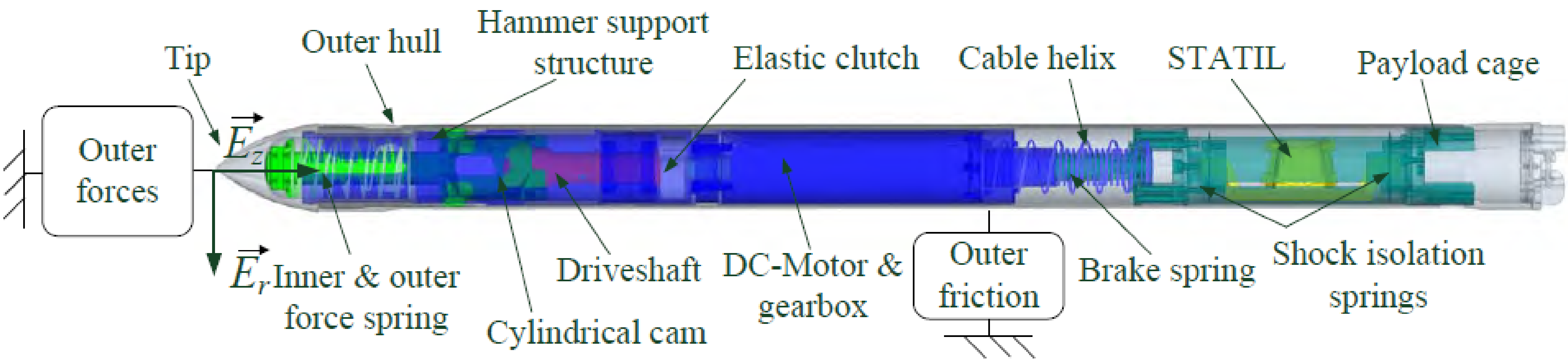


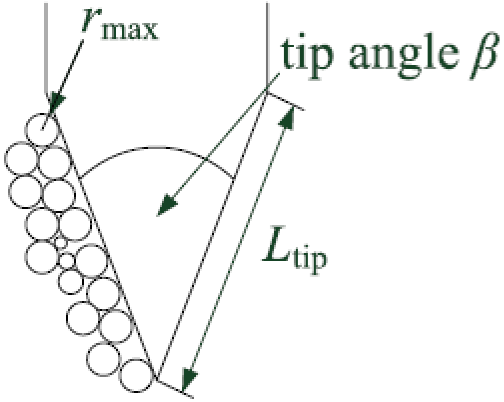
HP³: Mole Mechanism

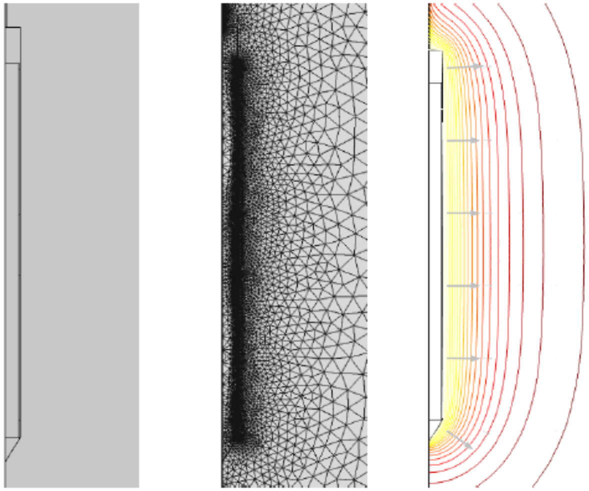
HP³: Mole Mechanism (BACKUP)



HP³: Mole Mechanism (MBS & Thermal Sim)







Lichtenheldt, Schäfer, Krömer
Hammering beneath the surface of Mars – Modeling and simulation of the impact-driven locomotion of the HP3-Mole by coupling enhanced multi-body dynamics and discrete element method
urn:nbn:de:gbv:ilm1-2014iwk-155:2

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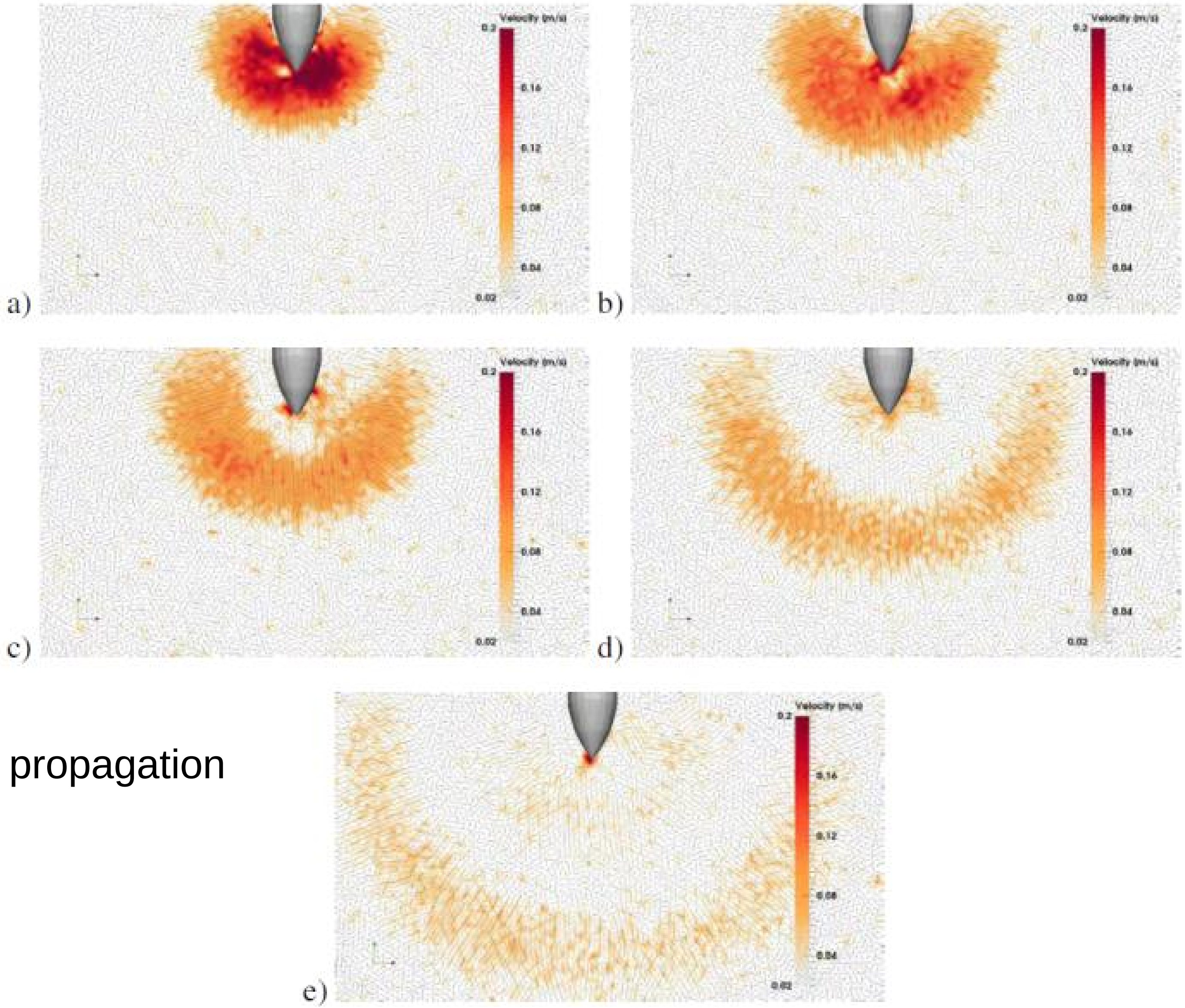

Shock wave propagation through soil

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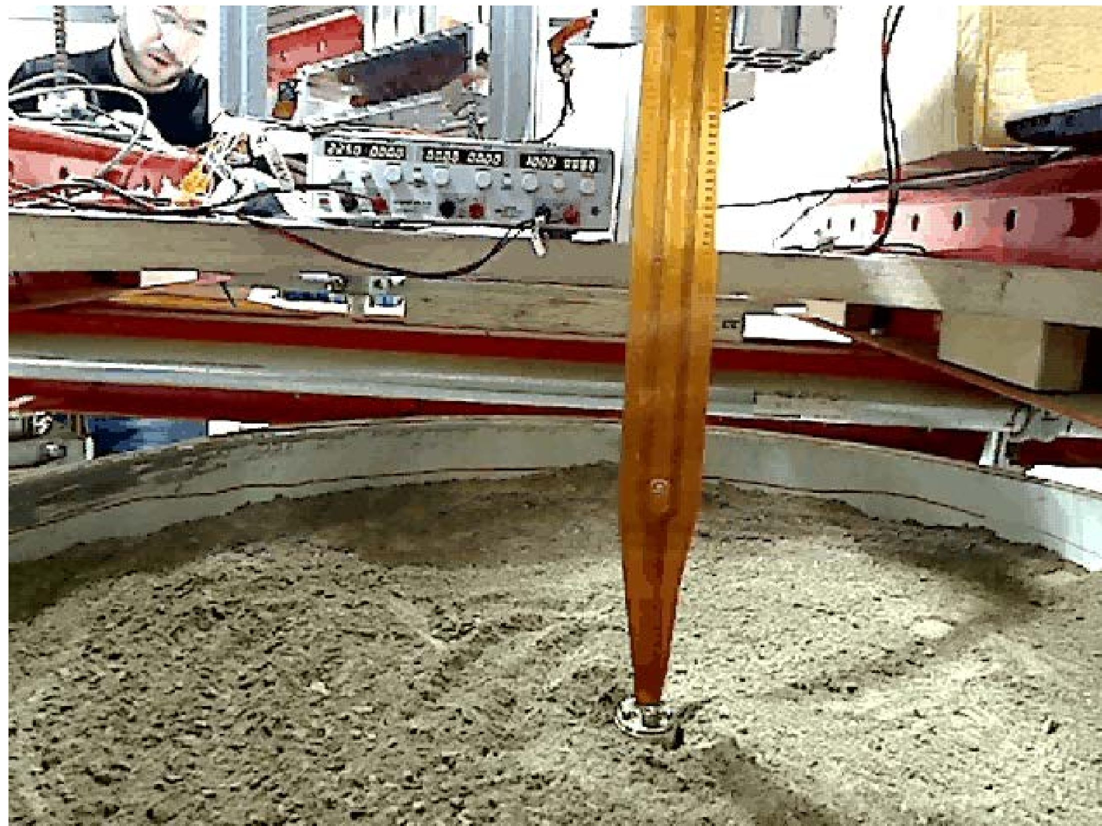
HP³: Deep Penetration Tests

- Stroke rate: 1 stroke per 4 seconds,
- Penetration rate: 5m in ~27h
- Rates primarily determined by available power/voltage from lander



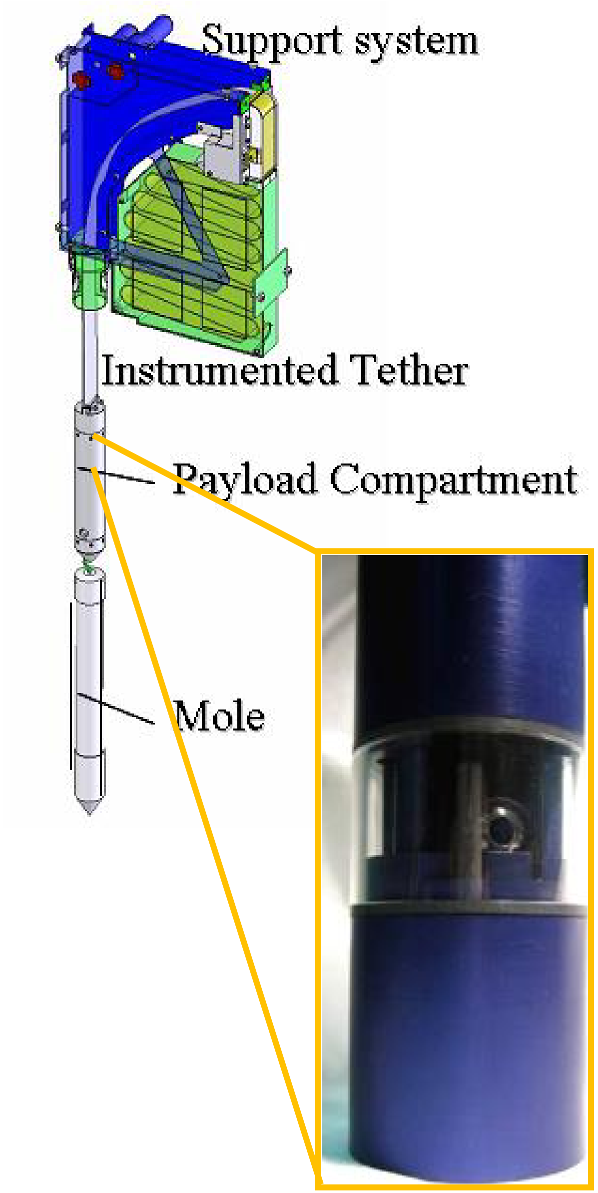
HP³: Flight Unit Ready!

DLR

Aqua- / Cryo-Mole

Aqua-Mole*

- Small mole systems – water / pressure tight
- In-situ characterization of underwater sediments with respect to mechanical properties (*recoverable <u>instrumented</u> mole)*
- Sampling of underwater (*recoverable <u>sampling</u> mole)*
- Geophysical measurements from moles embedded in underwater sediments, e.g. for seismicity and heat flow investigations (*non-recoverable instrumented mole* or a *recoverable instrumented mole)*



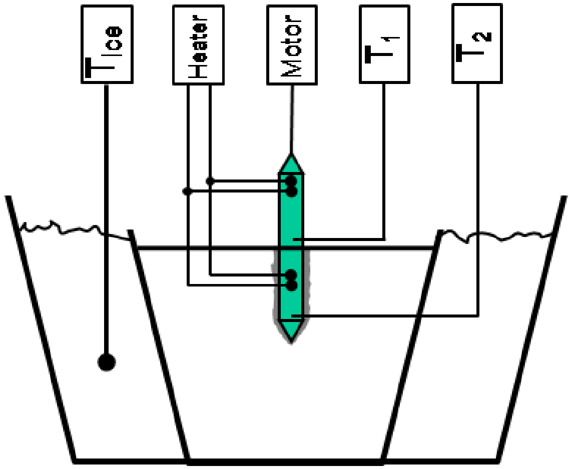
Cryo-Mole

- Sub-variant of the Aqua-Mole
- Equipped with additional heaters for use in snowy or icy environments.

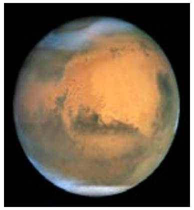
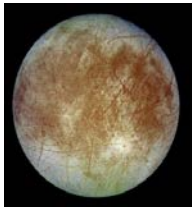
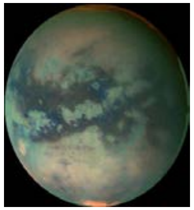
* Krömer, Richter / Oceans09

Aqua- / Cryo-Mole: Early proof-of-concept tests and results

- Heating/melting cycles in ice-soil mix
- Tip heating essential in case of very cold ice
- Combined melting and hammering allows intrusion (rough calculation of speed: 3 cm/h)



Aqua- / Cryo-Mole: Potential destinations

Body	Surface Material	Operating Temperature	Surface Pressure	Intrusion Depth
	Sediment or ice/snow	273K +/-?	>1 bar	?
	dust layer and ice with soil	210 K	6 mbar	1-10 m
	ice with dust and salt inclusions	110 K	$1x10^{-11}$ bar	3 m
	ice with methane/ ethane	95 K	1.5 bar	?

Conclusions

HP3 Status

- The InSight mission awaits launch in May 2018 and landing in September October/November 2018
- It carries DLR's Heat Flow & Physical Properties Package (HP3) which uses a penetrating mole to dig 5m into the Martian soil
- Opportunities for an Aqua-Mole
  - The Aqua-Mole could be a transfer from space to deep sea
  - It could be a transfer from deep sea / arctic environment into space (e.g. our long term perspective for exploration)

Way forward

- Define / formulate science cases and payload options
- (re-) do technical feasibility studies (water/sediments, snow, ice)