Universität Stuttgart
Institute of Space Systems


# Enabling technologies for lunar exploration

Prof. Dr. Sabine Klinkner @

13th EASN International Conference

# Mobility as a Key Feature

- Overcome lander restrictions: Access locally relevant / characteristic targets:

→ Local Mobility, >2…50 m reach

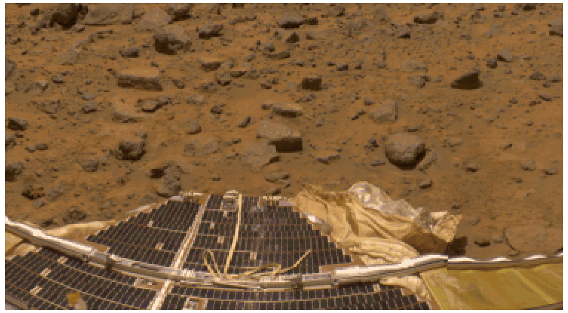
- Access regional / topographic Features: (craters, cracks, trenches, etc.)

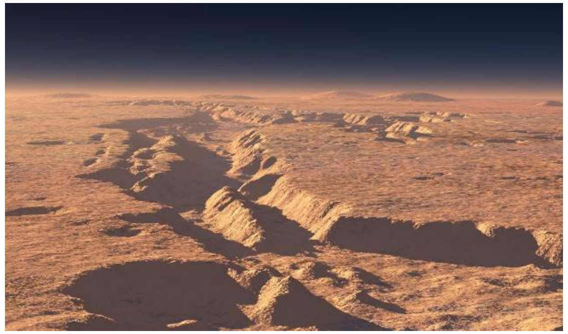
→ Regional Mobility, 1…10 km, potentially not ground based;
with passive EDLS: 1…100 km

- Access global Features (Volcanos, Plateaus, Mountains, etc.)

→ Global Mobility, >100…n•1000 km, mostly not ground-based,
(alternative.: several local/regional systems)

- Mobility is an enabling factor for exploration





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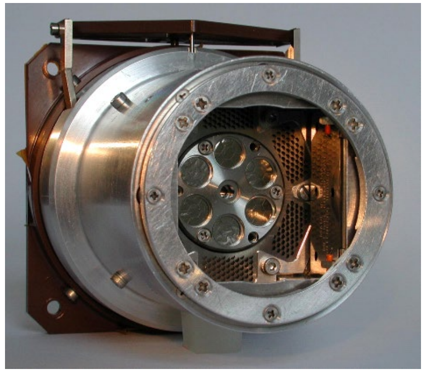
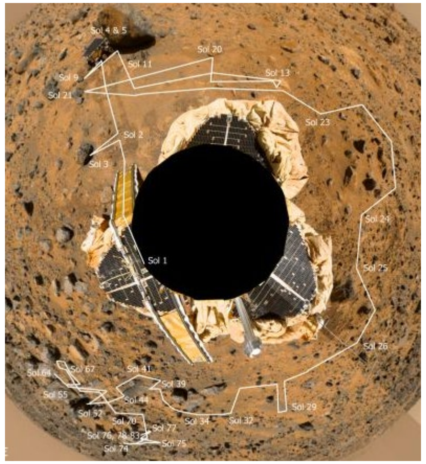
# Exploration Performance Drivers

- Perception capabilities:
  - Recognise / understand environment and targets
  - “see”, process, analyse targets / samples
- Mobility capabilities:
  - Reach targets
  - Access, touch, grasp, collect samples (digging, drilling, etc.)
- Operational capabilities:
  - Autonomy (signal delays, hard real-time requirements, mission duration constraints, ground interaction needs)
  - Unstructured / unknown environment: autonomous decision making, unexpected situations, contingencies Adaptability / flexibility of operations





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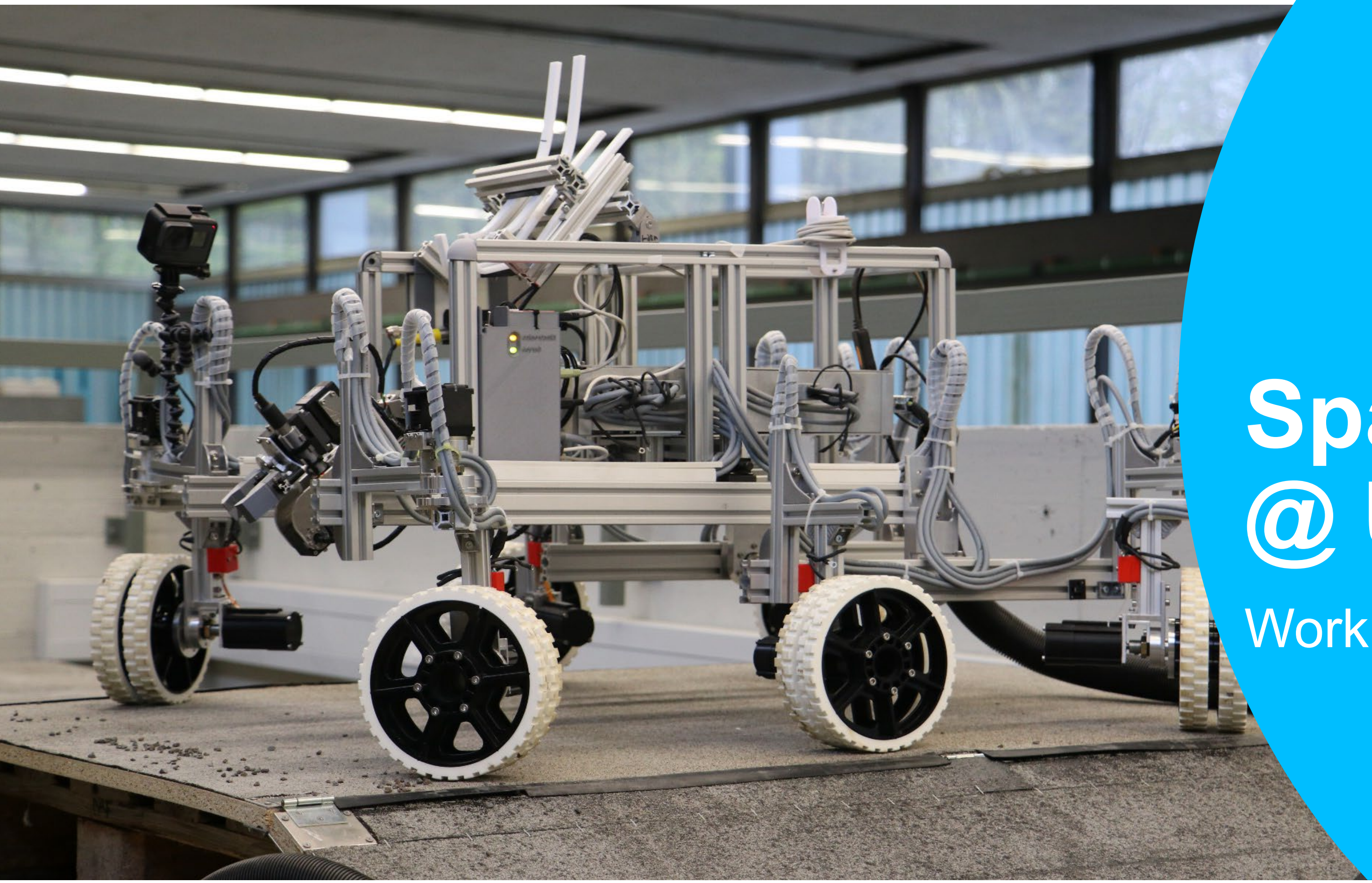
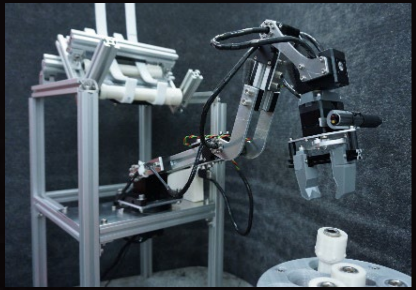
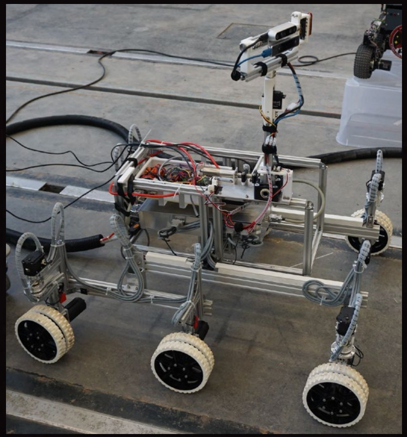


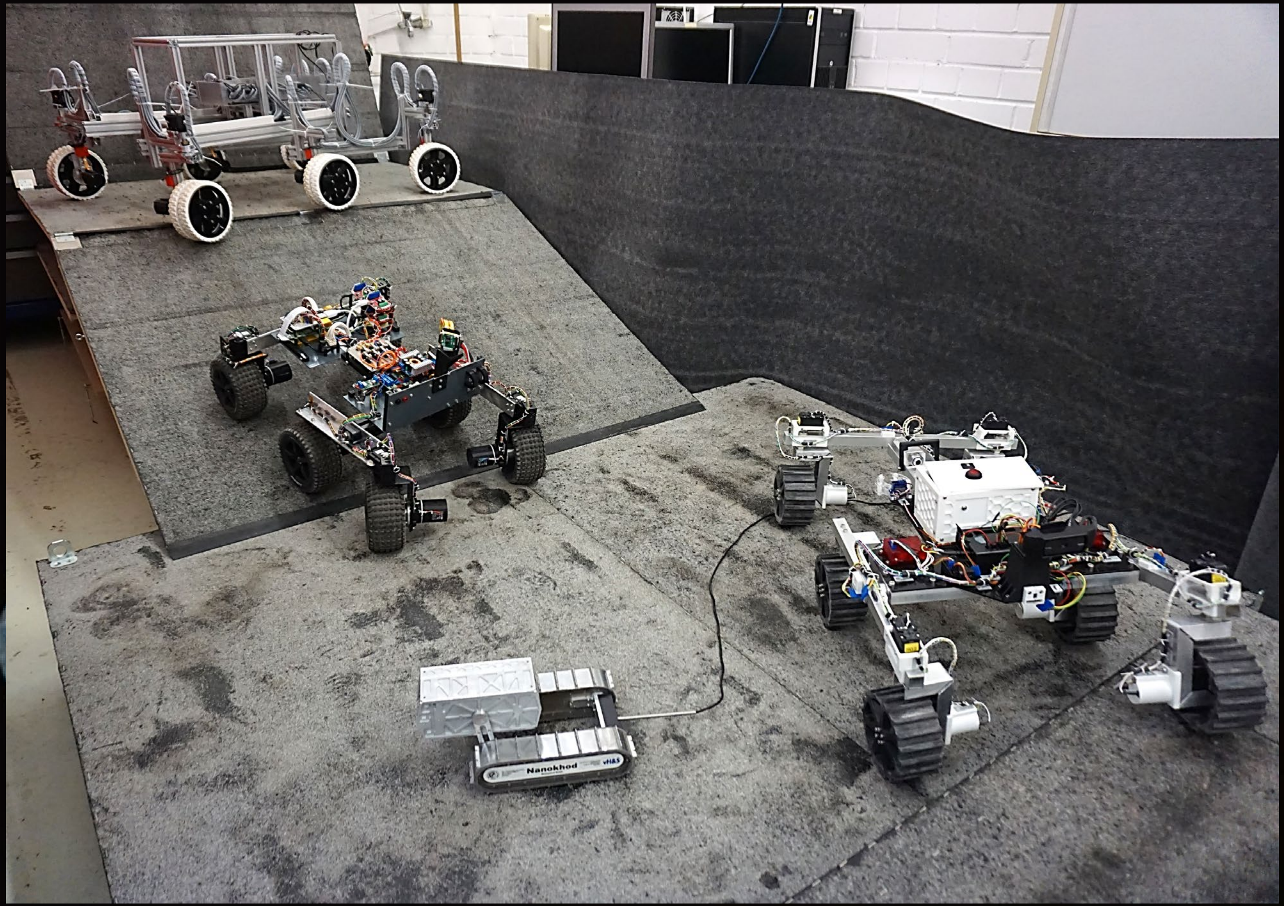
# Space Robotics @ University of Stuttgart

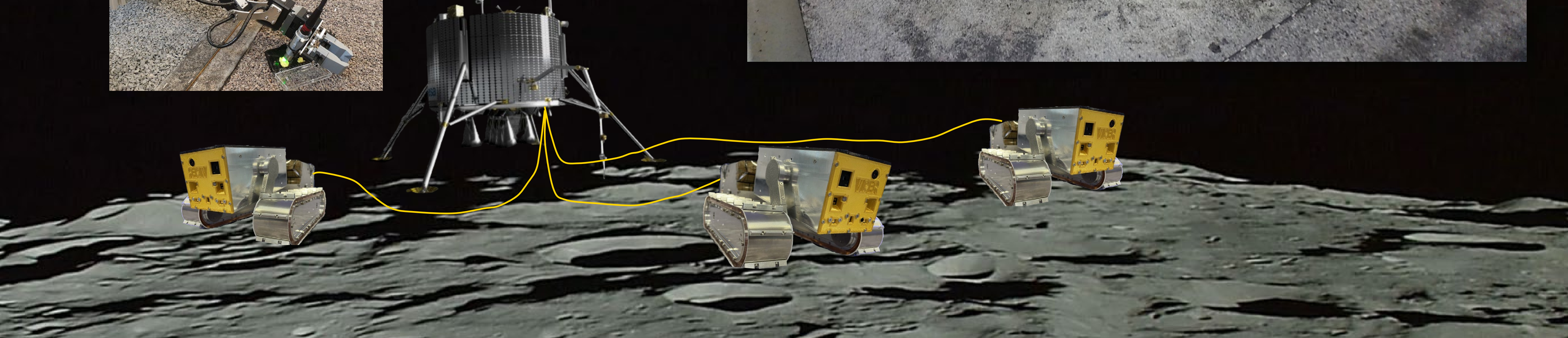
Working Group Space Robotics

# Rover Systems at University of Stuttgart









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# Nanokhod Development Activities

Enhanced Mobile Capabilities

Perceptive & Operational Capabilities

Development of a multi-mission Deployment and Operations Bay

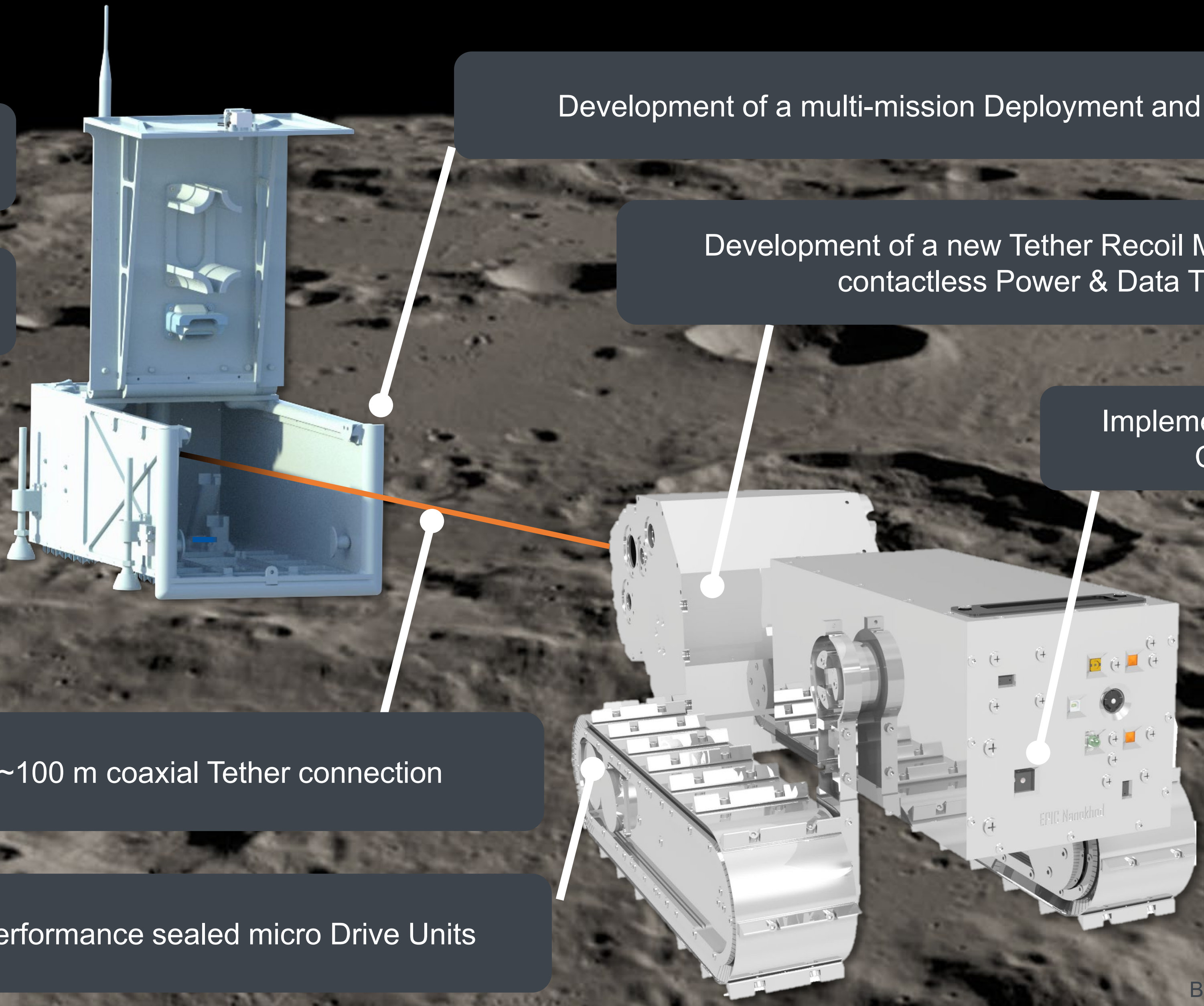
Development of a new Tether Recoil Mechanism with a contactless Power & Data Transfer

Implementation of Sensory Components

Analysis on Regolith Mitigation

Implementation of an ~100 m coaxial Tether connection

Development of high-performance sealed micro Drive Units




Background Image Credit: NASA/USGS

# Background of current Microrover Development

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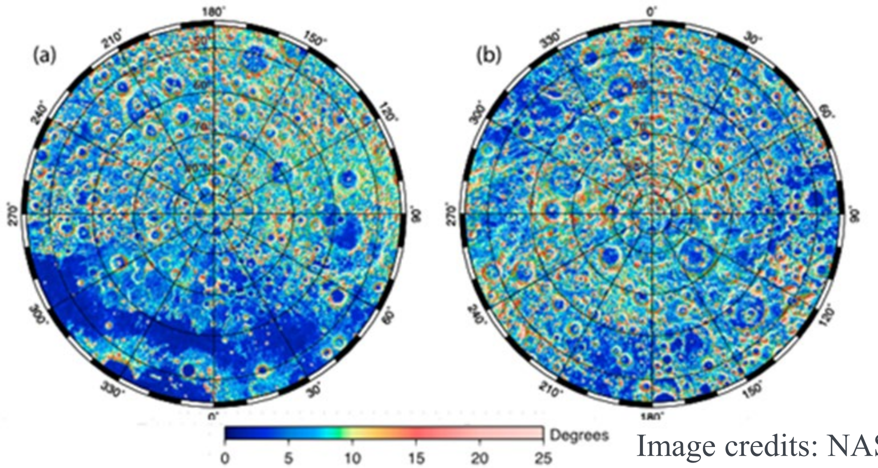
- Tethered system using synergies with lander or cooperating rover system
- High Payload to System Mass ratio ~1/3
- Mobile element for planetary surfaces, transporting and operating scientific instruments for in-situ measurements beyond contaminated landing site
- Surface mobility suiting environmental extremes
- Suited for pristine sites of scientific interest, such as craters and sky holes
- Enables swarm applications
- Since 2015 Development for a long-term lunar surface mission in cooperation with SME von Hoerner & Sulger GmbH



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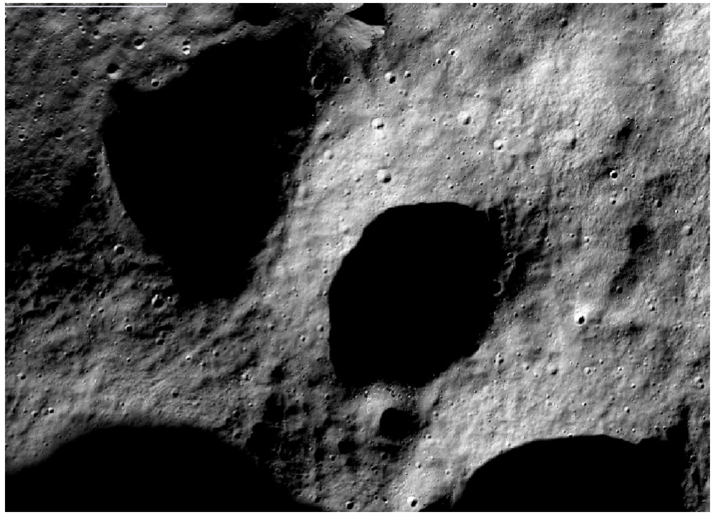
# Mission analyses

- The Nanokhod system with a system mass in the order of 3kg providing a system range of several 100m and a lifetime of >1 year
- Regions of scientific interest on the Moon
  - Craters
  - Permanently shadowed regions
  - Sky holes / Lava tubes
- Mission concepts and analysis
  - Studies on co-operational missions with large rovers
  - Swarm applications, providing redundancy and /or payload variety
  - Self-supplied Surface Element



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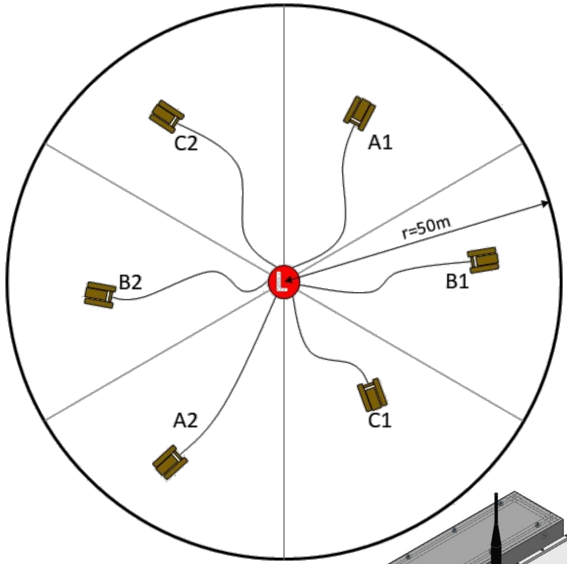


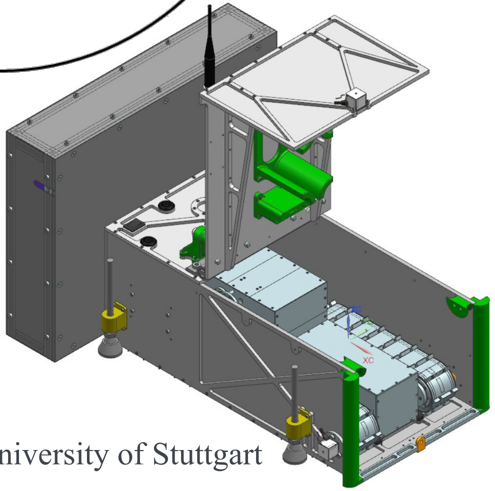

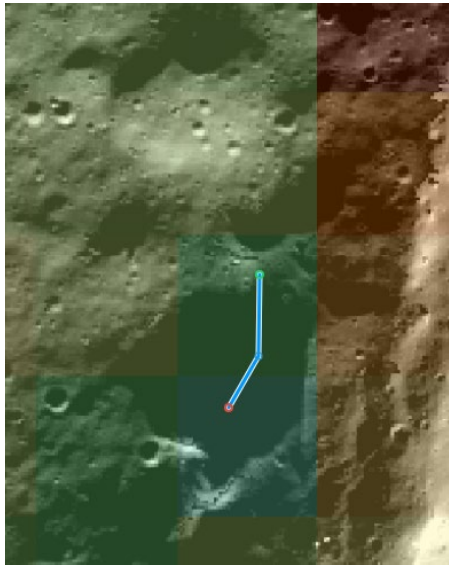

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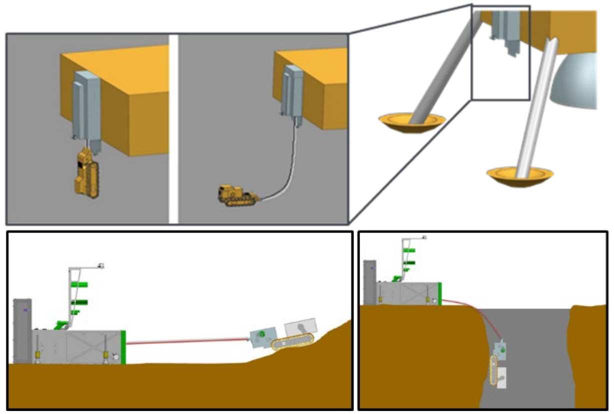
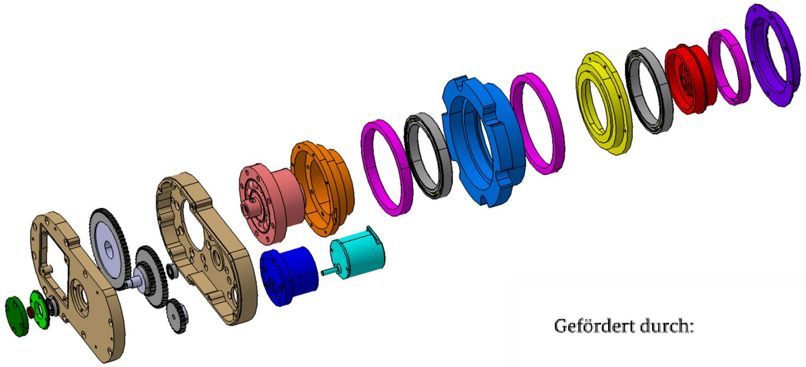
# Technological advances – Robotic Mechanisms

IRS University of Stuttgart DLR vH&S

- Redesign of drive units,
  - Improving torque margin
  - Adding sealing concepts
  - Updating materials and components
- Design of a Tether Recoil Mechanism
  - Increasing Exploration range
  - Covering Sealing concepts
  - Rappelling possibility
- Thermal Design study for lunar surface
  - Permanently Shadowed Areas
  - Lunar day conditions





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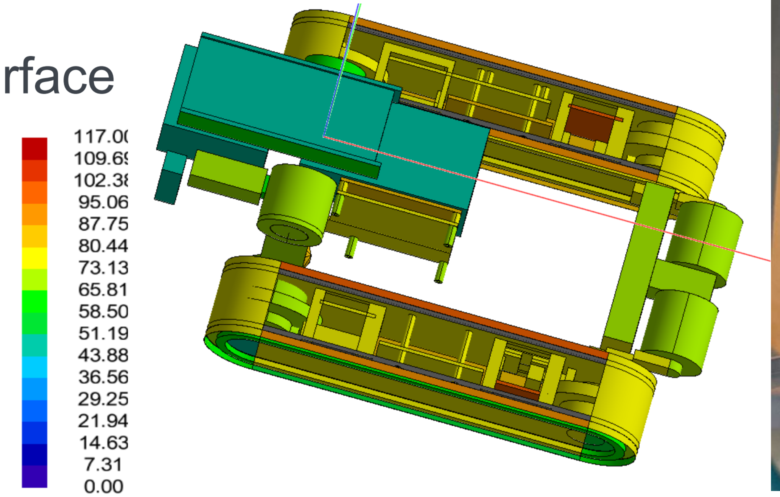
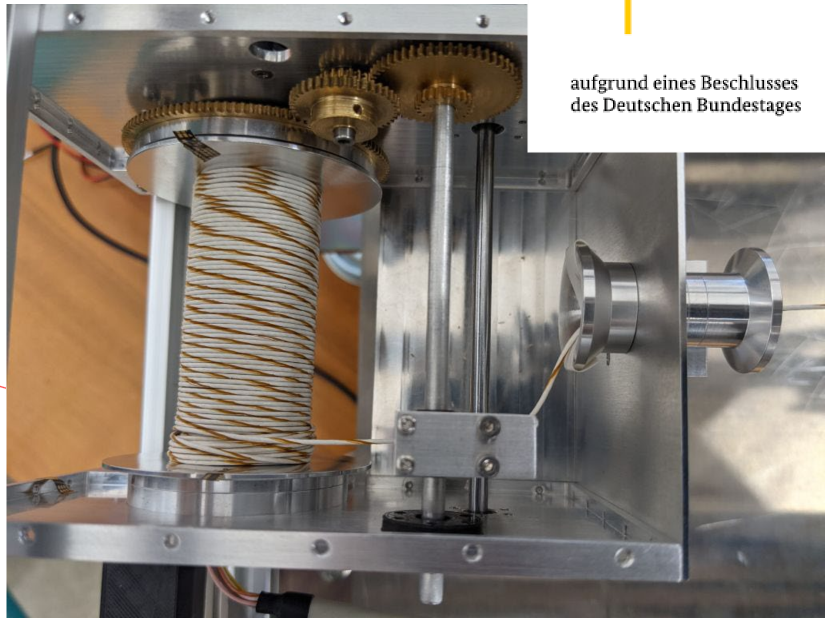


# Hybrid Tether Technology – The Key Capabilities

## Requirements and Design Drivers

**Primary System**

Transceiver Electronics

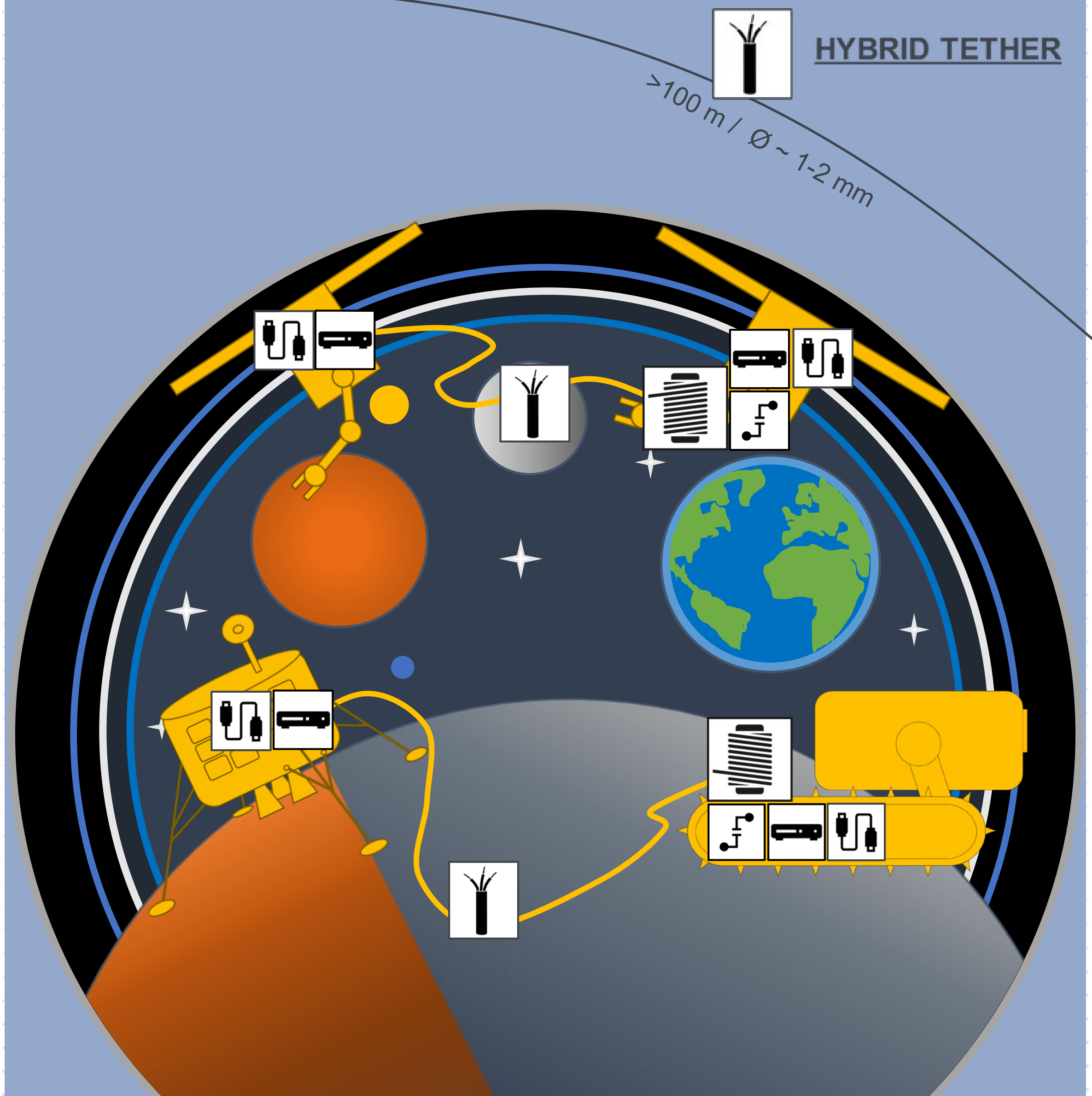
Interface Electronics

High Dynamic Field of Application

Environmental Extremes

Optimised Resource Utilisation

Reliable, Robust, & Safe Operation




Power Transfer

Data Communication

Mechanical Robustness

**Secondary System**

Tether Storage & Deployment System

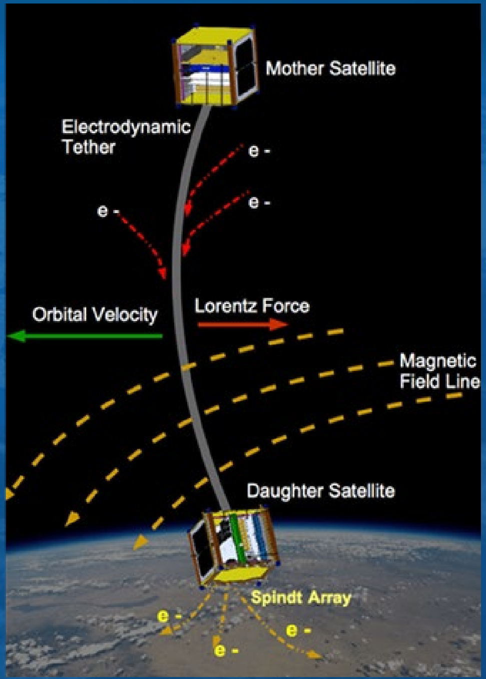
Contactless / Rotational Interface

Transceiver Electronics

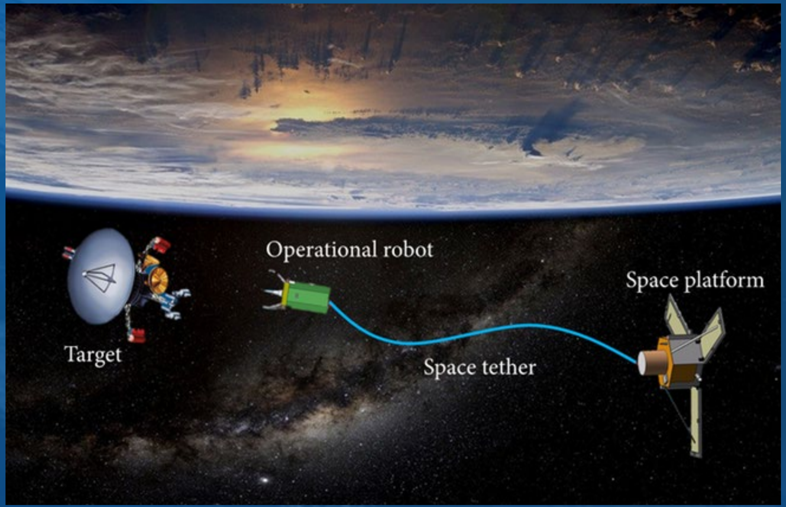
Interface Electronics

# Hybrid Tether Technology – The Vision

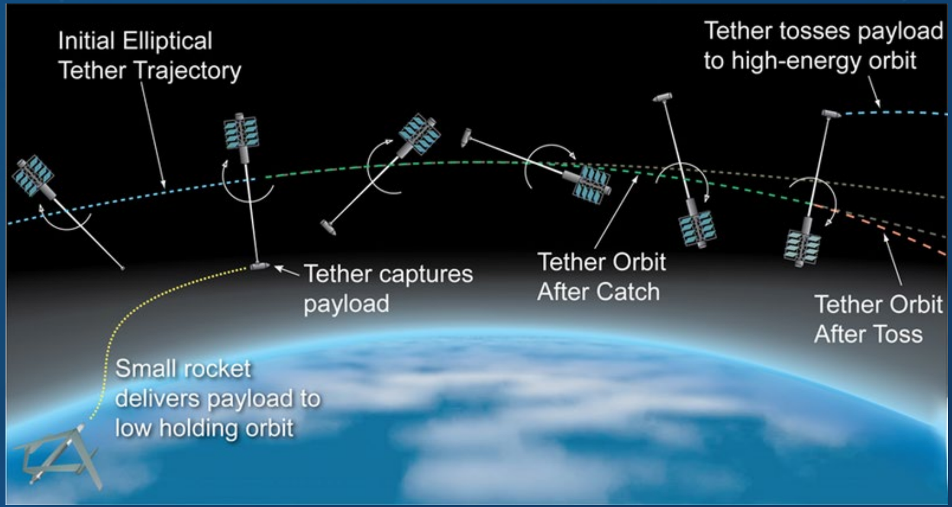
## Space Application: Propulsion, Debry Removal, Exploration, Infrastructure



Electrodynamic Tether [1]



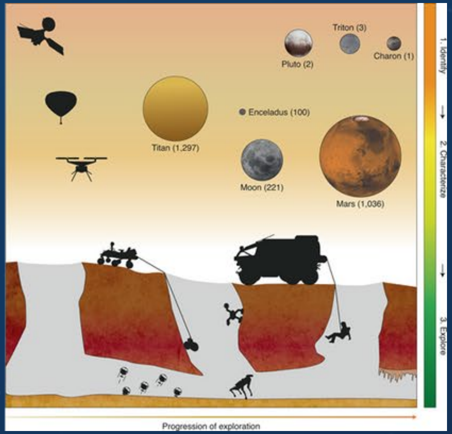
Space Debris Removal [2]



Interplanetary Transfer [3]


Crater Access, Permanently Shadowed Areas, Setup of Infrastructure [4]


Lava Tube Exploration [5]



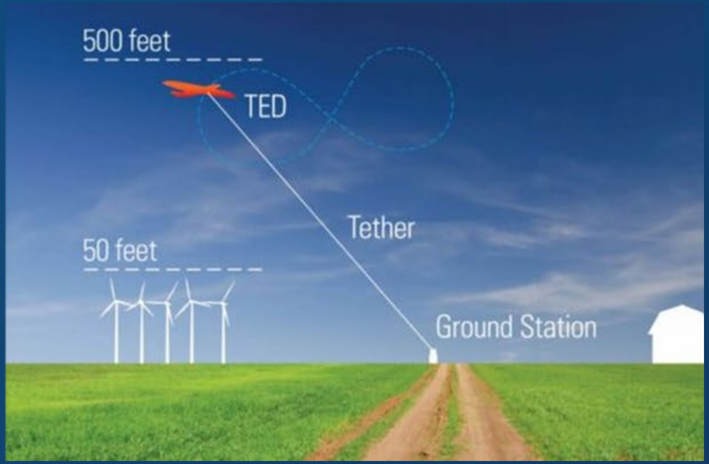
Exploration Roadmap [6]

# Hybrid Tether Technology – The Vision

## Space Application: Propulsion, Debry Removal, Exploration, Infrastructure


Subsurface Exploration & Instrumentation [7]

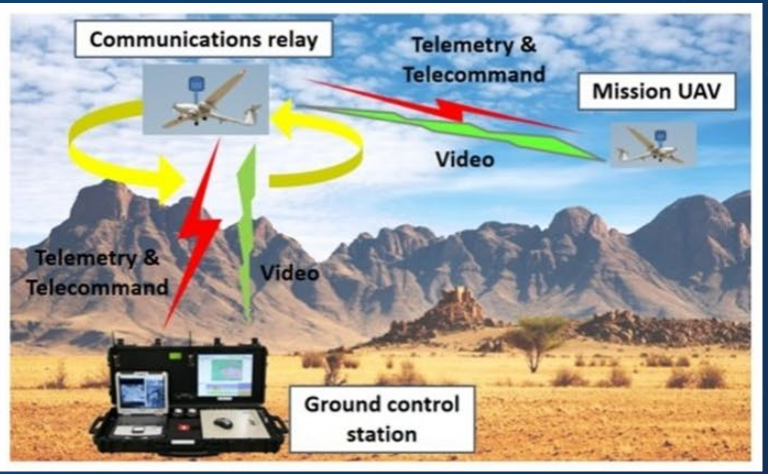

Disaster Management [8]



Tethered Wind Energy [9]


Cave Rescue / Exploration [10]

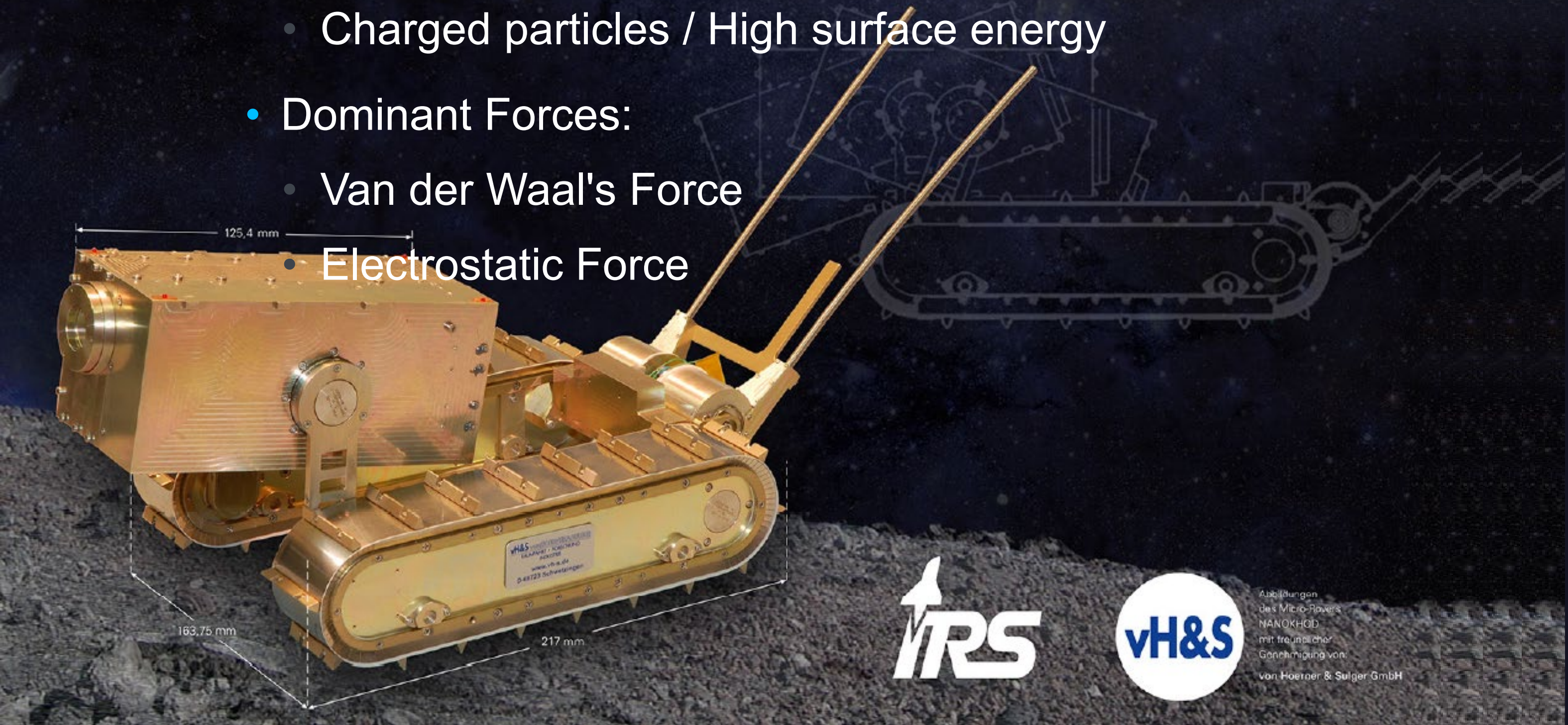

Tethered UAV, Security, Mobile Telecoms, etc.[11]



Remote Area Access [12]

# Background & Motivation

- Development of Dust Mitigation Strategies for a long-term Lunar Surface Operation
  - Excessive Dust Contamination on exposed surfaces
  - Design Driver for Future Lunar Surface Exploration / Human Return
- Regolith Characteristics:
  - Median: 70 um / Jagged geometry
  - Charged particles / High surface energy
- Dominant Forces:
  - Van der Waal's Force
  - Electrostatic Force





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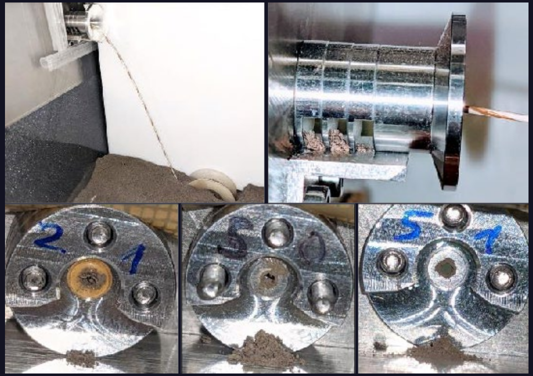
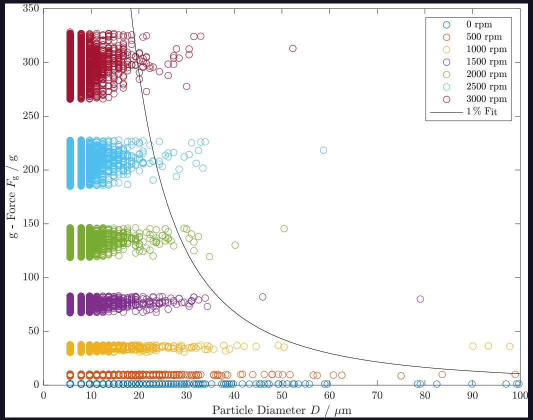
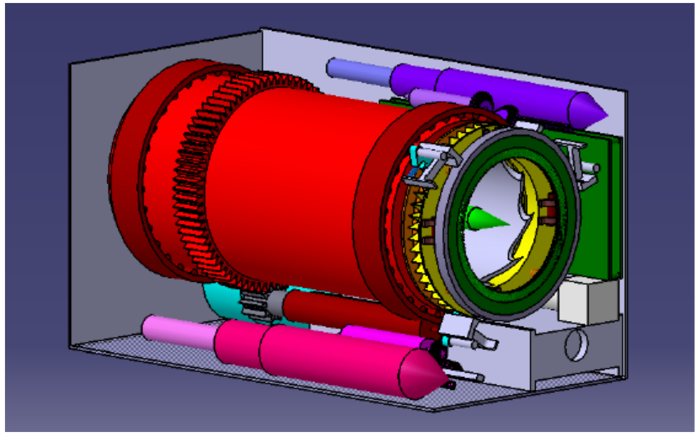




# Technological advances – Science Payloads

- Scientific payloads
  - Modified Lunar Volatiles Scouting Instrument as Nanokhod Payload instrument (TUM)
  - Miniaturised Raman Spectrometer in the Nanokhod PLC (DLR-OS)
  - Small sized time-of-flight cameras, radar and ground penetrating radar
- Sensor Components
  - Survey of sensor components
  - Sensor package focussing on visual and thermal applications
  - Sensor package focussing on Mineral detection and identification



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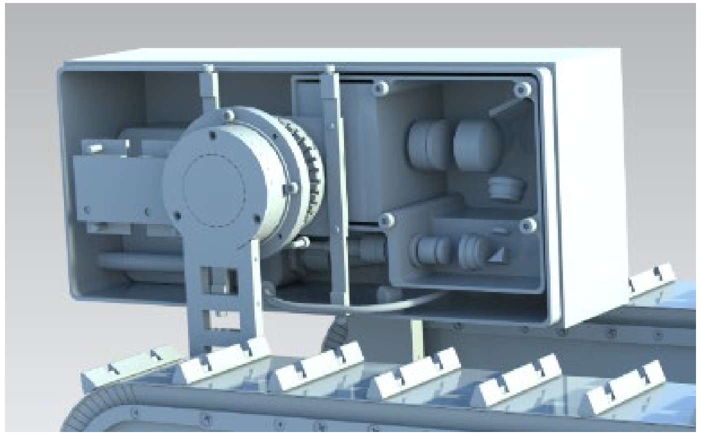

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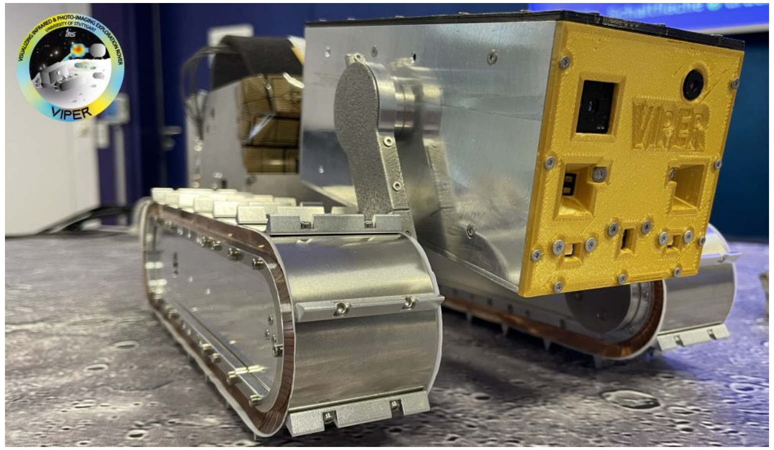


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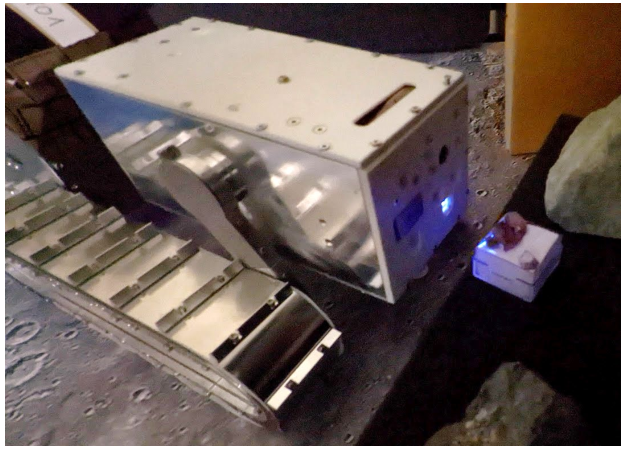

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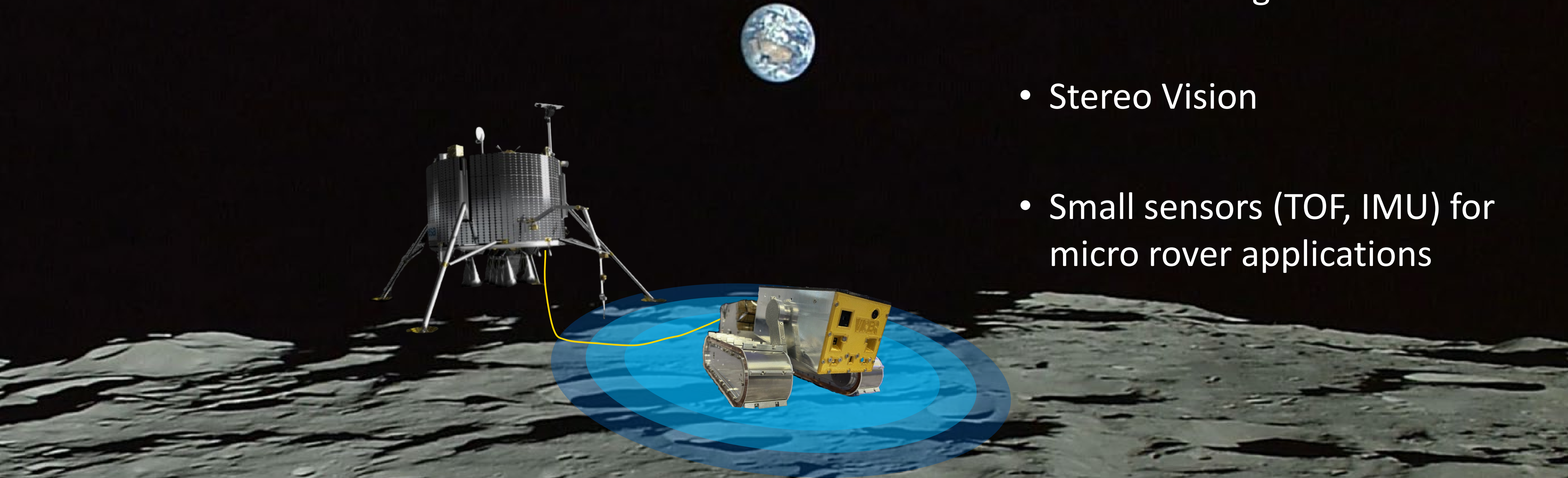
## Nanokhod micro rover

Ambient perception and mapping on planetary surfaces

→ Unstructured and uneven terrain

- Narrow LIDAR
- Structured Light
- Stereo Vision
- Small sensors (TOF, IMU) for micro rover applications



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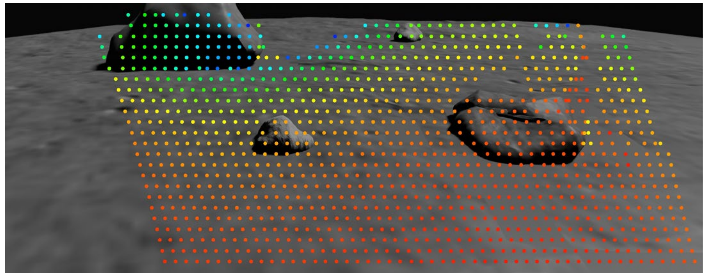
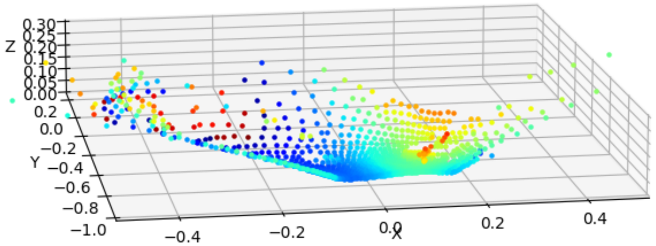
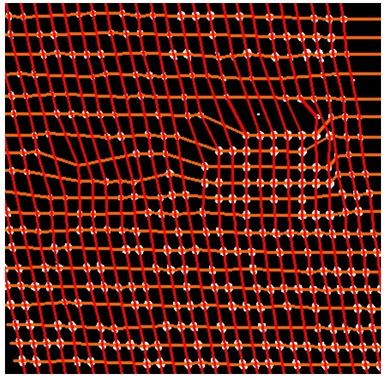
# Structured Light Depth Perception

- Starting with a line Laser
- Projection of Pattern
  - Test of suitable algorithms
  - Test of complete Pipeline
- Support by Stereo Vision Depth Perception
- Goals:
  - Detection of Tether
  - Miniaturisation/Scalability







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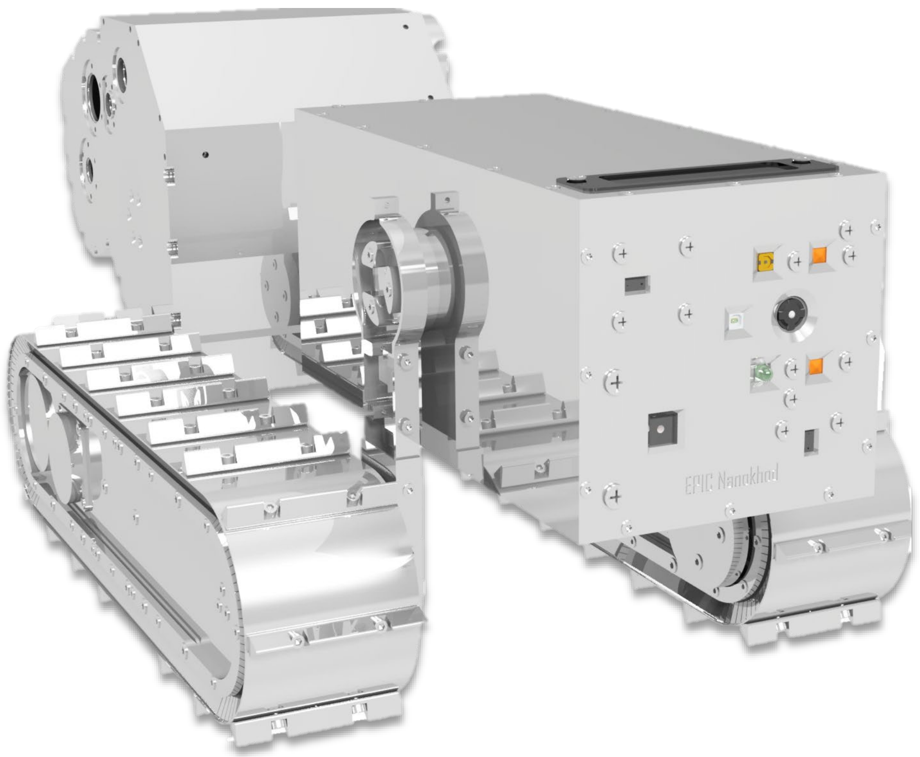
# Summary

- Nanokhod is a miniaturised system
  - adding scientific value at very low cost of resources
  - providing an operational range of several 100m
  - versatile concerning integration and operation of scientific payload
  - robust design (e.g. thermal extremes and regolith)
- Applying state-of-the-art technologies
  - Sealing concepts, Regolith mitigation
  - Spooling mechanism
  - Robust design of drive units
- Mission potential
  - Extremely suitable for the regions of high scientific interest
  - Low mass allowing for swarm applications



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# Thank you!

**Contact: Prof. Sabine Klinkner**

e-mail klinkner@irs.uni-stuttgart.de
phone +49 (0) 711 685-62677
www.irs.uni-stuttgart.de

University of Stuttgart
Institute of Space Systems
Department of Satellite Technology
Pfaffenwaldring 29
D-70569 Stuttgart

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