RIMRES:
A project summary

at ICRA 2013 -- Planetary Rovers Workshop
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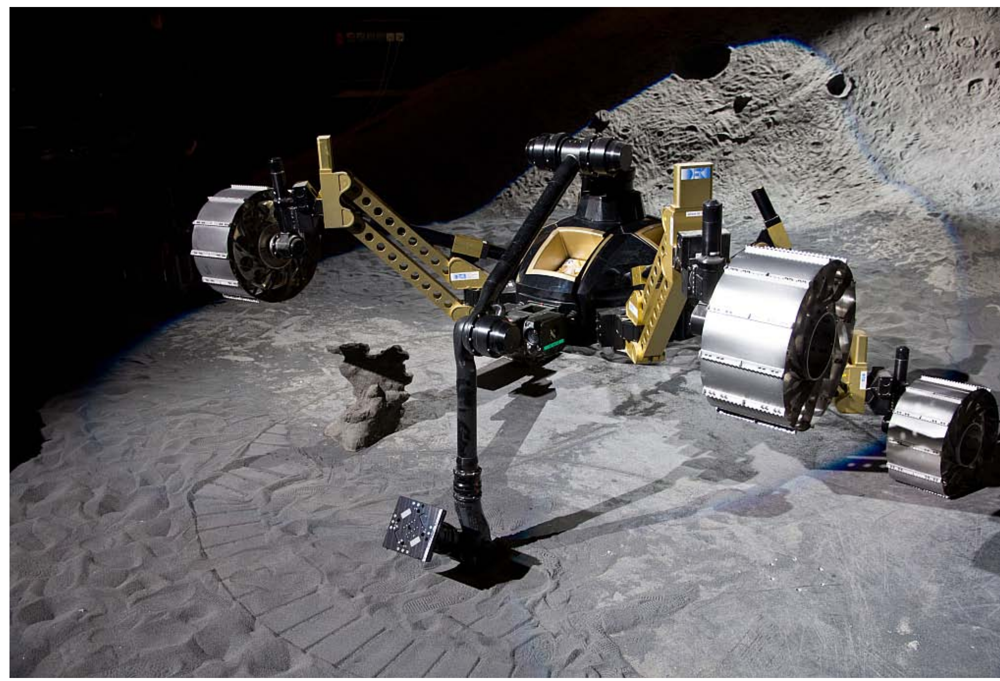


Acknowledgements

RIMRES has been sponsored by the Space Agency of the German Aerospace Center with federal funds of the Federal Ministry of Economics and Technology in accordance with the parliamentary resolution of the German Parliament.

Project partner: ZARM

Contributors: ASTRIUM, OHB System, DLR

Outline

- System Overview
- System Composition
  - Rover: Sherpa
  - Electro-Mechanical-Interface and Payload-Items
  - Scout: CREX
- Software Framework
- Lessons learnt & Summary
- Ongoing and Future Developments

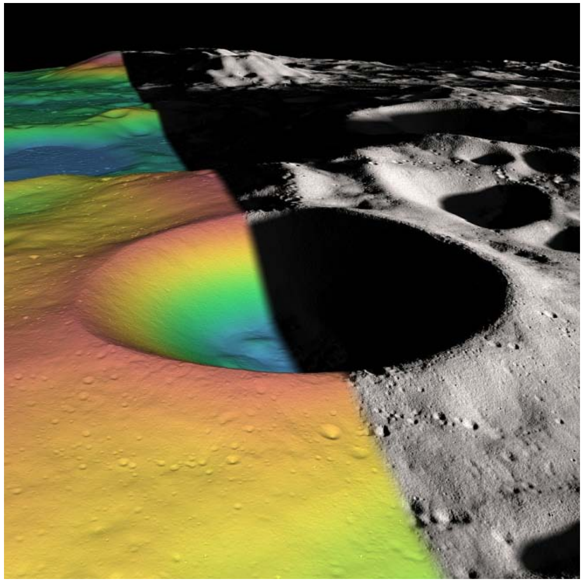
System Overview and Mission Scenario

Overview

- RIMRES addresses several aspects of a robotic lunar surface mission:
  - Robotic surface mobility: Combination of various locomotion principles
  - Cooperation of heterogeneous robots
  - Reconfigurability on different system levels
  - Modularity
  - Autonomy
- Multi-robot system, consisting of
  - Wheeled Rover with active suspension system and manipulator arm
  - Six-Legged scout robot
  - Different types of so called ‘Payload-Items’
    - Can be stacked to form payloads
    - Can be used to extend the capabilities of the mobile units
- Demonstration in an artificial crater environment in DFKI laboratories

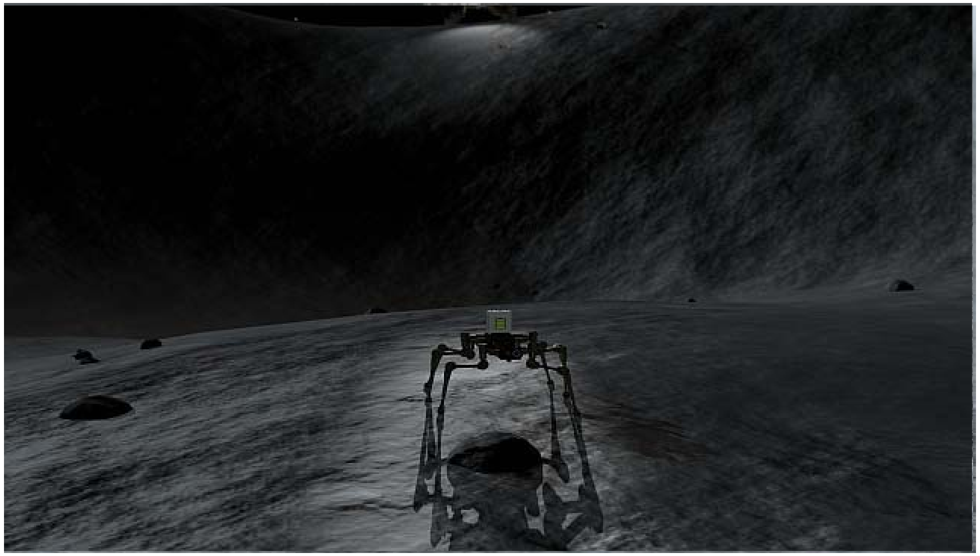
Aspired Mission Scenario

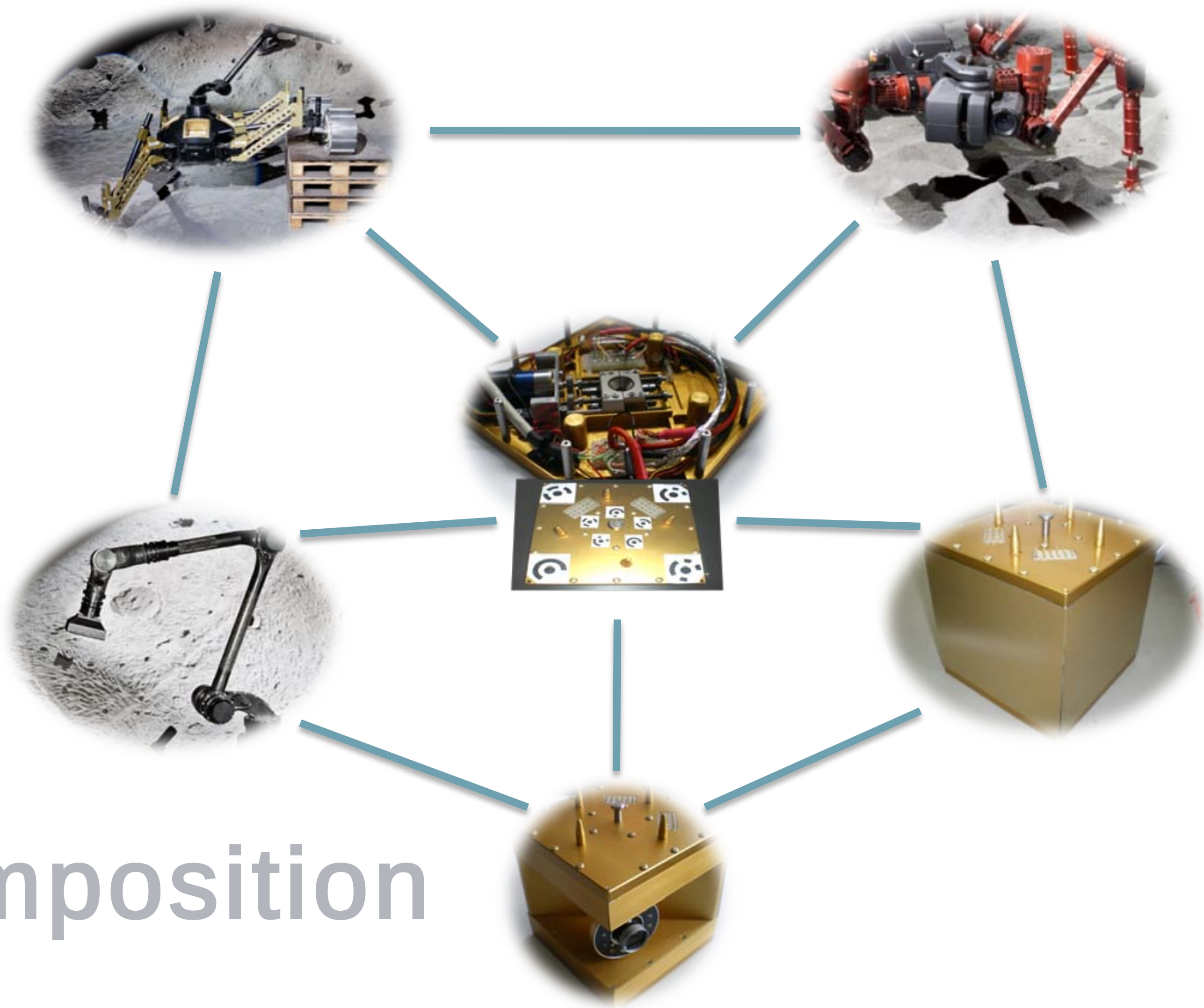
- Lunar Polar Crater Exploration
  - Search for volatile substances in permanently shaded regions
- Landing in regions with high illumination
- Transport of scout system to crater rim (wheeled rover)
- Deploy scientific instruments and/or simple communication infrastructure elements (modular payload-items)
- Deployment of scout at site of application
- Exploration of shaded regions by highly mobile scout system



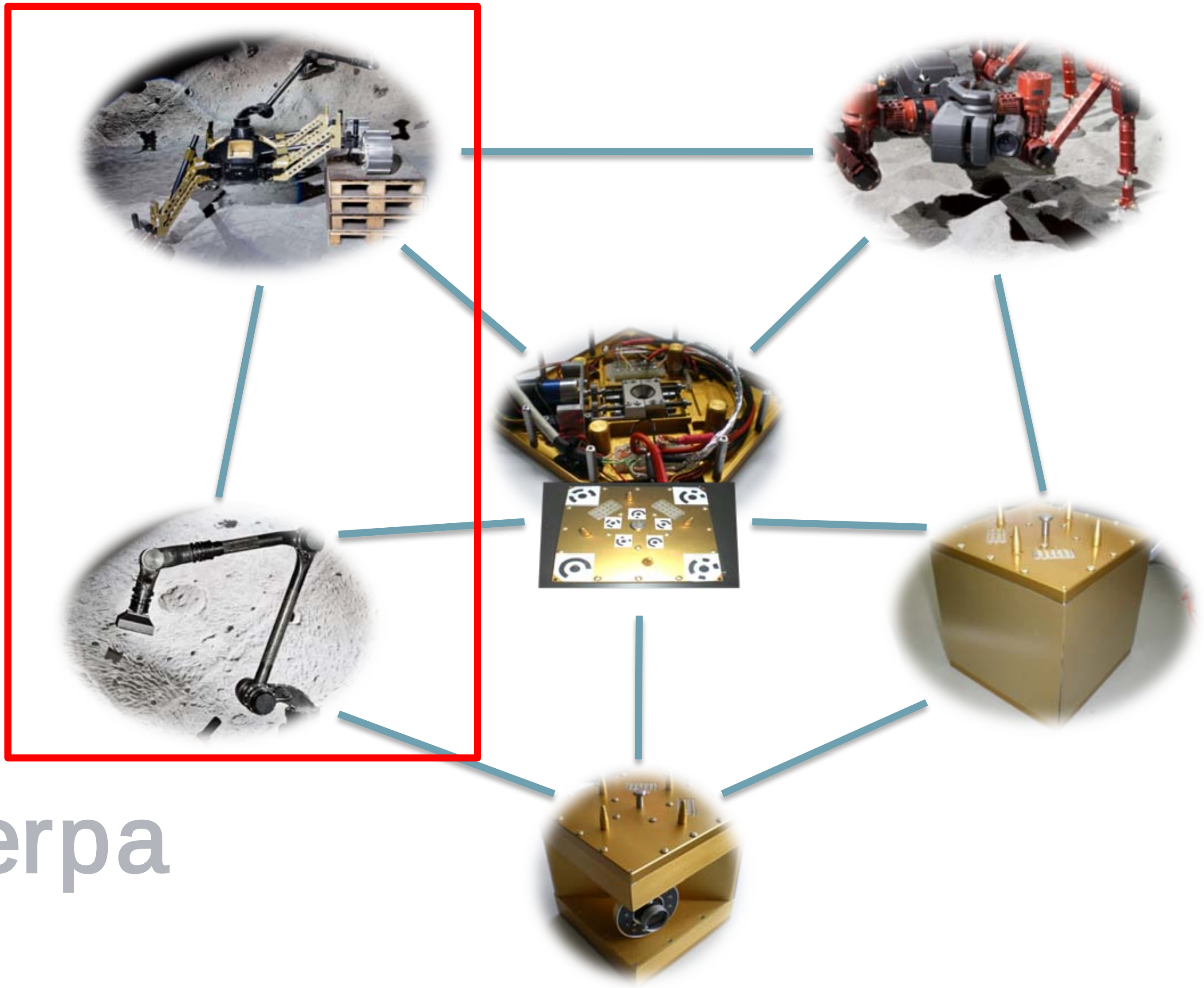
Example at lunar south pole: Illumination and hight map of Shakelton crater.

Picture taken from http://www.nasa.gov/mission_pages/LRO/news/crater-ice.html



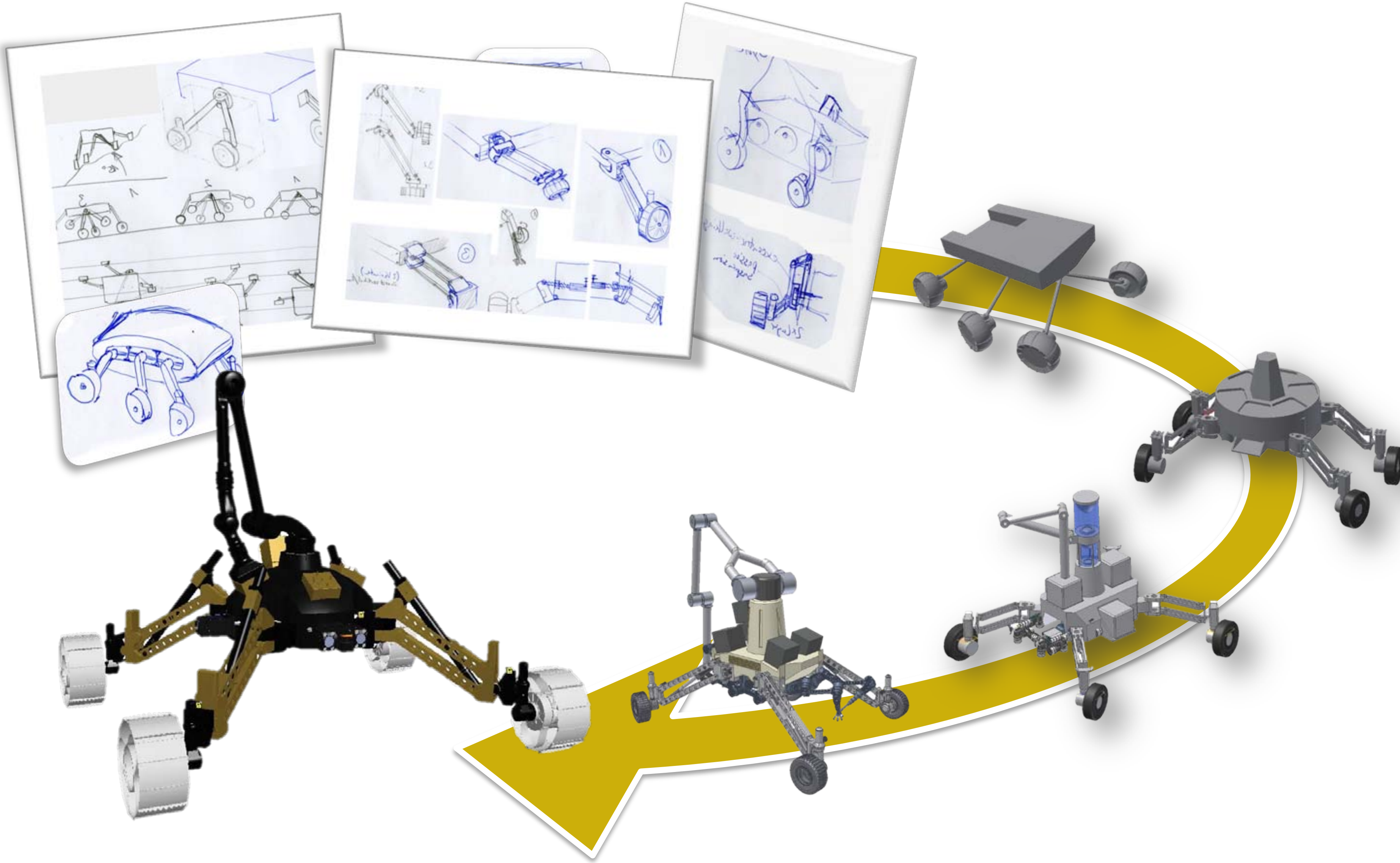


System composition

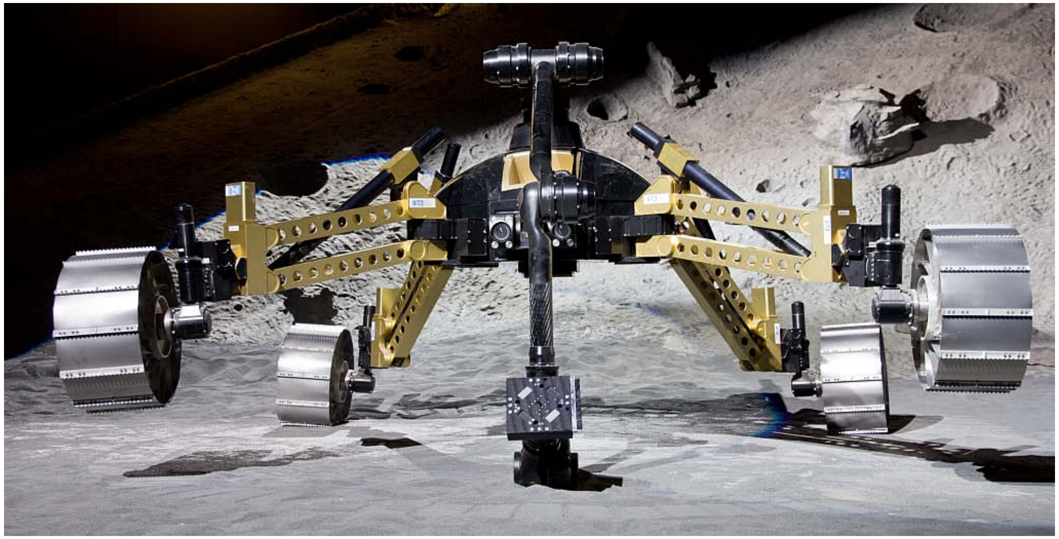


Rover: Sherpa

Rover concepts – From draft to …



… to final design and implementation

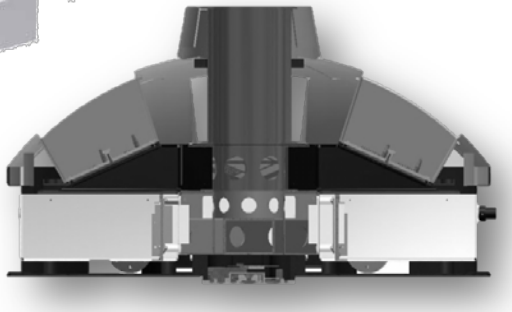


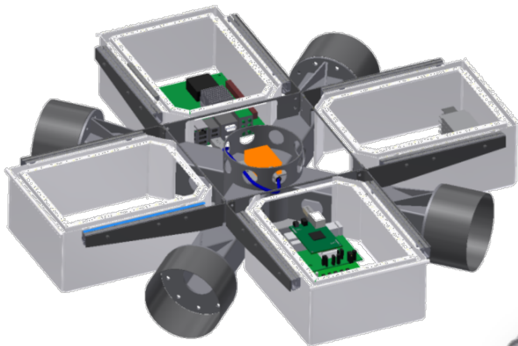
Key characteristics

Description	Value
Max. ground clearance	711 mm
Min. ground clearance (wheels above body)	189 mm
Square-shaped footprint in cross stance	2100 mm (high stance) to 2500 mm (body low)
Mass (w/o scout or payload-items, incl. manipulator)	approx. 160 kg
Mass of manipulator	25 kg
Length of fully stretched arm	1955 mm
Max. static load on stretched arm (stretched wrist)	183 N
Max. static load on stretched arm (hanging wrist)	537 N

Modularity of construction

- Mechanical Construction
  - legged-wheels
  - EMI receptors
  - compartments for electronics
  - manipulator adapter
  - wheel steering unit
  - camera housing

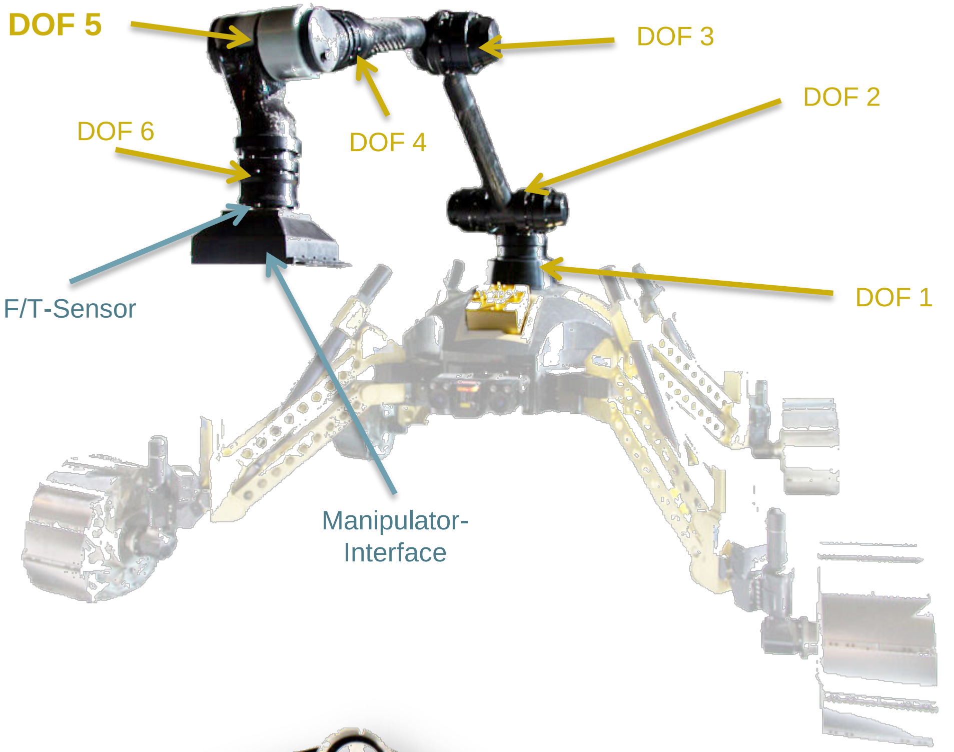




- Support of operation
  - locomotion platform
  - manipulator

Manipulator

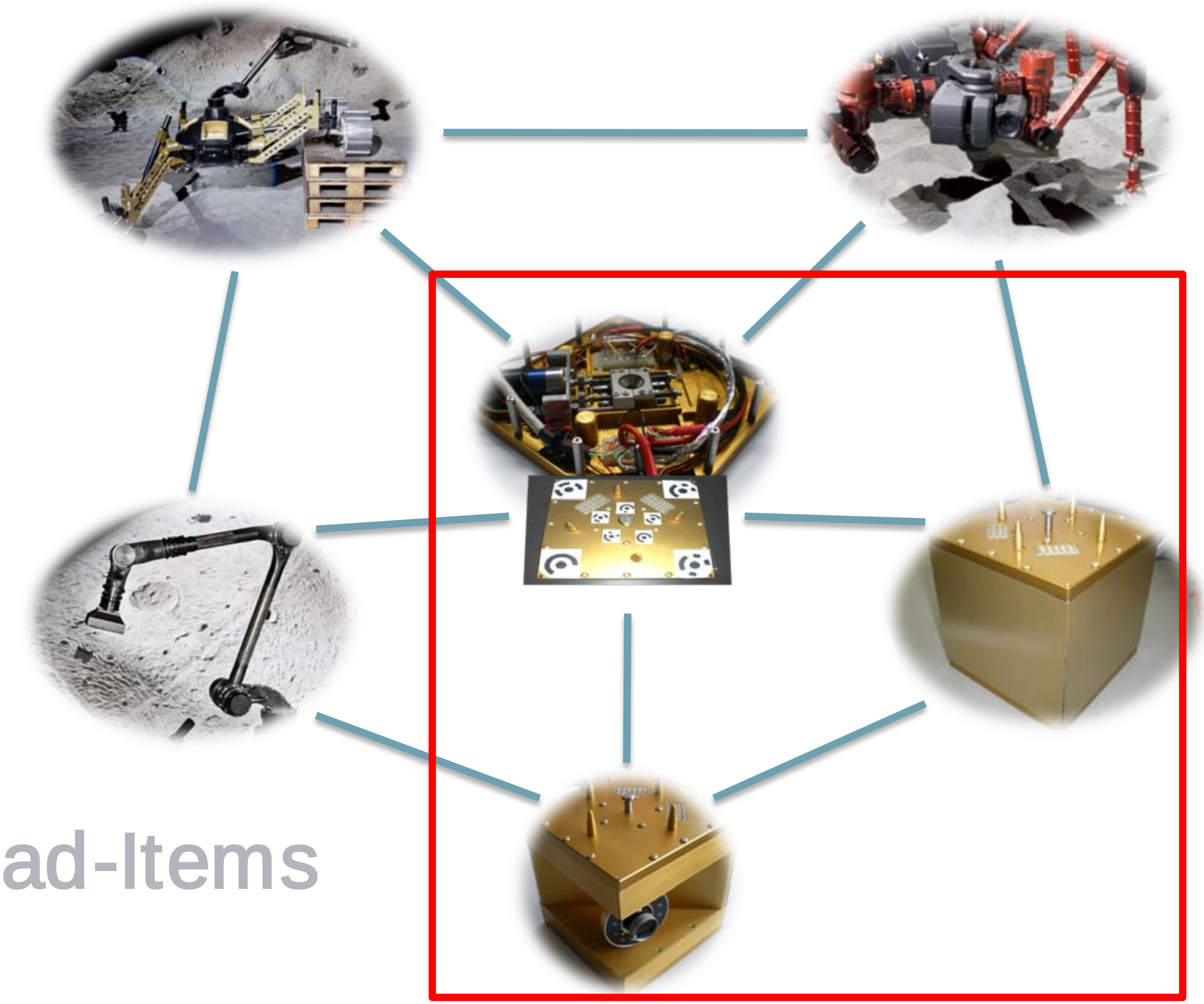
- General manipulation
  - 6 DOF
  - Interface as „partial P/L-Item“
- Stacking
  - 6-DOF FT-Sensor
  - Payload
    - dynamic 25kg, static 45kg
    - **DOF 5** with vertical orientation 60kg
    - Lifting from and deploying to body 100kg (reduced workspace)
- Locomotion support
  - 5th leg
- System-Inspection
  - using interface camera



Manipulator for locomotion (1)

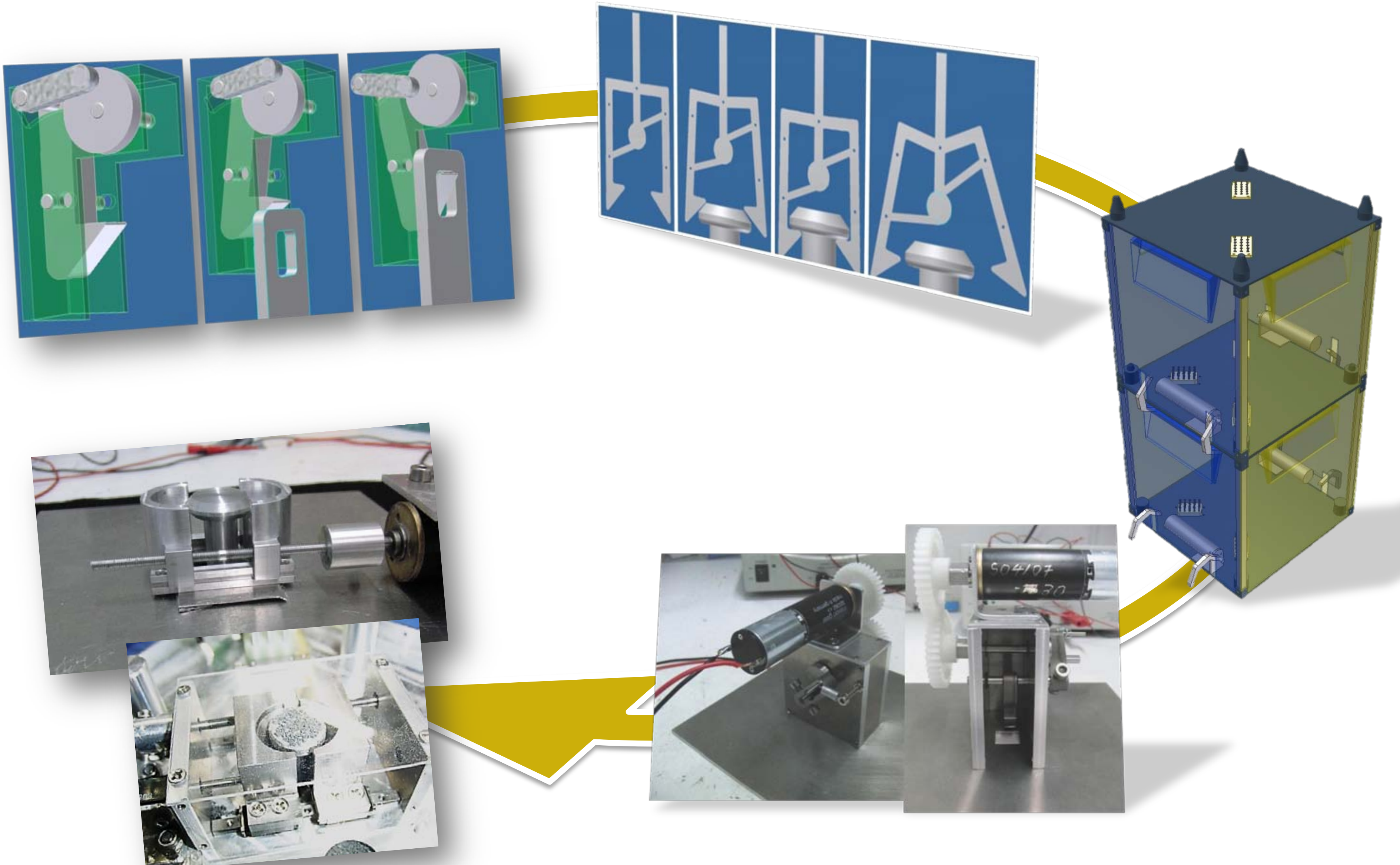
http://youtu.be/RQV2RpUikBo

Video: Sherpa uses manipulator as support to lift two legs

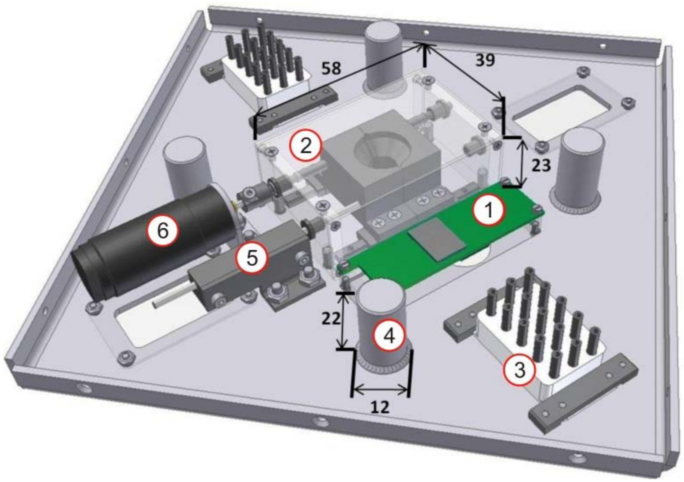


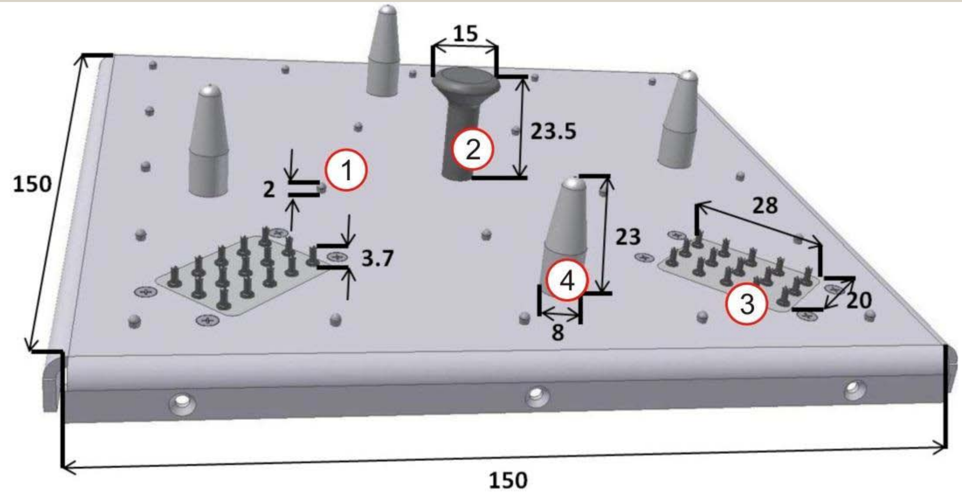
EMI and Payload-Items

EMI Iterations: Mechanical



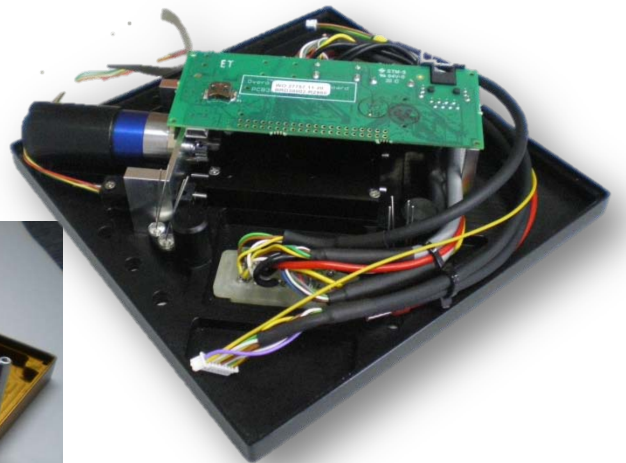
Final mechanical design EMI

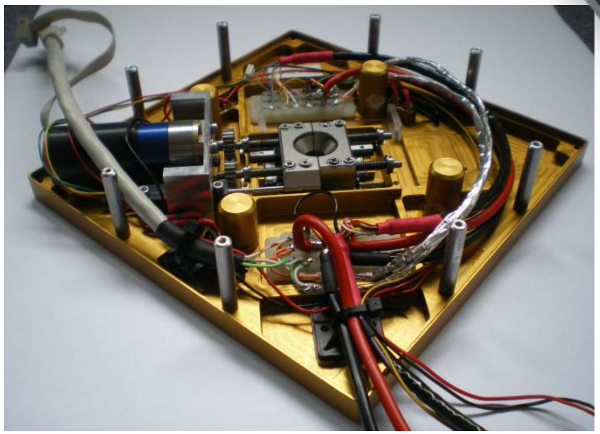


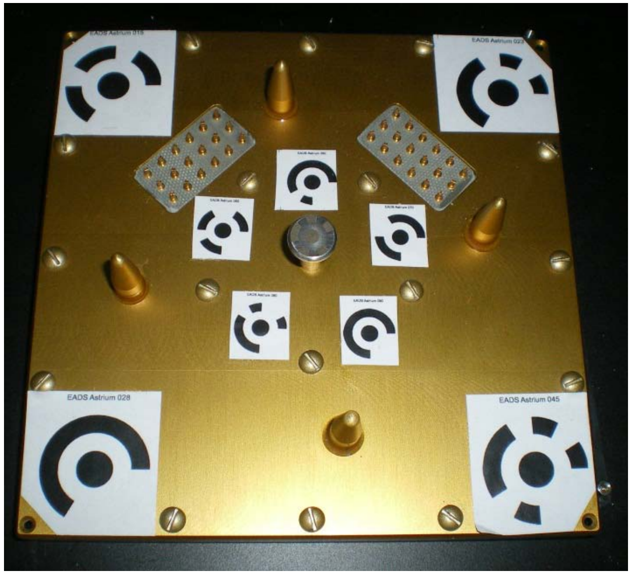


Top EMI

Bottom EMI





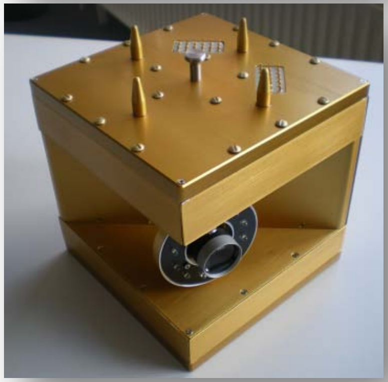


EMI Experiments

- Simulation of lunar dust accumulation, to measure effects on EMI functionality
- Mechanical locking
  - CREX with a weight of 27 kg
  - Function can be maintain up to
    - 40 kg in 30 deg,
    - 60 kg in 0 deg
- Power transfer across pair of pins
  - up 200W constant transfer
  - current implementation splits transfer across two pairs of pins

Payload-Items

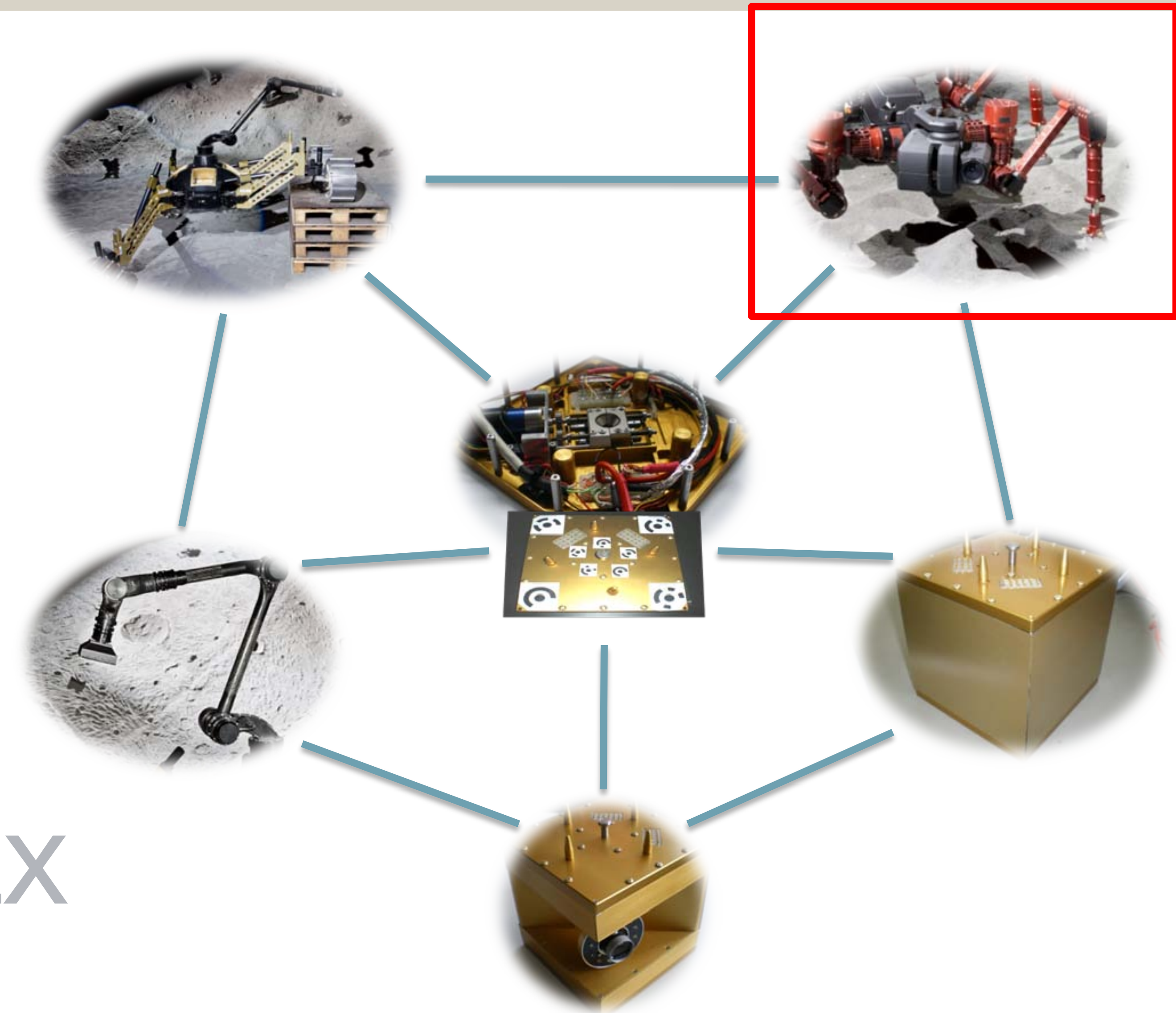
- Battery module
  - houses a single 48V/2,4Ah battery pack
  - allows for a second battery pack
  - simulation of a energy storage, e.g. as part of a setup for solar energy harvesting
- Camera module
  - Placeholder for data producing module (science module)
  - Commendable and generating significant data volume, handled by high-level software framework



Manipulator for stacking

http://youtu.be/ikUM8nUBMjI

Video: Sherpa uses manipulator for stacking



Scout: CREX

CREX: Crater Explorer

- Six-legged scout for the RIMRES-system
- Provides high locomotion capabilities in difficult terrains such as steep crater environments
- Legs can be reconfigured as grippers or sensing devices
- Passive EMI on back
  - Connection to rover
  - Payload bay for equipping with additional functionalities
    - Sensors
    - Extra energy packs
- Sensor head with laser range finder and monocular camera
- System specifications
  - 820x1000x220mm (standard posture)
  - Weight: approx 27kg
  - 27 DOF in total
  - Power consumption ca. 85W standing/ 105W walking

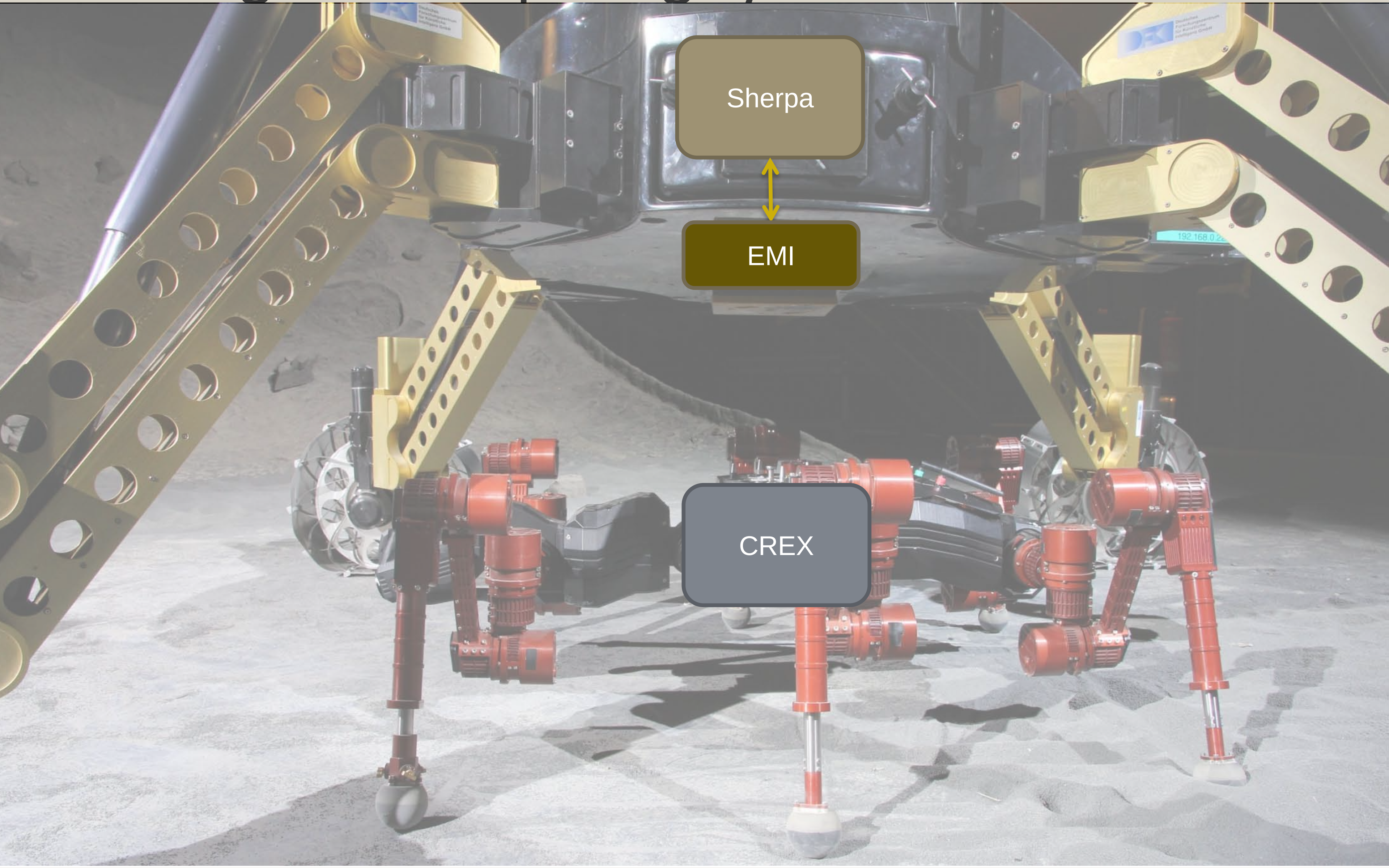
CREX and manipulator

http://youtu.be/H-XGX89DGoo

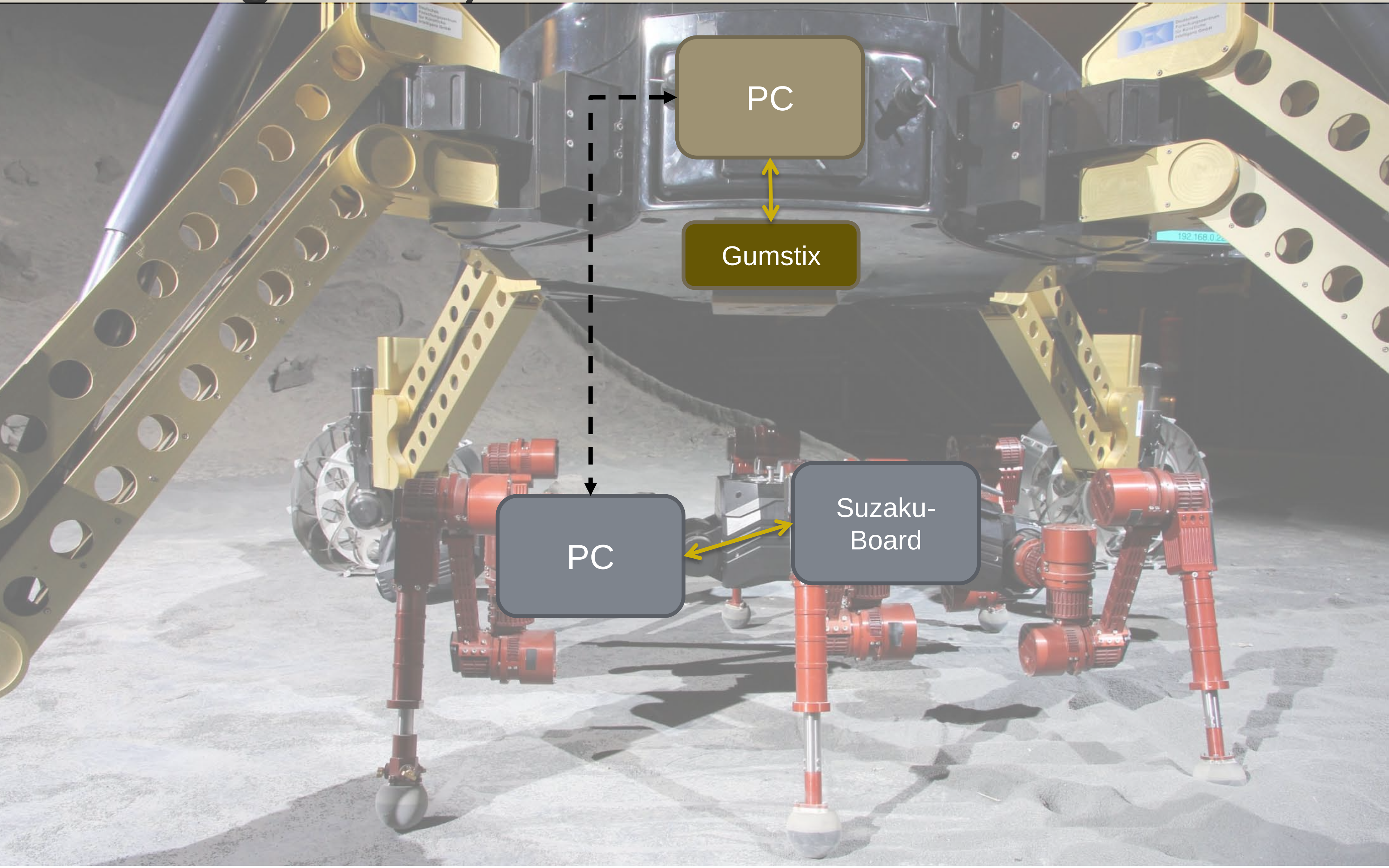
Video: CREX is lifted from high level to ground level

System reconfiguration via docking

Docking – Participating systems



Docking - Subsystems



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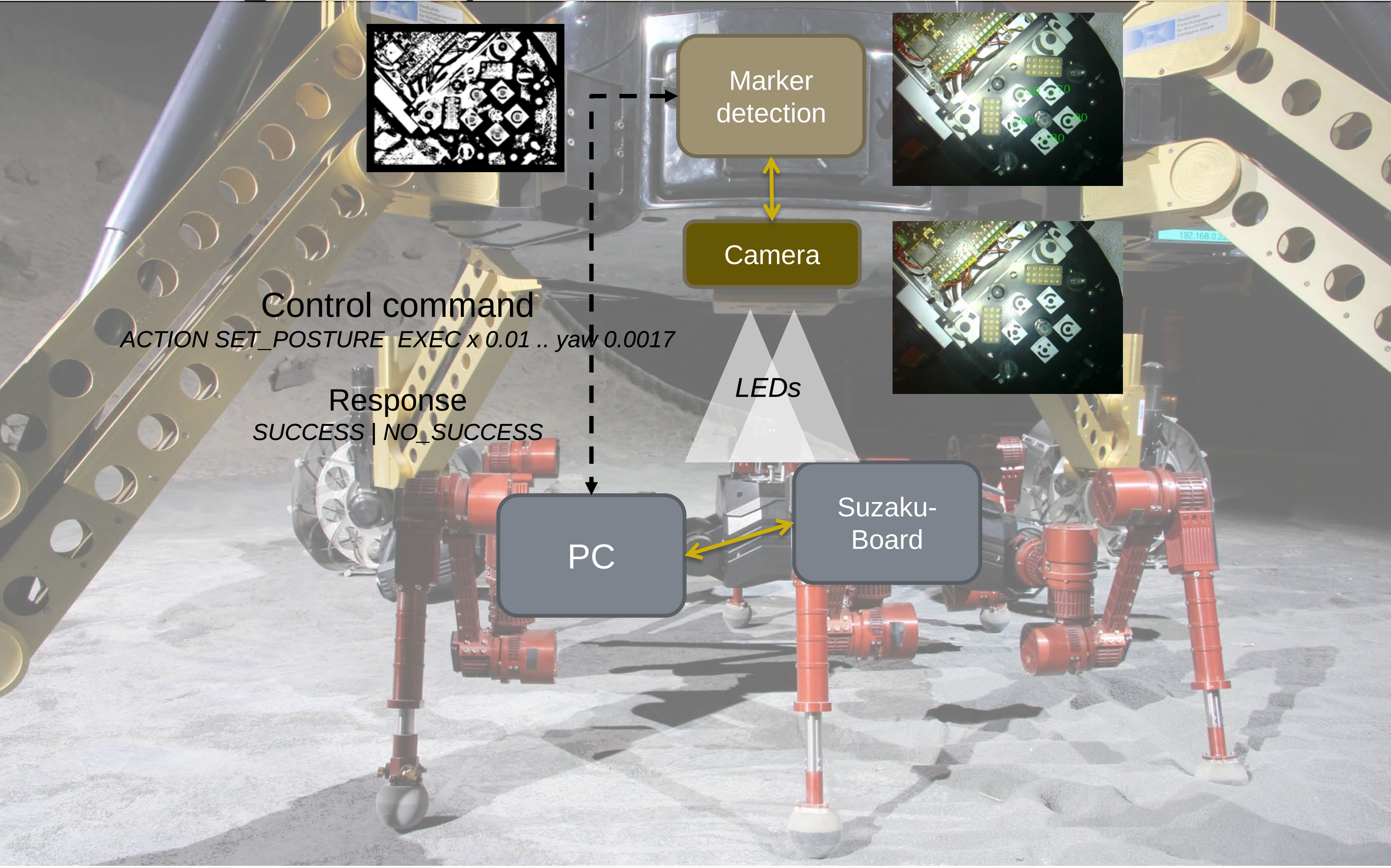
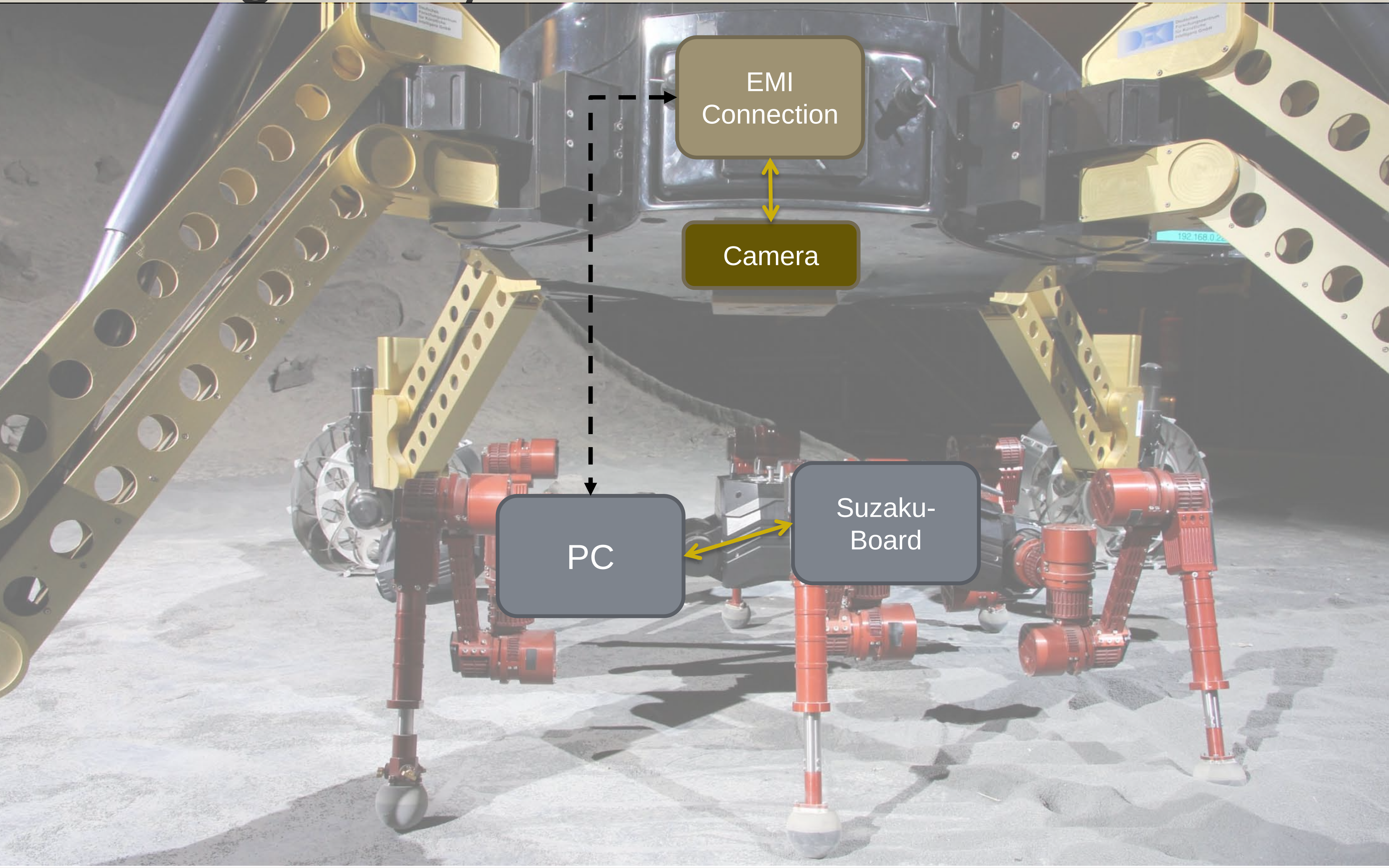
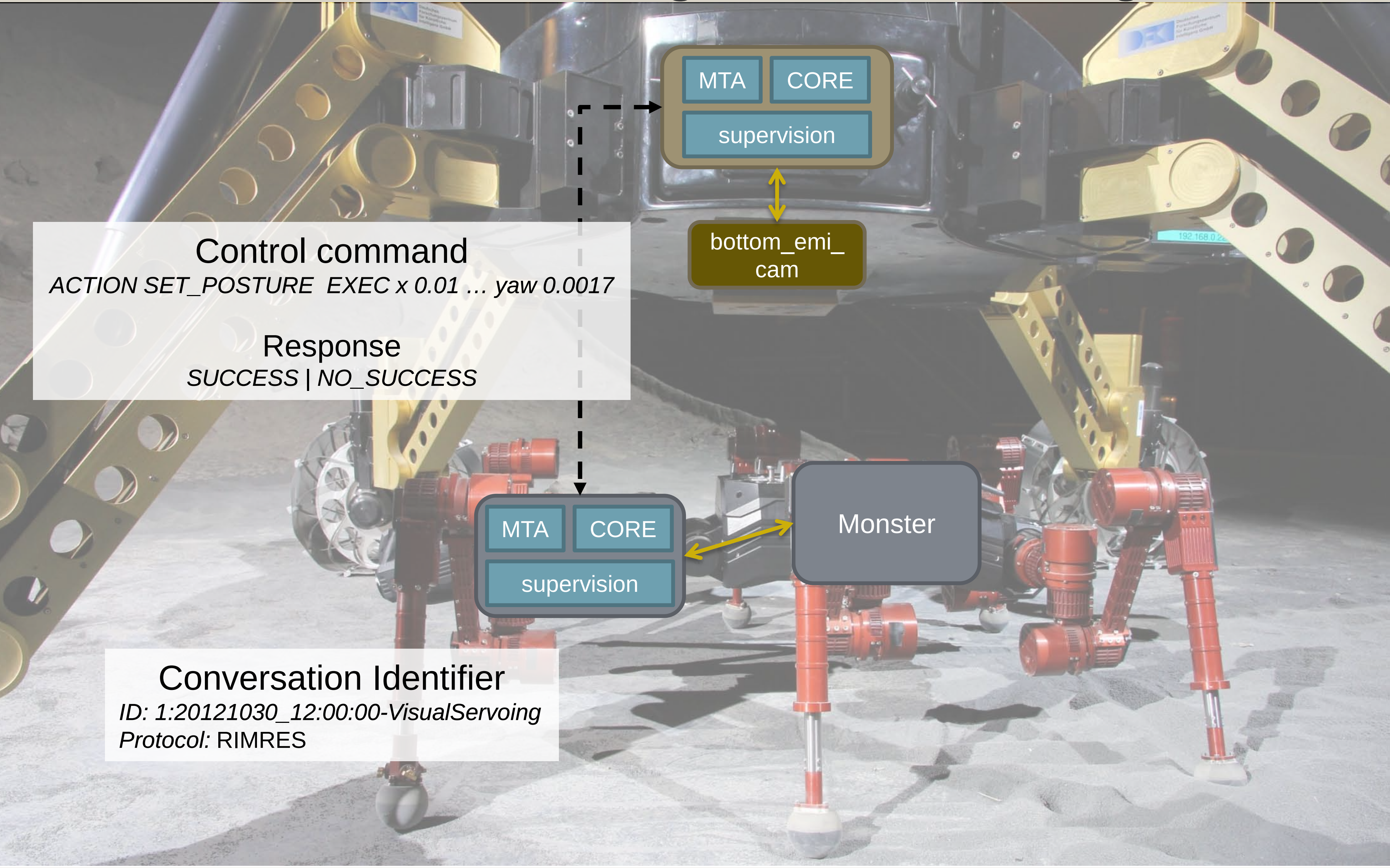


Docking - Subsystems



Communication – dialog-based commanding



Control command

ACTION SET_POSTURE EXEC x 0.01 … yaw 0.0017

Response

SUCCESS | NO_SUCCESS

Conversation Identifier

ID: 1:20121030_12:00:00-VisualServoing
Protocol: RIMRES

System inspection in monolithic state

http://youtu.be/KaQfs3U9SIg

Video: System inspection in monolithic state

Lessons learnt & Summary

Lessons learnt

- Hardware
  - Seemingly small devices such as the EMI can be as complex as ‘big’ systems and draw many resources
  - Things that can break will break (including COTS)
    - account for accessibility of all(!) systems (ideally), e.g. for changing electronics, checking fuses, wireless communication, …
  - Complexity of locomotion platform questionable, DOF not fully exploited
- Software
  - Invest early in setting up of a proper, smooth workflow for all(!) involved system platforms
  - Try generalized approach first, specialize late when deploying to individual systems
  - Make all features and functions directly accessible for mission operation
- Integration
  - requires hardware and software, finishing hardware late means less integration and testing time for software (if the deadline is on a fix date)
  - maintain a component database, i.e. track hardware and installed builds

Summary

- Unique mechatronic system comprising a hybrid rover, six-legged scout, and payload-items
  - a further step towards developing heterogeneous, modular and reconfigurable systems capable of complex activities
- Development of a software framework to control the heterogeneous, modular robotic system
  - model-based development , supporting modularity also at the software layer
  - embedding EMI as central device for realizing reconfigurability
- Many lessons learned regarding system design and handling system heterogeneity at software level

Future and ongoing development at DFKI

- IMPERA
  - April 2011 – March 2014
  - Integrated Mission Planning for Distributed Robot Systems
    - Multi-robot exploration strategies for space application
  - Applicable approaches for a system like RIMRES
  - A cooperation between DFKI Bremen and University of Kassel

- TransTerrA
  - May 2013 – February 2014
  - Semi-autonomous exploration of planetary surfaces to establish a logistic chain –
    - Explicit consideration of transferring technology to terrestrial applications
    - Building on top of technology of RIMRES

Remarks, questions , ...