Geophysical Monitoring Stations for Deployable Networks

ROBEX Sensorworkshop

27/04/2017, Vienna

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DLR

Introduction

- Geophysical monitoring station for future lunar seismic surveys

- Adaption to other scientific disciplines is possible

- Developed within the frame of the Helmholtz alliance *Robotic Exploration of Extreme Environments* (ROBEX)

- Concept inherited by DLR's Mobile Asteroid Surface Scout (MASCOT)
  - currently enroute to its target asteroid on-board JAXA's Hayabusa 2 mission

Motivation (ALSEP)

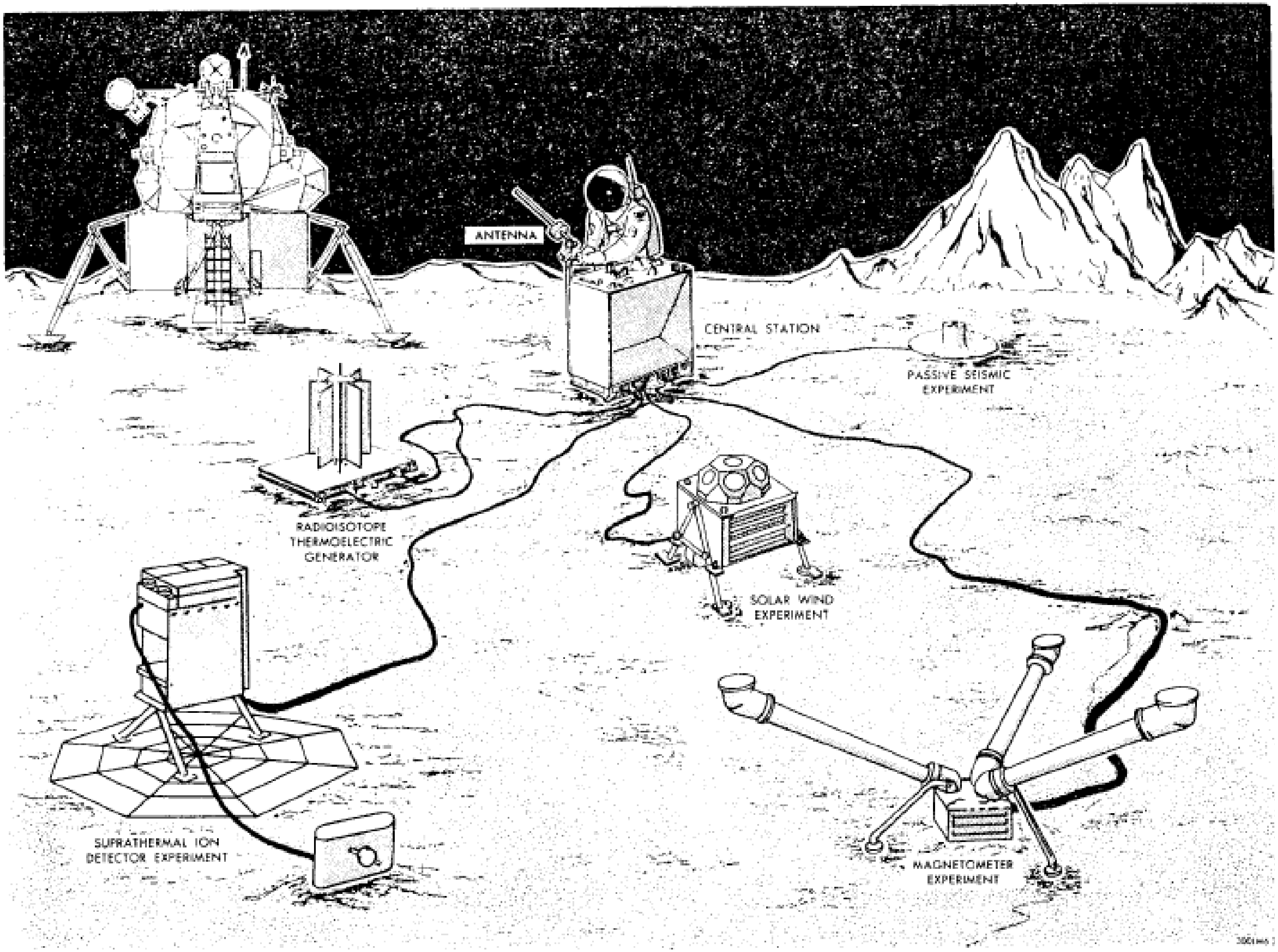


Figure 2.11-24. Apollo Lunar Surface Experiment Package Deployed (Typical)

Motivation (ALSEP)

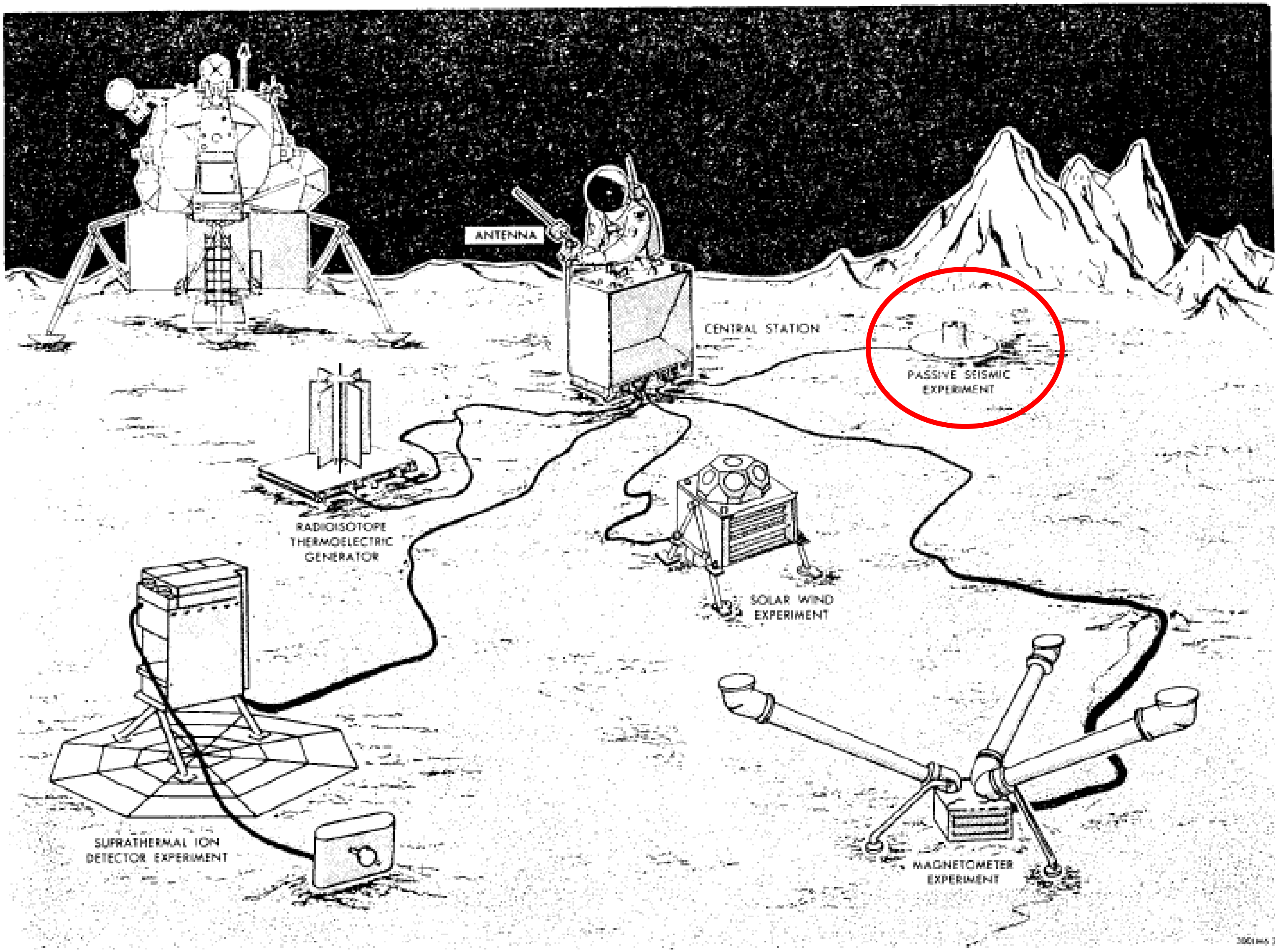
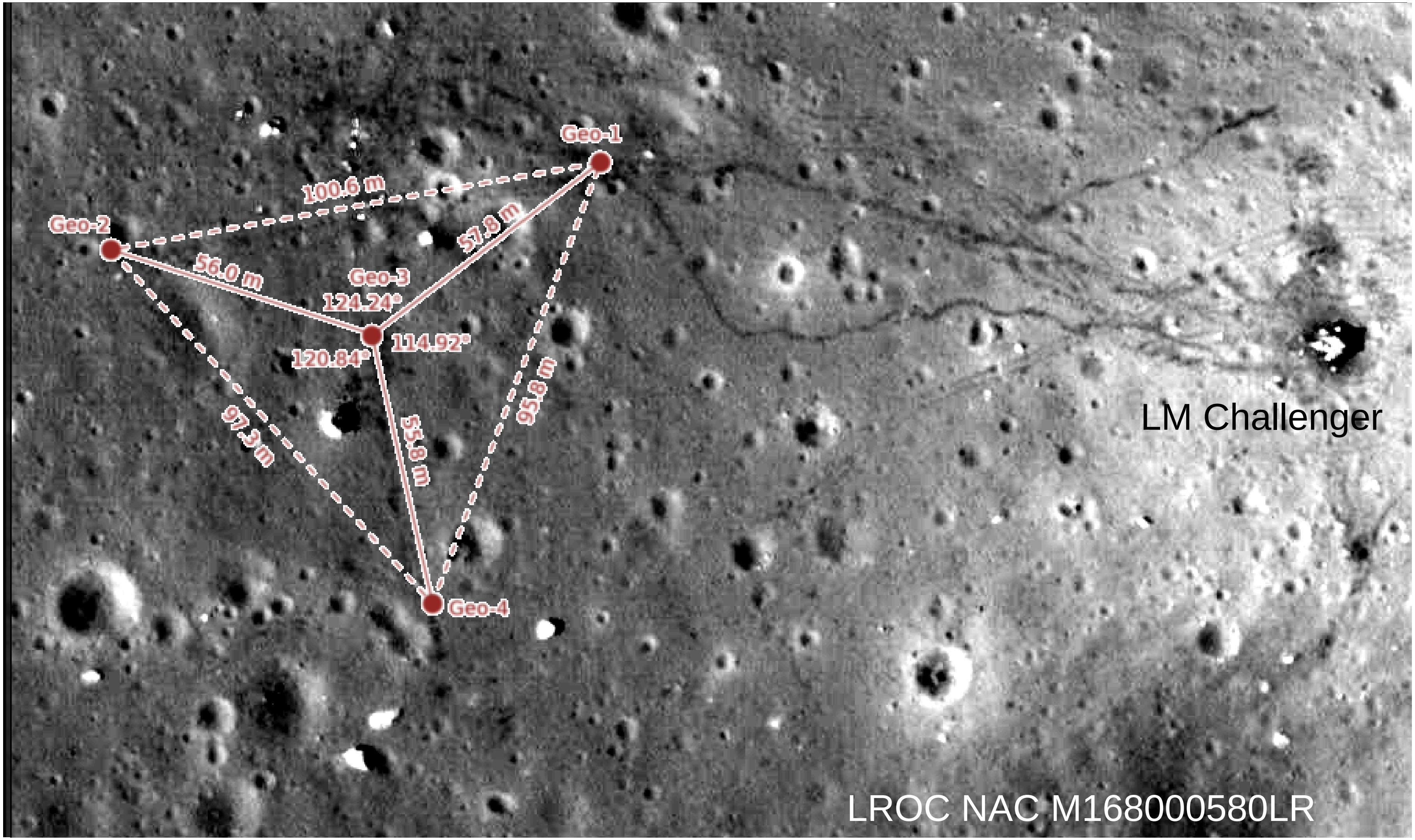


Figure 2.11-24. Apollo Lunar Surface Experiment Package Deployed (Typical)

Motivation (Apollo 17 Seismic Array)

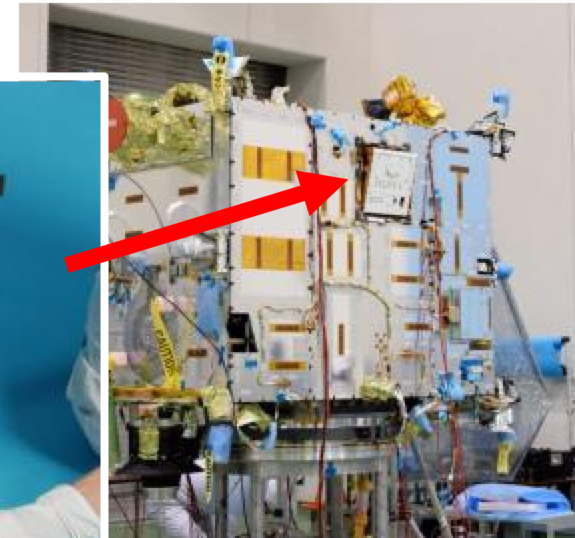


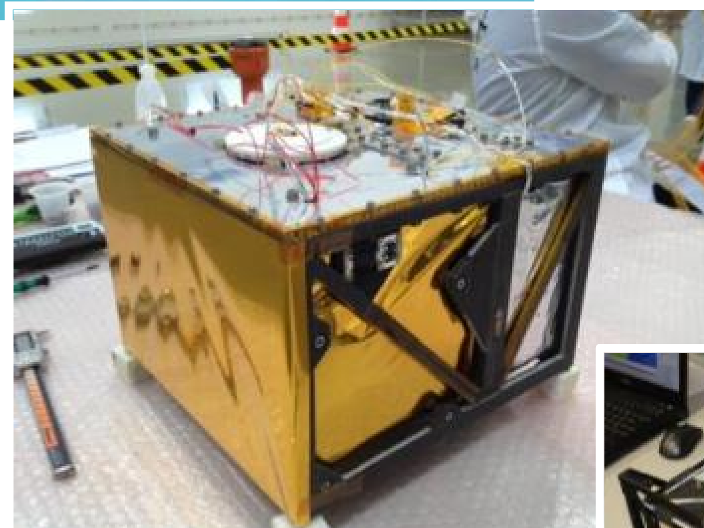
MASCOT
(Mobile Asteroid Surface Scout)

- 10 kg total mass
- 3 kg payload

- First concept studies 2009
- Launch Dec 2014
- Landing Sep/Oct 2018

- **P/L:**
  - Radiometer
  - Microscope
  - Wide-angle camera
  - Magnetometer





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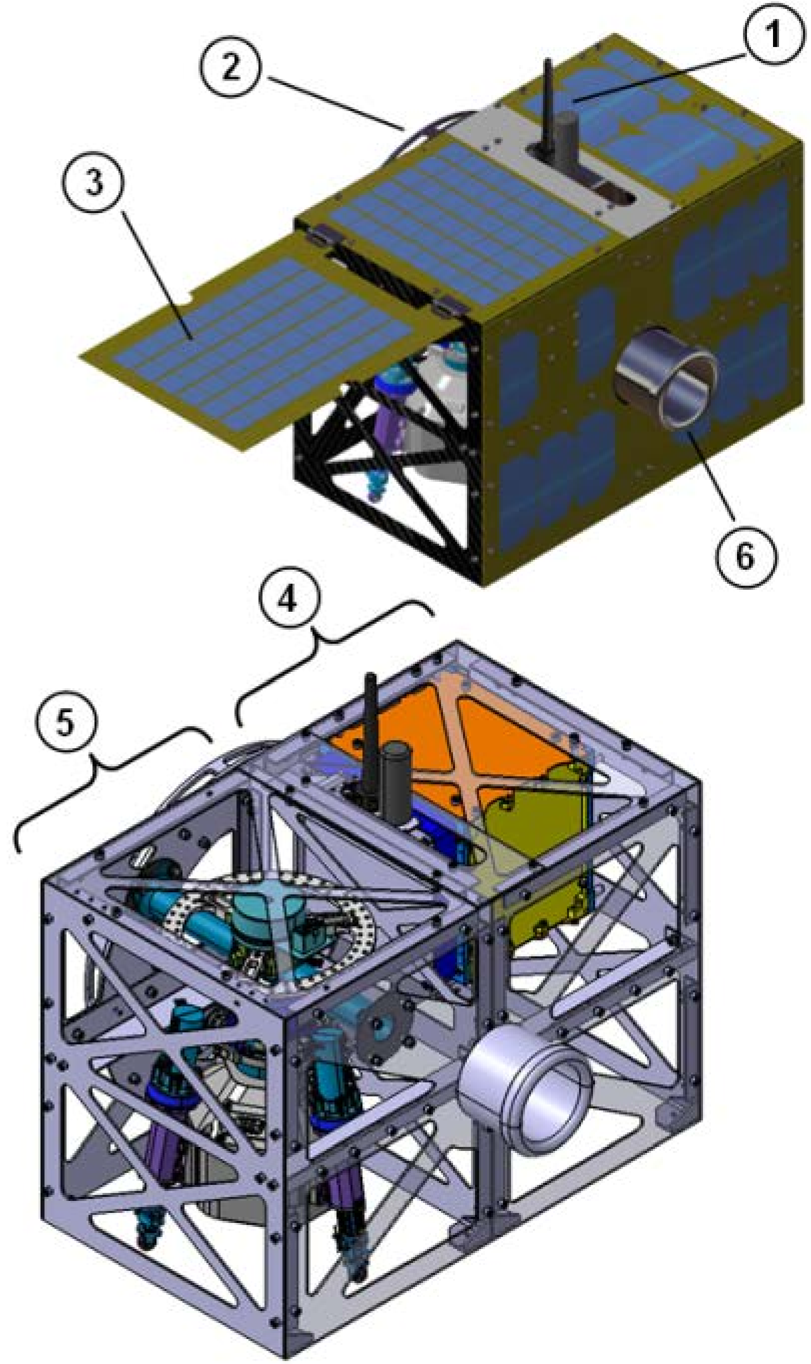
Remote Unit

- Highly integrated instrument carrier
- 340mm x 240mm x 200mm, ~10 kg
- Intended lifetime is up to several weeks
- Modular design enables accommodation of different payload types and adaption to various deployment concepts
- ROBEX reference scenario: Seismometer



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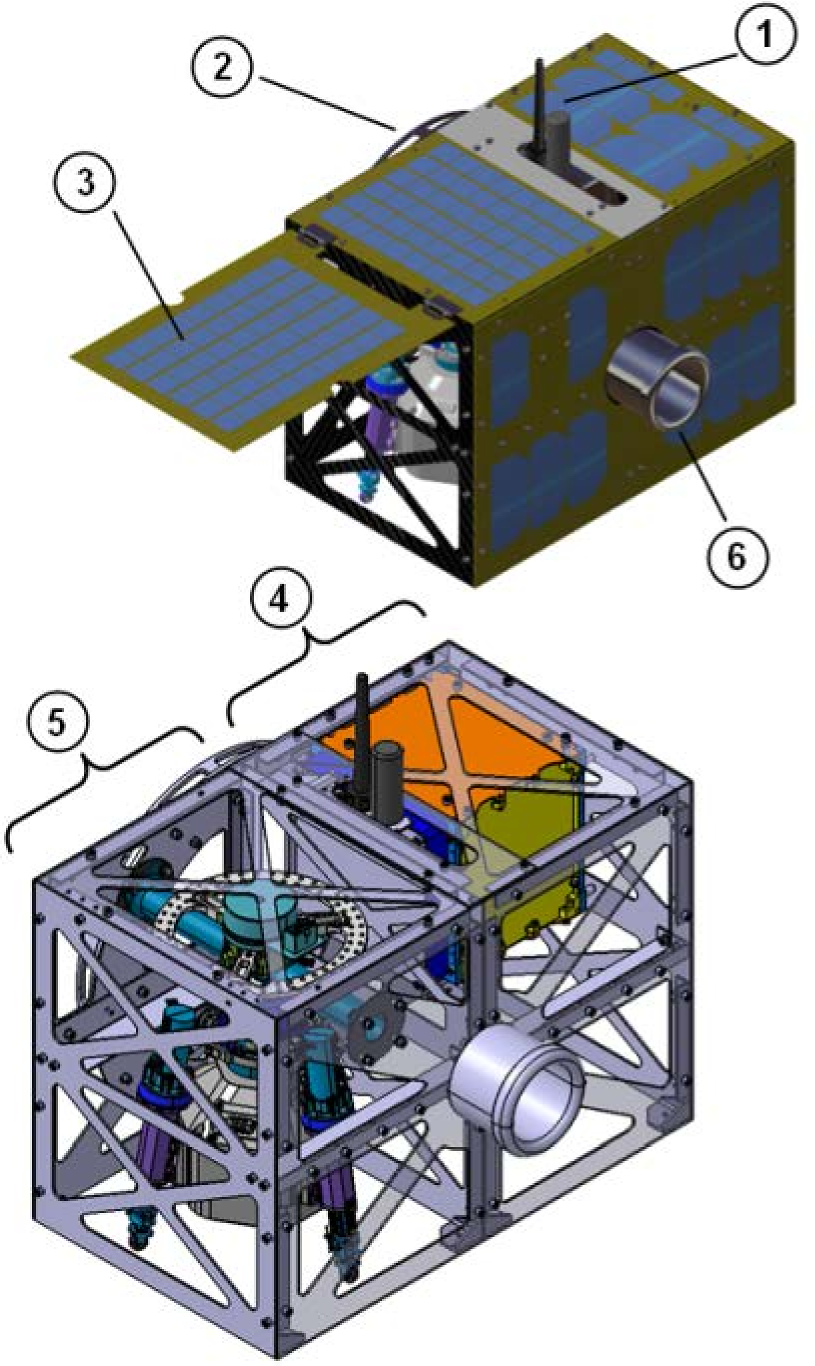
Remote Unit

1. Antennas
2. Docking interface to lander
3. Deployable solar array
4. Bus compartment
5. Instrument compartment with self-levelling seismometer
6. Grapple interface to a rover’s manipulator arm



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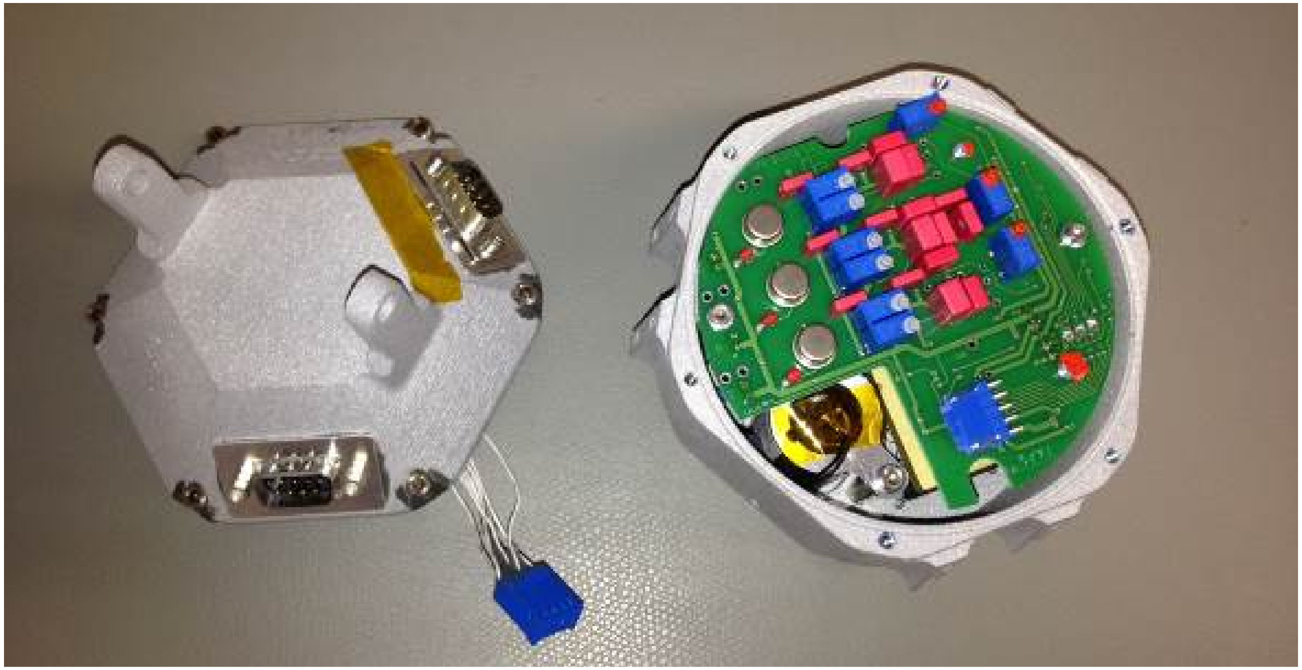
Seismometer

- Sensor: Modified Lennartz LE3Dlite Mark III short period seismometer
  - Three geophones and the internal electronics board are re-used

- Two variants of seismometer integration realized for development and test purposes
  - Lightweight but fixed installation
  - Heavier, more complex but self-levelling housing



Reference Mission Scenario

Goal of the reference mission is to

- show that a robotically deployed, maintained and operated infrastructure (here: a **seismic network** [*]) can produce high-quality and publishable data suitable to support meaningful scientific progress

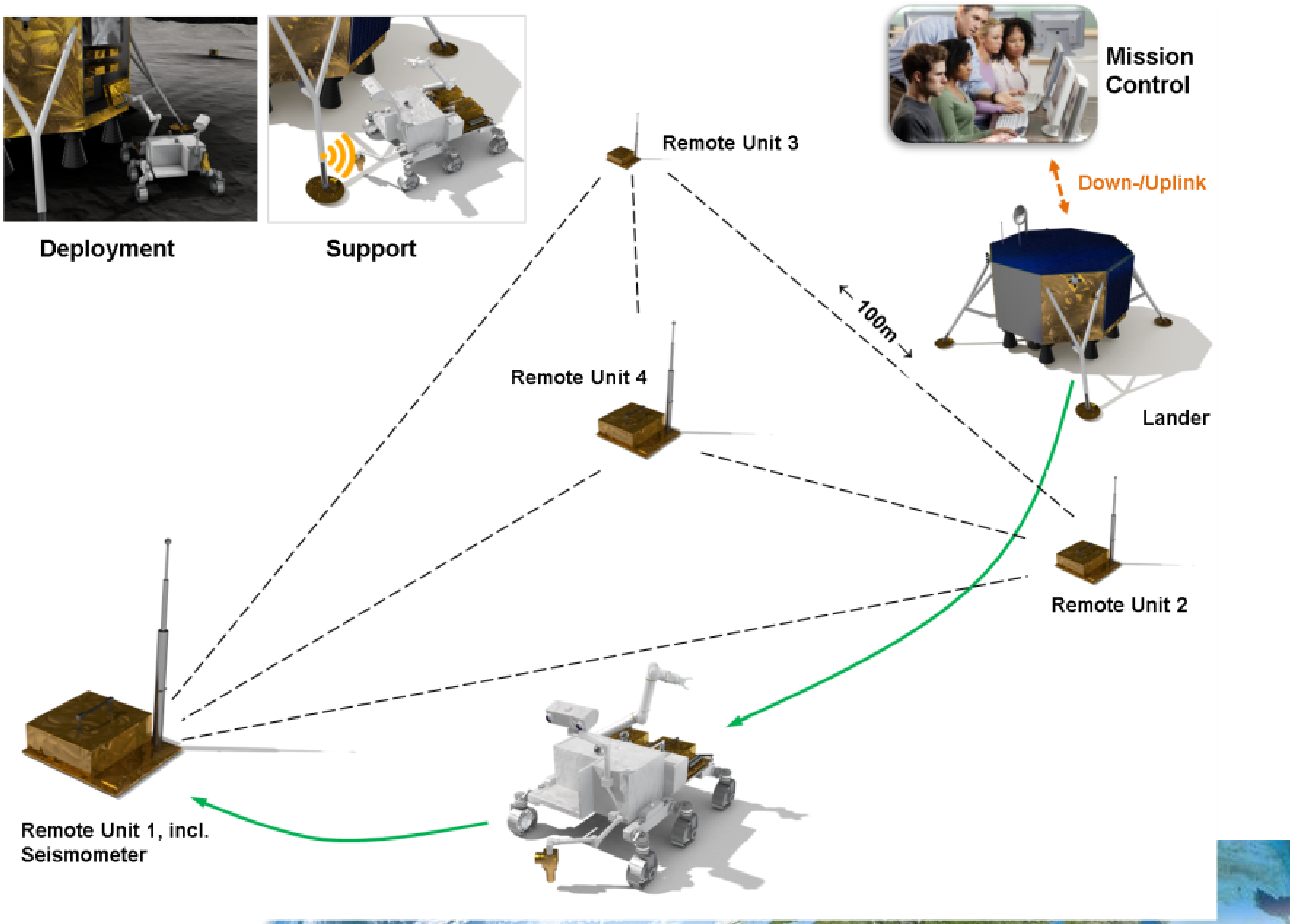
- demonstrate interoperability and verification of mission critical technology required to operate in a hostile environment

[*] Mission set-up usable for different, additional/complementary science objectives as well. Some other options to be assessed during pre-tests, but excluded from field test

Reference Mission Scenario

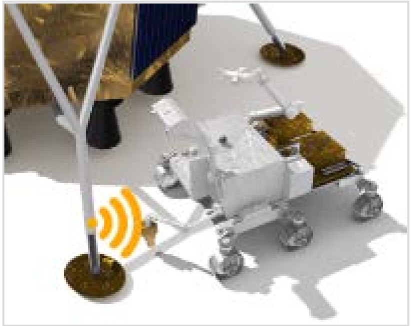
- Medium sized lunar lander
  - Deliver four seismic stations and the roving unit
  - ~1400kg landed mass / ~160kg payload
- Lightweight Roving Unit
  - autonomously deploys the monitoring stations w/ ground segment involvement only at check gates to assure and confirm the correct build-up

Reference Mission Scenario (Passive)



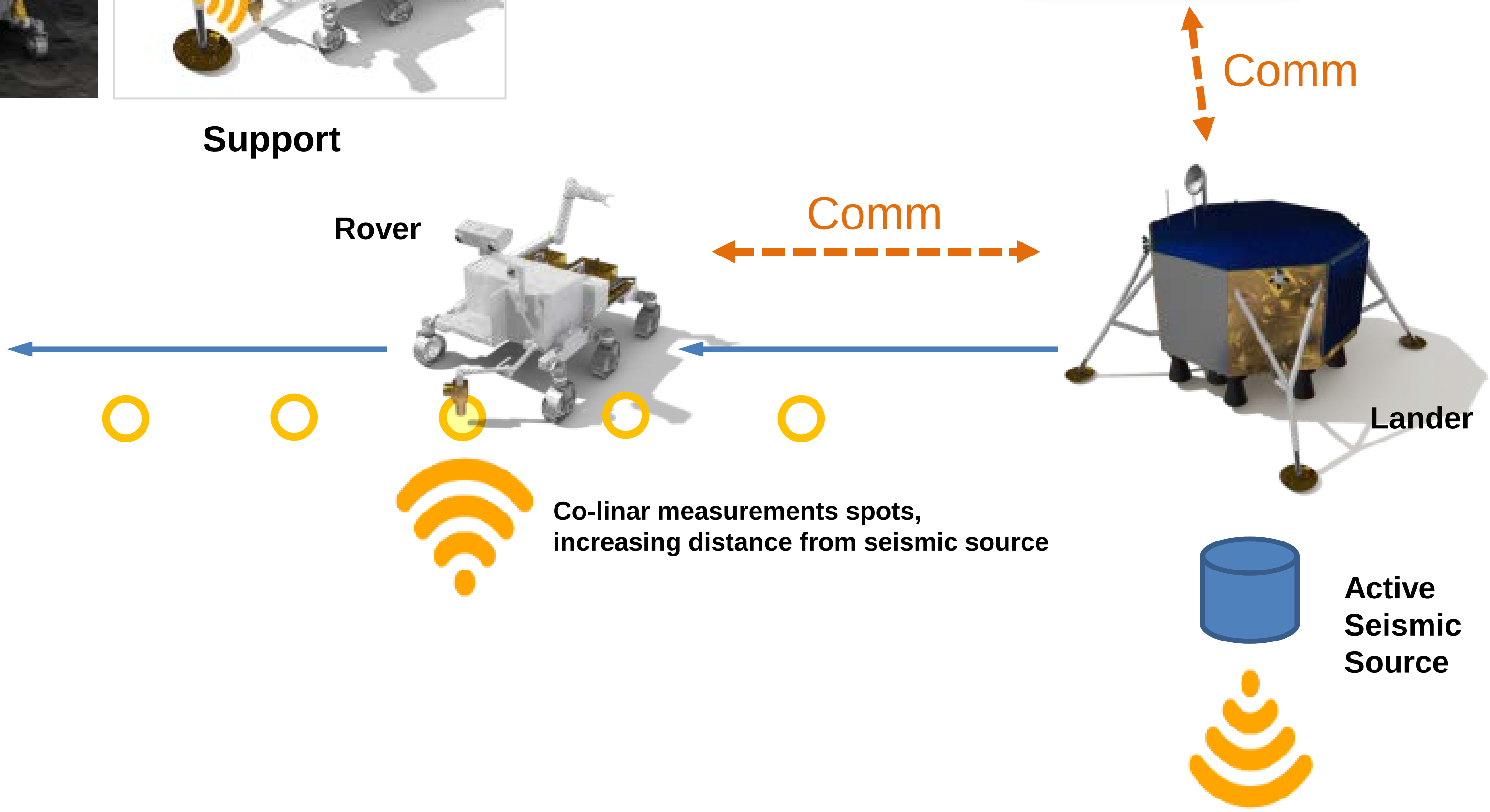
Reference Mission Scenario (Active)

Deployment



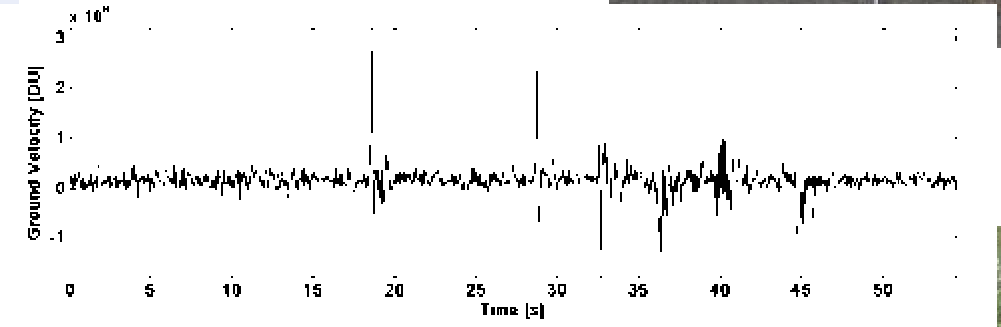
Support

Mission Control



Field Tests (Mt Etna, Sicily, Sep 2016)

- Key elements deployed in Moon analogue field test
  - monitoring station
  - rover
  - control center
- Prep of end-to-end mission demonstration of the active and passive scenario (summer 2017)
- Autonomous rover navigation and vision-based recognition of seismic P/L carrier incl. robot arm manipulation and handling of seismometer stations
- 5-kg hammer and aluminum disk used as active source,
  - usually done in short distance seismic profiling.
- Benchmark measurements between the telecommanded seismic station and off-the-shelf Lennartz seismometers as reference.



Alternatives to Seismic Network

- **Deployment of a Low Frequency Array (LOFAR)**
  - Monitoring stations at network nodes are equipped with antenna dipoles instead of seismometer
  - Deployment modes and lander/rover and rover/stations interaction is identical
- **ISRU/sample return demonstration**
  - Sampling tools and cache required
  - some lander/rover interactions are identical or reverse to current implementation
- ***Seismic network scenario chosen for reference mission, since it contains***
  - Network science (but less nodes than LOFAR)
  - Key interactions between elements (however no hand-overs back to lander)

Conclusions

- Seismic monitoring station as derivative of DLR's MASCOT spacecraft concept.
- Demonstration of technologies necessary for follow-on missions and a science case for future geophysical monitoring missions.
- Application purpose is either as a stand-alone station or as part of a larger network. Deployment mode is in both cases by robotic means.
- Adaption to other science cases possible.
- Intensive laboratory and field-testing in progress to verify and validate the involved technologies and the overall scientific approach.