The European Student Moon Orbiter (ESMO)

A Small Mission for Education, Outreach, and Science

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Facilitating Exploration Using Robotic Missions

- Sustainability of exploration in the long-term is (also) dependent upon the availability of a suitably qualified and skilled workforce
- Strong need to attract and train the next generation of space exploration engineers and scientists in order to avoid competency shortages in critical areas
- Key success factors
  - Inspirational activity
  - Accessibility
  - Learning by doing
  - Feasible challenge
  - Real operational environment
  - Effective knowledge transfer

Solution:
University students realise a small robotic lunar mission from end-to-end

Facilitating Exploration Using Robotic Missions

- Approach
  - Design, development, manufacture, assembly, testing and operations of all mission elements (platform, payload, ground segment) by university teams
  - Seniority guidance, technical support, project management and system engineering leadership by experienced ESA/industry team
  - All students experience space project lifecycle, system engineering, quality/product assurance, project reviews and related documentation, tools
  - Practical training in technical disciplines (mechanical, electrical, thermal)

- Benefits
  - Accelerated development of the space workforce
  - Confidence to perform more complex/challenging exploration missions
  - Potential technology innovation based on experience

What is ESMO?

- First European-wide student mission to the Moon
- Fourth mission in the ESA Education Satellite programme
- Hands-on space project aimed at fully preparing the future workforce for ESA's Science and Exploration programmes
- Opportunity for space science and engineering students to contribute to the scientific knowledge and exploration of the Moon
- Powerful education outreach tool to attract high school students into STEM subjects

SSETI Express

YES2

Mission Objectives

1) Launch the first lunar spacecraft to be designed, built and tested by students across ESA Member States and Cooperating States

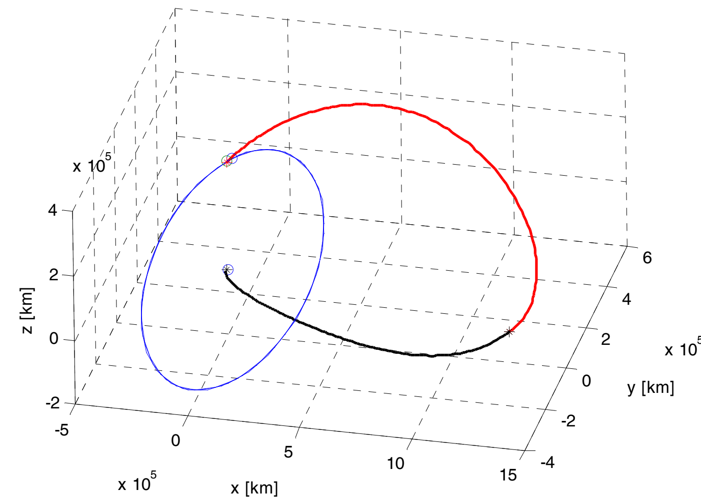
2) Place the spacecraft in a lunar orbit

3) Acquire images of the Moon from a stable lunar orbit and transmit them back to Earth for education outreach purposes

4) Perform new scientific measurements relevant to lunar science & human/robotic exploration of the Moon, in complement with past, present and planned missions

Mission Profile

- Launch:
  - Secondary/auxilliary payload into GTO
  - Launcher: TBC, multiple compatibility
  - Year: 2012/13



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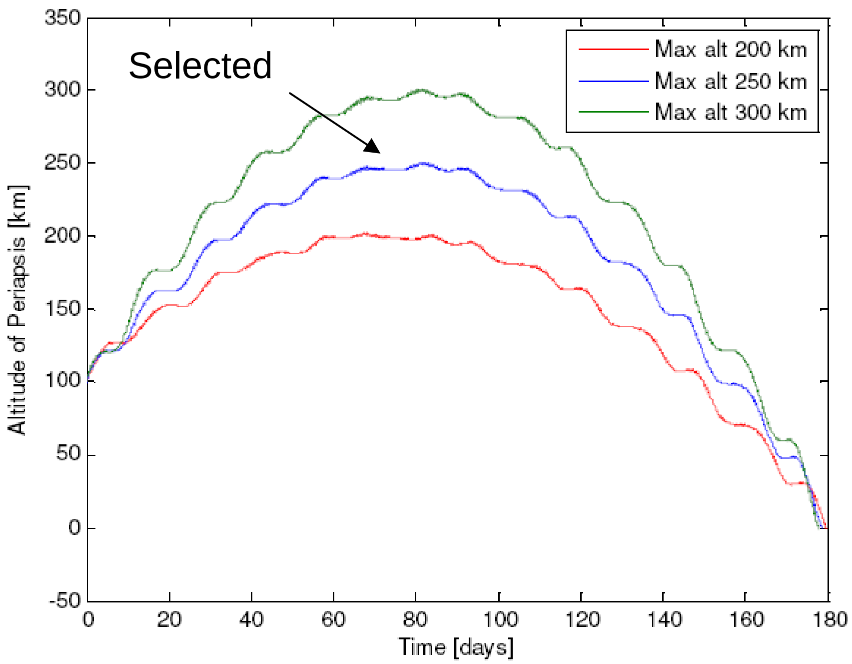
- Mission phases:
  - LEOP (1 month), lunar transfer (3 months), payload operations (6 months)

- Lunar transfer:
  - Weak Stability Boundary transfer via Sun-Earth L1
  - Manoeuvres with Chemical Propulsion system
  - Delta-V: 1200 m/s worst case from GTO to Lunar Operational Orbit
  - Intermediate burn strategy to raise apogee, reduce radiation belt exposure, phasing for departure

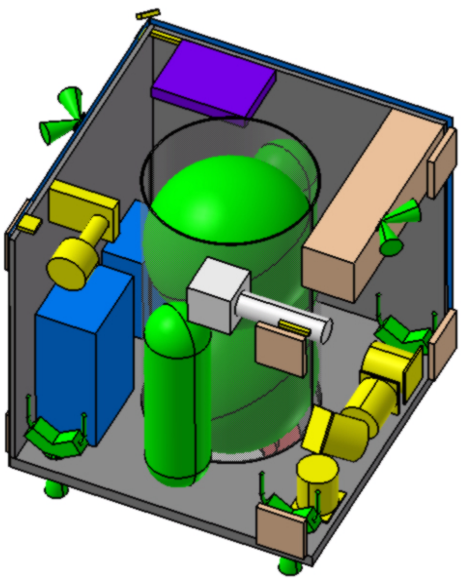
Lunar Operational Orbit

Parameter	Value
Periapsis altitude (km)	100
Apoapsis altitude (km)	3600
Eccentricity	0.522
Inclination (°)	89.9
Argument of periapsis (°)	293
Orbital lifetime	6 months



Space & Ground Segments

- Spacecraft:
  - 180 kg mini-satellite (wet mass)
  - 5 kg payload capacity
  - 3-axis attitude stabilisation
- Subsystems:
  - MON/MMH Bipropellant propulsion system & LEON2 dual redundant on-board processors (ESA)
  - Avionics, structure/thermal, payloads (universities)
- Mission control:
  - University control centre, SCOS2000 software
  - ESOC flight dynamics software
  - Student operations with support by expert team
- Ground stations:
  - 15 m S-band antennas in Malindi, Weilheim, Villafranca
  - Enhanced coverage for LEOP & burns by Perth, Kourou



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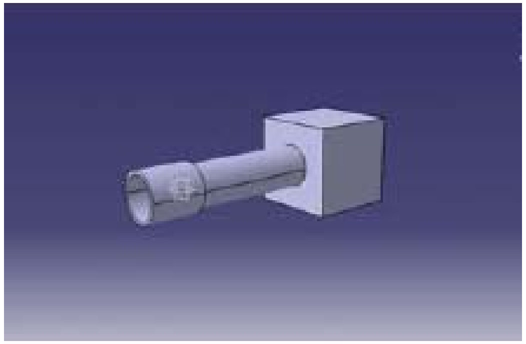
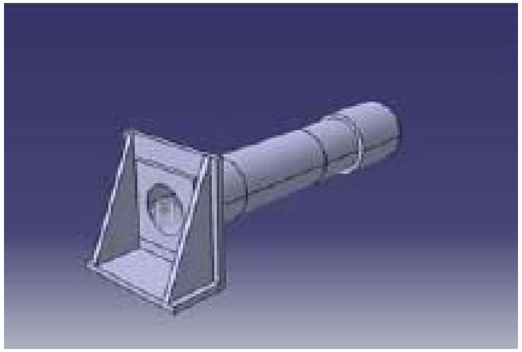
Narrow Angle Camera

- Objective: Outreach
  - provide images of the lunar surface to high schools upon request as part of a Moon lesson
- Operations
  - requests with surface location submitted by schools via web-based system
  - >5 images per day downlinked to Earth, distributed to schools with personalised overlay
- Design
  - 2.5 kg, 2.9° FOV, nadir pointing, refractive optics (6 lenses)
  - CMOS APS 1k x 1k detector, 400-1000 nm spectral range
- Performance
  - 10 m resolution images from 100 km altitude





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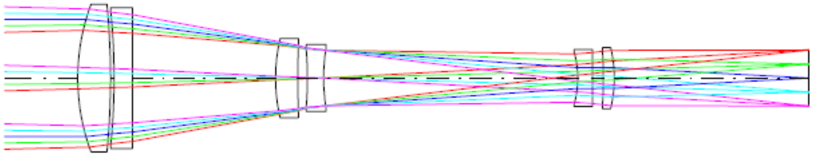
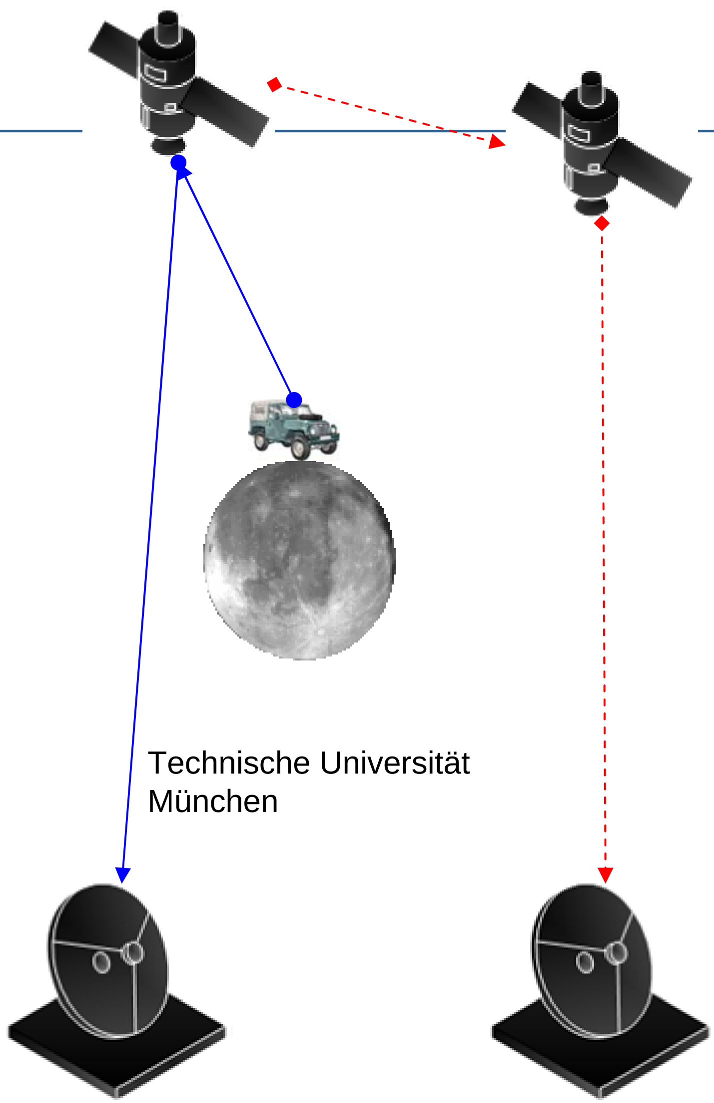


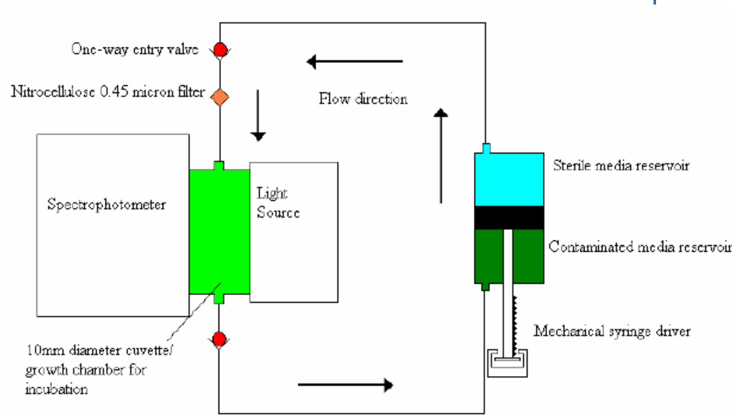
LunaNet

- Objective: Outreach & Technology
  - Allow high school students to 'ping' a lunar orbiter and send data packets to other schools via the Moon
  - Demonstrate communication protocols to establish a 'Lunar Internet'
- Operations
  - Allow routing of TMTC data between spacecraft, Lunar rovers, and Earth ground stations
- Design
  - SCPS-NP (OSI-Layer 3), an IP-like protocol with low overhead
  - SCPS-TP (OSI-Layer 4), a TCP-like protocol adapted for poor bit error rate
  - CCSDS-standardised



BioLEx (Biological Lunar Experiment)

- Objective: Science
  - study the effects of the radiation environment on biological material during transfer between Earth and Moon and during lunar operations
- Measurement
  - cell population growth using spectrophotometer system
  - radiation dose
- Operations
  - activated during all mission phases to determine different radiation effects on cell population growth
- Design
  - 1.4 kg mass, <5 W power
  - mechanically-driven syringe system
  - constant slow flow of new growth media to an incubation chamber allowing wasted media to be extracted



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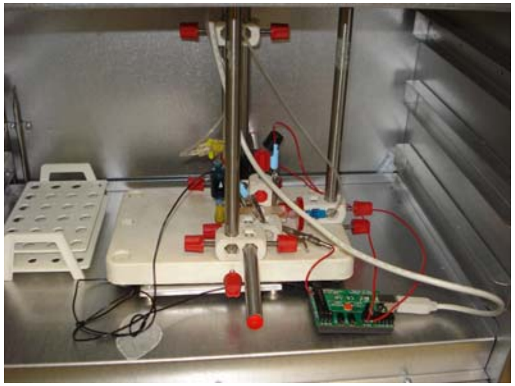
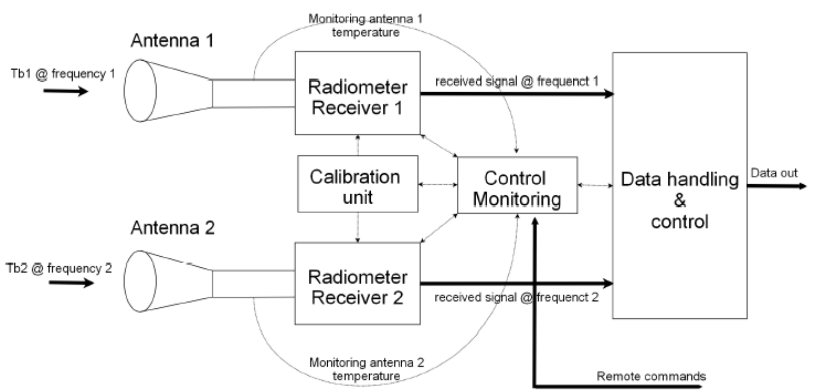


Passive Microwave Radiometer (Backup)

- Objective: Science
  - sounding of temperature at different depths of lunar regolith (1 and 3 m)
- Measurement
  - brightness temperatures at 3 GHz and 10 GHz
  - 60-100 km horizontal spatial resolution
- Operations
  - 1-4 s integration time per measurement
  - global coverage
- Design
  - 2.5 kg mass, <5 W power
  - 2 antennae, microwave receiver, calibration unit
- Performance
  - 1 K sensitivity



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Conclusions

- ESMO is:
  - a powerful hands-on education and public outreach tool for future science and exploration programmes
  - an accessible, attractive and inspirational project to high school and university students
  - an excellent preparation and training for the next generation of lunar explorers
  - able to perform scientific experiments at the Moon within the tight constraints of a mini-satellite
- ESMO has:
  - passed Phase A and proven feasibility
  - commenced preliminary design activities with over 200 students in 19 universities across Europe and Canada
  - received funding approval for implementation phases
- Final payload and launch opportunity still to be confirmed
  - high potential for international collaboration partnerships