HORIZON 2020

Searching for volatiles on the moon The LUVMI rover mass spectrometer

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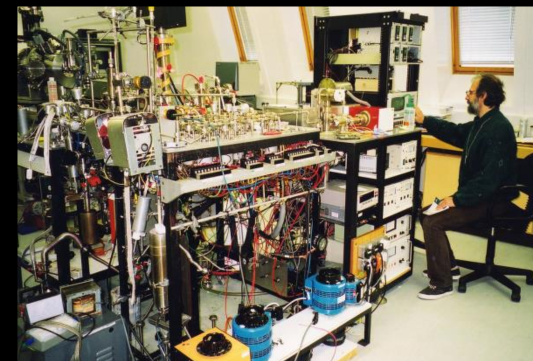
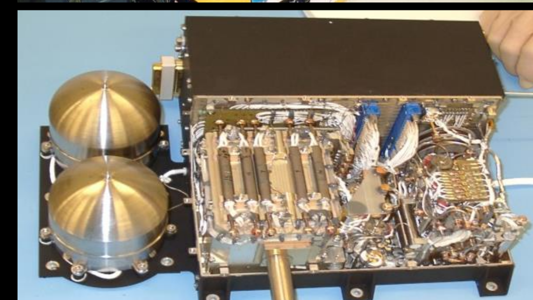
The Open University Space Instrument Group

- Laboratory analysis of meteorites
- Development of spaceflight instruments
- Mass spectrometry development
- Gas handling systems
  - Valves and gas storage
- Gas detection / characterisation
- Nano technology
  - Carbon Nano Tube fabrication / science





The Moon - Scientific Rational for volatiles

After the Apollo and Luna era the moon:

‘essentially waterless planet’[1]

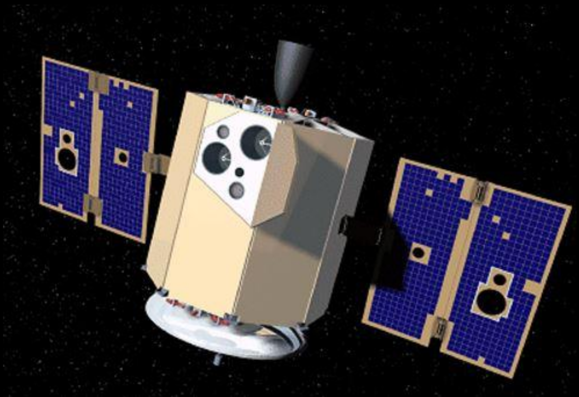
[1] - The Lunar Sourcebook (Heiken et al. 1991)

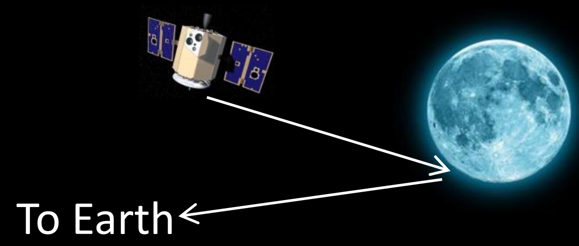
Water, water everywhere?

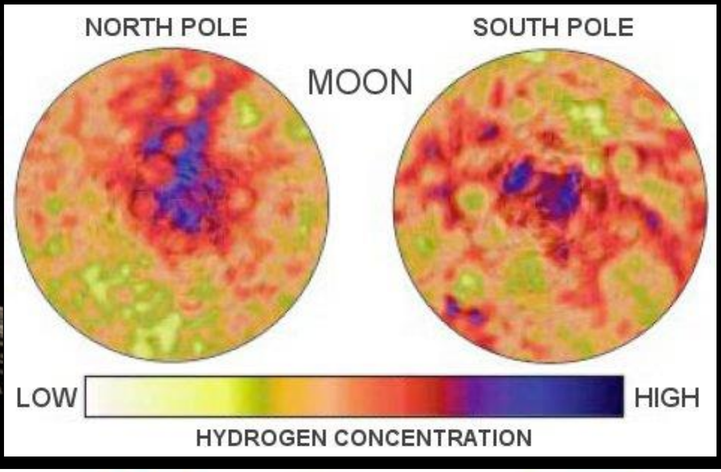
- Cold traps are areas in which the surface temperature is so low, that sublimation rates become negligible.
- For water ice, the surface sublimation rate drops below 1 kg/m^2 per billion years at temperatures below 100 K.
- Surface temperatures around and below 100 K can be found in permanently shadowed regions (PSR), which due to the low obliquity of the moons orbit of 1°32’, can be found in large numbers near the lunar poles

Early indications of Lunar water

- Two missions in the 1990s (Clementine and Lunar Prospector)
- Indications that there 'may' be deposits of water ice at the poles



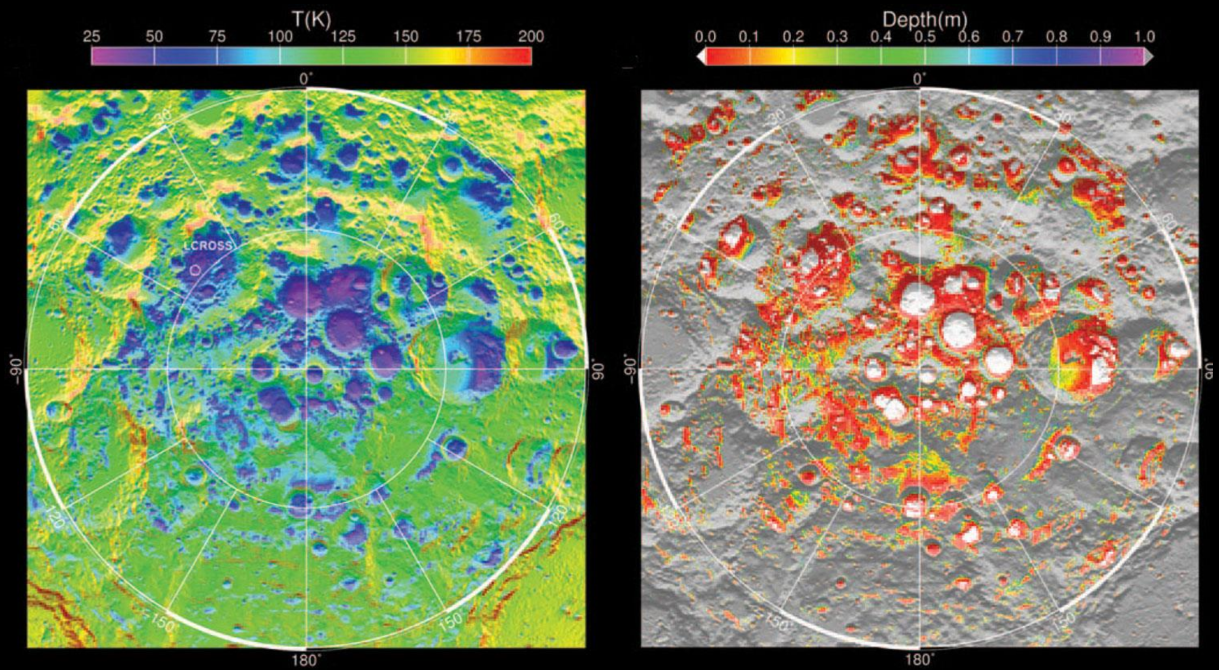




- Neutron spectrometer
- Elevated Hydrogen at poles
- Not what hydrogen is
- Water?

LCROSS & LRO

Surface temperature map of the lunar south pole obtained from data of the NASA Lunar Reconnaissance Orbiter (LRO



- So far the only direct observation of lunar water was performed during the LCROSS experiment, when the ejecta plume of an impactor in the Cabeus Crater of the lunar south pole was observed and a water content of 5.6 +/- 2.9 % was detected

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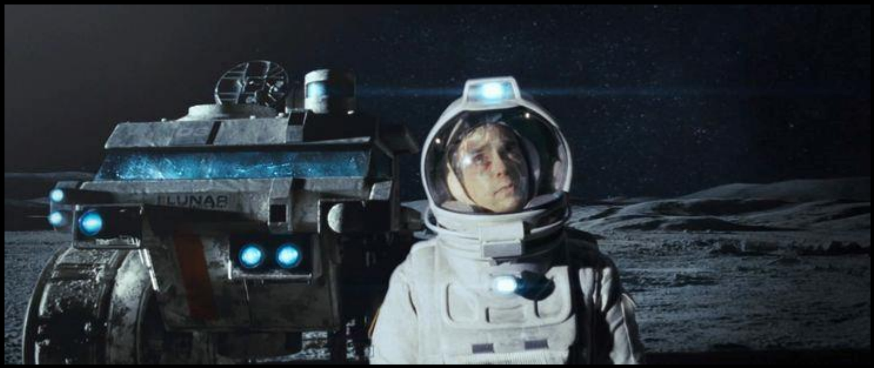
Why bother looking for water?

- Astronauts living on the Moon will need water
  - Take it with them
  - Use water already there
- ISRU – living off the land
  - Make long term habitability possible
- How much water?
  - More than 12 500 km^2 of PSRs on the moon
  - If top 1 meter contains 5% water there could be 2.0 x 10^{12} litres of water on the moon
  - Real potential for water mining of ISRU in the near future



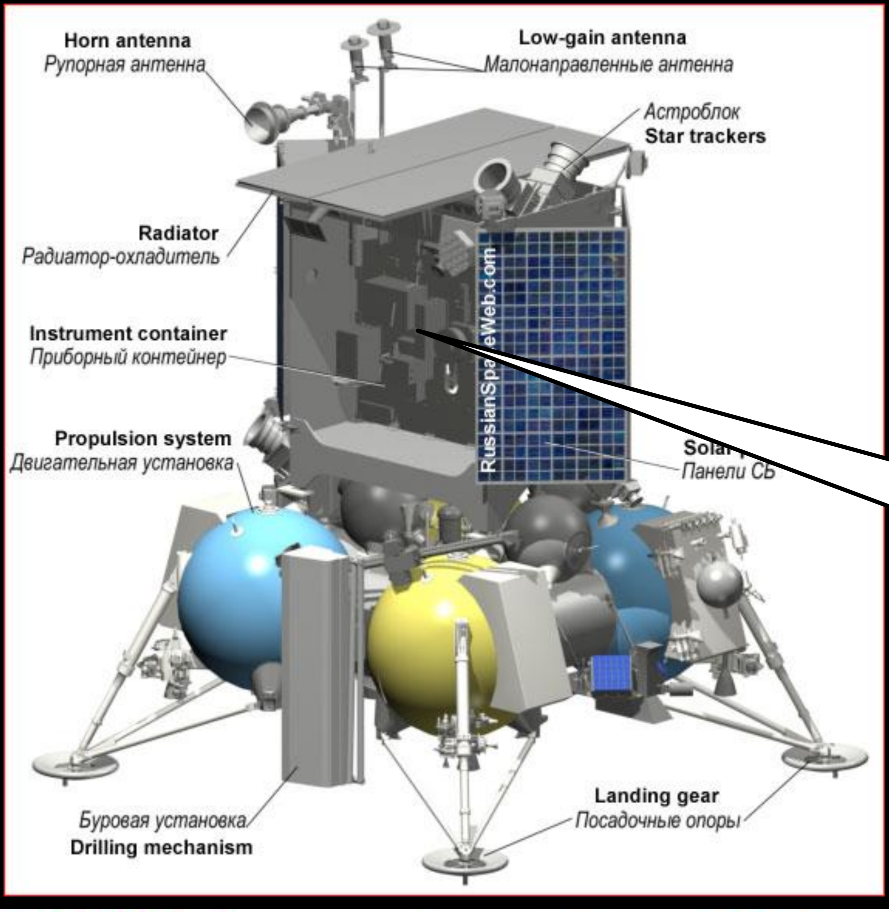
The Moon: The European Space Agency

- The European Space Agency has named the moon as the next destination for its human space exploration efforts beyond Low Earth Orbit
- ESA seeks to develop technologies that can enable human presence on the lunar surface, both from a technical and from an economic perspective.
- Substantial cost reductions could be achieved, if locally available resources were used, and earth to moon transportation costs were kept to a minimum.
- Perhaps the most interesting potential resource found on the lunar surface could be lunar volatiles

The need for ground truth measurements!

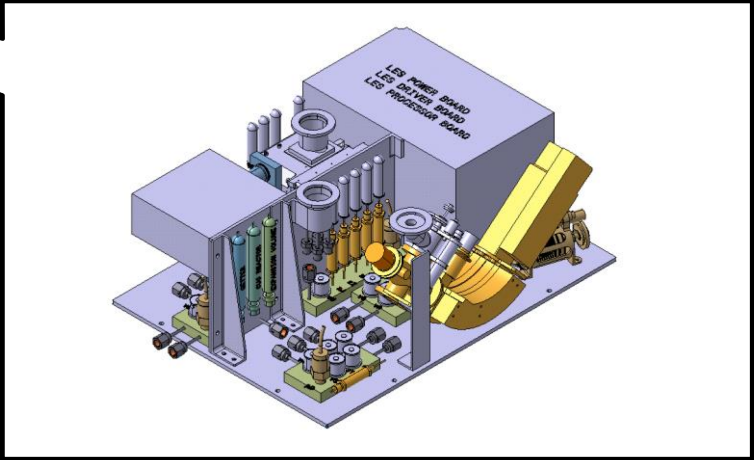
European Space Agency - Lunar instruments

PROSPECT - The Package for Resource Observation and in-Situ Prospecting for Exploration, Commercial exploitation and Transportation

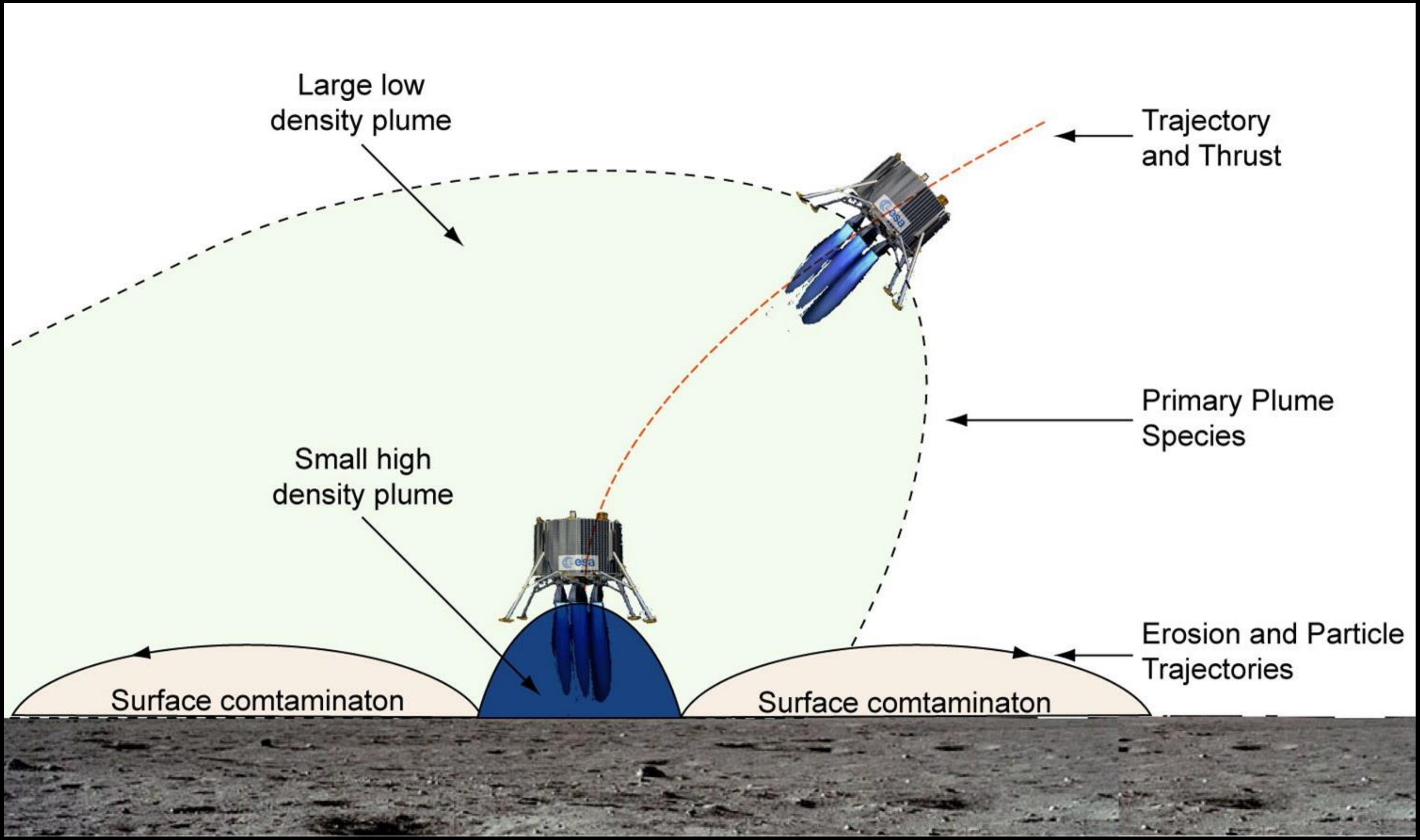


The PROSPECT Sample Processing and Analysis package (ProSPA)

- Russian Luna-27 mission
- Polar region in 2022
- Static lander
- Drill to sample sub-surface



The contamination issue?



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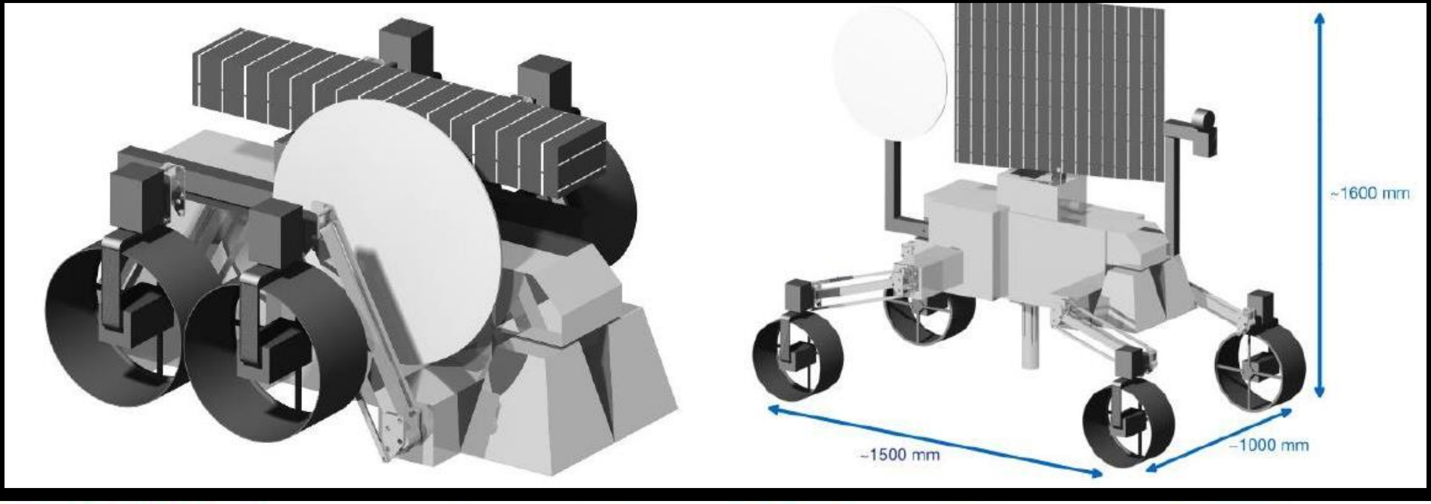
The need for mobility

- The Lunar Exploration Analysis Group (LEAG) :
  - there are enough uncertainties in the distribution of lunar volatiles implying that a non-mobile lander faces a significant risk of not finding volatiles or of “single data point” non-representative discoveries.
  - The scientific priorities can be fully addressed with a mobile payload that has the capability to access depths of 20 cm



‘LUVMI’
LUnar
Volatile
Mobile
Instrumentation

LUVMI – Mission Goals

Address top priorities established by the Lunar Exploration Analysis Group (LEAG) Volatiles Specific Action Team (VSAT):

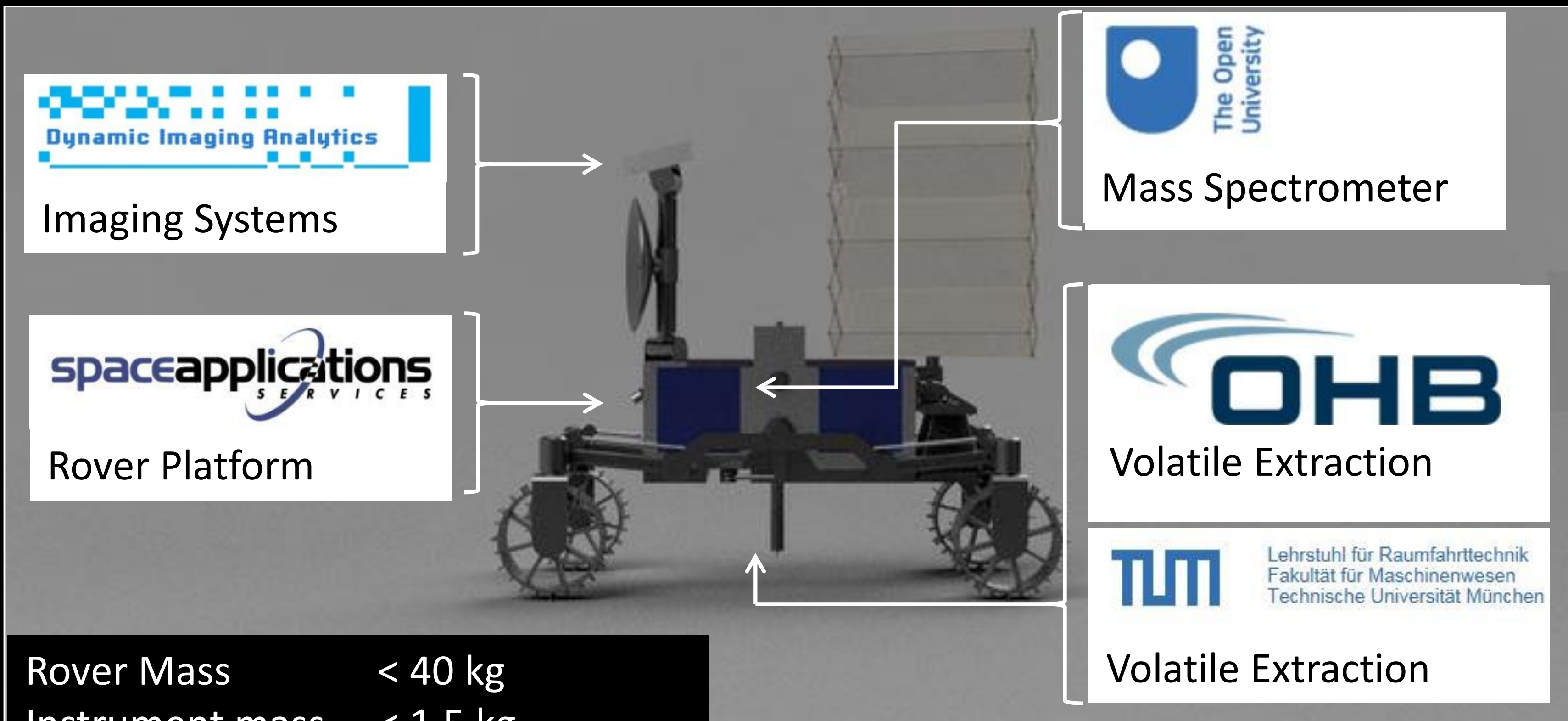
- Determining the variability of volatile distribution
- Identification of the chemical phase of volatile elements
- Analysis of physical and chemical behaviour of lunar soil with temperature
- Determining current volatile flux
- Access a PSR

- Use Mass spectrometer - universal detector
- Needs to be low mass / low power as limited resources available

Targets:

- H_2O
- CO_2
- CH_4
- H_2S
- NH^3
- SO_2
- C_2H_4
- CH_3OH

LUVMI rover concept



Rover Mass	< 40 kg
Instrument mass	< 1.5 kg
Life time	= 14 days
Ability to access PSR	

Horizon 2020 Programme

LUVMI Sampling methods

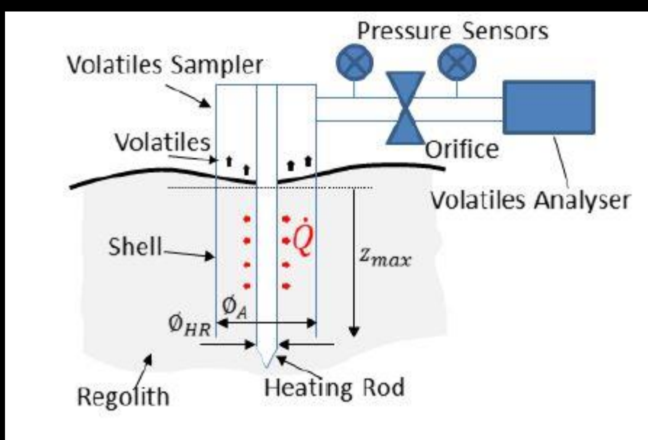
On the lunar surface, the following types of volatiles can be found:

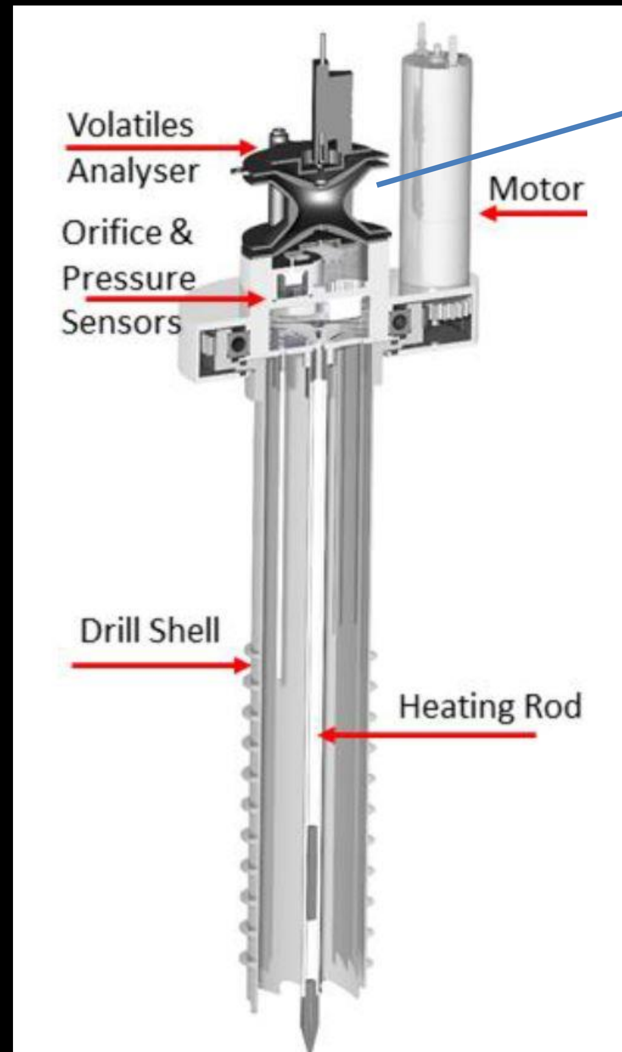
- Volatiles frozen in cold traps (physisorbed)
- Volatiles chemically bound (chemisorbed) to or enclosed in surface particles
- Free volatiles, cosmogenic or produced in-situ

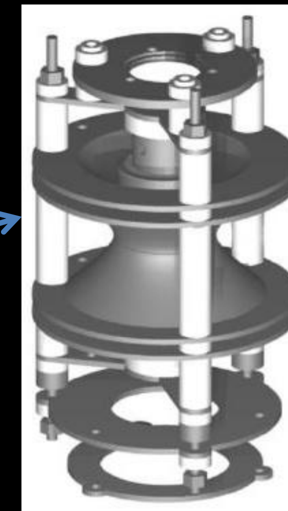
→ Extraction by heating

Volatile extraction and analysis

- Thermal extraction of volatiles through regolth heating
- Volatiles into MS
- Exosphere as 'pump'

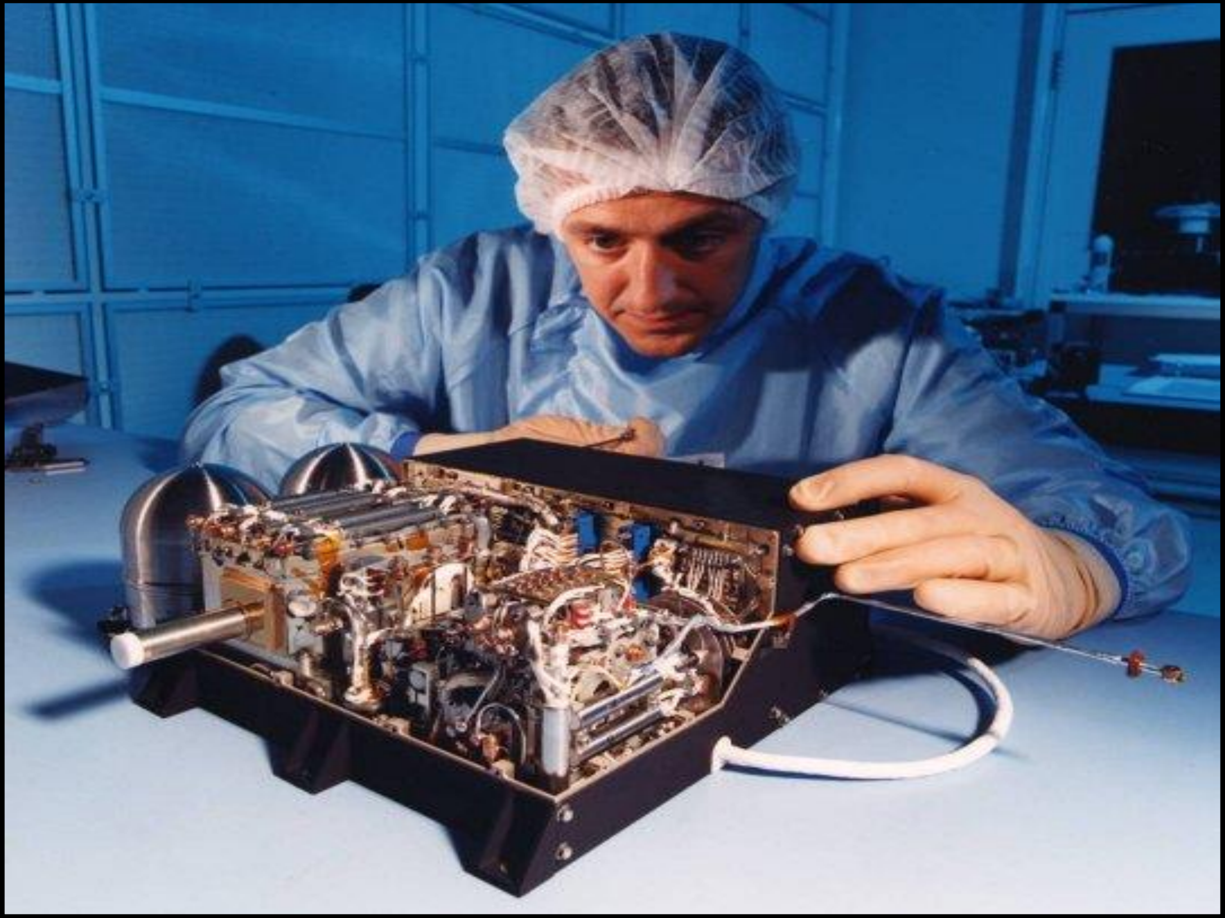






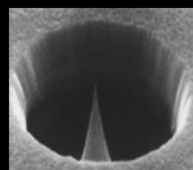
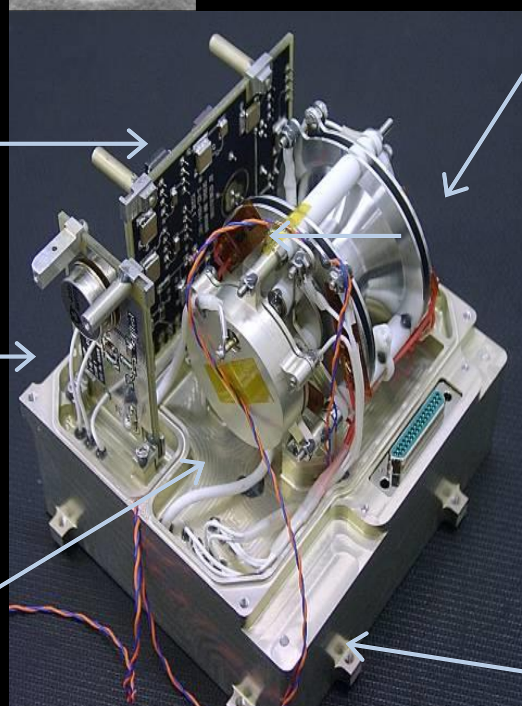
Ion trap
mass spectrometer

The Ptolemy GCMS – On the Rosetta/Philae lander



Ptolemy Ion Trap Mass Spectrometer

- Compact quadrupole Ion trap mass spectrometer (standard)
- Mechanically simple
- Space Heritage – Ptolemy (MS on Philae-Rosetta lander)

Mass Spectrometer characteristics

- Mass range 10 to 150 amu
- Resolving Power better than unit
- Sensitivity 1 ion/s at 10^{-10} mbar
- Dimensions 10 x 9 x 9 cm
- Electrode mass 50 g
- Overall mass ~ 500 g
- Power ~ 1 W

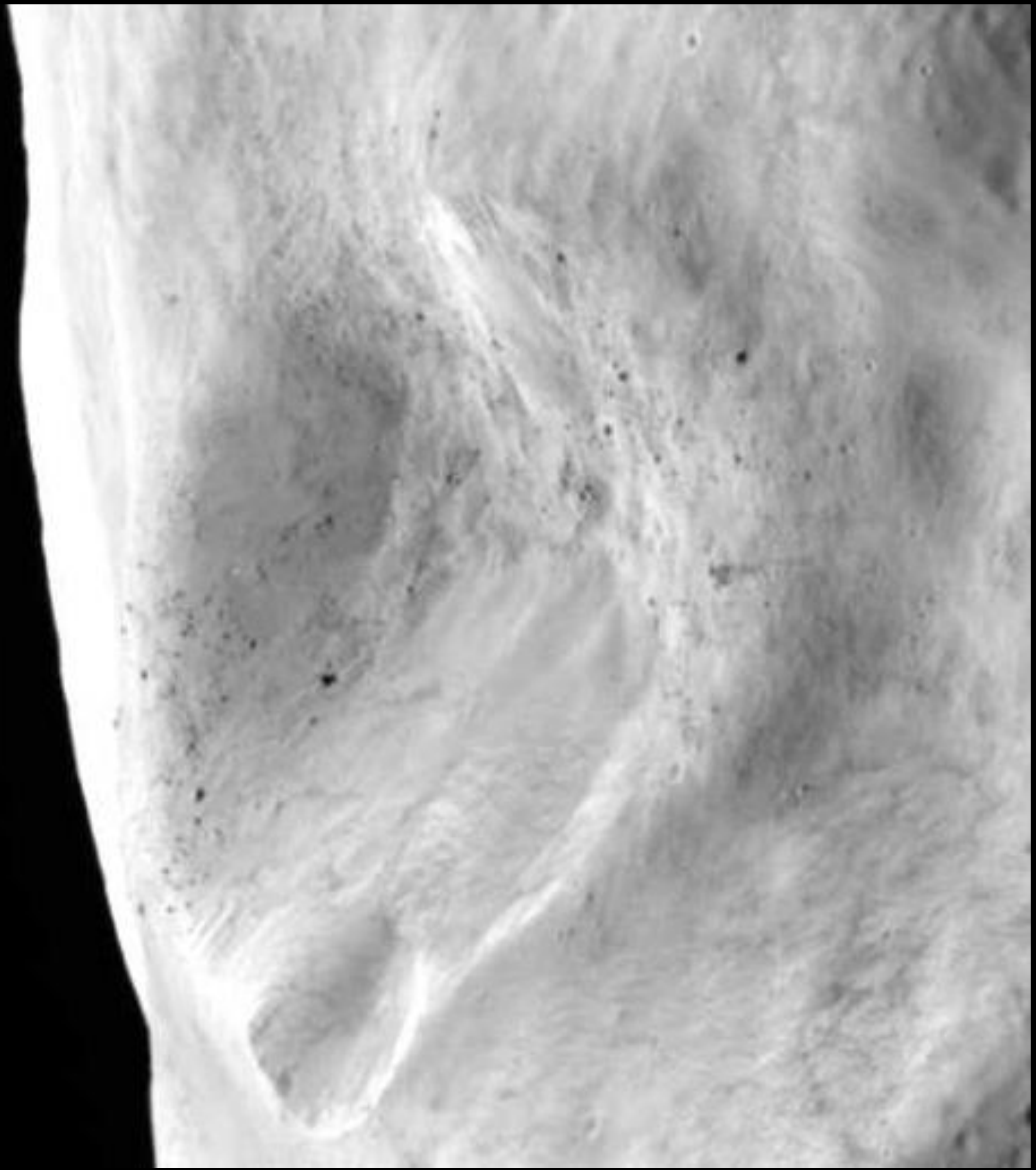
Lutetia – Rosetta flyby

Close approach 3160 km
10th July 2010

Rosetta in space for 6 years

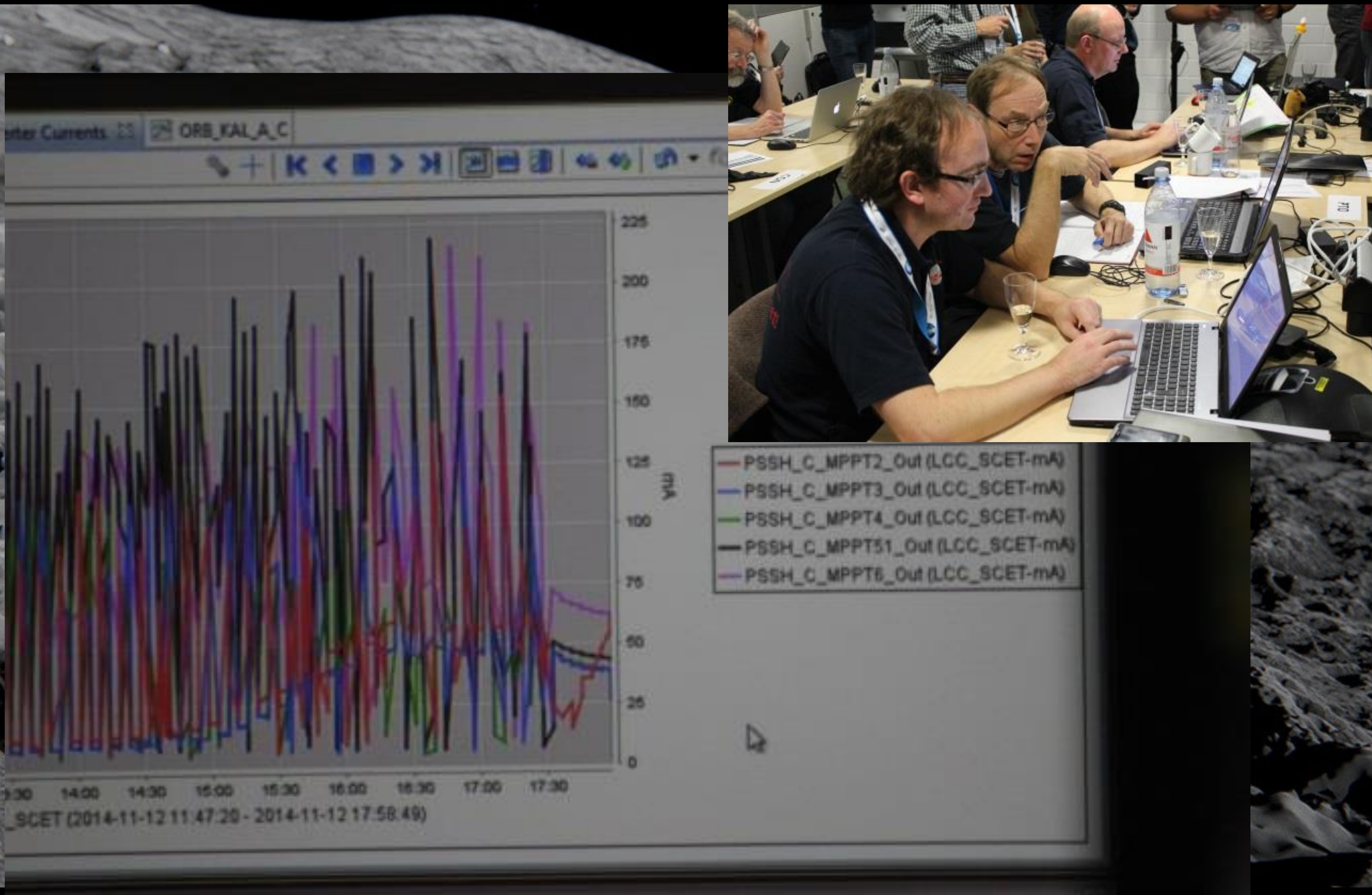
Exosphere?

Ptolemy capable of detecting an exosphere of 1×10^{-10} mbar



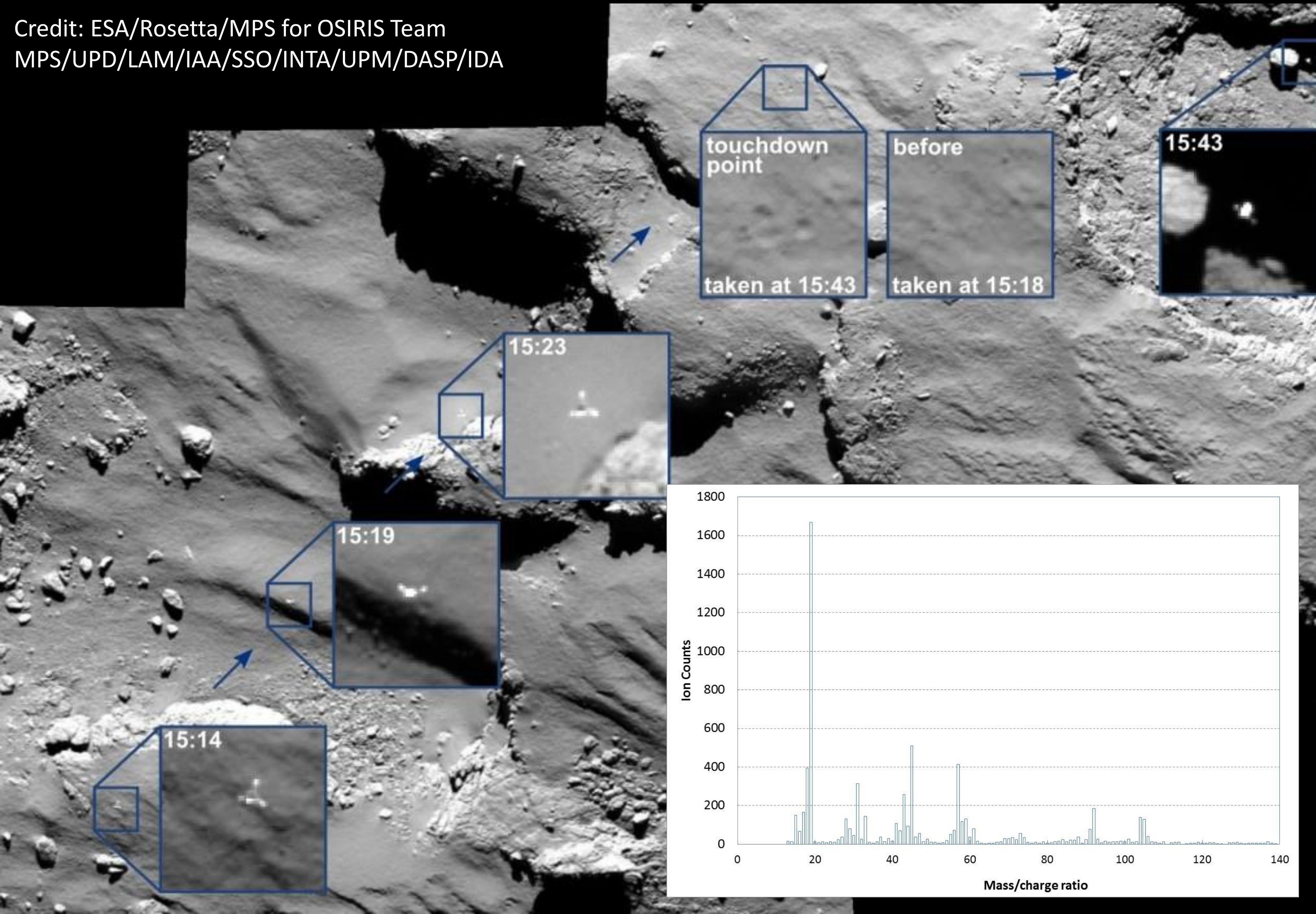
Lutetia size: 132x101x76 km

Definitely a harsh environment!



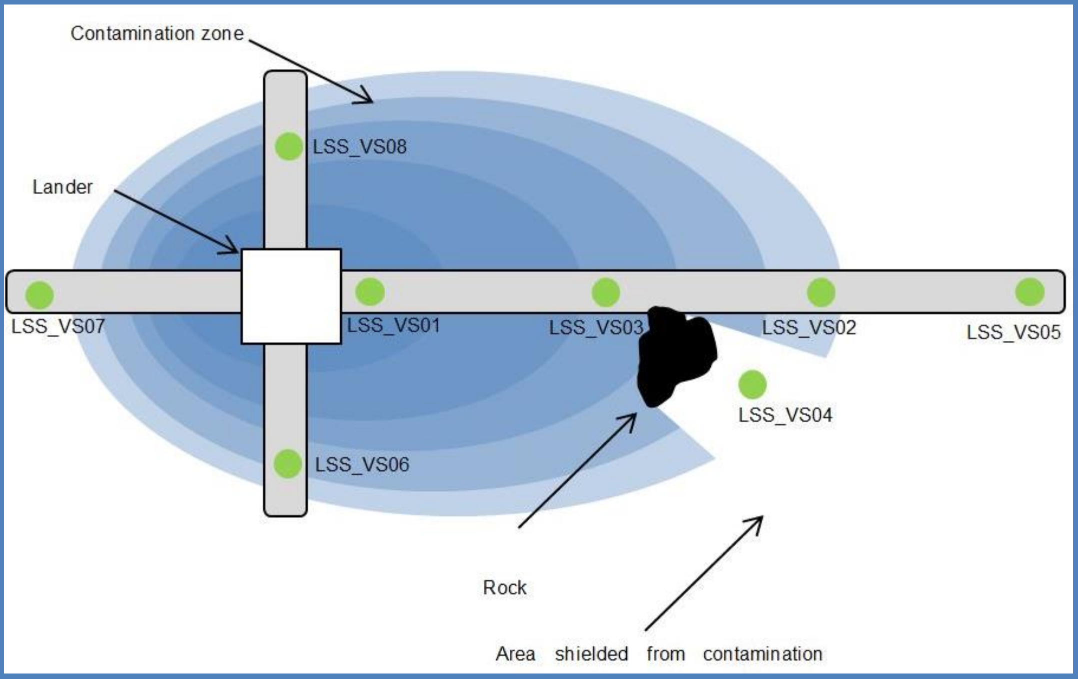
OSIRIS NAC image of Philae landing

Credit: ESA/Rosetta/MPS for OSIRIS Team
MPS/UPD/LAM/IAA/SSO/INTA/UPM/DASP/IDA

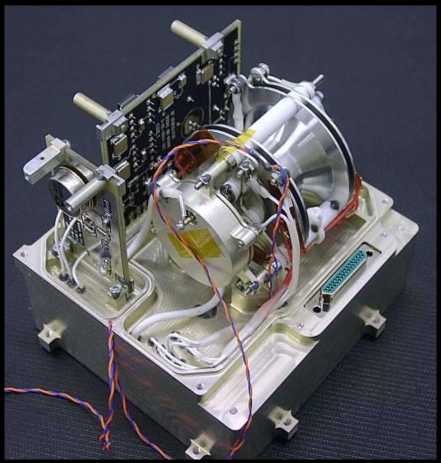


Concept of operations

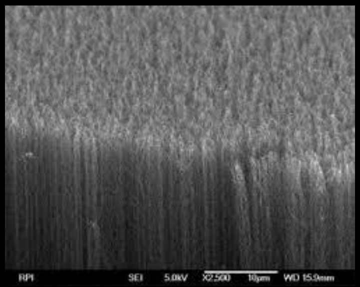
- Post landing check-out
- Rover egress
- Landing site survey
- Rock / Sun shadow illumination shadow
- Wide field area survey / prospecting (volatile hot-spots)
- Terminator passage
- PSR sampling



On-going work

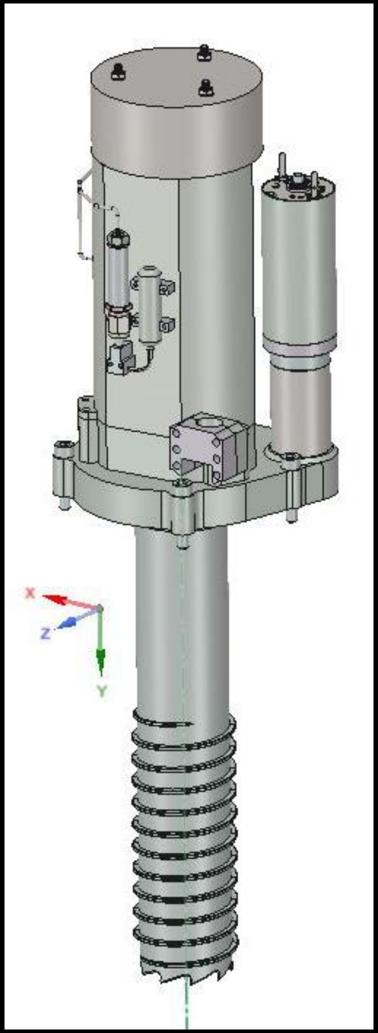


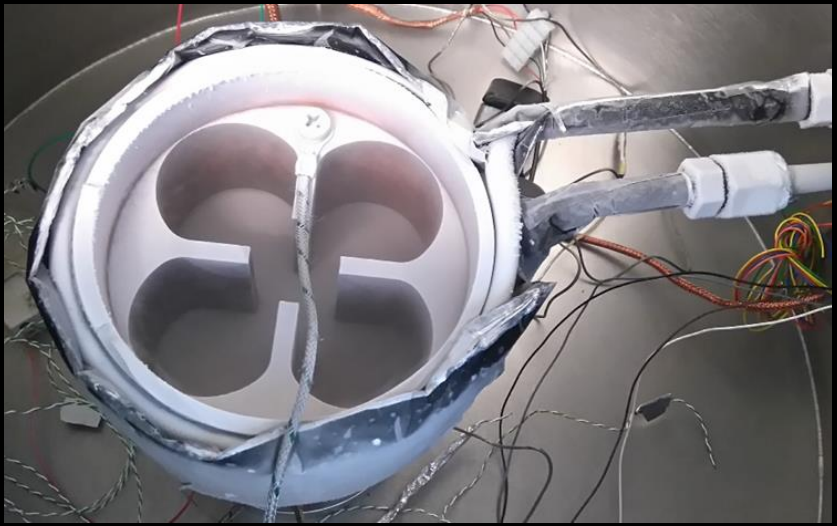
Ptolemy Ion trap mass spectrometer



Carbon Nano Tube
EI Ion source

Miniature gas valve and
Calibration gas system





Simulation chamber – volatile impregnated regolith

Future work

- 2018 integration of the mass spectrometer to the volatile extraction system
- Thermal vac testing
- Testing sampling and mass spectrometer systems together (TRL5/6)
- Seeking a lander for the LUVMI rover

Thank you for your attention

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