In-situ Studies of the Lunar Water Cycle using a CLPS-delivered ion-trap mass spectrometer (PITMS)

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A wet Moon

a) Primordial (interior) water

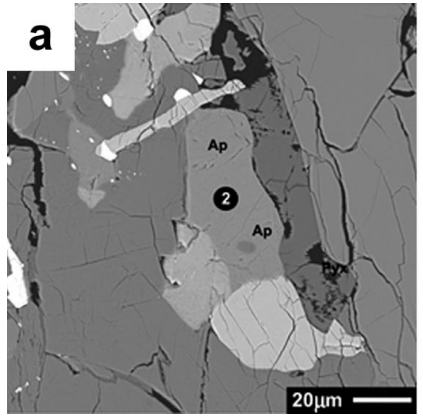
- Sample analysis of pyroclastic glasses and crystalline mare basalts
- Remote sensing of KREEP-rich magmatic sources and pyroclastic glasses

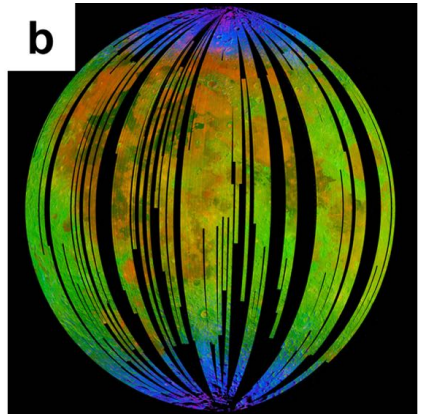
b) Surficial water (linked to solar wind and meteorites)

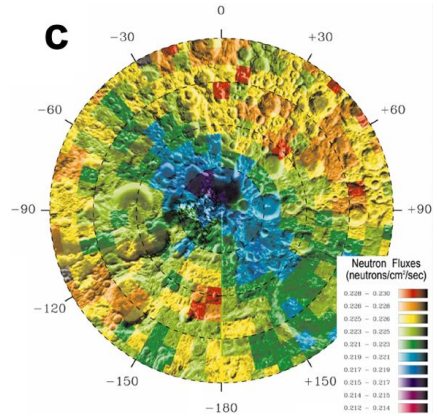
- Remote sensing in near-infrared
- Dependence on latitude(?) and diurnal cycle?

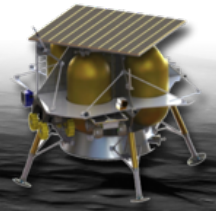
c) Polar (sequestered) water

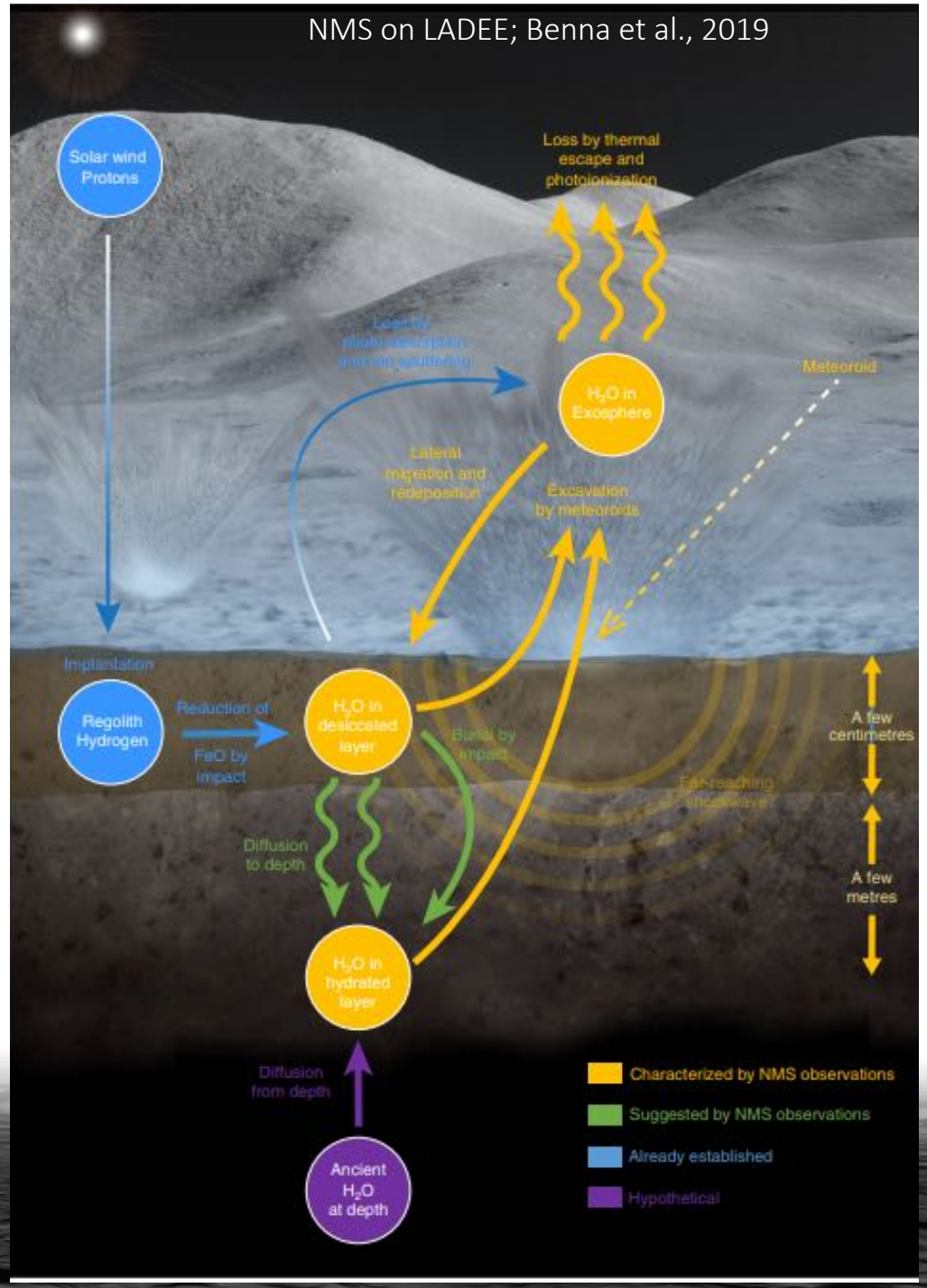
- Remote sensing: NIR, radar, neutrons
- LCROSS impactor





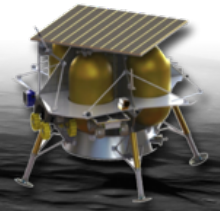






A lunar water cycle

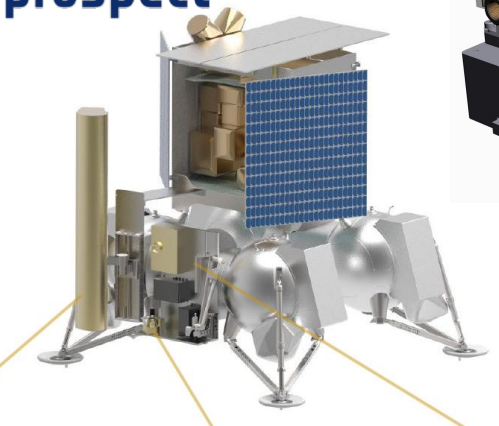
- Solar wind-implanted hydrogen produces water molecules, which diffuse vertically, and can be sequestered in the hydrated layer or lost at the surface
- Water from the hydrated soil is liberated by the far-reaching shockwaves generated by large micrometeoroids, water escapes or hops elsewhere
- To sustain water loss from meteoroid impacts, the hydrated soil layer requires replenishment from a deeper ancient water reservoir
- We need multiple measurements in multiple locations to build a global picture
- But there is a limit to the kinds of missions that can fly an instrument like NMS (11 kg; 43 x 25 x 37 cm)

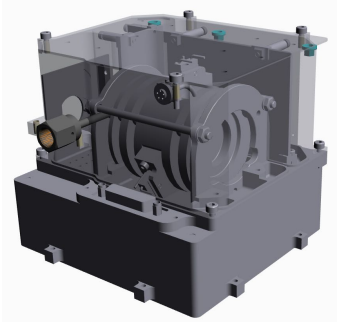


PROSPECT Ion Trap Mass Spectrometer

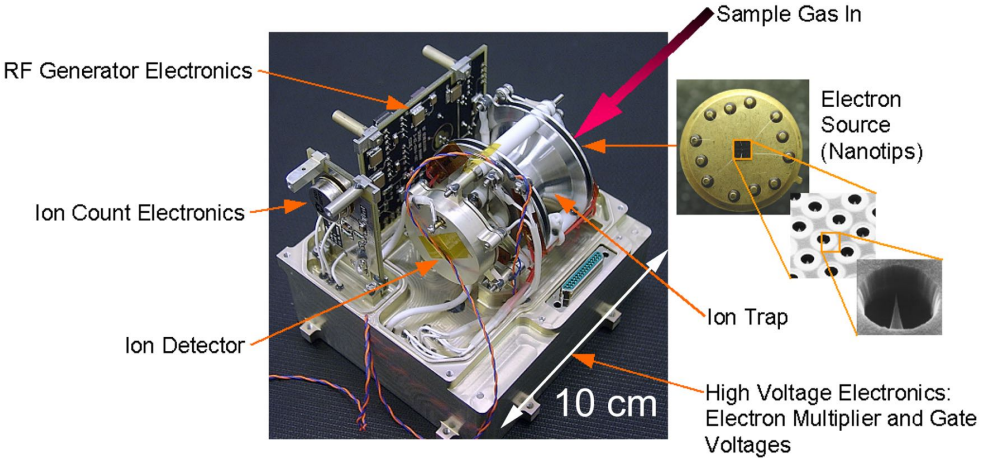
Luna-27 (2023)

esa prospect





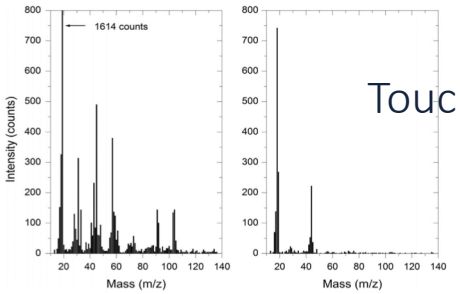
OU Ion Trap Mass Spectrometer (Rosetta Ptolemy)



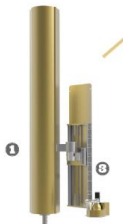
Quadrupole ion trap, electron impact ionisation, electron multiplier

m/z ~10 – 150, 10 spectra per s

1 kg, 10 x10x10 cm, 4-8 W



Touchdown on 67P

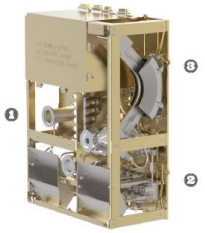


ProSEED

Excavates samples from lunar sub-surface for delivery to multiple instruments.

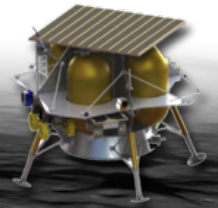
SIS

A Solids Inlet System for receiving, imaging, sealing and heating drilled samples.



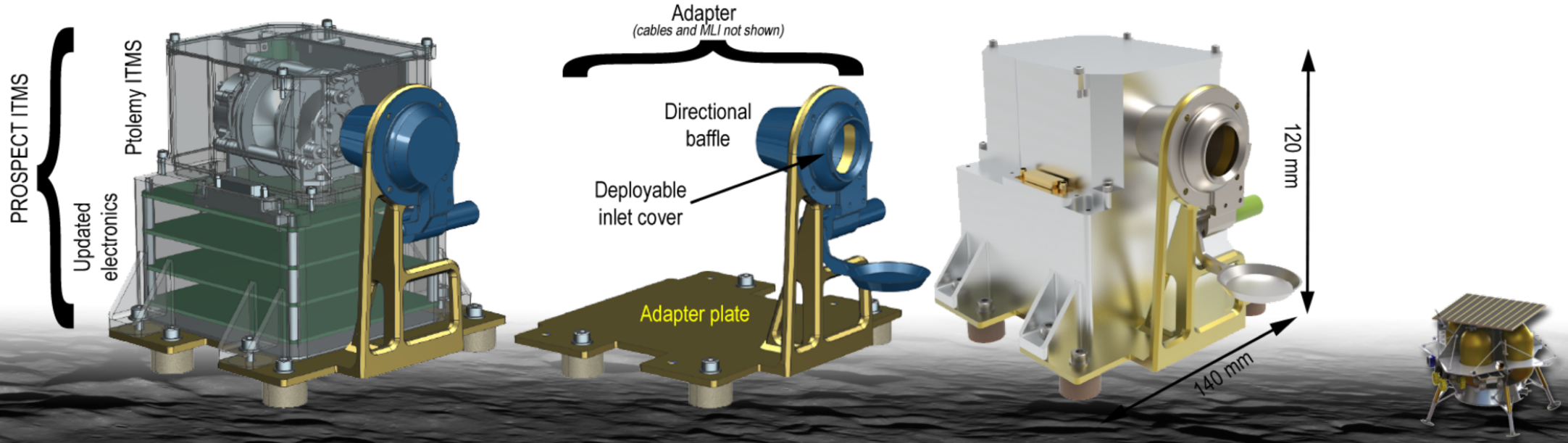
ProSPA

A miniature (37 x 27 x 13cm, 10kg) laboratory for chemical and isotopic analysis.



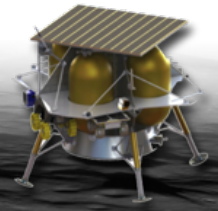
PITMS for NASA CLPS

- Characterize the lunar exosphere from the surface after descent and landing, and throughout the lunar day, to understand the release and movement of volatile species
- Leverage the PROSPECT program and develop the ITMS as a standalone mass spectrometer suitable for commercial lunar landers
- PITMS will consist of a PROSPECT-derived ITMS sensor and front-end electronics, newly developed controller and power supply boards, and a GSFC wrapper
- Lander-friendly: low resource (<2 kg, 4-8 W), simple interfaces, passive, landing site agnostic



PITMS on Astrobotic's Peregrine Lander

- Laccus Mortis in mid 2021!
- Operations commence soon after touchdown with the release of a dust cover
- ITMS continually scans m/z 2 (goal) to 150 at 10 Hz; mass spectra integrated to build S/N
- Expect to monitor decay in exosphere from its post-landing peak, punctuated by any stimuli that create transient increases
- Baseline PITMS is passive and relies on external stimuli
  - An enhancement would be to include active sources e.g. heaters, mechanisms to link cause and effect
- Baseline PITMS ionises by heated wire filaments as per LACE, LADEE NMS – high power
  - Future development is to use cold cathode source: low power, longer duty cycle, lower outgassing



The case for multiple PITMS flights

SCEM report: Goal 8a. Determine the global density, composition, and time variability of the fragile lunar atmosphere before it is perturbed by further human activity.

- Every lander adds to the lunar exosphere and covers its landing site in a veneer of **contamination**
  - Apollo ceramic sublimators (coolers) emitted water vapor detected on the surface by Apollo 12 Cold Cathode Gauge Experiment (CCGE) and in orbit by Apollo 15 Lunar Orbital Mass Spectrometer Experiment (LOMSE)
  - We can minimize contamination, but we can't avoid it: Rosetta spacecraft was still outgassing after 10 years in space! We can and should monitor the interaction between every mission and the Moon
- Lunar water is part of a **volatile cycle**
  - Dependence on latitude – solar incidence and temperature
  - Dependence on hemisphere – leading/trailing asymmetry in micrometeorite input
  - Dependence on diurnal cycle – some landers may observe the dawn fountain, survive multiple cycles
- Mass spectrometers are a workhorse of **planetary science**
  - Active experiments where we disturb the regolith or acquire a sample
  - In situ dating!!