PRIME-1: MSolo Overview and Results

MSolo Science Team

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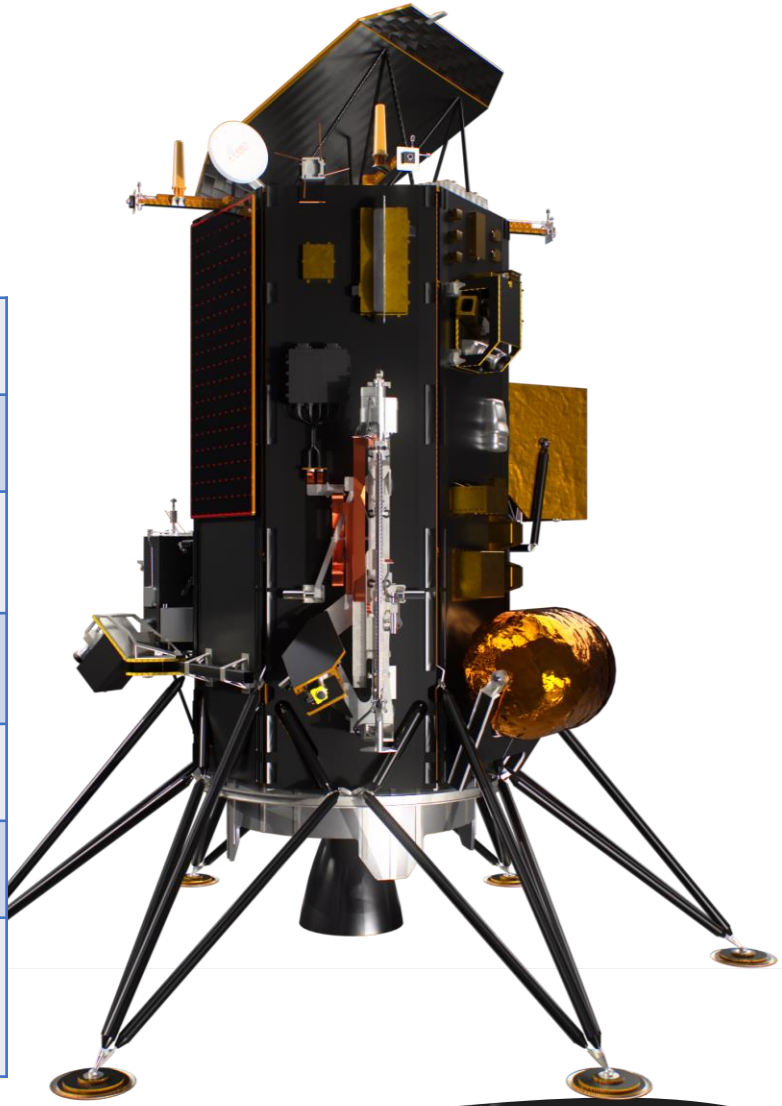
PRIME-1 Overview

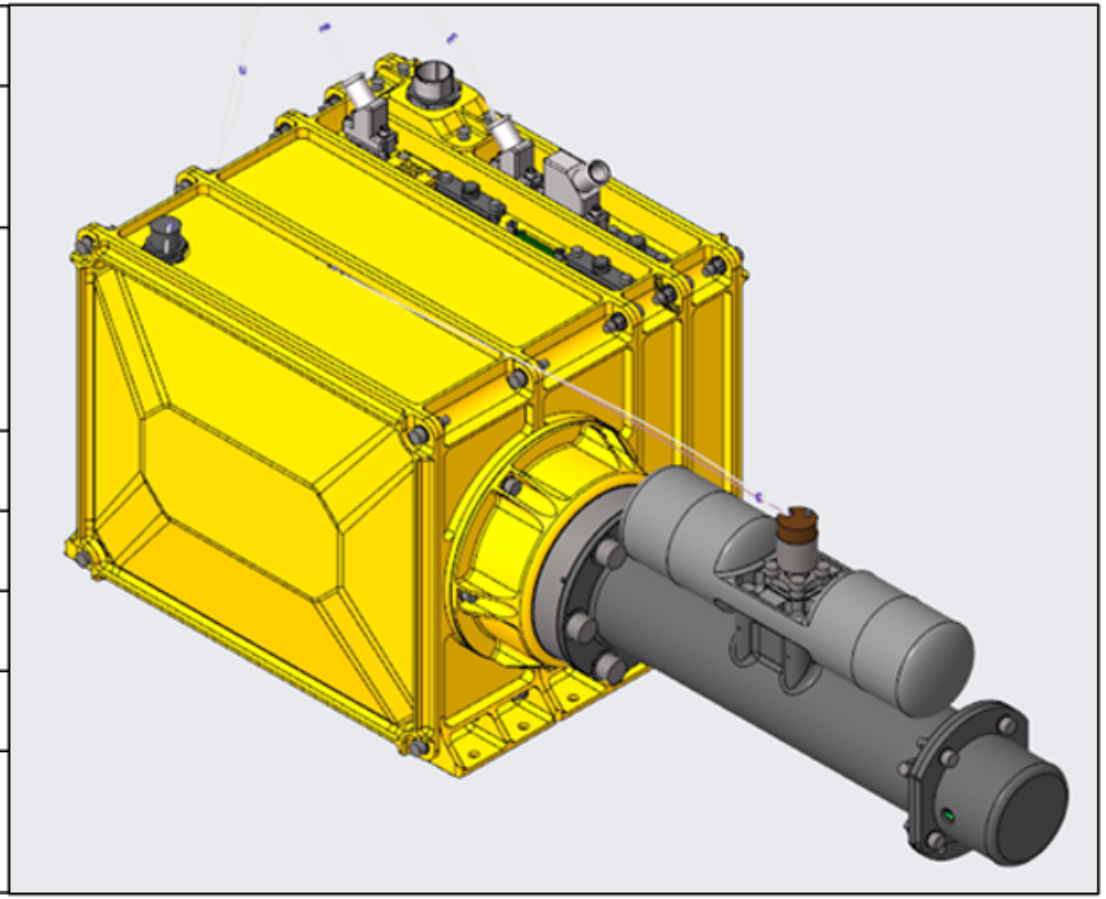
- Polar Resources Mining Experiment (PRIME-1) Payloads
  - Mass Spectrometer Observing Lunar Operations (MSolo)
  - The Regolith and Ice Drill for Exploring New Terrains (TRIDENT)
  - Visible imager for PRIME-1: 0.1 pix/cm camera to view cuttings pile

Launch	February 27, 2025 00:16 UTC
Landing:	March 6, 2025 17:28 UTC
Target Landing:	Mons Mouton 84.7754° S, 29.1280° E
Final Site	84.79059° S, 29.19567° E (~500m from target)
Planned Mission duration	~10 Days (240 hours)
Actual Mission duration	~ 0.5 Days (~12 hours)
Lander	“Athena”, Intuitive Machines IM-2 (IM vehicle class: Nova-C)

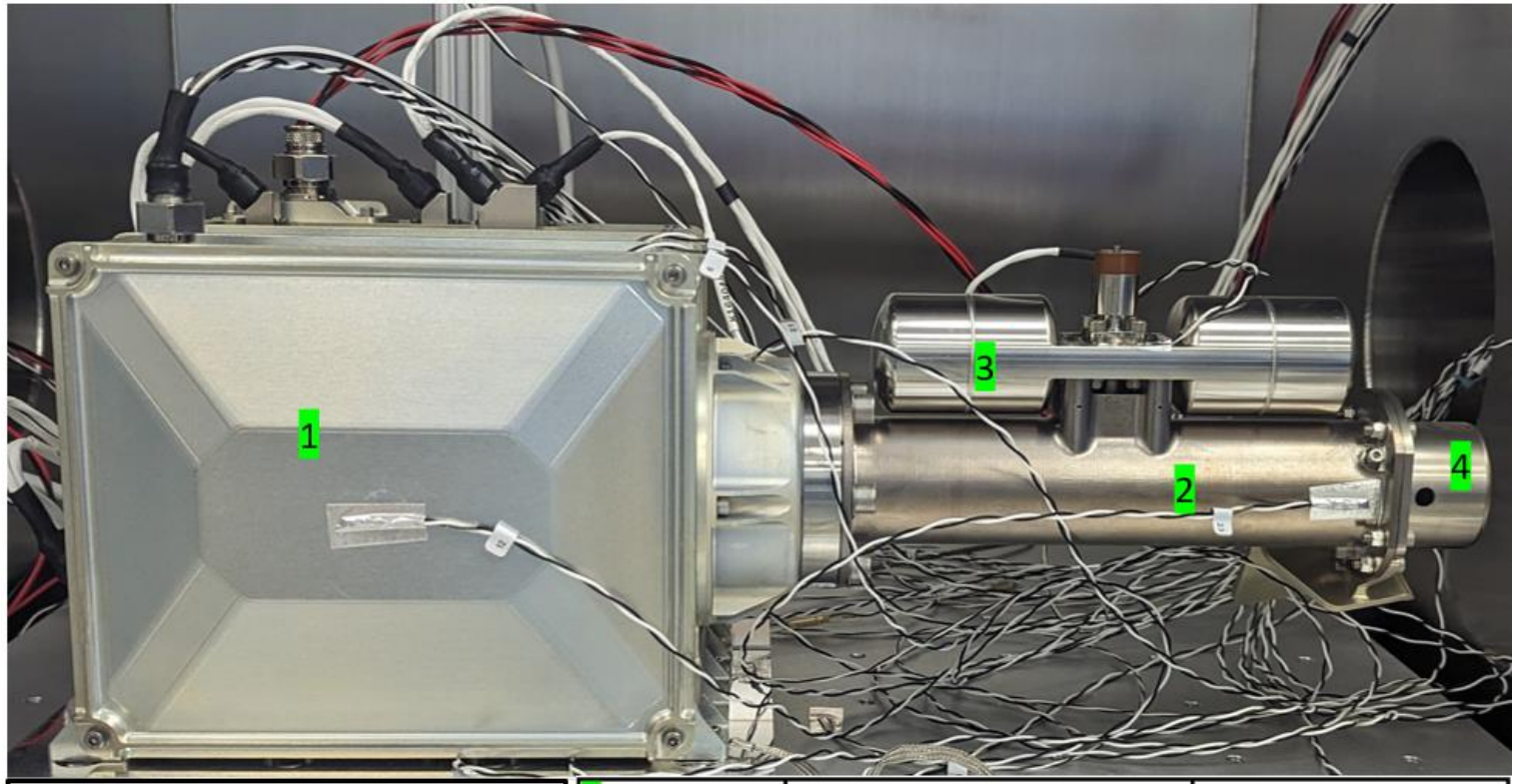


MSolo Overview

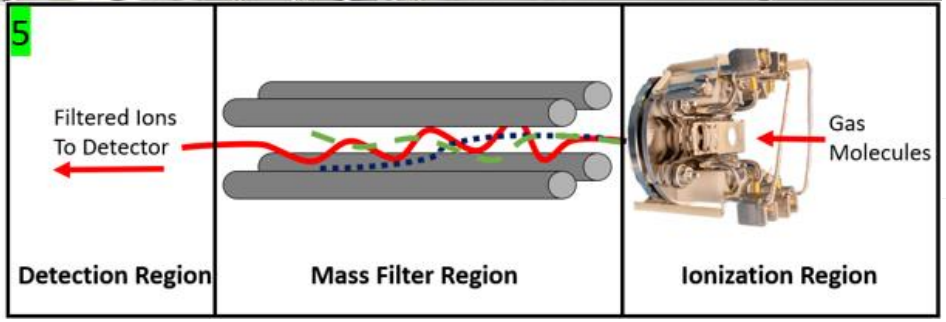
Instrument Name	MSolo
Mass	4.8 Kg (instrument only) 7.2 Kg (with radiator)
Dimensions	18 x 18 x 46 cm (instrument only) 31 x 41 x 46 cm (instrument and bracket)
Power	At 28V Nominal 34W Peak 40W
Mass Range	m/z 1 to 100
Input Voltage	22V to 33.6V
Data Rate	Average 16kbps
Thermal	Survival -40°C to 75°C Operating -10°C to 45°C



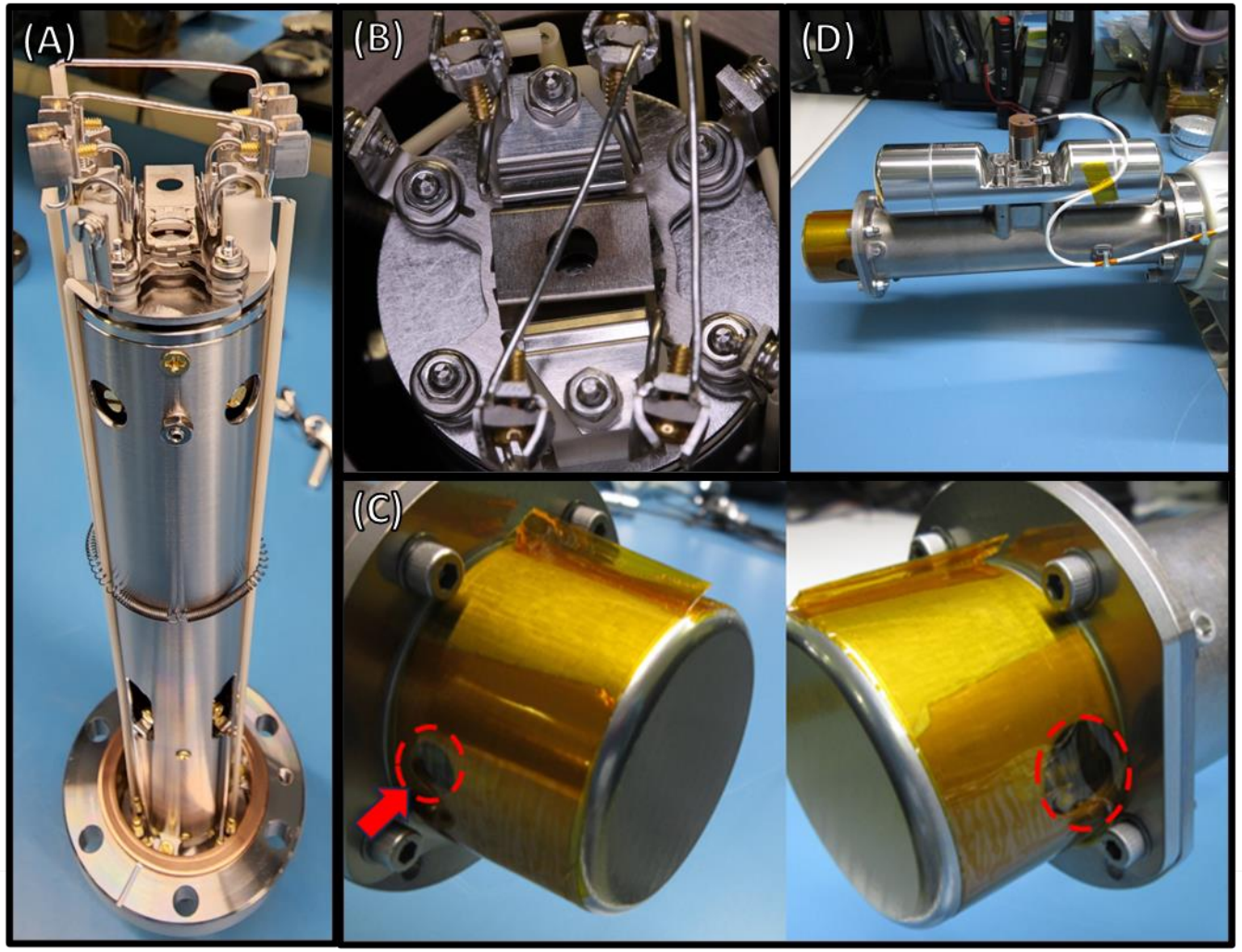
MSolo Overview

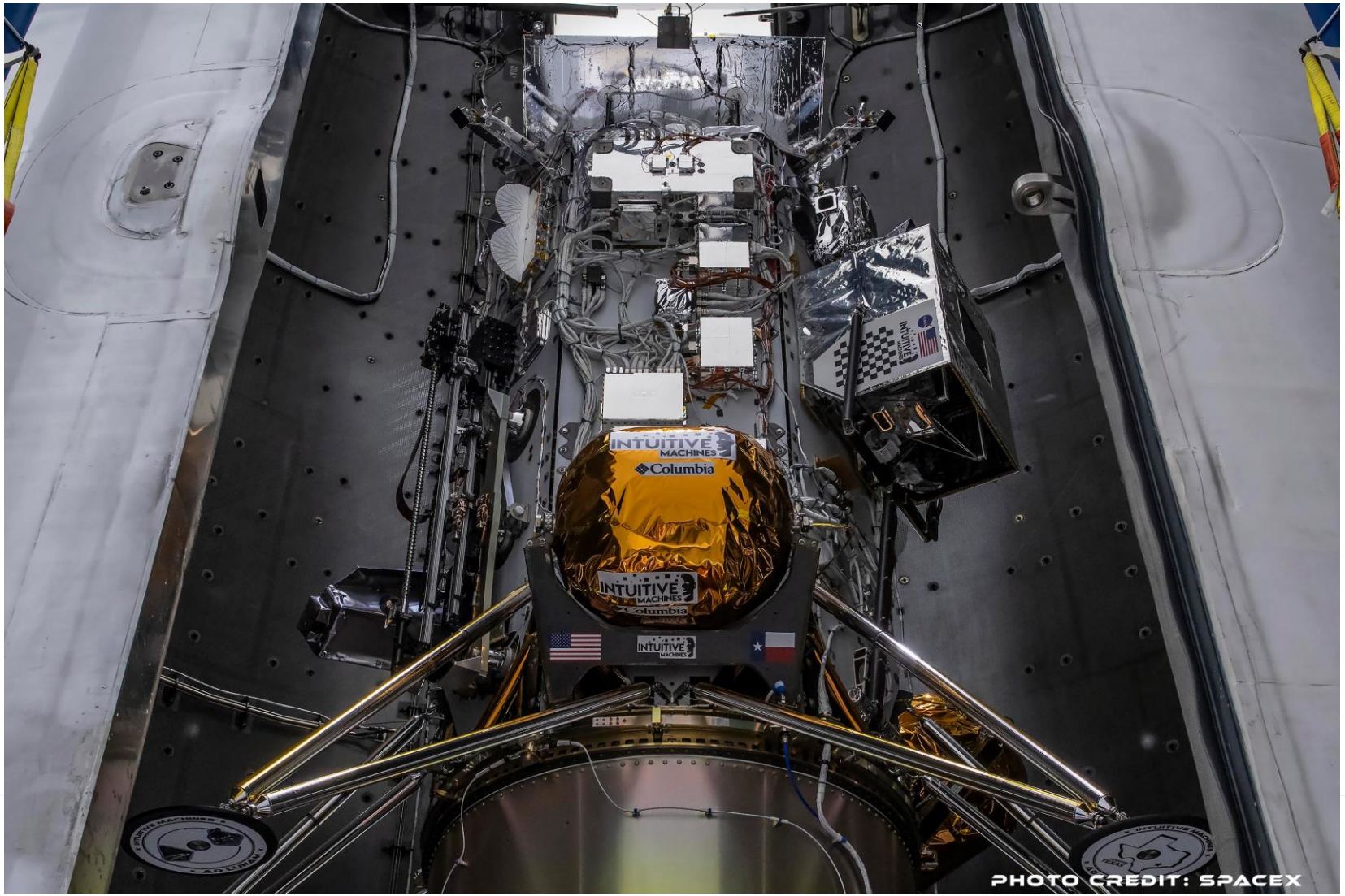


1) Electronics Chassis
2) Sensor Shroud
3) Calibration Gas System
4) Contamination Cover
5) Subsections of Mass Spectrometer Sensor



MSolo Overview

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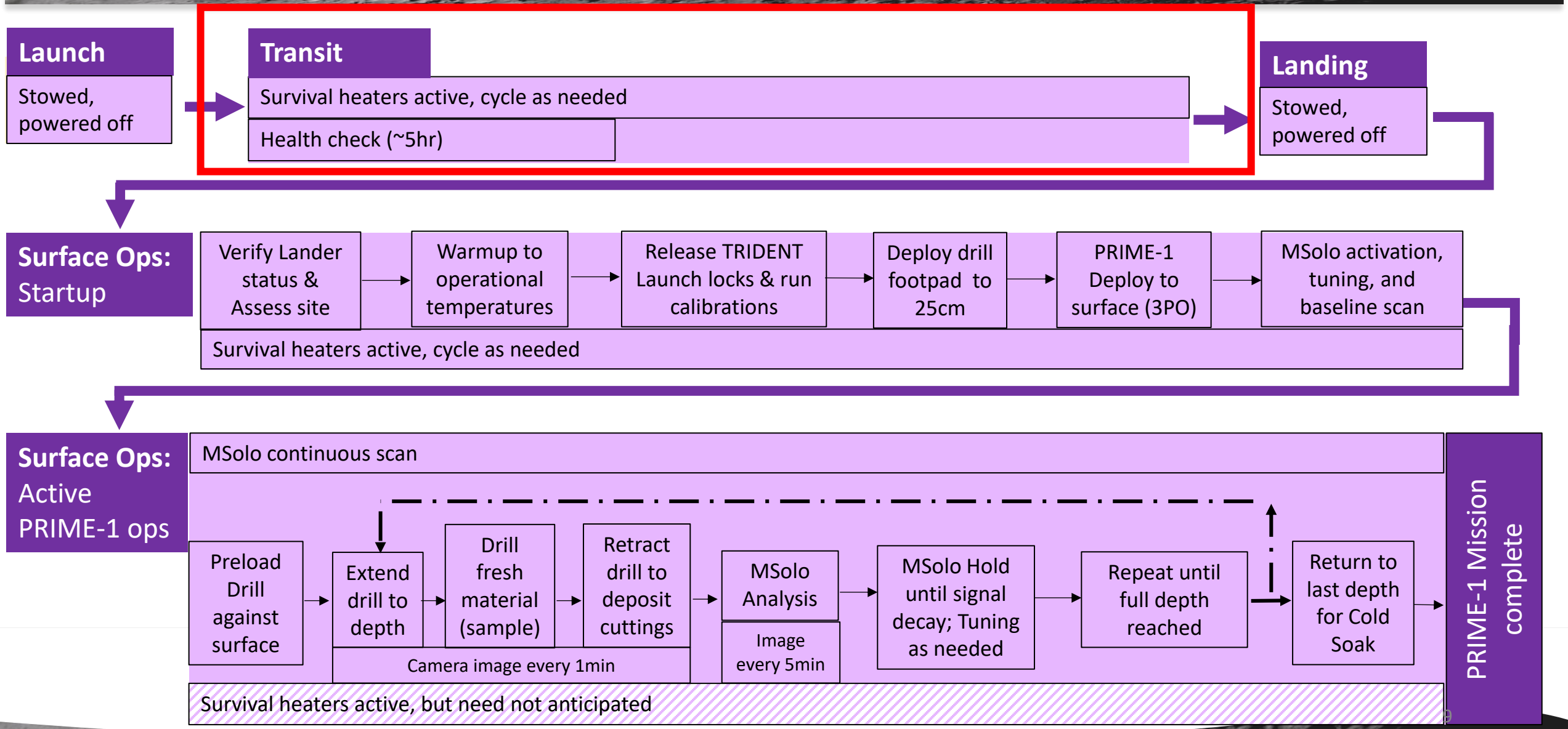
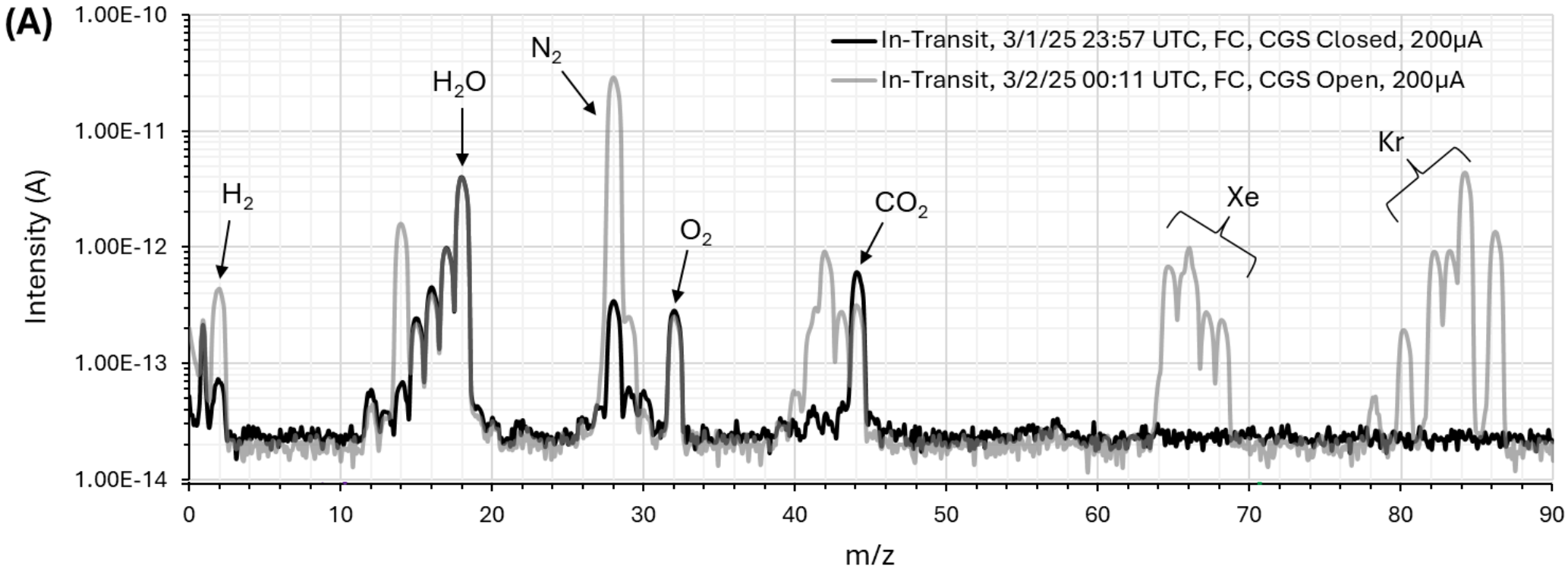
From Earth to the Moon

MSolo Concept of Operations (planned)



Transit Data

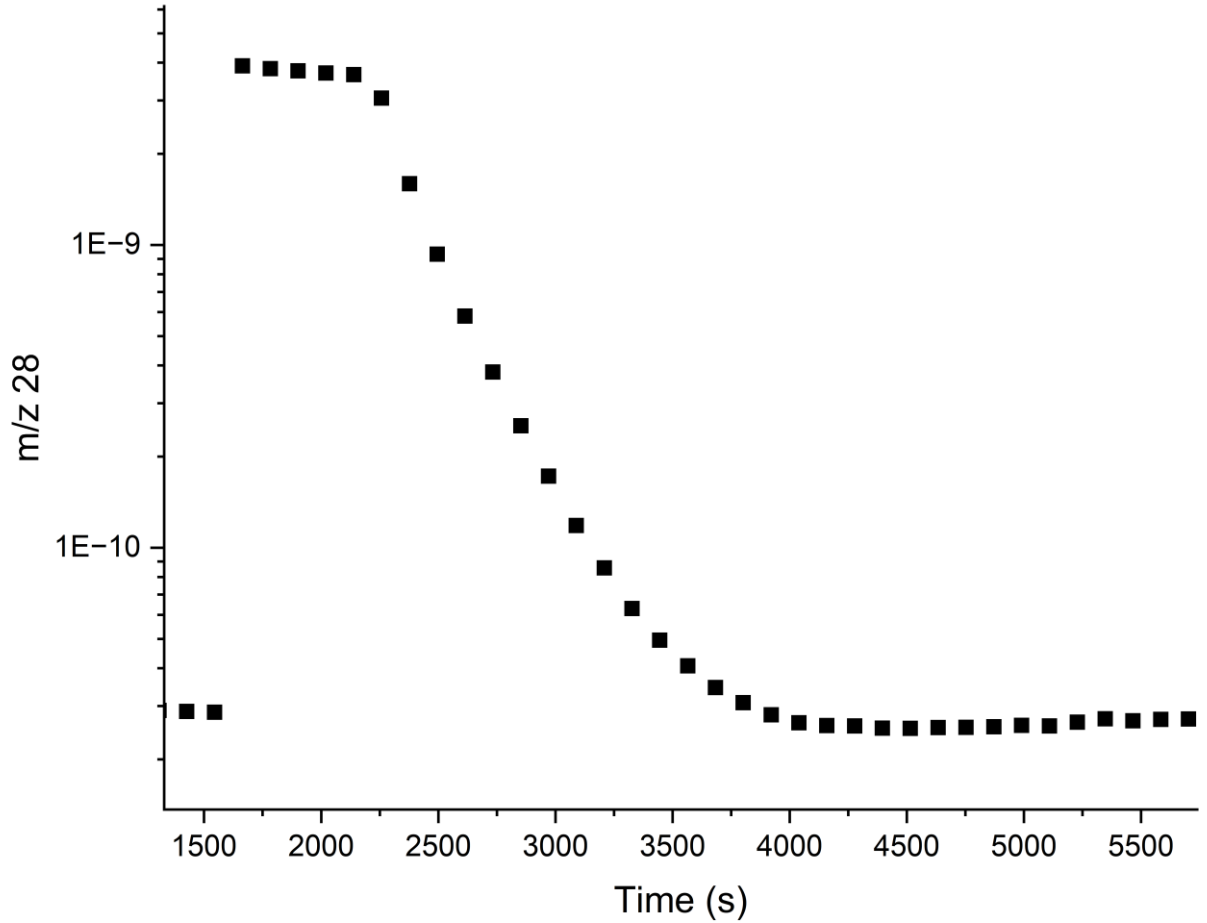
Figure courtesy of Matt Hancock



- The first thing to notice is that the instrument performed beautifully. Peak shapes look great, tuning is good, as is sensitivity.
- Before opening the calibration gas, the primary compounds detected were:
  - N_2/O_2 (Earth air), CO_2 (combustion product), and H_2O/H_2 (Earth water/combustion product)
- With CGS (Calibration Gas System) open
  - N_2, H_2, Kr (single and doubly ionized), Xe (doubly ionized)

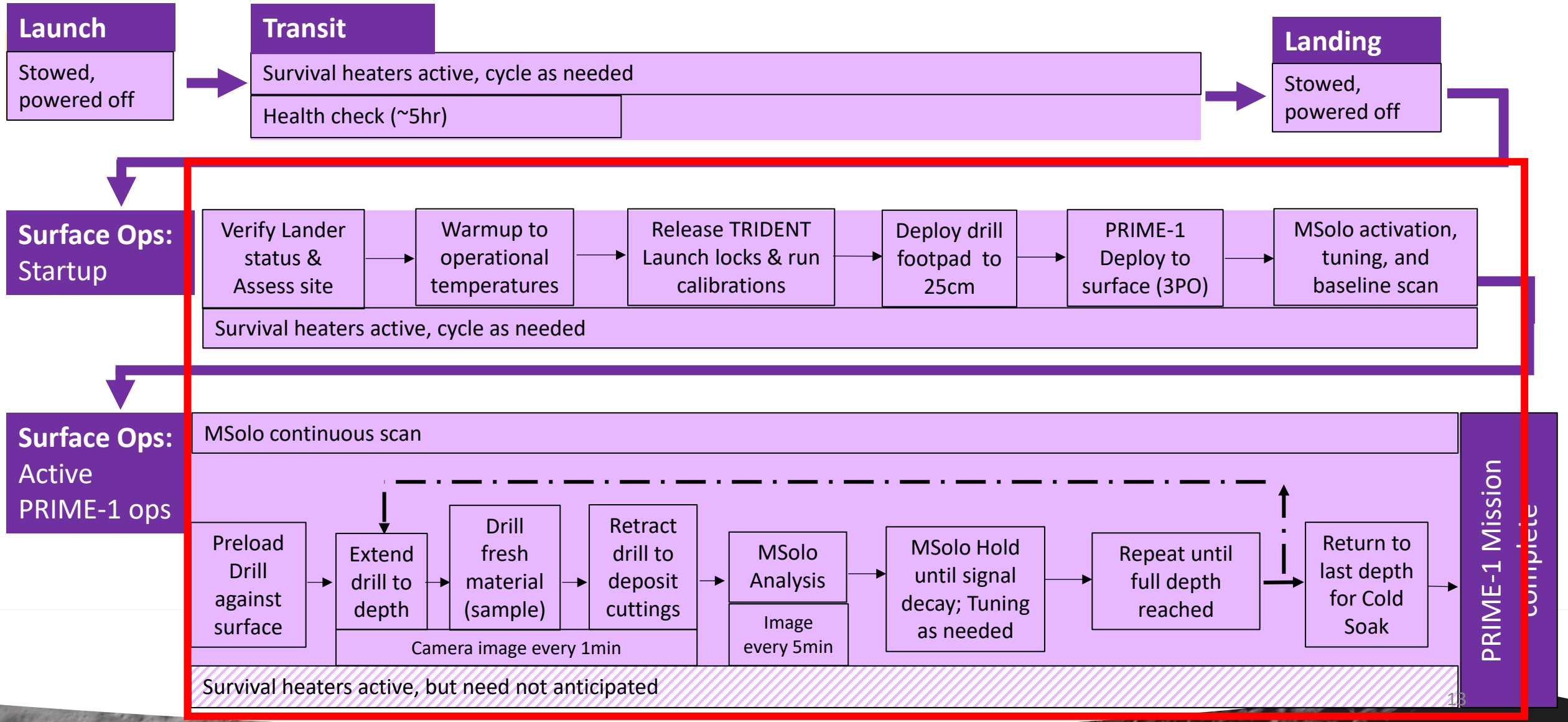
Things I (Doug) learned

- Hard vacuum isn't as good a pump as I expected ☺.
- We seemed to be seeing air in our spectra, multiple days after launch. The sensor was not hermetically sealed.
- The cal gas dissipation rate (see figure at right) was essentially the same as what we saw in the lab.

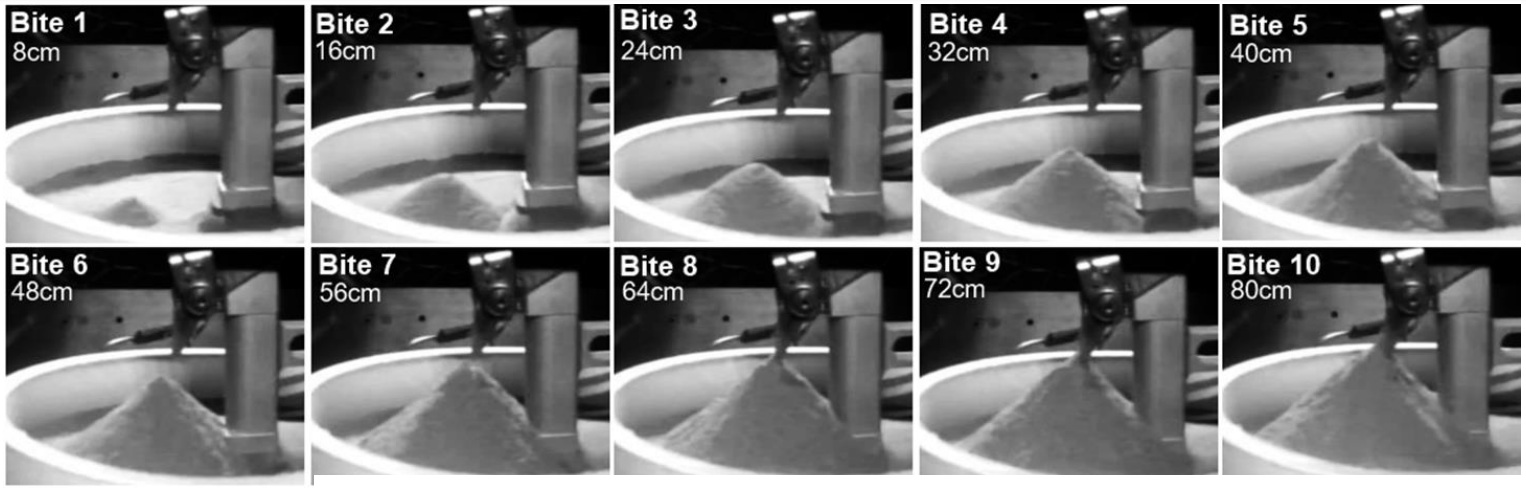


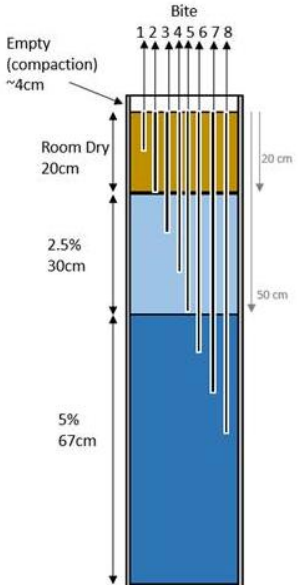
Landed operations

MSolo Concept of Operations (planned)

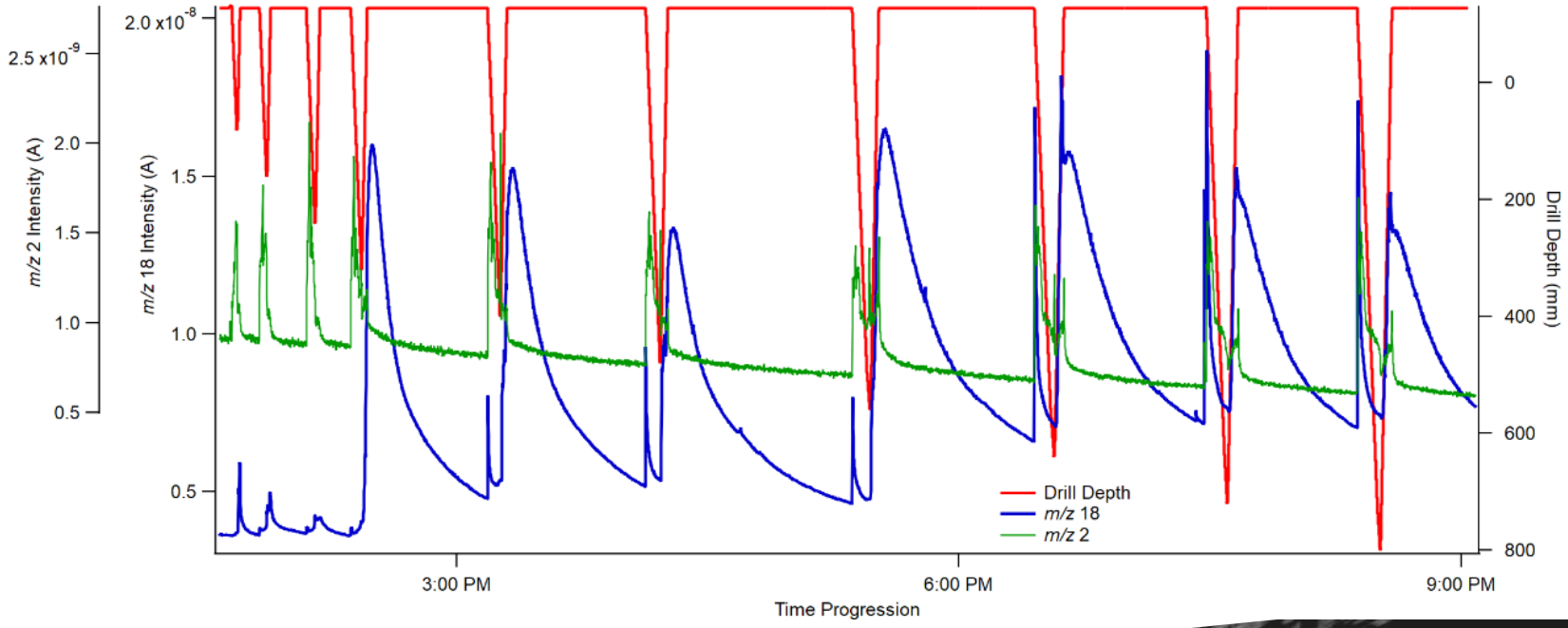


Expected Results for Icy Drilling



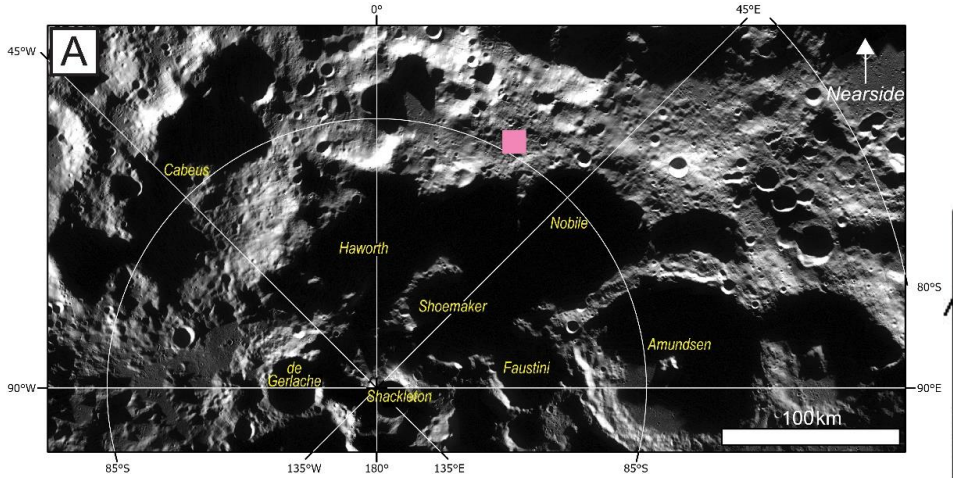


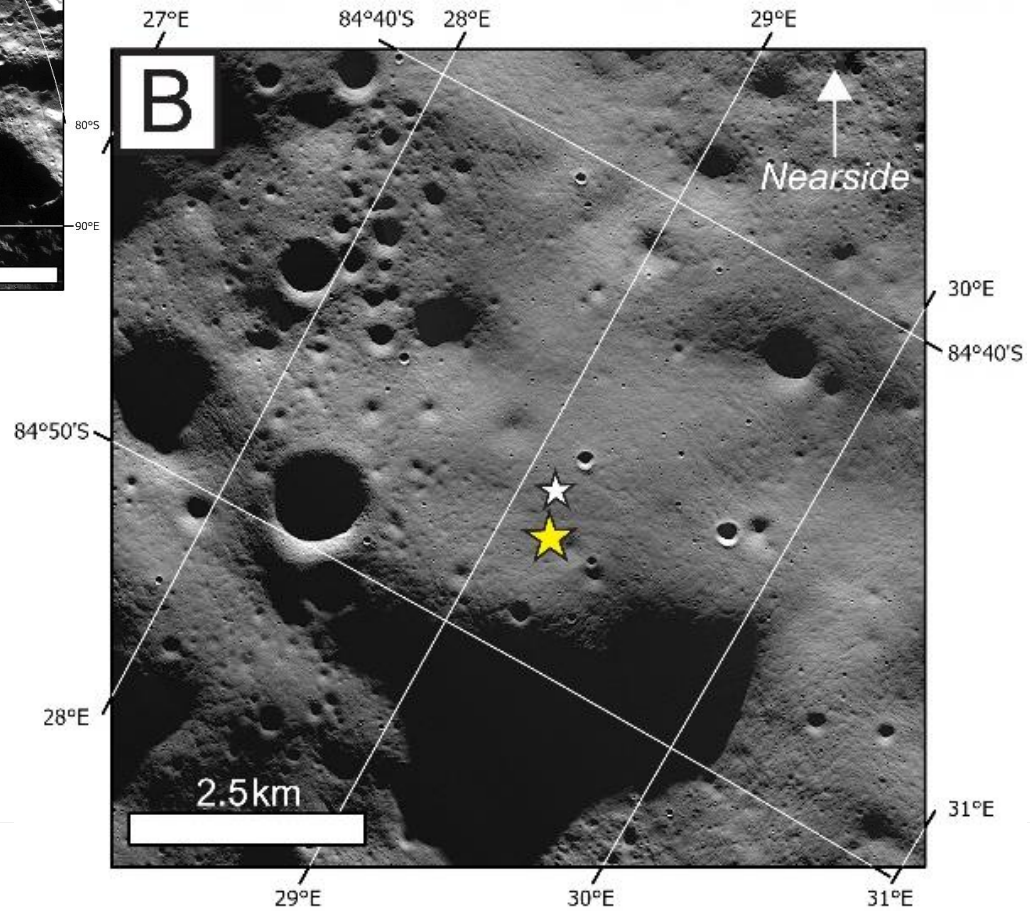
Bite #	Bite Depth, cm	Water content
1	0-10	Room dry
2	10 - 20	Room dry
3	20 – 30	2.5%
4	30 - 40	2.5%
5	40 - 50	2.5%
6	50 - 60	5.0 %
7	60 - 70	5.0 %
8	70 - 80	5.0 %

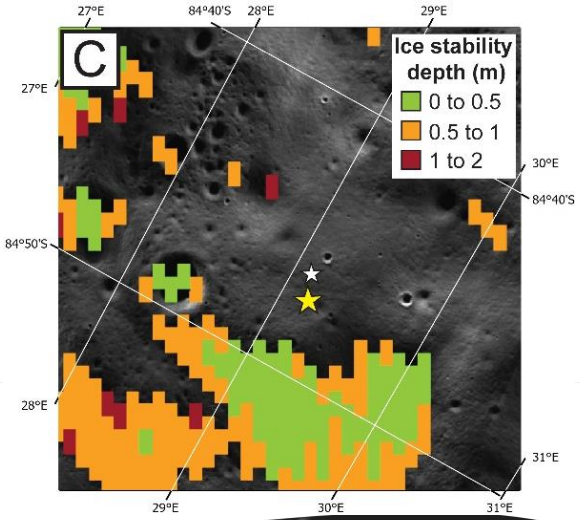


Landing Site

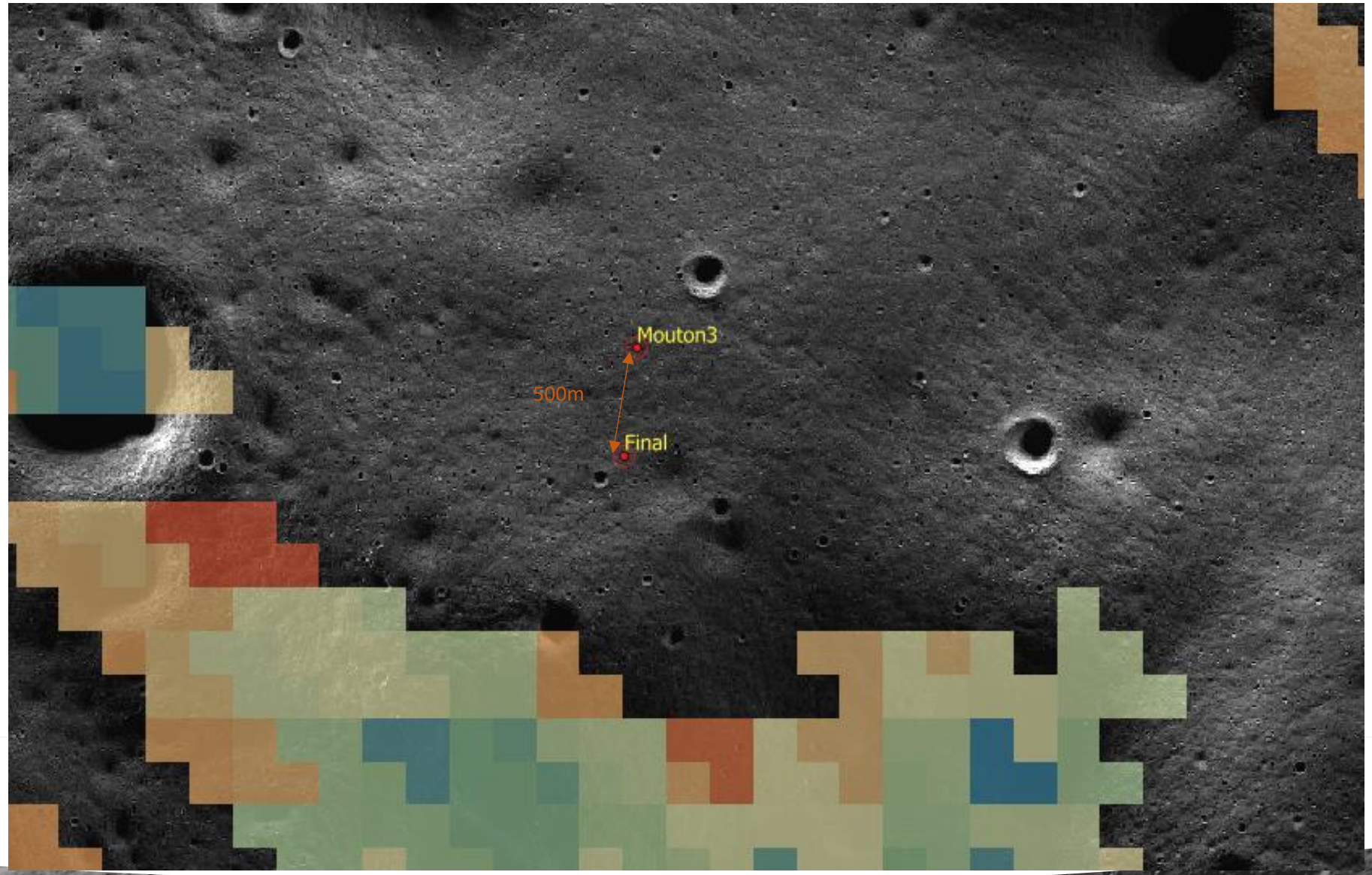
Figures courtesy of Matt Hancock

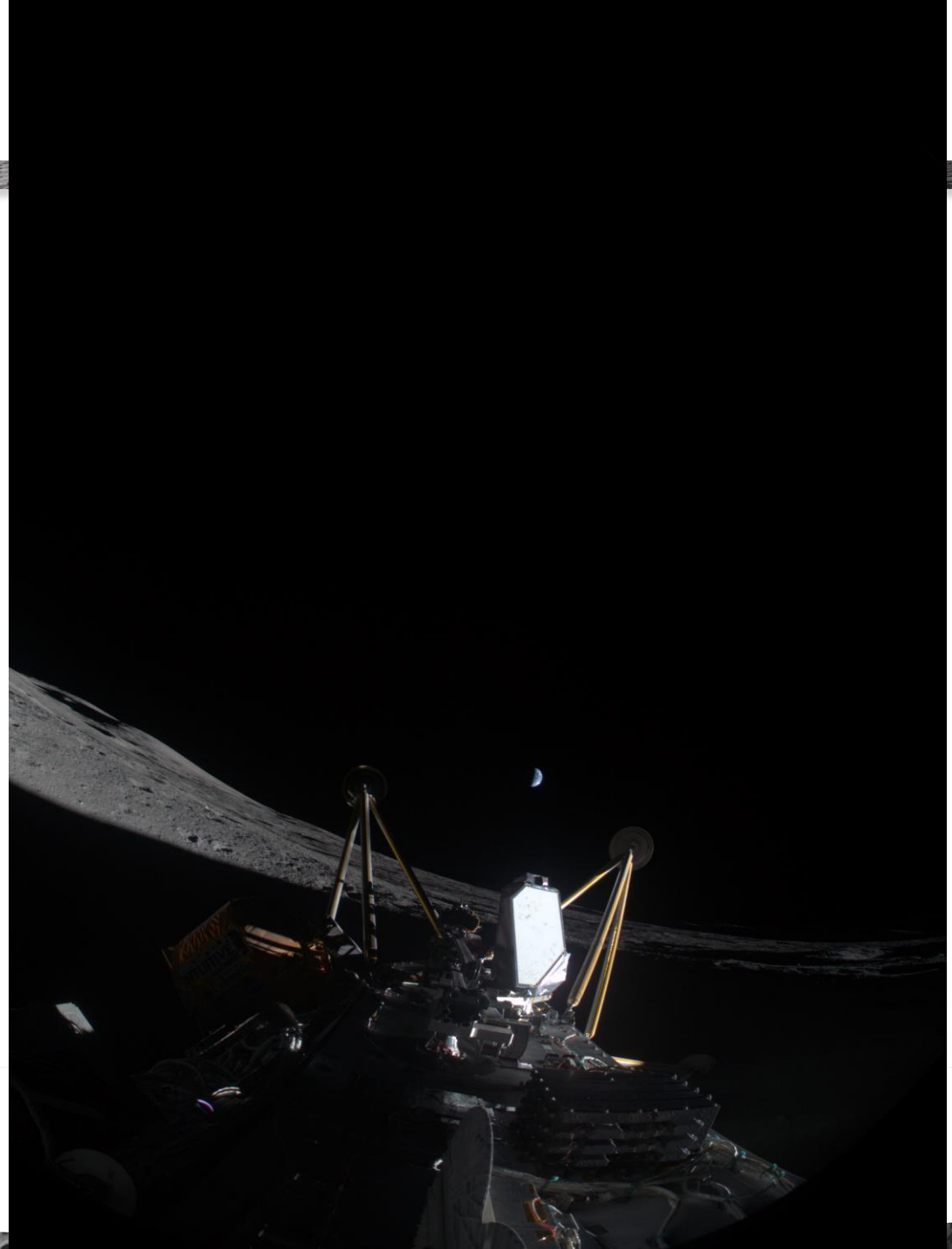




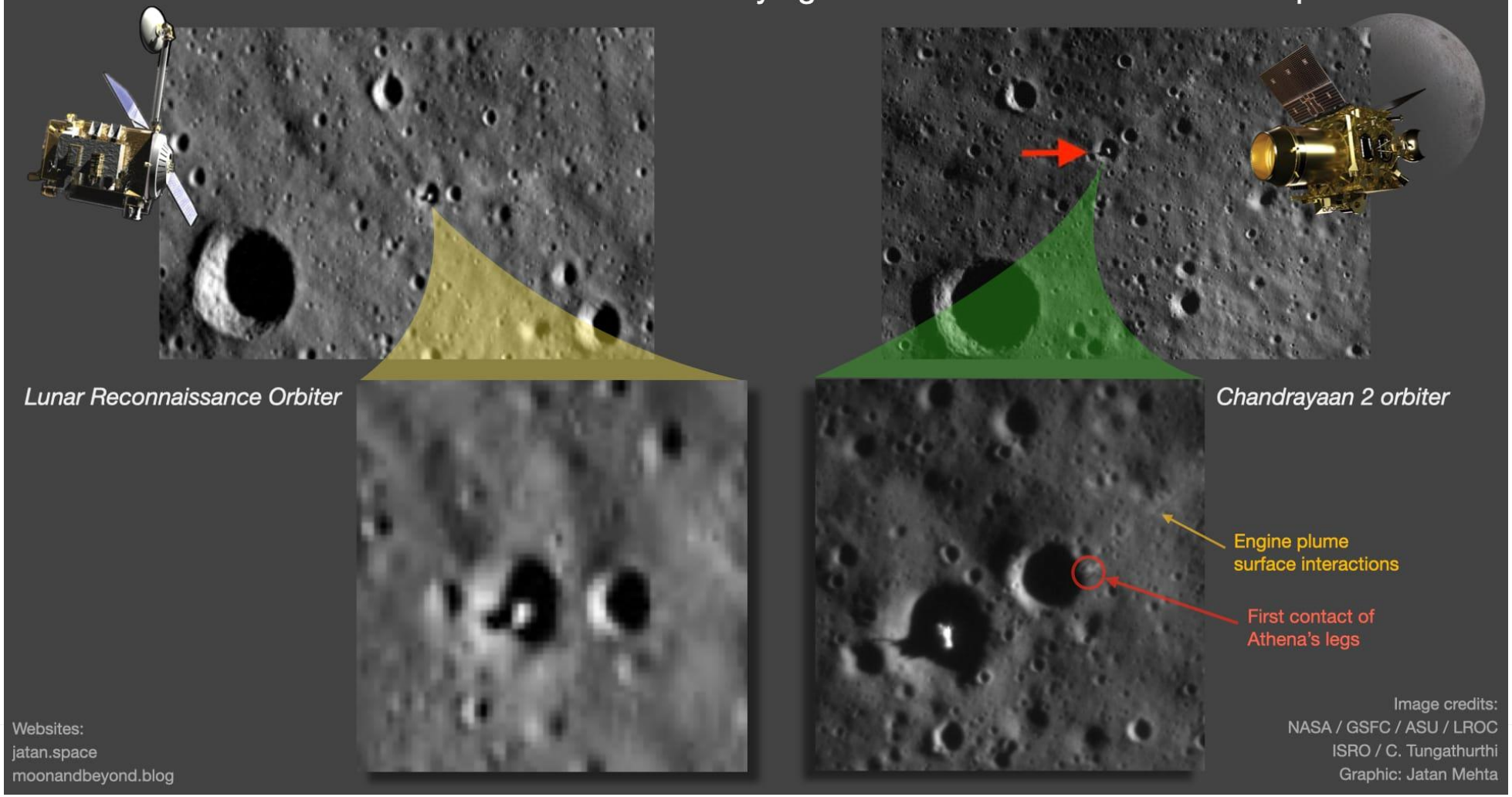


Now, to what actually happened





Orbital views of the IM-2 Athena lander lying on its side on the Moon's south pole

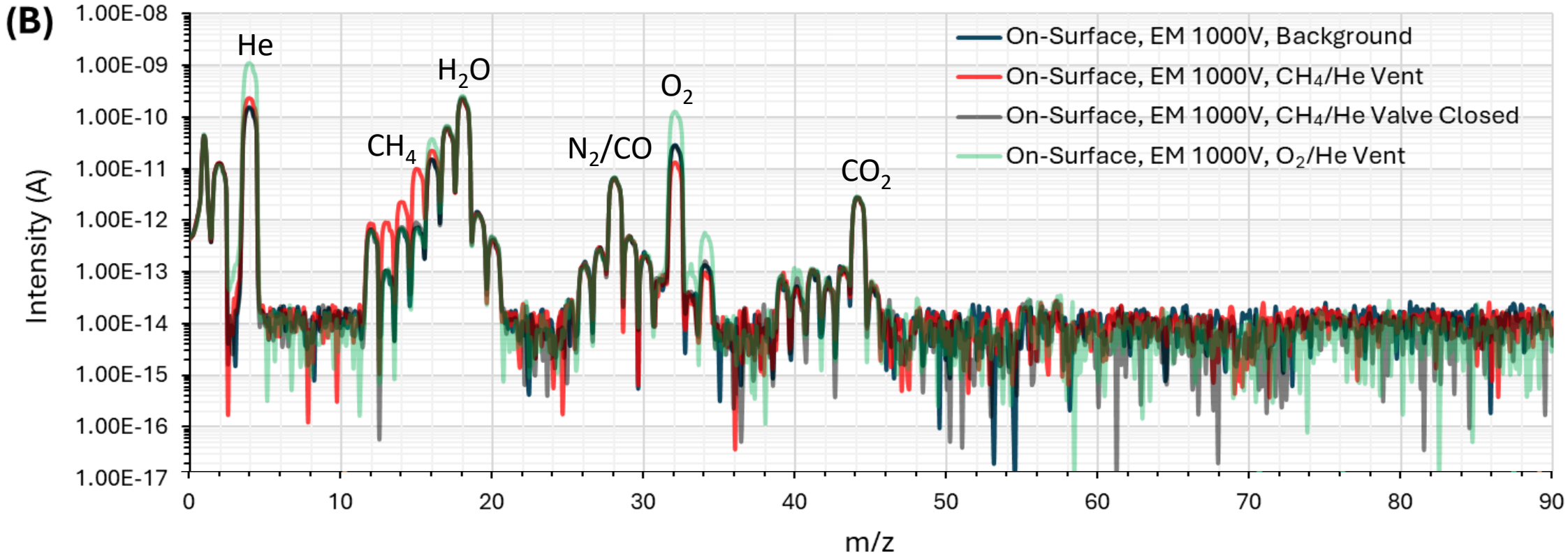


MSolo surface operations

- MSolo was powered on 3 times, doing scans at 10 parts per amu, 0-90 m/z.
- We captured 43 scans, 40 complete scans, 3 partial scans.
- Again, the spectra looked really good despite the really rough landing.
  - The filament survived
  - Tuning was good, not perfect. This could have been corrected if we had the time to retune, which was part of our nominal plan.
  - Sensitivity was not as good as in transit. We don't really know why but maybe it was due to dust on the filament/ion source/rods?
- While MSolo was powered on, IM-2 vented their CH_4 and O_2 tanks, both pressurized with He.
- MSolo also opened the CGS again, and collected a few data points of cal gas before being turned off.

Sample surface data

Figure courtesy of Matt Hancock



- These spectra shows that despite the rough landing, the instrument performed well on the lunar surface. Peak shapes are great, sensitivity and tuning are good.
- The plot show spectra from before (black) and after IM-2 vented first their methane (red) then oxygen (light green) tanks.

Lessons Learned and Conclusions

Lessons learned

- Be very familiar with your instrument (surface operations don't always go as planned)
- Contrary to (my) expectations, Earth air stuck around much longer than I thought it would and our transit and landed spectra were dominated by what we brought with us. Baking out a MS and/or leaving it on for long enough to remove contaminants is necessary to get the best sensitivity.
  - Based on lab results (shown previously) we believe that, had we landed in an icy region, we would have seen H_2O above the post-landing background.

Conclusions

- Perhaps the biggest results of this mission is that it validated the MSolo model. A COTS instrument, space hardened, can operate well in space and on the lunar surface.
- Because MSolo is a COTS instrument, development and testing are hardware rich and software/measurement approaches can be developed on flight-like hardware with commercial-level costs. **THIS IS A HUGE ADVANTAGE!!!**