The ROLSES radio science instrument on the Intuitive Machines Commercial Lunar Lander

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6th Global 21-cm Workshop

15 September 2023

see Burns+ 2021, *Planetary Science Journal*, 2, 44B

Courtesy of Intuitive Machines

NASA's Artemis & CLPS Program


SLS


Commercial Lunar Payload Services (CLPS)


The Gateway in Lunar Orbit

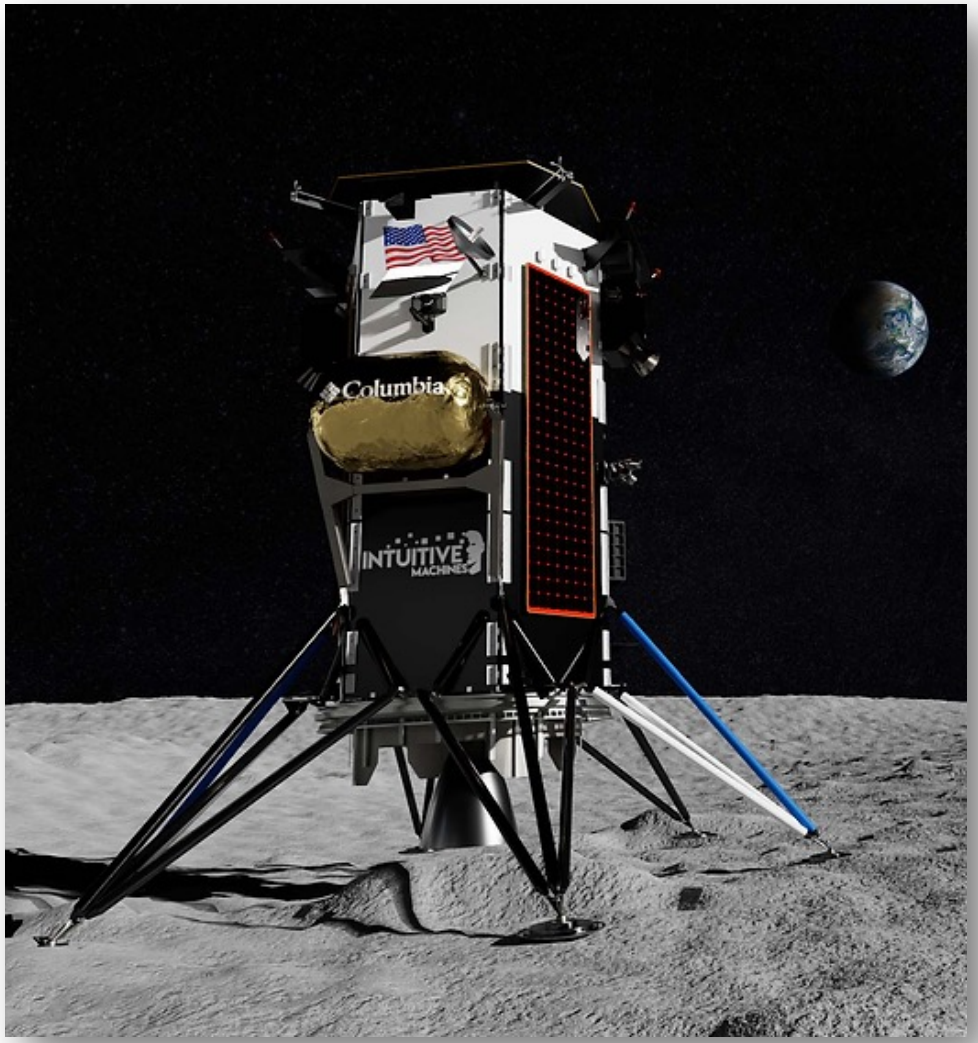

Orion


First Woman and First
Person of Color to the Moon


Artemis Base Camp

Courtesy of NASA

NASA Commercial Payload Services (CLPS)

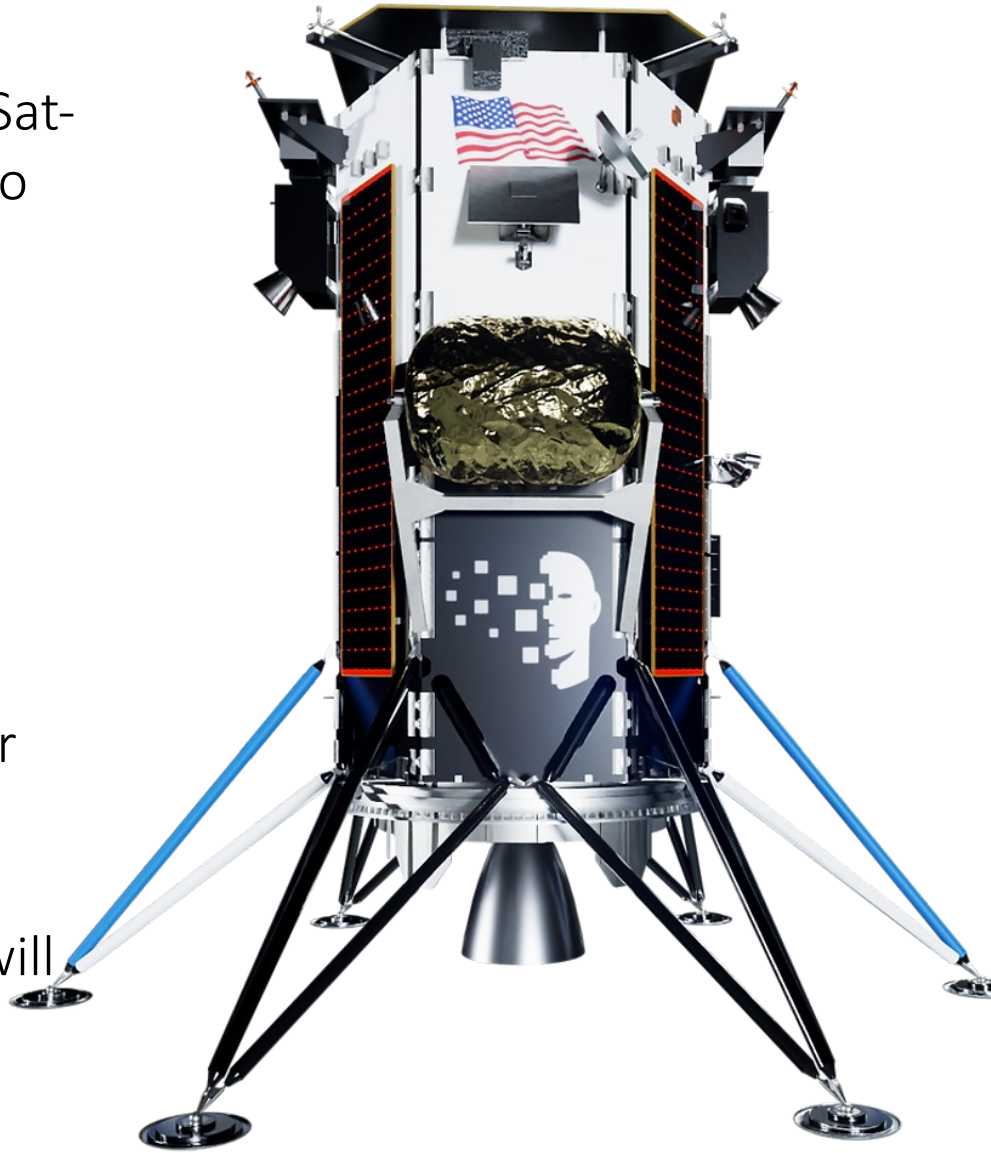


Courtesy of Intuitive Machines

- "NASA's Commercial Lunar Payload Services (CLPS) initiative allows rapid acquisition of lunar delivery services from commercial companies for payloads that advance capabilities for science, exploration or commercial development of the Moon…under the Artemis approach"
- **Delivery Timeline**
  - *Astrobotic* will carry 11 payloads to Lacus Mortis, a larger crater on the near side of the Moon.
  - *Intuitive Machines* will carry multiple payloads, including our ROLSES radio science experiment, to Moon's South Pole with a landing now expected by November-2023.

Intuitive Machines Payloads (IM-1)

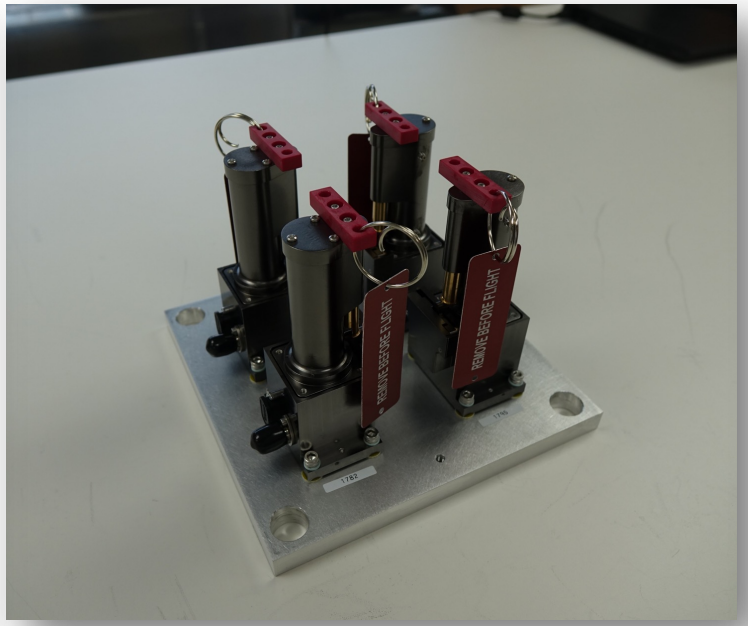
- **Lunar Node 1 Navigation Demonstrator (LN-1):** LN-1 is a CubeSat-sized experiment that will demonstrate autonomous navigation to support future surface & orbital operations.
- **Stereo Cameras for Lunar Plume-Surface Studies (SCALPSS):** SCALPSS will capture video and still image data of the lander's plume as the plume starts to impact the lunar surface until after engine shut off, which is critical for future lunar and Mars vehicle designs.
- **Low-frequency Radio Observations for the Lunar Surface (ROLSES):** ROLSES will use a low-frequency radio receiver system to determine the plasma sheath density and scale height. Also, ROLSES will explore the effects on the antenna response of the lunar environment. In addition, the ROLSES measurements will confirm how well a lunar surface-based radio observatory could observe and image solar radio bursts.



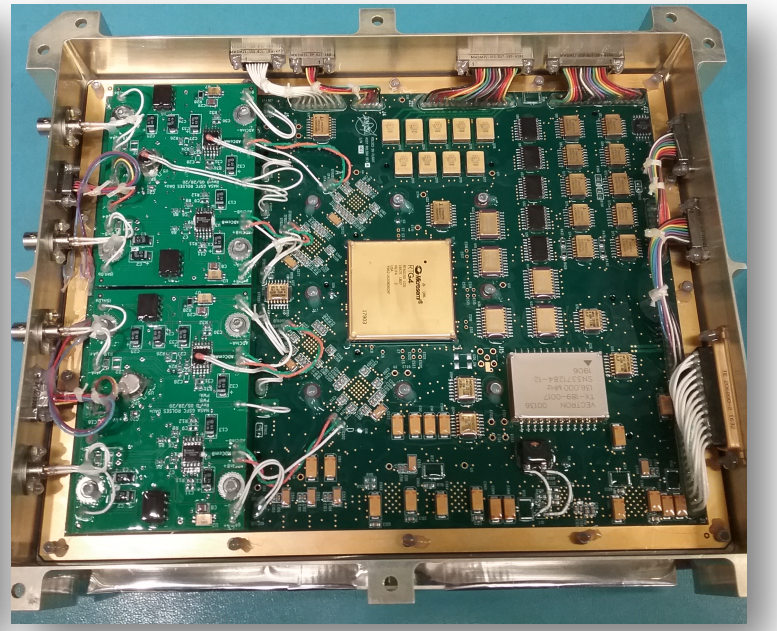
Courtesy of Intuitive Machines

https://www.intuitivemachines.com/lunawesome-photos?pgid=ko1mw3k2-74a26877-e975-49f6-b0a2-5b136310f3e9

IM-1 with ROLSES antennas deployed



Stowed STACER antennas



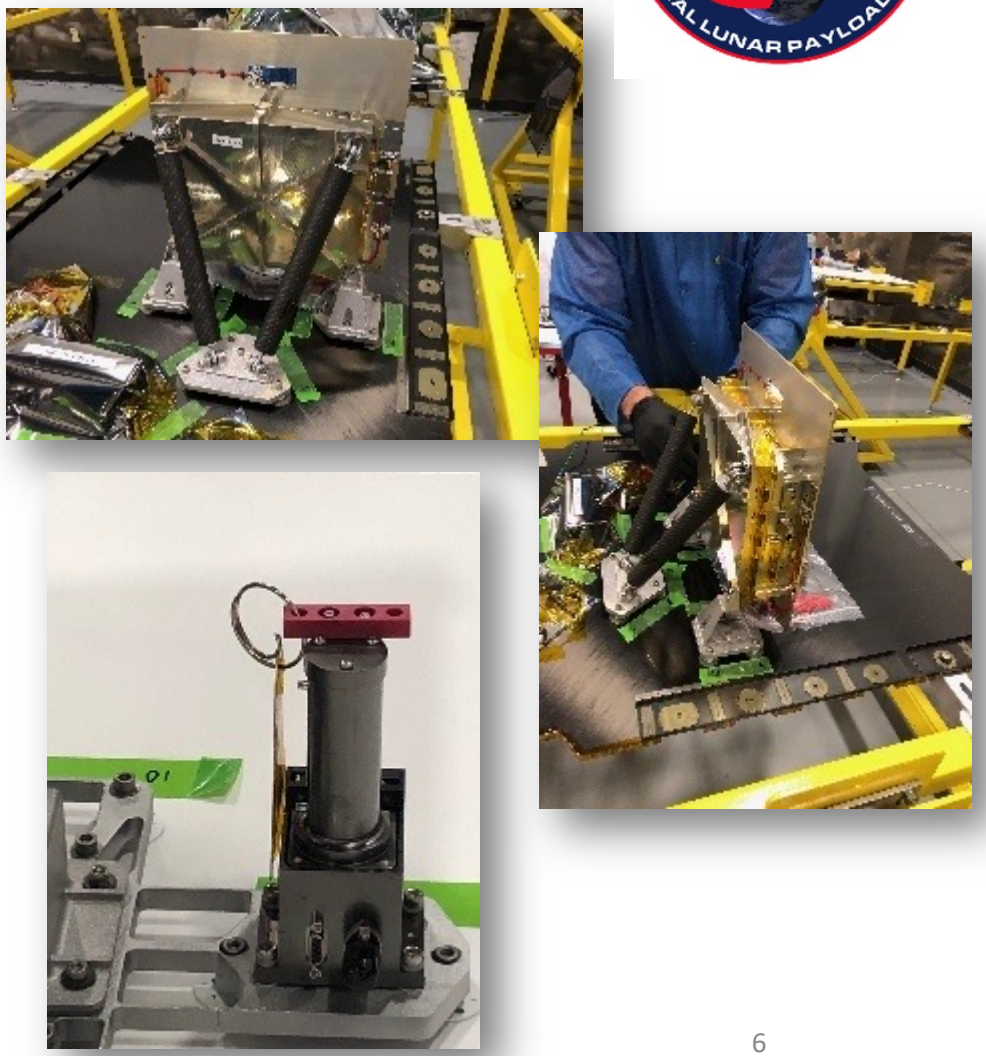
ROLSES spectrometer board

Radio wave Observations at the Lunar Surface of the photo-Electron Sheath (ROLSES)

- ROLSES Instrument Team: Nat Gopalswamy (PI), Robert MacDowall, William Farrell, Jack Burns, Damon Bradley, Michael Reiner, Ed Wollack, Mike Choi, Scott Murphy, Rich Katz, Igor Kleyner, Richard Mills, Pietro Sparacino, and Victor Gonzalez-Leon.
- ROLSES instrument is a new build with heritage from NASA SMAP Earth Remote Sensing satellite:
  - Four 2.5-m monopoles forming cross-dipole antennas.
  - Radio spectrometer with 2 bands: 2 kHz – 1 MHz and 300 kHz – 30 MHz.
- Scheduled to land on lunar nearside using *Intuitive Machines (IM-1) Nova-C.*

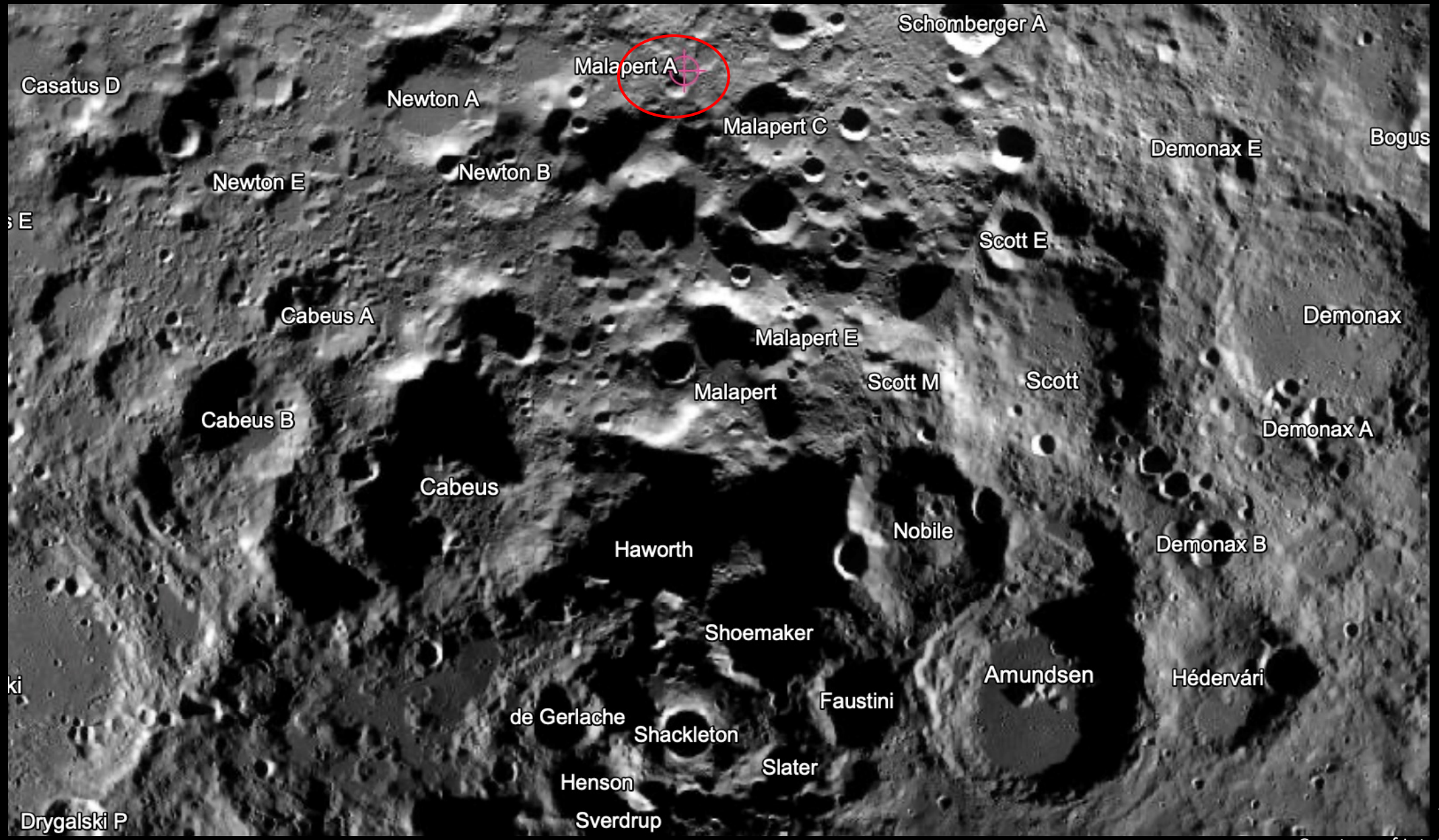
ROLSES Instrument Parameters

- Frequency coverage: 2 kHz - 30 MHz
- Instrument Mass: 13.1 kg.
- Mechanical volumes: Total with radiators is 9200 cm^3.
  - Electronic & thermal control box: : 20cm x 25cm x 8cm
  - Preamps (4) each 5 cm x 5 cm x 2 cm
  - Stacer antenna deployer base units 21 cm x 5 cm x 5 cm
- Power: average is 25 W.
  - Requires 1.25 A @ 7 Vdc for 35 sec to deploy each Stacer antenna
- Data rate: ~ 17 kbps



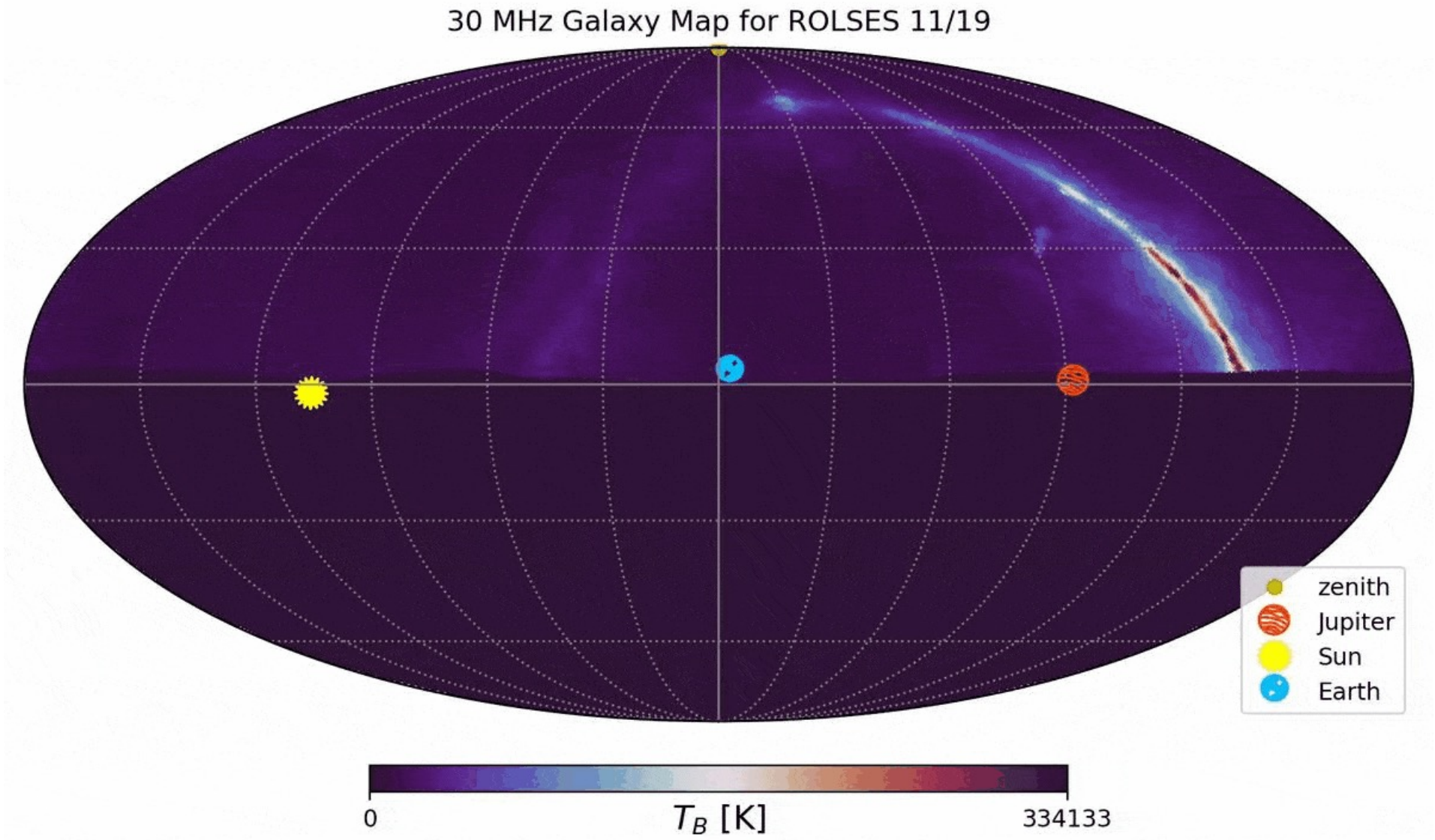
Images of integration of payload onto Lander panels
Courtesy of Intuitive Machines.

IM-1 LANDING SITE – THE MOON'S SOUTH POLE



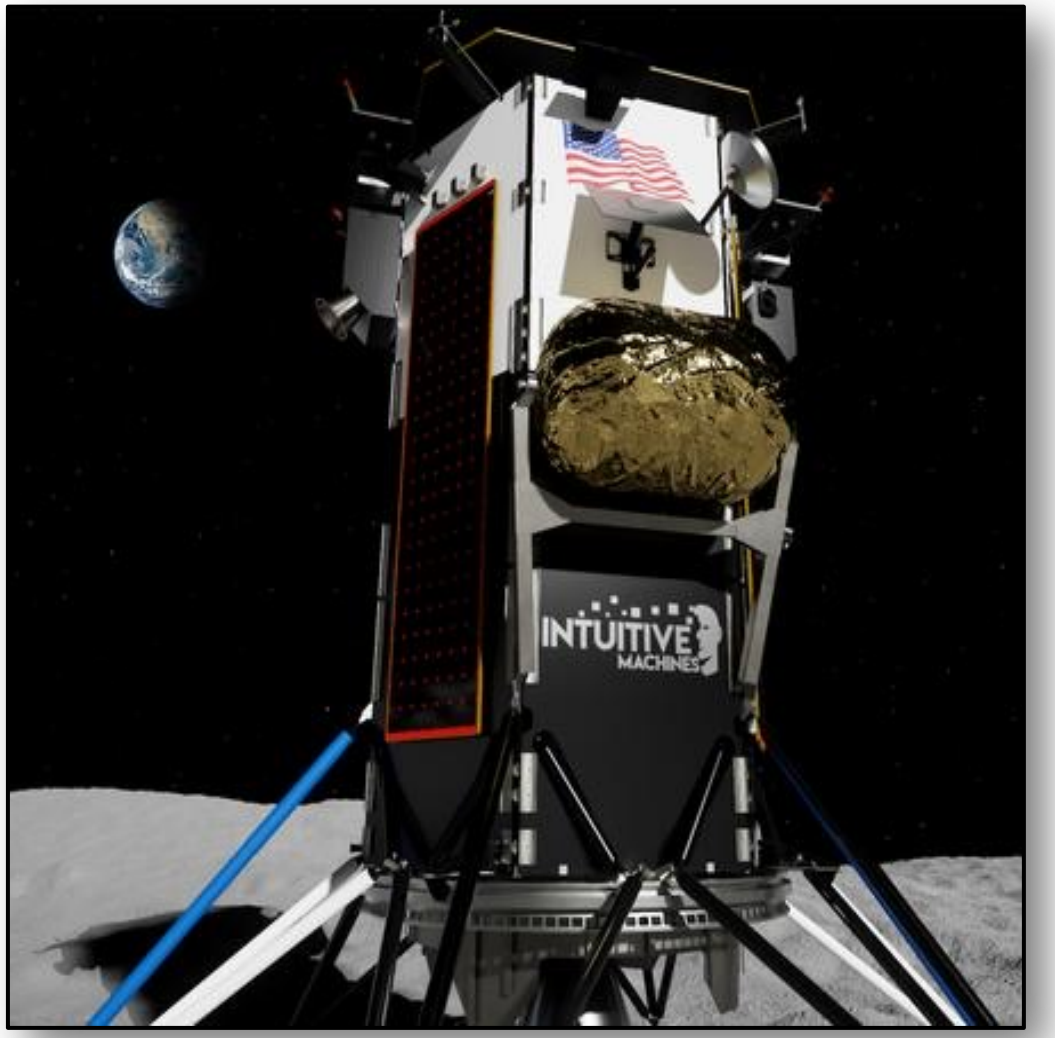
Courtesy of Intuitive Machines

The Radio Sky at Malapert-A IM-1 Landing Site



Credit: Wong, Hibbard, Burns, Rapetti

Preliminary (freshly produced)



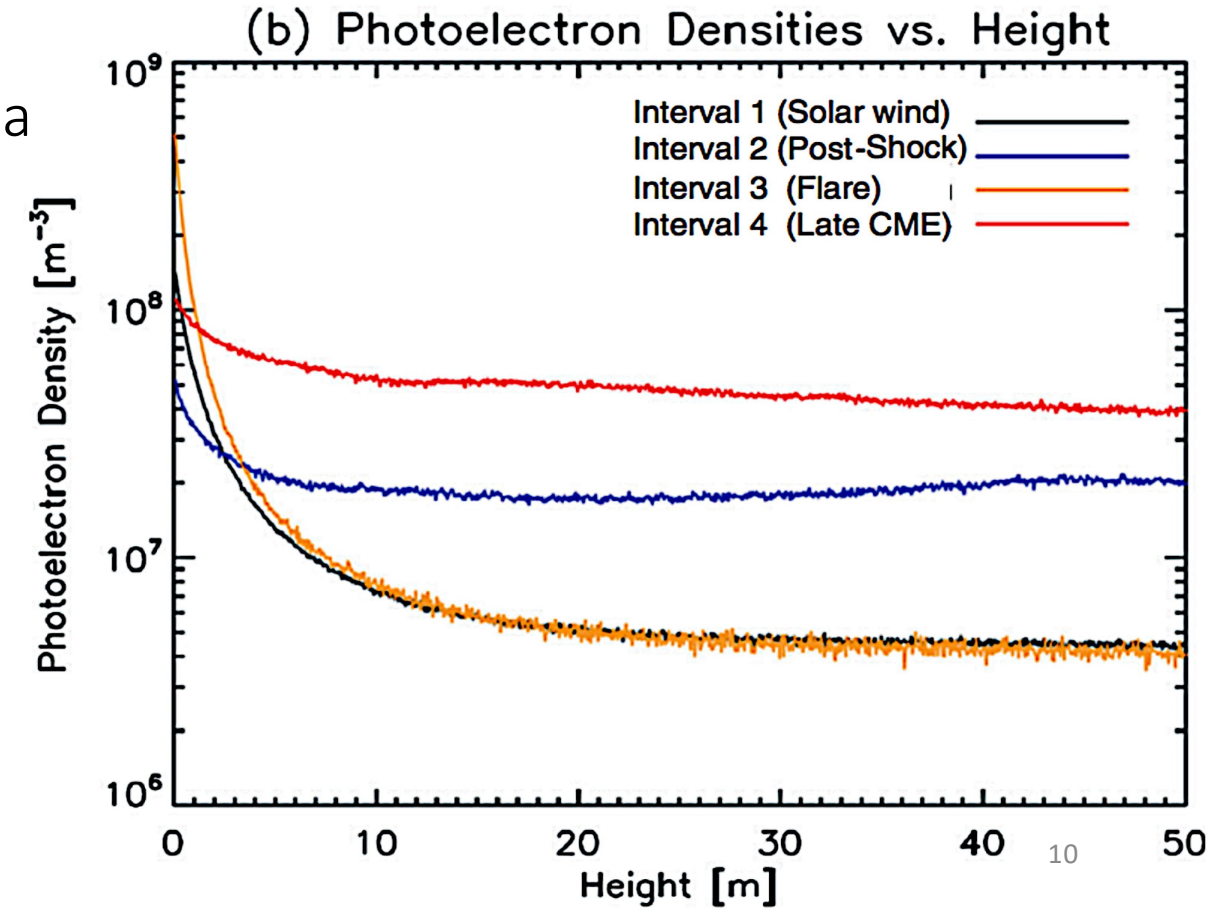
Courtesy of Intuitive Machines

ROLSES Science Goals

- Determine the electron sheath density from ~1 to ~3 m above the lunar surface by measuring electron plasma frequency.
- Demonstrate detection of solar, planetary, & other radio emission from lunar surface.
- Explore Galaxy radio spectrum at <30 MHz.
- Aid development of lunar radio arrays.
- Measure the local EM environment, including that from the lander.
- Measure reflection of incoming radio emission from lunar surface and below.

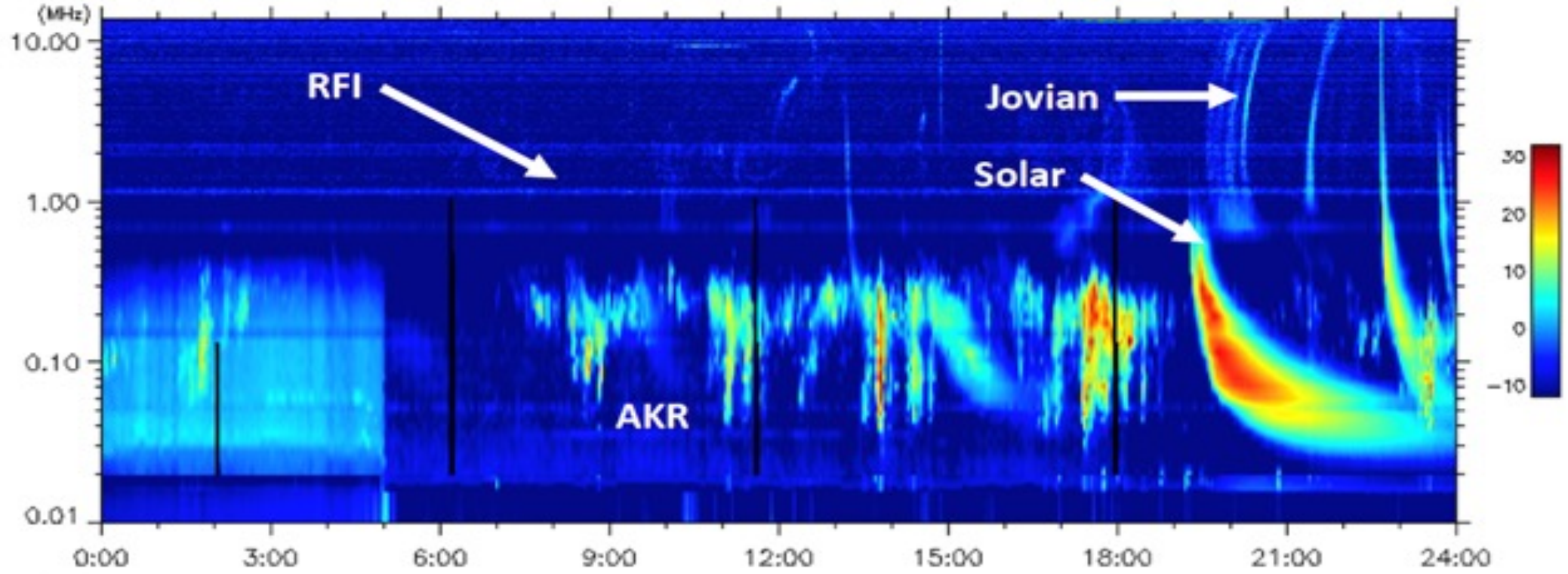
Lunar surface photoelectron sheath

- ROLSES measures photoelectron sheath density from 0 to ~3 m above lunar surface.
- May contribute to astronaut safety.
- Important to determine effects on the antenna response of larger lunar radio observatories on the lunar surface.
- Photoelectron density as a function of height is shown at right from Poppe & Horanyi [2010] for various solar wind environments. At 1 m height in typical solar wind, density is 5 x 10^7 m^{-3} corresponding to plasma electron frequency (f_{pe}) ~ 64 kHz.



Farrell+

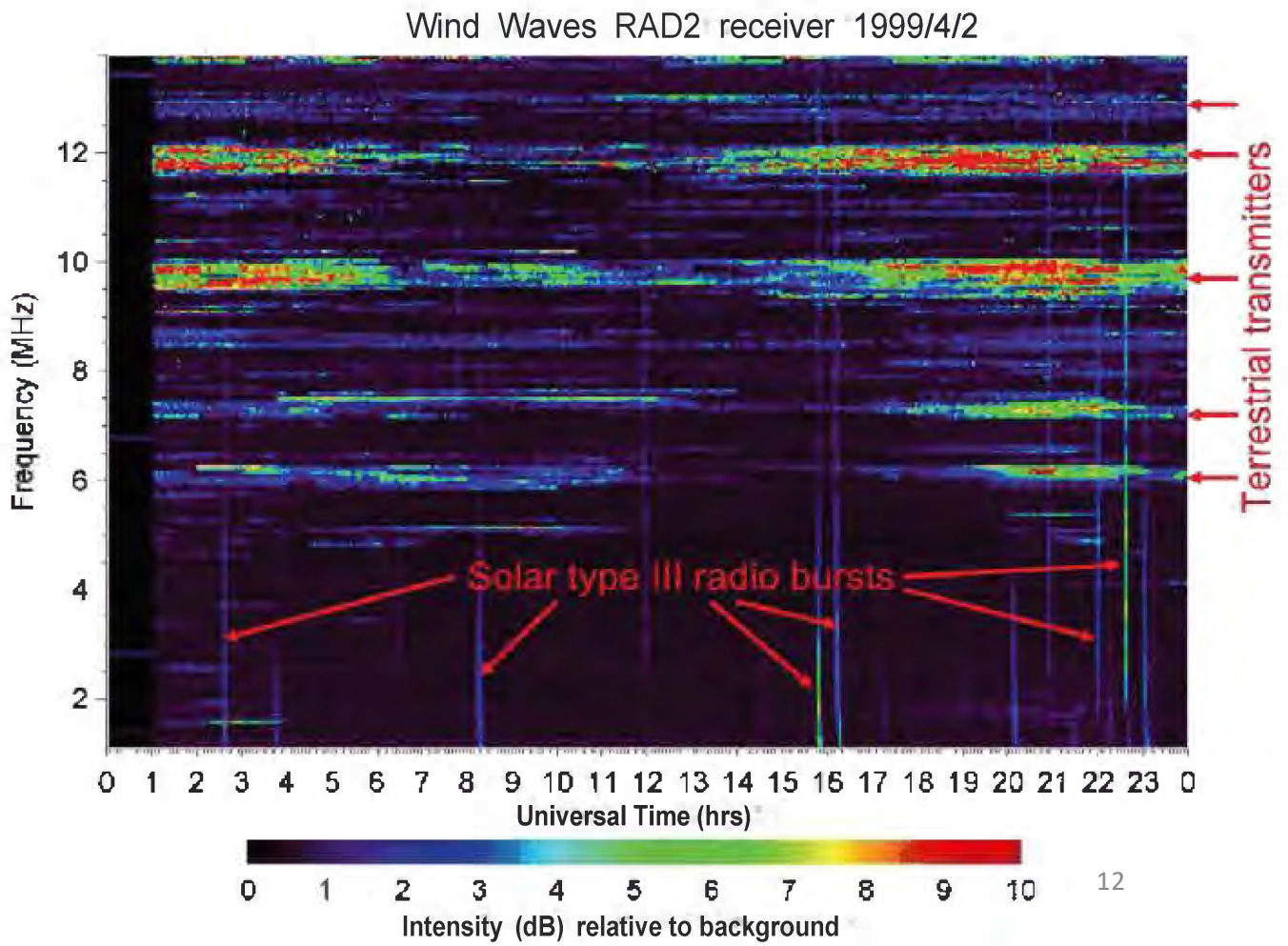
Demonstrate detection of solar, planetary, and other radio emission from lunar surface



The WAVES instrument on the Wind spacecraft at Solar-Earth L1 shows solar radio bursts, Earth's auroral radio bursts, terrestrial ground-based transmitters, and Jovian radio emissions, during the 24 hr interval of 2/20/2012. ROLSES could do the same.

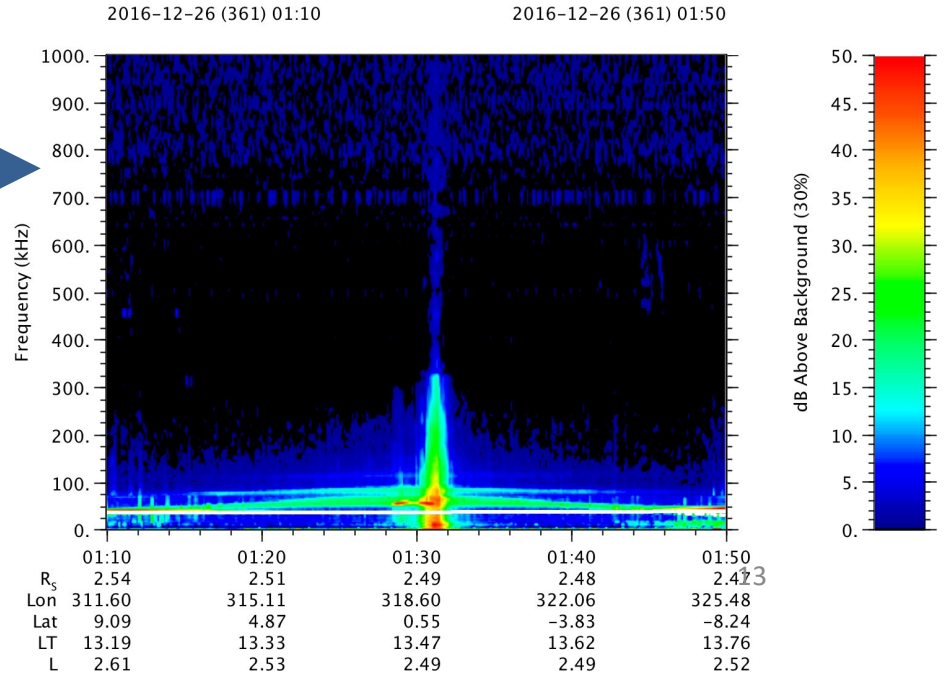
Measure current range/intensity of Terrestrial RFI

- ROLSES will provide continuous spectra of radio frequency interference (RFI) from terrestrial transmitters for ~10-day mission, to confirm suitability of a near-side radio observatory image solar radio bursts at 0.01 to ~10 MHz.
- Plot RFI observed by Wind/WAVES in 1999 when it passed the Moon.



Interplanetary/Interstellar Dust Impacts

- Lander may be struck by dust particles, which releases electrons and ions, affects the surface photoelectron environment, & creates signals that may be detectable.
- Surveyor 5 observed a “horizon glow” on the Moon that might be produced by scattered light from electrostatically -elevated dust.
- Plot shows dust signal detected by the Cassini when crossing the Saturn F-ring.
- ROLSES might detect dust impacting the NOVA-C lander in similar way. Time resolution of 5 seconds does not permit detecting individual dust particles but could detect dust “clouds”.



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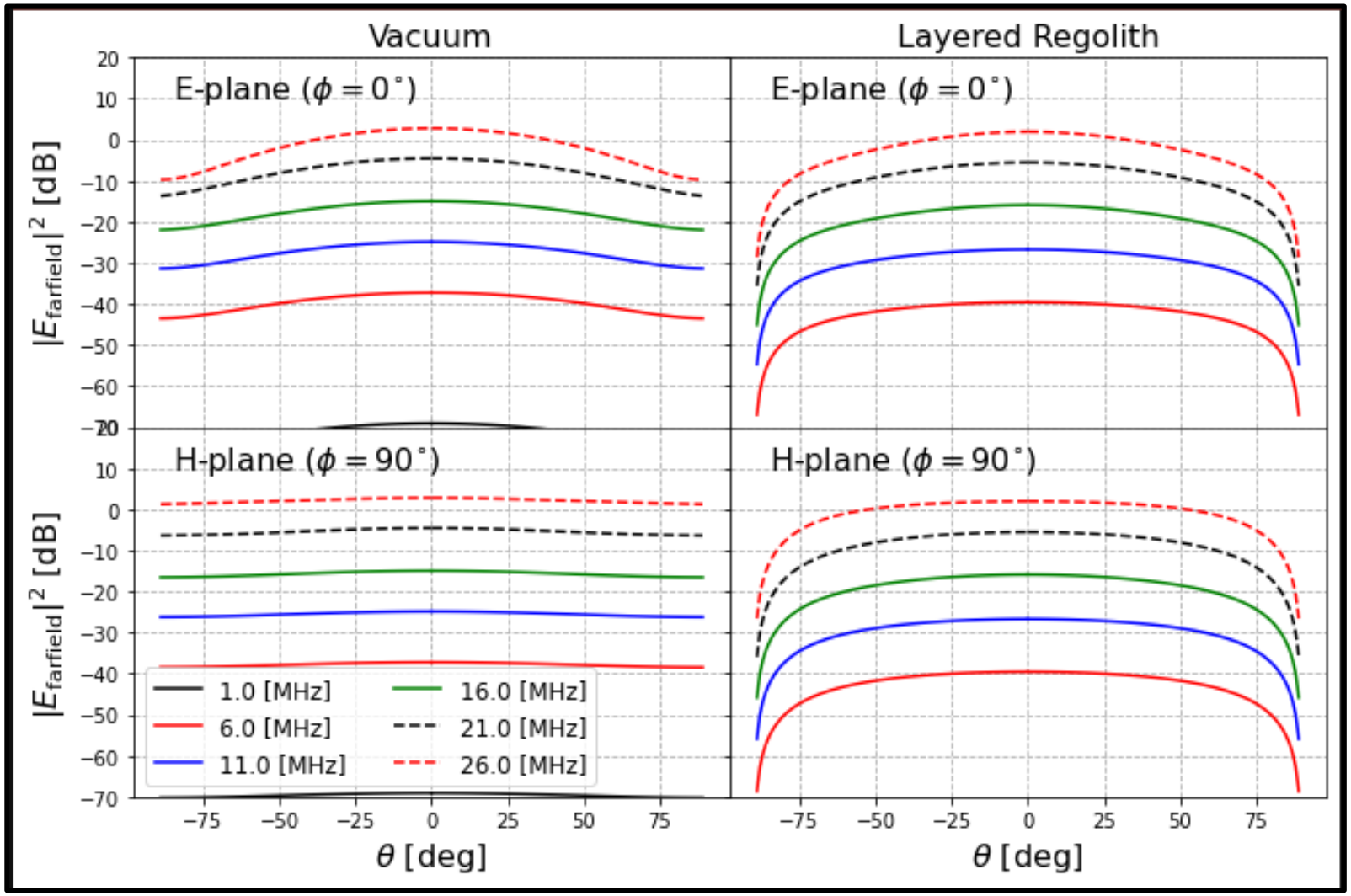
CST Microwave Studio EM simulations of the ROLSES dipole beam, including the IM-1 lander, in free-space and on the lunar surface

Analysis courtesy of Bang Nhan, NRAO



ROLSES delivery to the Moon on Intuitive Machines-1 lander in Q4 2023

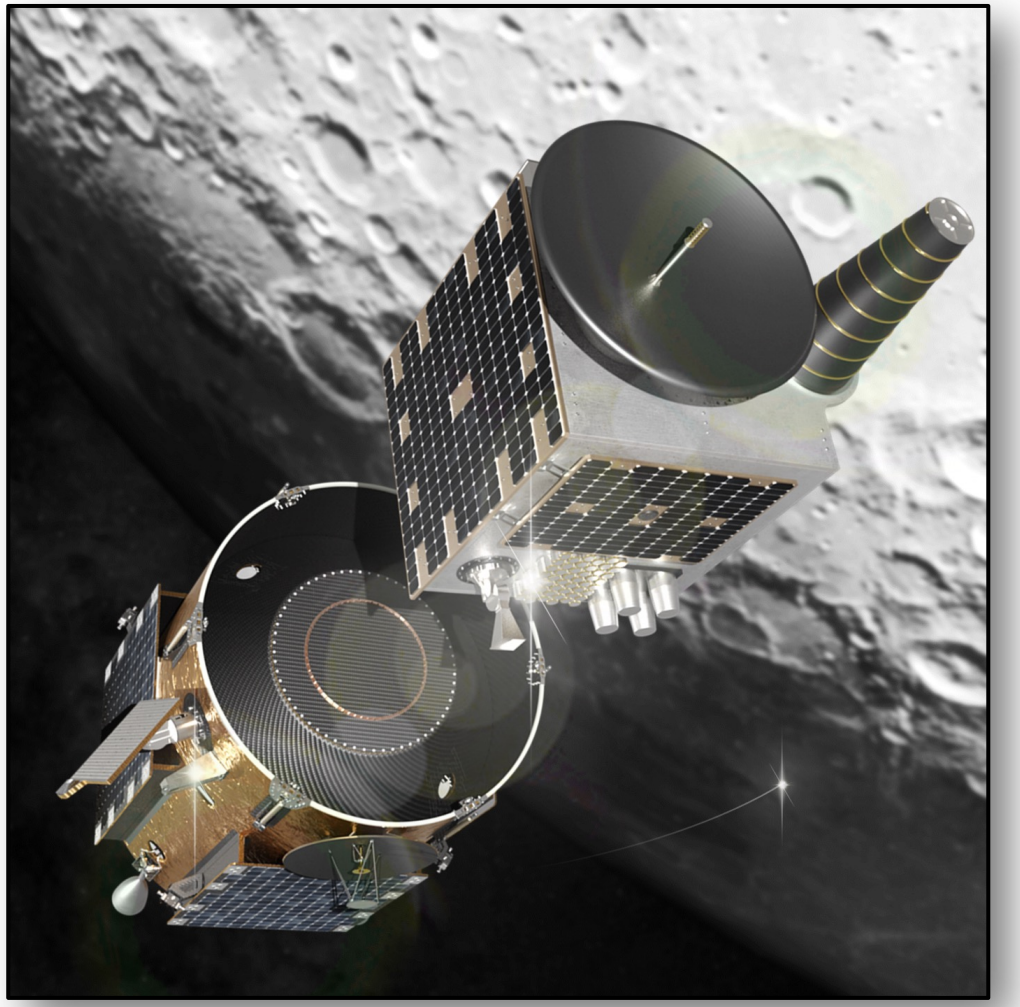
Courtesy of Firefly Aerospace

Lunar Surface Electromagnetics Experiment (LuSEE-Night)

The first 21-cm cosmology observations from the lunar far side at night. Launch in January 2026.

Stuart D. Bale (PI), Neil Bassett, Jack Burns, Johnny Dorigo Jones, Keith Goetz, Christian Hellum-Bye, Sven Herrmann, Joshua Hibbard, Milan Maksimovic, Ryan McLean, Raul Monsalve, Paul O'Connor, Aaron Parsons, Marc Pulupa, Rugved Pund, David Rapetti, Kaja Rotermund, Ben Saliwanchik, Anže Slosar, David Sundkvist, and Aritoki Suzuki

Bale+, 2023, https://arxiv.org/abs/2301.10345



Deployment of *Lunar Pathfinder* communications satellite as part of LuSEE-Night mission.
Courtesy of NASA

The Path Forward

- NASA's CLPS program is a high risk/high reward program that could be a game-changer with regular access to the lunar surface 2-3 times per year.
- The first NASA radio science payload, *ROLSES*, is planned to land at the South Pole in Q4 2023. It will measure the electron plasma sheath near the surface, the Galaxy spectrum at <30 MHz, and the EM interaction with the dielectric lunar subsurface.
- *ROLSES* will inform the design & observational strategy for *LuSEE-Night*. *LuSEE-Night* will make the first night time observations of the radio band corresponding to the early Universe's Dark Ages.
- These CLPS radio science missions will prepare the way for a future array of low frequency radio antennas on the lunar surface possibly in conjunction with Artemis astronauts.