**Lunar Volatiles Integrated Survey Packages.**

Robert L. Staehle[1], R. Glenn Sellar[1], Pamela E. Clark[1], Craig Hardgrove[2], Adrian Tang[1], Yonggyu Gim[1], Paul Hayne[3], Sabrina Feldman[1] ([1]Jet Propulsion Laboratory, California Institute of Technology), ([2] Arizona State University), ([3] University of Colorado-Boulder)

**Introduction:** Will Artemis astronauts pass over or near scientifically revealing or resource-relevant volatile deposits? To find out, we propose three integrated instrument packages to perform a surface/subsurface volatiles survey accompanying Artemis crews to the lunar surface in a near-polar region:

1. 3 kg, 11W (CBE) package attached to the crew rover to measure:
   a. Neutron Spectrometer (NS) discerning H>1 wt-% to ~1 m depths;
   b. Ground-Penetrating Radar (GPR) mapping subsurface dielectric discontinuities >1% by volume indicative of water ice to ~10 m depth;
   c. Multi-band IR Camera (MIRC) mapping expression of ice at 0.5 - 1% of surface area and ice mixtures of $H_2O$, adsorbed OH-, $CO_2$, $CH_4$, & $NH_3$.
2. 3 kg, 11W package for a crew-deployed Sojourner or AXEL-class rover to make the same measurements in areas of deep shadow and down steep slopes too risky for the crew.
3. 6 kg, 10 W hand-held package to enable the crew to make finer spatial NS and GPR subsurface measurements across small craters, behind larger rocks casting shadows, and following other terrain features that may dictate volatiles sublimation and deposition.

Each of these instrument packages would utilize the same detectors and instrument electronics, with packaging flexible to enable accommodation on the two rovers of very different sizes, and on the hand-held package used somewhat like a terrestrial metal detector. The mass would be greater for the hand-held package because it will require more mass for batteries and other services provided to the other instrument packages by their host rovers.

For the two rover implementations, no crew interaction would be required, provided that the instrument package could be positioned such that the MIRC can see ahead (or behind), and the GPR can be provided with an unobstructed ~90 deg conical view downward, e.g., from the underside of the rover. The NS could be located anywhere on the rover, however, care should be taken to increase the radial distance from any radioisotope power system. All three can be mechanically and electrically integrated. Back-room near real-time data analysis could advise the crew of noteworthy measurements, enabling rapid changes to traverse and drill sites if warranted by new science considerations.

In this synergistic instrument combination:

MIRC **identifies** $H_2O$ (on the surface), and can indicate other volatile ices if present; **mapping** locations of surface concentrations. If there has been a cometary source of $H_2O$, then C- and N-bearing compounds are likely present at small fractions of water abundance and can provide quantitative clues to lunar ice origin. A viable source of C and N in small quantities could be critical to food production for permanent crew presence in a sustainable future.

NS **quantifies** the bulk abundance of H-containing species (e.g., $H_2O$, $CH_4$/hydrocarbons, $NH_3$) **below** the surface.

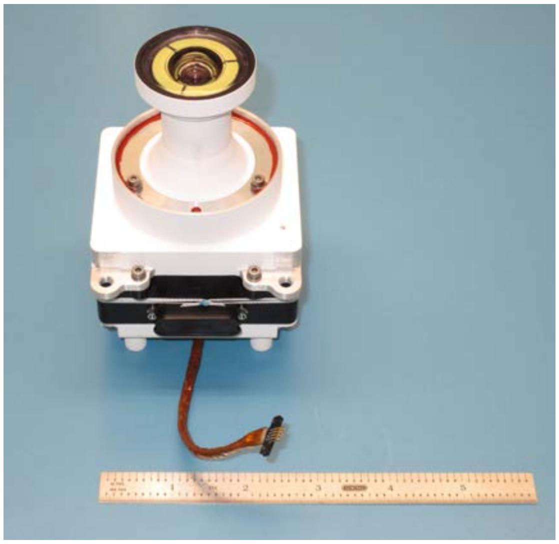
GPR provides the **depth profile**, especially layering or other dielectric constant/density discontinuities.

MIRC could utilize backend electronics derived from the 0.7 kg Mars2020 Enhanced Engineering Camera (EECAM), combined with a commercial or JPL-developed High Operating Temperature Barrier Infrared Detector (HOT-BIRD), to reduce cooling requirements. Illumination source is an open trade, including scattered sunlight and IR headlamps on a rover or astronaut helmets.

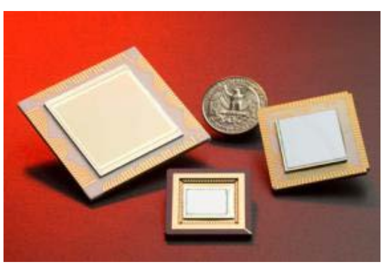
NS could utilize detectors and electronics developed for the LunaH-Map CubeSat's Miniature Neutron Spectrometer (Mini-NS). LunaH-Map is nearing completion for launch aboard Artemis 1. Its Mini-NS consists of two detectors with 4 sensor modules each. Each detector can support up to four sensor modules, which (for a given H abundance) will decrease the required integration time.

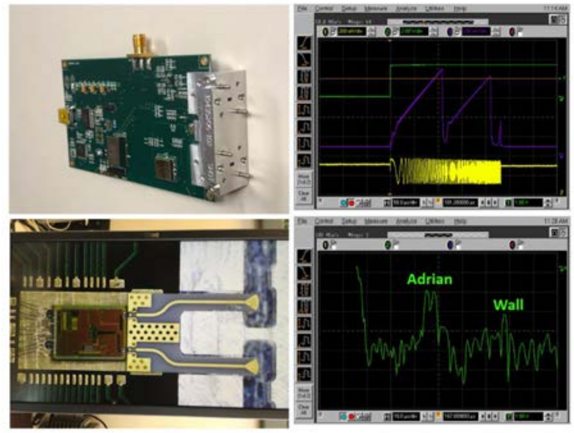
GPR could utilize software-defined transmitter and receiver techniques enabled by CMOS System-on-a-Chip (SoC) capabilities being developed for dramatic miniaturization of RF electronics and demonstrated on the ReckTangLE-II limb-sounding payload flown during the 2019 Columbia Scientific Balloon Facility Ft. Sumner (Texas) campaign.

Cost estimates can be discussed at the Workshop, and are highly dependent on instrument hosting interfaces, hardware class (A, B, C, or D), and crew safety & certification requirements.

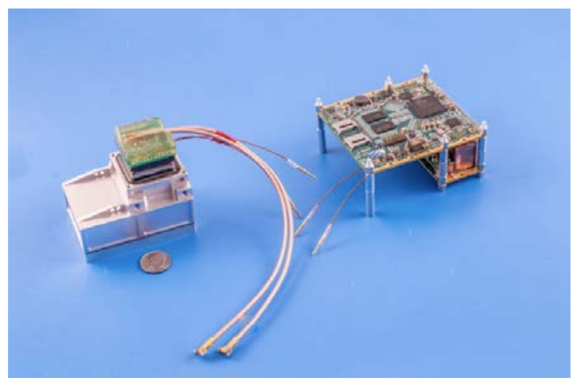


Mars 2020 Navcam (above). EECAM electronics (below) measure 57 x 57 x 65 mm on a side. JPL HOTBIRD detectors (two images below) can operate 20C warmer than HgCdTe for equivalent noise characteristics.






A W-Band Hybrid RF-Digital radar previously developed by JPL team. A direct-sequence spread-spectrum digital radar recently demonstrated by our team contains many of the same components and functions as the proposed All-digital GPR Radar.



A single LunaH-Map detector and PMT module (L) offers enough sensitivity when rover-borne ~1 m off the lunar surface, compared to the 8 detectors orbiting 10s of km above the lunar surface. Digital and analog electronics on R.