An Ultra-Compact Imaging Spectrometer for the Moon

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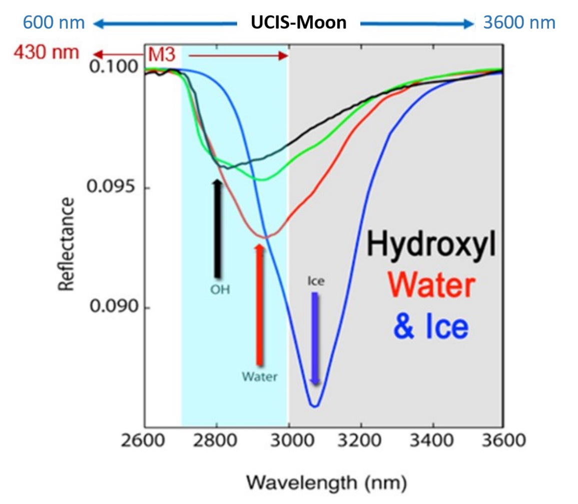
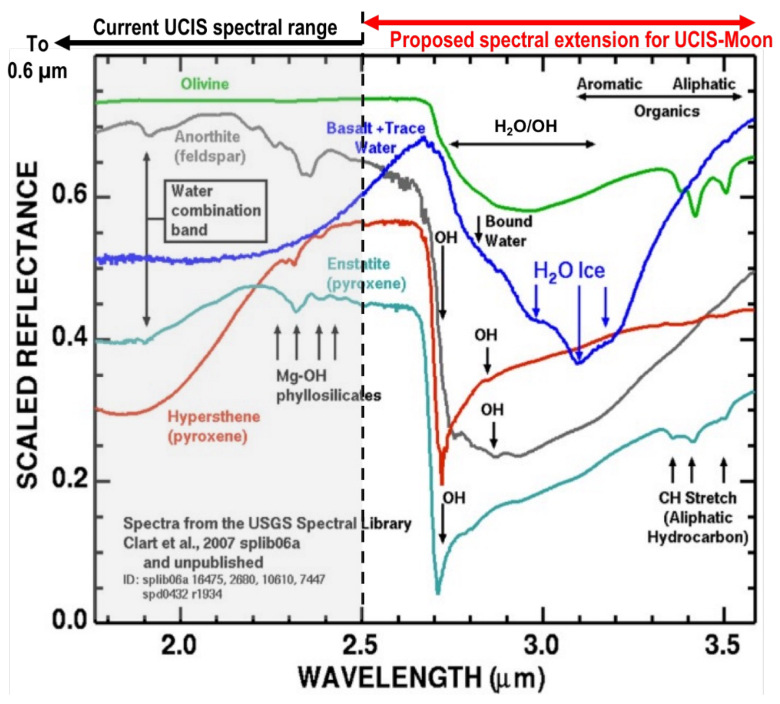
Overview

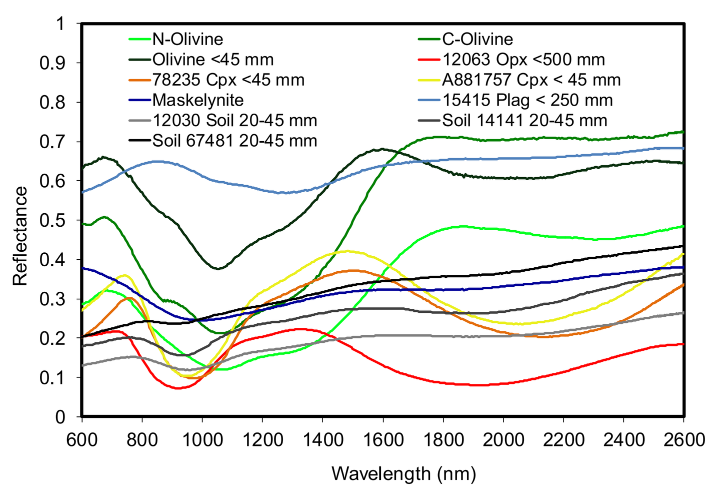
- We are developing the Ultra-Compact Imaging Spectrometer (UCIS) [1,2] for a future landed lunar mission in the Development & Advancement of Lunar Instrumentation (DALI) program
- **UCIS-Moon is a short wavelength infrared (SWIR) imaging spectrometer** that will achieve key lunar science goals (Table 1) by extending original UCIS capabilities in spectral range, field of view, and environmental tolerance while limiting mass and power resources
- UCIS-Moon can also use on-board analysis to maximize the science yield in case of restricted bandwidth downlinks.
- Expected TRL 6 in end of Dec. 2022

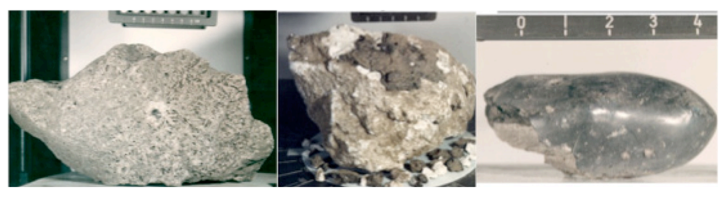


UCIS-Moon extends beyond the M[3] range to capture the full 3 µm spectral region with high SNR to determine the form and abundance of OH species, molecular H_2O, and ice at the surface (modified from [3]).

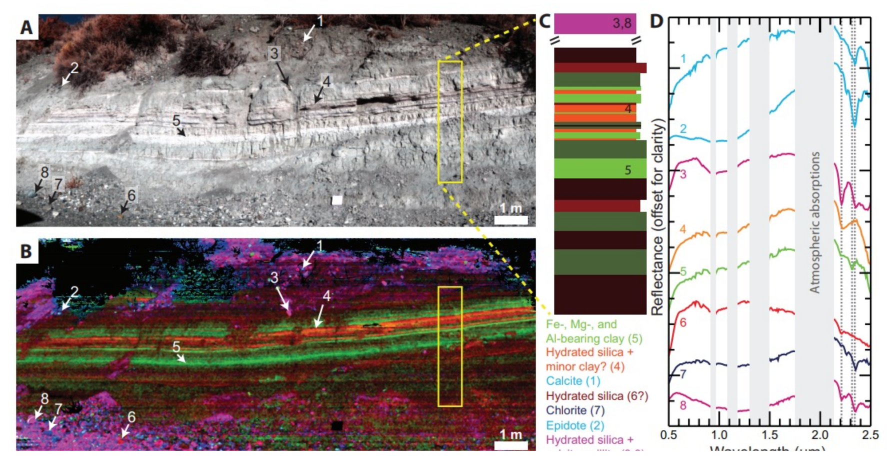


Laboratory measurements showing the character and diversity of volatiles distinguishable with spectral range of UCIS-Moon.





UCIS-Moon will differentiate spectra from common lunar minerals (top) and resolve millimeter to meter variability in lunar rocks at distances from meter to tens of meters (example lunar variability in Apollo samples on bottom. Scale bars are cm)



Data similar to UCIS-Moon from a terrestrial outcrop. (A) Visible color (B) Compositional information from spectrometer, (C) Cartoon stratigraphic section, (D) Representative spectra. From [4].

UCIS-Moon will deliver in-situ information about *volatiles* and *lunar geology* by spectroscopically mapping OH species, molecular H2O, water ice, and common lunar minerals with spatial context at a resolution from centimeters to meters.

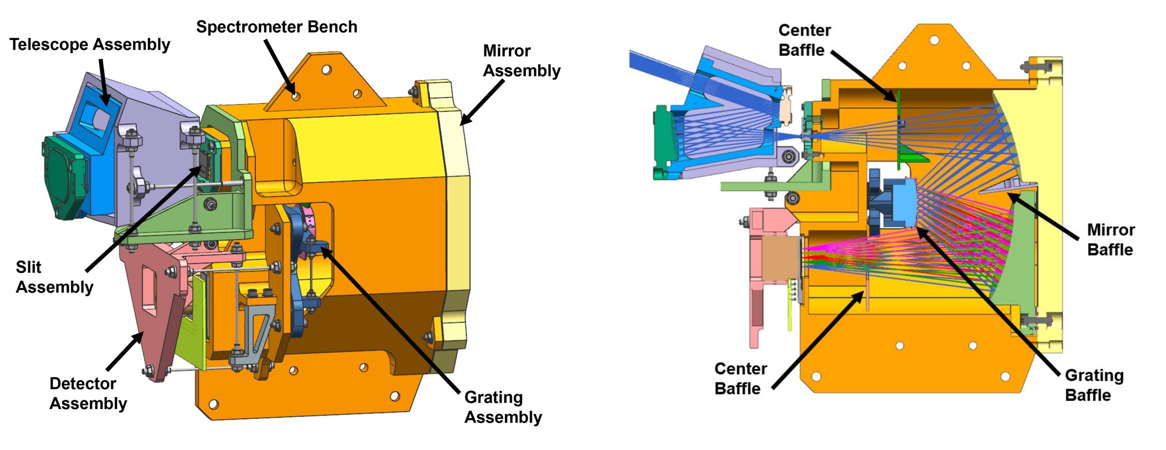
Goal	Objective	Measurement Requirements
Volatile Goals: Understand sources, distribution, temporal variability, and ISRU potential of lunar volatiles	Resolve OH and H_2O absorption bands at the scale of rocks and outcrops	1.85 – 3.6 µm spectral range with ≤20 nm spectral sampling and SNR ≥50
	Spatially resolve mineral absorptions, OH, and H_2O absorptions at the scale of rocks and outcrops.	IFOV ≤ 1.7 mrad (5 mm at 3 m, 5 cm at 30 m)
	Temporally resolve OH and H_2O concentration in rocks and regolith; monitor temporal variability of solar wind generated OH	Measurements at multiple times of the lunar day, including very early to mid-morning and afternoon to late evening to capture periods of possible volatile content change
Geology Goals: Understand Igneous Processes; Lunar Stratigraphy; and Space Weathering on the Moon	Identify key minerals and lithologies; map spectral properties of rocks & soils of multiple exposure ages	0.6 – 2.5 µm spectral range with ≤20 nm spectral sampling and SNR ≥100
	Map the spatial relationships between materials	IFOV ≤ 1.7 mrad (5 mm at 3 m, 5 cm at 30 m)

Expected Characteristics	
Platform	Lunar lander/rover
Wavelength Range	600 – 3600 nm
Sampling	10 nm
Spectrometer architecture	Offner
FOV	>= 30 deg
IFOV	1.15 mrad
SNR	>100 @ <2500 nm >50 @ >2500 nm
Spectral uniformity	<5% (req. <10%)
Spatial uniformity	<5% (req. <10%)

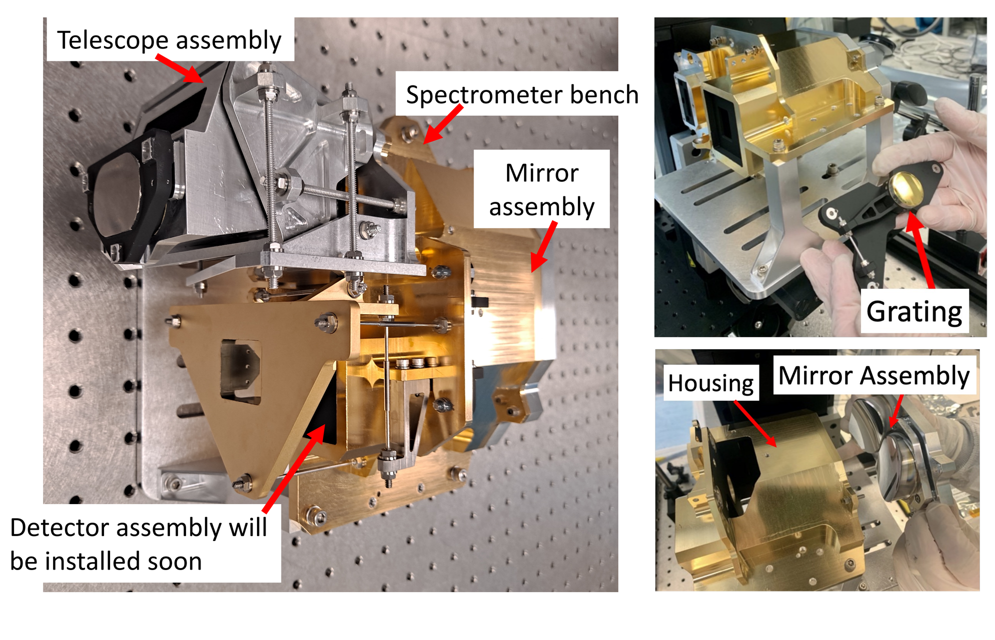
Estimated Physical Properties	
Mass	~6 kg (OBE, FPIE, PSU)
Volume	400 x 575 x 235 mm
Power	~35W (max), ~1.5W (standby)

Optical Design

Preliminary optical design accommodates 600 pixel-cross track field CHROMA focal plane array and fulfills science-driven measurement requirements



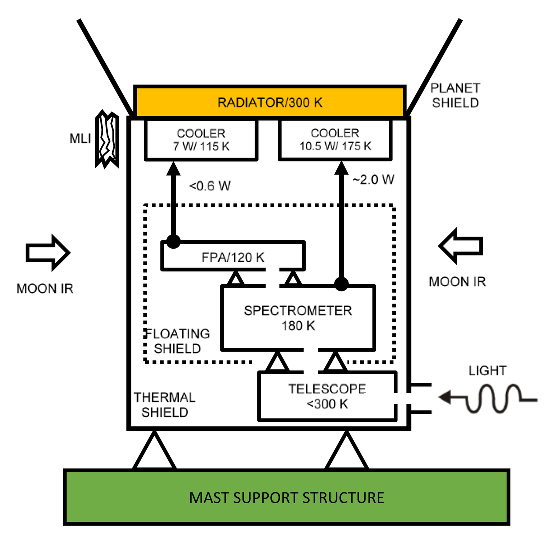
Left: UCIS-Moon optomechanical model; *Right:* Section view showing optical elements



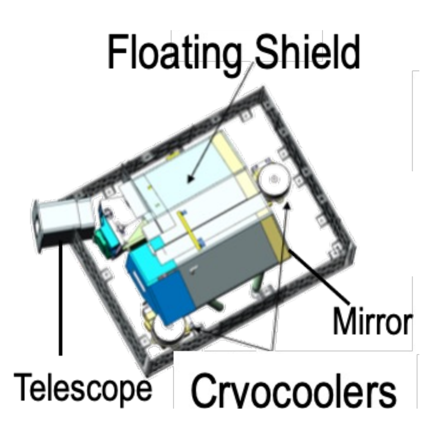
Left: UCIS-Moon optomechanical hardware assembly with telescope (silver) and spectrometer housing (gold); *Right top:* Grating installing; *Right bottom:* Mirror assembly being installed into housing.

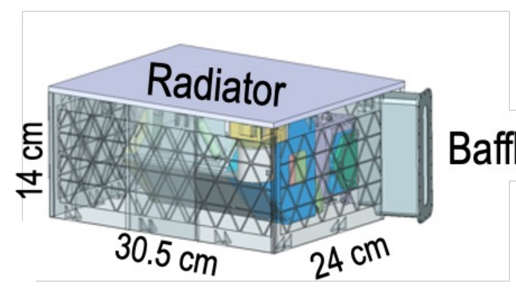
Operation in Lunar Thermal Environment

- Focal plane array (FPA) and spectrometer need to operate at 120K and 180K respectively
- Using two active cryocoolers (Ricor K50N) to offer the greatest operational flexibility and accommodate many different landing sites



Thermal block diagram for the spectrometer assembly

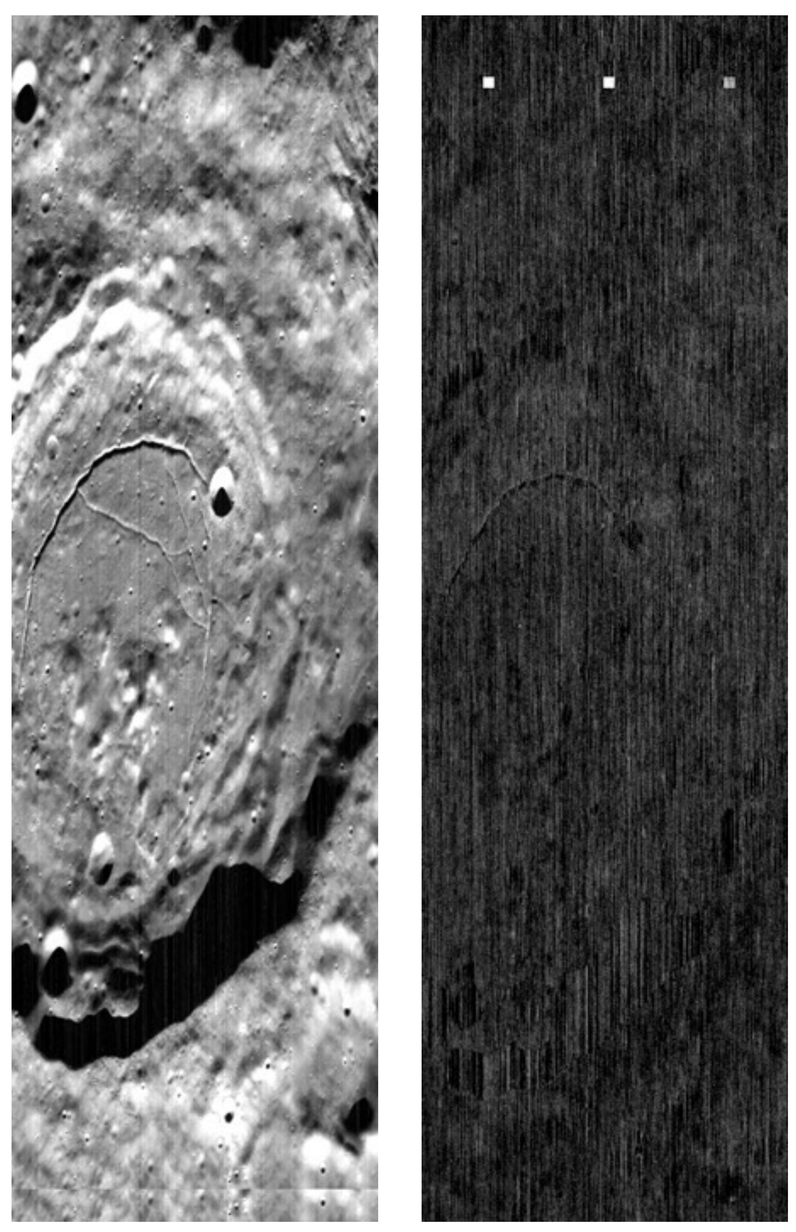




Placement in thermal shroud

Onboard Data Processing

- Ported matched filter mineral detection software to flight-ready snapdragon processor.
- End-to-end analysis chain is self-contained and performs dark subtraction, flat fielding, radiometric calibration and matched filter detection to identify small subpixel concentrations of known target materials.
- We have reconfigured it for mineral and volatiles detection, and evaluated it on terrestrial and lunar case examples.
- In lunar case, we generated synthetic targets by first extrapolating M3 flight data to the UCIS-M wavelength range, and then adding absorption features of small OH, H2O, and water ice concentrations.
- The lunar case was run on a snapdragon processor on the International Space Station on Oct 18, 2021.



Test scene derived from M3. Three surface features were injected with different volatiles - OH, molecular H2O, and water ice with 10% band depth. (left) Near-infrared intensity channel (right) detection result, with brighter pixels in the detection image corresponding to a stronger match.

Acknowledgements

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