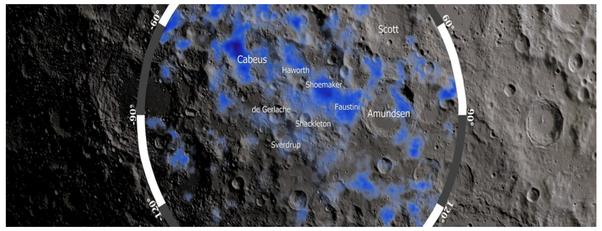
Instrument for Performing Laser-Induced Breakdown Spectroscopy (LIBS) in a Lunar Permanently Shadowed Region (PSR)

Problem Statement

Evidence suggests that water ice deposits on the Moon are scattered non-uniformly throughout permanently shadowed regions (PSRs). Mapping the location and concentration of the ice could facilitate its extraction and use for lunar operations.



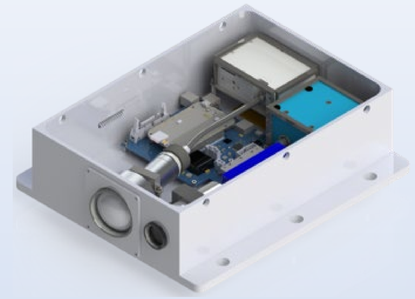
NASA Lunar Reconnaissance Orbiter (LRO) water concentration data projected onto a map of lunar PSRs.

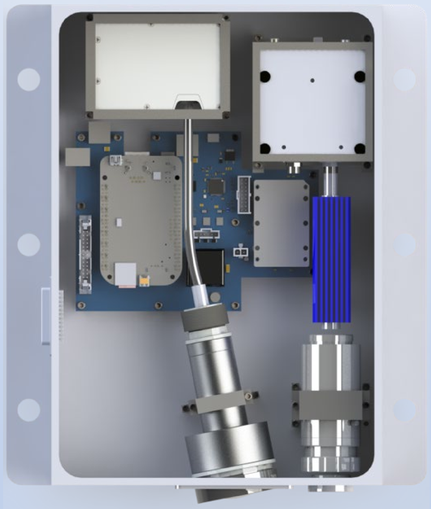
Thesis Statement

Oasis, a laser-induced breakdown spectroscopy (LIBS) instrument designed to provide detailed, locally procured data on water concentration in PSRs, directing the Artemis Program towards areas where their water-ice mining efforts will have significant return on investment.

LIBS

Laser-induced breakdown spectroscopy is a chemical analysis technique in which a pulsed laser is focused onto a target, which is excited to a state of plasma. As the plasma cools, characteristic wavelengths are emitted from elements or molecules in the plasma. Emitted light is captured by collection optics and guided into a spectrometer for spectral analysis.





Top: Isometric view of payload
Bottom: Top view of payload
*both views omit the lid to show internal components

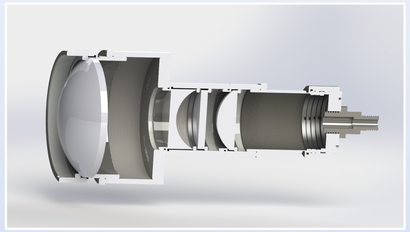
Oasis System Design

Science & Optics: The Oasis LIBS system ablates lunar regolith with a MicroJewel DPSS 1064-nm Nd:YAG laser and collects emissions with an Ocean Optics FLAME-T-VIS-NIR spectrometer. Our team developed custom optical systems for both of these instruments. The laser optical system focuses the laser beam in order to yield the power density required for ablation (5 W/cm). The spectrometer optical system filters out emissions from the laser beam itself (which unfiltered would saturate and potentially damage the spectrometer) and collimates light from the plasma emissions. Lag time between laser fire and spectrometer sampling is minimized in order to maximize photon capture.

Electronics: Oasis uses a Beaglebone Black Industrial as its flight computer, which communicates with the host craft, controls the instrumentation, and monitors the thermal control system. A custom PCB is used to interface components and ensure each component receives the appropriate input voltage. The flight computer has custom software libraries to reliably control the laser and spectrometer.

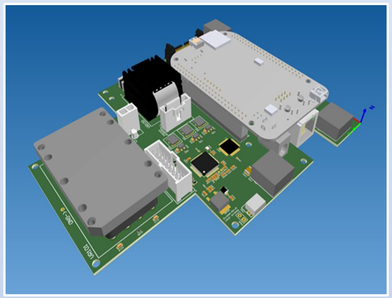
Thermals: Oasis has a thermal control that maintains a desired temperature range within the payload. Etched foil heating elements controlled by a dedicated thermal logic controller (TLC) are used to warm the components by conduction, and an optical coating applied to the housing exterior ensures consistent heat loss by radiation. A pulse-width-modulated (PWM) signal amplified through N-MOSFET gates varies the heat output of the heating elements.

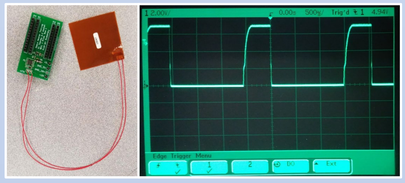
Structures: The Oasis structural housing has flanges to attach to the host. Components are secured with standoffs tapped into the housing floor and baseplates when necessary. The spectrometer optical system is angled toward the point of ablation to maximize data quality and is mounted into the housing wall with a custom interface.



Spectrometer optical system

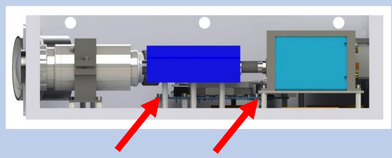
Custom PCB with flight computer attached

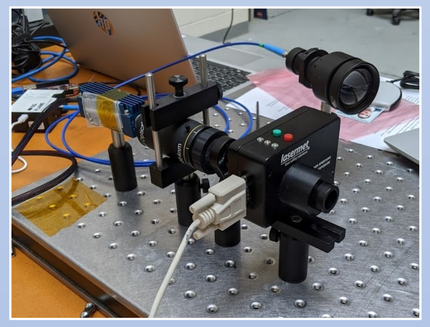


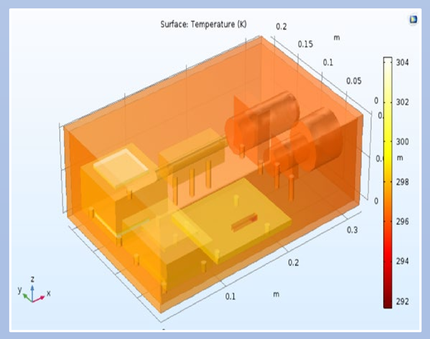


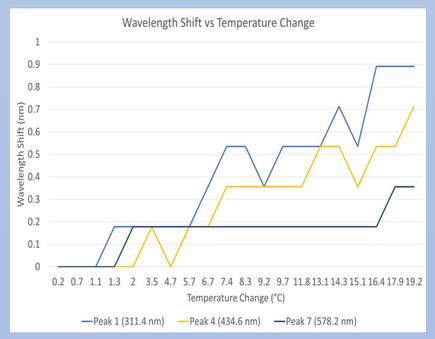
Left: TLC wired to heating elements
Right: Voltage on MOSFET gate relative to ground

Longitudinal cross section of payload to expose standoffs









Top Left: Laser and spectrometer optical systems on NRL test bench
Top Right: Ablation of lunar regolith simulant sample
Bottom Left: COMSOL Multiphysics simulation of payload showing temperature distribution of the payload; these simulations showed that the heat loss did not exceed the heat output of the payload components and heaters
Bottom Right: Wavelength shift in spectrometer readings plotted against temperature (resolution of spectrometer is 1.33 nm); wavelength shifts are all below 1.33, therefore they are not discernable by the spectrometer

Conclusions

Verification Method	Conclusions Drawn
Preliminary LIBS testing at Naval Research Laboratory (NRL) facility	Verified laser's ability to ablate lunar regolith simulant (with focusing optics) Verified software's ability to control laser and spectrometer Verified thermal system's ability to maintain operating temperatures during laser firing Indicated the need for an external spectrometer trigger
Instrument sensitivity test	Indicated that spectrometer readings are negligibly affected by expected temperature variation
Thermal logic controller (TLC) testing	Verified the TLC's ability to control heater output through a PWM signal
COMSOL Multiphysics simulation	Verified that the thermal control system can maintain operating component temperatures

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