air-LUSI is a NASA ESTO AITT Demonstration Program

2 year project to measure the lunar irradiance at high altitude with low uncertainties over the Vis-NIR spectral range

- 3 deployments planned
- 1 Engineering Flight and two Demonstration Flights

It is all about the uncertainties

What uncertainties constitute a successful demonstration?

- AITT Proposal: we are trying for 0.5 % uncertainties
- Tom Stone, USGS: A lunar irradiance model with 0.5 % to 1.5 % absolute uncertainties relative to the SI makes the Moon a viable (affordable) on-orbit source for
  1. Transfer to Orbit Effects
  2. Ensuring consistency between the calibrations not only of overlapping but also non-overlapping sensors (to help minimize gap effects)
  3. Possibly/potentially as an absolute SI traceable on-orbit calibration source
- GSICS/CEOS-IVOS Lunar Calibration Workshop, December 2014.
  - A Workshop objective was to provide the international community with a validated and traceable version of the ROLO Model GSICS Implementation of the ROLO model (GIRO). One of the goals was getting absolute uncertainties under ~ 1 %.

At the end of the Program, we would be satisfied to have a sub-1 % lunar irradiance data set that we have confidence in.

Engineering Flights

Expectations were to Integrate air-LUSI into the ER-2 and Demonstrate functionality of sub-systems in-flight

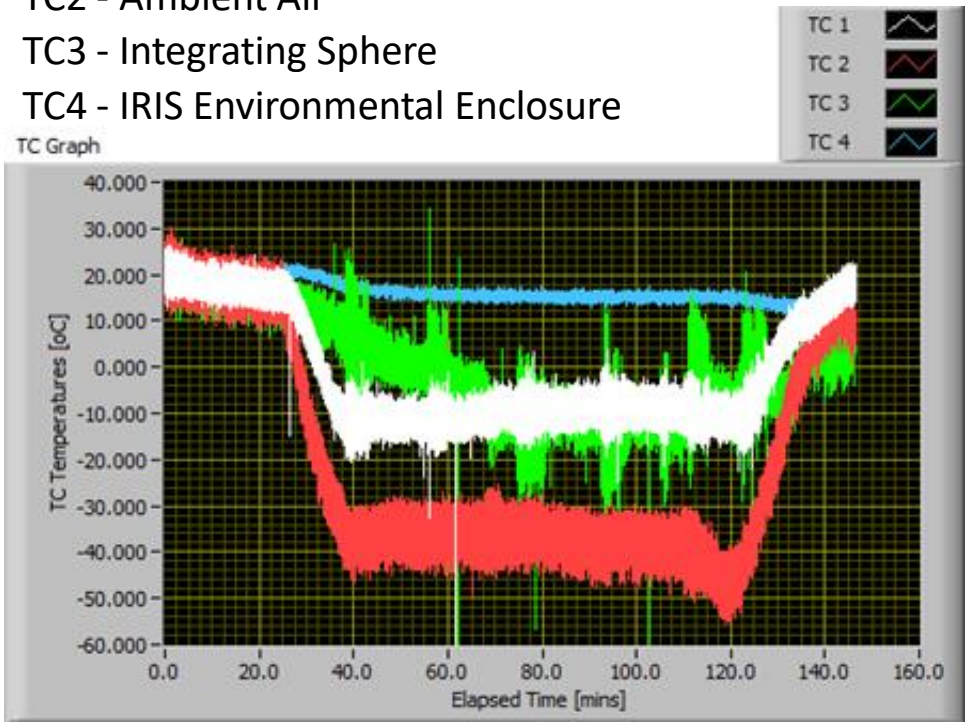
NASA: Return the pilot and the aircraft safely to the ground

Key Elements for Low Uncertainty

- Create a laboratory environment inside the IRIS box
- Radiometric Stability of the Telescope
  - Spectrograph stability
- Characterization and calibration of both IRIS and the Reference Spectrograph
- Field calibrations
  - In the laboratory at Armstrong pre- and post- integration into the aircraft
  - In the hanger pre- and post flight
- MLI blanketing, heaters and thermostats to control temperature
- In situ monitors
  - LED stability source
  - Thermocouples
  - Pressure sensor

Heaters with thermostats to control temperature
Thermocouples to monitor and control temperature

TC1 - Fiber Bundle
TC2 - Ambient Air
TC3 - Integrating Sphere
TC4 - IRIS Environmental Enclosure



Environmental Enclosure (blue) and the Ambient Air (in the aft-body) (red) Seemed to work

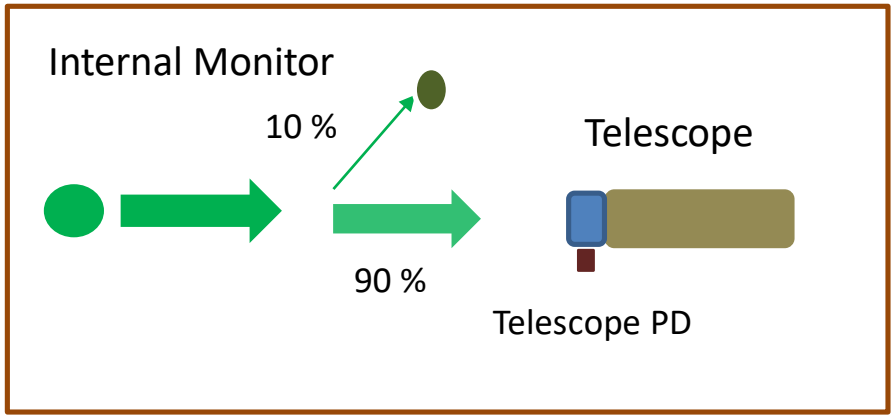
TC3, green, on the integrating sphere, had come loose, so we can explain that temperature measurement.

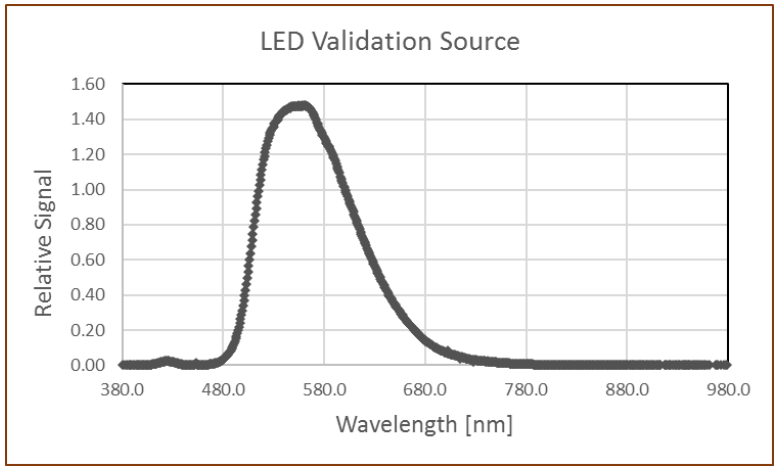
Measurements from TC1, the fiber bundle (white) are problematic; the control set point was +20 °C ±10 °C.

Pressure in the box was stable

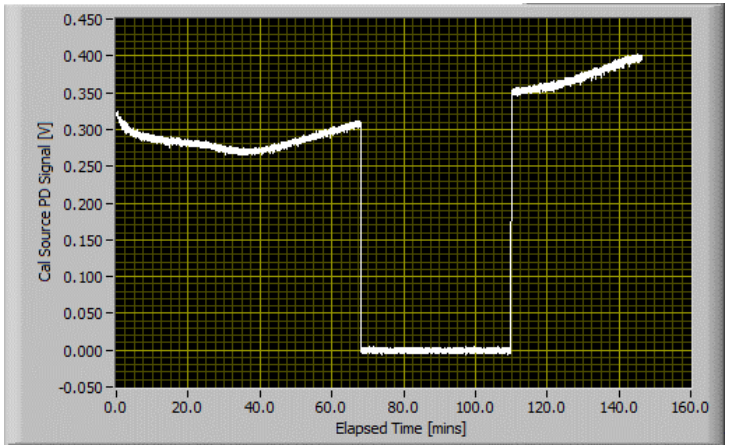
Thermocouples did not have a reference. We now have the proper reference.

In-situ LED monitoring

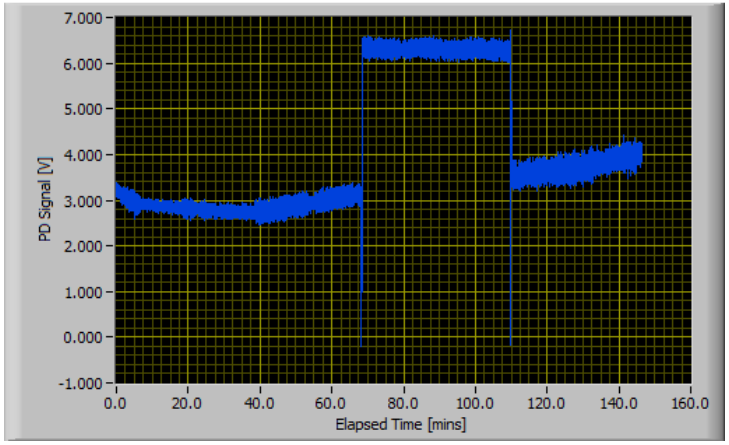




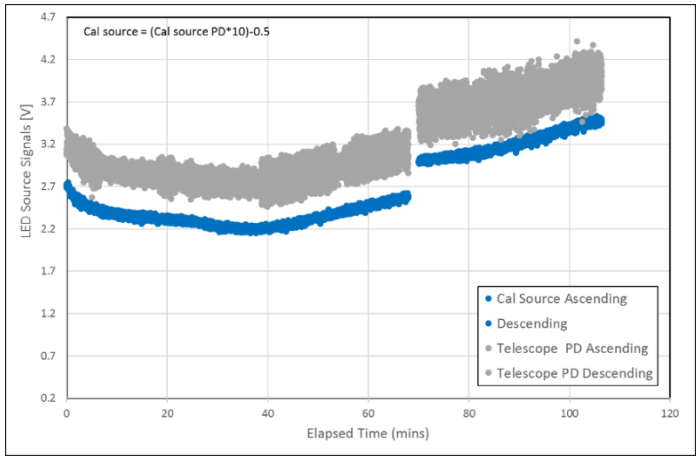
LED PD

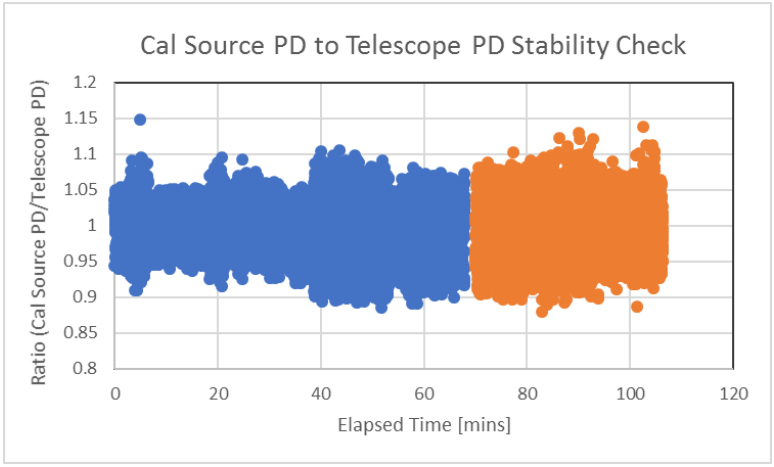


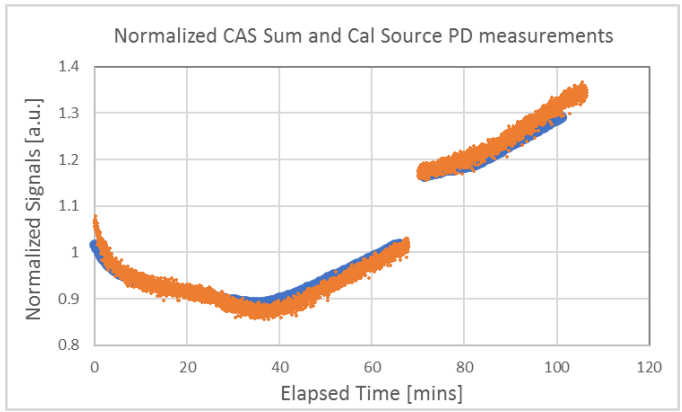
Telescope PD



In-situ LED monitoring



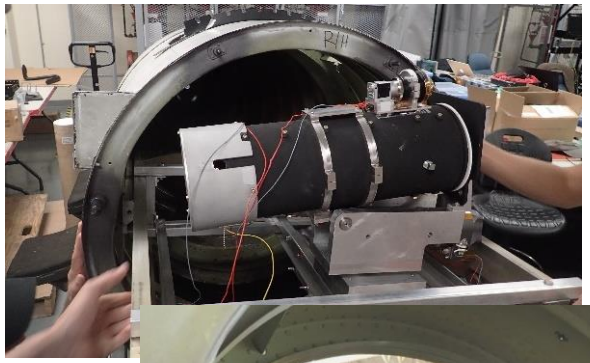


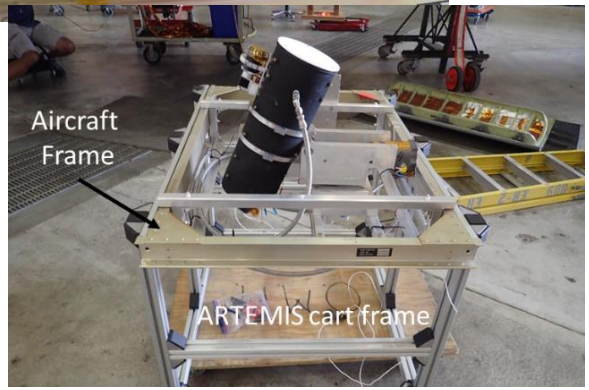


Increased LED output to improved Telescope PD S/N

Pre- and post-flight calibrations in the hanger

we would take the telescope out of the aft-body and put it on the ARTEMIS cart





In-situ Calibration

Protocol: Calibrate the system pre- and post-flight.
We ended up with 3 in-situ calibrations
pre-EF1, post-EF1 (afternoon), pre-EF2 (evening)
Nothing was moved between post-EF1 and pre-EF2 calibrations
We did not do a post-EF2 calibration

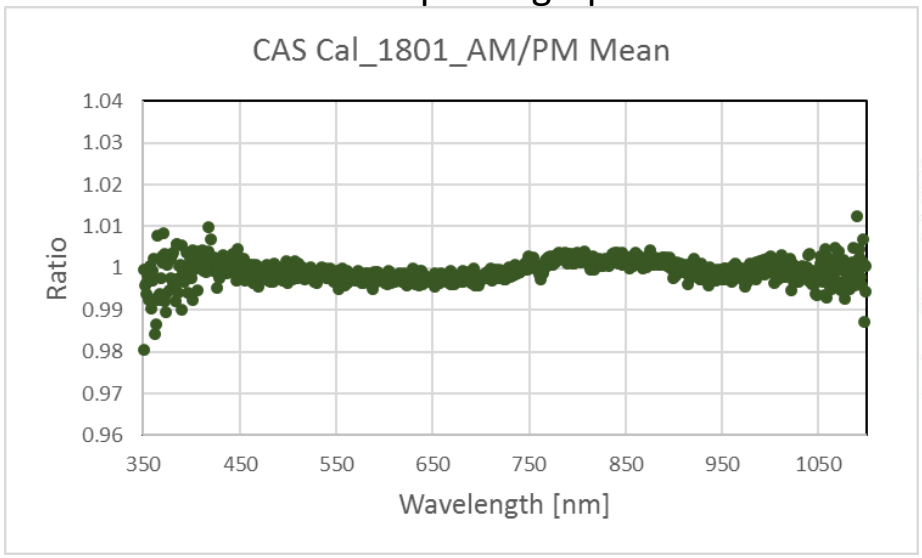
Post deployment calibration back at NIST

airborne Lunar Spectral Irradiance (air-LUSI) mission

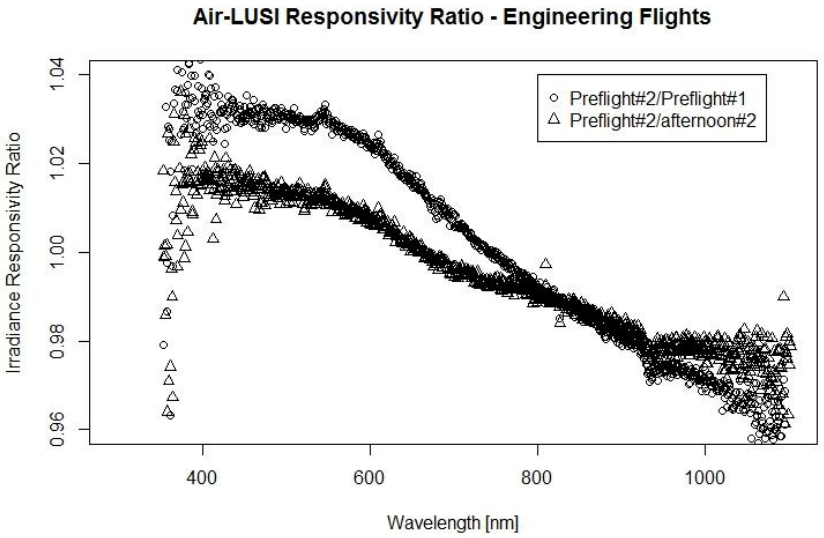
PI: Kevin R Turpie, UMBC/JCET

Calibration Issue: Comparing the two Aug 1 calibrations
The setup was not changed; this is a repeatability test.

Reference Spectrograph



Air-LUSI



The Reference Spectrograph repeated well;
Telescope repeatability ± 2 %; attributed to alignment or temperature or both

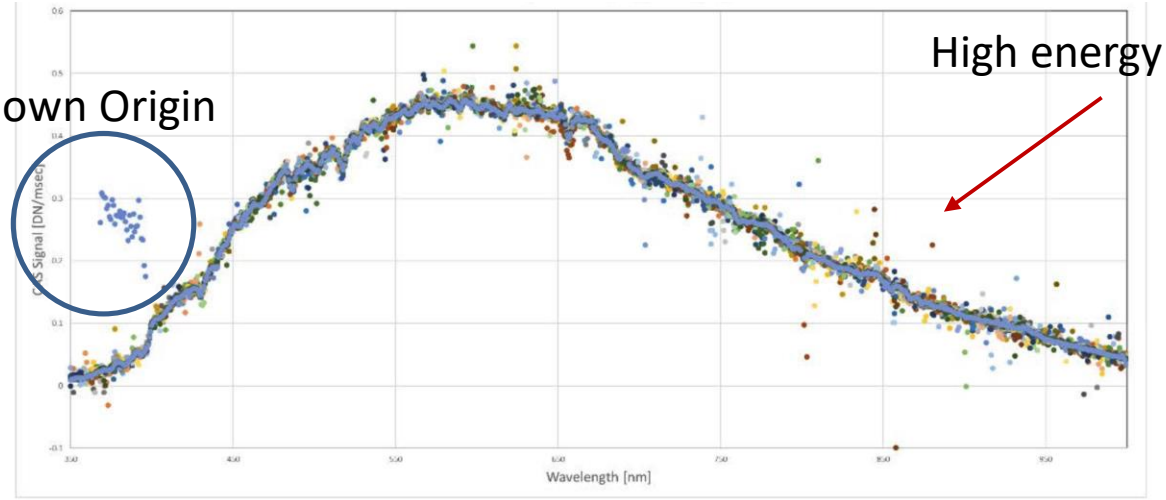
Alignment testing has been done at NIST
Thermal testing is underway; should finish in a week two.

Post-deployment calibration at NIST was used to determine the Lunar Irradiance

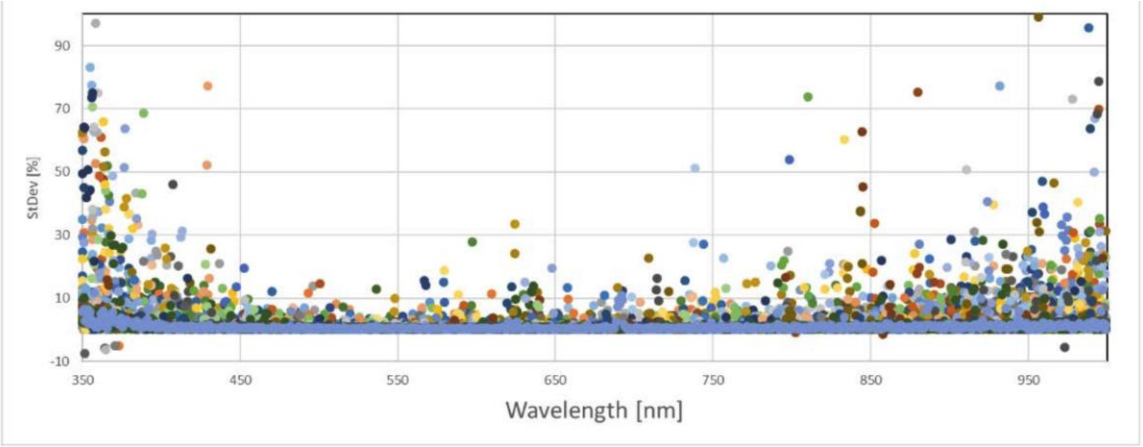
airborne Lunar Spectral Irradiance (air-LUSI) mission

PI: Kevin R Turpie, UMBC/JCET

Air-LUSI Lunar Measurements



StDev [%], 3 spectra averaging

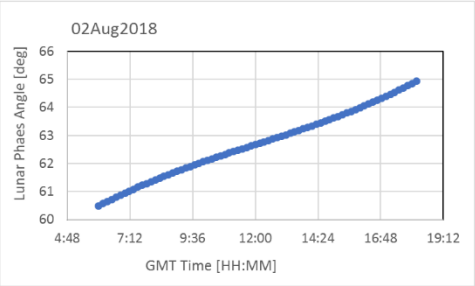


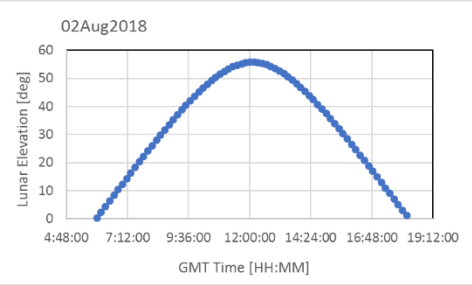
airborne Lunar Spectral Irradiance (air-LUSI) mission

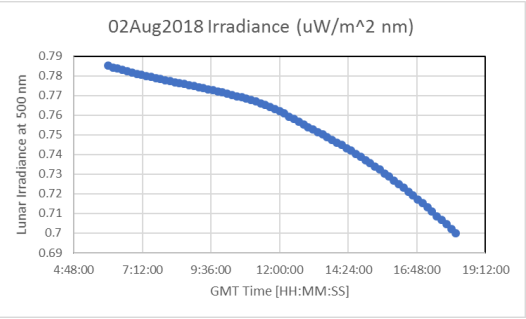
PI: Kevin R Turpie, UMBC/JCET

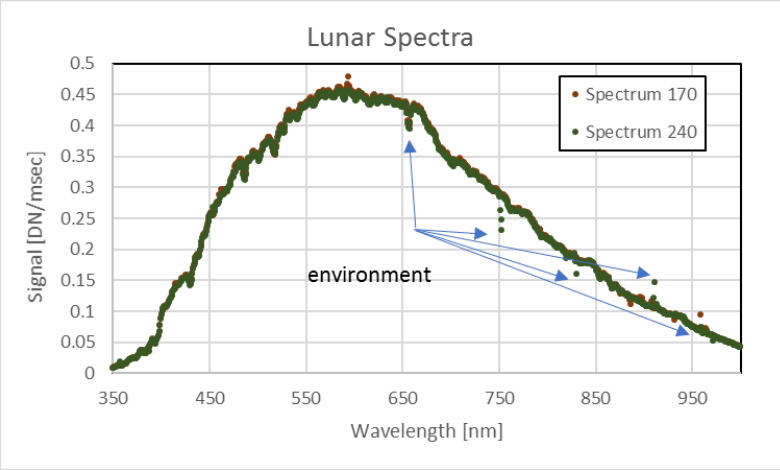
On-orbit Measurements of the Moon: EF#2 Signal-to-Noise

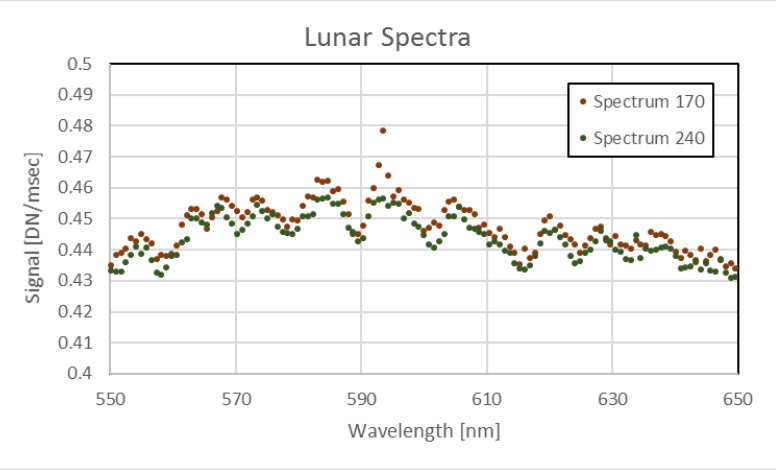
Lunar Irradiance changes slightly during flight







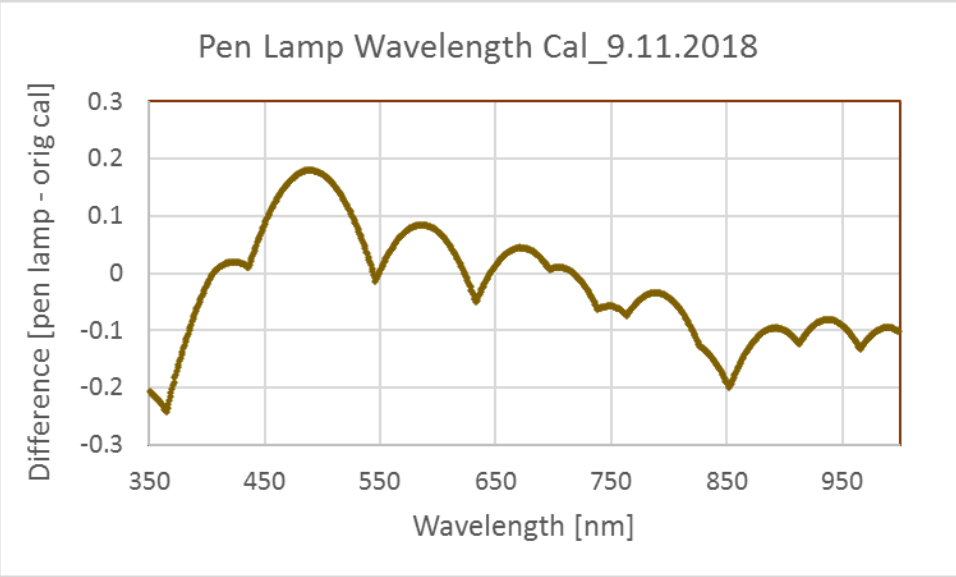




Measurements have the precision needed to see those changes

Observed small spectral errors in our measurements of Fraunhofer lines

Told us a wavelength calibration needed



Still to do:

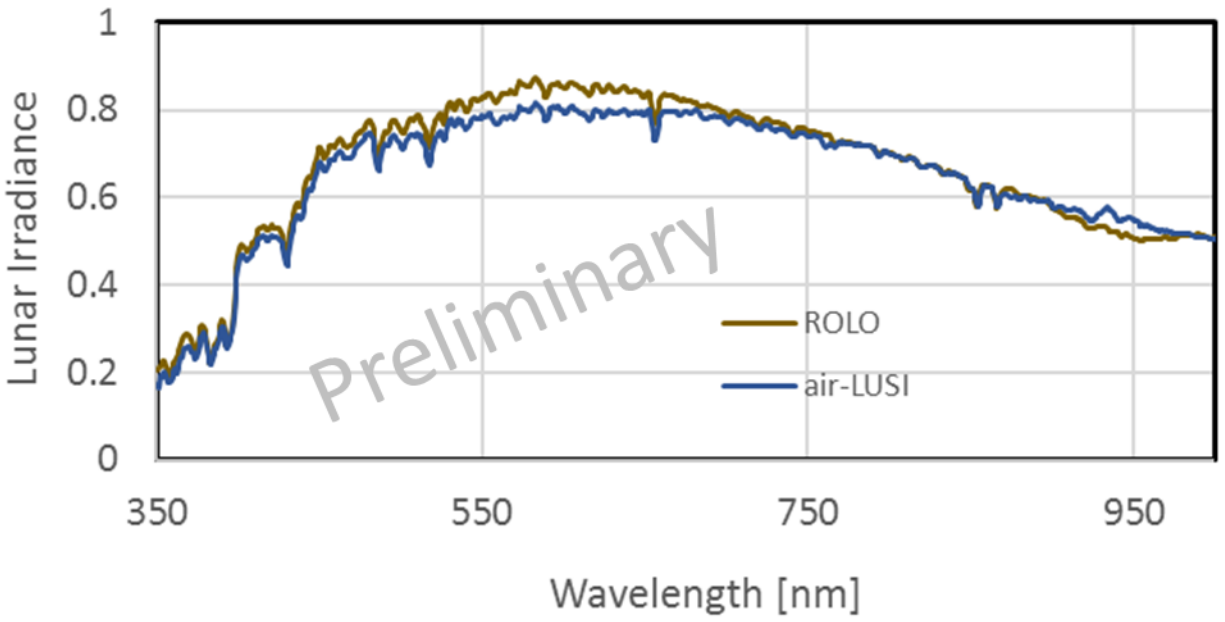
Improved Wavelength Calibration using SIRCUS

Wavelength Calibration of the Reference Spectrograph

Quick Comparison between air-LUSI Measurements and the spectral distribution of the ROLO Model

Engineering Flight #2 Lunar Irradiance

Quick-look comparison between the air-LUSI-measured and the ROLO Model-predicted lunar irradiances (provided by Tom Stone)



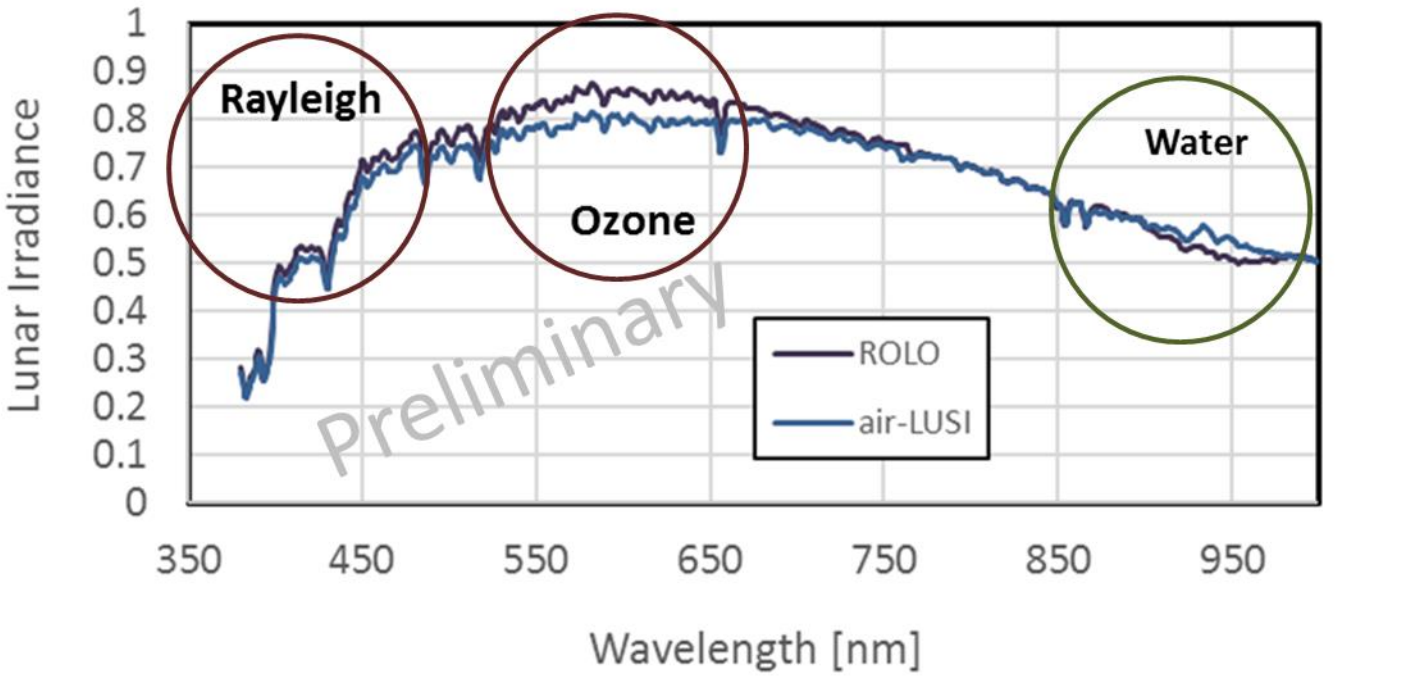
ROLO data provided by Tom Stone

airborne Lunar Spectral Irradiance (air-LUSI) mission

PI: Kevin R Turpie, UMBC/JCET

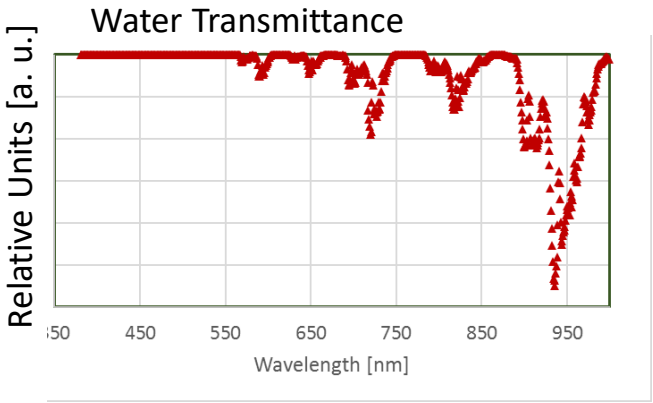
Lunar Measurements

Instrument Calibration

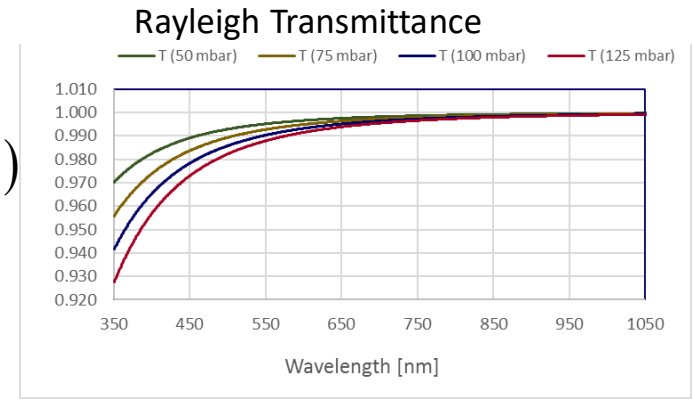


Correcting air-LUSI responsivity for Water Absorption in the Calibration and Atmospheric Scattering in the Lunar measurements

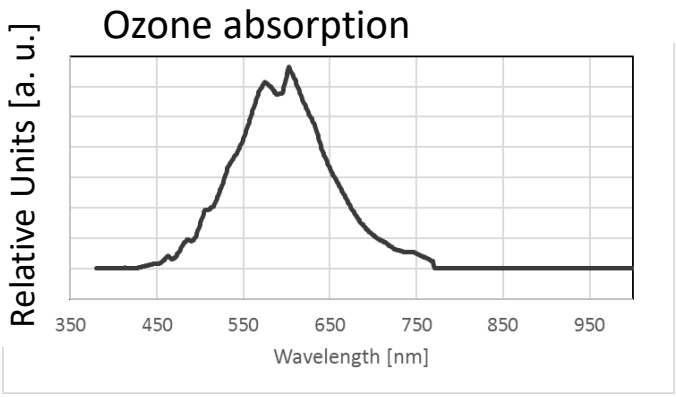
α



$f(mbar)$



β



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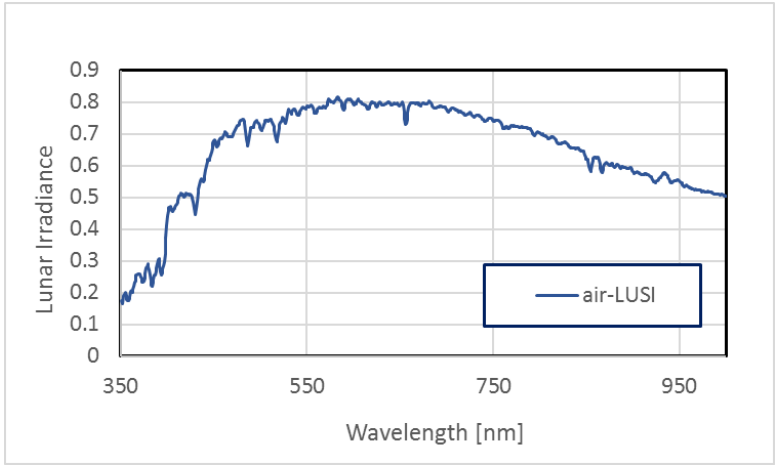

Scaling was done empirically to minimize differences between Measurement and Model.

Air-LUSI corrections significantly reduced the differences between Measurement and Model. The Science Team needs vet this ad hoc approach - and improve on it – before results are publicized.

Looking at the Uncertainty Budget

	Target	Field	Lab
CAS to FEL Cal	0.3%	0.3%	0.3%
CAS measurement of sphere	0.2%	0.2%	0.2%
D1	0.1%	0.4%	0.2%
D2	0.2%	0.4%	0.2%
LUSI measurement of sphere	0.2%	0.2%	0.2%
LUSI measurement of Moon	0.2%	0.4%	0.4%
Atmospheric Correction	0.2%	1%	1%
Stability	0.1%	10%	0.3%
Total	0.55%	10%	1.2%

Let me replace Reproducibility of the calibrations

with the Stability of the spectrograph

Demonstration Flights

Hoping for April 2019, May is still viable

If we miss those windows, the next opportunity is in August