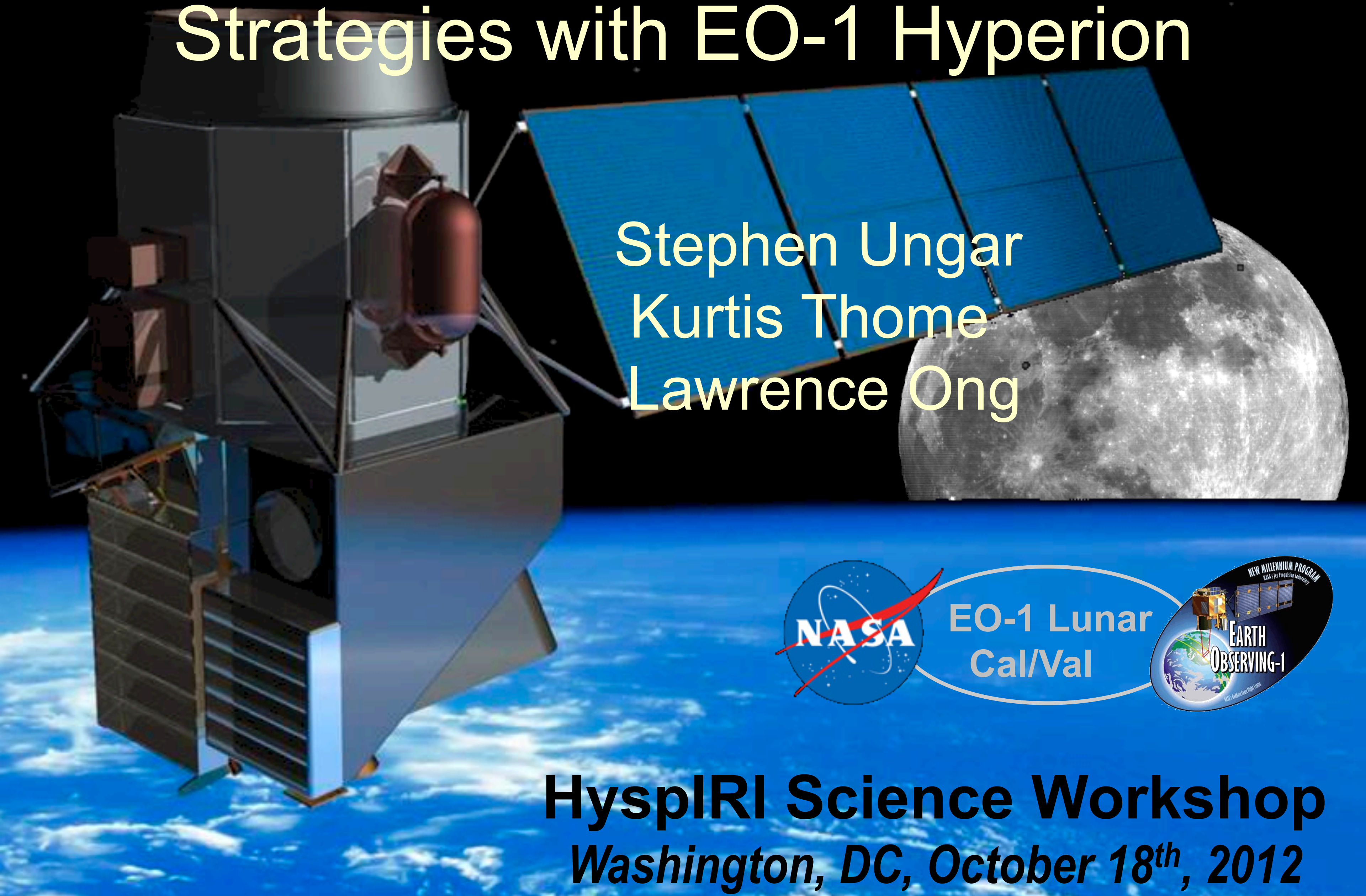
Prototyping HyspIRI VSWIR Calibration Strategies with EO-1 Hyperion



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EO-1 Lunar Cal/Val

NASA

NEW MILLENNIUM PROGRAM

EARTH OBSERVING-1

HyspIRI Science Workshop

Washington, DC, October 18th, 2012

EO-1 Hyperion Calibration Strategy

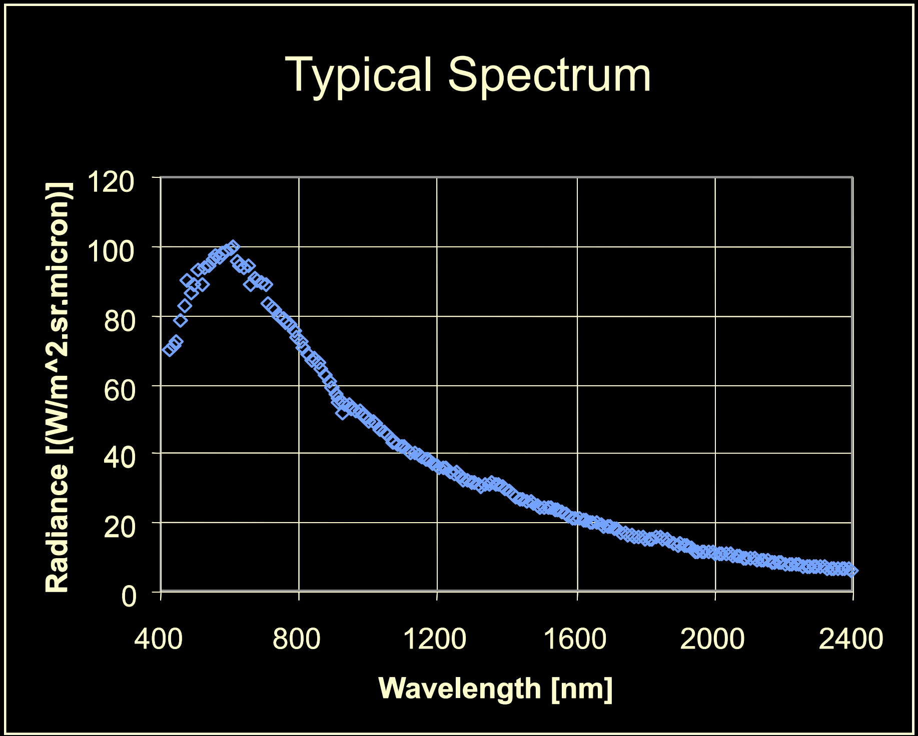
- Primary mode relies on fairly frequent views of a well characterized solar illuminated diffuser *panel.*
- Monthly lunar views (using the earth view optical path) serve to monitor the stability of the solar observing system.
- Additionally, onboard lamps are helpfully in establishing short term fluctuations in the observing system response.
- Periodic observations of well characterized ground targets (i.e. vicarious calibrations) are used as a further check on changes in the observing system response.
- Statistical trending techniques are used to monitor changes in relative detector-to-detector response within each band.

EO-1 views the moon *monthly*

(EO-1 ALI Pan band)

Near-Full Moon

(EO-1 Hyperion)



Cumulative Spectral Radiance

Why EO-1 views the moon *monthly!*

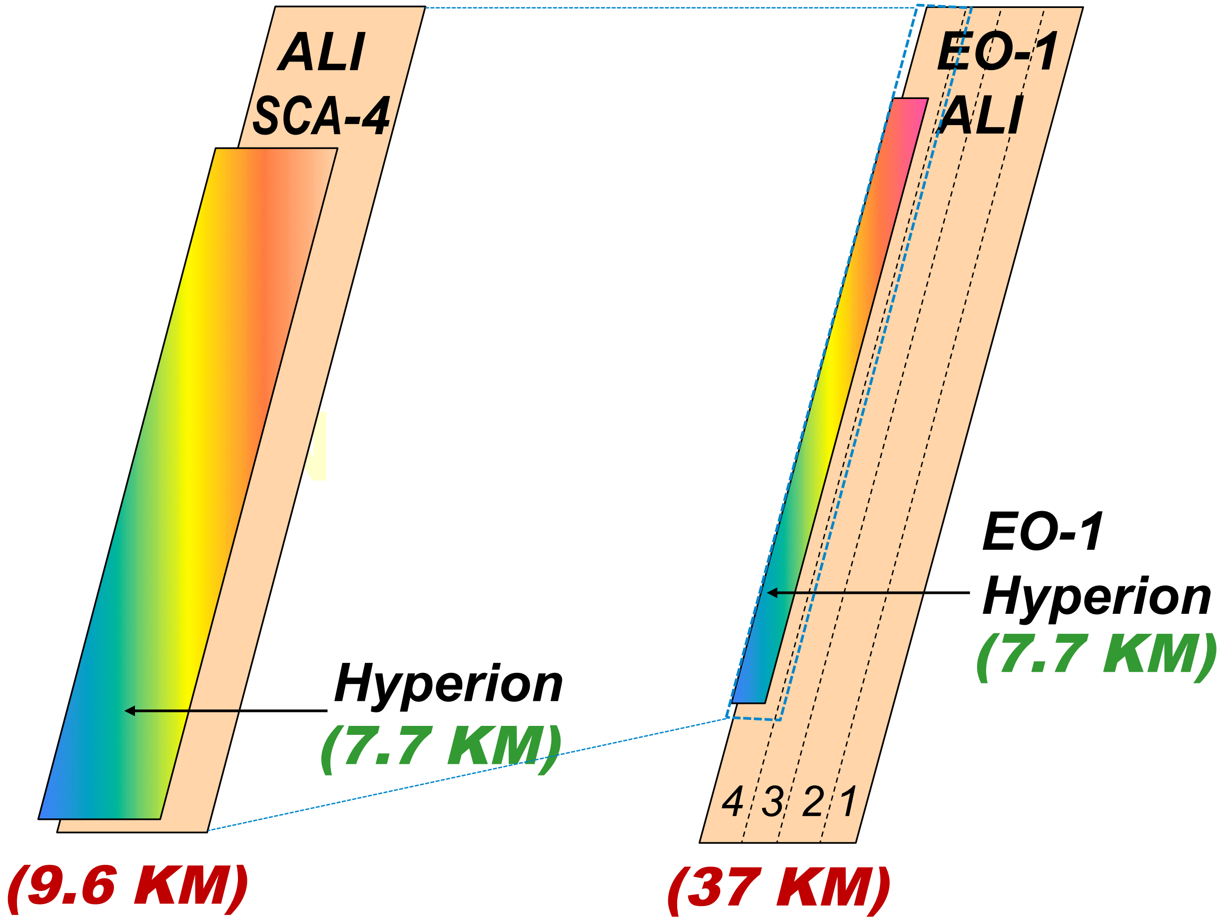
Lunar Calibration

Calculate the integrated lunar spectral irradiance ($E_M(\lambda)$) and compare with the USGS Robotic Lunar Observatory (ROLO) lunar irradiance model

What I have learned from EO-1 Views the Moon

- Accommodating lunar views certainly has implications for spacecraft design and operations.
- Not accommodating lunar views has implications for the Climate Science community's requirement for generating high quality long term Climate Data Records (CDRs).
- With some forethought, missions can be structured to accommodate lunar looks, subject to non-debilitating operational limitations, with modest cost impact.
- The international calibration/validation community has strongly endorsed use of the moon as the most expedient route to NIST quality absolute calibration needed for incorporating multi-satellite data into long term CDRs.

ALI and Hyperion Ground Tracks

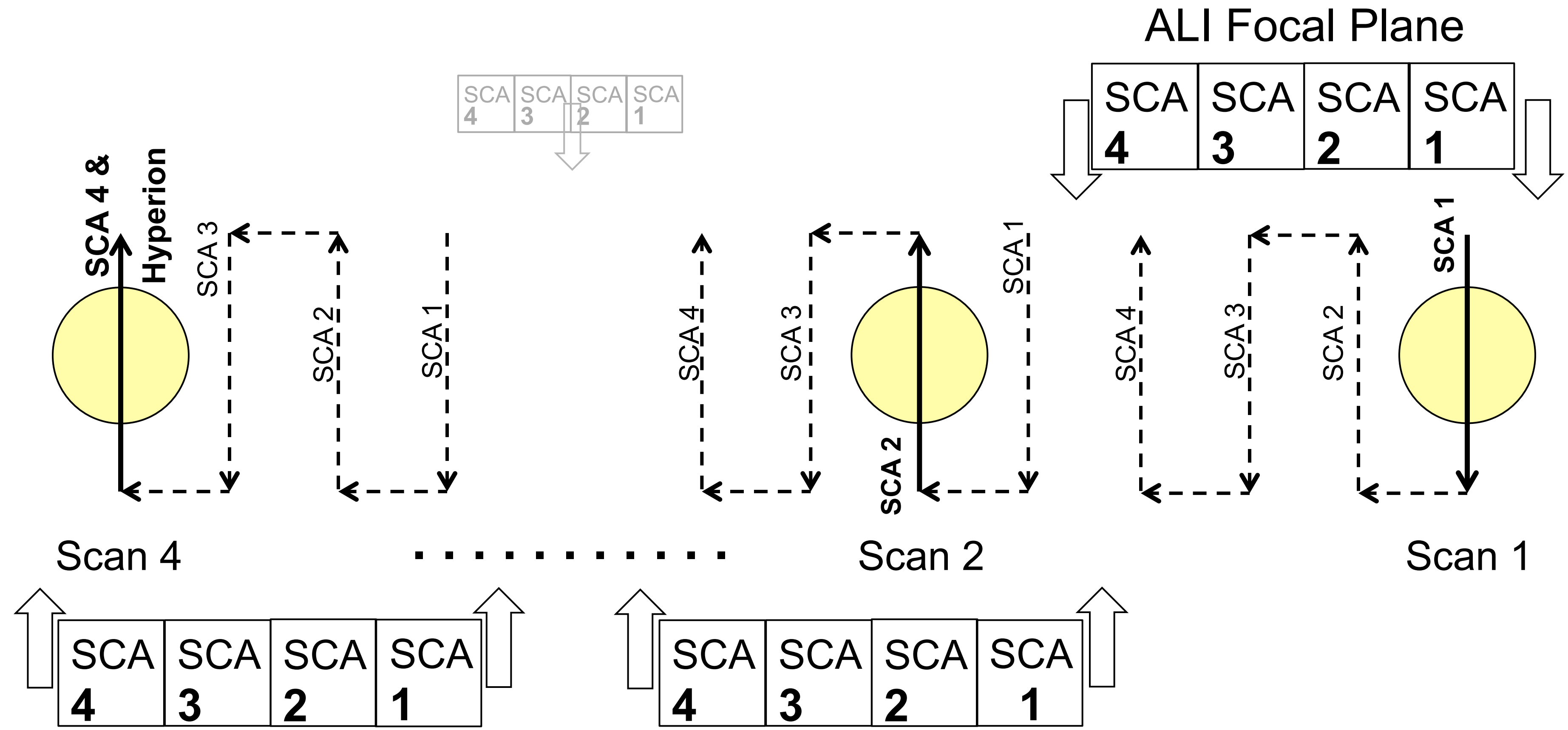


The Advanced Land Imager (ALI) is comprised of four Sensor Chip Assemblies (SCAs).

EO-1 Lunar Calibration Sequence
December 2000 – December 2011

- Lunar Cal's have been performed monthly, with both ALI and Hyperion powered-on, at a +7.4° from full lunar phase angle.
- The lunar disk is an approximately (½)° object at EO-1's orbital location. This fits within the viewing angle of the Hyperion and each ALI SCA.
- During the lunar acquisition process, the S/C is maneuvered to scan an image of the moon for each SCA successively.
- Since the Hyperion is not co-aligned with the ALI SCA 4, the spacecraft pointing for each month alternates between SCA4 and Hyperion.

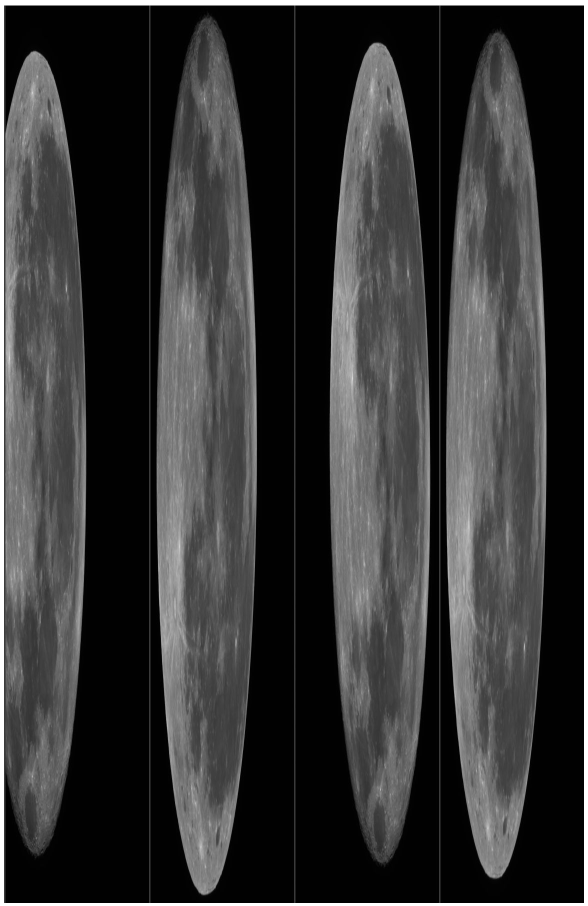
EO-1 Lunar Calibration Sequence
December 2000 – December 2011



EO-1 Lunar Images

Calibrated ALI Images

SCA4 SCA3 SCA2 SCA1

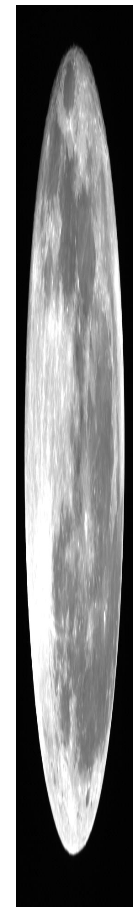


Typical ALI Images from Lunar Scans. One band from each of the 4 SCAs are shown here.

Differences in scan lengths are due to pitch rate differences.

In addition, the start times for each band within their respective SCA are different due to offsets in the chip geometry.

SCA4 is clipped because this sequence is centered on the Hyperion sensor.



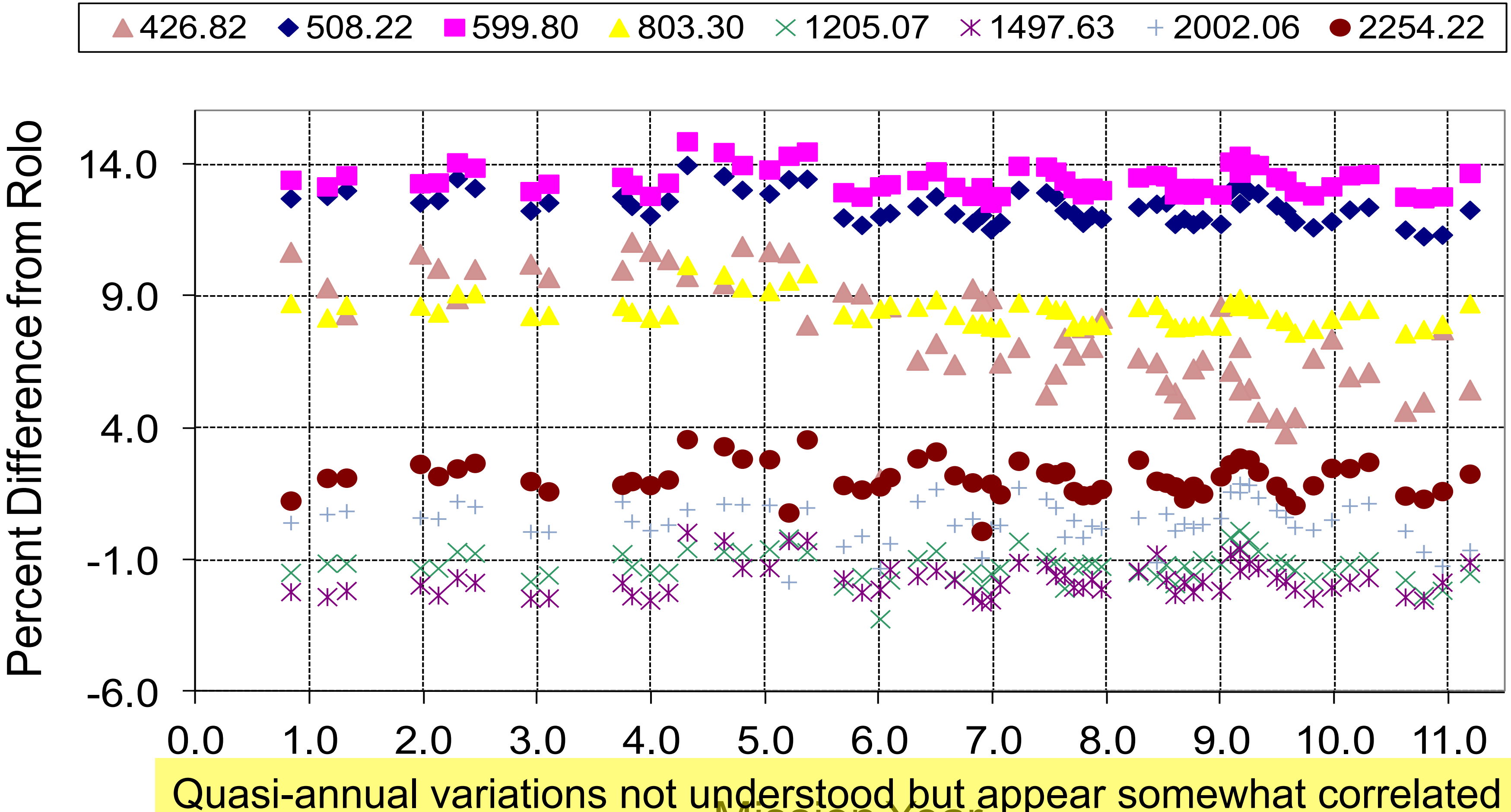
Calibrated Hyperion Image

The image shown was concurrently acquired with the ALI SCA4 image to the left.

Approximately 140 collects taken todate!

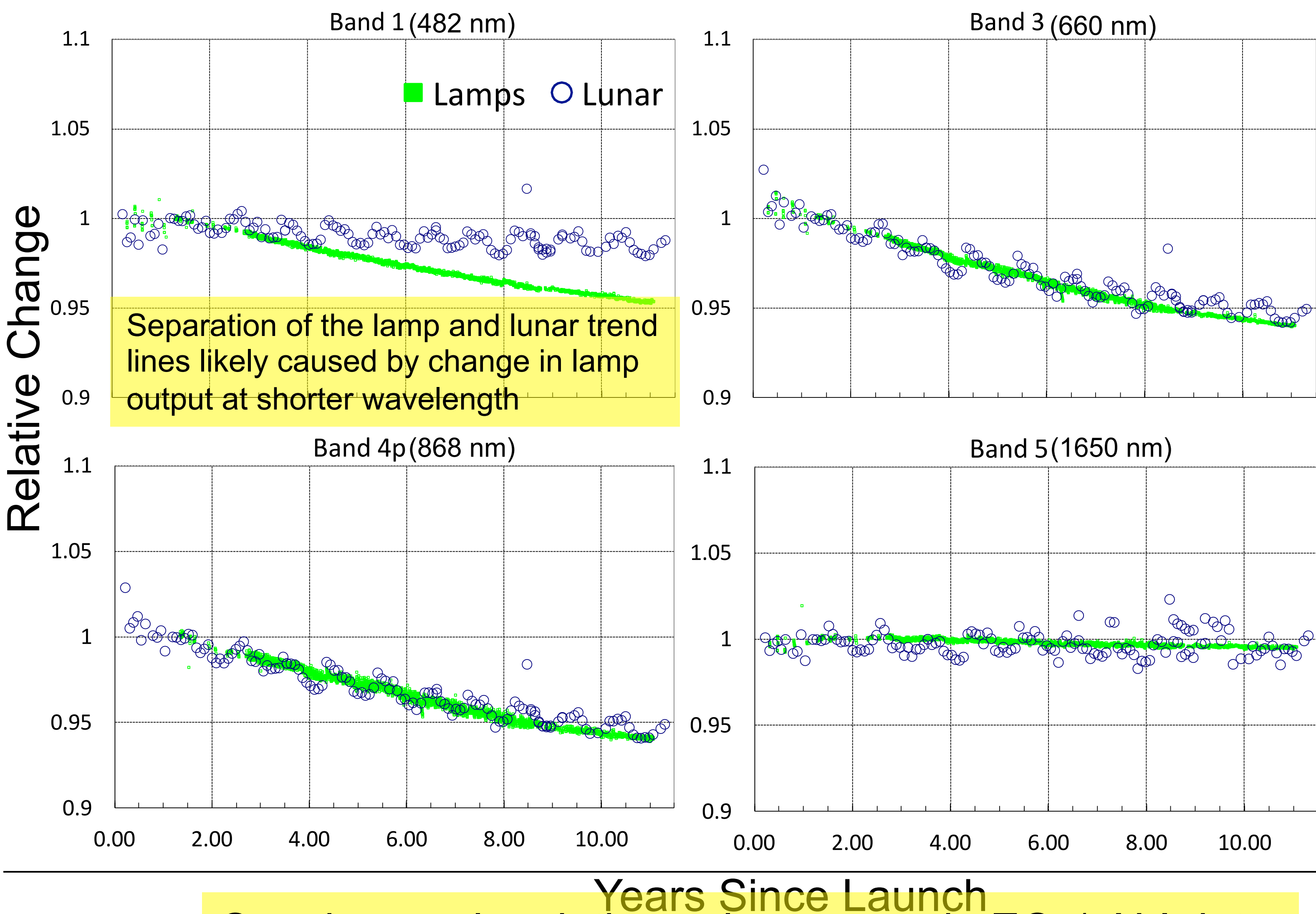
Hyperion Lunar Trends

Comparison of Hyperion integrated lunar responses with the USGS Robotic Lunar Observatory (ROLO) model for selected bands.



Quasi-annual variations not understood but appear somewhat correlated with the Sun-Moon and Spacecraft-Moon selenographic coordinates.

Temporal Trends of Selected Bands



Quasi-annual variations also appear in EO-1 ALI data

Summary of ROLO Comparisons

- The ROLO model provides a convenient avenue to conduct overall trending of instrument performance.
- Unable to characterize individual detectors
- Quasi-periodic trends observed – under investigation
- Absolute calibration?

Hyperion Lunar Observations

- Hyperion Lunar observations are potentially highly valuable for the lunar calibration of instruments on both polar-orbiting and geostationary satellites.
- Lunar spectra can be convolved with the spectral response function of any given instrument.
- The relationship between moon phase angle and spectral changes for selected channels require further investigation.

Future Use of EO-1 Lunar Images

Objective: develop a satellite-based lunar calibration strategy which will serve as the basis for cross calibrating space borne passive optical observing systems.

*The EO-1 Hyperion imaging spectrometer will be used to develop an exo-atmospheric spectral radiometric database for **a range of lunar phase angles surrounding the fully illuminated moon.***

***Initial studies include** a comprehensive analysis of the existing 11 year collection of monthly (plus some additional) lunar acquisitions.*

*Further studies select **specific lunar surface areas,** such as lunar maria, and their stability in the presence of lunar nutation and libration using a newly developed observing strategy to expand the EO-1 lunar dataset to include more phase angles during the next several years.*

Hyperion Lunar Calibration Activities

Hyperion is being used to slowly scan the lunar surface at a rate which results in up to **32X** oversampling to **effectively increase the SNR**. Several strategies, including comparison against the USGS RObotic Lunar Observatory (ROLO) model, will be employed to **estimate the absolute and relative accuracy** of the measurement set.

There is an existing need to ***resolve discrepancies as high as 10% between ROLO and*** *solar based calibration of* ***current NASA EOS assets****. Analysis of this dataset will lead to the development of strategies to ensure more accurate cross calibrations when employing the more capable, future imaging spectrometers.*

Hyperion Lunar Calibration Activities

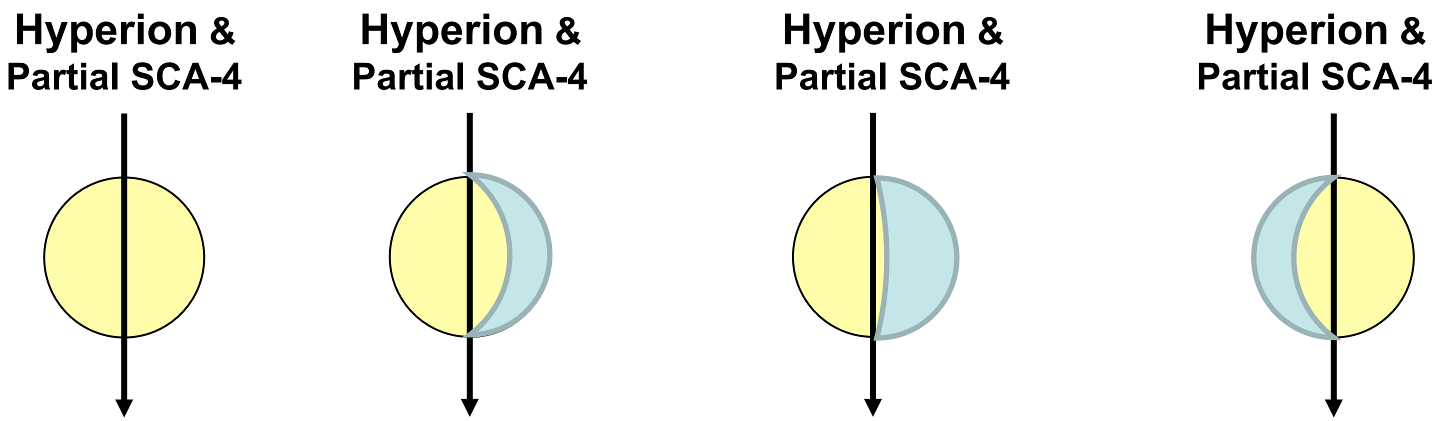
The techniques developed through this activity can be employed by future high quality orbiting imaging spectrometers (such as **HyspIRI,** HISUI, SHALOM and EnMap) to further refine calibration accuracies.

These techniques will enable the consistent cross calibration of existing and future earth observing systems (full spectral and multi-spectral),including those that do not have lunar viewing capability.

When direct lunar viewing is not an option for an earth observing asset, orbiting imaging spectrometers can serve as transfer radiometers relating that asset's sensor response to lunar values through near contemporaneous observations of well characterized stable ***CEOS*** *test sites.*

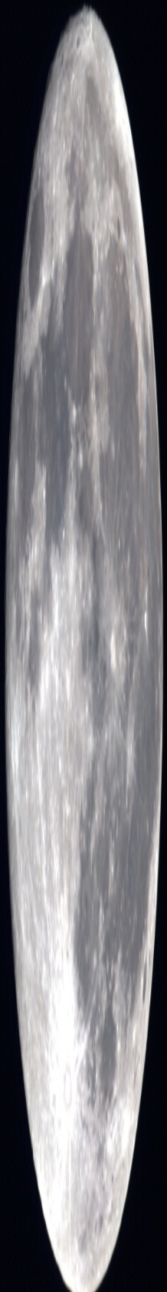
New Lunar Calibration Sequence

- ALI Cals performed monthly at +7.4° from full lunar phase angle
- Hyperion Cals performed monthly at -7.4° lunar phase angle
- During the Hyperion lunar acquisition process, the S/C is maneuvered to scan an image of the moon at a **32X** oversampling rate
- Additional Hyperion lunar acquisitions will be obtained at a variety of lunar phase angles



Hyperion Lunar Views

Oversampled by 8X



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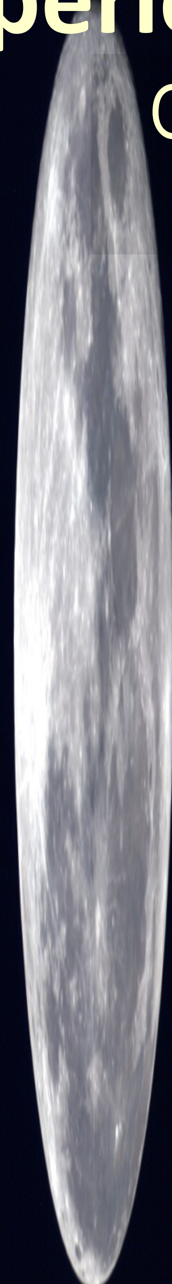

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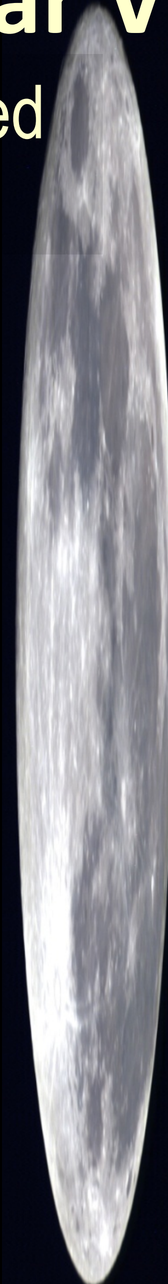

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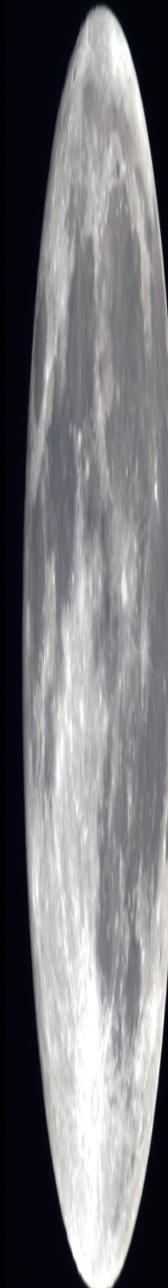


12/21/10

Hyperion Lunar Views

Averaged (Aggregated) Oversampled Images

1/01/10

4/28/10

6/27/10

12/21/10

Rotated Averaged (Aggregated) Oversampled Images

1/01/10

4/28/10

6/27/10

12/21/10

New Hyperion Lunar Strategy

Controlled Slow Scan to Oversample by ~32X

Level-0 Hyperion Data

← ORIGINAL

AGGREGATED →

Initial attempt provided oversampling at 28X but premature start of observation resulted in data cut-off

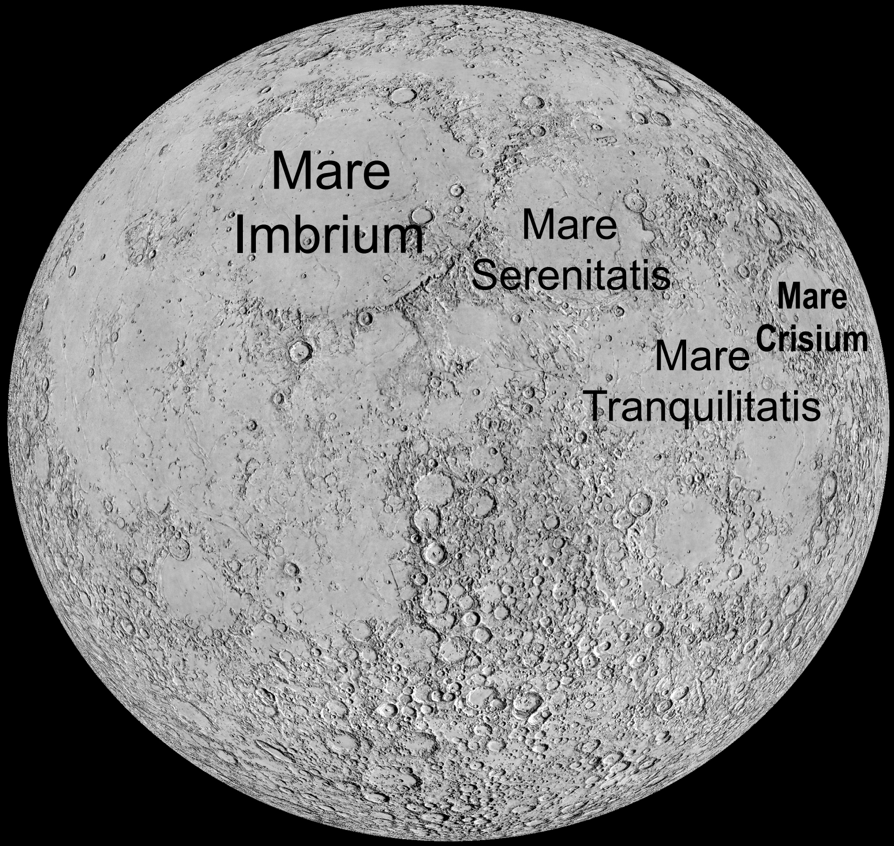
Next attempt corrected this and provides 30X oversampling

Hyperion views the moon *monthly*

(EO-1 ALI Pan band)

(Selected sites)

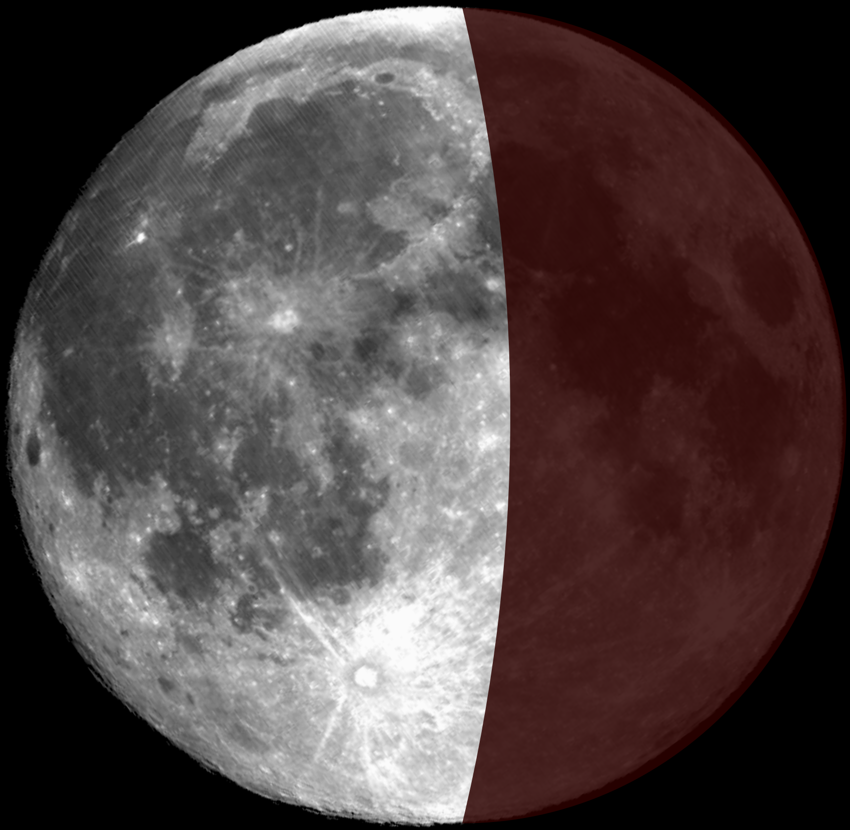
Full Moon



USGS Lunar Map

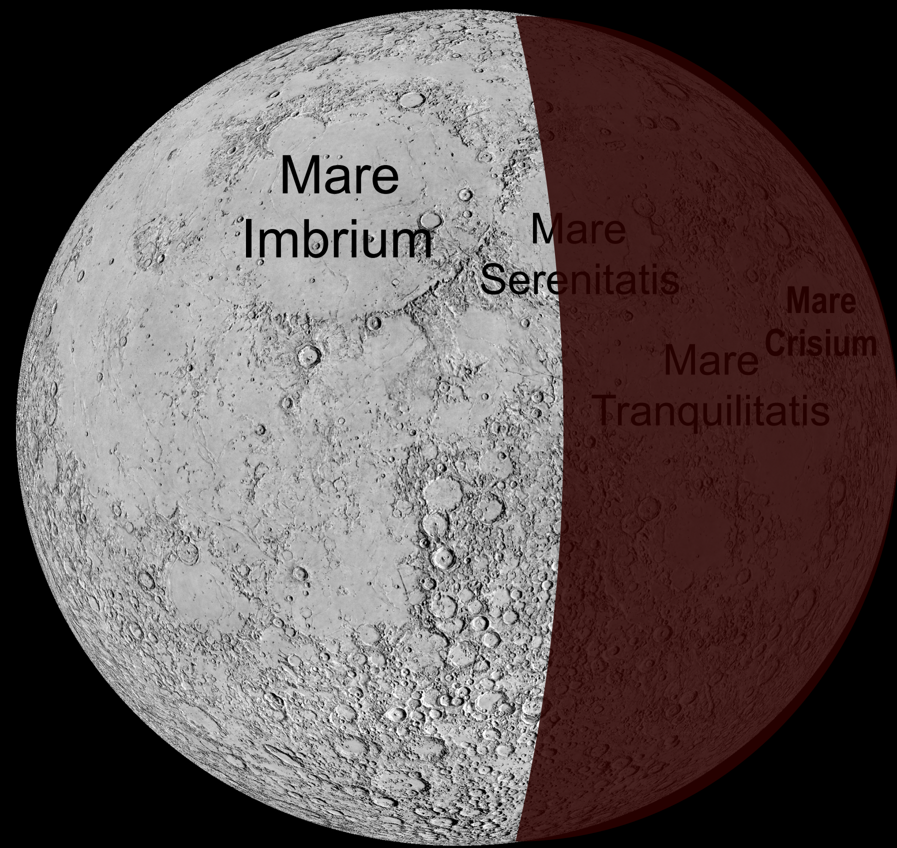
Hyperion views the moon *at multiple phases*

(EO-1 ALI Pan band)



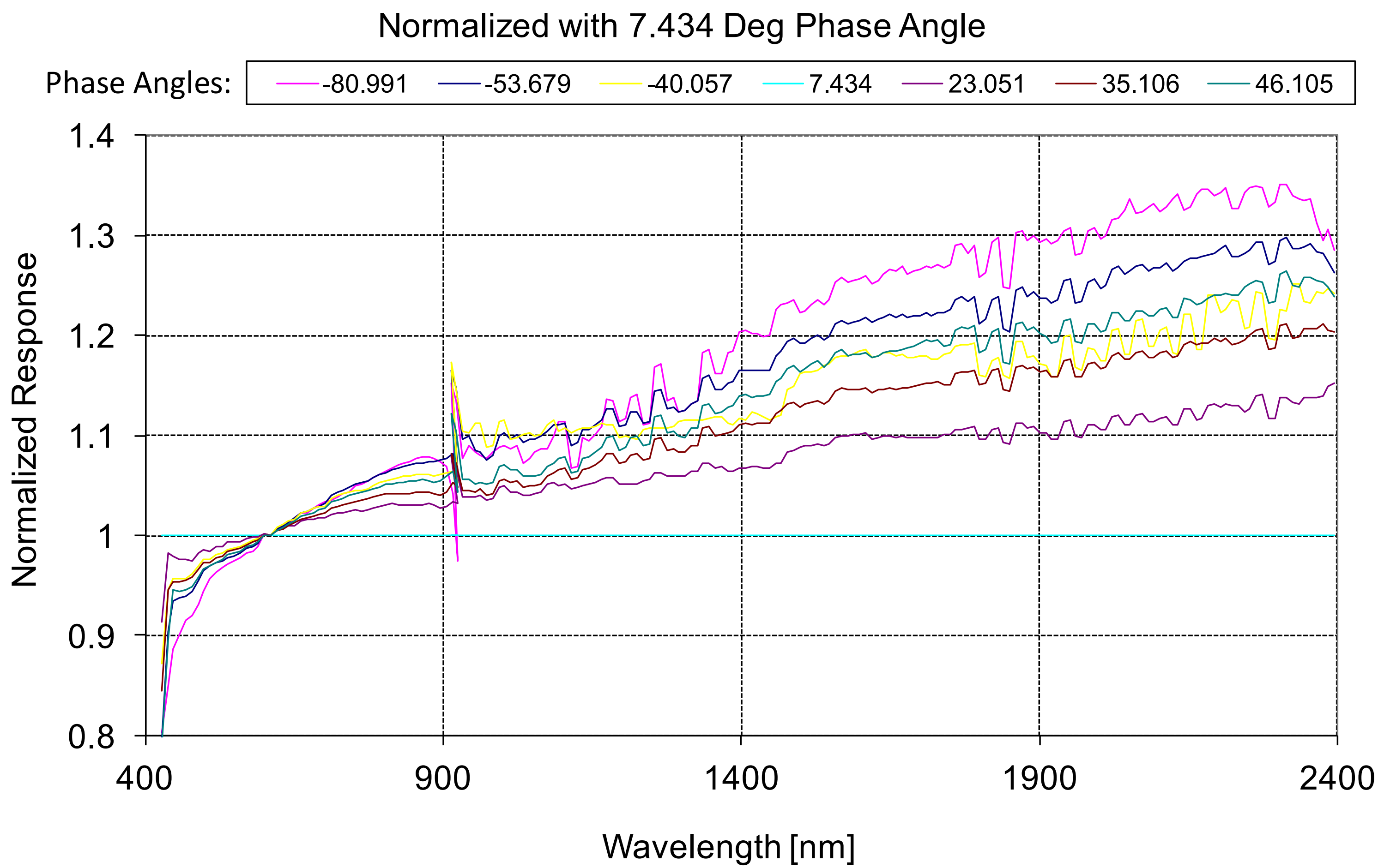
Partial Moon

(Selected sites)

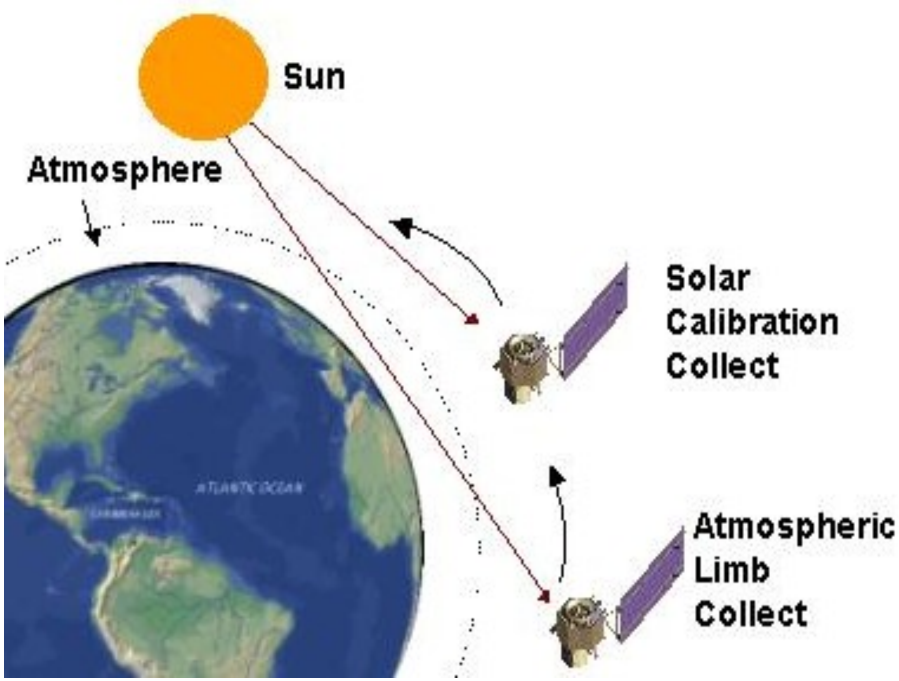


USGS Lunar Map

Hyperion Lunar Observations Show Spectral Variation with Phase Angle



Hyperion Spectral Calibration atmospheric absorption lines



Hyperion Spectra – red

Atmospheric Reference – black

Diffuse Reflectance of cover – blue

Identification of Spectral Features