Landsat 8 Operational Land Imager (OLI) & EO-1 Lunar Calibrations

GSICS Lunar Calibration Workshop
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The Landsat Calibration and Validation Team
December 2, 2014

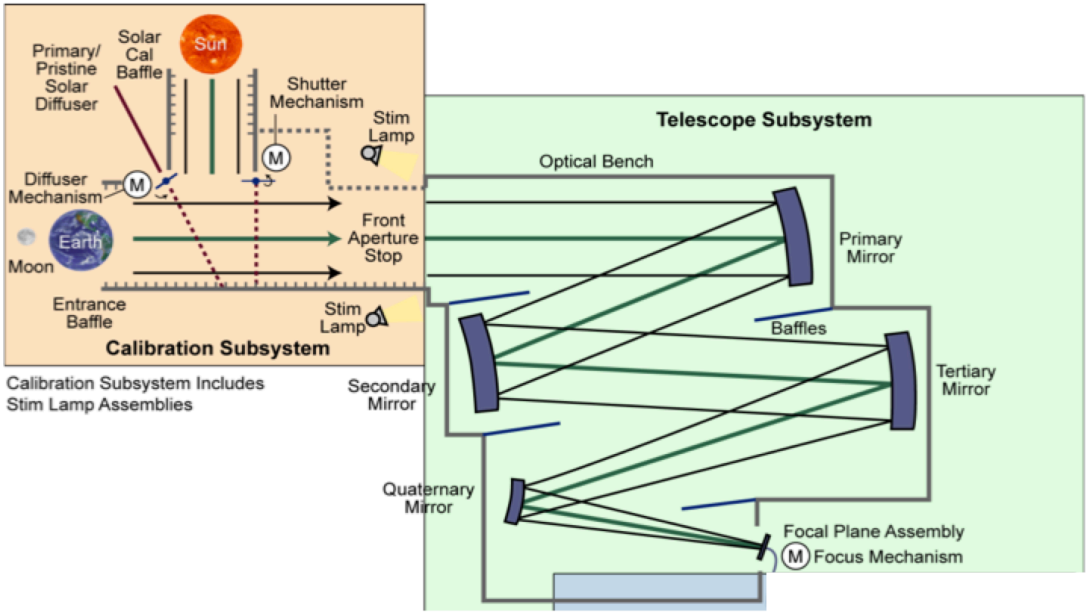
Landsat-8

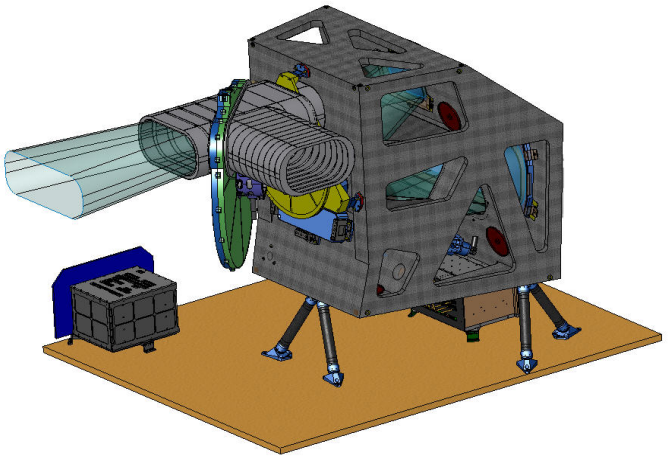
The latest in the Landsat series
Launched 2/11/2013
Two Instruments (OLI and TIRS)
705km 16-day repeat (WRS-2) –
8 days out of phase with Landsat-7

http://landsat.gsfc.nasa.gov, http://landsat.usgs.gov
Data available: http://earthexplorer.usgs.gov and http://glovis.usgs.gov
See also:*Remote Sensing*, Special Issue on Landsat-8 Characterization and Calibration, 6, 2014 (partially published):http://www.mdpi.com/journal/remotesensing/special_issues/landsat8#published

OLI Overview

- Pushbroom VIS/SWIR sensor
- Four mirror telescope with front aperture stop
- FPA consisting of 14 sensor chip assemblies, passively cooled





- Key instrument requirements
  - Cross-track FOV 185 km
  - S/C altitude 705 km
  - Geodetic accuracy*
    - Absolute 65 m
    - Relative 25 m
  - Geometric accuracy**
    - Absolute 12 m

Knight, E.J.; Kvaran, G. Landsat-8 Operational Land Imager Design, Characterization, and Performance. *Remote Sensing* **2014**, *6*(11), 10286-10305; doi:10.3390/rs61110286.

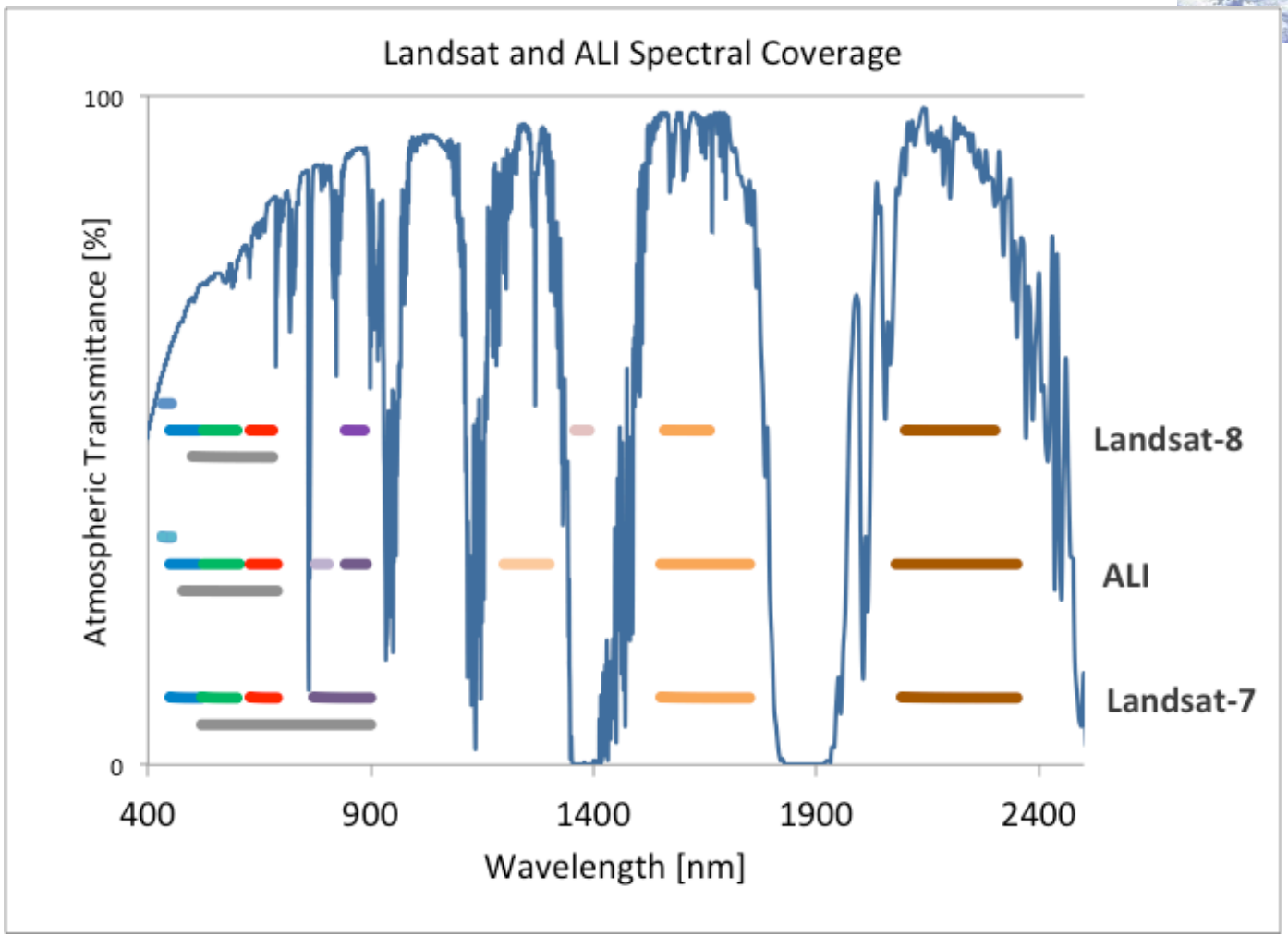
OLI Focal Plane

- 9 bands (6 VNIR (including pan); 3 SWIR)
- 14 Focal Plane Modules
- 6916 Active Detectors per MS band per detector select per FPM (x2 for Pan)
- 48412 Active VNIR detectors per select (2 selects)
- 20748 Active SWIR detectors per select (3 selects)
- 69160 Active Detectors in Detector Select "0";
- 159068 Active Detectors Total (plus blind band)

Band Name	Band (nm)	Bandwidth (nm)	GSD (m)	SNR at Ltyp (Req)
Coastal/ Aerosol	443	20	30	238(130)
Blue	482	65	30	368(130)
Green	562	75	30	304(100)
Red	655	50	30	227(90)
NIR	865	40	30	202(90)
SWIR 1	1610	100	30	266(100)
SWIR 2	2200	200	30	327(100)
PAN	590	180	15	146(80)
Cirrus	1375	30	30	161(50)

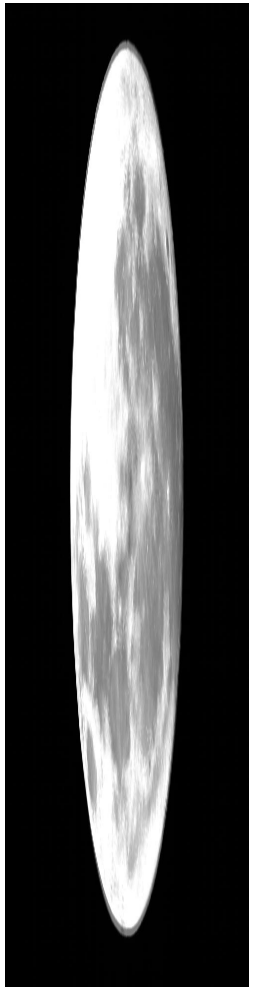
Summary of the operational land imager focal plane array for the Landsat Data Continuity Mission
Kirk A. Lindahl ; William Burmester ; Kevin Malone ; Ronald J. Schrein ; Ronda Irwin ; Eric Donley ; Sandra R. Collins
Proc. SPIE 8155, Infrared Sensors, Devices, and Applications; and Single Photon Imaging II, 81550Y (September 16, 2011); doi: 10.1117/12.896005

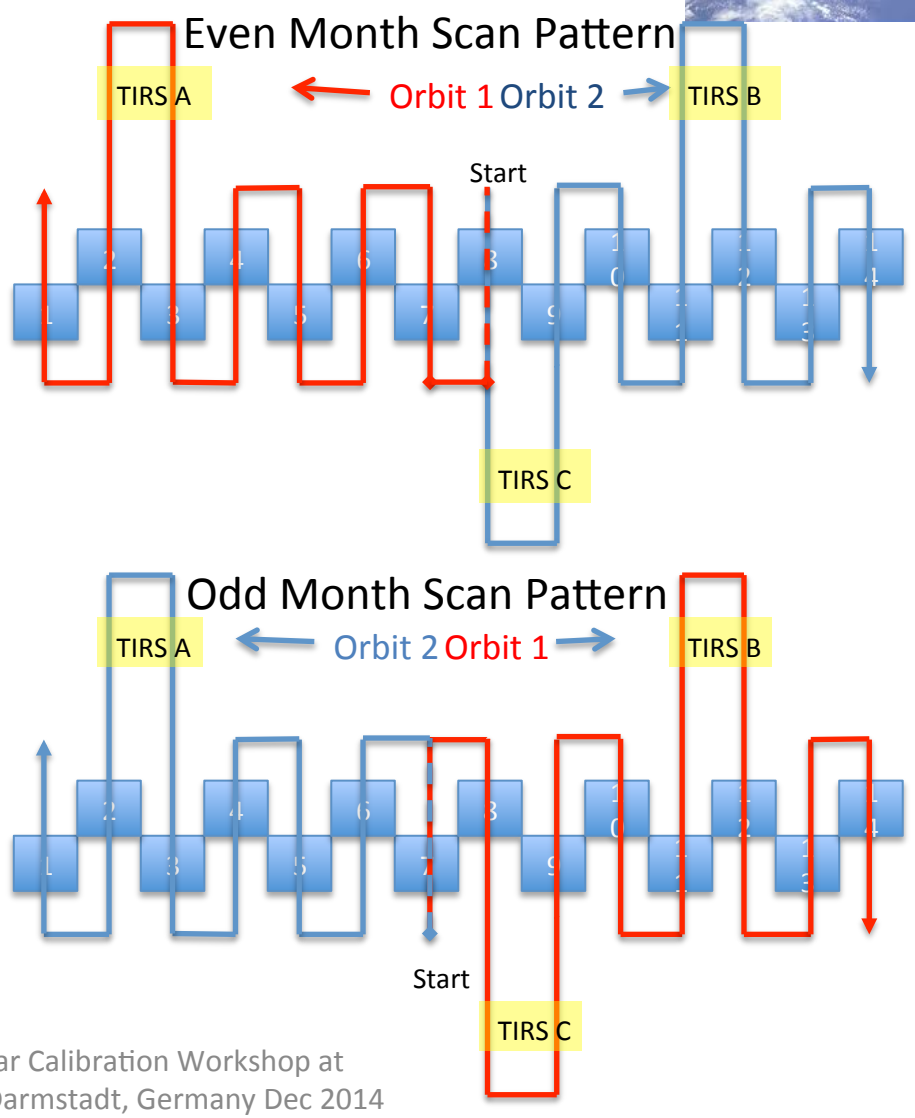
OLI Spectral Coverage



Landsat-8 Lunar Maneuver

- Lunar Cals are performed monthly between 5 and 9 deg lunar phase angle
- The spacecraft maneuvers from nominal earth acquisition to point at the moon.
- The moon is imaged by a spacecraft pitch motion.
- The pitch rate is constant and well controlled during the imaging interval.
- Roll and Yaw rates are negligible.
- Orientation of the scan is along the terminator such that the bright limbs are at the top and bottom of the image.This provides better estimates of the lunar y-size



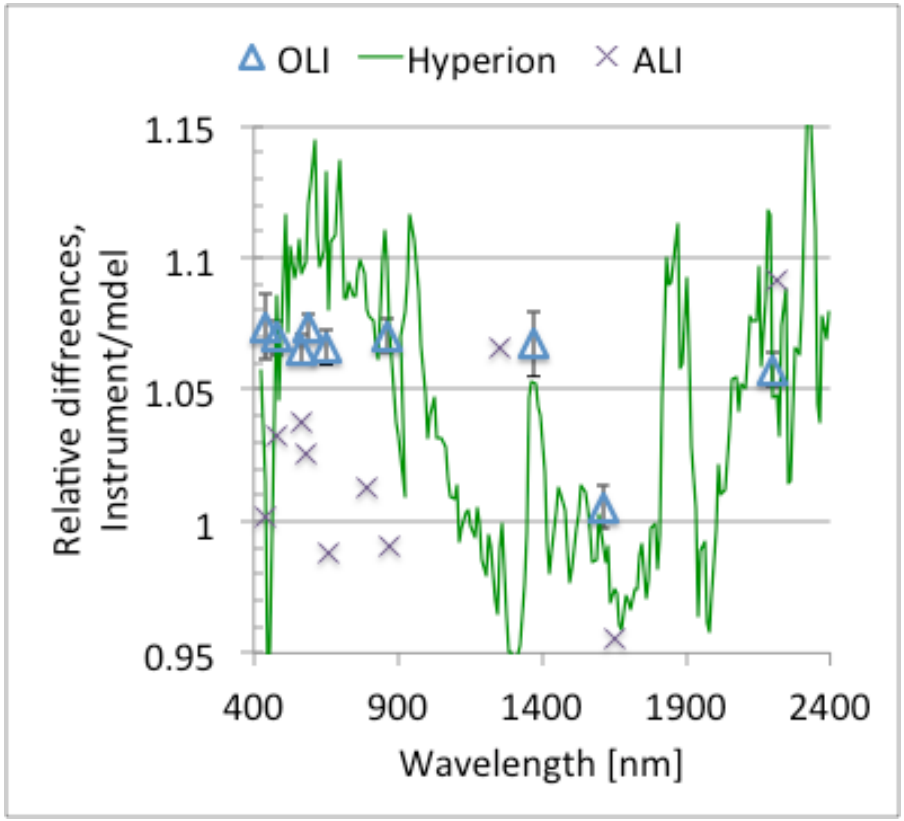


Sample OLI Lunar Image

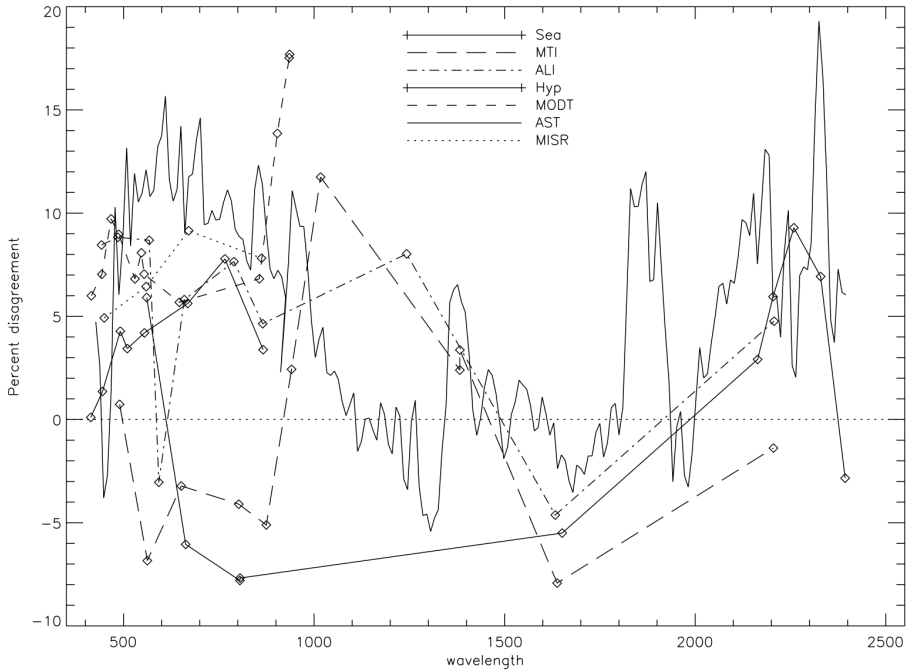
Lunar data processing steps

- Begin with radiometric corrected data sets, Level1R
  - Radiance units,
  - Dark current correction via shutter closed collects that occur before and after lunar collects,
  - The L1R images are oversampled by about a factor of ~8,
- Threshold image to create a lunar disk image mask.
  - Option to apply median filter to remove any impulse noise in the image.
- Integrate irradiance on the threshold image.
- Estimate apparent along track lunar disk extent (y-size).
- Extract spacecraft positions (J2000) at the lunar image times from the ancillary data files .
- Compare instrument irradiances with those derived from USGS lunar Irradiance model code (provided by USGS Flagstaff) at GSFC.

Differences with the USGS Lunar Irradiance Model - comparison with other platforms

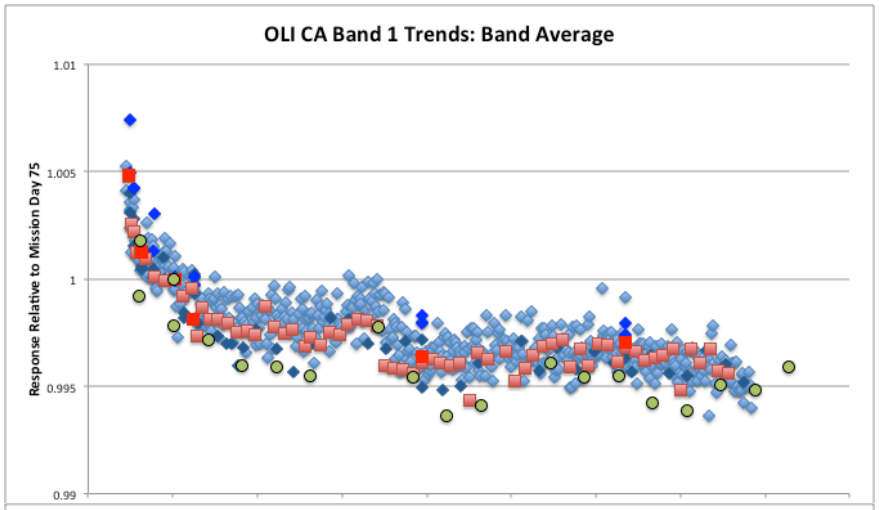


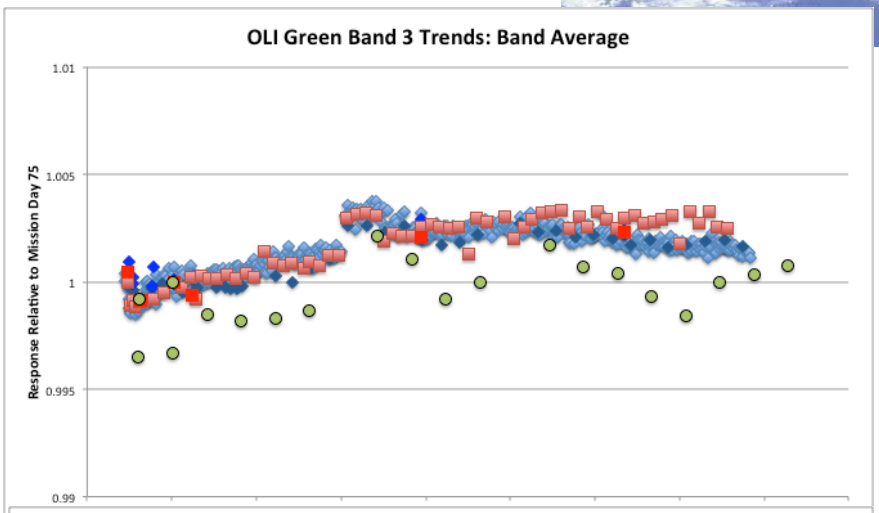
EO-1's 14 years of lunar calibrations have been useful for trending of instrument relative stability and on-orbit performance. Lessons learnt have been implemented for Landsat-8

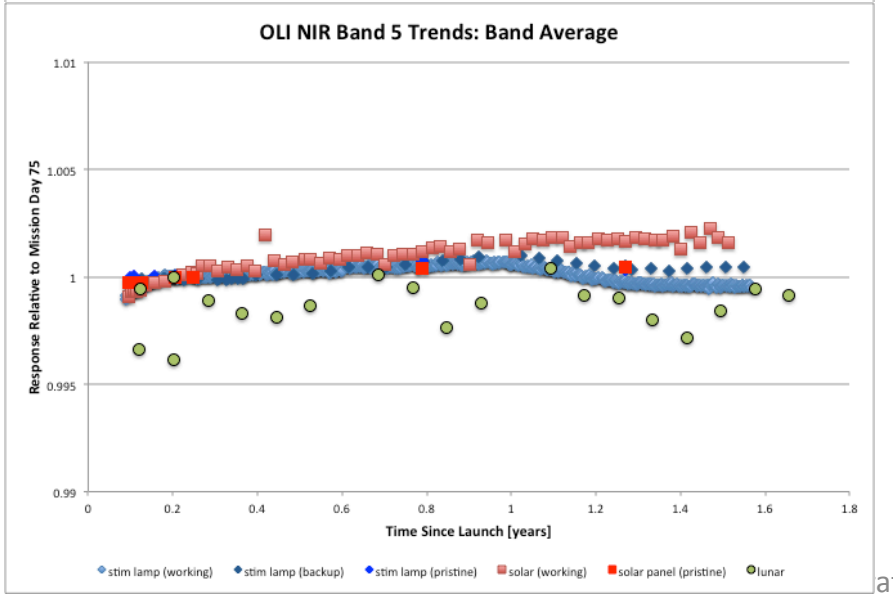


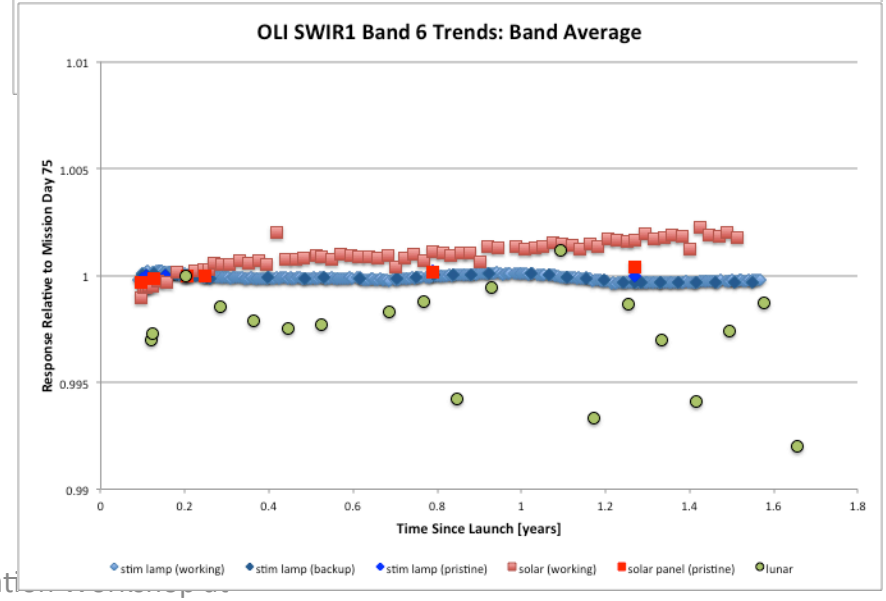
Kieffer & Stone
Astronomical Journal June 2005

Sample trending results - OLI







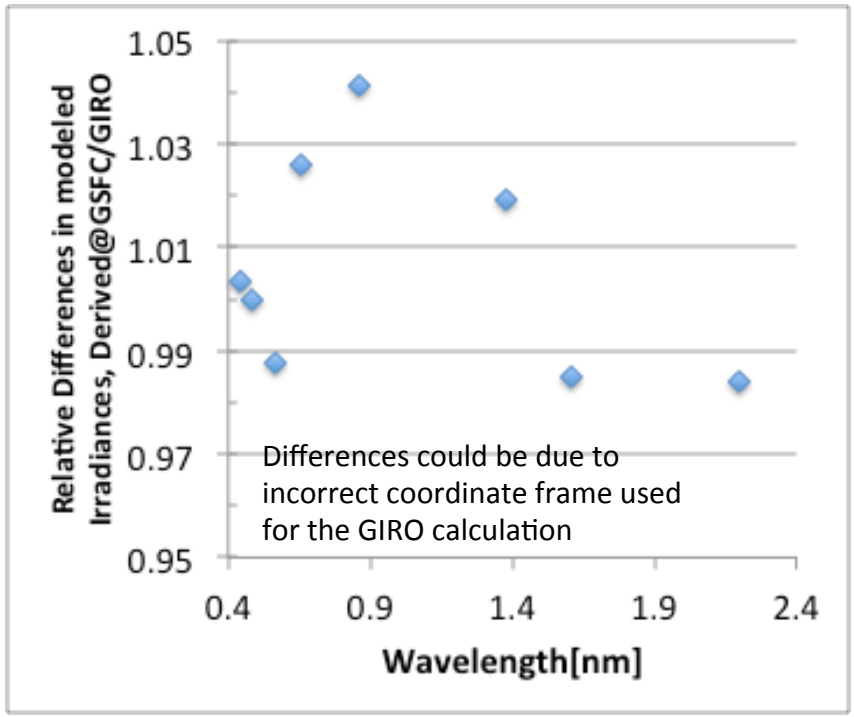


GIRO implementation

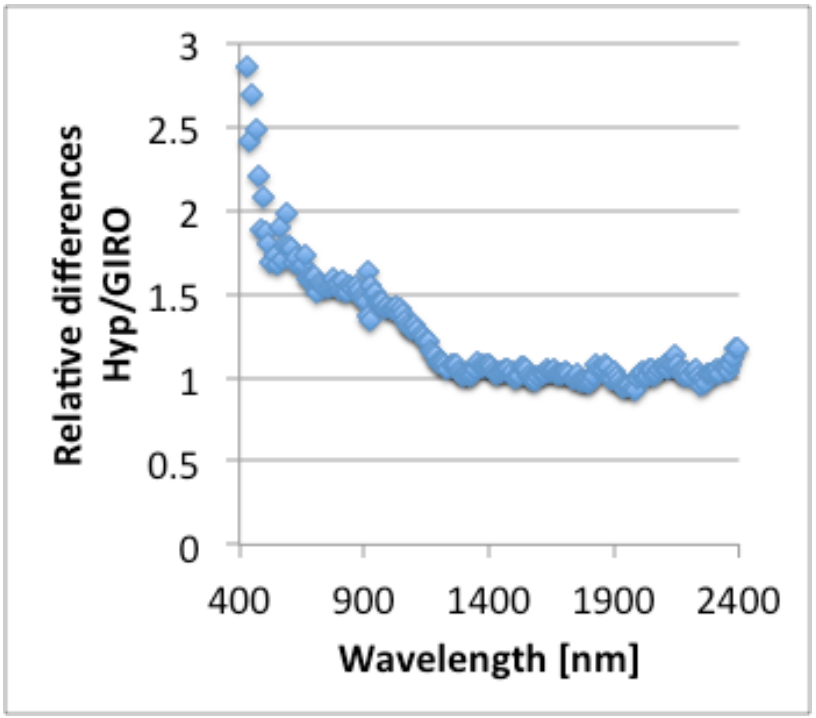
- Data set from March 2014.
- Sample netCDF files for the spectral response functions (SRFs) and integrated irradiance have been generated.
  - There are currently no provisions for Lunar *Ysize* in GIRO input section.
- Tested SRFs and sample data for compatibility of GIRO software (including version 4) with local linux server
  - Irradiances are available for the 30m multi-spectral bands
  - Imagettes (TBD)
- Comparison of model results from GIRO as well those derived from the USGS Lunar Irradiance model code at GSFC is continuing.

Preliminary comparisons

Differences in model irradiances for the OLI bands



Comparing GIRO and Hyperion reflectances



- Work in progess…
  - Relatively large differences, especially in the reflectance comparisons for visible bands under investigation

Summary

- Differences in absolute calibration between the model and instrument irradiances are about 6%.
- Differences in the modeled irradiances from GIRO and those derived at GSFC are being evaluated.
- However, lunar observations can be useful as a relative calibration tool to supplement other on-orbit calibration processes.
- Lunar images are also useful to explore image artifacts, eg. stray light.
- Currently also evaluating the use of geometrically corrected lunar images (spatially resampled) for trending of instrument calibration stability.
- Consider opportunities for further reference observations for model improvement, eg. extension of the EO-1 and other platforms which are near the end of their mission life as orbiting lunar observatories, implementing a lunar observatory on the International Space Station, Aeronet?

Backup – Instrument image artifacts

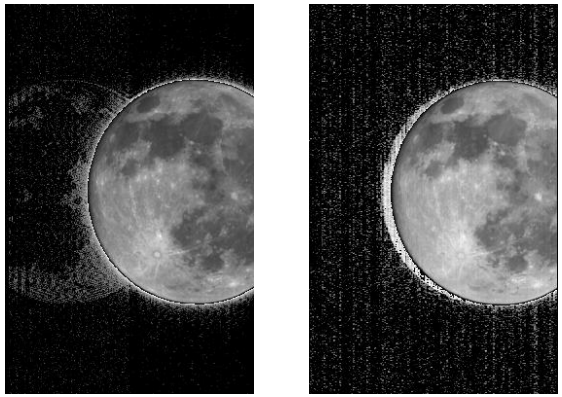
EO-1 straylight artifacts

Band 1’ Band 3 Band 5

ALI

Band 22 Band 150

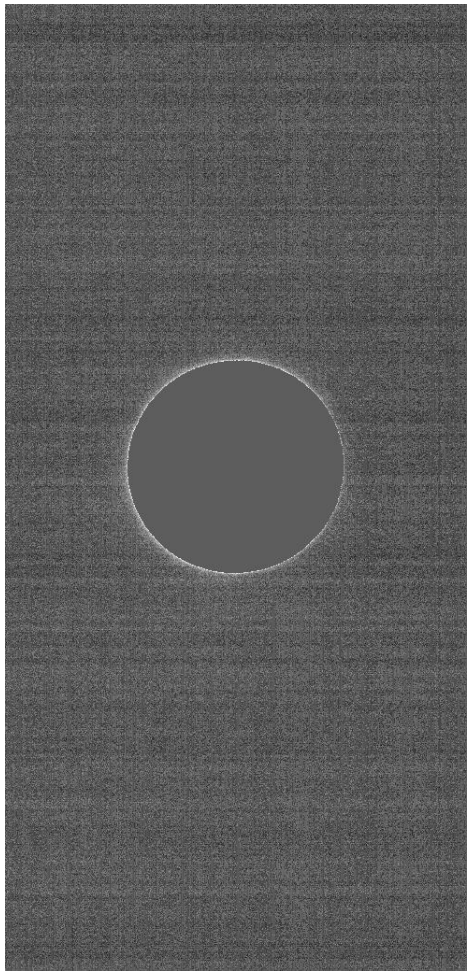
Hyperion



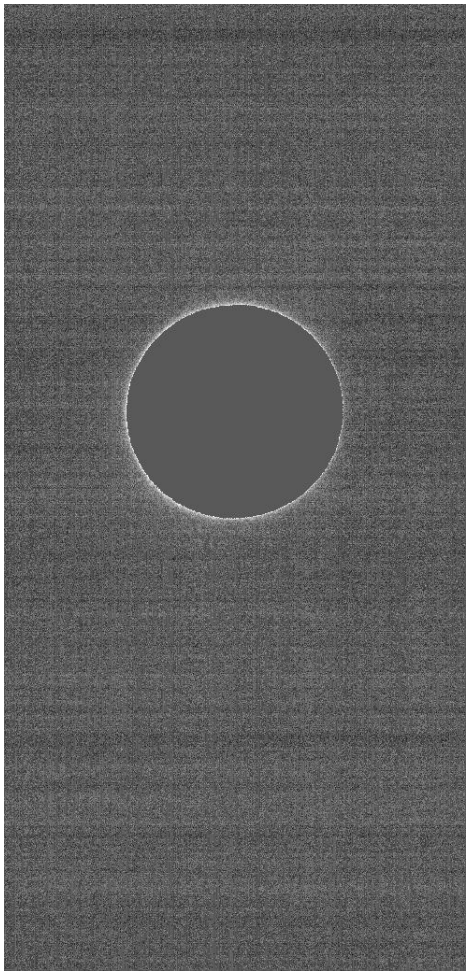
Note: Backgound is highly stretched

Stray light is negligible in the OLI

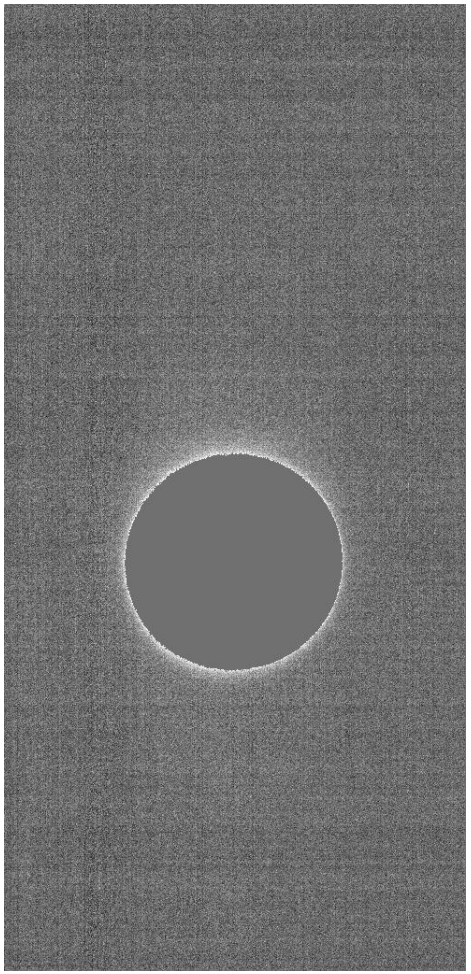
Green



NIR



Cirrus



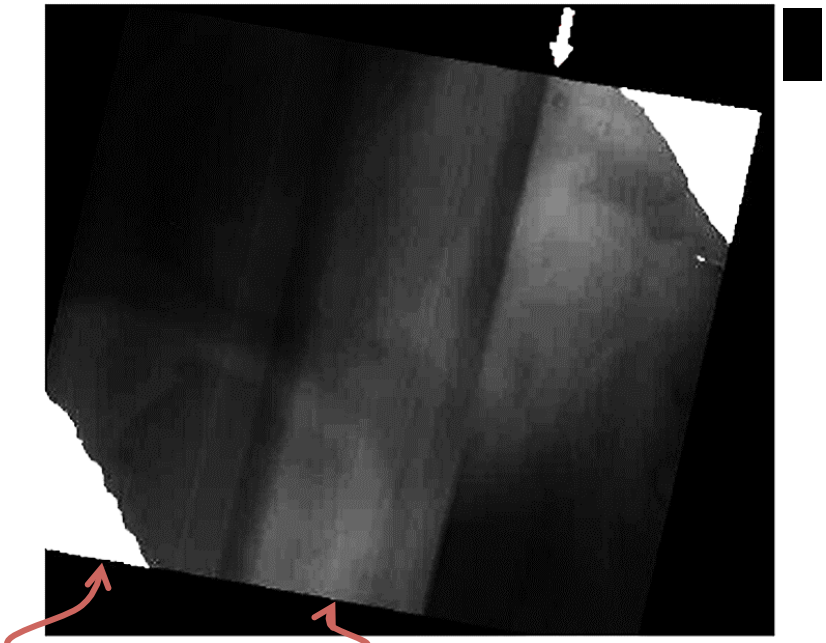
Example of stray light mitigation

Landsat-8 TIRs

- Banding artifacts observed in certain Earth scenes expected to be uniform (e.g.- open water)
- Effect varies from scene-to-scene
- Effect varies within scene

Context view from EarthExplorer

Example scene with varying along-track banding (band11)

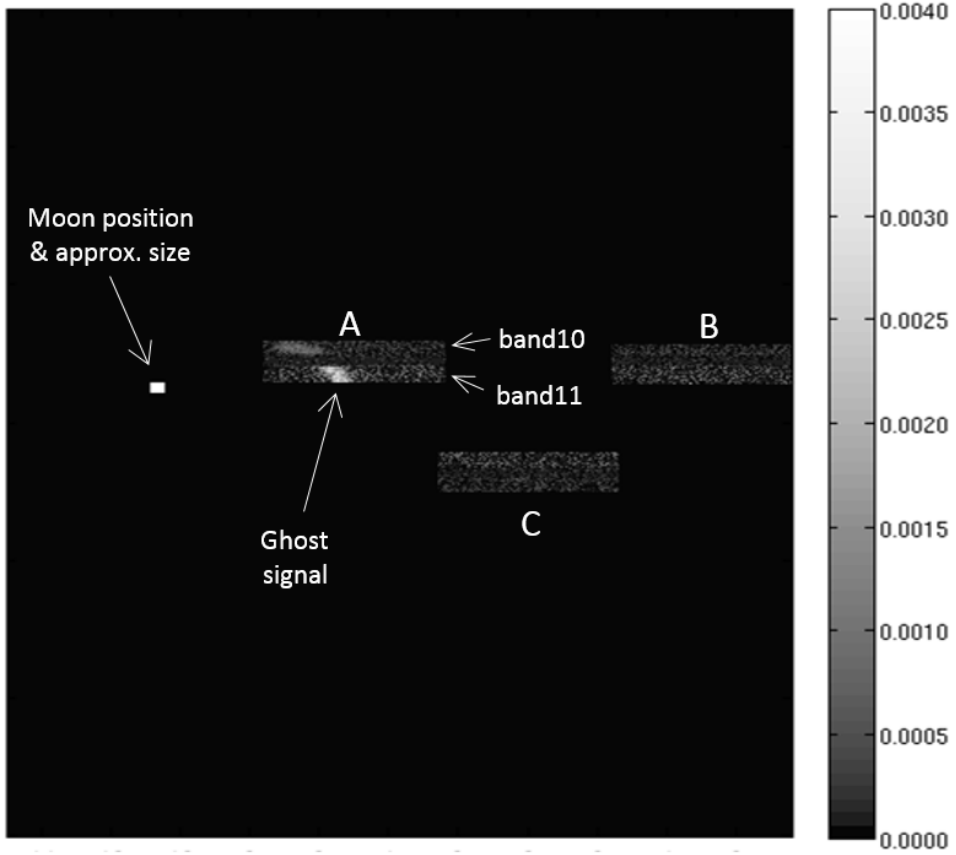


Banding observed especially near the boundary between adjacent focal plane arrays

Work performed by Matt Montanaro
Landsat-8 Calibration/Validation

Landsat-8 TIRs straylight mitigation – determination of source location

- Lunar position relative to boresight known from observatory pointing telemetry
- Signal on arrays expressed as a fraction of direct moon signal (when moon is directly imaged)
- Information from lunar obsevations used to refine optical models.



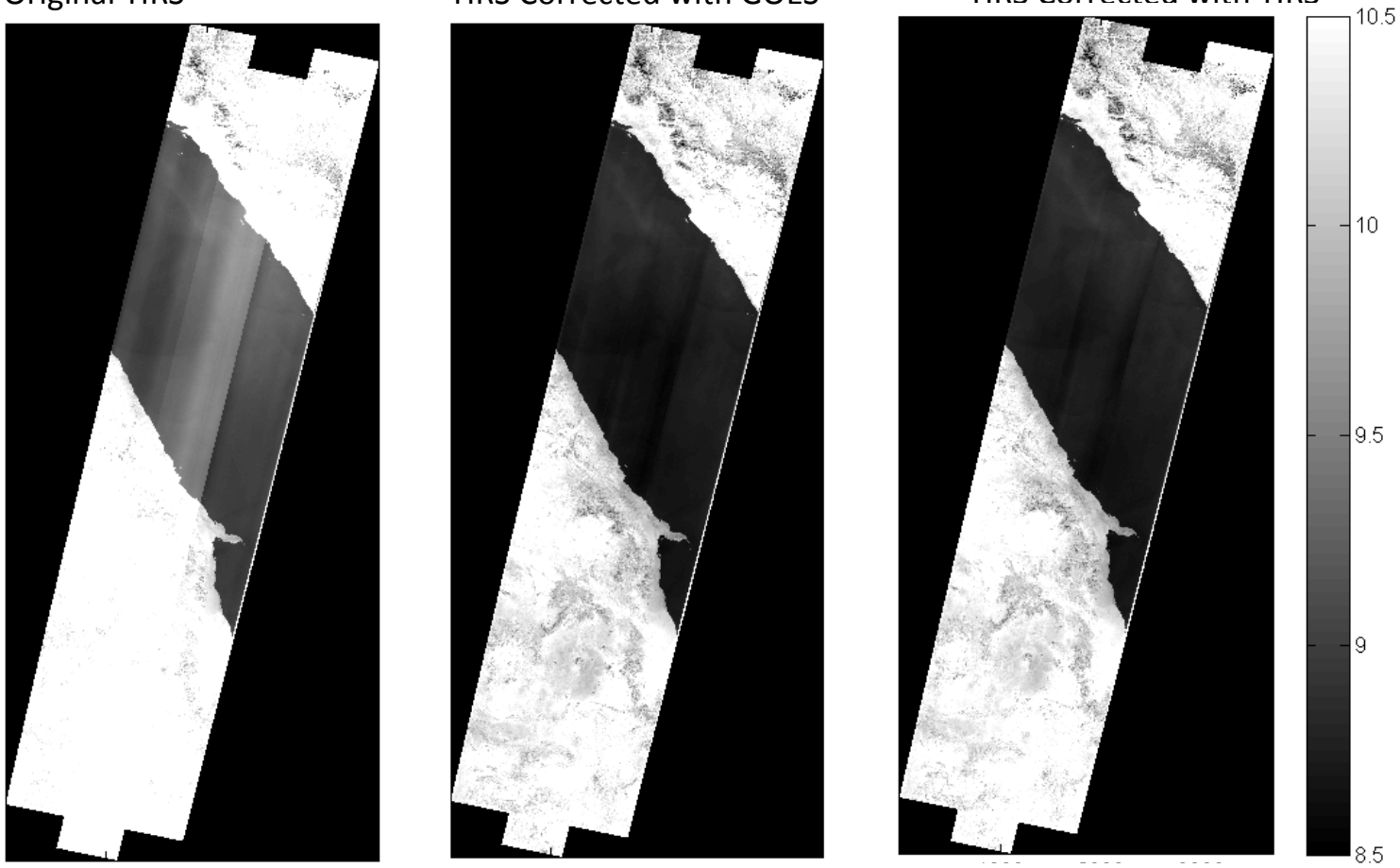
Work performed by Matt Montanaro
Landsat-8 Calibration/Validation

TIRs Straylight mitigation

Original TIRS

TIRS Corrected with GOES

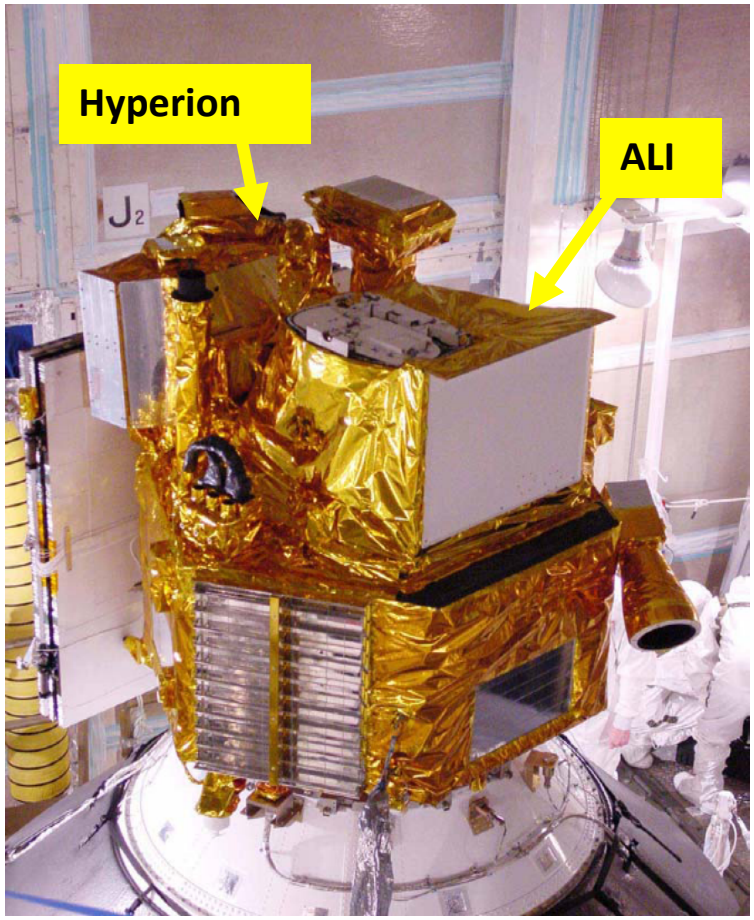
TIRS Corrected with TIRS



Work performed by Matt Montanaro
Landsat-8 Calibration/Validation

Path173 DOY2013279

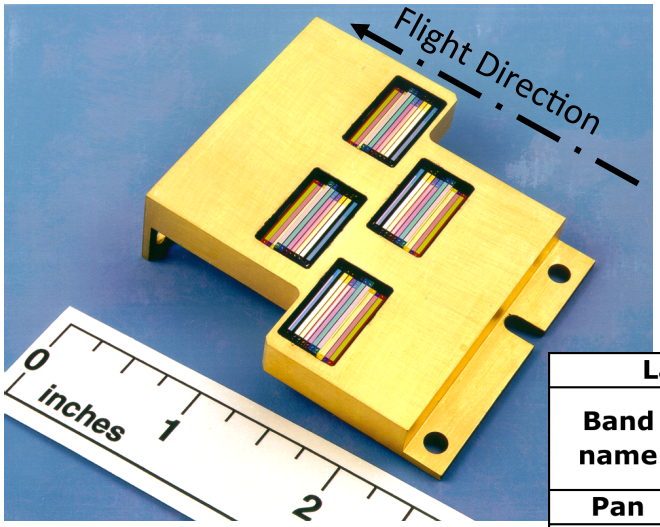
EO-1



- EO-1 was launched on Nov 21, 2000
- Initially at a 705 km Sun Synchronous circular orbit inclined at 98.2°
- Was in formation with the AM constellation 1 minute behind Landsat7 and 15 minutes ahead of Terra
- Orbit lowering maneuvers conducted between late 2005 to early 2007; continued to do inclination burns to maintain MLT until Feb 2011.
- Currently at approximately 09:10 MLT with a mean altitude of about 670km.
- A technology validation mission for Landsat earth observations
- Designed for one year mission; now in its 14th year 2000 scenes goal; over 78000+ scenes in archive and available for to the general public.
- Special issue publications:Geoscience and Remote Sensing Special Issue, Vol 41, Number 6, June 2003; and IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing (JSTARS), Volume 6, Issue 2, Part 1, April 2013 See: http://eo1.gsfc.nasa.gov for additional references

EO-1 ALI

MS/PAN Flight Module



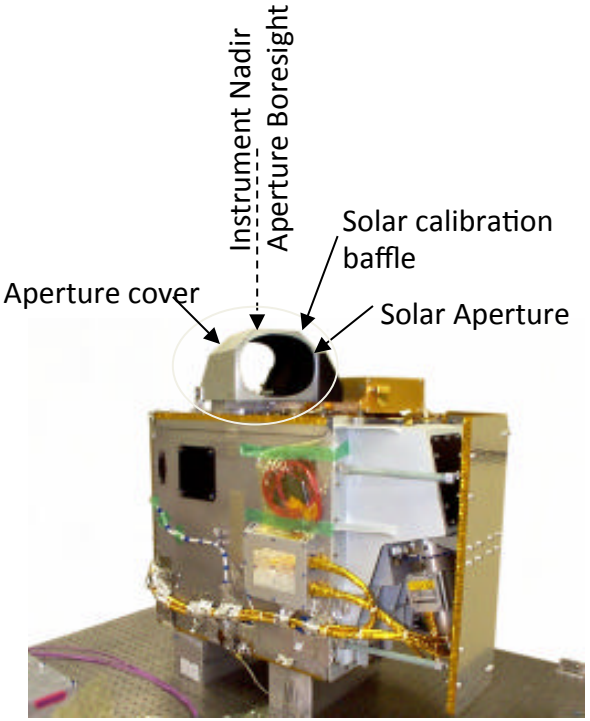
The Advanced Land Imager (ALI) is a multi-spectral pushbroom sensor system and served as the prototype for the *Operational Land Imager (OLI)* on Landsat 8.

Landsat/ALI spectral coverage

Landsat 7 ETM+			ALI			Landsat 8 OLI		
Band name	**Center-wavelen [nm]**	**Band-width**	**Band name**	**Center-wavelen [nm]**	**Band-width**	**Band name**	**Center-wavelen [nm]**	**Band-width**
Pan	710	380	**Pan**	585	210	**Pan**	590	180
			1p	443	20	**Coastal Aerosol**	443	20
1	485	70	**1**	483	65	**Blue**	483	65
2	560	80	**2**	565	80	**Green**	563	75
3	660	60	**3**	660	60	**Red**	655	50
4	835	130	**4**	790	30	**NIR**	865	40
			4p	868	45			
5	1650	200	**5p**	1250	100	**-**	-	-
				-	-	**Cirrus**	1375	30
			5	1650	200	**SWIR 1**	1610	100
7	2220	260	**7**	2215	270	**SWIR 2**	2200	200

Hyperion Instrument Overview

Hyperion is a grating-based imaging spectrometer that provides global spaceborne spectral measurements to address Earth science issues. Now a pathfinder for the Hyspiri Mission.

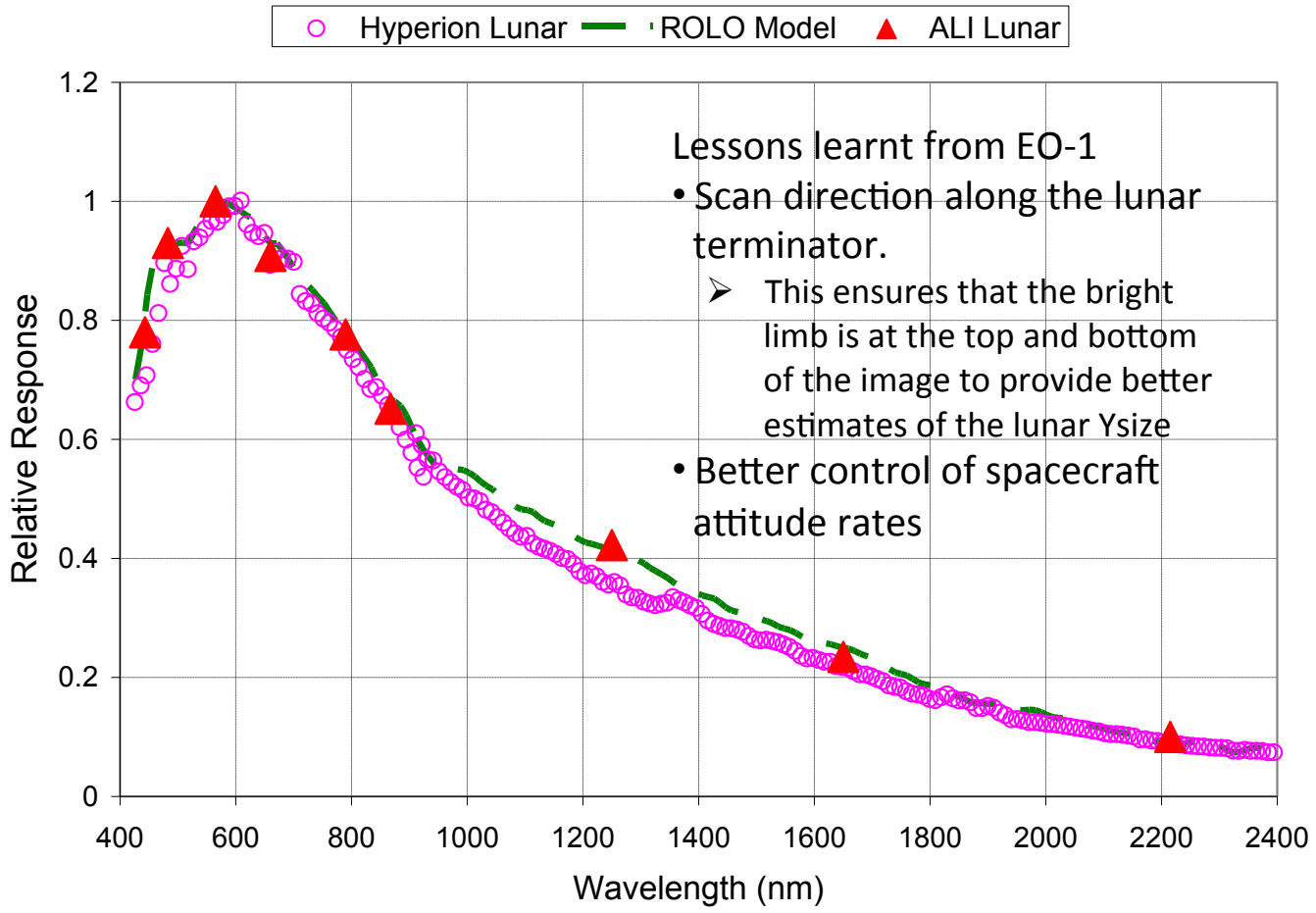


A three mirror astigmate telescope (f11) design, 12cm primary aperture.

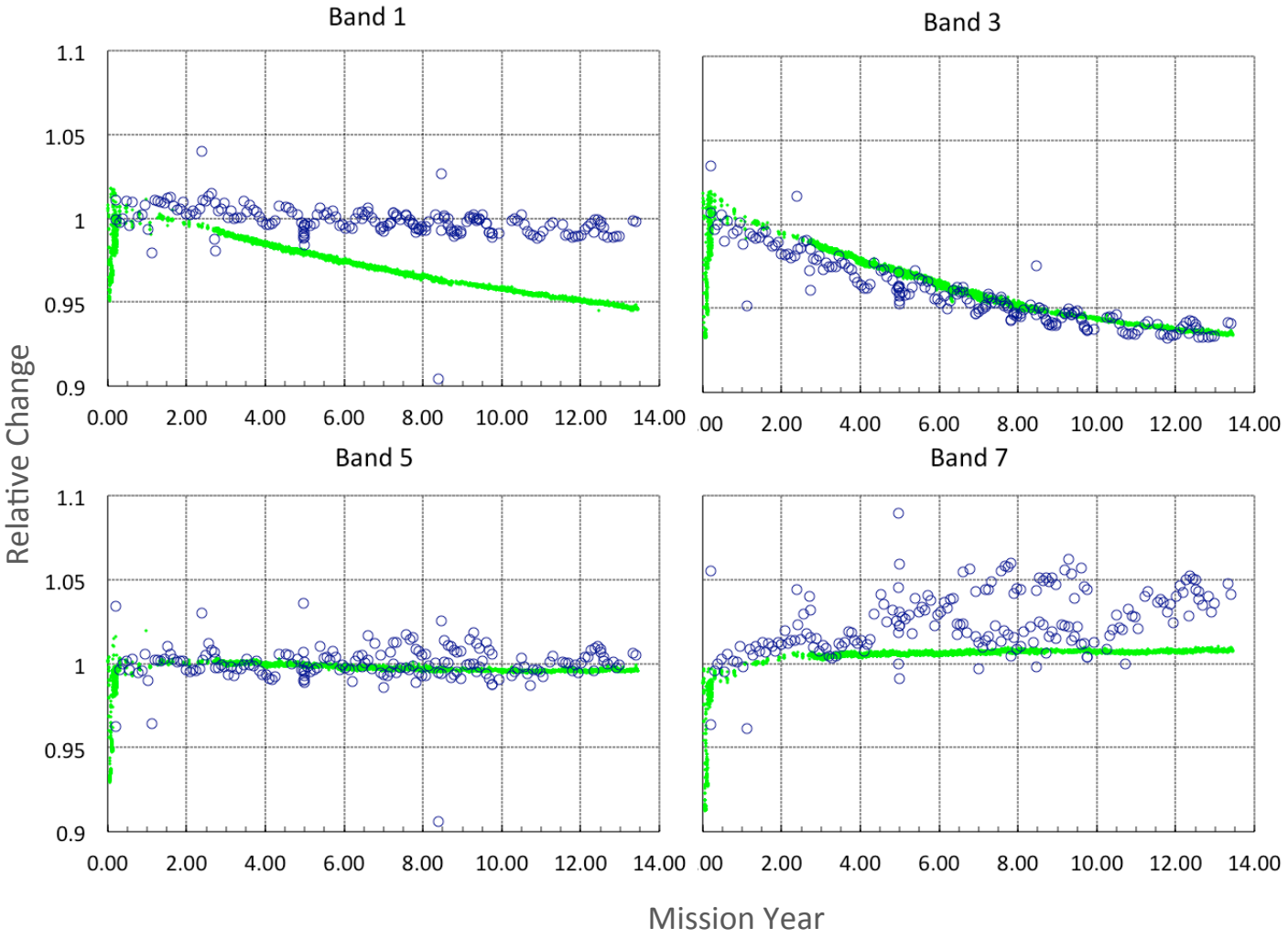
Convex Grating spectrometers with CCD VNIR and HgCdTe SWIR detectors (60µm pixels)

Parameters	Hyperion
Wavelength Range	400-2500nm
Number of Calibrated Spectral Channels	196
Spectral Resolution	10nm
Data Quantization	12-bits
Ground Sample Size	~30m
Total Swath	~7km

Measured Lunar Spectra

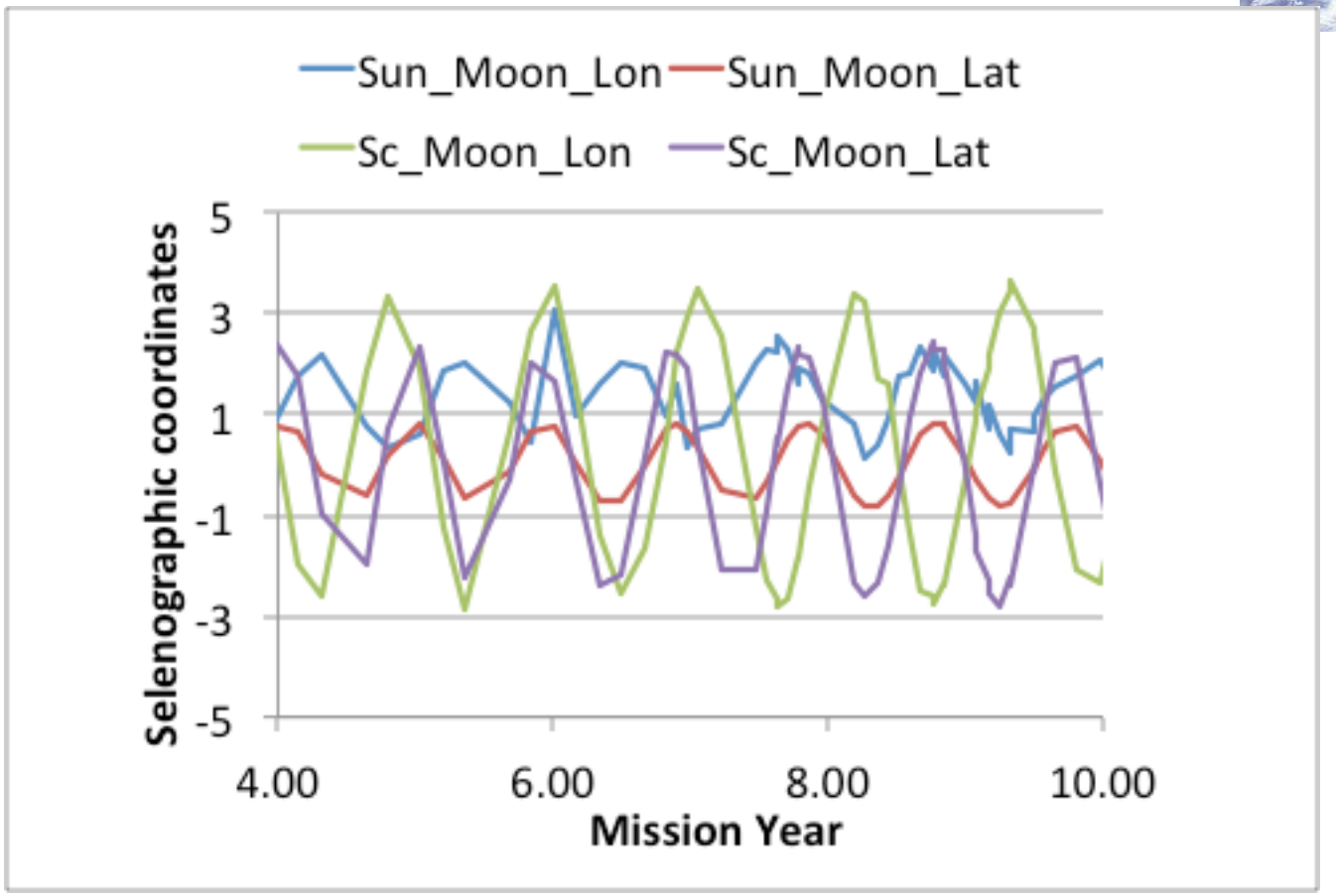


ALI Lunar Trends (Selected Bands)



- Except for the shortest wavelengths, the ALI trends from the lamps and lunar calibration are consistent, albeit larger scatter in the SWIR bands.
- Quasi-annual variations appear correlated to the solar and spacecraft selenographic coordinates. Initially presented at the Lunar calibration workshop at Calcon 2006

“Libration” Effects



Hyperion Trends