National Aeronautics and Space Administration

LDCM/OLI Instrument Performance Overview

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LDCM Science Team Meeting

data continuity mission

LDCM
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NASA GSFC / USGS EROS

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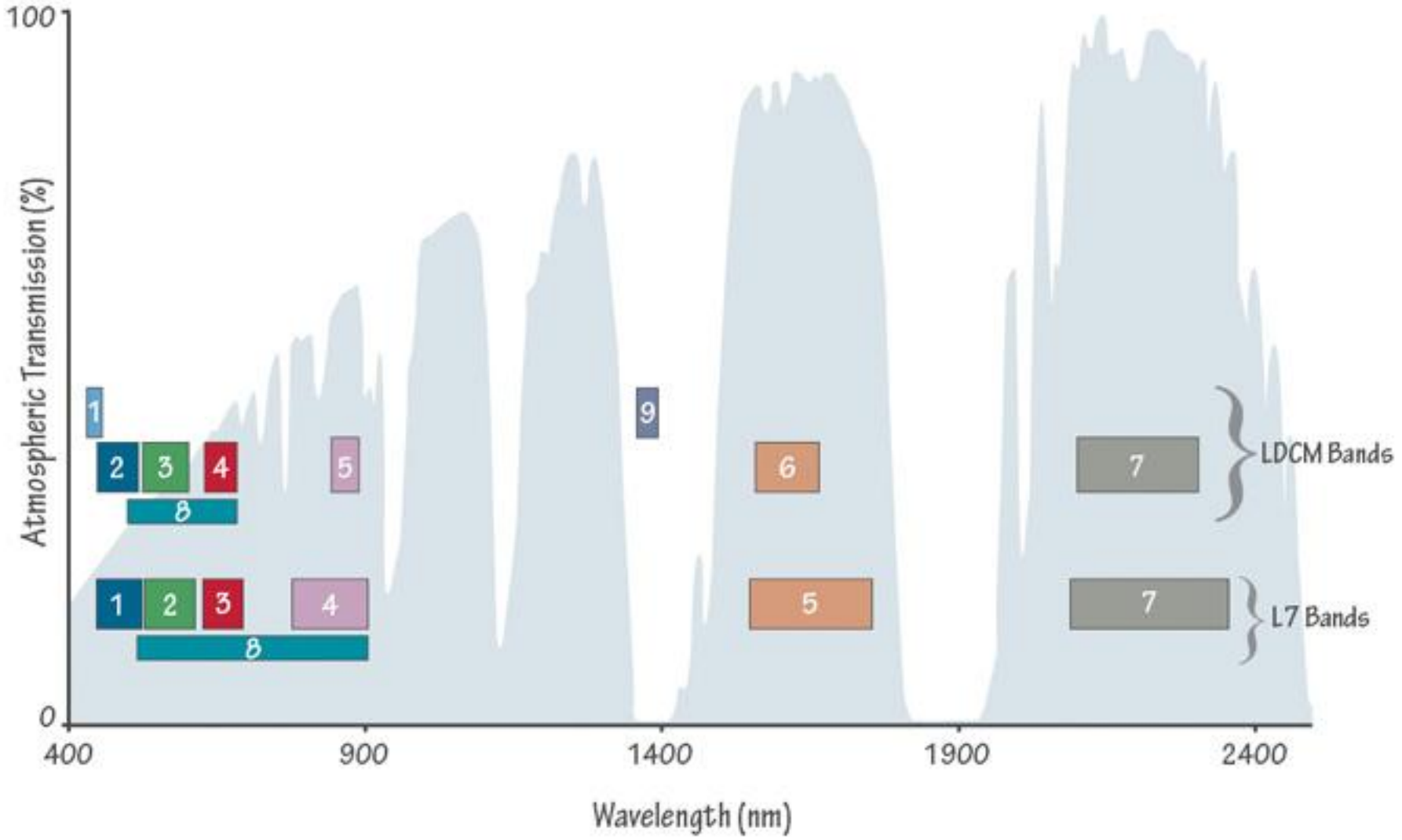
Outline

- Basic Band Requirements
- Several Driving Requirements
- Instrument Overviews:
  - Operational Land Imager (OLI)
- Top Level Performance Results:
  - Geometric/Geodetic
  - Spatial
  - Radiometric
  - Spectral
- Conclusions
- Future Work

OLI & ETM+ Spectral Bands



LDCM and ETM+ Spectral Bands

L7 ETM+ Bands				LDCM OLI Band Requirements			
	GSD	*"color"*	*min-max (nm)*	*GSD*	*"color"*	*min-max (nm)*	
				30 m	**Coastal/Aerosol**	0.433 - 0.453	**Band 1**
Band 1	**30 m**	**Blue**	0.450 - 0.515	**30 m**	**Blue**	0.450 - 0.515	**Band 2**
Band 2	**30 m**	**Green**	0.525 - 0.605	**30 m**	**Green**	0.525 - 0.600	**Band 3**
Band 3	**30 m**	**Red**	0.630 - 0.690	**30 m**	**Red**	0.630 - 0.680	**Band 4**
Band 4	**30 m**	**Near-IR**	0.775 - 0.900	**30 m**	**Near-IR**	0.845 - 0.885	**Band 5**
Band 5	**30 m**	**SWIR-1**	1.550 - 1.750	**30 m**	**SWIR-1**	1.560 - 1.660	**Band 6**
Band 6	**60 m**	**LWIR**	10.00 - 12.50	**N/A**			
Band 7	**30 m**	**SWIR-2**	2.090 - 2.350	**30 m**	**SWIR-2**	2.100 - 2.300	**Band 7**
Band 8	**15 m**	**Pan**	0.520 - 0.900	**15 m**	**Pan**	0.500 - 0.680	**Band 8**
				30 m	**Cirrus**	1.360 - 1.390	**Band 9**

OLI and ETM+ Radiometric Performance

Signal-to-Noise Ratios (SNR)

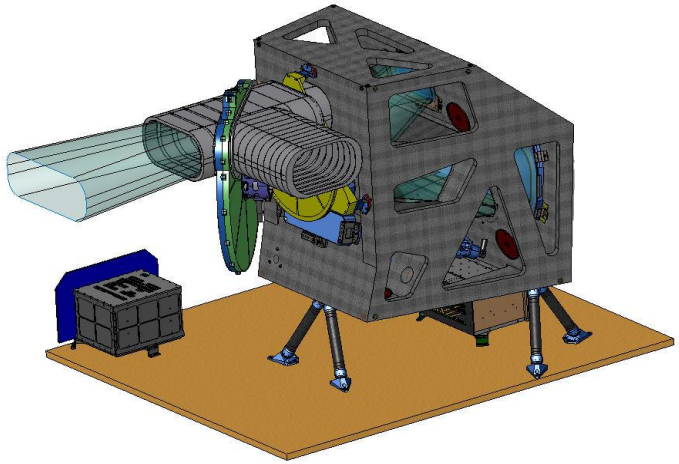
	$L_{typical}$ SNR		L_{high} SNR	
Band	ETM+ Performance	OLI Requirements	ETM+ Performance	OLI Requirements
Coastal/Aerosol	N/A	130	N/A	290
Blue	40	130	140	360
Green	40	100	190	390
Red	30	90	140	340
NIR	35	90	250	460
SWIR 1	35	100	190	540
SWIR 2	30	100	140	510
Pan	16	80	90	230
Cirrus	N/A	50	N/A	N/A

Several Driving Requirements

- Nadir Swath Width >185 km; 15/30/100 m GSD; @ S/C altitude of 705 km
- Wide spectral coverage (Deep Blue – NIR, SWIR, TIR)
- Geo-registration & Accuracy
  - Band-to-band: 4.5 meters or less
    - in the line and sample directions at the 90% confidence level
  - Geodetic Accuracy: Absolute 65 m / Relative 25 m
  - Geometric Accuracy: 12 m
- **Signal to Noise Ratio (SNR)** & Dynamic Range (DNR)
- Radiometric Accuracy
  - *Calibration stability*
  - Stray light (diffused scatter and ghosting)
- Uniformity
  - Spatial (Distortion/GSD, Edge Response)
  - Spectral (PPU effects between spectra)
  - Radiometric (Coherent noise, pixel-to-pixel stability & non-linearity, spectral uniformity)

Operational Land Imager (OLI)

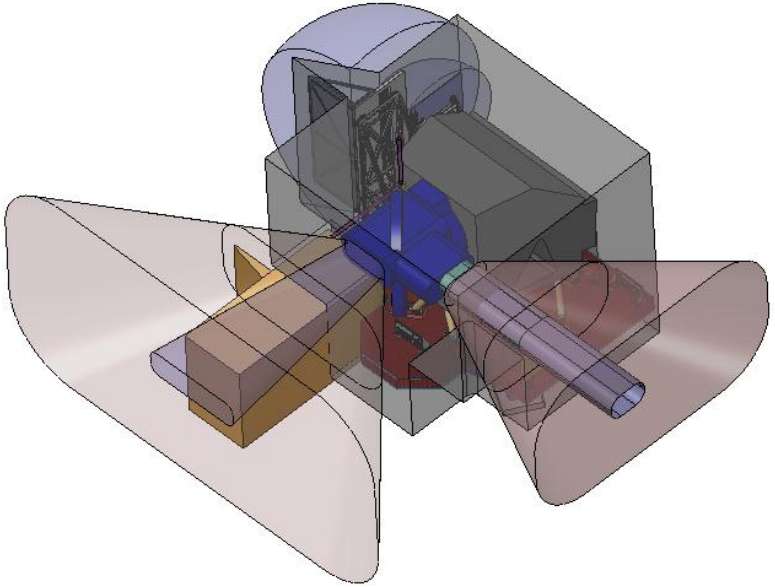
- Collects 400 scenes per day using pushbroom design
  - Coincident with TIRS data collection
- Covers a 185 km swath
- Collects data for nine shortwave spectral bands
  - Provides continuity with seven TM and ETM+ shortwave spectral bands
  - Adds two new bands
- Provides a 30 m spatial resolution
  - 15 m panchromatic band
- Collects calibration data
  - Internal cal lamps, shutter collects, solar panel, lunar views, vicarious field campaigns

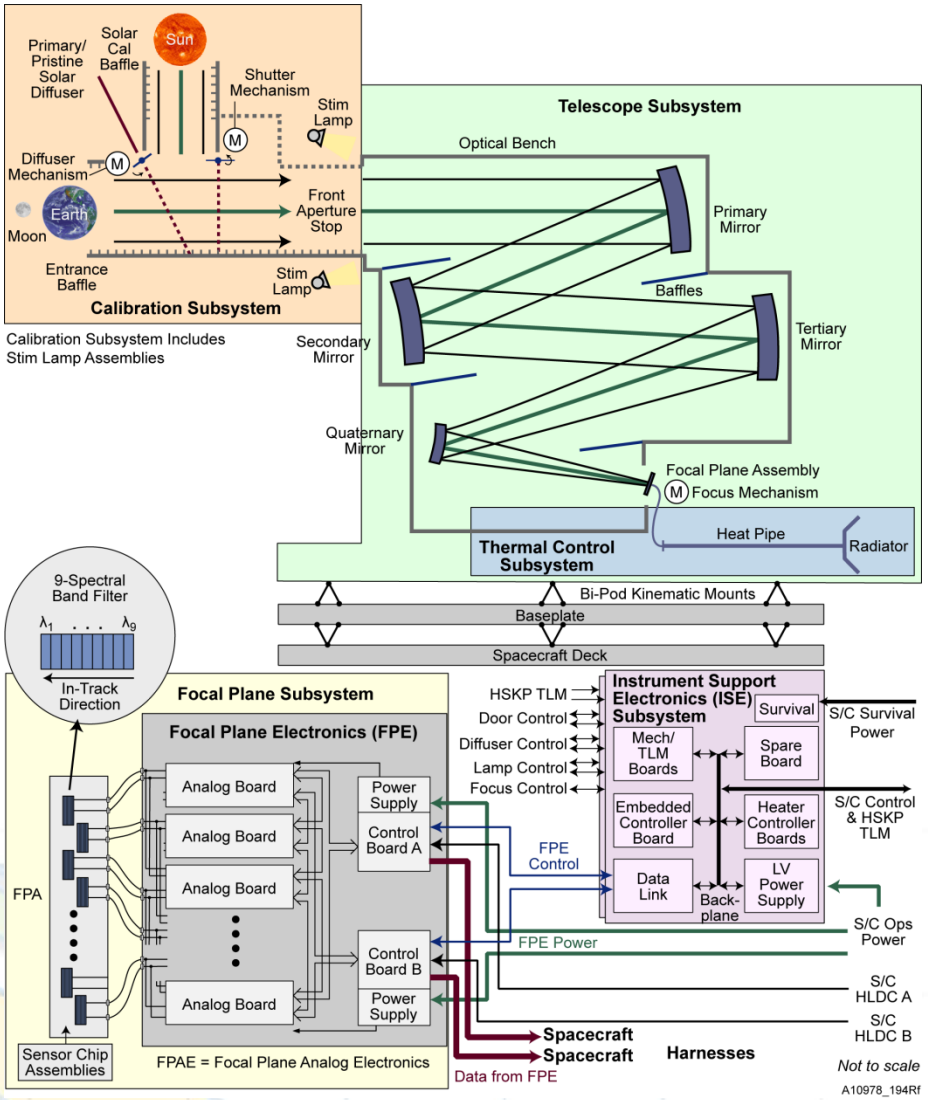


Courtesy of BATC

OLI is a fairly simple instrument
(slide created and provided by Ed Knight of BATC.)

- Pushbroom VIS/SWIR sensor
- Four-mirror telescope with front aperture stop
- FPA consisting of 14 sensor chip assemblies, passively cooled
- On-board calibration with both lamps and full aperture diffusers





Top Level Performance Results

- **Geometric/Geodetic**
- Spatial
- Radiometric
- Spectral

Geometric/Geodetic Performance

- ETM+ Band-to-Band registration (B-to-B) was found to typically be <0.05 pixels or better
  - in line and scan direction (excluding band 6 - TIR)

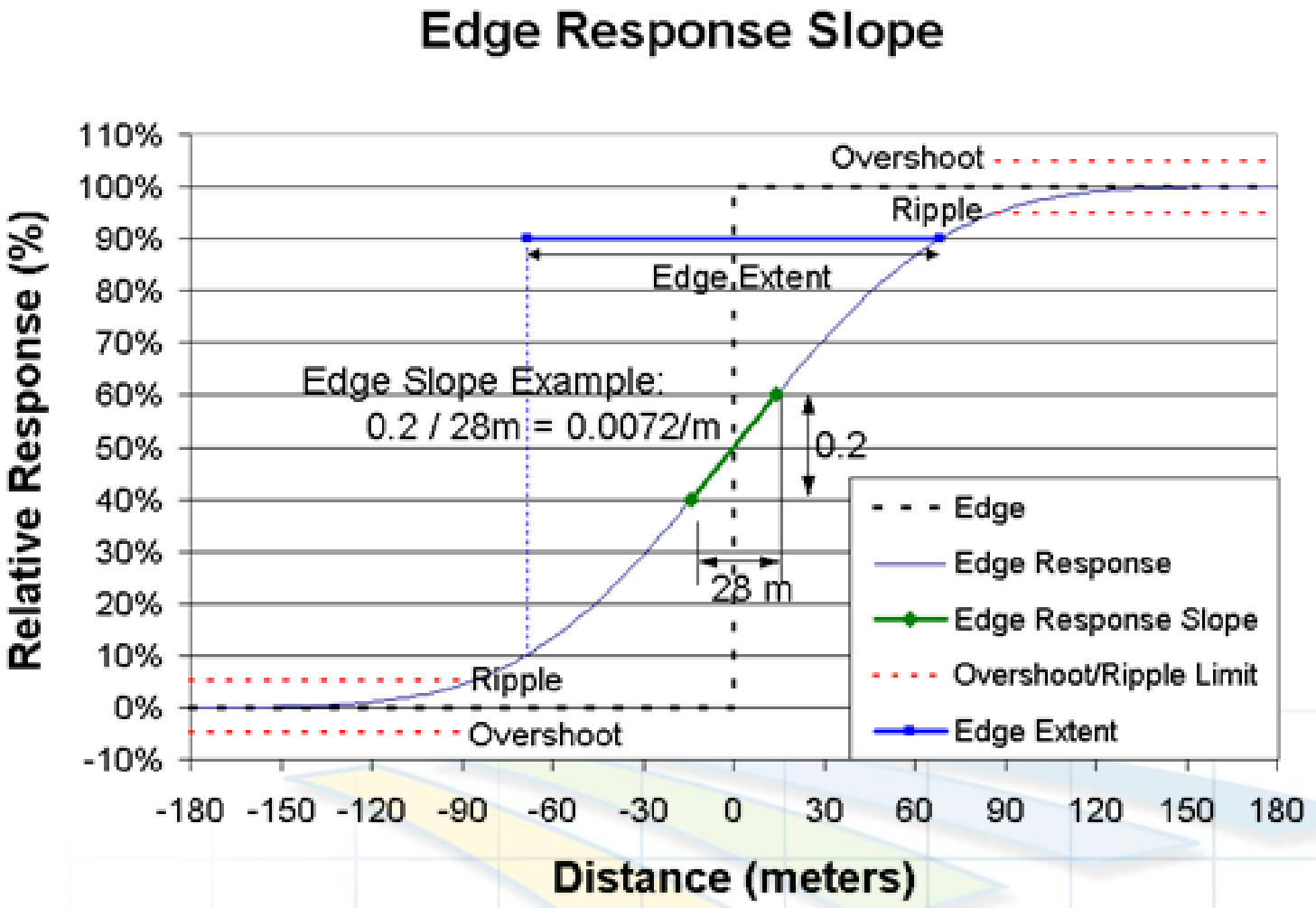
- ETM+ Geodetic Accuracy:
  - Pre 4/2007 97% scenes better than 50 meters RMSE
  - Post 4/2007 65% scenes better than 50 meters RMSE

- The use of staggered focal plane modules and non-coincident spectral band imaging increases the engineering difficulty of meeting the B-to-B and Geodetic registration.
- LDCM has been shown to meet its Geospatial/Geodetic requirements by analysis using the pre-flight measurements and opto-mechanical models for the Space Craft, OLI, and TIRS.
  - Final verification will occur during IOC.

Top Level Performance Results

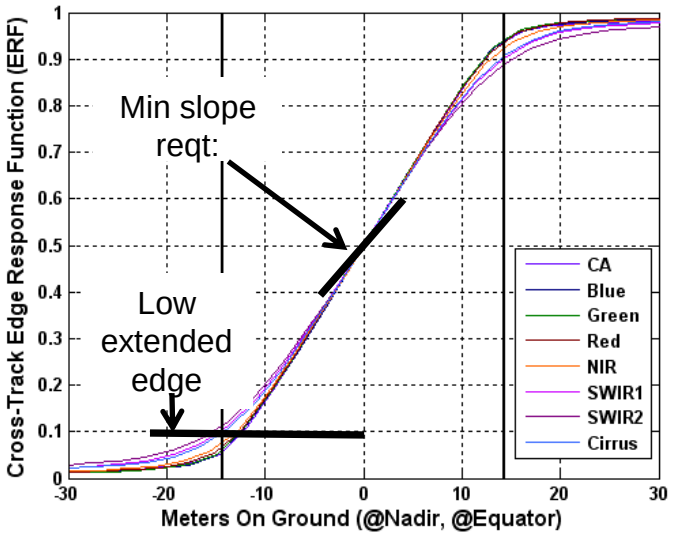
- Geometric/Geodetic
- **Spatial**
- Radiometric
- Spectral

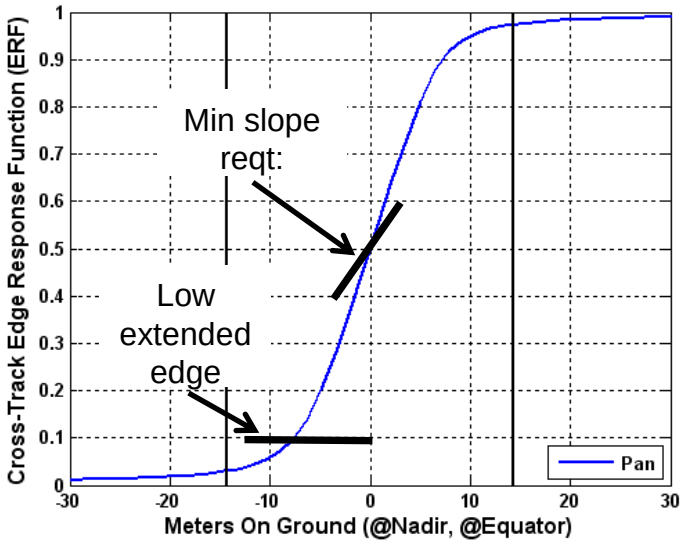
Relative Edge Response and Extent Definitions



OLI Spatial Performance looks excellent

- Spatial Performance
  - Measured spatial response has:
    - Steep slope (exceeding reqts)
    - Low extended edge (good half edge extent)
    - No ripple/overshoot
- Geolocation
  - Performance depends on both instrument and spacecraft; final measurements made during initial on-orbit checkout



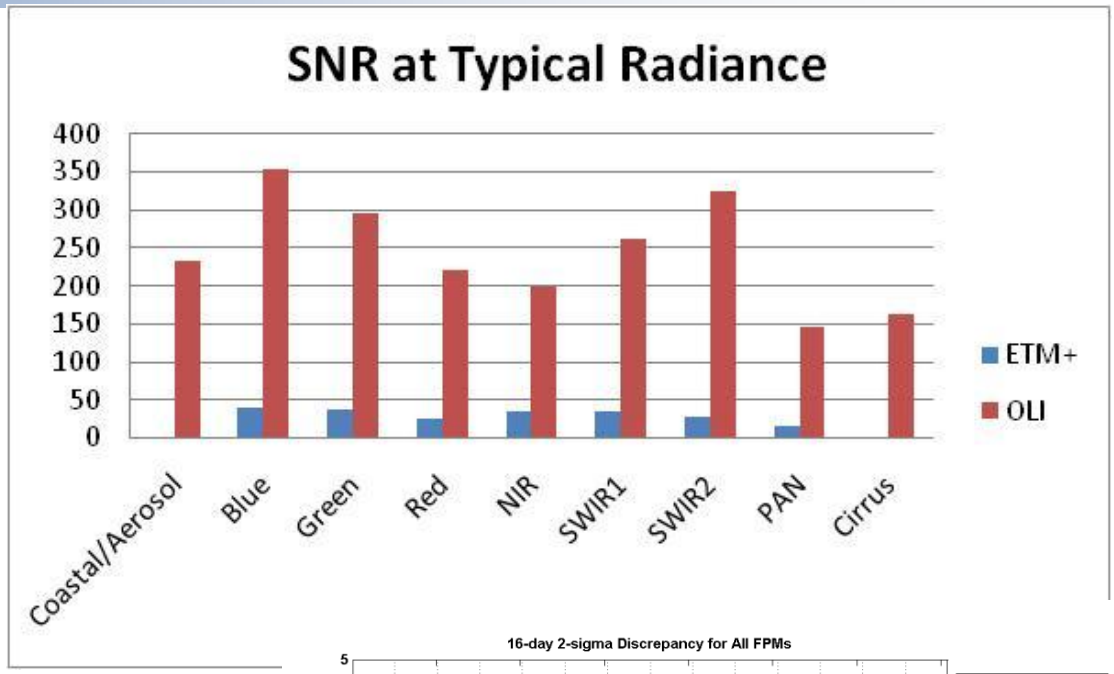


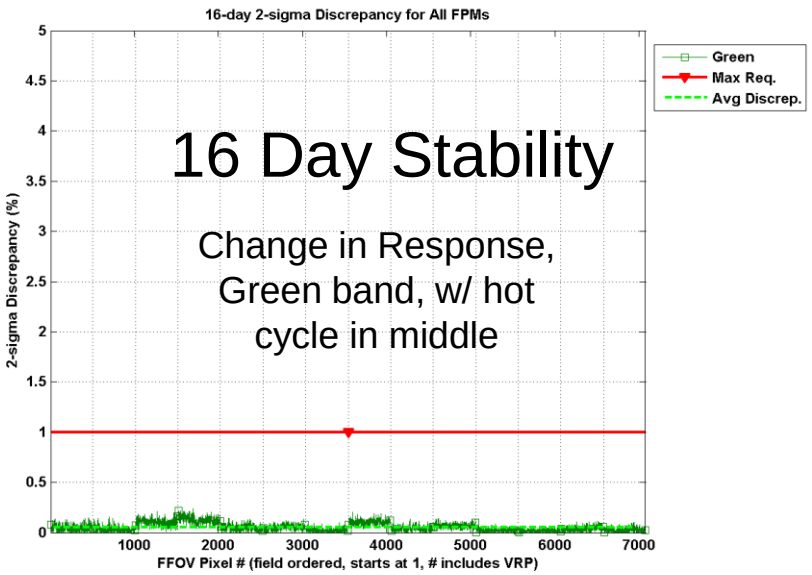
Top Level Performance Results

- Geometric/Geodetic
- Spatial
- **Radiometric**
- Spectral

OLI Radiometric Performance looks excellent
(adapted from slide provided by Ed Knight/BATC)

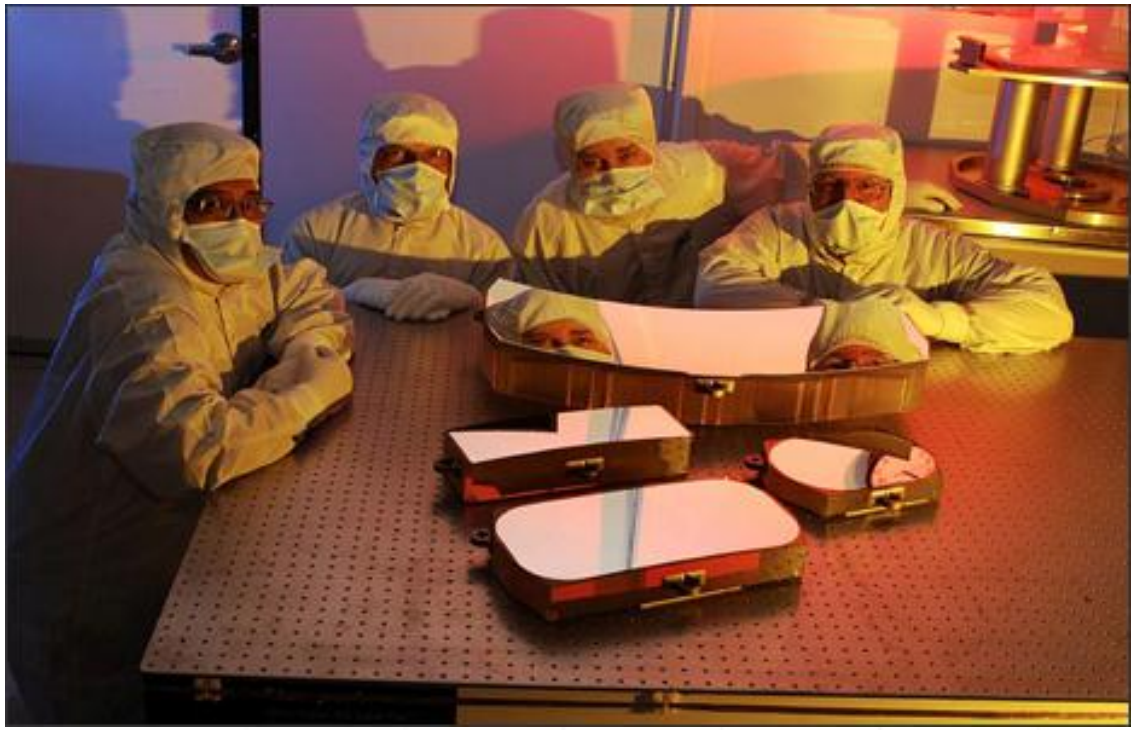
- SNR
  - SNR significantly exceeds requirements and heritage
- Calibration
  - Stability over 60 seconds (2 standard scenes) is excellent
    - <0.02% 2σ
    - Stability over 16 days (time between Solar Diffuser Cals) is excellent
      - <0.54% 2σ for all but Cirrus Band which is <1.19%





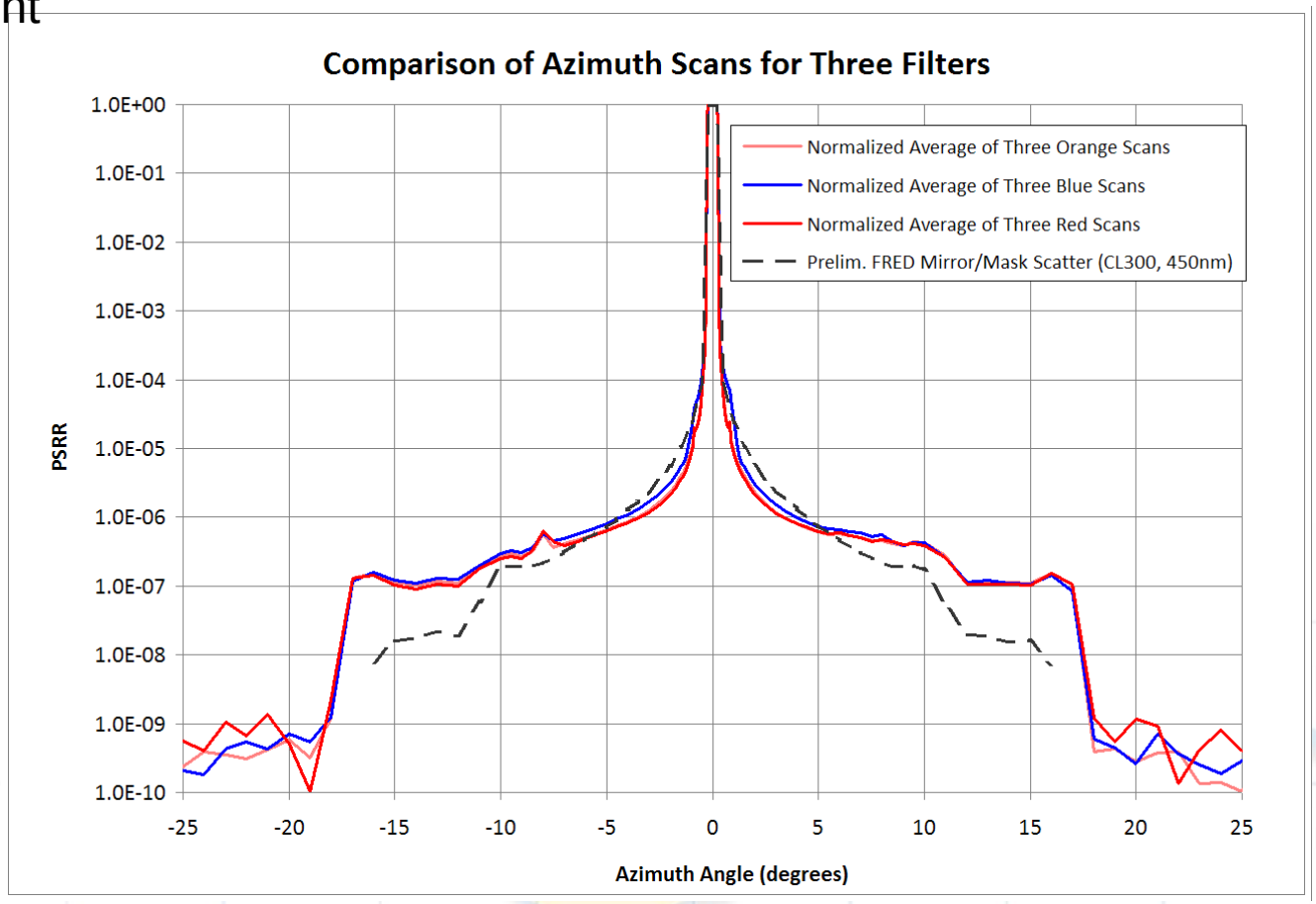
OLI uses 4 large state-of the-art Silver coated mirrors in the telescope.

- The mirrors project the image onto the detector arrays.
- They are large so they will provide:
  - a 15.1 deg. FOV.
  - 15/30 meter resolution
  - enough light collect for good sensitivity
- They must be ultra-clean and ultra-smooth to reduce scattered light.



OLI Stray Light Testing

- Tests using BATC state of art stray light facility; had tremendous results
- Background light from facility undetectable (detector noise dominated)
- Reference point: 9 orders of magnitude is difference between 10:30 am sun and ¼ moonlight



Pixel-to-Pixel Uniformity (PPU)

- ETM+Relative detector-to-detector normalization, i.e., striping less than ± 0.1%
  - This high degree of PPU is expected due to the low number of detectors and the nature of a whiskbroom scanner with a narrow IFOV.
  - Based on analyses of uniform scenes and internal calibration data estimate.

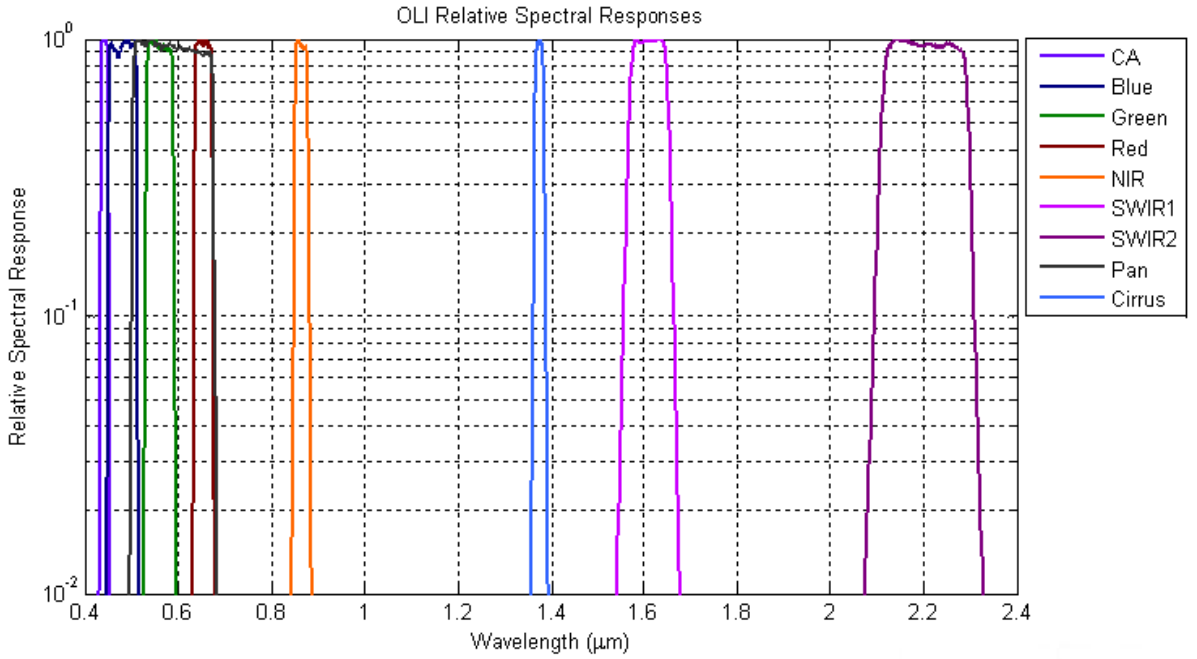
- LDCM OLI & TIRS PPU requirement is approximately 0.5% depending on the nature of the PPU artifact.
  - In general this requirement has been shown to be met with very few outliers.
  - Several factors contribute to this artifact and they have been measured independently and “Summed” in the system level models.
    - Detector-to-detector gain and offset/dark current stability
    - Uncorrected non-linearity
    - Spectral uniformity
    - Coherent noise
- Work is currently in progress using the NASA/USGS and RIT DIRSIG image simulators to demonstrate the impacted of the estimated effects.

Top Level Performance Results

- Geometric/Geodetic
- Spatial
- Radiometric
- **Spectral**

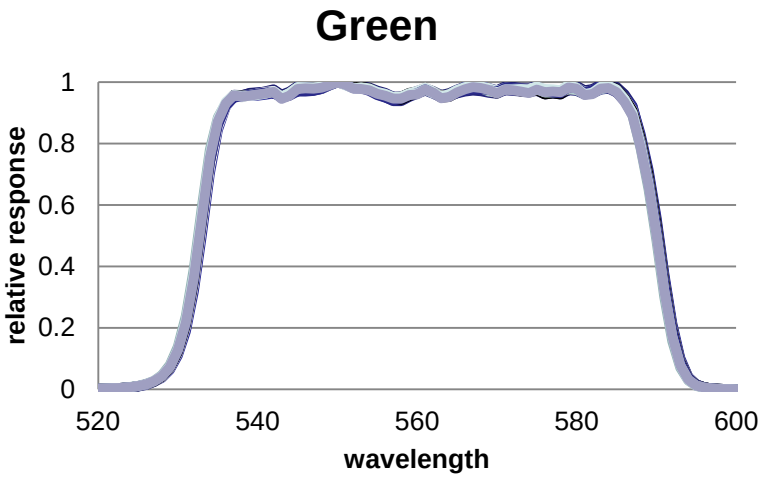
OLI Spectral Performance

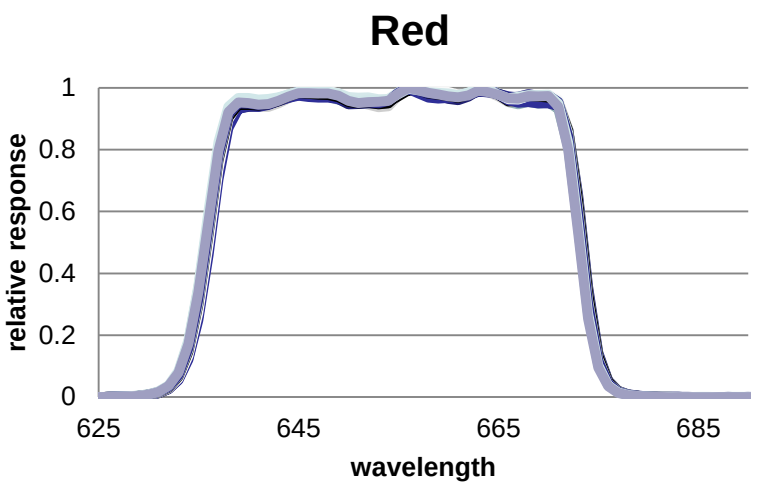
- Spectral Performance
  - Relative Spectral Responses have desired sharp bandpasses
  - Out-of-Band Response typically below 10^{-4}
  - **Only 4 pixels** have anomalous response (high Out-of-Band response in red)
  - Uniformity very good

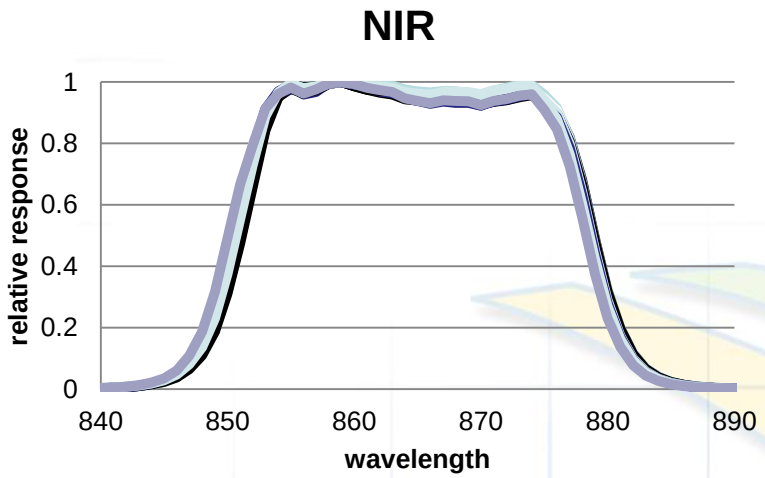


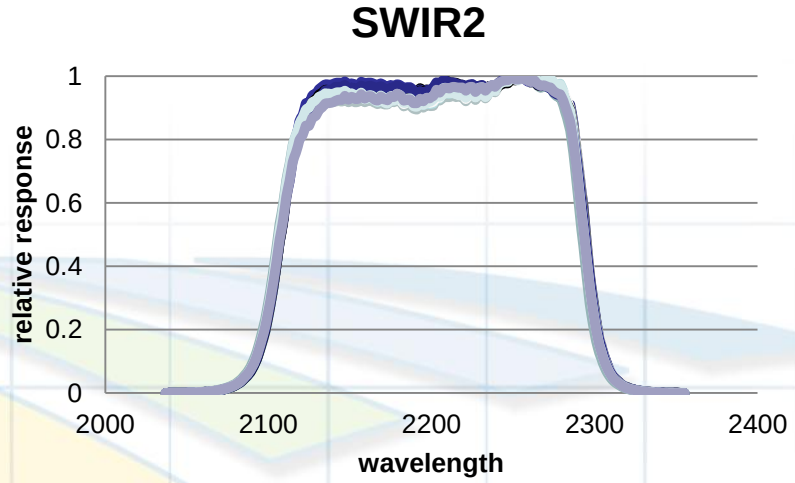
OLI Instrument Relative Spectral Response (RSR) Uniformity

- FPM average RSRs Demonstrating the high degree of spectral uniformity across the FOV.

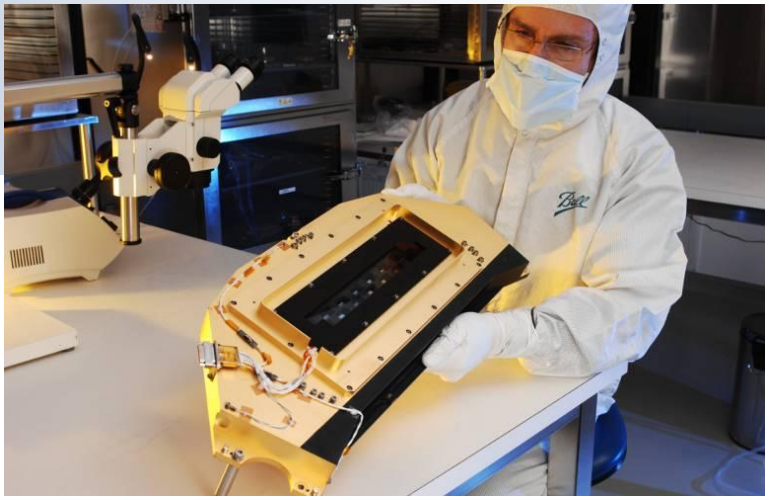




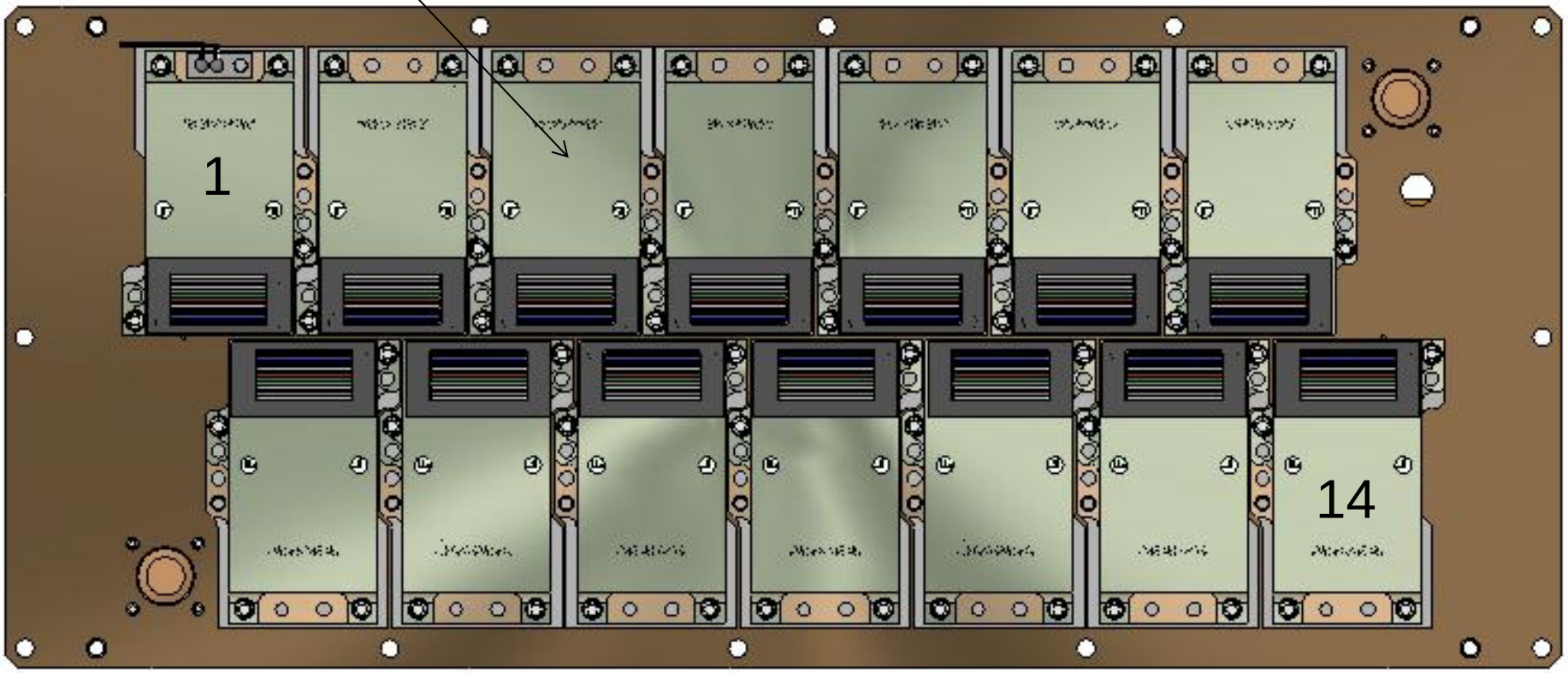




OLI Focal Plane Assembly



Focal Plane Module



Future Work

- Continue Calibration/Validation and Linearity Special Study Data Analyses.
- Develop/update Detailed Sensor Models based on Cal/Val measurements.
- Additional simulations of impact of sensor model on image quality.
  - Spectral shift induced errors between scene spectra and solar diffuser spectra.
- Explore ways that using detailed sensor model to improve image quality and end-user products.
  - Use detailed knowledge of RSR.
- Initial on-orbit checkout and on-orbit validation.

Conclusion

- LDCM's Instruments have demonstrated they will meet of exceed the requirements for Landsat-8.
- The OLI as-measured performance will provide a significant increase in the quality of the medium resolution reflective Landsat data, especially in the area of SNR.
- Work remains in understanding the higher order artifacts and behaviors and then to use this information to further refine the image data.

Acknowledgements and Credits

- The following persons contributed significant expertise, effort, and material towards the preliminary results shown here. Many others unnamed here were also instrumental in the success. Our apologies to anyone inadvertently left off this list.
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