National Aeronautics and Space Administration

The Landsat Data Continuity Mission Operational Land Imager: Pre-Launch Performance

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Ball Aerospace & Technologies Corp.

LDCM LANDSAT

data continuity mission

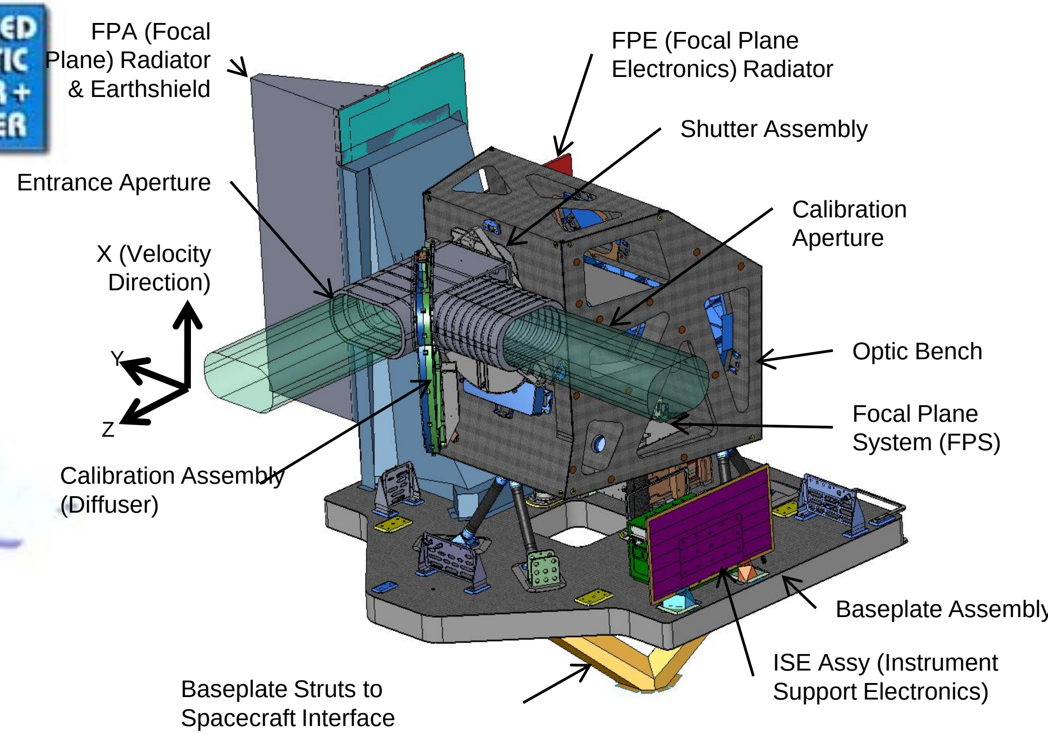
OLI Presentations

- The Landsat Data Continuity Mission Operational Land Imager: Pre-Launch Performance Characterization --- Brian Markham—NASA Goddard Space Flight Center; Edward Knight, Brent Canova, Eric Donley, Geir Kvaran, Kenton Lee — Ball Aerospace & Technologies Corp.
- Operational Land Imager: Radiometric Calibration Overview --- Geir Kvaran — Ball Aerospace & Technologies Corp.
- Reflectance Factor Measurements of the OLI Flight Diffusers --- Stuart Biggar, Nikolaus Anderson—University of Arizona; Linda Fulton, Geir Kvaran, Harlan Kortmeyer—Ball Aerospace & Technologies Corp.
- The OLI Radiometric Scale Realization Round Robin Measurement Campaign -- Hansford Cutlip, Jerold Cole—Ball Aerospace & Technologies Corp.; B. Carol Johnson, Stephen Maxwell—NIST; Milton Hom, Brian Markham, Lawrence Ong—NASA Goddard Space Flight Center; Stuart Biggar—University of Arizona, College of Optical Sciences

Outline

- Instrument Description Overview
- Summary of Testing
- Summary of Test Results

The Operational Land Imager (OLI) represents a generational change in Landsat technology

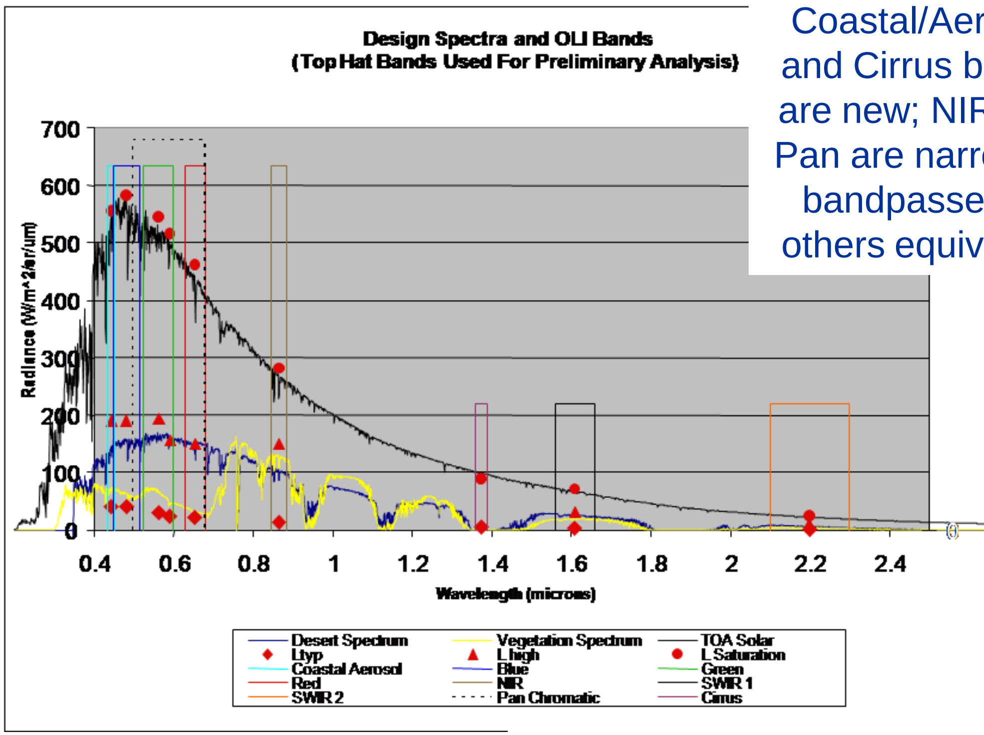


- Whiskbroom imager
- Obscured telescope
- 1020 cm^2 aperture
- 8 bits transmitted to ground
- VIS/SWIR and IR

- Pushbroom Imager
- Unobscured telescope
- 143 cm^2 aperture
- 12 bits transmitted to ground
- OLI is VIS/SWIR only (TIRS does IR)

OLI Maintains Landsat Legacy

- Landsat Continuity Mission demands
  - Accurate spectral and spatial information
  - Frequent synoptic earth views
  - NIST calibrated over time
  - Precise geo-referenced data



Coastal/Aerosol and Cirrus bands are new; NIR and Pan are narrower; bandpasses of others equivalent

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

Band Name	CW (nm)	Bandwidth (nm)	GSD (m)	SNR
Coastal/ Aerosol	443	20	30	130
Blue	482	65	30	130
Green	562	75	30	100
Red	655	50	30	90
NIR	865	40	30	90
SWIR 1	1610	100	30	100
SWIR 2	2200	200	30	100
PAN	590	180	15	80
Cirrus	1375	30	30	50

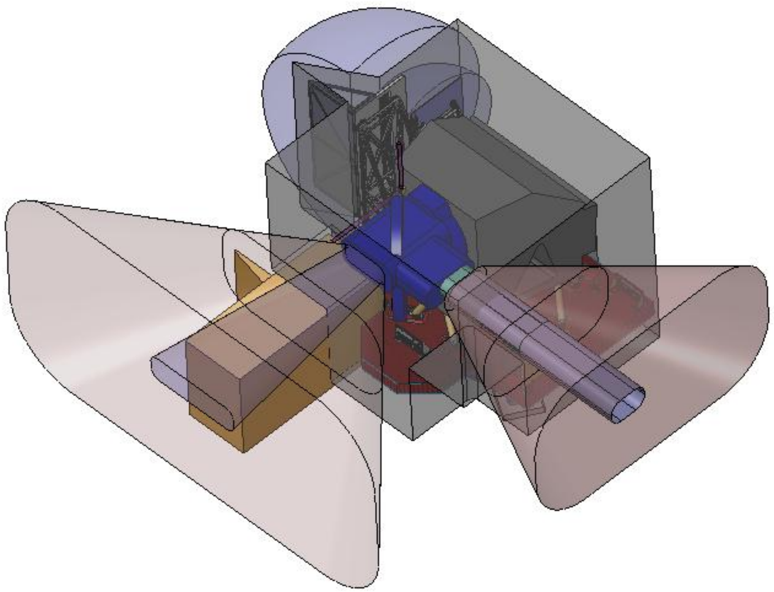
Visible/NIR SWIR

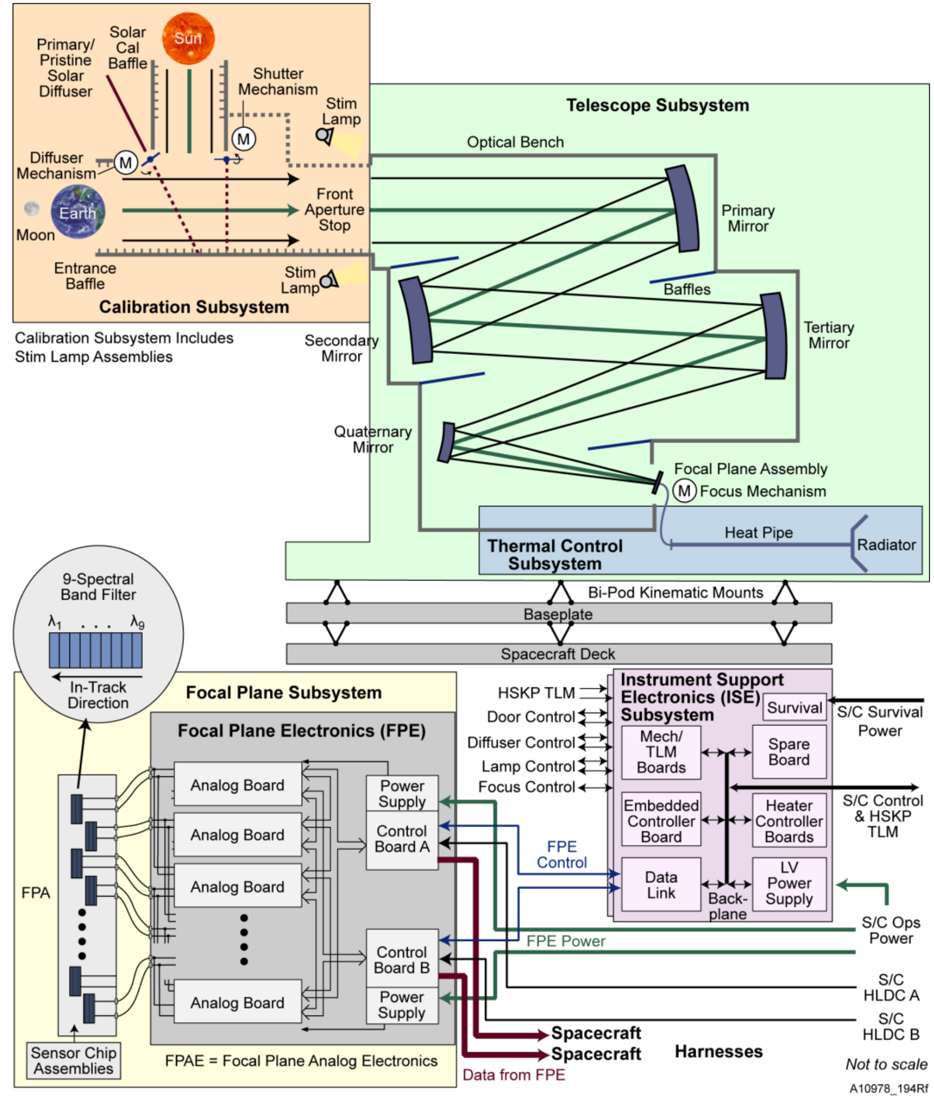
*No terrain compensation
**w/ terrain compensation

Note: Geometric reqts are tighter for OLI

OLI is a fairly simple instrument

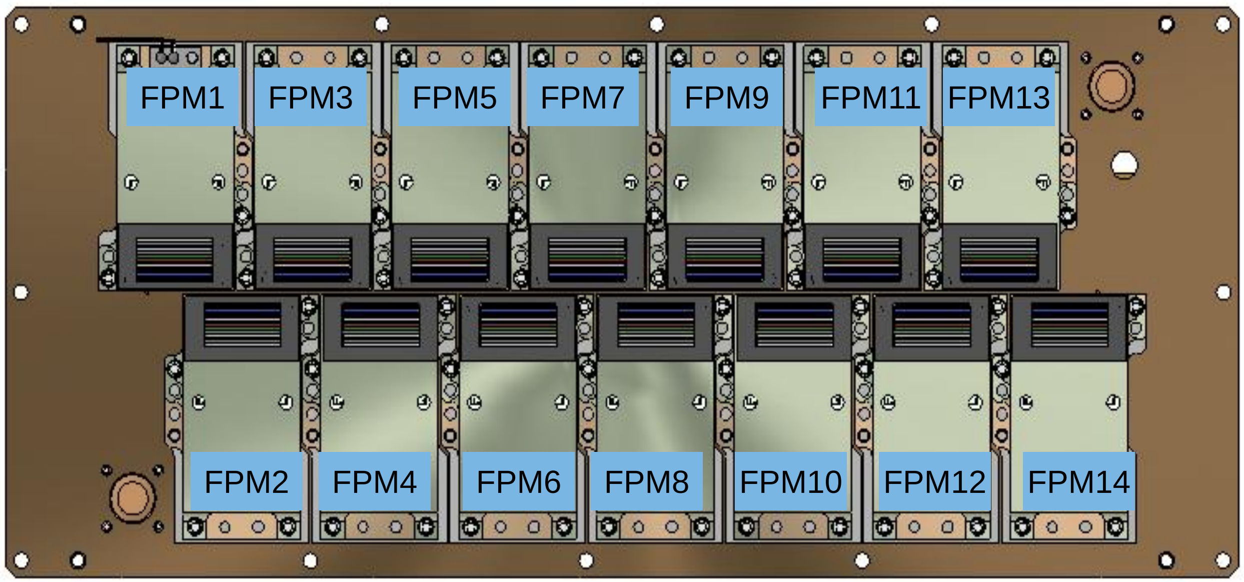
- Pushbroom VIS/SWIR sensor
- Four-mirror telescope with front aperture stop
- FPA consisting of 14 sensor chip assemblies, passively cooled
- On-board calibration with both lamps and full aperture diffusers





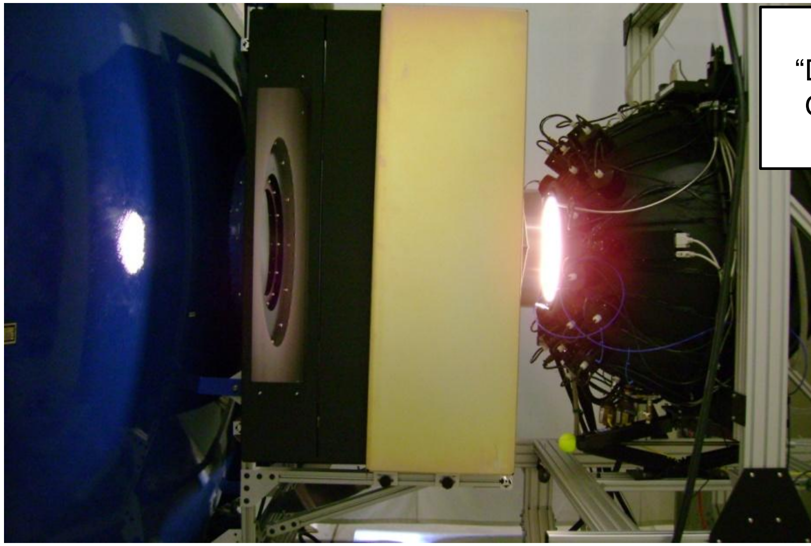
OLI Focal Plane

- Focal Plane Array
  - Consists of 14 modules to cover the 15-degree field of view
  - 6919 detectors per multi-spectral band (13832 for Pan band)
- Focal Plane Module (FPM)
  - 494-detector array for each multi-spectral band (988 for Pan band)
  - Silicon PIN detectors for VNIR bands, HgCdTe detectors for SWIR bands
  - Butcher-block filter assemblies cover the detector arrays



OLI Is Complete*

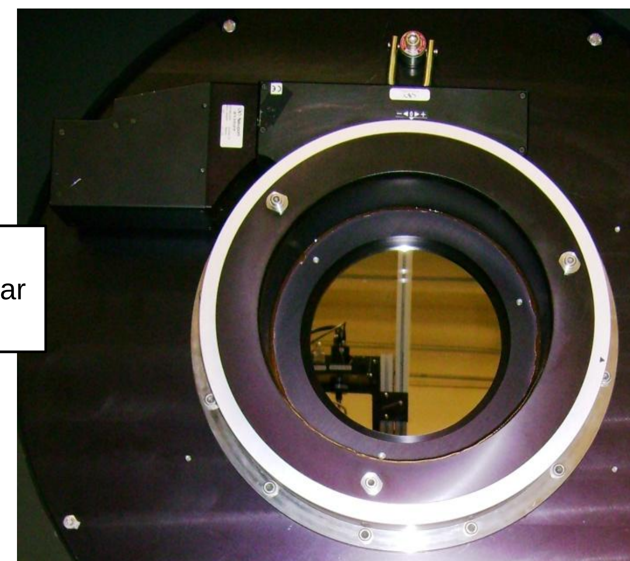
Radiometric and Spectral Tests Completed with traditional spheres and monochromators



Aligning "Death Star" Calibration Sphere

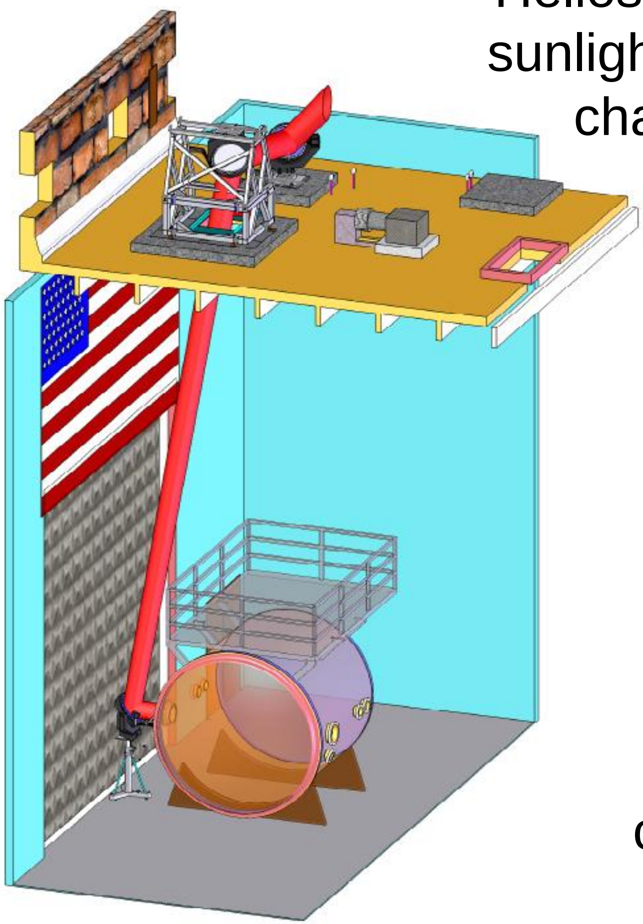
Inspecting heliostat alignment

Spectral Measurement Assembly



Large aperture linear polarizer

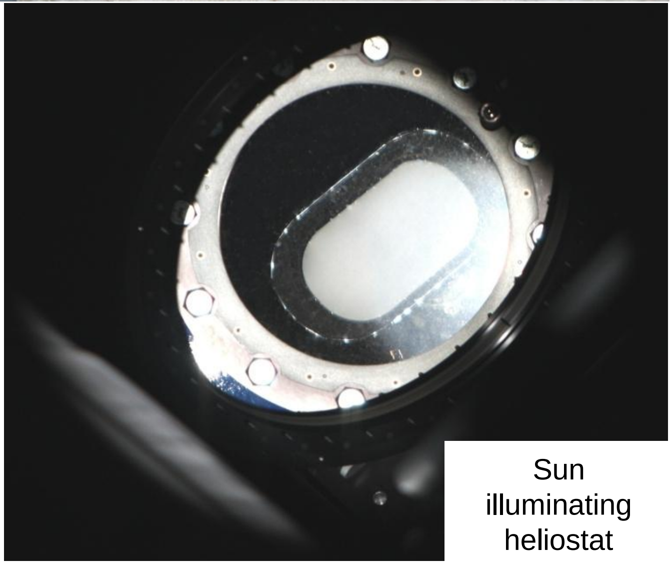
Heliostat Calibration provides transfer of calibration to orbit



Heliostat steers sunlight into T/V chamber

Measuring Heliostat Transmission

Atmospheric transmittance characterized by University of Arizona

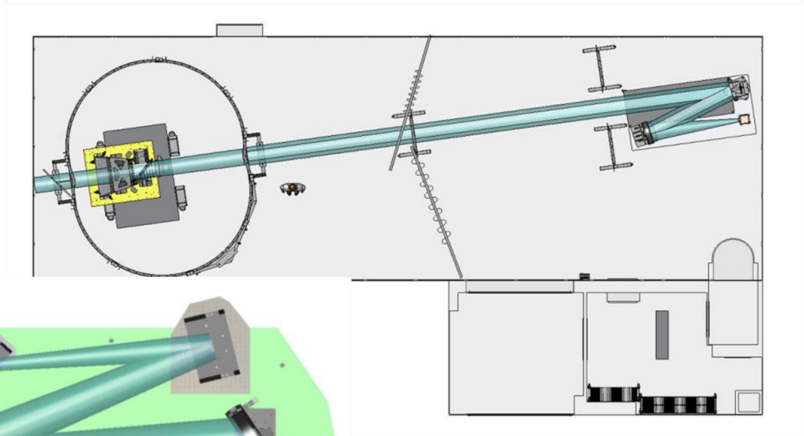


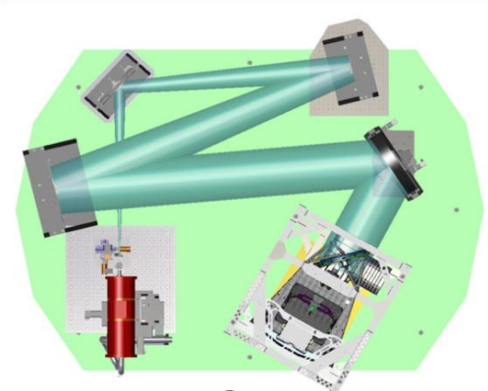
Sun illuminating heliostat

Extensive Spatial Characterization

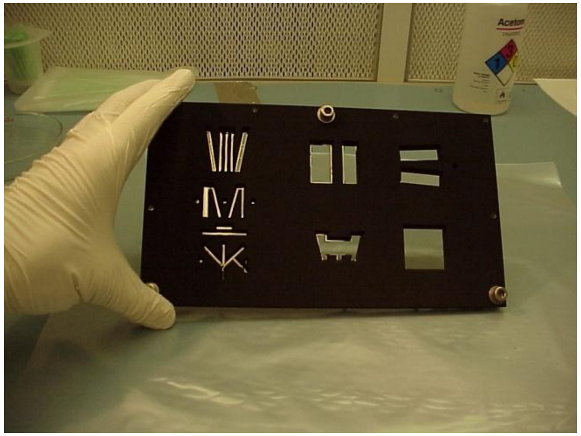
- **Conducted stray light characterizations in state of art facility**
- **Other Spatial Characterizations with BATC's Horizontal Collimator Assembly (HCA)**
  - **Collimator and instrument in Vacuum**
  - **Various spatial targets used to conduct characterizations of edge response, ghosting, bright target recovery, pointing**

Stray light facility

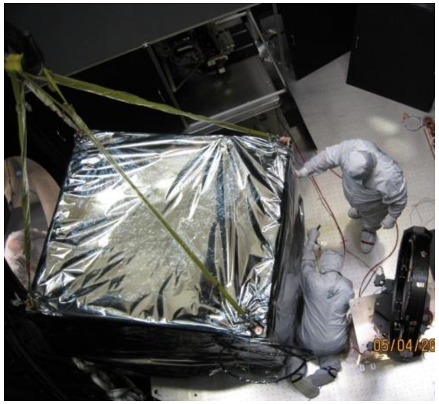




HCA



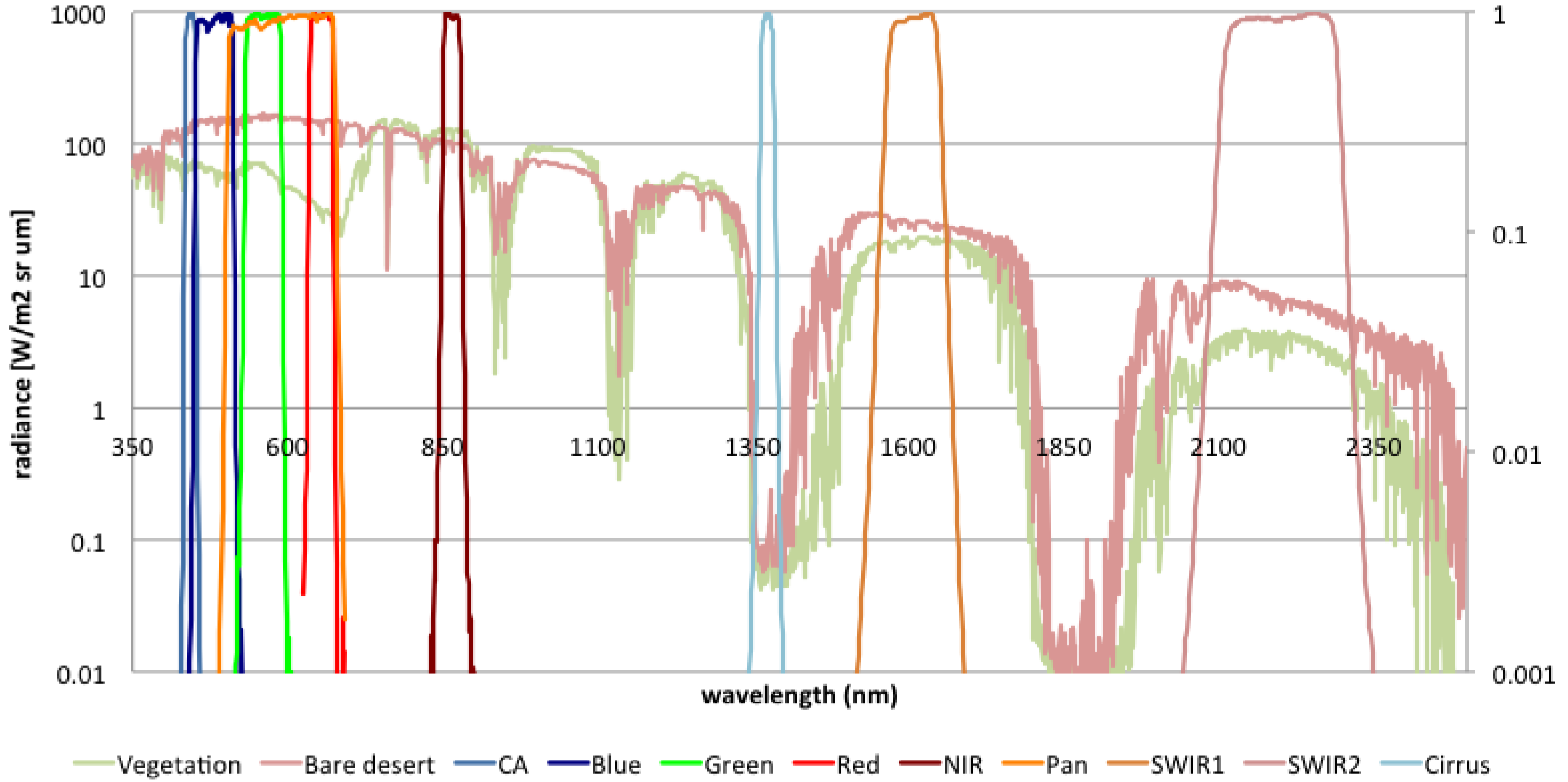
Spatial targets used for testing



OLI being lowered into chamber for spatial testing

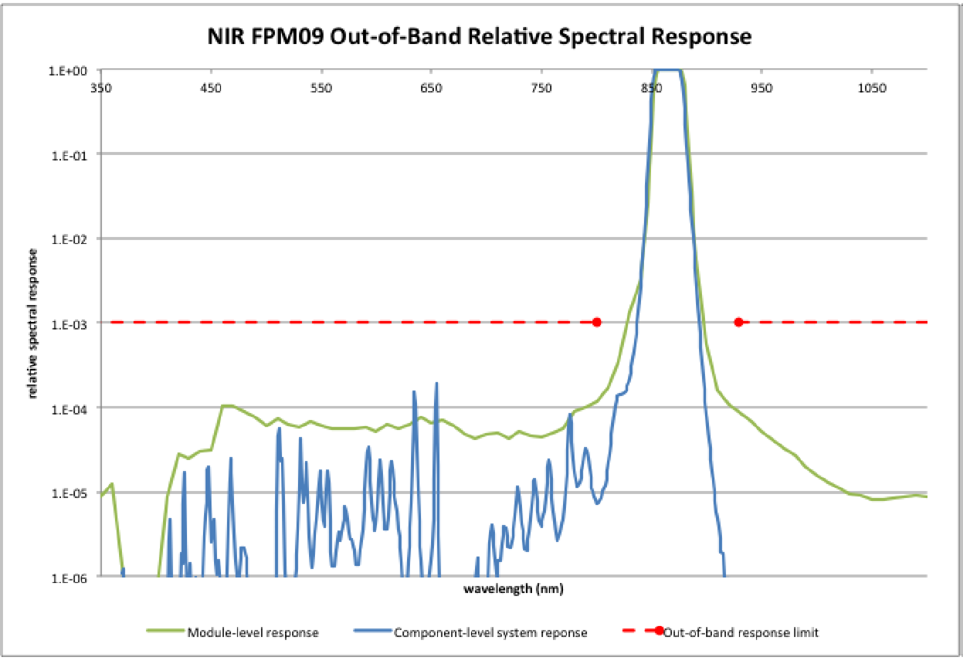
Spectral Performance - In band

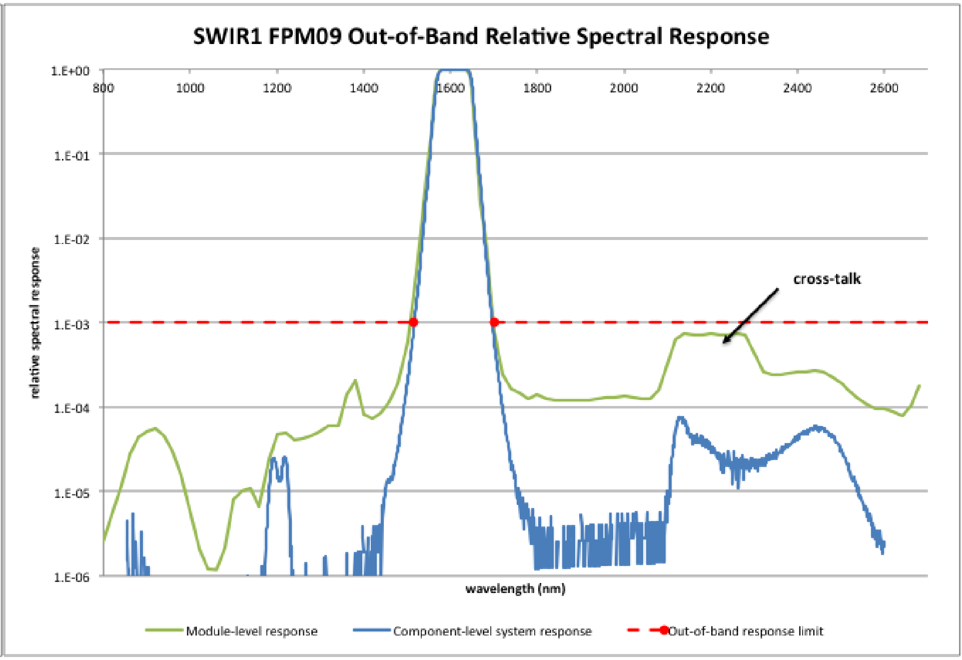
- **Relative Spectral Responses have desired sharp bandpasses**



Spectral Performance – Out-of-band

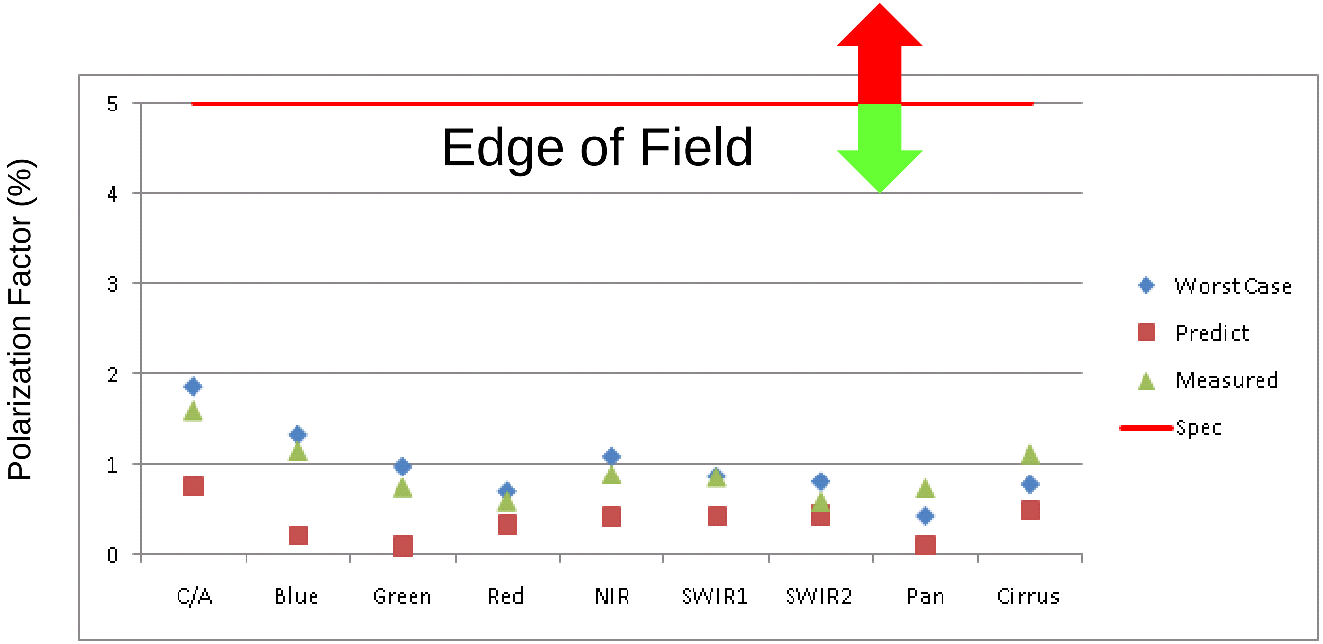
- Out-of-band response
  - Measured at Focal Plane Module (Detectors + filters) level; focal plane fully illuminated; optics contribution (mirrors + window) analytically added
  - Typically 10^{-4} or better (approximate stray light level in test set up)
  - Some SWIR band crosstalk – most likely within detector *material*—within requirements





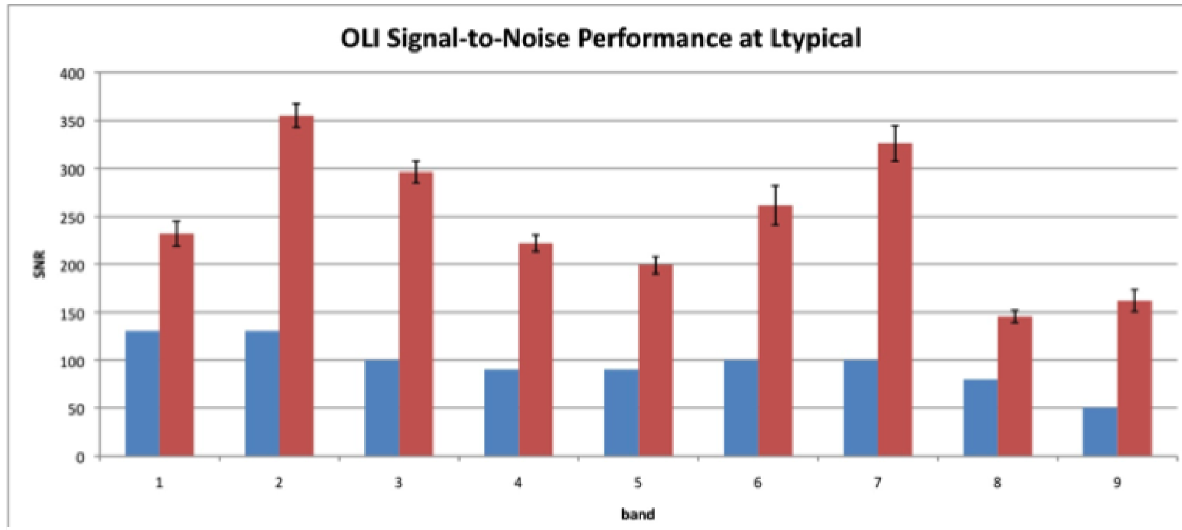
Polarization Performance

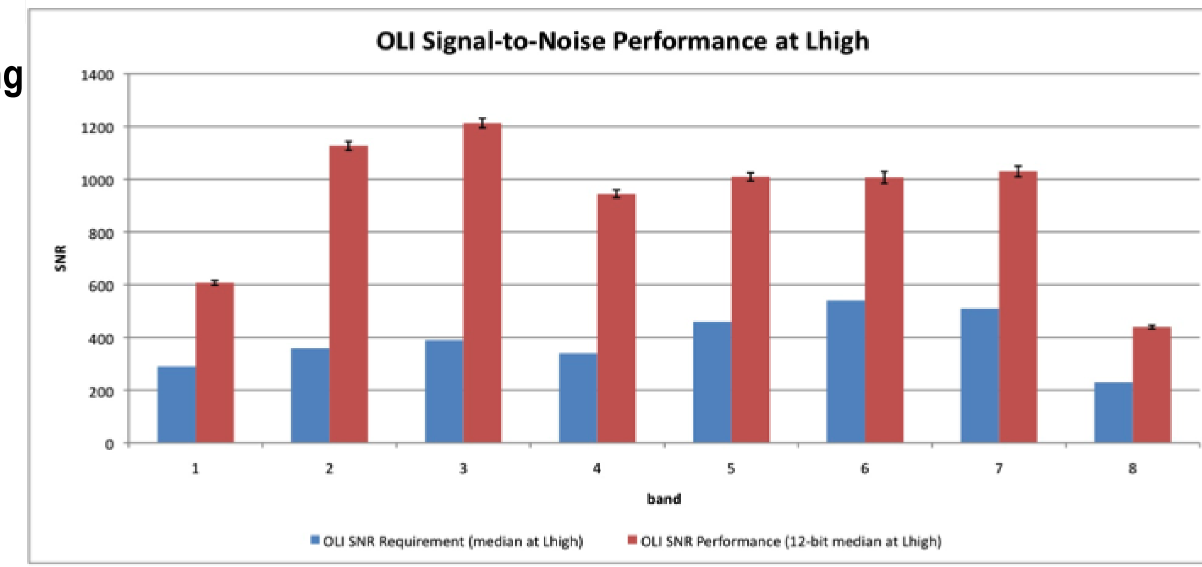
- **Polarization**
  - Polarization Sensitivity well below 2%
  - Will not alter measured signal from highly polarized scenes such as canopies and water



Radiometric Performance

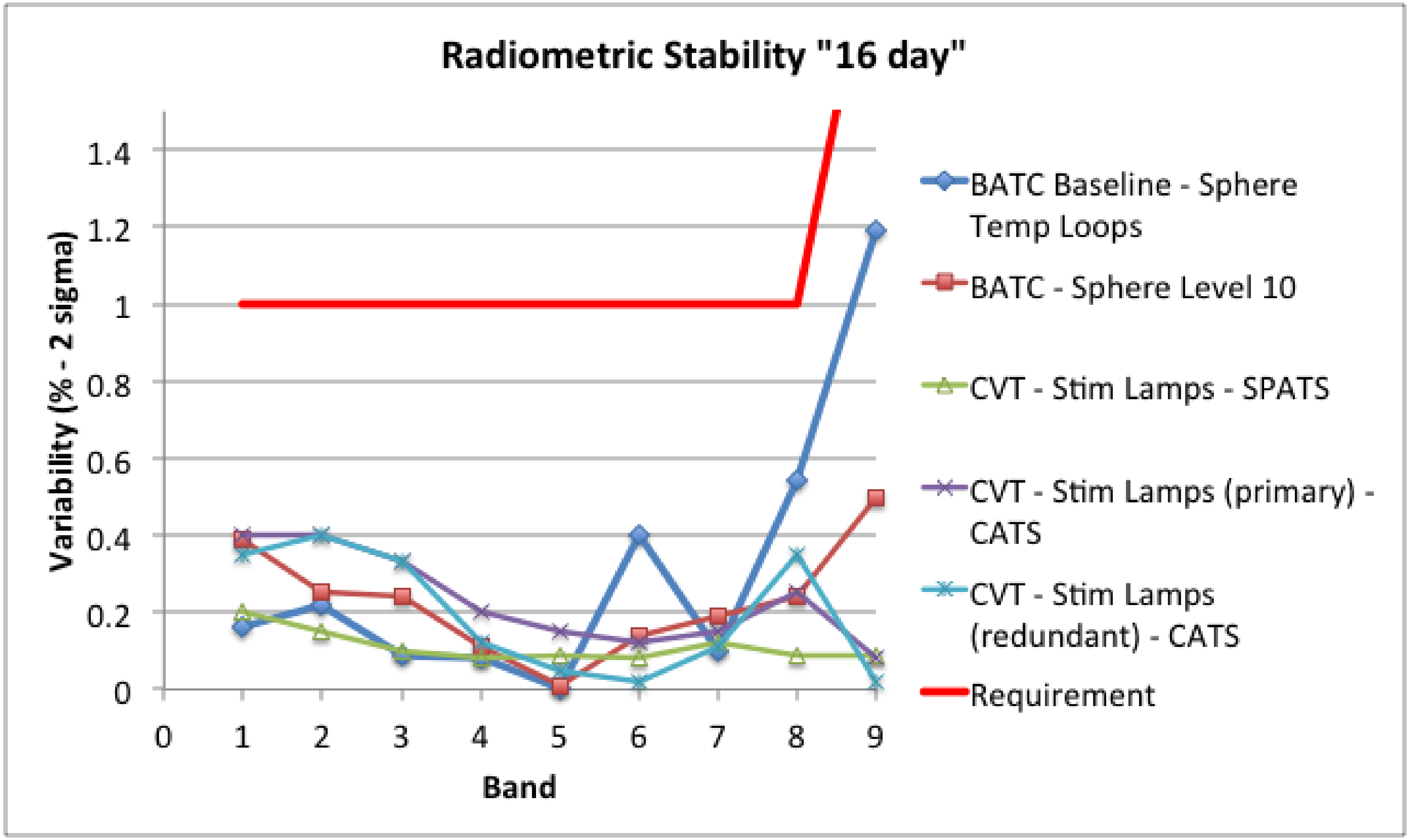
- **SNR**
  - SNR significantly exceeds requirements and heritage
- **Calibration**
  - Radiance uncertainty ~3.5%
    - Extensive round robin for NIST traceability
    - Transfer-to-Orbit uncertainties measured
  - Reflectance uncertainty ~2.5%
  - To be discussed in upcoming presentations





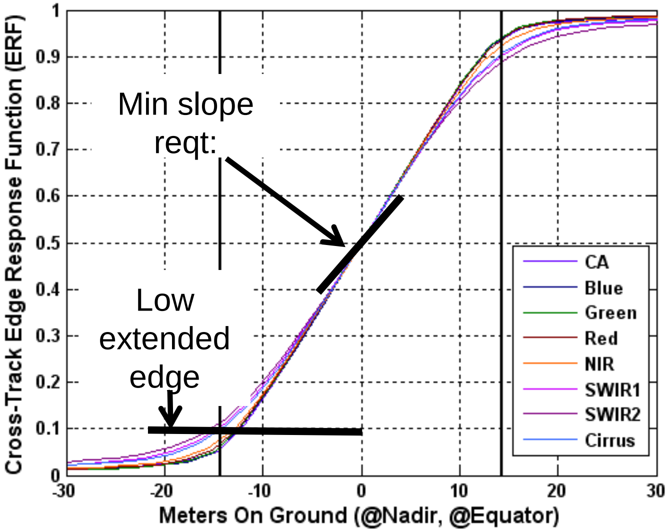
Radiometric Performance - Stability

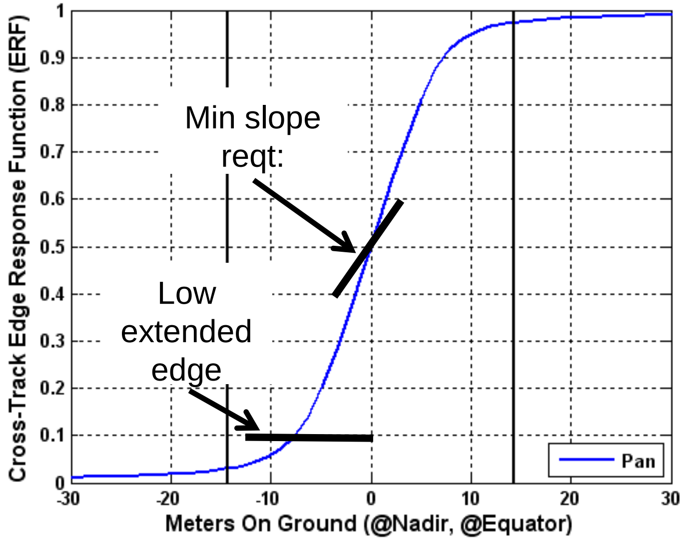
- **Stability over 16 days (time between Solar Diffuser Cals) is excellent**
  - <0.54% 2σ for all but Cirrus Band which is <1.19%



Spatial Performance

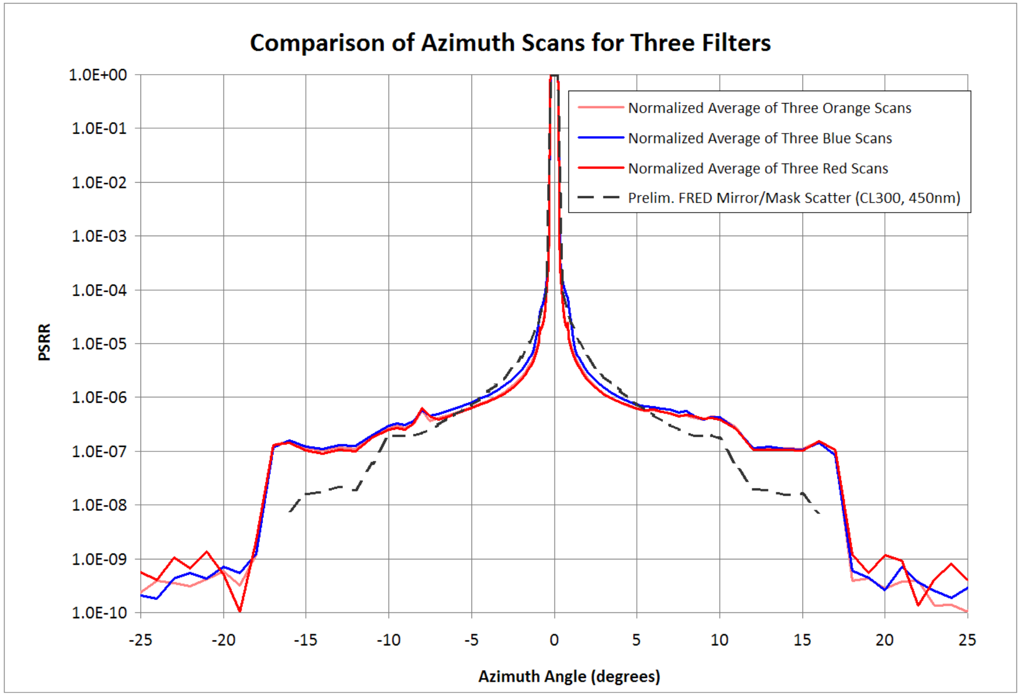
- Spatial Performance
  - Want sharp edges for change detection
  - Measured spatial response has:
    - Steep slope (exceeding reqts)
    - Low extended edge (good half edge extent)
    - No ripple/overshoot
- Geolocation
  - Want good pointing knowledge, again for change detection
  - Performance depends on both instrument and spacecraft; final measurements made during initial on-orbit checkout
  - Pre-launch instrument measurements mapped line of sight of all detectors to reference pixel/boresight to ~1/10th of a pixel
  - On target to have absolute geometric accuracy of <1/2 pixel





OLI Stray Light Testing Complete

- **Tests using BATC state-of-the-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**



Stray Light Ninjas

Summary

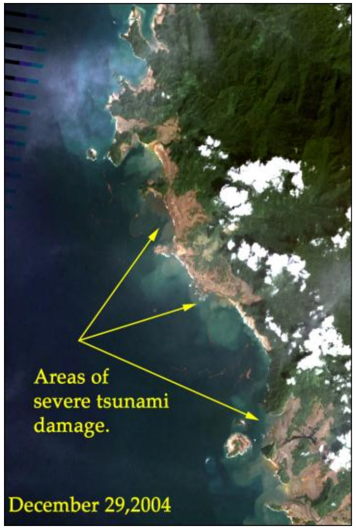
- **OLI represents a generational change from ETM+ , but must preserve data continuity and therefore maintain solid calibration.**
- **Instrument design focuses on simplicity**
  - **Pushbroom vs. whiskbroom instrument**
- **Thorough pre-launch calibration and characterization complete**
  - **With unique BATC calibration facilities**
- **Performance meeting user needs**

Slides for Session Introduction

Landsat Data Continuity Mission (LDCM) Overview

Mission Objectives

- **Provide continuity in the multi-decadal Landsat land surface observations to study, predict, and understand the consequences of land surface dynamics**
  - **Land cover/use change**
  - **Human settlement and population**
  - **Ecosystem dynamics**
  - **Landscape scale carbon stocks**
  - **Resource management/societal needs**



Landsat 7 data used to aid Indonesian government with tsunami relief efforts (David Skole, Michigan State University)

LDCM Data Needed to Address NASA Earth Science Focus Areas, Questions, and Applications

Focus Areas	*Science Questions*
• Carbon Cycle, Ecosystems, & Biogeochemistry • Water & Energy Cycle • Earth Surface & Interior	- What are the changes in global land cover and land use, and what are their causes? - How do ecosystems, land cover & biogeochemical cycle respond to and affect environmental change? - What are the consequences of land cover and land use change for human societies and the sustainability of ecosystems ? - What are the consequences of increased human activities on coastal regions?

Instruments

- **Operational Land Imager – BATC**
- **Thermal Infrared Sensor – GSFC**

Spacecraft

- **Orbital**

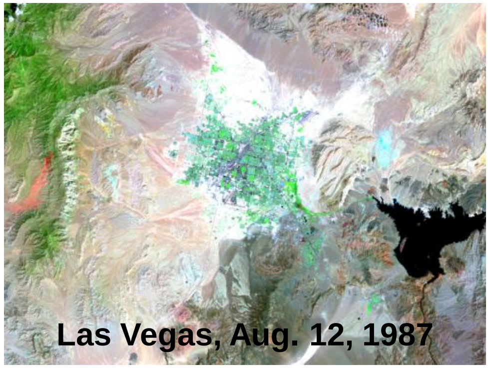
Mission Team

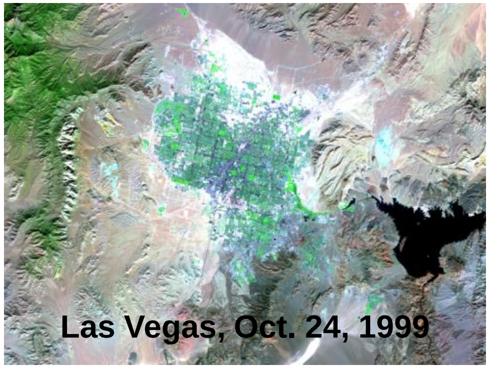
- **NASA Goddard Space Flight Center**
- **Dept. of Interior's United States Geological Survey (USGS)**
- **NASA Kennedy Space Center**

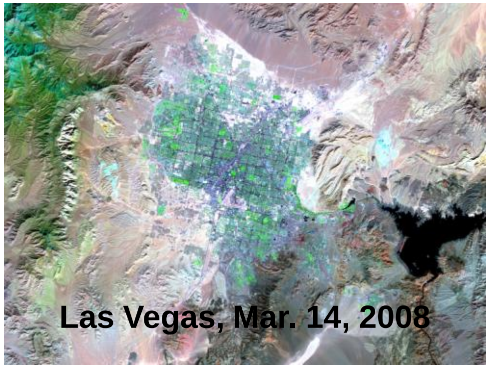
Launch Readiness Date – December 2012

LDCM Mission Overview

- Mission Description
  - 1 satellite
  - 5 year mission
    - 10 years of propellant
  - After declaration of operational readiness, responsibility for LDCM transitions to USGS
- Orbit
  - 705 km at equator
  - 98.2° Inclination Sun-Synchronous
  - 16-day ground repeat
  - 10am mean local time (descending node)
- Spacecraft
  - 3-axis stabilized
  - Instrument Accommodation
    - OLI
    - TIRS
- Launch
  - Launch Vehicle - Atlas V 401
  - Date: December 12, 2012


Las Vegas, Aug. 12, 1987


Las Vegas, Oct. 24, 1999


Las Vegas, Mar. 14, 2008

Landsat and LDCM Spectral and Spatial Requirements

	Landsat-5/7 TM/ETM+ Bands (µm)			LDCM Band Requirements (µm)			
				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	OLI
	Band 3	30 m Red	0.630 - 0.690	30 m Red	0.630 - 0.680	Band 4	
ETM+	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	60/120m* LWIR	10.40 - 12.50	120 m LWIR-1	10.30 –11.30	Band 10	TIRS
				120 m LWIR-2	11.50 –12.50	Band 11	
	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	OLI
				30 m Cirrus	1.360 - 1.390	Band 9	

Spotlight Session—LDCM

Preflight Calibration for the Thermal Infrared Sensor on the Landsat Data Continuity Mission

Kurtis Thome, Dennis Reuter, Ramsey Smith—NASA/Goddard Space Flight Center; Allen Lunsford—Catholic University of America; Matthew Montanaro, Brian Wenny —Sigma Space Corporation; Zelalem Tesfaye—Bastion Technologies, Inc.

The Landsat Data Continuity Mission Operational Land Imager: Pre-Launch Performance Characterization

Brian Markham—NASA Goddard Space Flight Center; Edward Knight, Brent Canova, Eric Donley, Geir Kvaran, Kenton Lee—Ball Aerospace & Technologies Corporation

Operational Land Imager: Radiometric Calibration Overview

Geir Kvaran—Ball Aerospace & Technologies Corporation

Reflectance Factor Measurements of the OLI Flight Diffusers

Stuart Biggar, Nikolaus Anderson—University of Arizona; Linda Fulton, Geir Kvaran, Harlan Kortmeyer—Ball Aerospace

The OLI Radiometric Scale Realization Round Robin Measurement Campaign

Hansford Cutlip, Jerold Cole—Ball Aerospace & Technologies Corporation; B. Carol Johnson, Stephen Maxwell—NIST; Milton Hom, Brian Markham, Lawrence Ong—NASA Goddard Space Flight Center; Stuart Biggar—University of Arizona, College of Optical Sciences

Landsat Data Continuity Mission On-orbit Calibration and Validation Development

Ron Morfitt, Esad Micijevic—Stinger Ghaffarian Technologies, Inc.; Brian Markham—NASA Goddard Space Flight Center

Calibration of Satellite Imagery, Recalibration of the Past, Through the Present, and into the Future Using Invariant Sites

David Aaron, Larry Leigh—South Dakota State University; Nathan Leisso, Jeffrey Czapla-Myers—University of Arizona