



Calibration overview for the Thermal Infrared Sensor (TIRS) on the Landsat Data Continuity Mission

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Introduction



Much of the success of the Landsat program can be traced to its emphasis on calibration

- Meeting the quality of the Landsat heritage is a challenge
 - Rigorous attention to NIST-traceability of the radiometric calibration
 - Knowledge of out-of-band spectral response
 - Characterizing and minimizing stray light
- Combination of preflight and inflight methods
 - Laboratory
 - Onboard
 - Vicarious

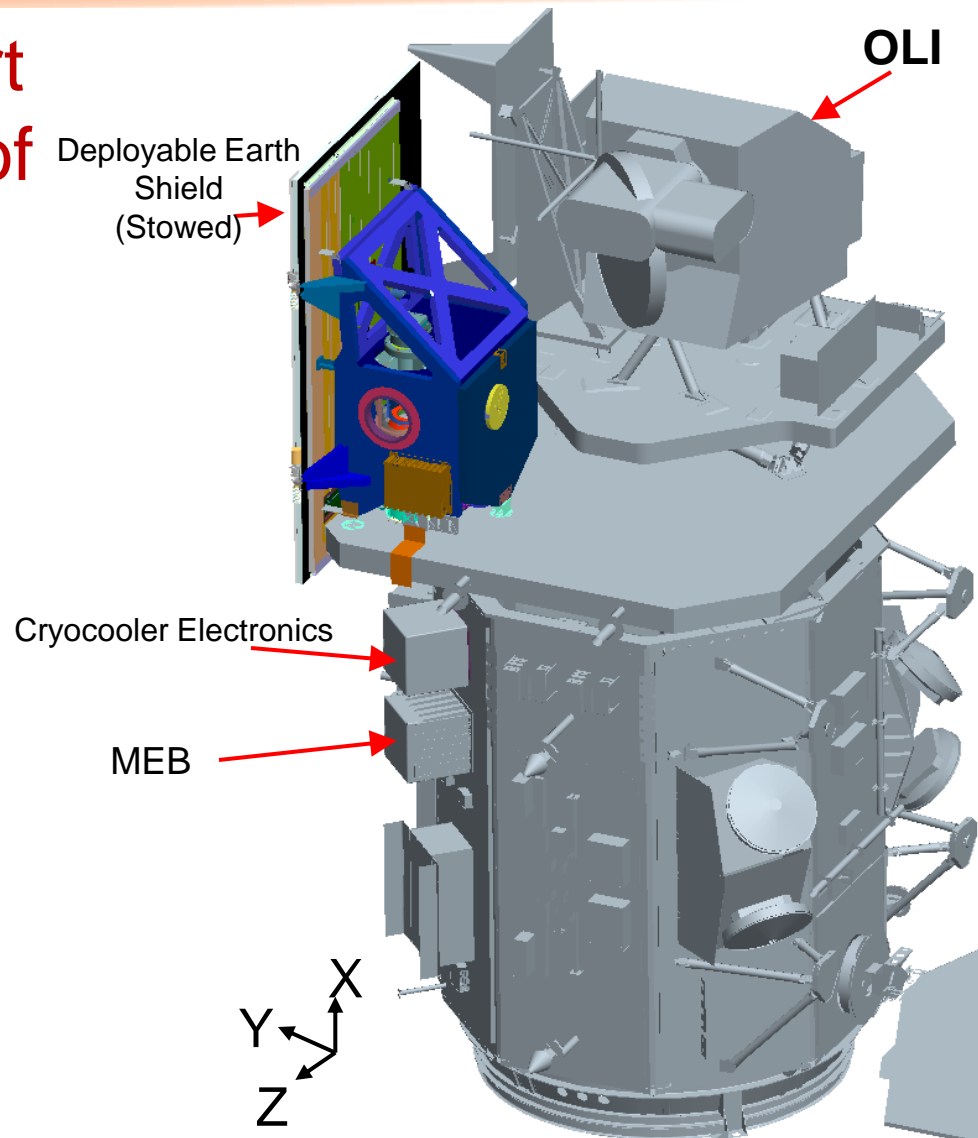


Describe calibration methods for the Thermal Infrared Sensor (TIRS)

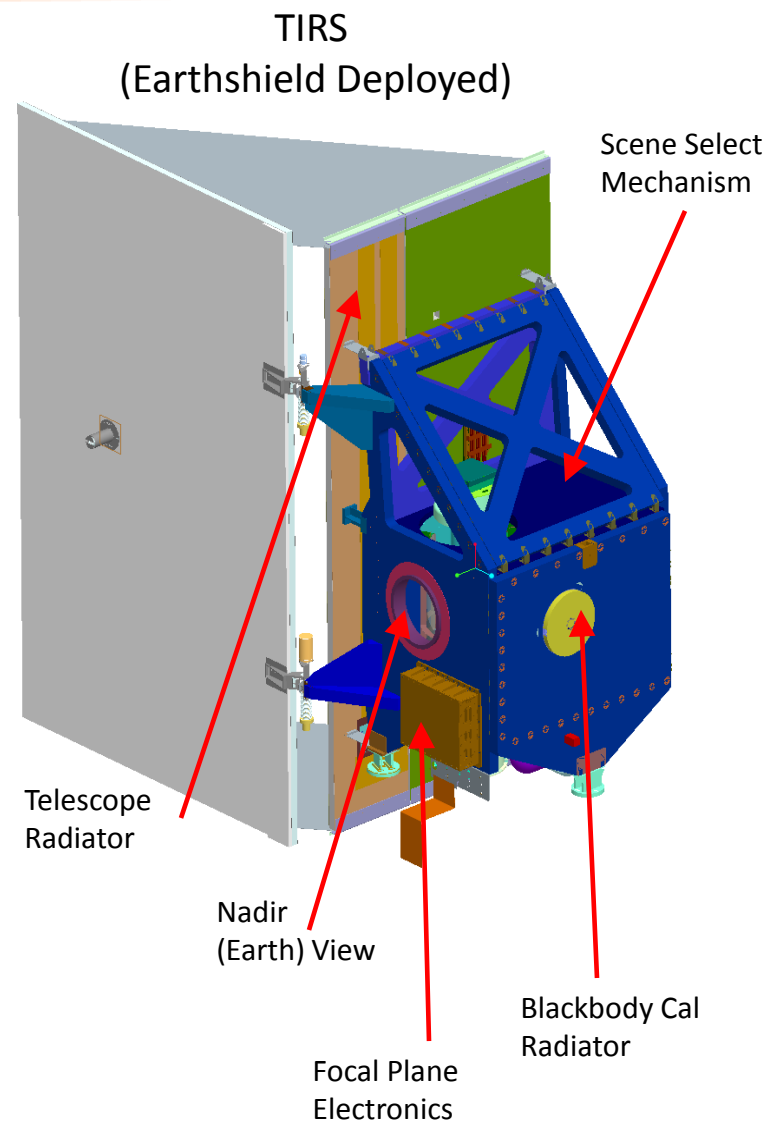
- TIRS continues the Landsat program's thermal IR capabilities
- Describe TIRS
- Prelaunch testing
 - Radiometric and spectral tests
 - Geometric and spatial tests
 - Calibration test equipment
- On-orbit testing
- Conclusions

TIRS operates in concert with but independent of Operational Land Imager

- Will produce radiometrically-calibrated, geo-located data
- United States Geological Survey/ Earth Resources Observation and Science (EROS) facility developing operational algorithms
- OLI and TIRS data merged into a single data stream

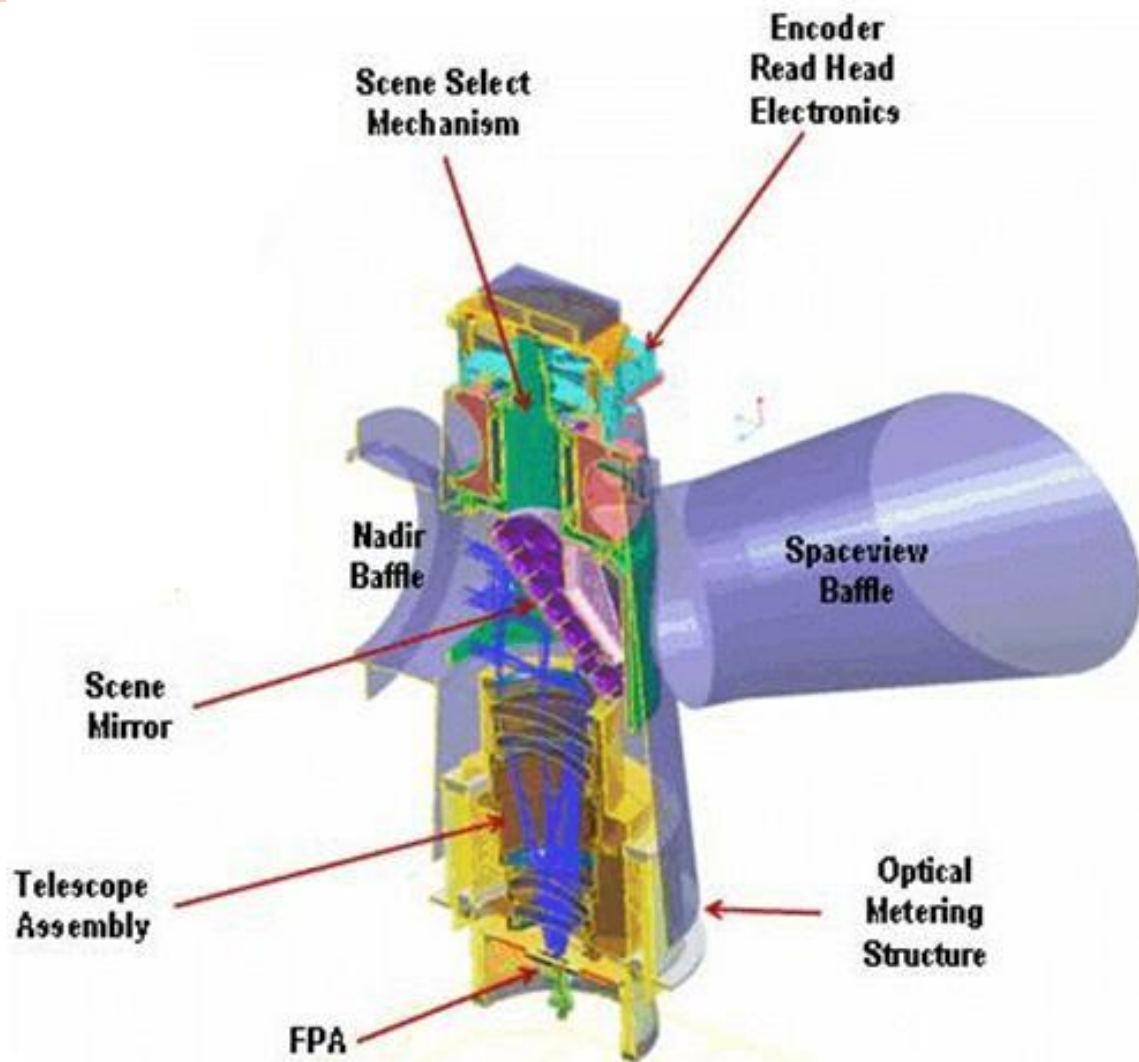


- Quantum well infrared photodetector (QWIP) focal plane array built in-house at GSFC
- Pushbroom approach
- 2-Channel IR spectral imager
 - 10.8 μm and 12 μm
 - 1 μm bandwidth
 - Allows split window atmospheric correction technique
- 185 km swath width (15° FOV)
- 100 meter spatial sampling
- TIRS delivery December 2011
- 3-year life, Class C instrument



TIRS Implementation

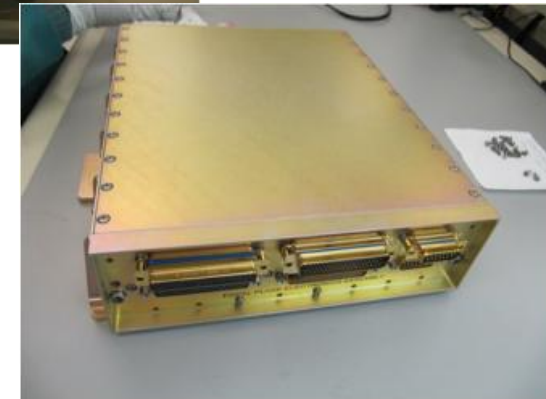
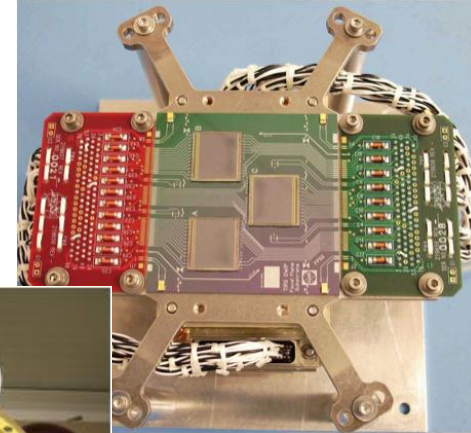
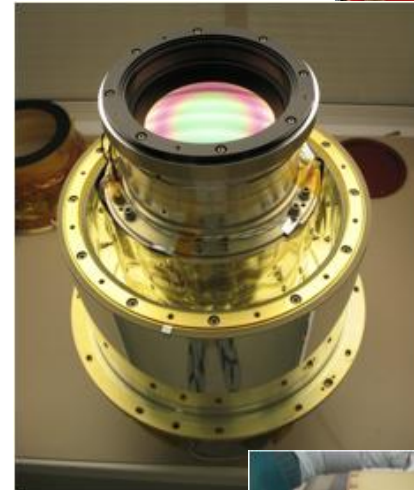
- Precision scene select mirror to select between calibration sources and nadir view
- Two full aperture calibration sources
 - Onboard variable temp black body
 - Space view
 - Calibration every 34 minutes
- NIST Traceable radiometric calibration



Recent milestones

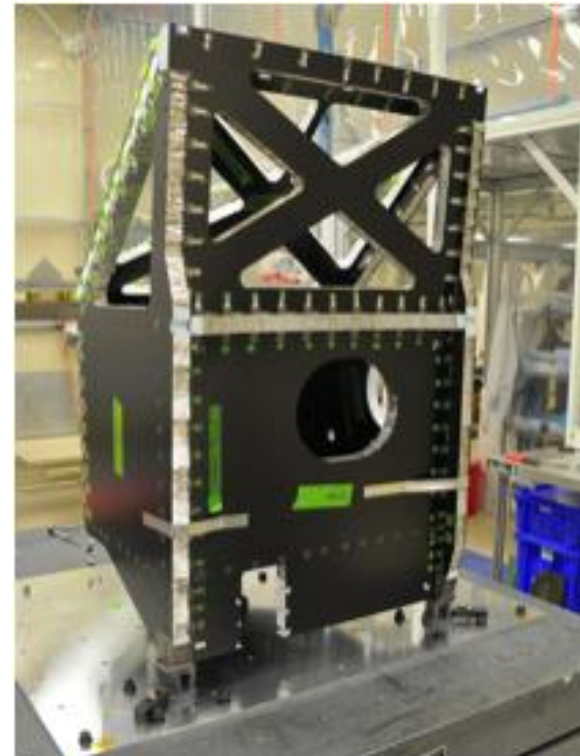
Work is progressing towards a
December 2011 delivery

- Functional performance model (FPM) testing was completed November 2010
- Testing of flight instrument subsystems began January 2011
 - Focal plane array
 - Telescope
 - Focal plane electronics

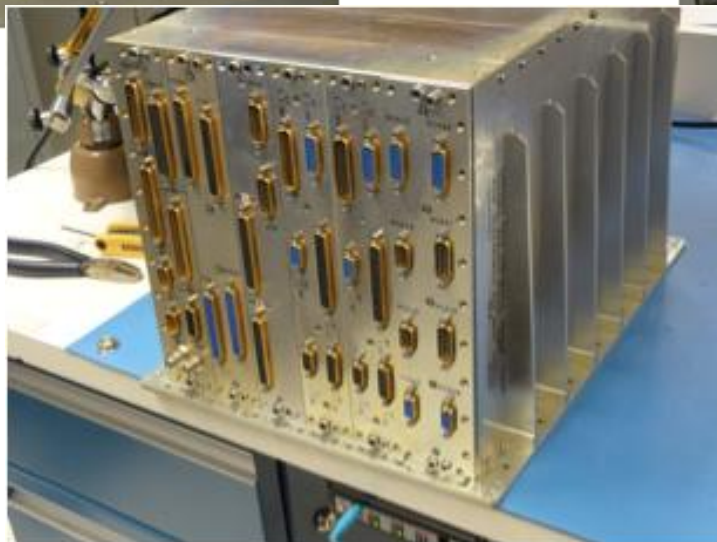
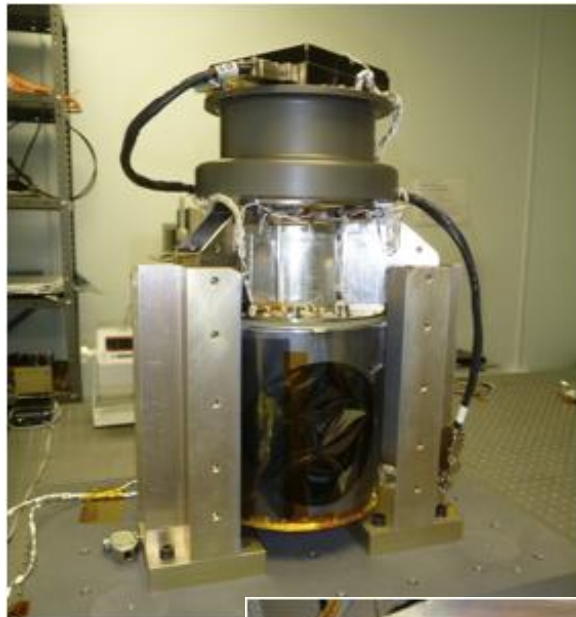


Phased testing permits development of key subsystems during initial sensor characterization

- Testing of focal plane with filters, telescope optics, and flight electronics provides baseline data for instrument level calibration
- Concurrent development of
 - Instrument structure
 - Scene select mechanism
 - Earth shield mechanism
 - Cryocooler
 - Main Electronics Box

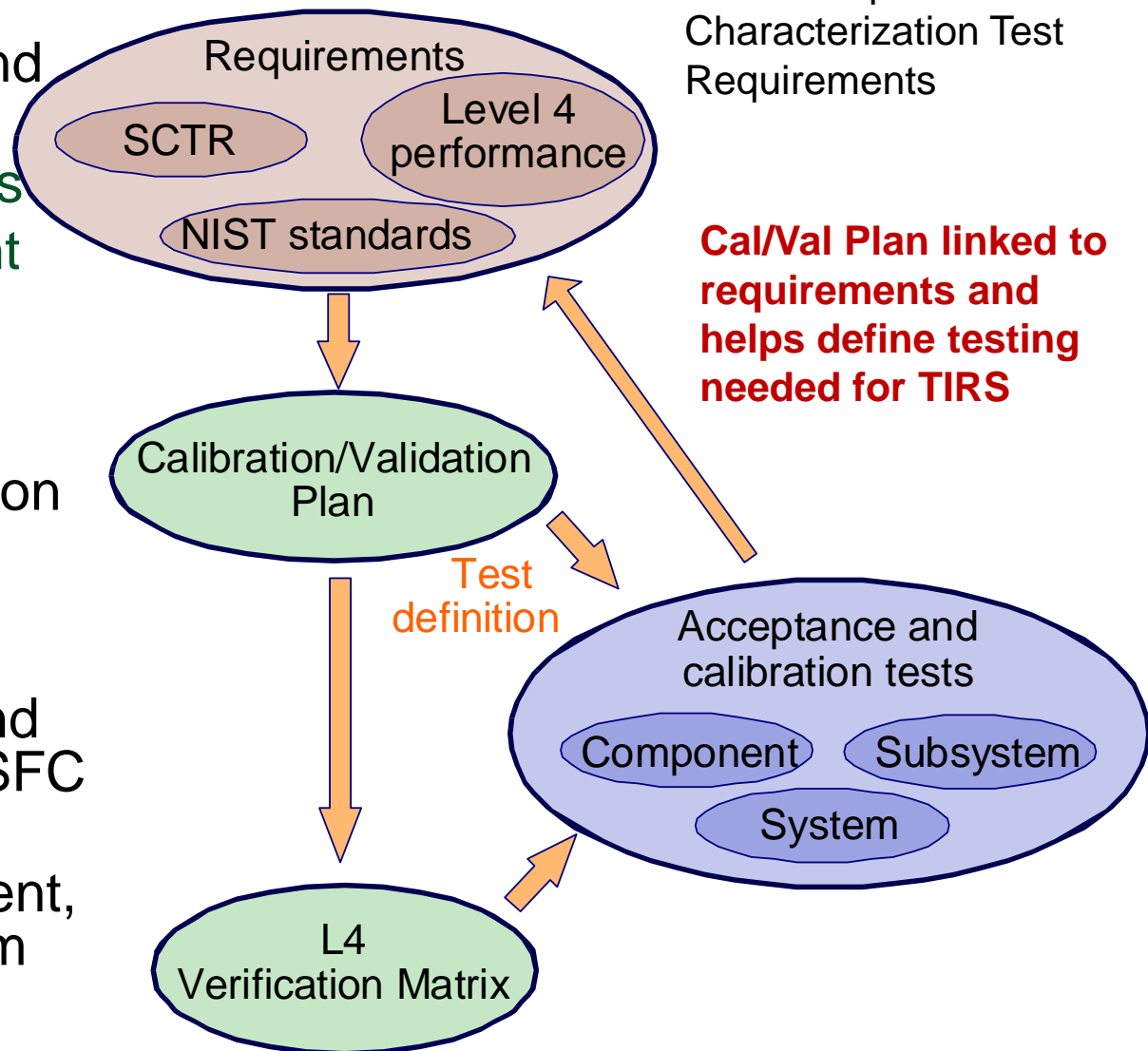


Recent milestones



Calibration Approach

- Calibration tests are designed to understand sensor behavior
 - Verify requirements
 - Develop instrument model
 - Provide accurate science data
- Requirement verification is necessary but not sufficient for sensor characterization
- Acceptance testing and calibration done at GSFC
- TIRS performance measured at component, subsystem and system level



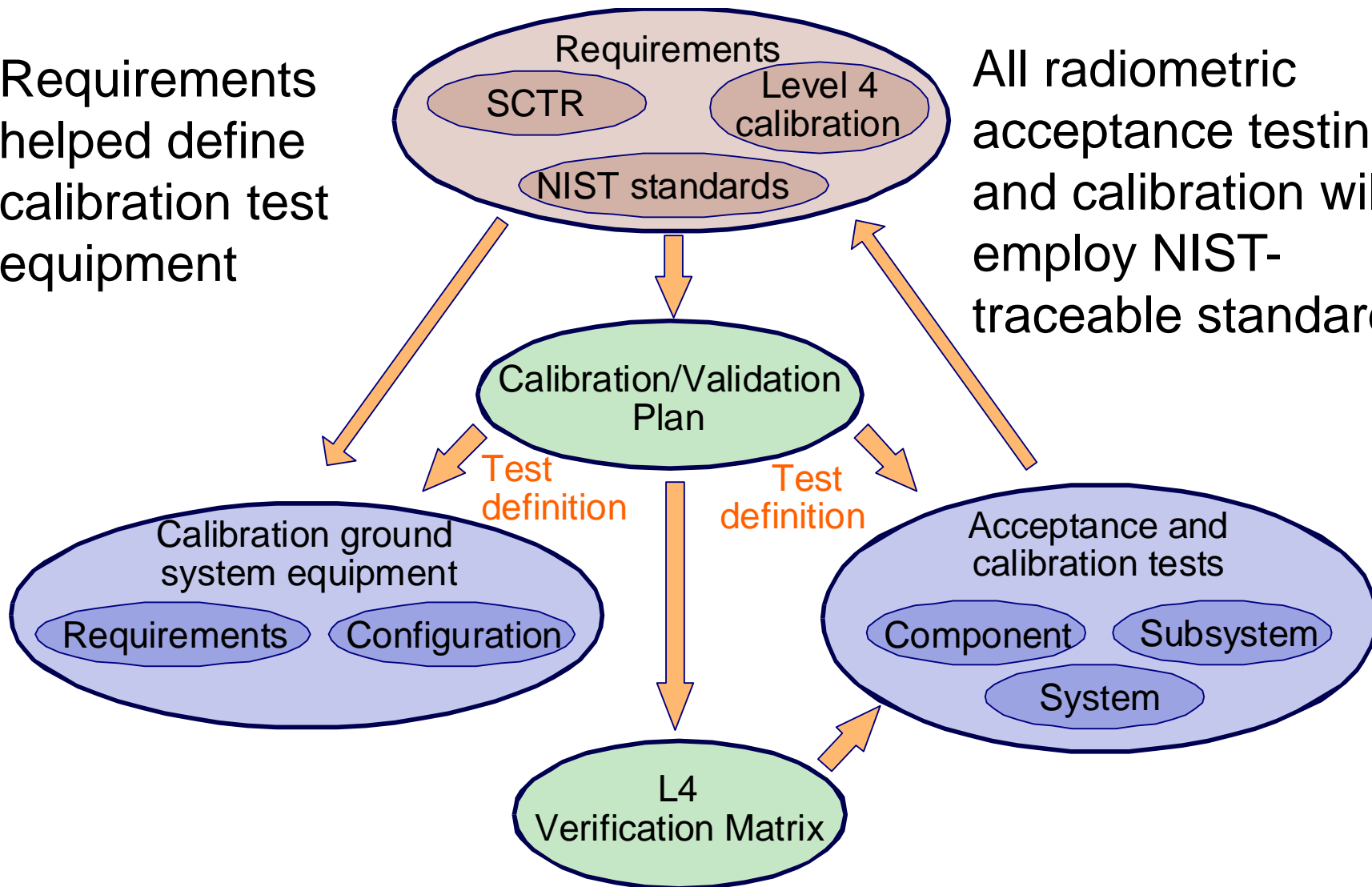
SCTR - Special Characterization Test Requirements

Cal/Val Plan linked to requirements and helps define testing needed for TIRS

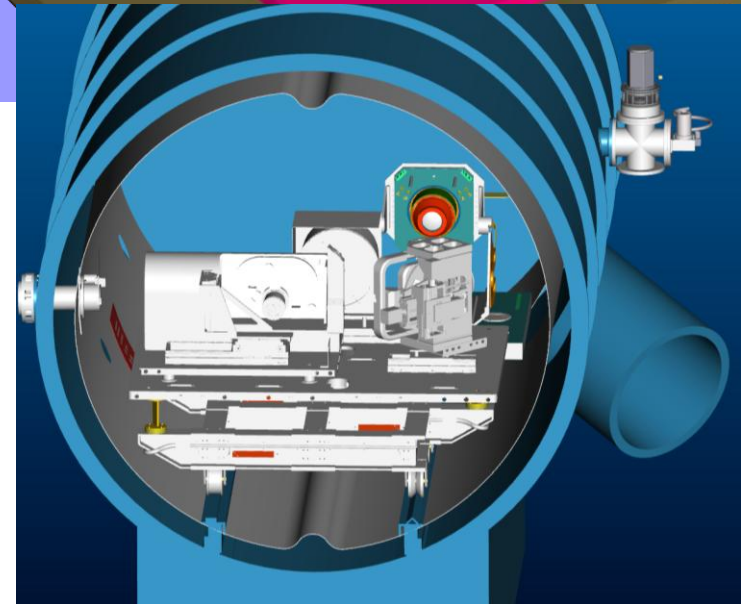
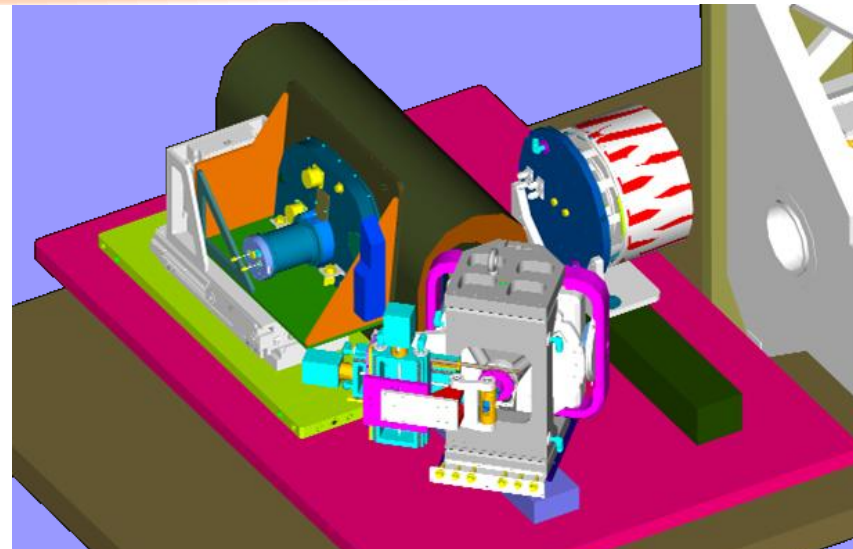
Calibration test equipment

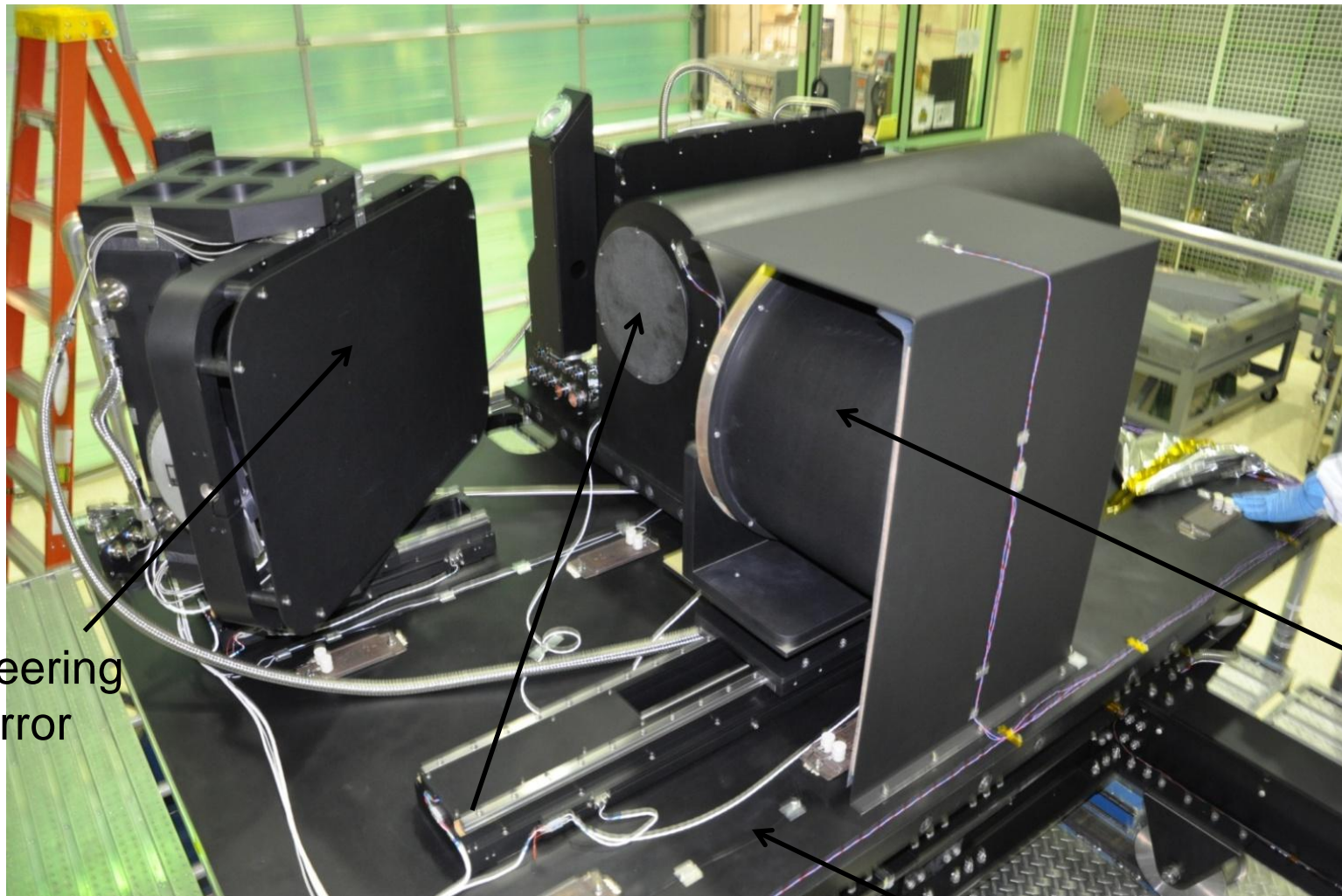
Requirements helped define calibration test equipment

All radiometric acceptance testing and calibration will employ NIST-traceable standards



- 16" Diameter source covering full field and aperture of TIRS (**Flood Source**)
- Target Source Module (**GeoRad Source**)
 - Blackbody Point Source w/ filter & chopper
 - All reflective, off-axis parabola collimator
 - Motorized target and filter wheels
 - 13" square steering mirror system permitting coverage of full aperture and field
- Cooled enclosure over entire system
- External Monochromator (**Spectral Source**)
- Components mounted to common base plate





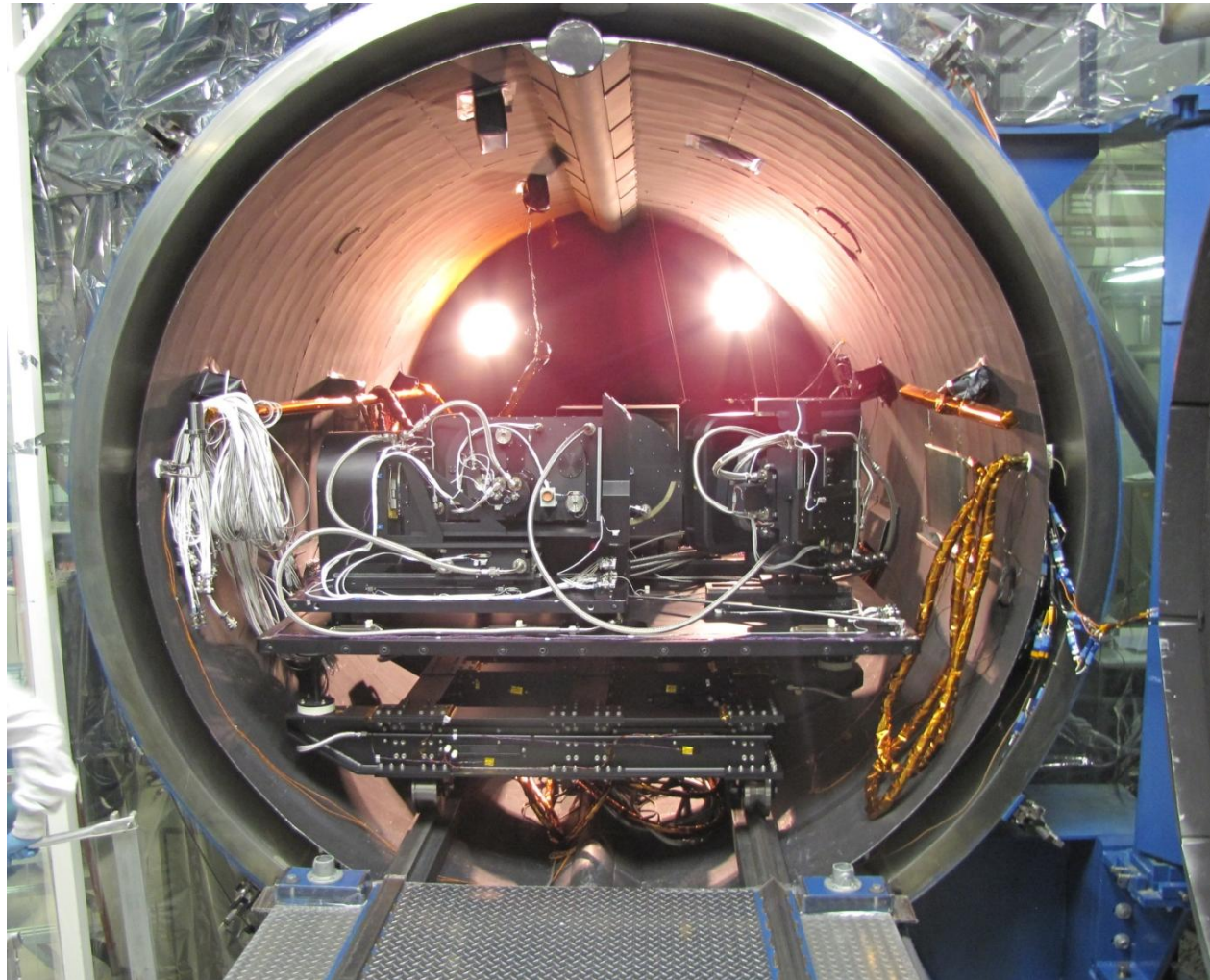
Steering
Mirror

Flood
Source

Point
Source

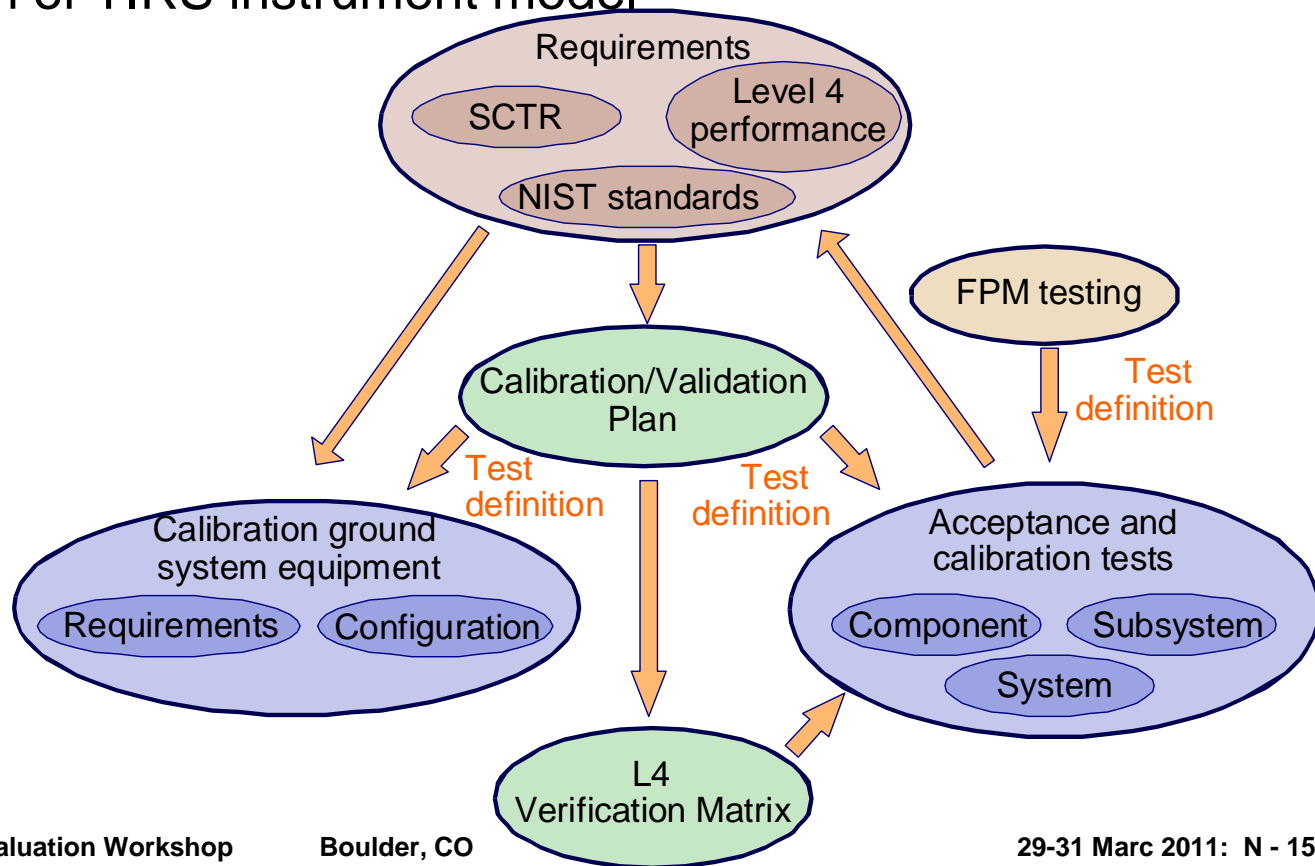
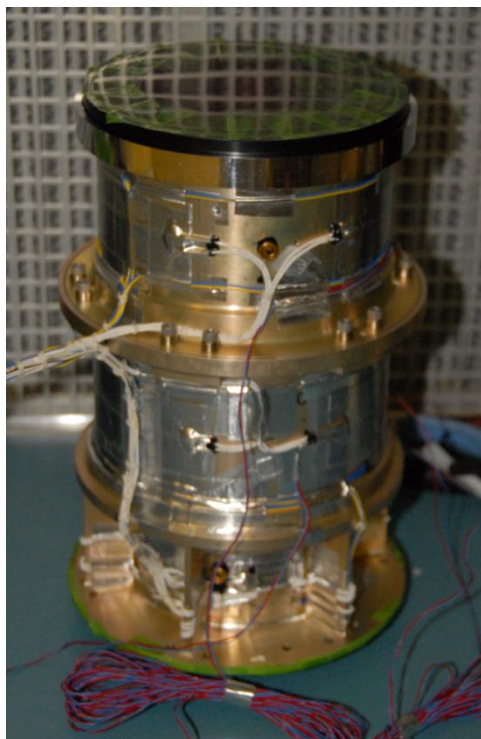
Base Plate

- Developed by ATK in Logan through a contract with MEI
- Delivered July 2010
- Testing and evaluation took place during Functional Performance Model testing



FPM and calibration

- Functional performance model was developed to
 - Test procedures
 - Test calibration algorithms
 - Understand calibration ground system equipment
- Early evaluation of TIRS instrument model





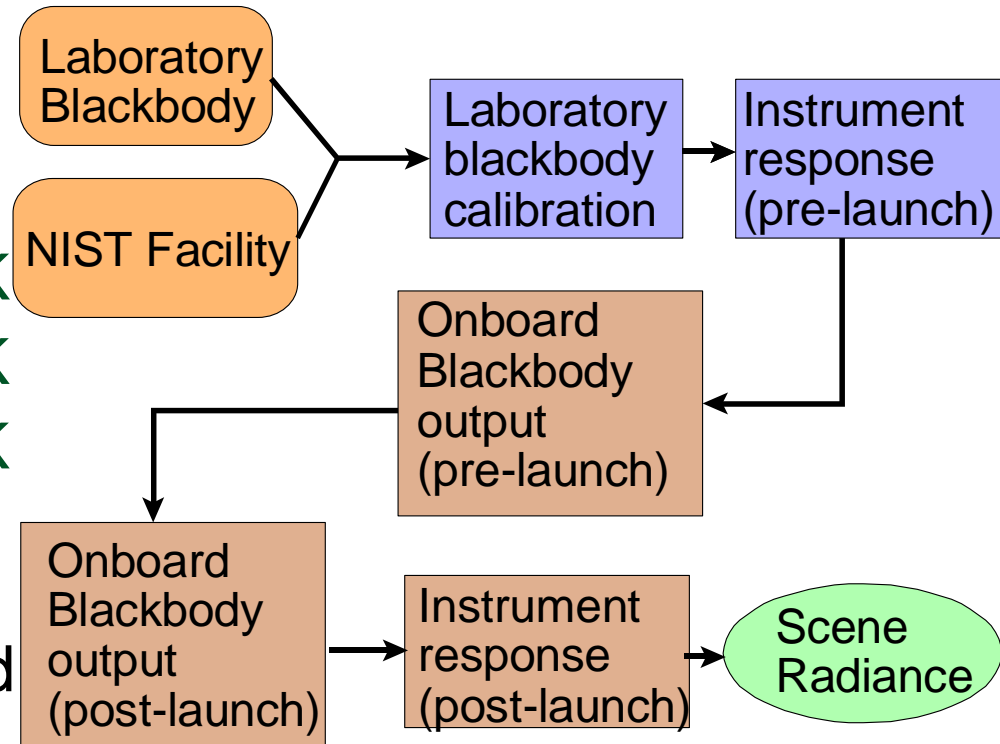
Flight testing

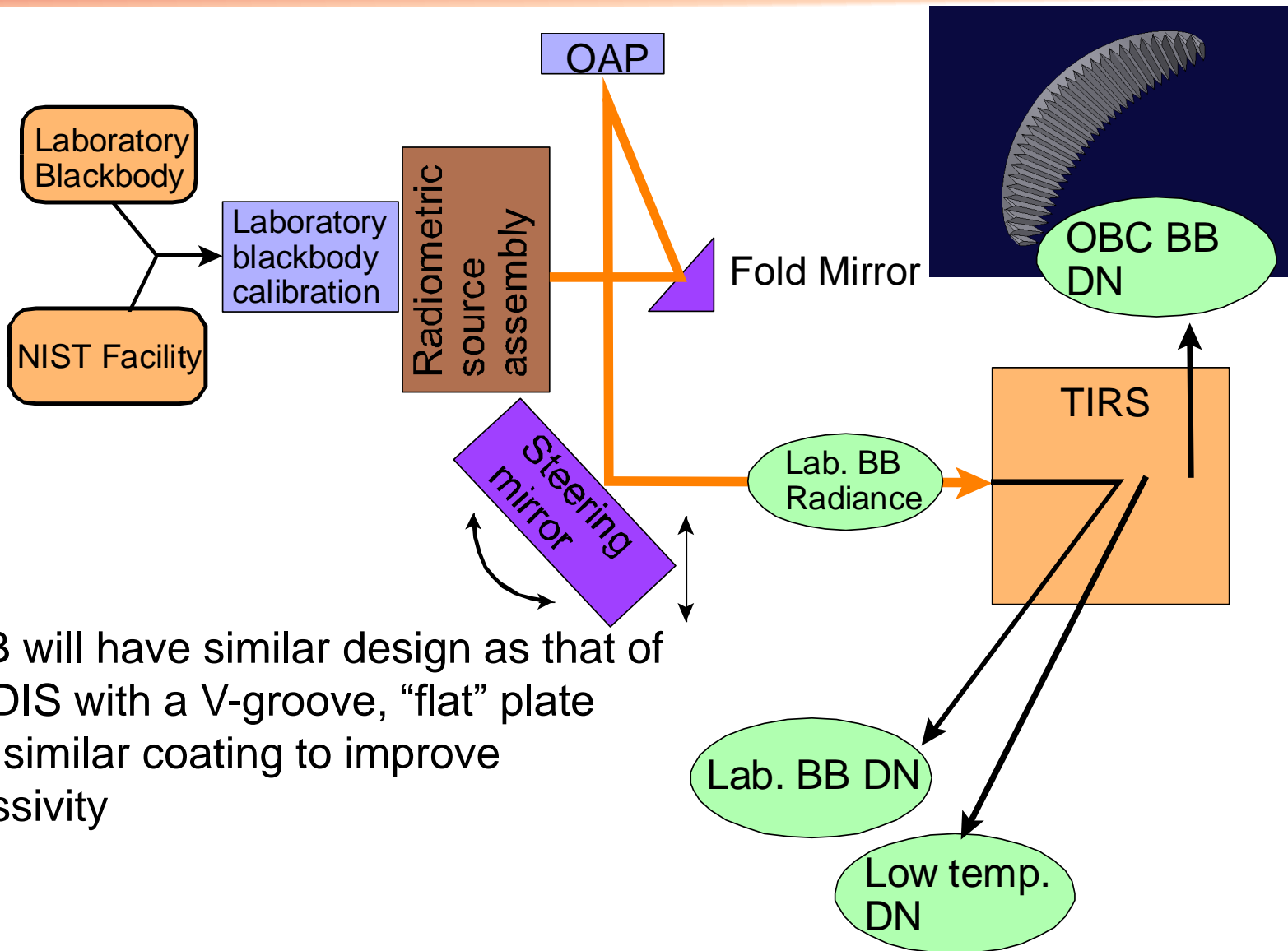


Calibration of flight hardware is taking place in three phases

- Calibration 1
 - Subsystem level
 - Comprehensive evaluation of radiometric, spectral, and spatial characteristics
- Calibration 2
 - Initial calibration of the onboard calibrator
 - Pre vibration testing
- Calibration 3
 - Post vibration
 - Verifies requirements

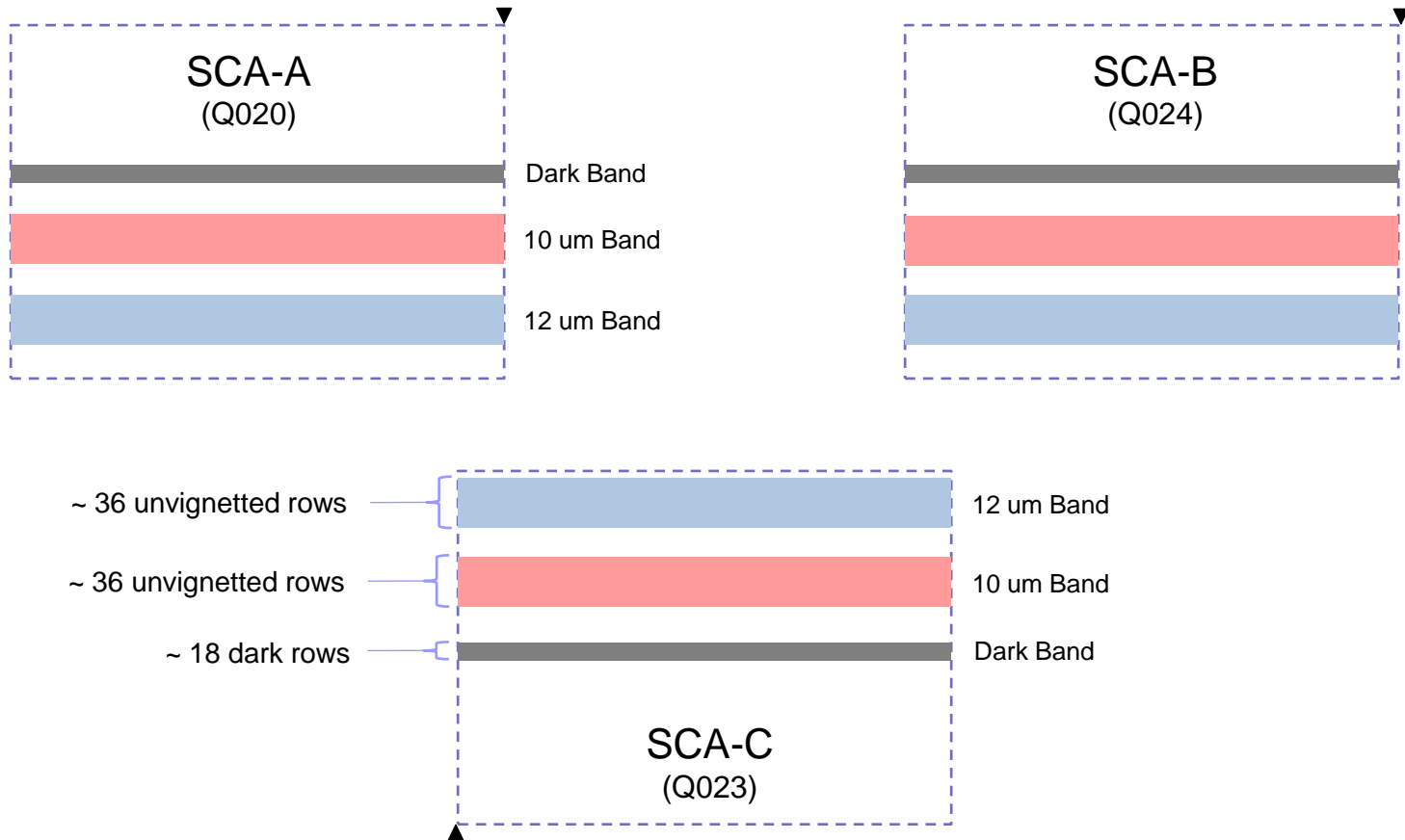
- Blackbody source characterization is a key element in meeting the radiometric uncertainty requirement
 - $\leq 4\%$ for 240 K to 260 K
 - $\leq 2\%$ for 260 K to 330 K
 - $\leq 4\%$ for 330 K to 360 K
- Must be established relative to National Institute for Standards and Technology (NIST) standards





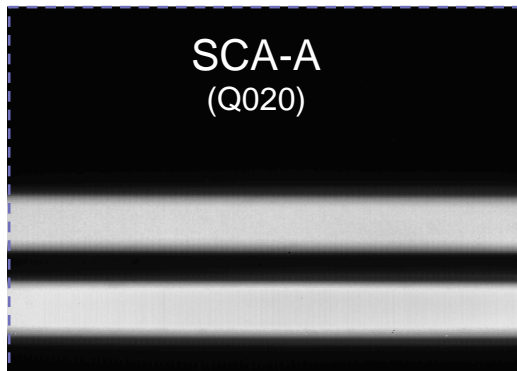
OBB will have similar design as that of MODIS with a V-groove, “flat” plate and similar coating to improve emissivity

Focal Plane Science Regions

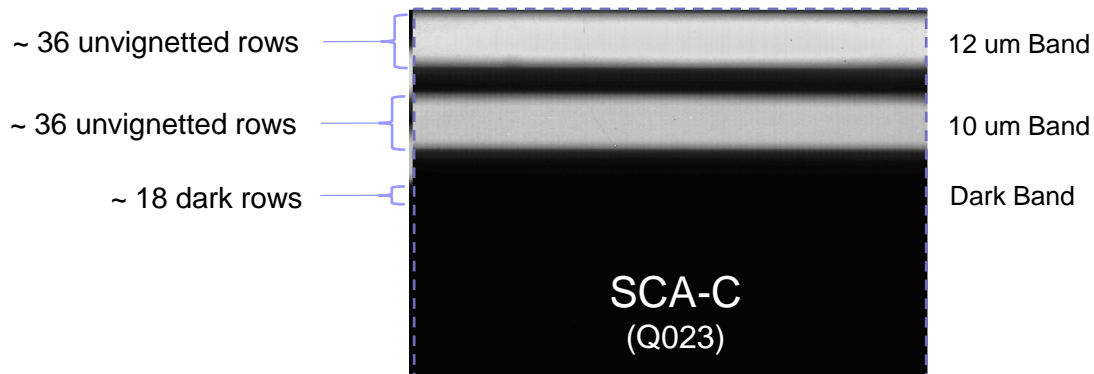


▲ = col/row origin

Science Regions – Actual Image

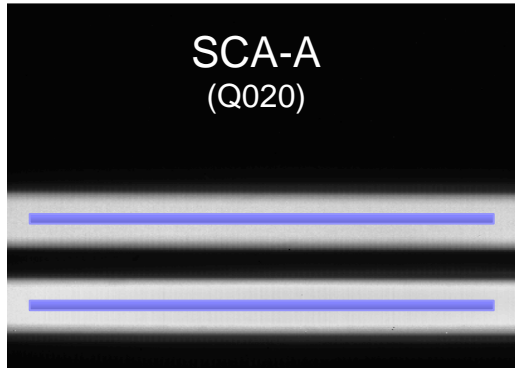


Dark Band
10 um Band
12 um Band



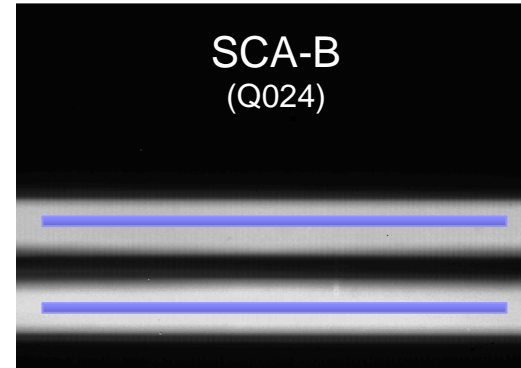
Preliminary Signal-to-Noise

Viewing a 280 K Extended Blackbody. Note: Non-flight focal plane electronics



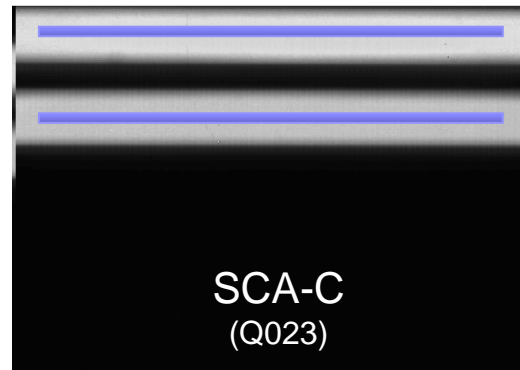
SNR ~ 1000

SNR ~ 900



SNR ~ 900

SNR ~ 800



SNR ~ 900

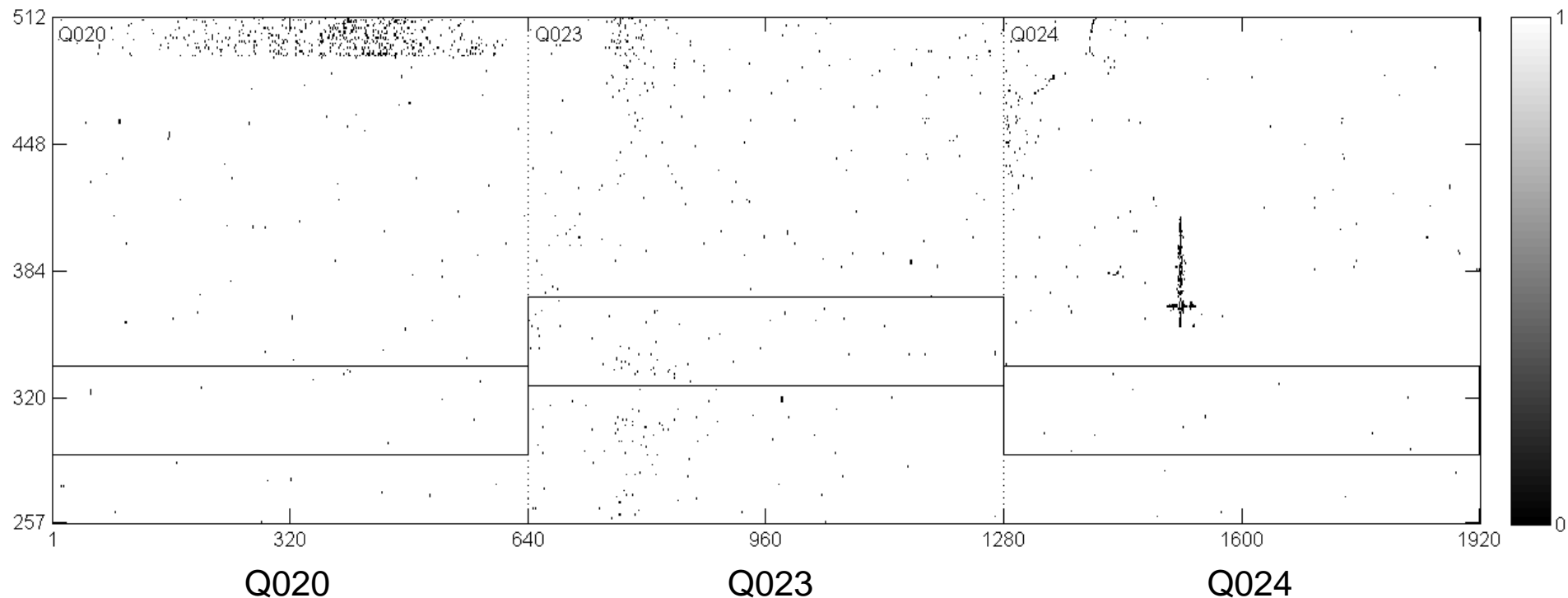
SNR ~ 1000

10.8 micron Spectral Uniformity map

Used measured filter and measured QWIP response:

White (1) = Pass all requirements

Black (0) = Fail at least one requirement



•Can always find perfect row or combine 2 rows to create a perfect row

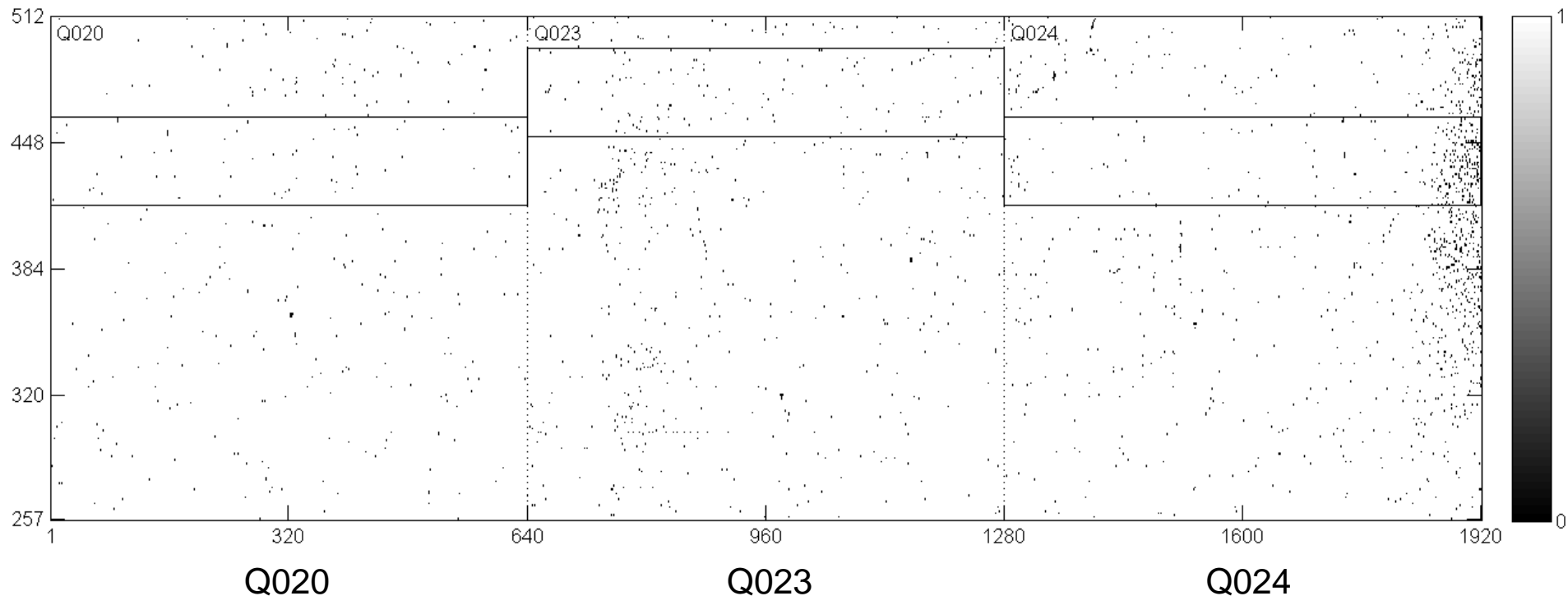


12 micron Spectral Uniformity map

Used measured filter and measured QWIP response:

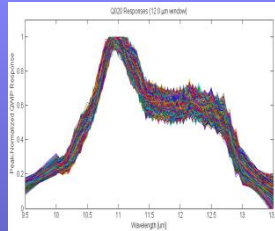
White (1) = Pass all requirements

Black (0) = Fail at least one requirement

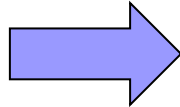


•Can always find perfect row or combine 2 rows to create a perfect row

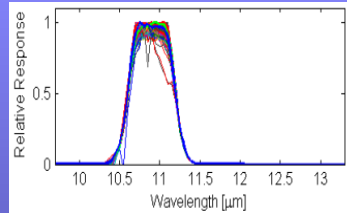
Spectral Responses of QWIPs



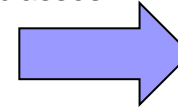
Define filter



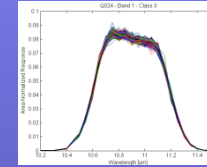
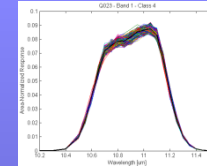
Spectral response of Band



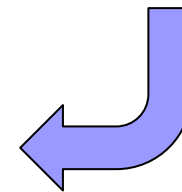
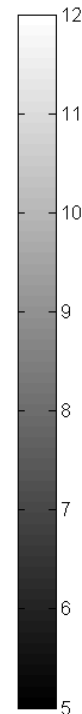
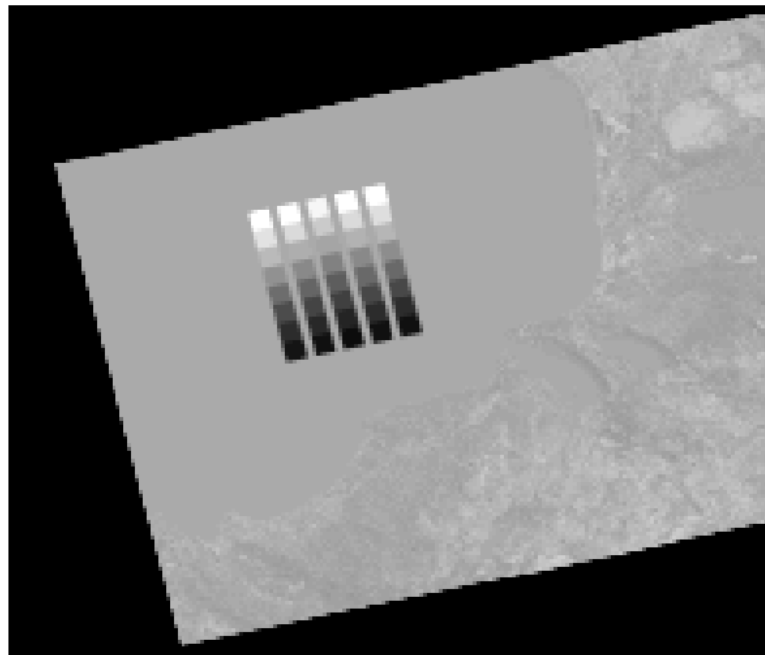
Select extreme classes



Example Different Responses



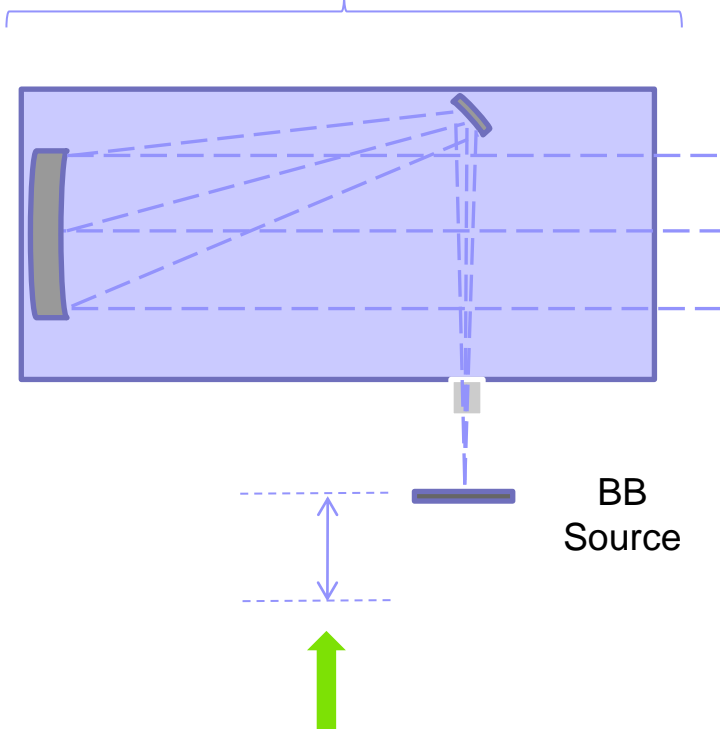
[W/cm²/sr/um]



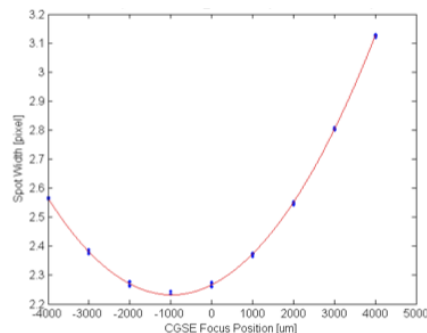
Use class mean to simulate TIRS scene

Result:
Validates spectral
uniformity of rows
chosen

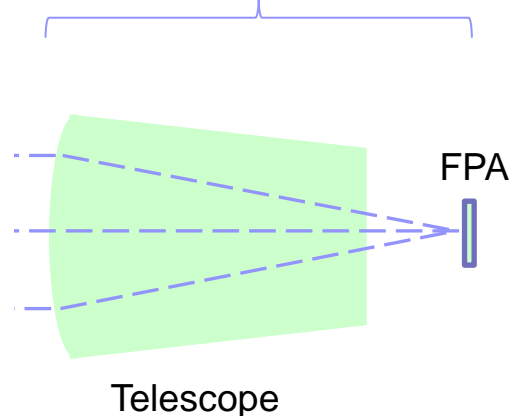
CGSE



Vary CGSE Focus...



TIRS

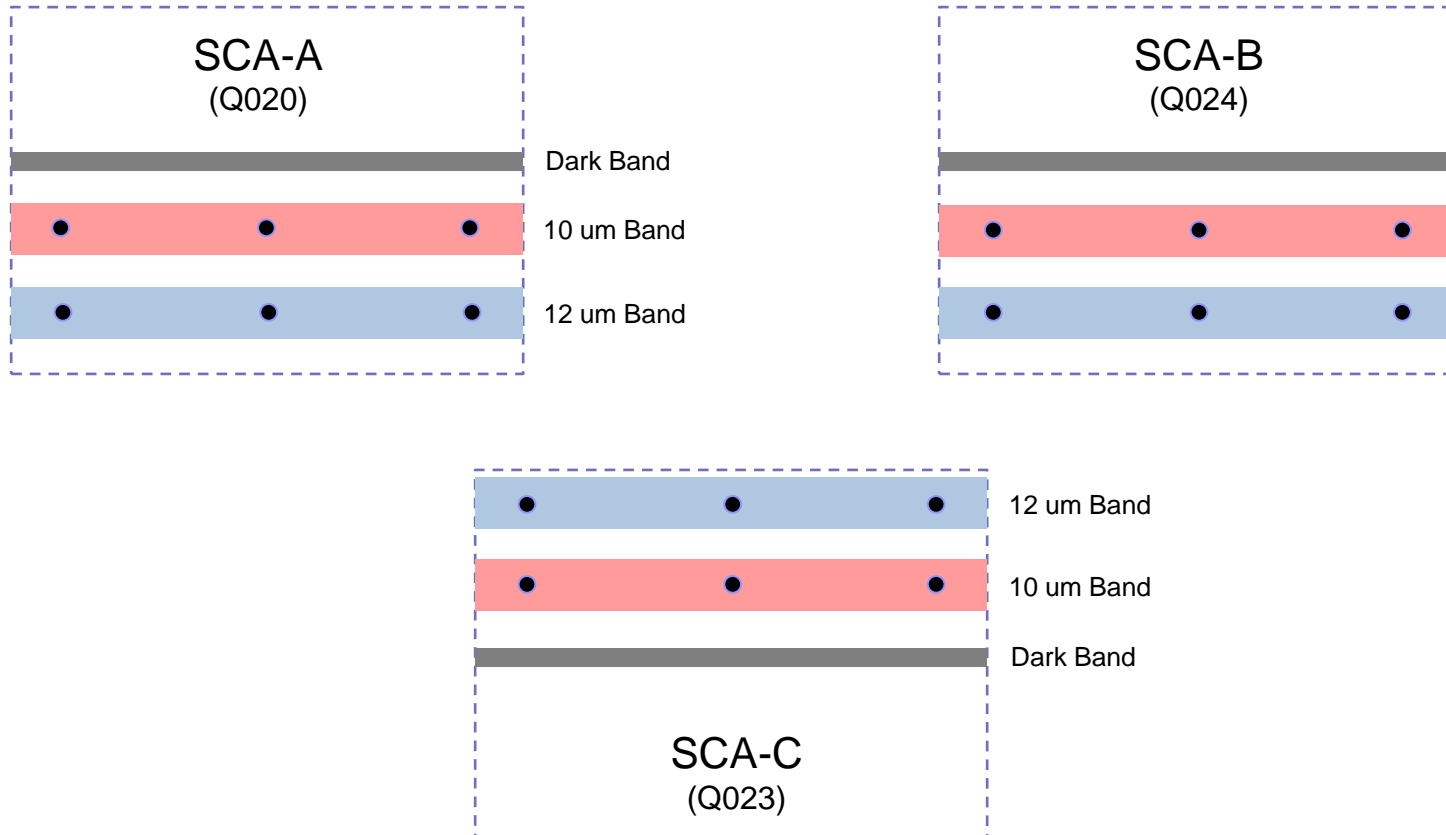


...record change in TIRS spot size

- Focus offset used to define shims
- Flight focus met in 1 shim step

Focal Plane Focus Locations

Focus measurements taken at three locations on each band as indicated below:





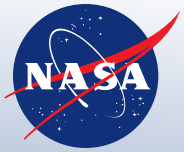
On orbit calibration



- On-orbit testing will follow past efforts for similar sensors
 - Verify sensor calibration and noise performance on orbit
 - Evaluate onboard calibrator performance
- On-board blackbody is used as the primary path to derive on-orbit radiometric calibration
 - Intercomparison with ETM+ and other sensors
 - Ground sites and simultaneous nadir overpass (SNO)
- Geometric approaches
 - Cold deserts for OLI to TIRS registration
 - Hot spots for band-to-band registration
 - OLI comparison
 - Lunar views (recovery time, ghosting)
- Three-month commissioning and checkout phase schedule is still under development



Near-term plans



Work over the next 6 months concentrates on subsystem deliveries

- Delivery date is December 31, 2011
- Have nearly one month of schedule slack against delivery date
- Subsystem deliveries to I&T:
 - Flight Scene Select Mechanism March 2011
 - Flight Structure March 2011
 - Flight Earth Shield Mechanism March 2011
 - Flight Cryocooler March 2011
 - Flight MEB June 2011
- Pre-Environmental Review (PER) August 2011



TIRS status



TIRS flight instrument is being integrated at GSFC for a December 2011 delivery

- Flight instrument assembly has begun
 - Flight optical system with focal plane and filters has gone through focus
 - Flight electronics have been integrated to focal plane
- Undergoing a first round of performance testing
 - Functional performance model testing completed November 2010
 - Focus is complete on flight instrument
 - Calibration testing of flight subsystem will be complete by end of April



Summary



- TIRS is benefitting greatly from active support of all partners including NASA GSFC, LDCM, USGS, NASA HQ, Orbital Systems (Spacecraft Provider)
- Finalizing calibration error budgets
- TIRS requirements have led to development of
 - Component, subsystem, and instrument-level tests
 - Test equipment
- Test procedures will be evaluated during initial calibration at the subsystem level
- Schedule, while aggressive, is being met and fully expect the sensor delivery before end of year