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

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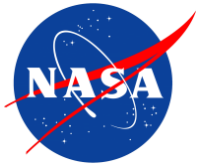


Introduction

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

Outline

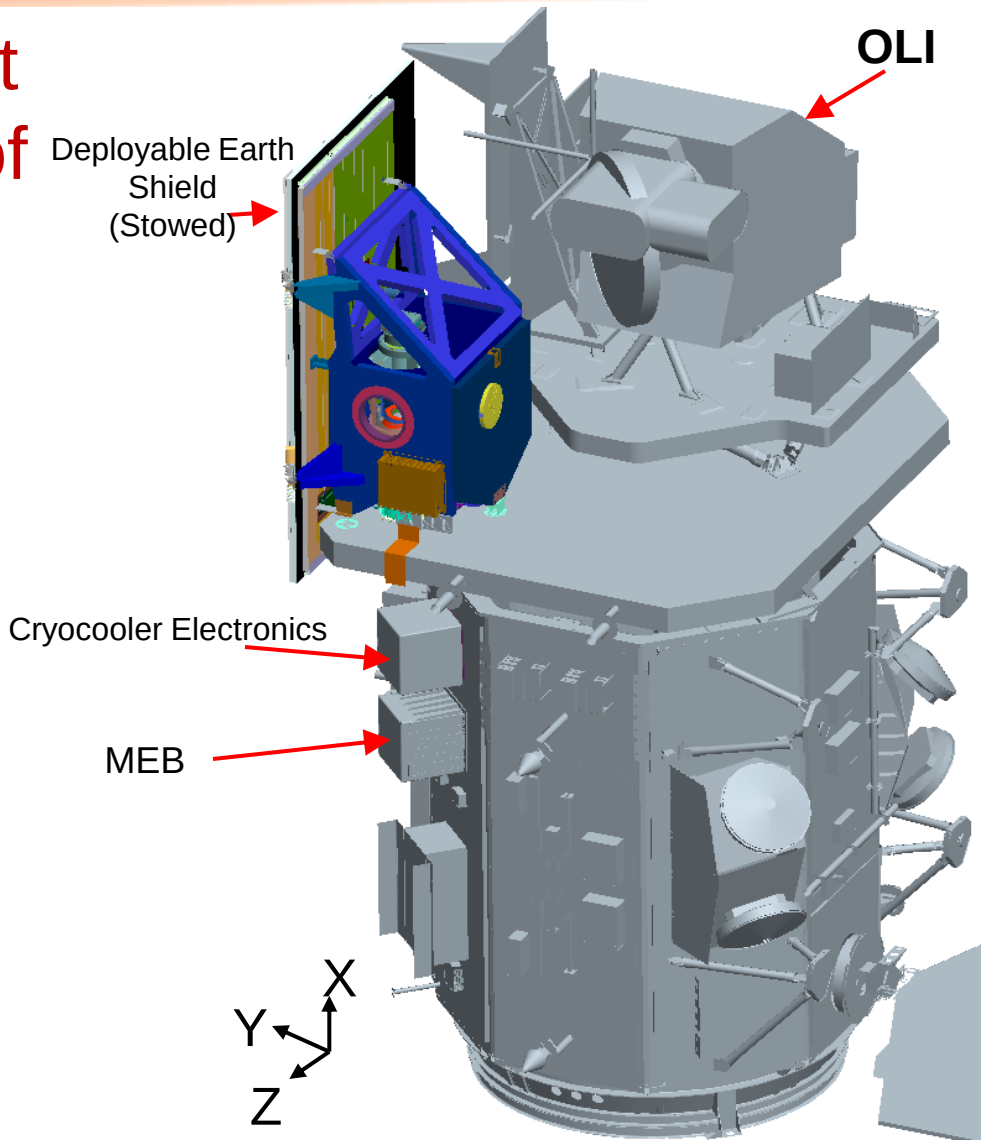
Describe calibration methods for the Thermal Infrared Sensor (TIRS)

- 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

LDCM spacecraft

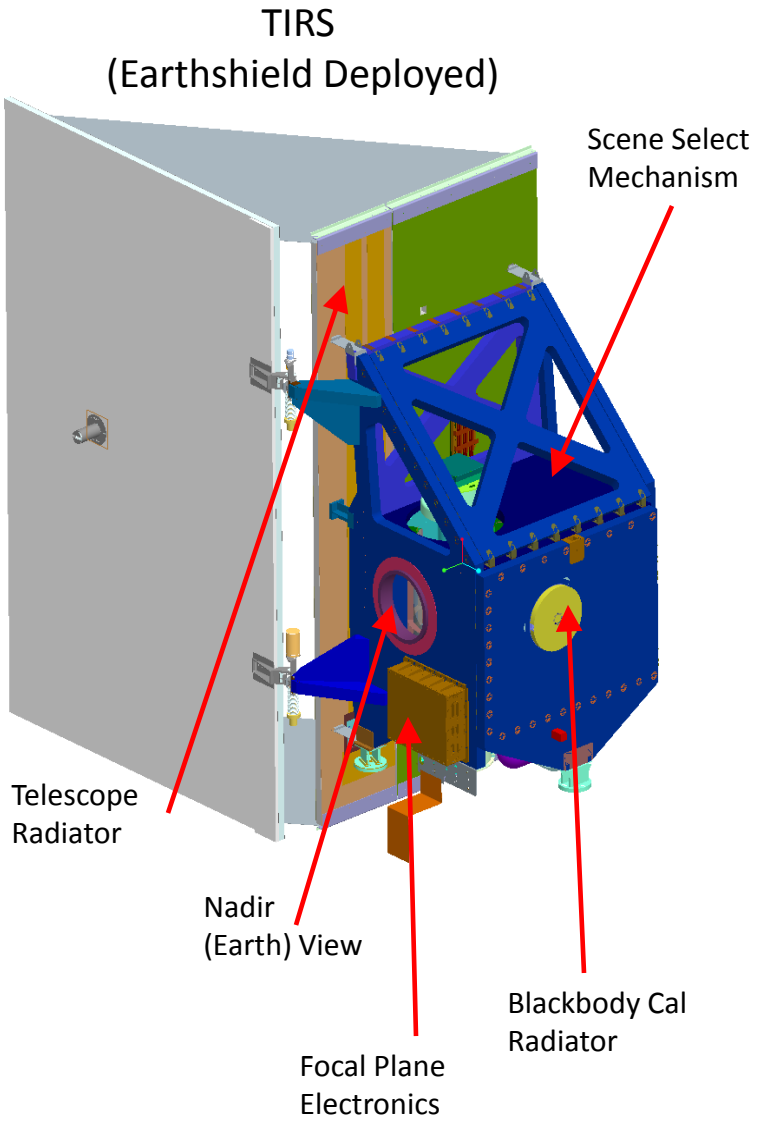
TIRS operates in concert with but independent of Operational Land Imager

- 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



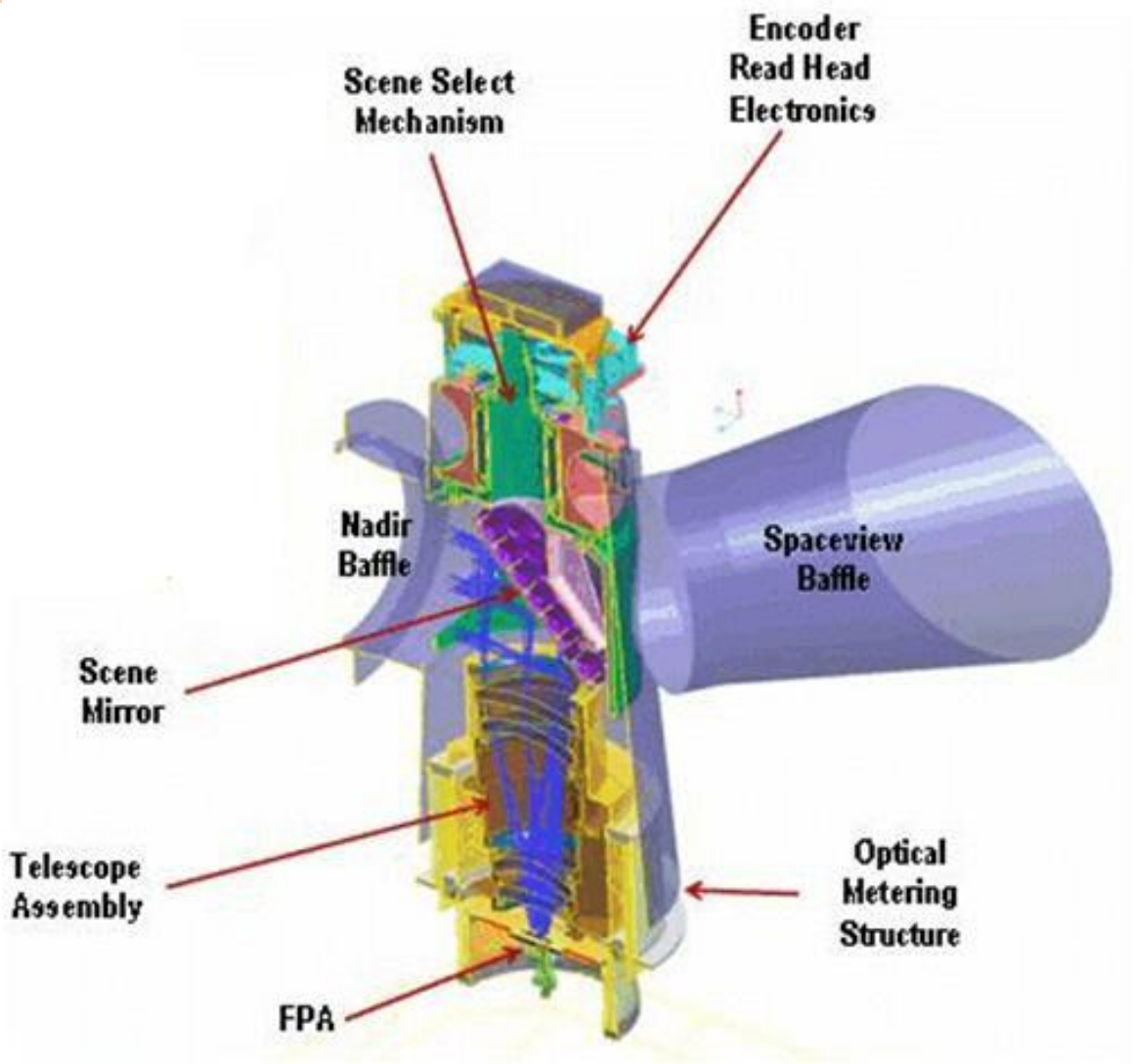
TIRS Overview

- 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

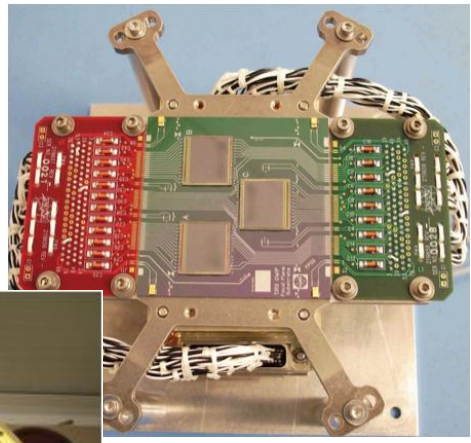
- Precision scene select mirror to select between calibration sources and nadir view
- Two full aperture calibration sources
  - Onboard variable temp black body
  - Space view
  - Calibration every 34 minutes
- NIST Traceable radiometric calibration

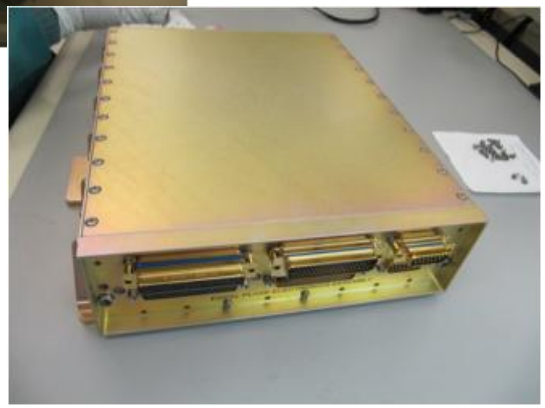


Recent milestones

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



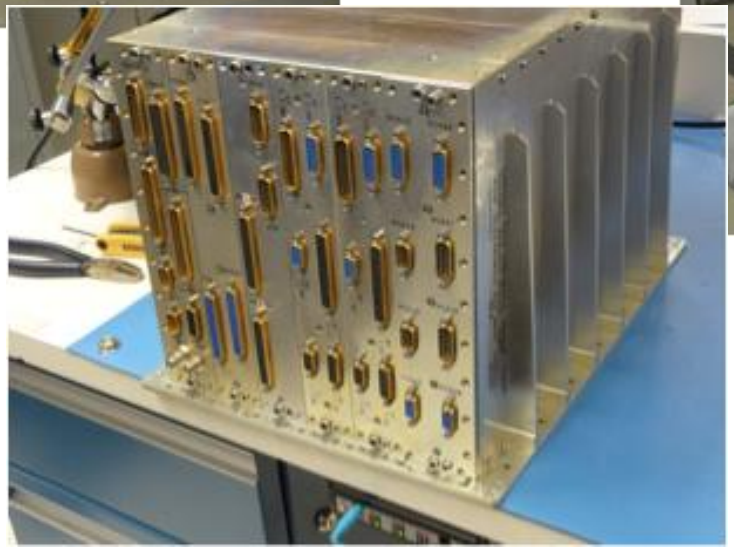


Recent milestones

Phased testing permits development of key subsystems during initial sensor characterization

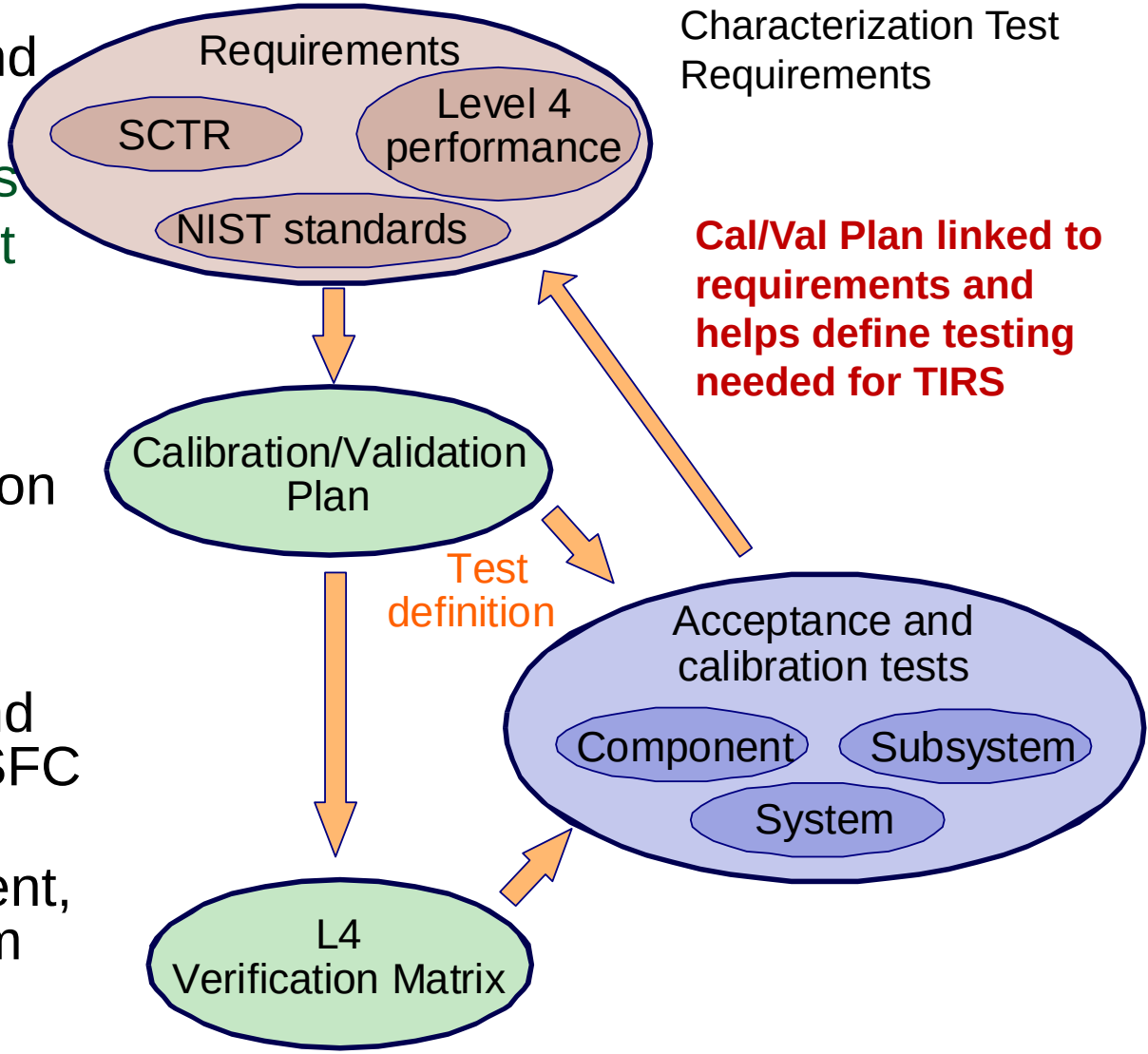
- Testing of focal plane with filters, telescope optics, and flight electronics provides baseline data for instrument level calibration
- Concurrent development of
  - Instrument structure
  - Scene select mechanism
  - Earth shield mechanism
  - Cryocooler
  - Main Electronics Box

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

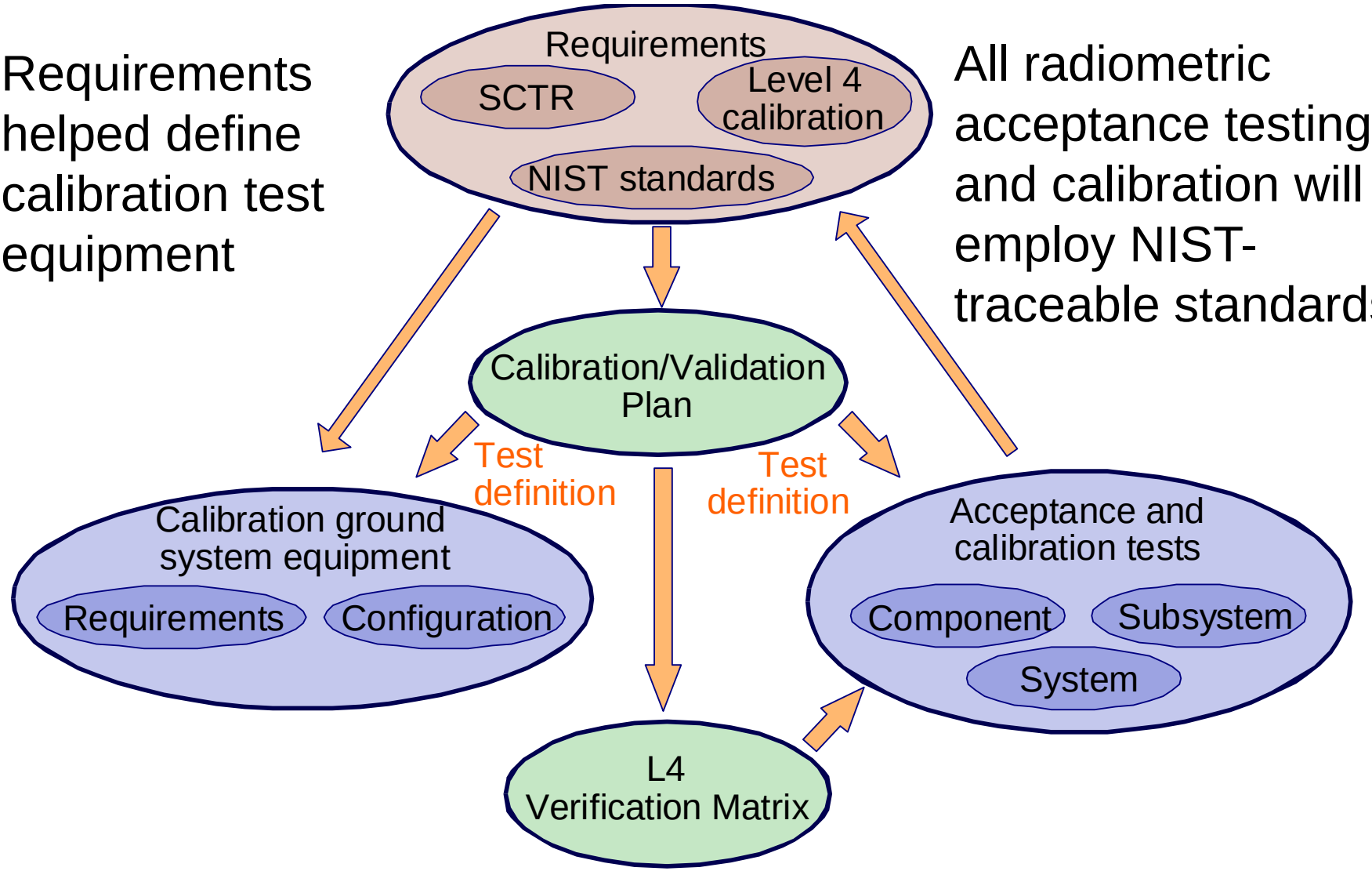


SCTR - Special Characterization Test Requirements

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

Calibration test equipment

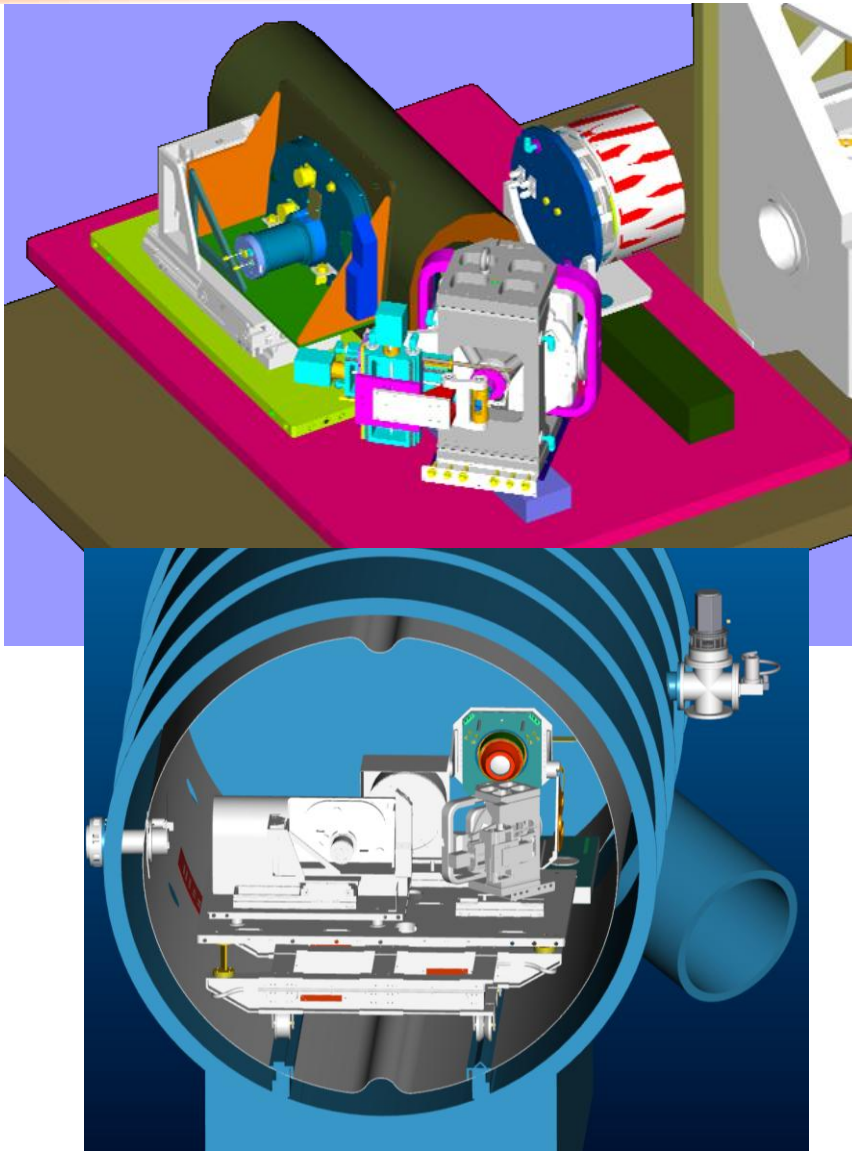
Requirements helped define calibration test equipment



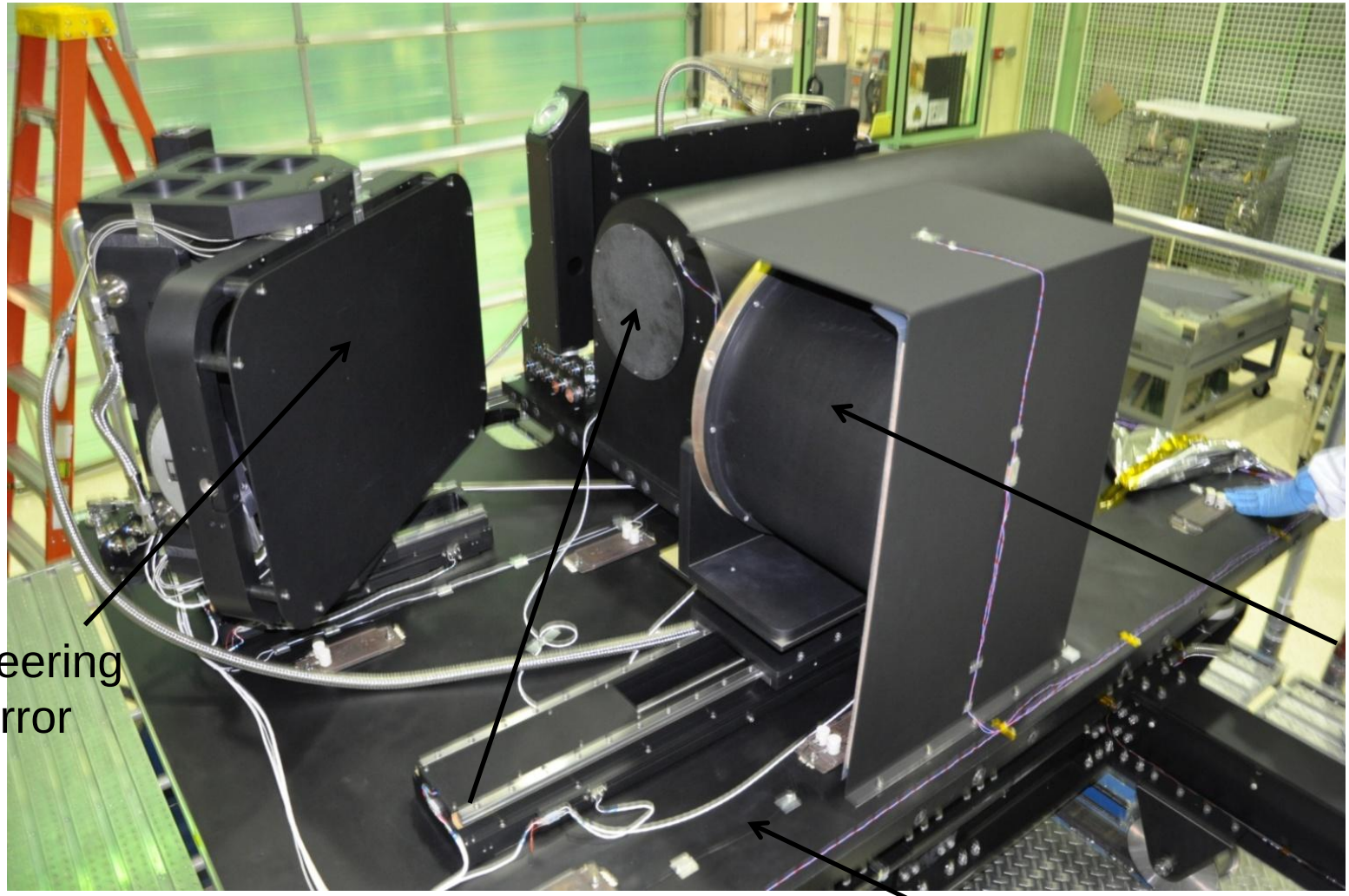
All radiometric acceptance testing and calibration will employ NIST-traceable standards

Calibration System

- 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

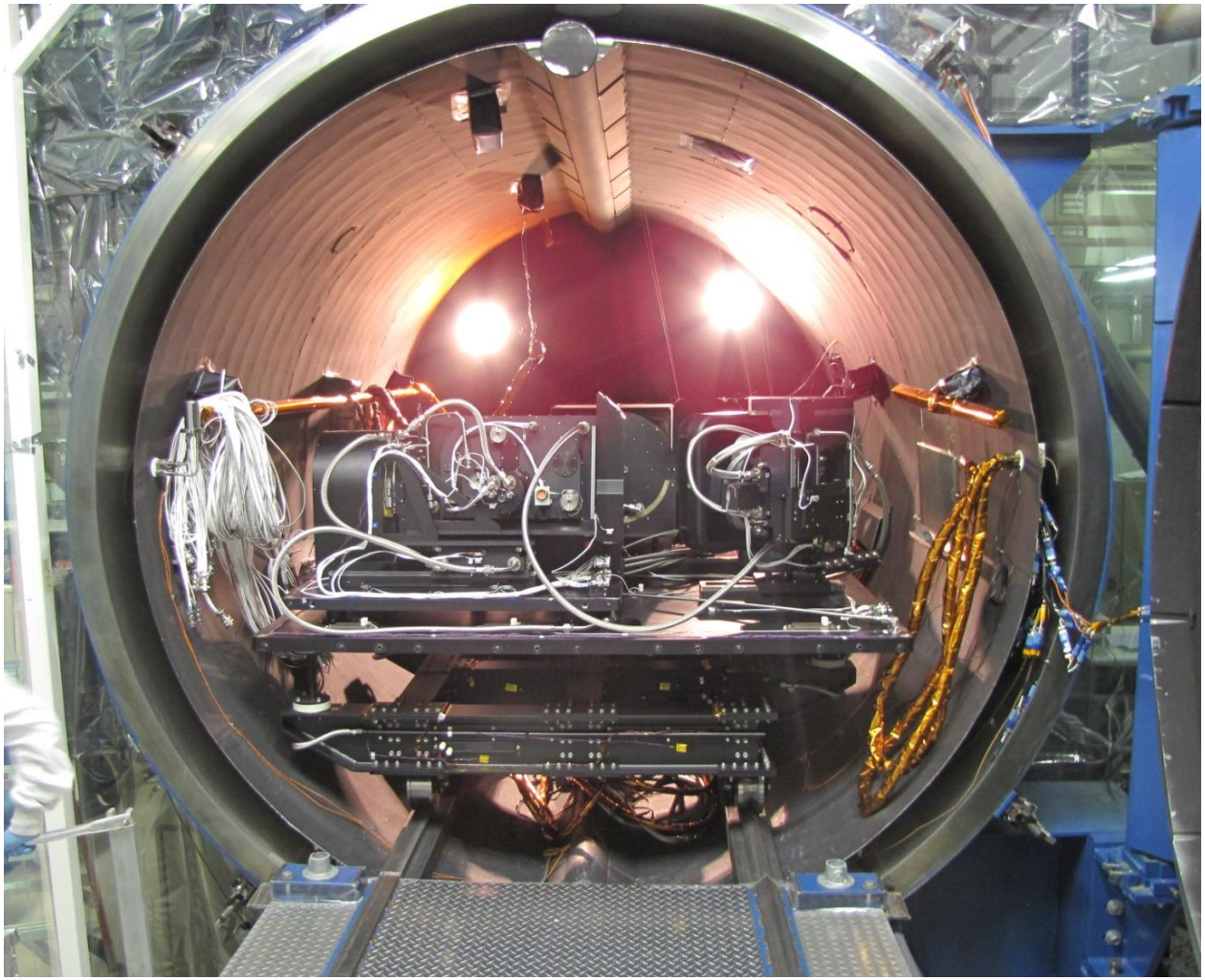


Calibration System



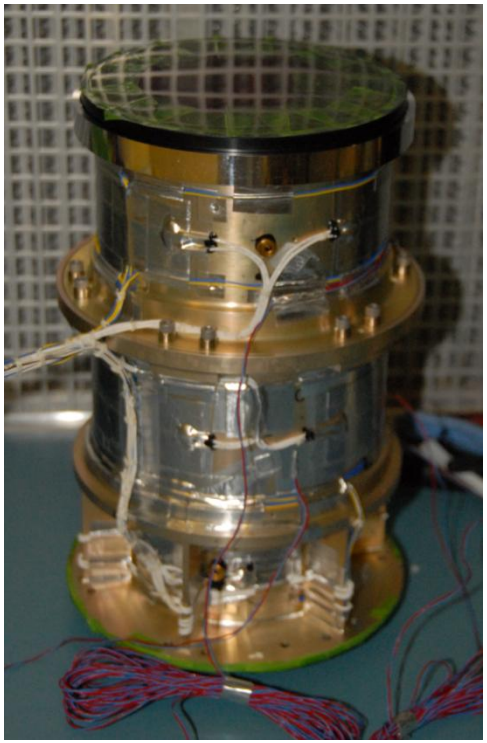
Calibration equipment in chamber

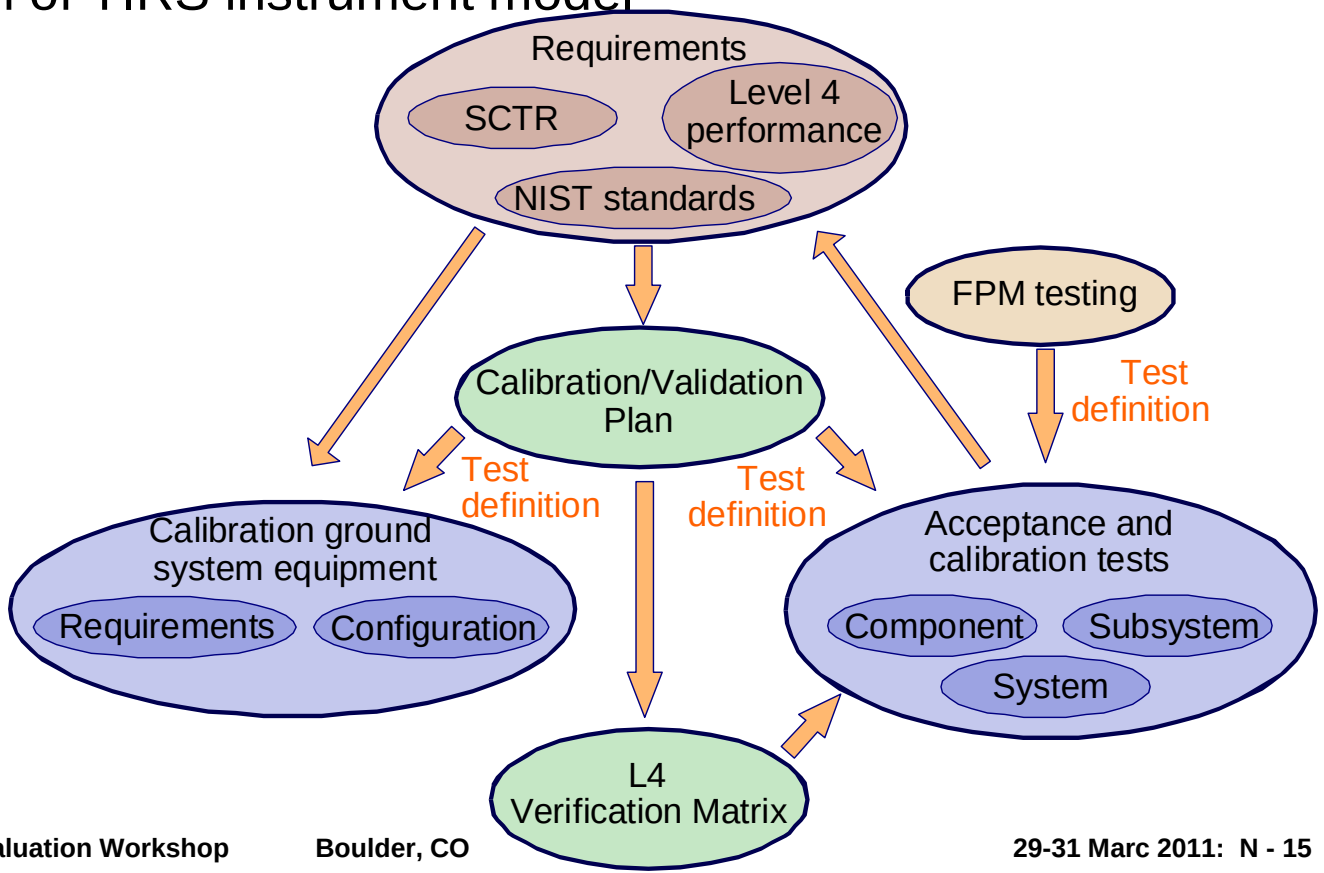
- Developed by ATK in Logan through a contract with MEI
- Delivered July 2010
- Testing and evaluation took place during Functional Performance Model testing



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





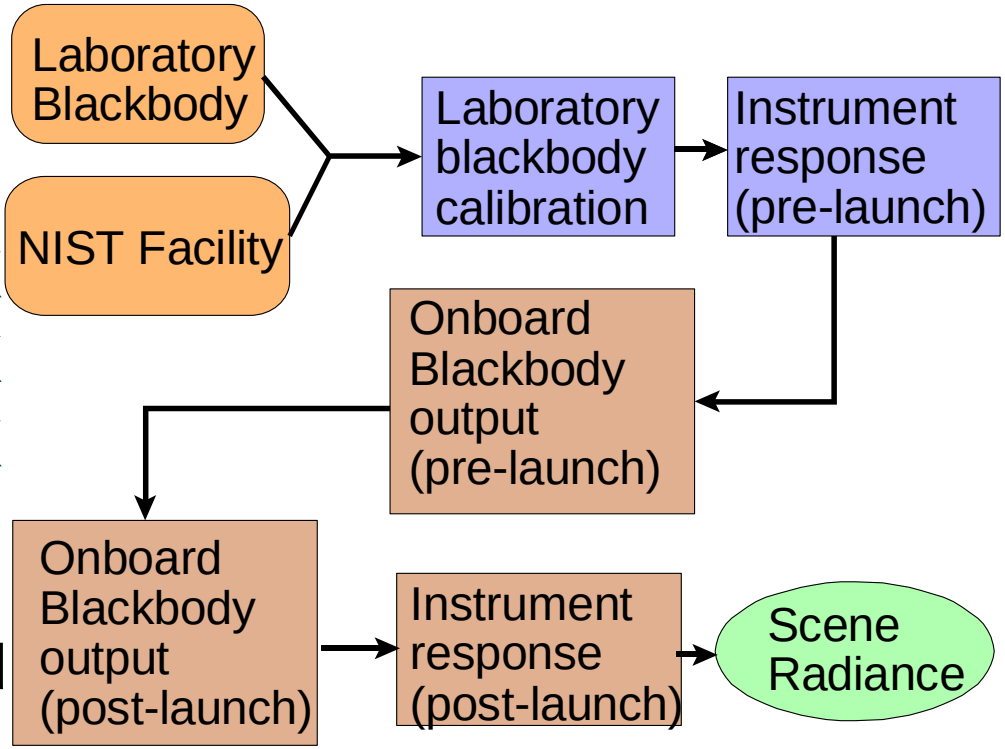
Flight testing

Calibration of flight hardware is taking place in three phases

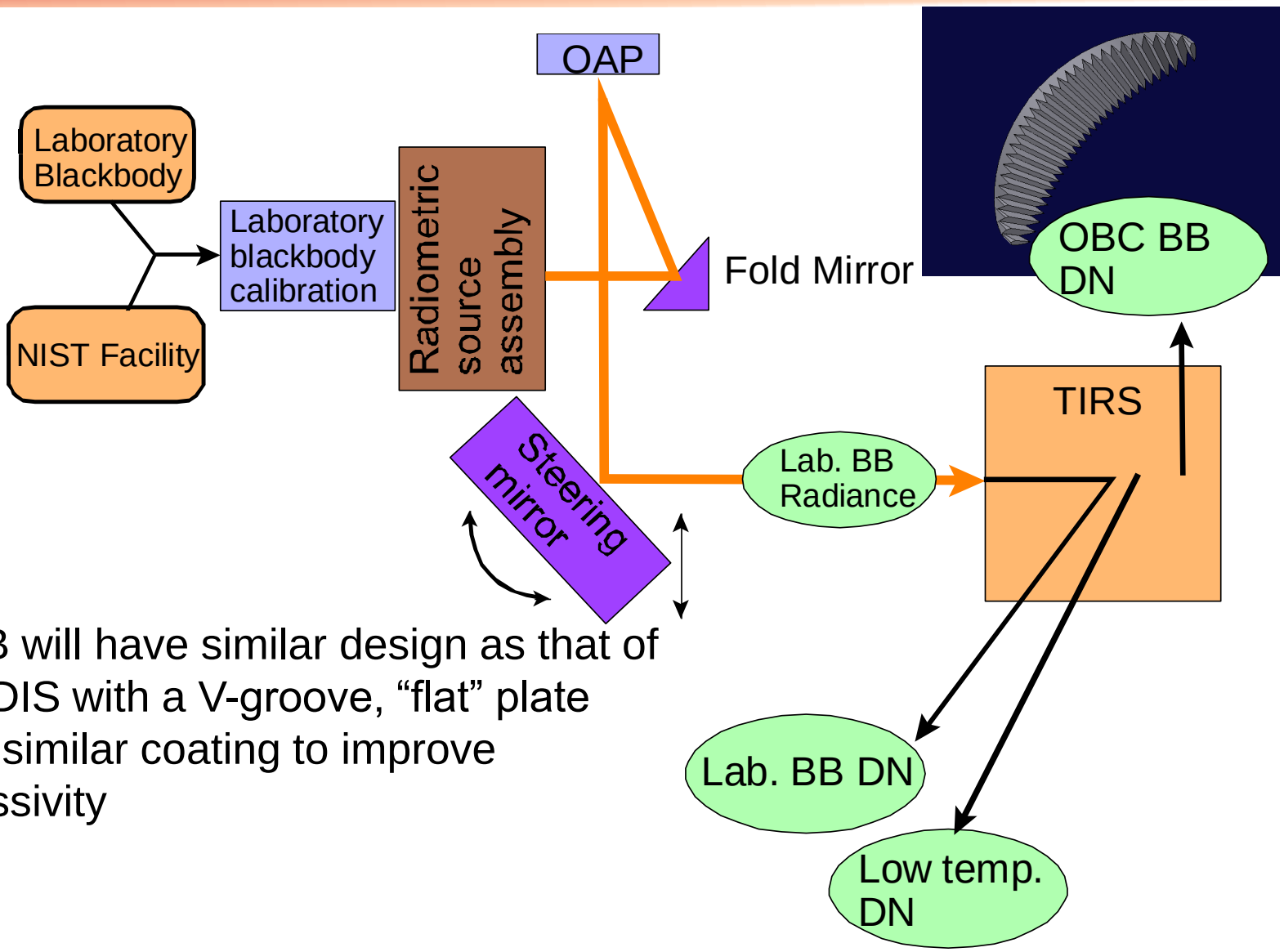
- Calibration 1
  - Subsystem level
  - Comprehensive evaluation of radiometric, spectral, and spatial characteristics
- Calibration 2
  - Initial calibration of the onboard calibrator
  - Pre vibration testing
- Calibration 3
  - Post vibration
  - Verifies requirements

NIST-traceable absolute radiometry

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

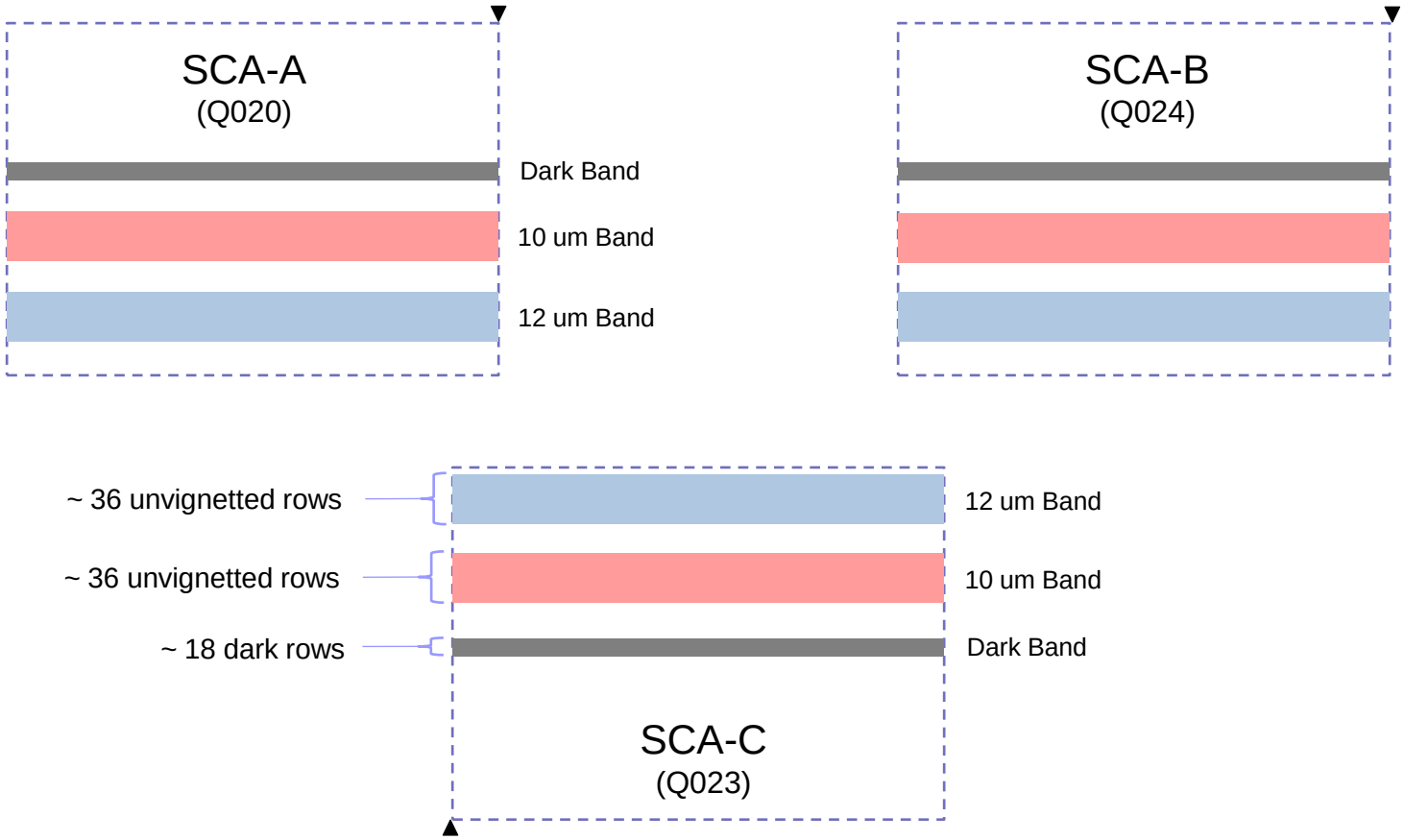


Onboard blackbody characterization



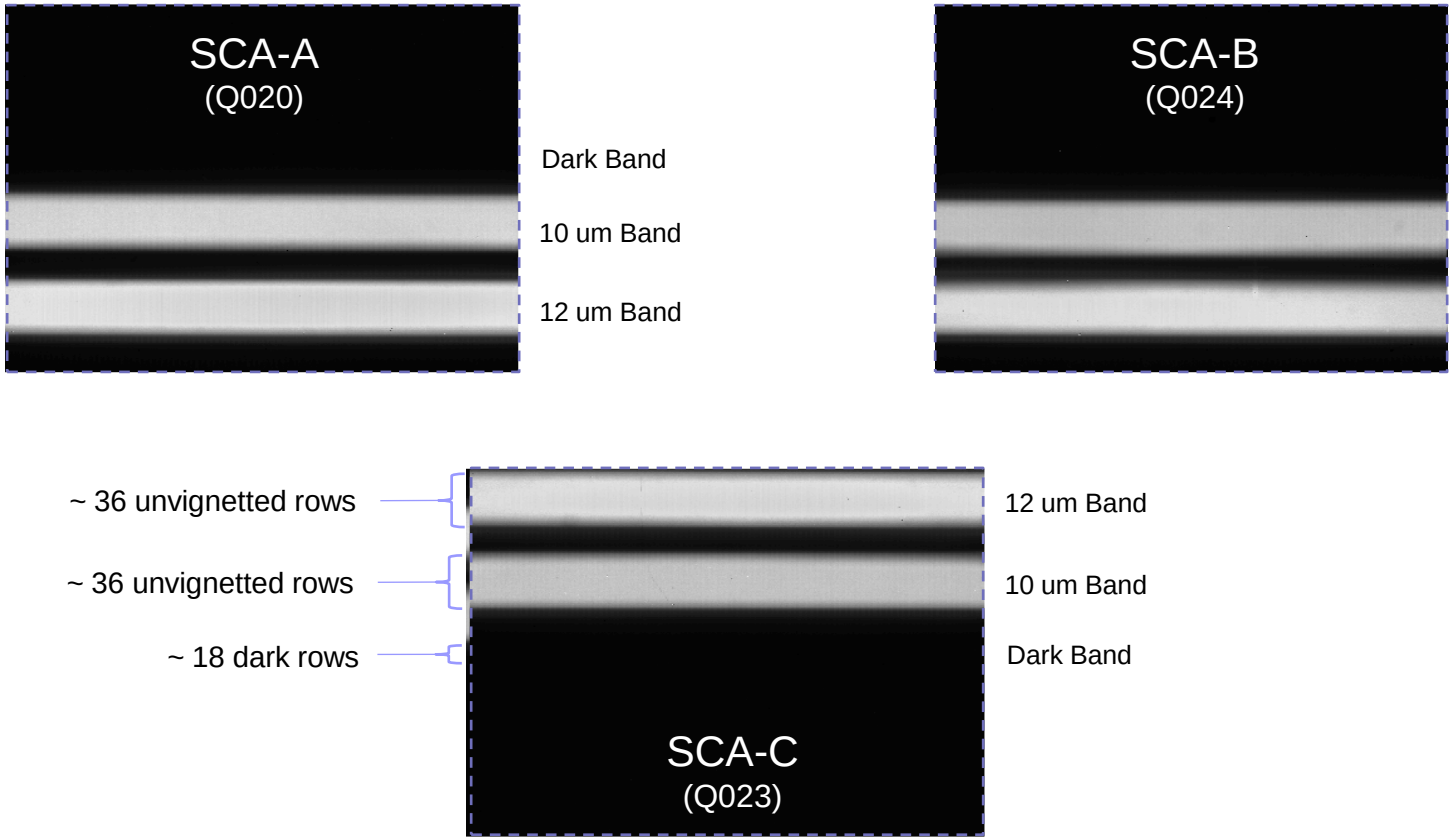
OBB will have similar design as that of MODIS with a V-groove, “flat” plate and similar coating to improve emissivity

Focal Plane Science Regions



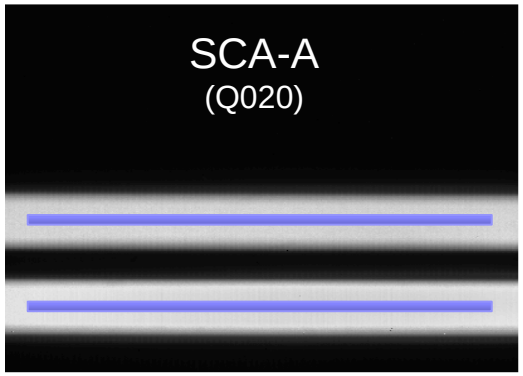
▲ = col/row origin

Science Regions – Actual Image



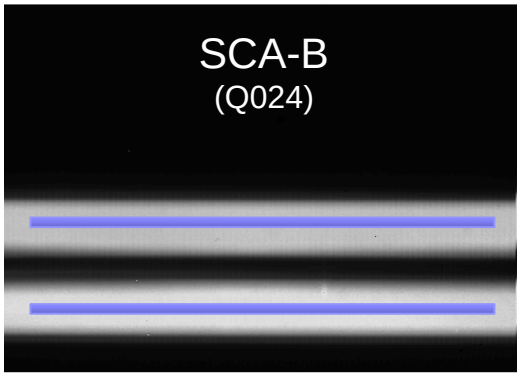
Preliminary Signal-to-Noise

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



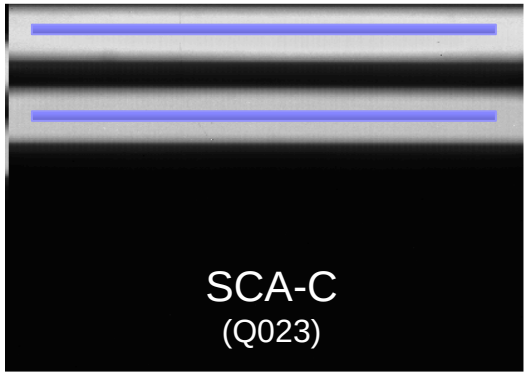
SNR ~ 1000

SNR ~ 900



SNR ~ 900

SNR ~ 800



SNR ~ 900

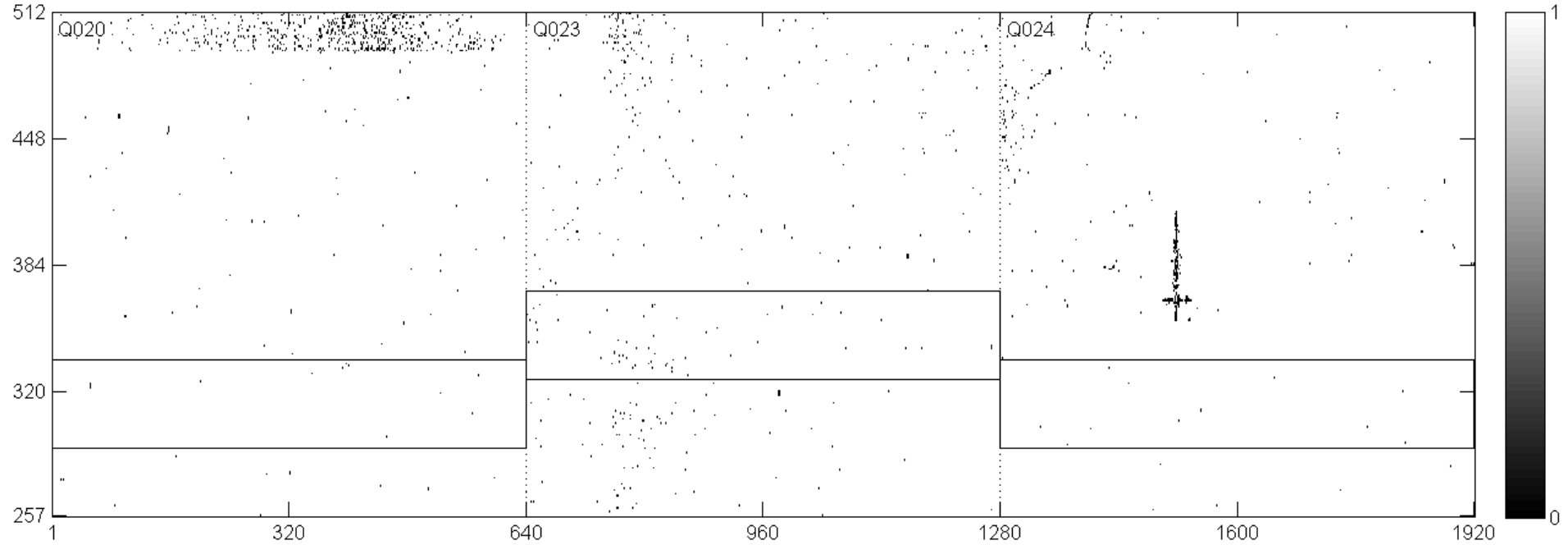
SNR ~ 1000

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



Q020 Q023 Q024

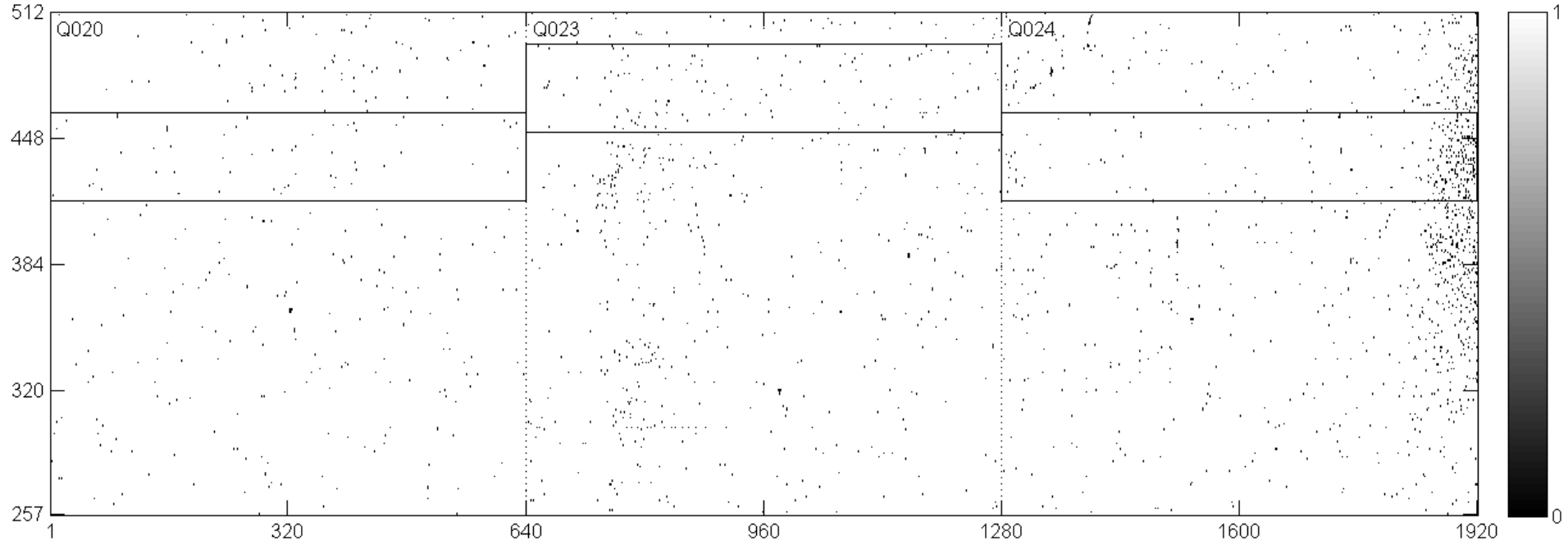
•Can always find perfect row or combine 2 rows to create a perfect row

12 micron Spectral Uniformity map

Used measured filter and measured QWIP response:

White (1) = Pass all requirements

Black (0) = Fail at least one requirement

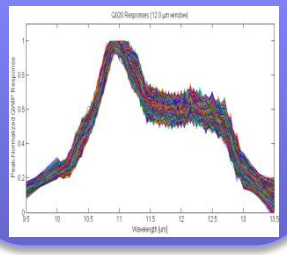


Q020 Q023 Q024

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

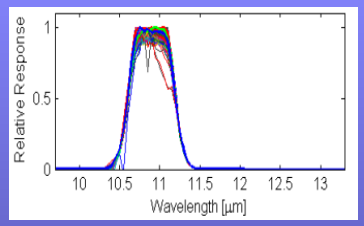
Spectral Uniformity Analysis

Spectral Responses of QWIPs



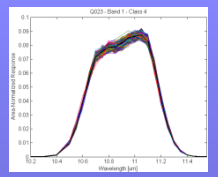
Define filter

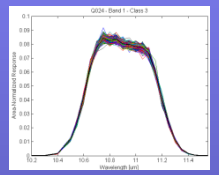
Spectral response of Band



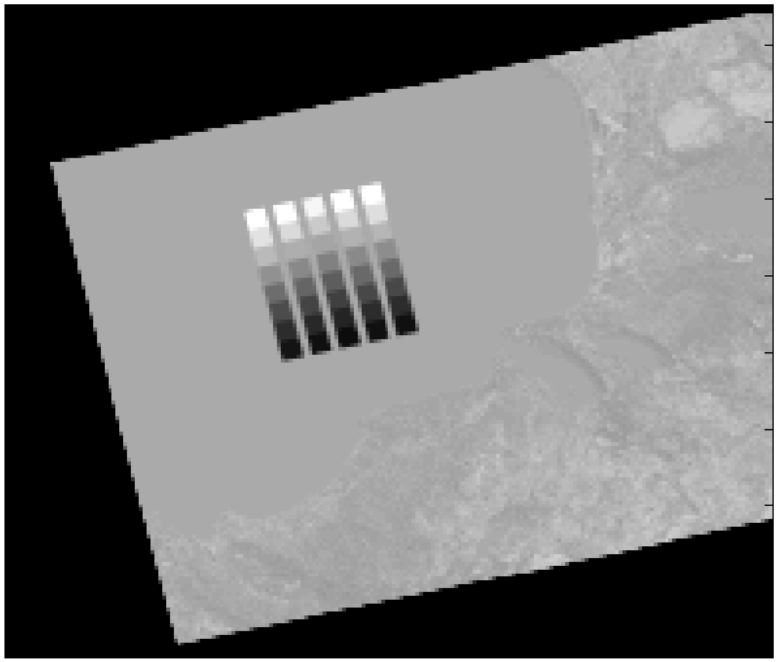
Select extreme classes

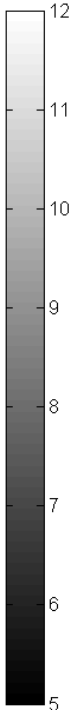
Example Different Responses





[W/cm2/sr/um]

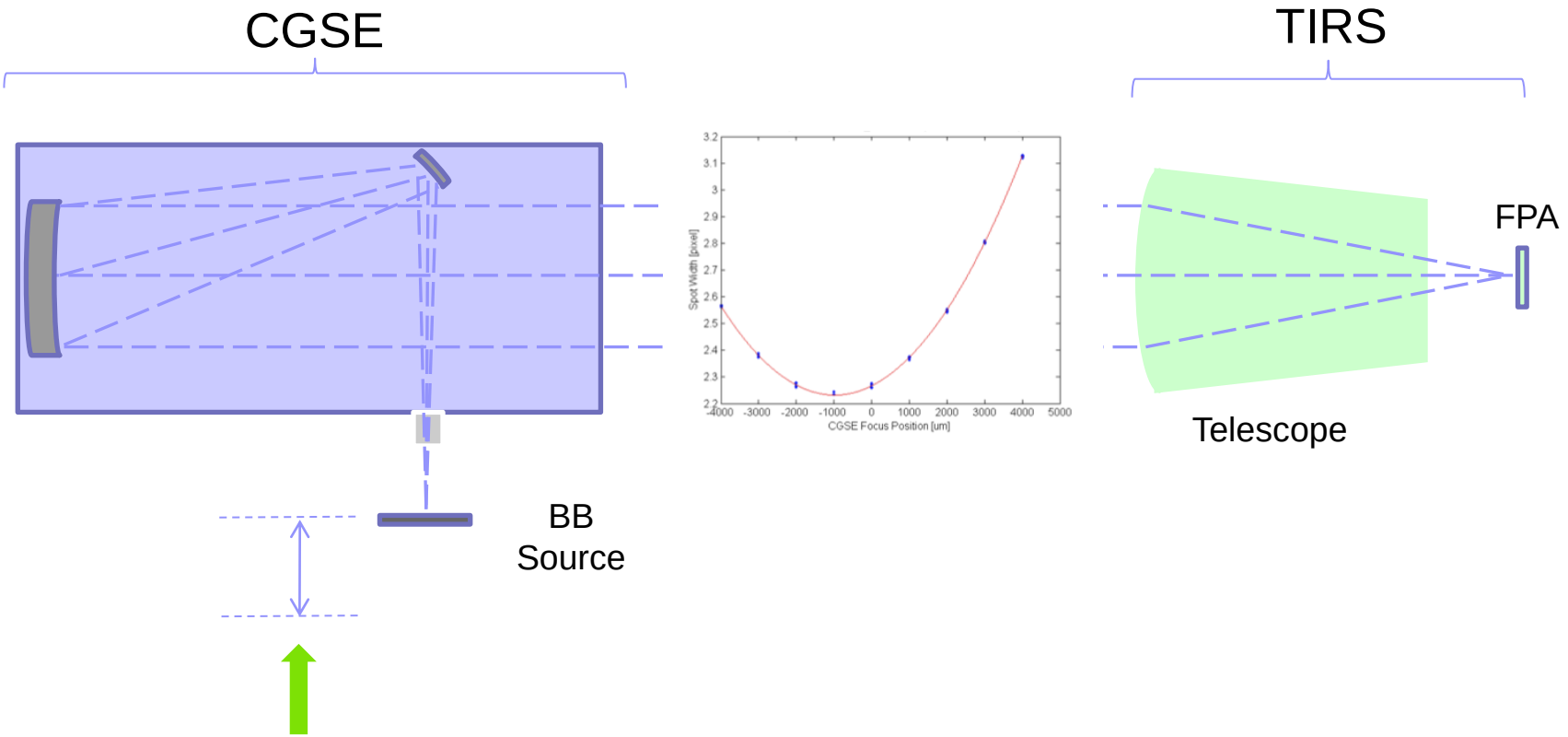




Result:
Validates spectral uniformity of rows chosen

Use class mean to simulate TIRS scene

TIRS Focus Procedure



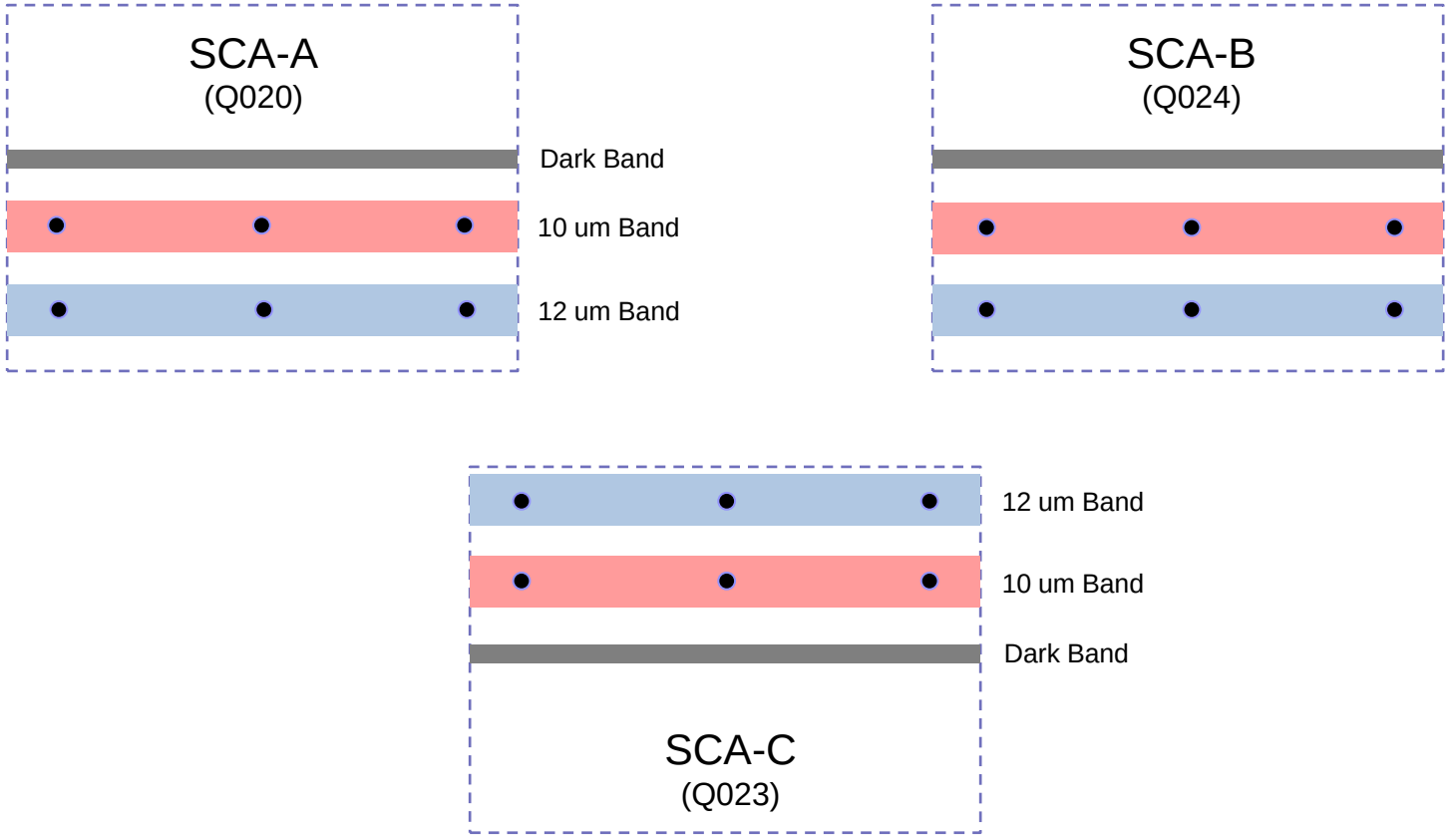
Vary CGSE Focus…

…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