# Post Launch Calibration and Testing of The Advanced Baseline Imager on the GOES-R Satellite

William Lebair, C. Rollins, John Kline, M. Todirita, J. Kronenwetter

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Overview

- Geostationary Operational Environmental Satellite R (GOES-R)
    - Next generation NOAA satellite
    - Advanced Baseline Imager (ABI) multi-channel radiometer

- Initial on-orbit calibration and performance characterization of ABI
    - Post Launch Tests (PLT's) to establish baseline for post launch performance
    - Unique challenges due to large number of detectors for sixteen channels
    - Six month PLT period

- Presentation of planned PLT's
    - Motivation
    - Details

Advanced Baseline Imager (ABI)
(http://www.goes-r.gov/spacesegment/abi.html)
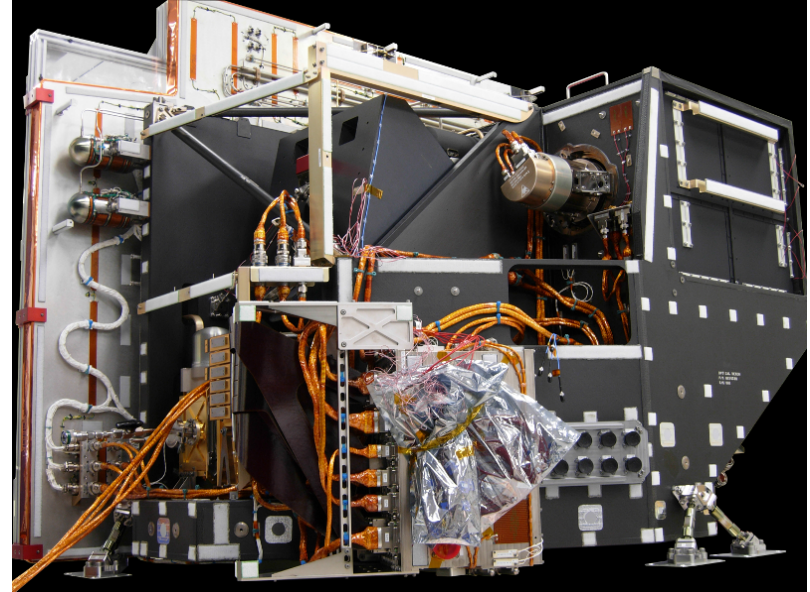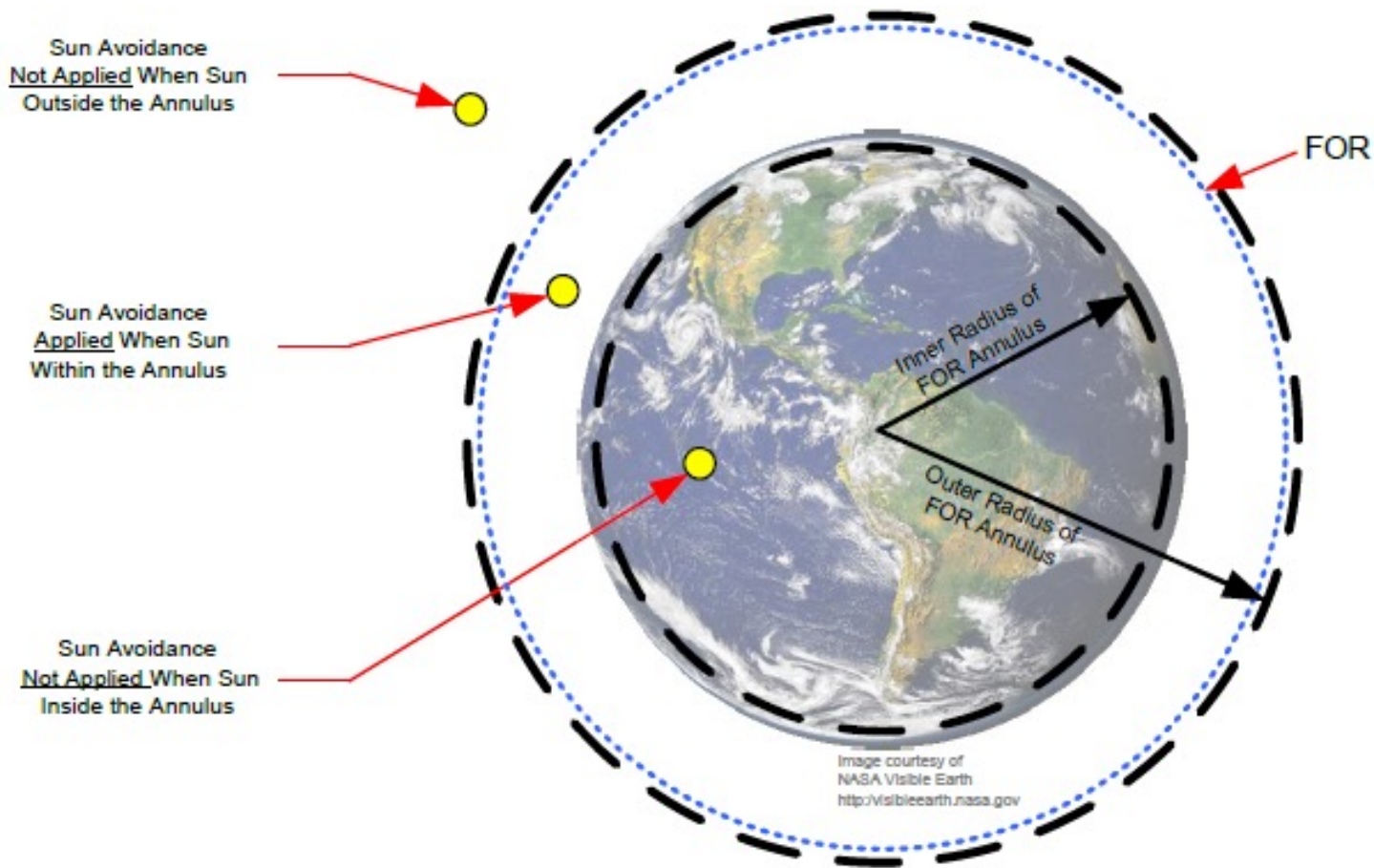
PLT Introduction

- ## Health and safety
  - Solar avoidance
  - Detector screening
  - Scanner and scan encoder performance tracking

- ## Radiometric testing
  - Basic calibration and trending
  - Calibration stability
  - Noise performance
  - Dynamic range
  - Repeatability
  - Desert scene observation

- ## Final tests
  - Image navigation and registration (INR)
  - Image quality

GOES-R removed from thermal-vacuum chamber (GOES-R Newsletter 2015)

Health and Safety PLT's

Solar Avoidance

Sun Avoidance Not Applied When Sun Outside the Annulus

Sun Avoidance Applied When Sun Within the Annulus

Sun Avoidance Not Applied When Sun Inside the Annulus

FOR

Inner Radius of FOR Annulus

Outer Radius of FOR Annulus

Image courtesy of NASA Visible Earth http://visibleearth.nasa.gov

- Motivation: Confirm solar avoidance algorithm prior to Optical Port Cover opening
- Demonstrate avoidance of exclusion zone
  - 0.5 degree margin for FOV reaching edge of sun
  - Demonstrate truncated scan with cover closed with two sun locations

Detector Screening

- ABI channels consist of line Focal Plane Arrays (FPA's) with multiple columns of detectors for redundancy
  - Best Detector Selection (BDS) used to choose detectors for each row
  - BDS choices may change with cool-down cycles
- Motivation: Screening process for performance on-orbit
  - Image collections
    - Solar Calibration Target (SCT) diffuser
    - On-board thermal reference – Internal Calibration Target (ICT)
    - Space look
    - Ground scene
- Four-step procedure
  - Visual/Near Infrared (VNIR) channel images of SCT
  - Emissive channel images of ICT while adjusting bias voltages on FPA's
  - 30-second stare at ICT
  - 2.4-second stare at Earth target (large, time-stable area)
- Evaluation
  - Gain and stability, offset and stability, and noise

Operational Detectors

VIS/NIR Ch.'s 1-3   SWIR/IR Ch. 4-16
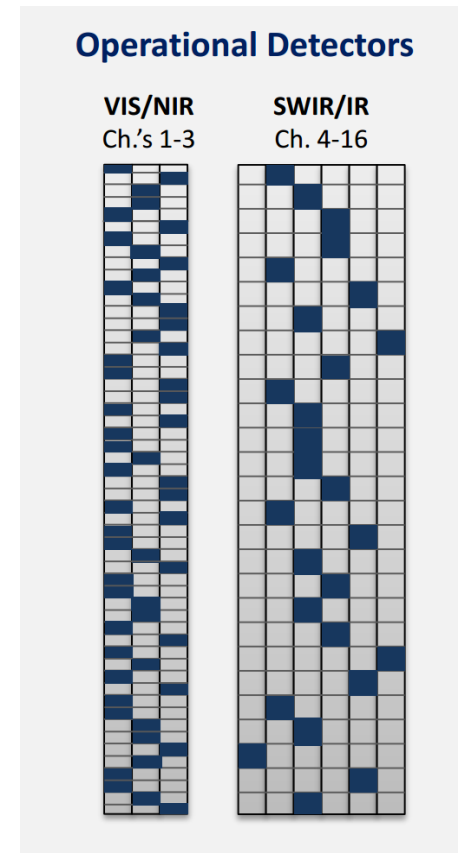
Typical layout of optimized set of detectors (Padula 2015)

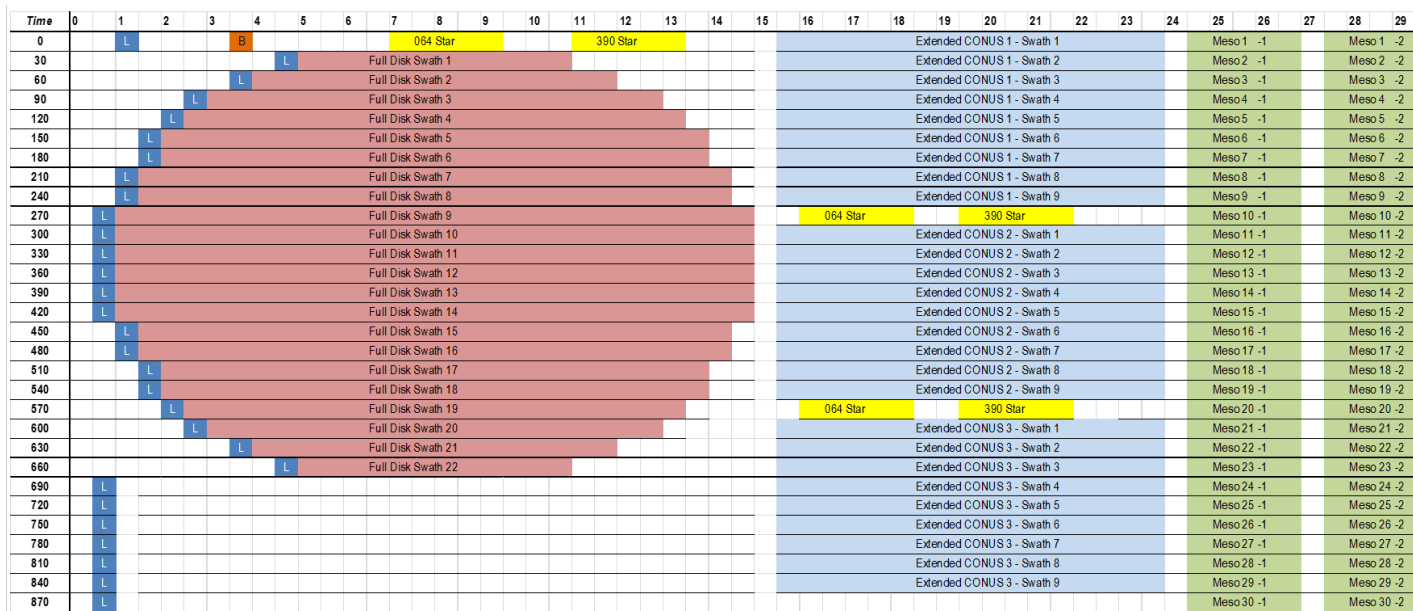# Scan Encoder Fine Track Error Trending

- Motivation: Track changes in commanded versus executed scan mirror position

  – Depends on encoder calibration coefficients and on environmental/aging factors

- Pre-defined pointing scenarios

- Results in telemetry

  – Trended over time
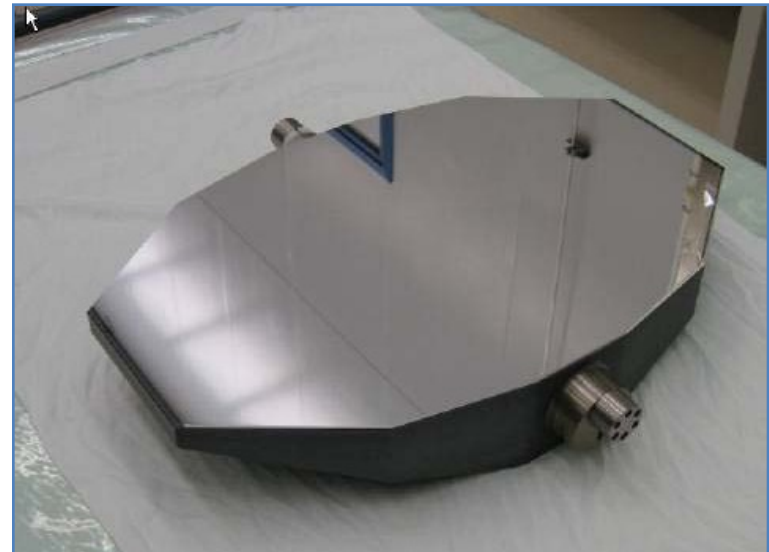
ABI Scan Mirror (Mandt 2009)

Radiometric PLT's

IR Radiometric Calibration Stability

15-minute Mode 3 timeline with 3 CONUS images and ICT look (Gerth 2014)

- Motivation: Demonstrate channel-to-channel repeatability
  - Requirement for thermal channels < 0.2
- Mode 3 timeline
  - 15 minute duration
  - 3 Continental United States (CONUS) images and ICT look
- Comparison of Mode 3 timelines over 24 hours
  - Spatial average of CONUS images before and after ICT look
  - Difference tracked as effective delta temperature
  - Determine drift in calibration coefficients needed for 0.2 K specification failure

Alignment Assessment
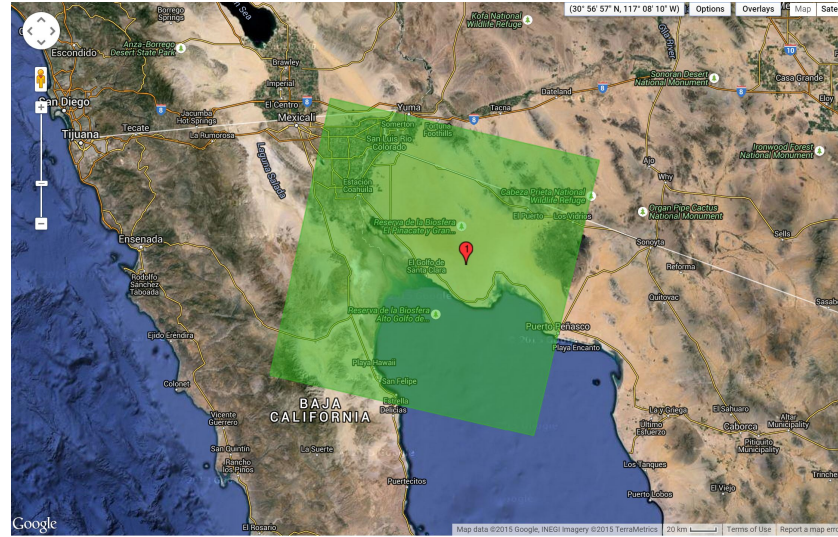
Footprint of Landsat-8 data for Sonoran
Desert/Gulf of California coastline (USGS 2016)

- Motivation: Determine and correct for misalignment between ABI and S/C attitude determination system
  - Ties navigated LOS to S/C attitude determination
  - No star positions for this PLT (later PLT will refine using stars)
- Comparison between Landsat and ABI
  - Landsat Ground Control Point (GCP) residuals
  - 3-axis navigation offsets
  - Diurnal profiles
 - Line of site motion compensation (LMC) coefficients

IR NEdT and Dynamic Range Characterization
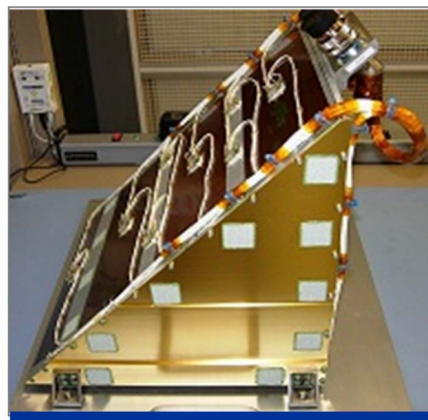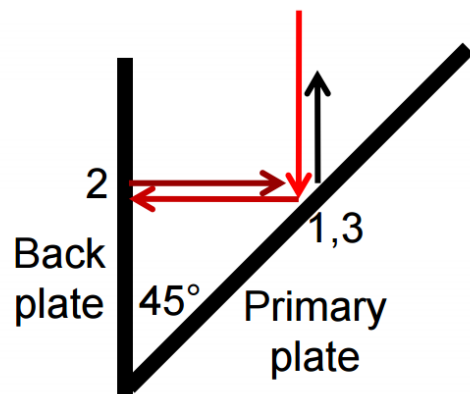
3-bounce ICT for emissive channel calibration (Griffith 2016)

- Motivation: Establish beginning-of-life (BOL) performance
    - Noise Equivalent delta Temperature (NEdT)
    - Dynamic Range (DR)
    - Quantization Step Size (QSS)
- Long-duration (2-second) ICT and space looks
    - NEdT at single ICT temperature compared to ground test
    - 2-scene measurement extrapolated to saturation for DR
    - QSS calculated assuming linearity based on ground test

System Linearity
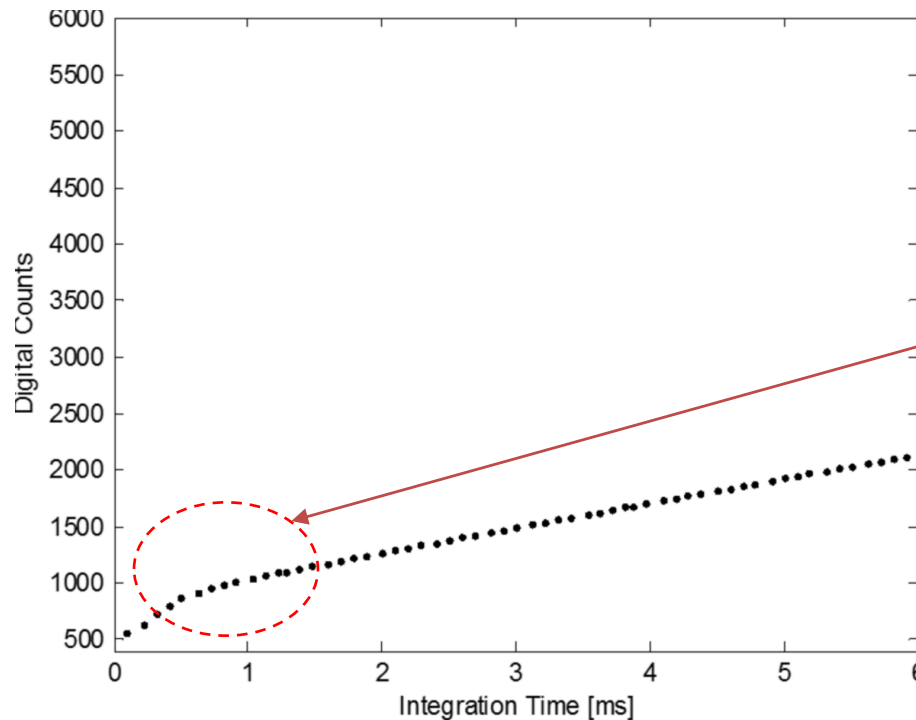
Unlike Landsat TIRS, ABI is expected to behave linearly over operational DR

Measurement of linearity using digital counts versus integration time for Landsat thermal IR sensor, TIRS (Montanaro 2014)

- Motivation: Demonstrating linearity over operational DR
- Changing integration time while starting at target
  - SCT for VNIR channels and ICT for emissive channels
  - Constant increments except for 3.9 micron channel (different step size for higher sensitivity)
 - To demonstrate < 1% nonlinearity

IR Radiometric Repeatability Characterization

Full Disk

CONUS

Stare

ICT stares used to compile simulated Full Disk and CONUS
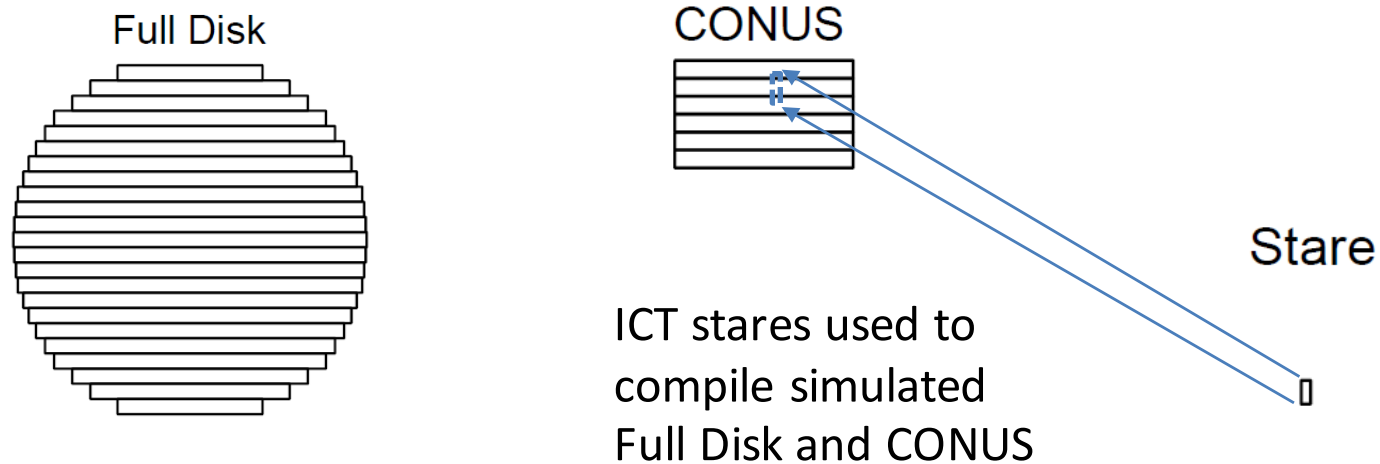
ABI scan patterns (Griffith 2016) simulated by ICT stares

- Motivation: Measure repeatability of adjacent pixels and between swaths/channels/images
  - Specifications are < NEDT difference
  - Typical operational use would be CONUS (every 5 minutes) or full disk images (every 15 minutes)
- Synthetic images using ICT looks
  - Pixel to pixel: local RMS row deviation from mean of 3 R x 10 C sub-images
  - Swath to swath: boundaries of swaths in CONUS images (comparison of neighboring rows from two swaths)
  - Channel to channel: Successive CONUS images in two channels; average temperature difference
  - Image to image: Successive CONUS images; average temperature differences

VNIR Radiometric Calibration Trending
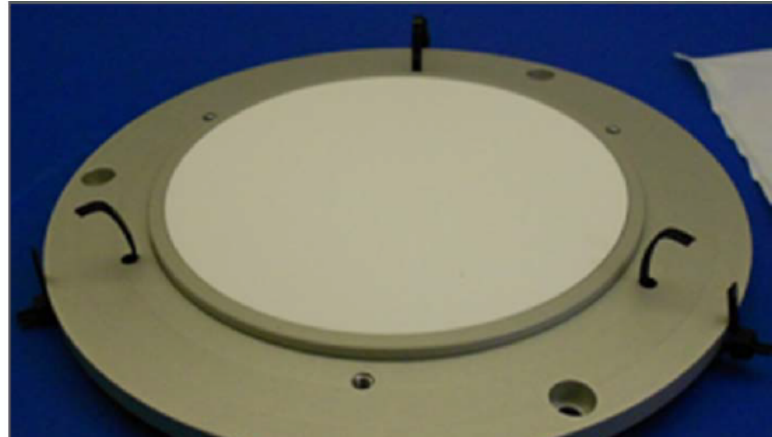
ABI Solar Diffuser (Griffith 2016)

- Motivation: Baseline trending measurements and calibration stability
- Frequent solar calibrations during PLT phase to establish baseline
  - Two-point (solar diffuser and space) calibration
  - BDS detectors for each row of VNIR channels
  - Comparison to ground test
  - Long-term trending and information on appropriate decrease in solar calibration frequency post-PLT

Desert VNIR Monitoring
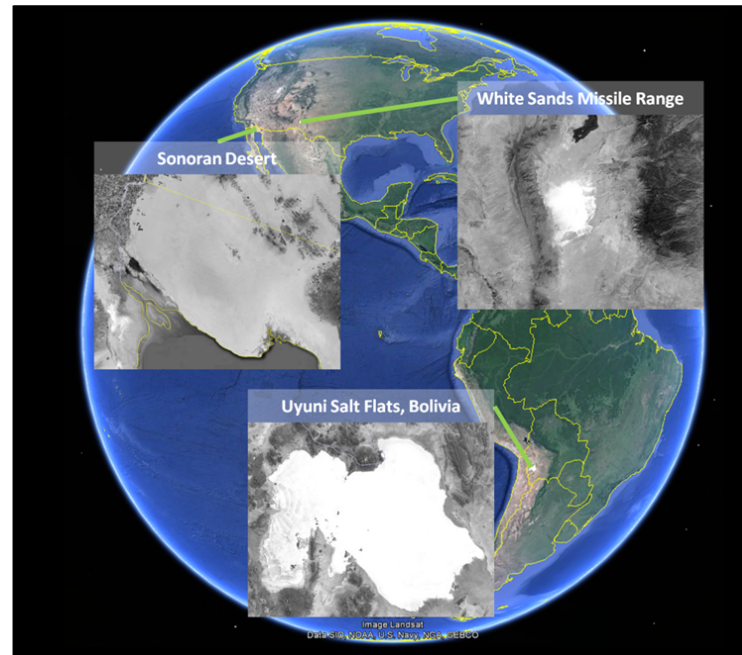
Desert validation target for routine PLT north/south scan (NSS) collections

- Motivation: Vicarious ground-truth validation of on-board calibration
  - Trending of detector performance
  - Alternative calibration methodology in case of SCT failure
- NSS over three targets
  - Sonoran Desert, White Sands Missile Range, Uyuni Salt Flats, Bolivia
  - Six NSS – one for each VNIR channel
  - ~ 200 km ground track; collected within +/- 7.5 minutes local solar noon

Image Quality and Image Navigation and Registration (INR) PLT's

Coherent Noise

Coherent noise structures such as these can be identified as spatial frequencies

Landsat-8 Band 3 coherent noise off coast of Gulf of Panama (USGS)

- Motivation: Compare coherent noise performance with ground measurement
  - Identifying spatial frequencies > 25% NEdN
  - Looking for in-family peformance
- Synthetic full disk images using ICT and space observations
  - Timeline to mimic full disk collection
 - 2D Fourier transforms

Spatial Uniformity Characterization over Field of Regard
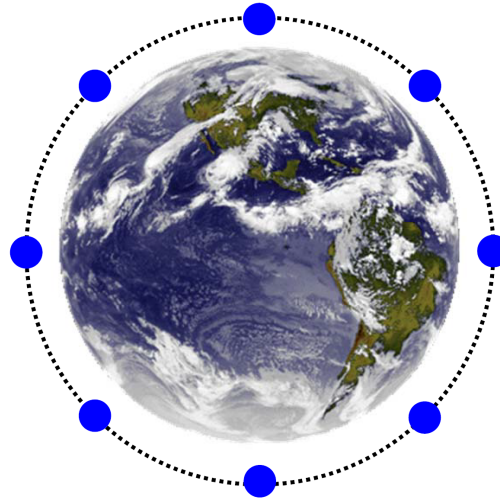
Possible locations for spatial uniformity characterization (Griffith 2016)

- Motivation: Measure BOL spatial variation in response over Field Of Regard (FOR)
  - Confirm validity of scan mirror emissivity/reflectivity coefficients
  - Check against required 0.3% uniformity
- Characterized using space looks
  - ICT calibration, followed by eight locations equally spaced around Earth
  - Long duration looks (25 seconds)
  - Repeated every four hours for a total of 24 hours
 - Run Spatial Uniformity Calibration PLT if needed

LOS Estimation Filter Performance Characterization and Tuning
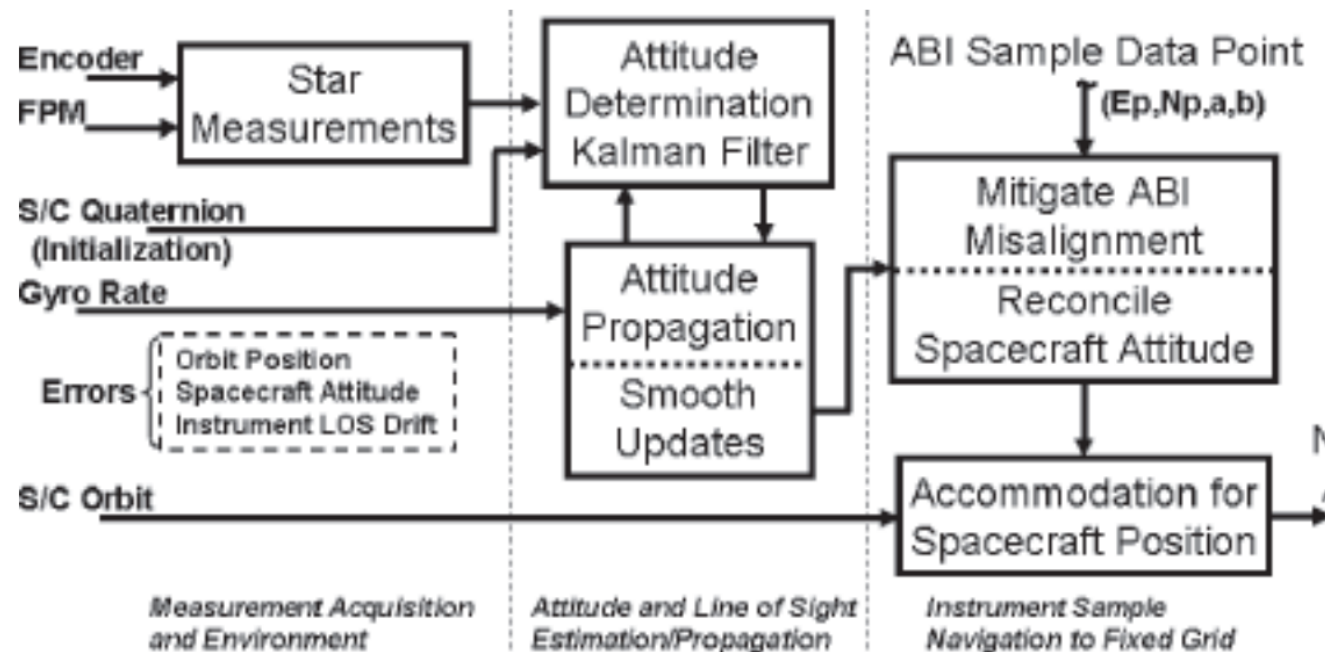
ABI Image Navigation and Registration (INR) Process (Ellis 2008)

- Motivation: Orbital measurements for Line-of-Sight (LOS) estimation filter
  - Characterize performance
  - Characterize LOS diurnal profile for use in computing tuning parameters
- Star measurements
  - Navigated to fixed grid with current INR parameters
  - Navigation errors and measurement noise parameters extracted to use in LOS filter

Co-registration Characterization Analysis (MWIR/LWIR offset)
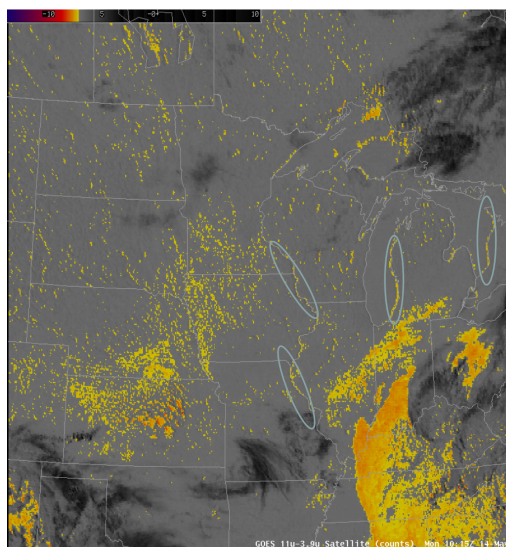
False detection of fog on GOES-13 due to ~1 pixel misalignment between 10.7 um and 3.9 um bands (Grotenhuis 2013)

- Motivation: Measure co-registration error between Mid-Wave IR (MWIR) and Long-Wave IR (LWIR) channels
  - Difference in navigation between spectral channels for a given pixel in the same frame
  - Check against required limit of 11.2 microradians
- Star measurements
  - MWIR 3.9 micron channel compared to an LWIR channel (TBD)
 - Offset extracted using star measurement residuals

INR Earth Pointing Platform Deployment Assessment
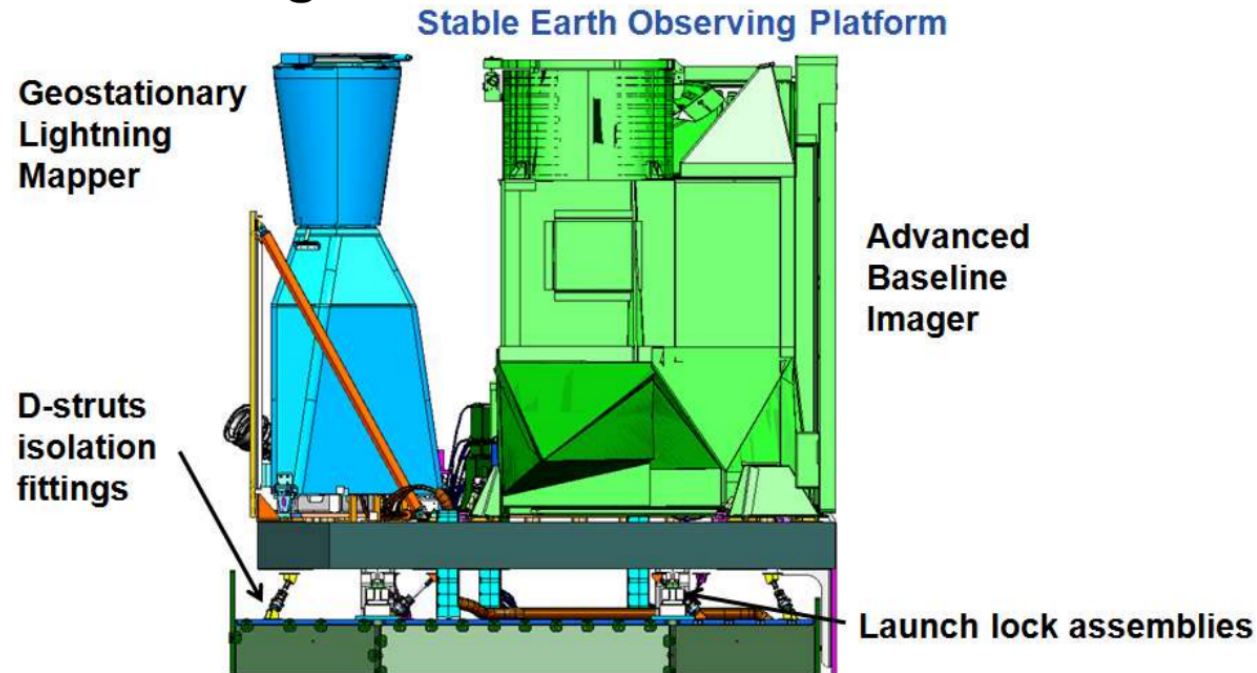
Earth Pointing Platform (EPP) and launch locks (Jolly 2014)

- Motivation: Assess INR performance before and after EPP launch locks are released
- INR assessments using Landsat comparison
  - Landsat GCP's and image-to-image tie-points from Level 1B ABI imagery
  - Navigation assessment (comparison with GCP)
  - Within frame (distance between pairs of control points in image with GCP's)
  - Frame-to-frame, swath-to-swath, and channel-to-channel (distances between GPC's or tie-points in each)

Spatial Resolution Characterization
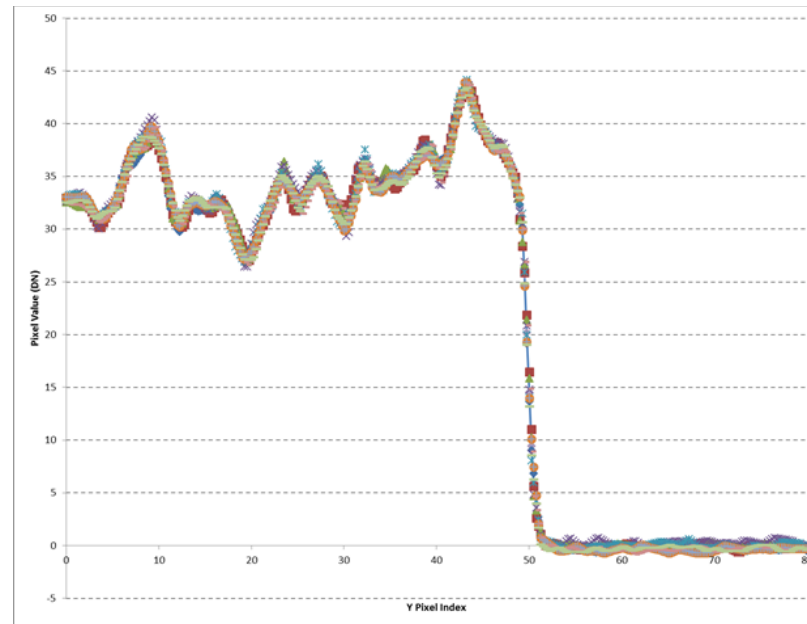
Edge sampling in early AHI-8 lunar images (courtesy of Japan Meteorological Agency, JMA) used to demonstrate that AHI-8 met or exceeded ABI requirements

- Motivation: Measure BOL Modulation Transfer Function (MTF) performance
  - Check if within family of ground performance baseline
  - Determine if ABI focus adjustment is needed
- Lunar edge as on-orbit target for East/West (E/W) and North/South (N/S) MTF
  - Sharp edge with large brightness contrast
  - Sub-pixel Edge Spread Function (ESF) assembled from one or a concatenation of images
  - Spatial derivative (ESF) → Line Spread Function (LSF); Norm. mag. Fourier Transform (LSF) → MTF
  - E/W MTF at full scan and 1/10 scan rates & N/S MTF at 1/10 scan rates to compare to ground test

Lunar Trending for Performance

Lunar image from AHI-8 (Takahashi 2015)

- Motivation: VNIR calibration target
  - VNIR calibration trending
  - Relative spectral response of scan mirrors across FOR
- Lunar imagery when moon in FOR but outside Earth limb
  - Two images per month (one per Earth side)
  - At least one set of images of Moon transiting through North or South end of FOR to evaluate scan mirror spectral response

3.9 Channel Stray Light Characterization
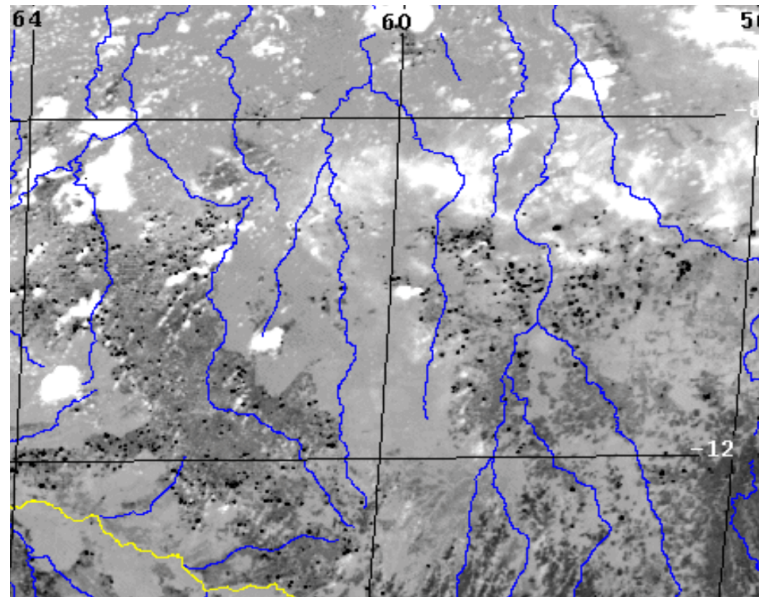
GOES-R proxy data created from 2004 MODIS data (Gurka 2014)

- Motivation: Characterize and quantify stray light due to known sneak path
  - Hardware approach developed to mitigate sneak path past field stop and scattering off beam splitter
  - Strongest on 390 channel, but may be detectable throughout VNIR
  - Present for solar incidence angles between 10 and 15 deg. south of nadir Line of Sight (LOS)
  - Verify accuracy of stray light modeling predictions
- Full disk images at appropriate times and beta angles
  - S/C local midnight +/- 1 hour (every five minutes)
  - Beta angles between -14.44 deg and -7.5 deg (sun position from 19 deg south to 10 deg south)
  - Image differencing to suppress Earth radiance and identify stray light

Summary

- Large and varied assortment of PLT's planned

- Health and safety

- Quantify and characterize performance
  - Radiometric
  - Image quality
  - Navigation
  - Comparison to ground test

- Tune and trend performance
  - Optimize selected parameters
  - Trending to confirm performance or need for changes in parameters

- Goal is a well-characterized, optimized, state-of-the-art instrument

Advanced Baseline Imager (ABI)
http://www.goes-r.gov/mission/images/overview/ABII.jpg

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Japan Meteorological Agency (JMA); image courtesy of Mr. Masaya Takahashi, Scientific Officer at JMA.

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