Overview of Image Quality Performance of the GeoEye-1 High Resolution Imaging Satellite

Nancy E. Podger, PhD

GeoEye

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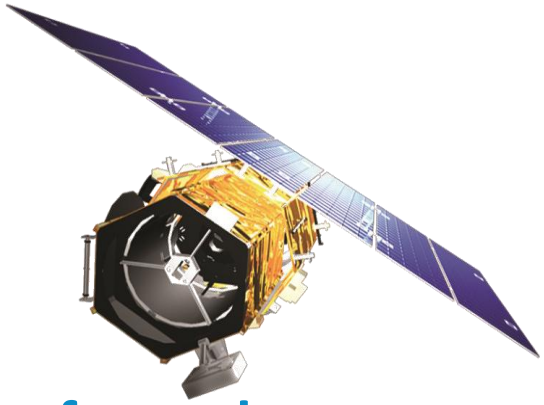
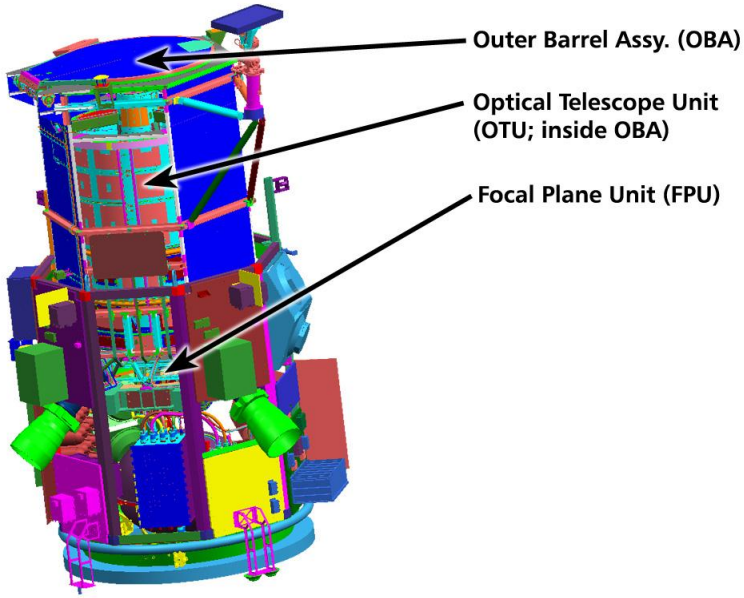
Overview



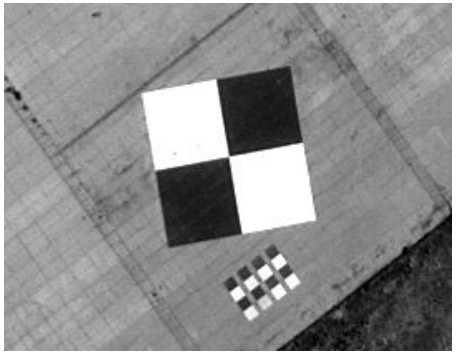
- Overview of Major Calibrations
- Overview of Image Quality Assessments Performed
- Relative Radiometric Calibration Methodology
- Focus Calibration Methodology



Overview of Major Calibrations for the GE-1 sensor

- **Geometric**
  - Geometric calibration provides the mapping of the satellite sensor for geopositioning imagery.
- **Radiometric**
  - Relative radiometric calibration is a detector equalization process to reduce pixel-to-pixel and sub-array to sub-array variations.
  - Absolute radiometric is the mapping between digital pixel values and at aperture spectral radiance.
- **Focus**
  - Focus calibration is the process of determining the best focus position of the secondary mirror of telescope.

Overview of Major Image Quality Assessments



MTF Range – Spring, TX

- **MTF Analysis -**
  - MTF is a metric to quantify the sharpness.
  - GeoEye maintains a MTF Range - Assessed quarterly
  - 1Q12 Camera Level
    - Assessment of spacecraft/payload performance
      - relative radiometric tables only
      - No synthetic array interpolation
    - Pan 10K – MTF value 0.14 +/- 0.01, Nyquist MTF of spec 0.1
  - 1Q12 Product Level
    - Measured at the earliest customer product level
      - MTFC kernel applied at the cost of noise
    - Pan 10K – MTF value 0.16 +/- 0.01, Nyquist MTF of spec 0.1
- **Signal-to-Noise Measurements**
  - Measurements are analyzed using flat field imagery
  - All bands are within spec

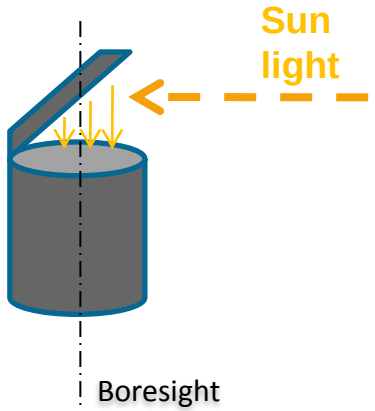
Overview of Major Image Quality Assessments (cont.)

- **Time Delay Integration (TDI) Selection Optimization**
  - TDI selection controls detector exposure time (charged integration time)
  - TDI stages for GE-1
    - Panchromatic - 8,16,32,48,64
    - Multispectral - 3, 6, 10, 14, 18, 21, 24
  - Optimum selection of TDI is needed to consistently obtain wide dynamic ranges without saturation when imaging.

- **Visual assessment of operational imagery for artifact/anomaly characterization and resolution.**

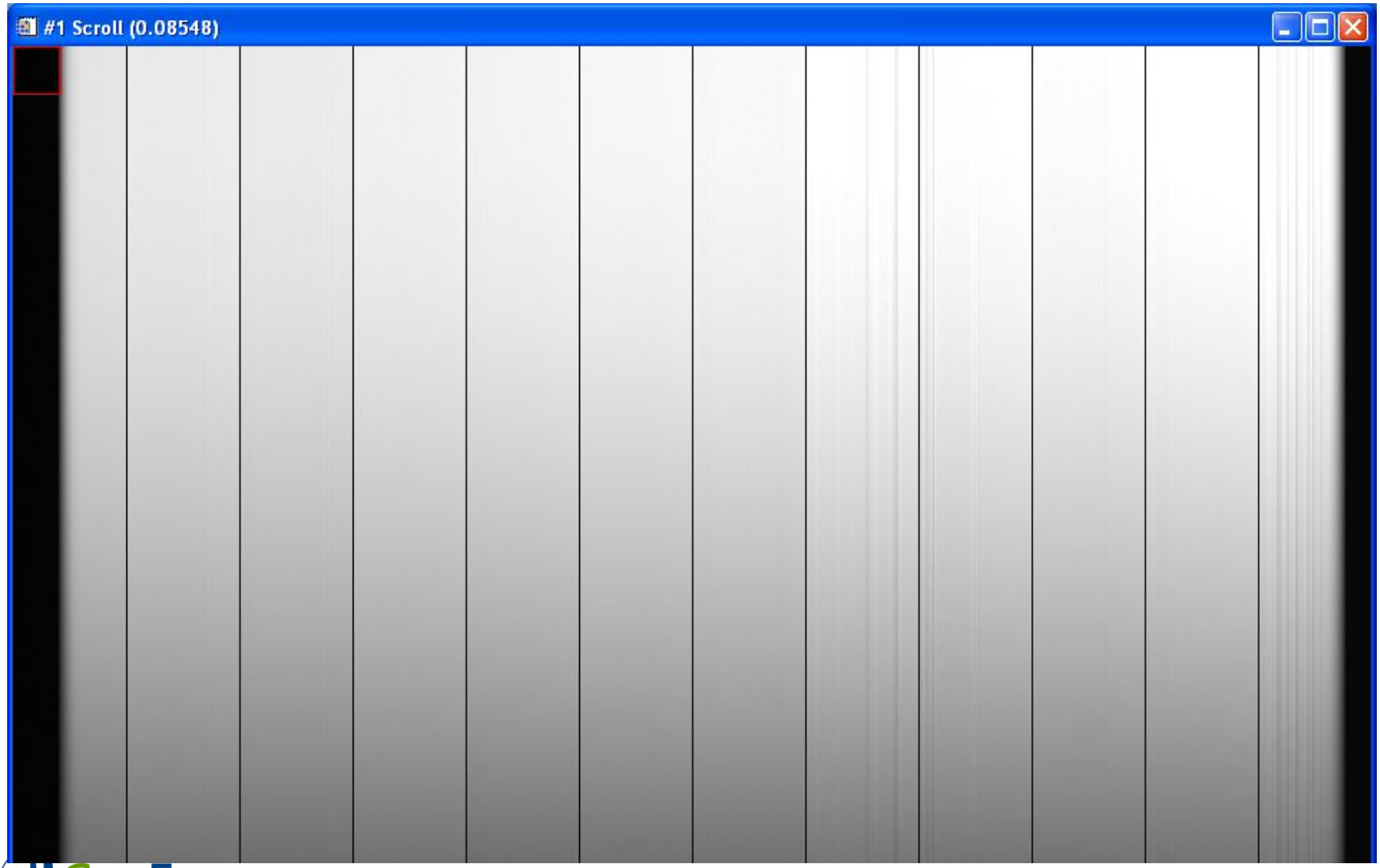
Relative Radiometric Calibration

- **Purpose: Detector equalization to reduce pixel to pixel and sub-array to sub-array (tap) variations.**
- **Relative calibration data is performed analyzing flat field data collected in for numerous modes (band, aggregation, line speed, TDI).**
- **Flat field data is acquired by imaging the camera door.**
  - Camera door was coated with a highly reflective paint to produce a diffuse surface.
  - Door opens or closes to allow illumination through the dynamic range of sensor.
    - The sensor must be positioned so that the sun's rays are normal to the both the camera's boresight axis and the camera door hinge.
    - The radiance increases until door has opened to approximately 45 degrees.
  - The door is also imaged while close to obtain dark current data



Relative Radiometric Calibration Data – Uncorrected

MS3, Reverse, 1x1, 6 TDI



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Relative Radiometric Calibration Methodology

- **Dark current value per detector**
  - Calculated from data acquired when the camera door is closed.
  - An average value from approx. 100 scan lines is calculated for each detector.
- **Gain correction**
  - Seven illumination (light) level responses are calculated from the door data for each detector
    - average of approximately 100 lines.
  - The dark current value is subtracted from each light levels for each detector.
  - Target responses for each light level is determined by the mean value of the 500 middle detector values.
  - The target responses and the light levels for each detector make up a lookup table
    - Piecewise linear interpolation during image reconstruction for any digital pixel value

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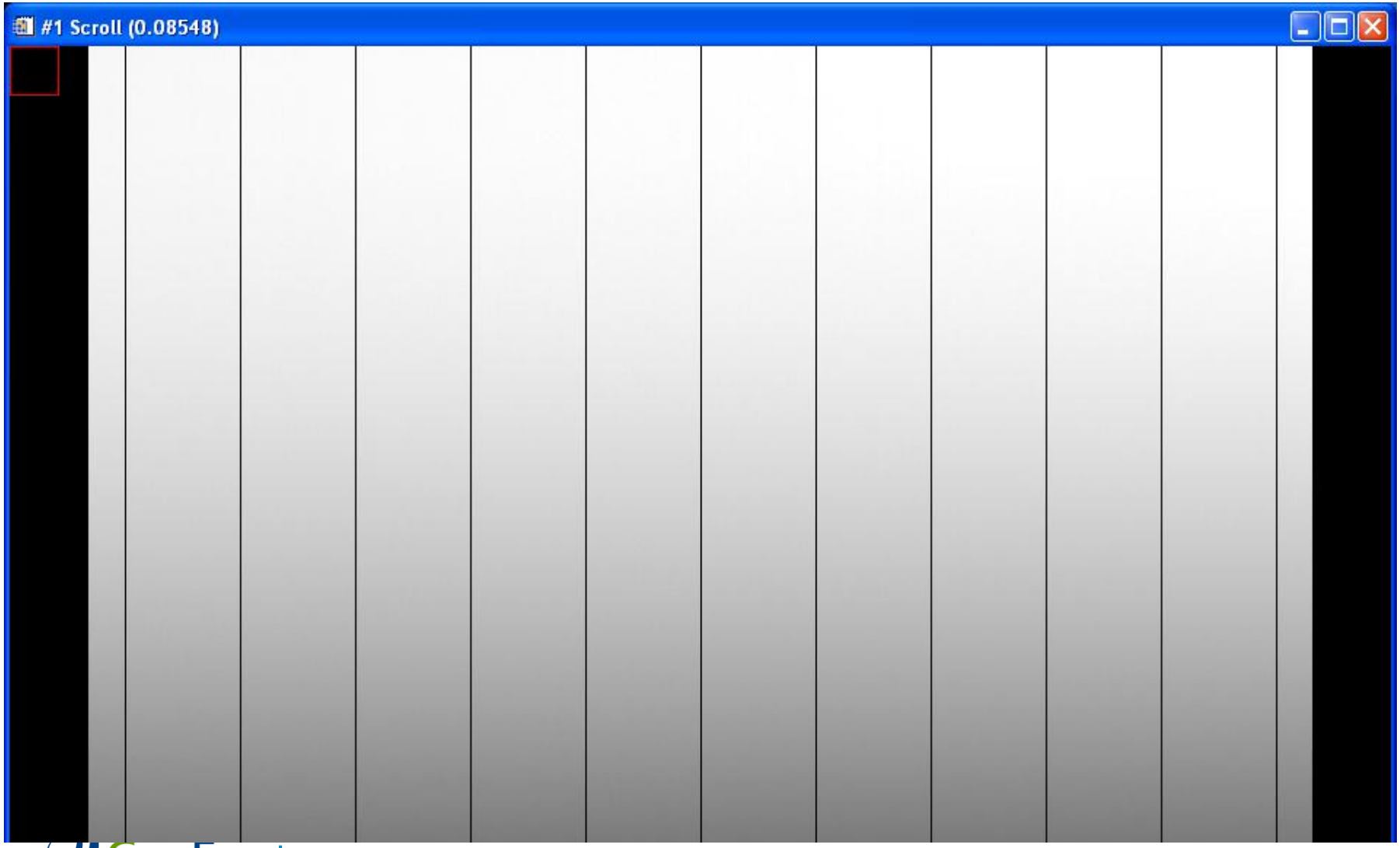
Relative Radiometric Calibration Data – Corrected

MS3, Reverse, 1x1, 6 TDI



Verification of Relative Radiometric Calibration

- **Metrics to assess calibration**
  - Streaking - measure of pixel-to-pixel variation
  - Banding - measure of sub-array to sub-array variation
- **Verification of Calibrated Camera Door Data**
  - Streaking and banding metrics are measured across the focal plane and throughout the dynamic range.
- **Verification of Operational Image**
  - Visual inspection
  - Banding metrics are measured in homogeneous areas of adjacent sub-arrays.

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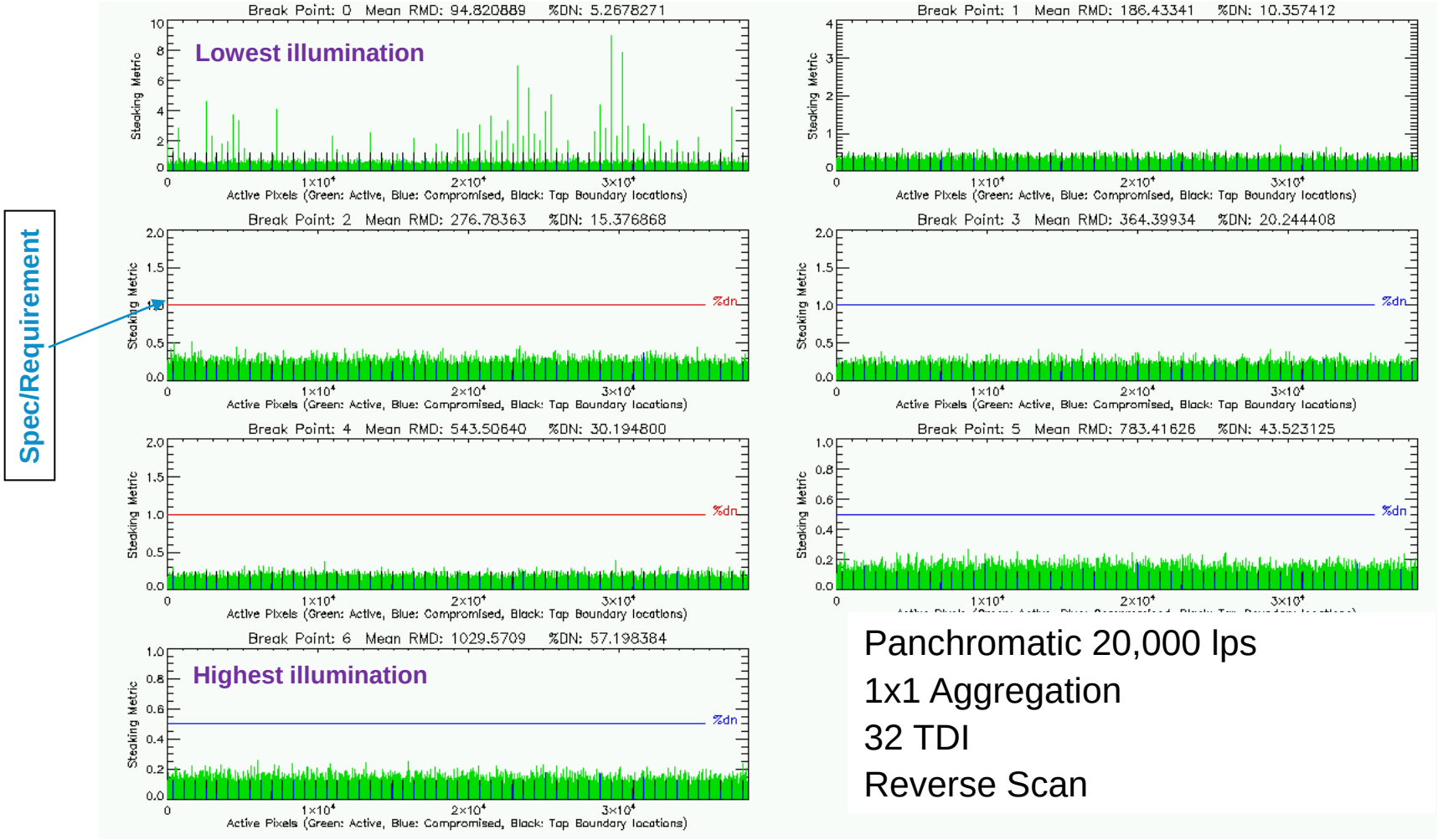
Representative Streaking Metrics



Panchromatic 20,000 lps
1x1 Aggregation
32 TDI
Reverse Scan

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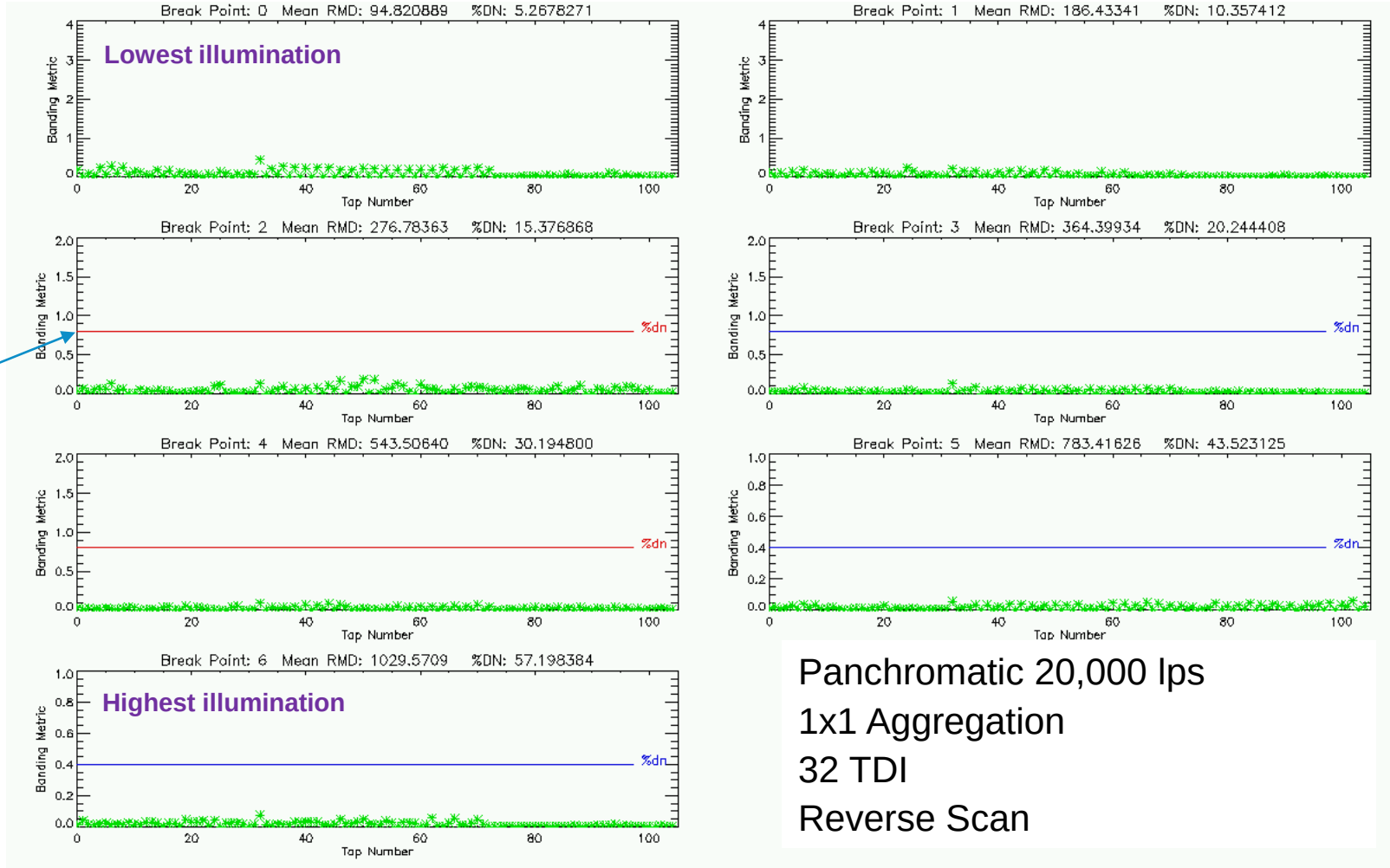
Representative Banding Metrics



Panchromatic 20,000 lps
1x1 Aggregation
32 TDI
Reverse Scan

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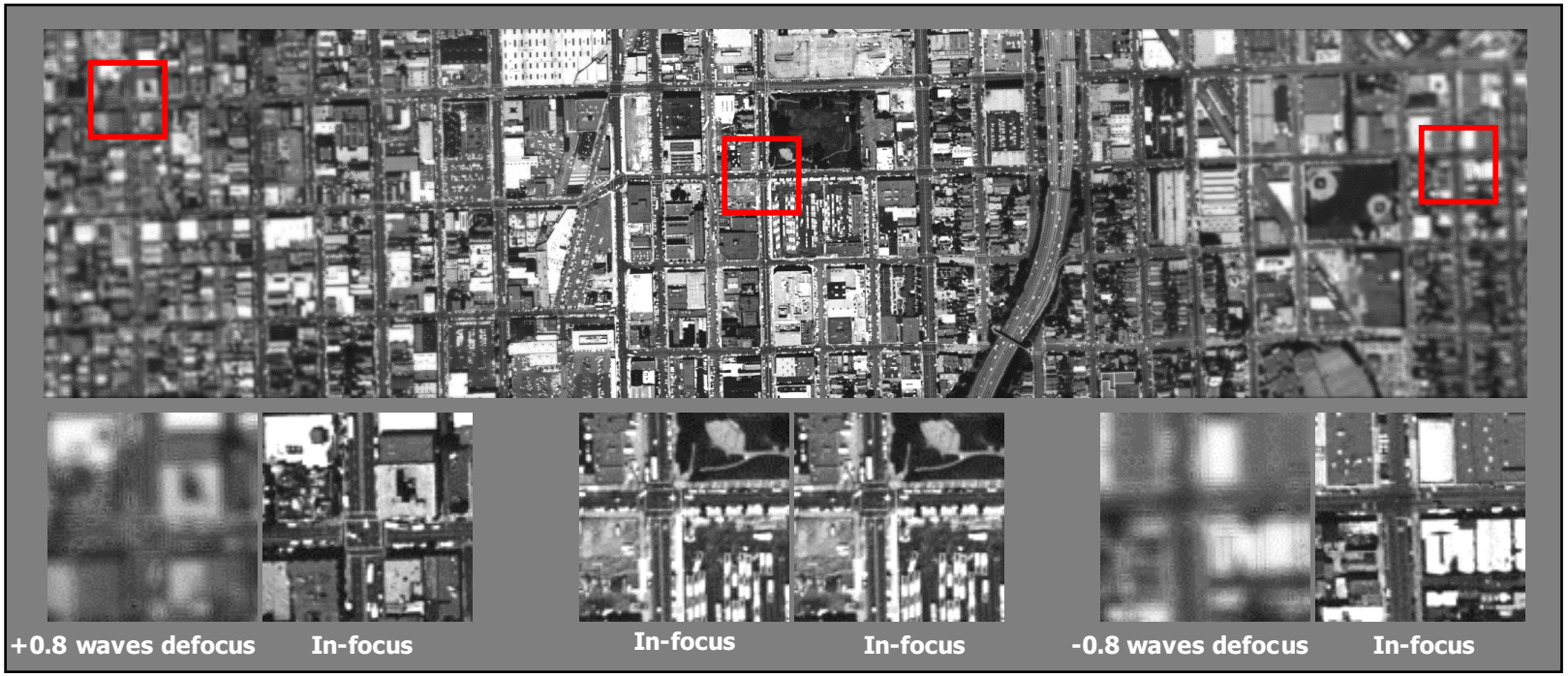
Focus Calibration

- **Focus calibration is performed to determine the best focus position of the secondary mirror of telescope.**
- **Methodology for Obtaining Best Focus**
  - Acquire a “through-focus” image by continuously changing focus during a scan by slewing secondary mirror.
  - Measure image sharpness by a digital edge detector throughout the “through-focus” image.
  - A polynomial curve is fitted to the edge detector metrics and the maximum determines the optimum focus (secondary mirror position).

Focus Calibration – “Through-focus” scan



-120 steps

+120 steps

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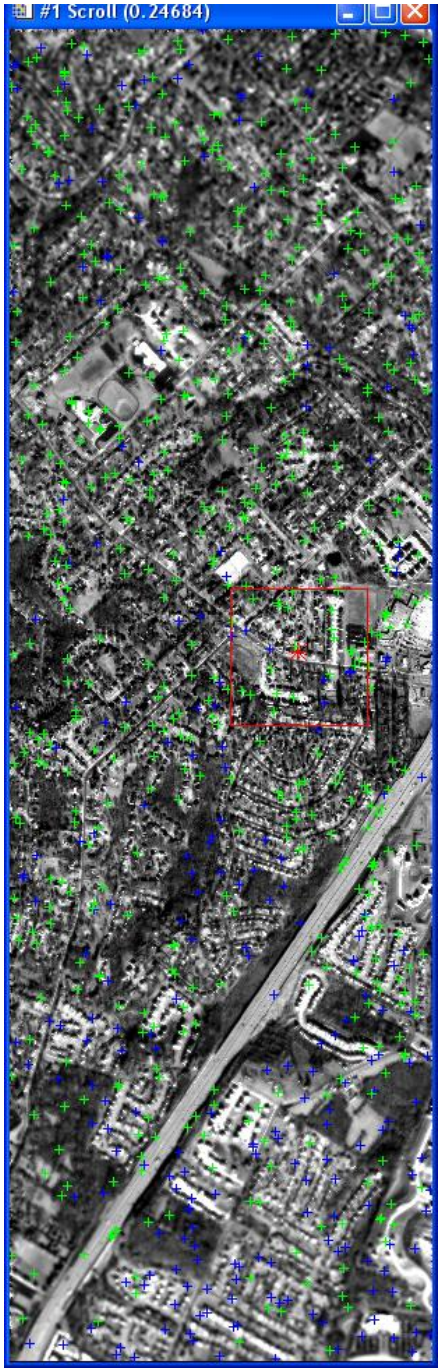
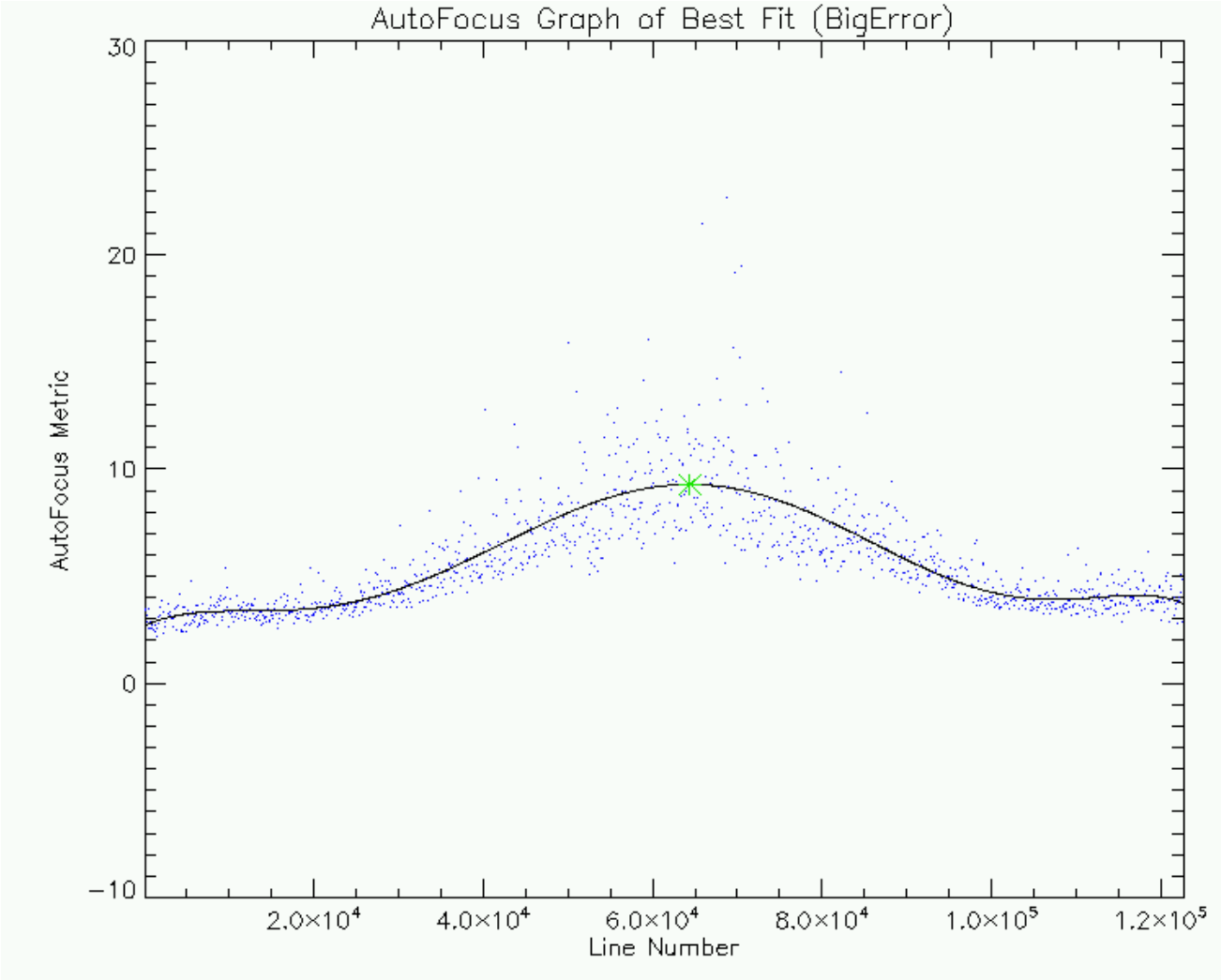


Automatic focus determination.



Summary

- **The GE-1 system continues to provide high quality imagery**
- **GE-1 remains in specification**
  - Radiometric
  - Geometric
  - MTF
  - SNR
- **Scans are continuously monitored to maintain high image quality.**

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Questions?

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Absolute Radiometric Calibration

- **Purpose: Determination of calibration coefficients to convert digital numbers (DN) to spectral radiance (mW/(cm²*str*μm)).**

$$L_{band} = Coef_{band} * DN_{band} + Offset_{band}$$ **(Note: offset = 0.)**

  - Coefficients vary according to camera setting.
    - Line rate, TDI, scan direction.
  - Coefficients contained in metadata delivered with image products.
- **Current coefficients are based on pre-launch measurements.**
  - Uncertainty ≤ 10% across 5-19% of saturation levels.
  - Uncertainty ≤ 5% across 20-90% of saturation levels.
- **On-orbit verification of absolute radiometric coefficients are performed by**
  - Analyzing responses from measuring radiometric stars – analysis underway
  - Measuring terrestrial target – analysis underway

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