# ECOSTRESS

## *ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station*

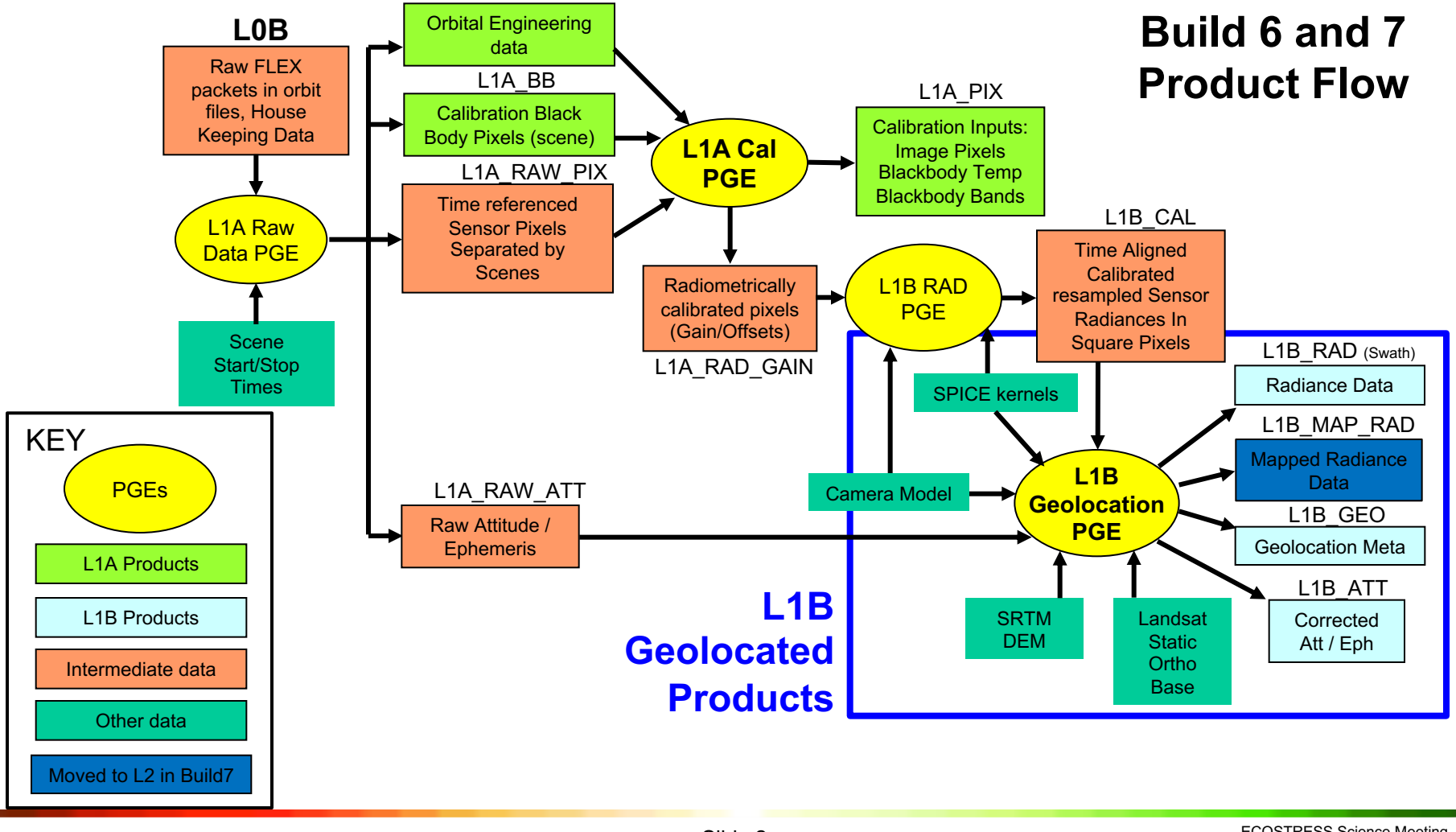
## L1 Calibration and Geolocation Review

Science Team Meeting
12APR2022

Thomas L. Logan, JPL
Michael M. Smyth, JPL
Jet Propulsion Laboratory, California Institute of Technology

© 2022 California Institute of Technology. Government sponsorship acknowledged.

# L1 Data Flow Diagram



## L1A Updates for Build 7

- A new “FieldOfViewObstruction” Flag is provided in the Standard Metadata.
  - “Yes/No” codes identify View Obstruction due to ISS Solar Panels.

- Two underperforming focal plane (FPA) pixels have been identified in the 10.5micron band.
  - They correspond to product scan Lines 1 and 110, repeating in 128 line intervals:
    - Lines 1, 129, 257, 385, 513, 641, etc.
    - Lines 110, 238, 366, 494, 622, 750, etc.
  - These scan lines are now marked as “Bad Data” code -9999.
    - Bad Data lines are not interpolated.
  - Users of Build 6 data should be aware of quality issues with these lines in L2 Products.

## L1B Updates for Build 7

- A variety of miscellaneous L1B Upgrades.
  - New Radiance gain/offset adjustment parameters have been implemented, and will be managed by the Science Team.
  - Added HDF5 product compression.
  - L1B_Map_RAD product has been moved to the L2 product line.

- Geolocation and Co-Registration Improvements:
  - New Expanded Co-Registration Metadata.
  - New Co-Registration improvements.

- Scan-to-Scan Segment Alignment Improvements are in development for Build 7.1

# L1B Geolocation

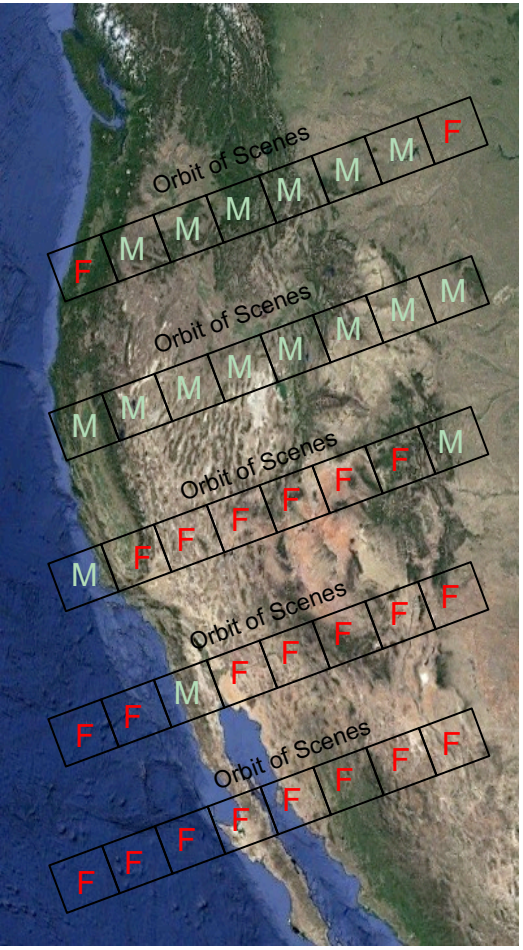
- Geolocation calculates the Latitude and Longitude of each image pixel.
- Latitude and Longitude are calculated from Spacecraft Attitude or Attitude corrected by an Orthobase (i.e., Earth Map Image).
  - ECOSTRESS does **not** have a Star Tracker for attitude/orientation correction.
  - ECOSTRESS extrapolates ephemeris/pointing/timing (BAD*) information from the ISS to the camera system on the JEM module and 1553 HK/Telemetry Data.
    - Errors include ISS altitude, pitch, yaw, roll, time, drift, and camera jitter.
    - Composited errors at the ECOSTRESS module are estimated as:
      - 2.5km error at 1-sigma**
      - 7.5km error at 3-sigma
  - Attitude correction is performed by co-registration/matching an ECOSTRESS image with a similar wavelength ortho-rectified Landsat map mosaic.
    - The ortho-mosaic map is based on Landsat7 imagery circa 2000.
    - The estimated positional accuracy of the map mosaic is 0.5-0.6 pixel (Pan).
- Pixel Latitude and Longitude coordinate files are passed to L2 processing.

* BAD: ISS Broadcast Ancillary Data
**Documented in: "Level-1B Resampling and Geolocation Algorithm Theoretical Basis Document (ATBD)," JPL D-94641

## Geolocation From Co-Registration

- Geolocation correction is only possible for scenes where image matching with the Orthobase can be performed.
- Automated Image Matching is performed by a grid of FFTs between the ECOSTRESS Scene and the Landsat Orthobase.
- Automated Image Matching may fail for a variety of reasons:
  - Image is over water/ocean.
  - Image is cloudy.
  - Image lacks ground features that can be matched
    - Fog; Poor Lighting; Non-Descript Terrain
- Images without Geolocation Matching use the available ISS positioning information which can be 2.5km to 7.5km from true geographic location.

# Orbital Geolocation from Scene Matching




Orbital Attitude Geolocation extrapolated from Matched Scenes

Every Scene Matched and contributes to orbital Attitude

Geolocation for Failed Scenes interpolated from Between Matched Scenes

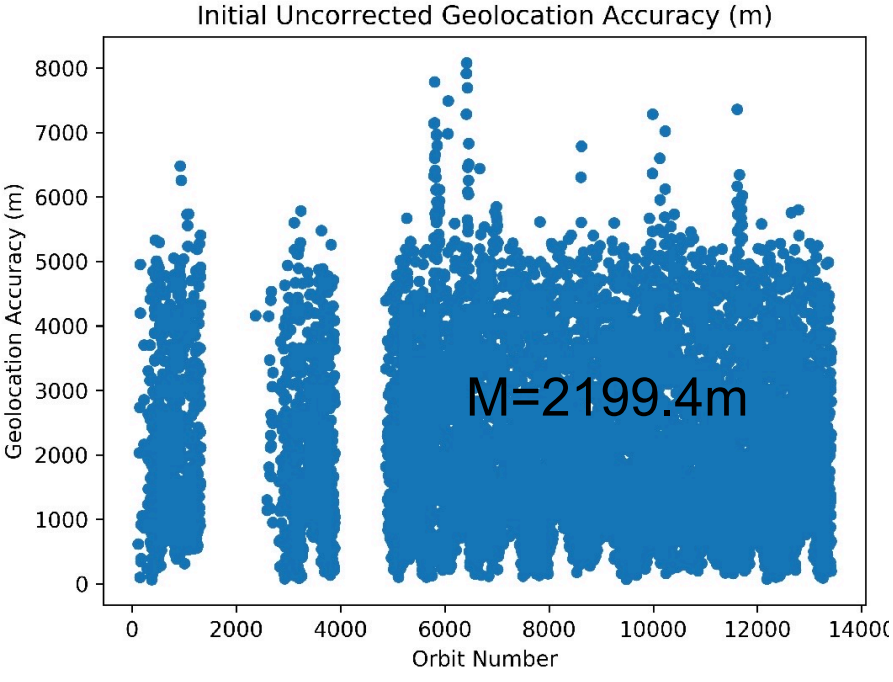
Orbital Attitude extrapolated from Single Matched Scene

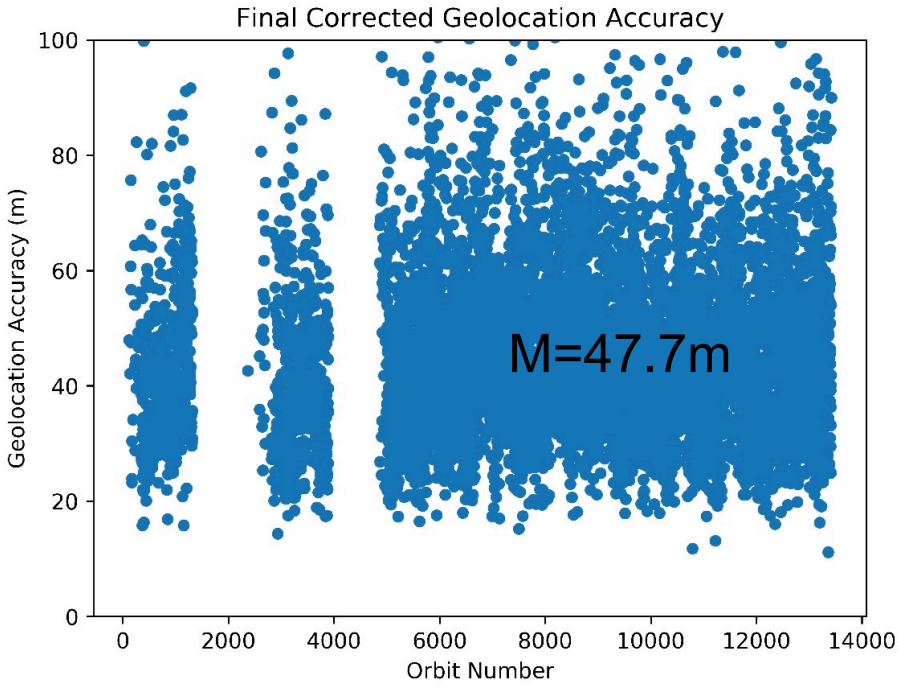
Geolocation Failed; Using ISS Attitude information

Matched Scene to orthobase
Failed Scene Matching due to Water, Clouds, Other

## Typical Orbital Error Correction

- Plots of Individual Scene Errors Before and After Geolocation Correction
  - Average 2.2 kilometer Error Reduces to 48 meters



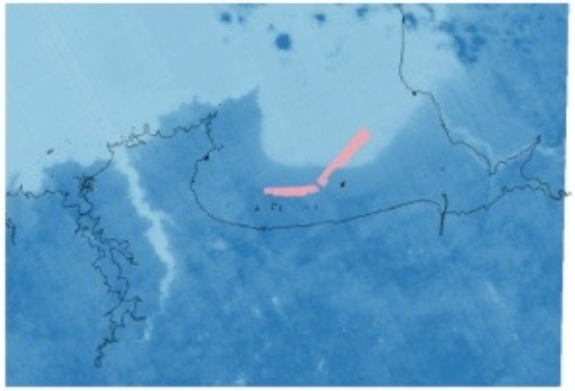




Data Statistics Compiled 17NOV2020

# Geolocation Issues

## User Test Case

- Early morning scenes can be difficult to register to the Landsat TIR orthobase because of variable overnight temperature cooling effects upon the local terrain. A few false starting matches (bad seed) can then produce mis-registration errors.

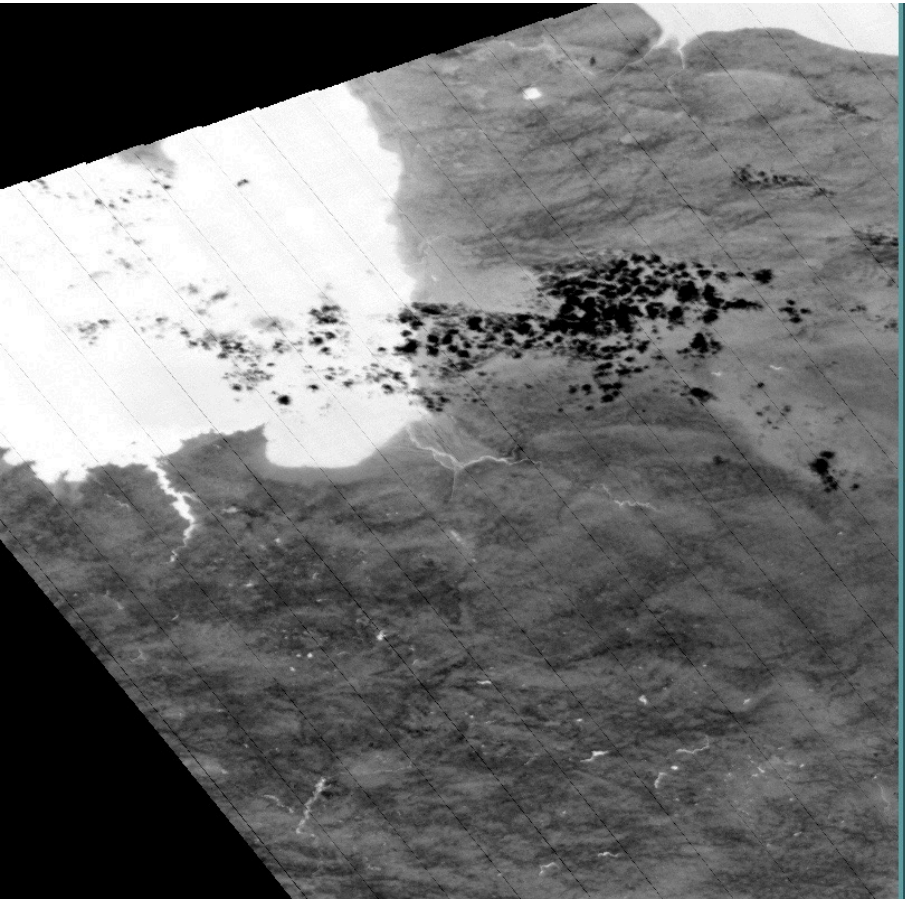


3798_001 No clouds **8.8 km error**
Build ID 0503
Orbit Correction TRUE

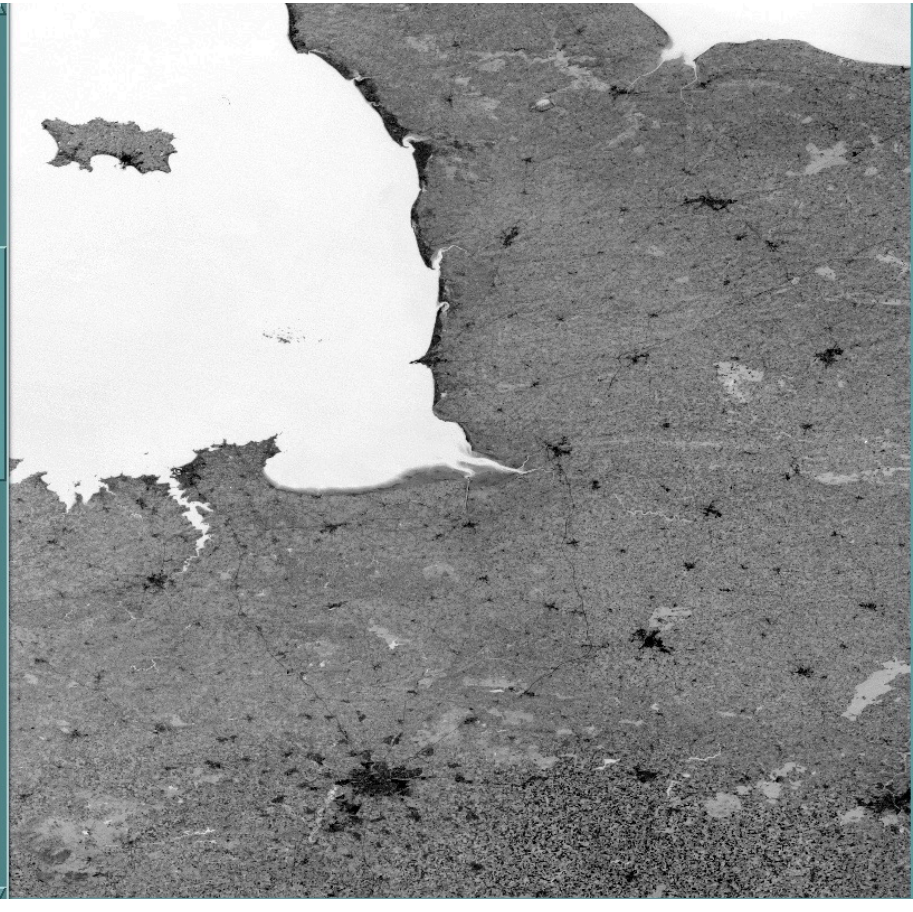
(User-Supplied Picture)

# Geolocation Issues

## Early Morning Scenes Look the Least Like the Orthobase



ECOSTRESS 03798_001 B4 Scene Detail



Landsat7 TIR Orthobase Detail (inverted)

## Build 7 Geolocation Improvements

- Improved Geolocation QA Metadata:
  - Build6 Geolocation QA is binary: Match / No Match in Orbit
    - /L1GEOMetadata/OrbitCorrectionPerformed="TRUE"
    - A single metadata value represented the entire orbit.
    - Value indicates if matching occurred somewhere in the orbit, or failed everywhere.
    - Does not provide information as to the quality of the match.
  - Build7 Provides a more descriptive QA flag:
    - Best – Image matching was performed for this scene, expect good geolocation accuracy.
    - Good – Image matching was performed on a nearby scene, and correction has been interpolated/extrapolated. Expect good geolocation accuracy.
    - Suspect – Matched somewhere in the orbit. Expect better geolocation than orbits w/o image matching, but may still have large errors.
    - No Match – No matches in the orbit. Expect largest geolocation errors.

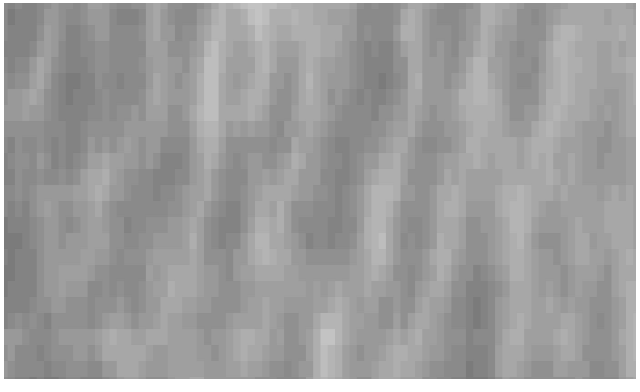
## Build7 Geolocation Improvements (cont.)

- Improved Co-Registration and Geolocation:
  - FFT (Fast Fourier Transforms) are used to create scene tiepoints.
  - On fail, Build7 will adjust specific FFT parameters and try again.
  - Up to **4 full-scene co-registration re-tries** are attempted.
  - Parameter modifications include:
    - Changing the initial spatial matching location (seed).
    - Increase/decrease the areal size of the FFT.
    - Increase least-squares tolerance.

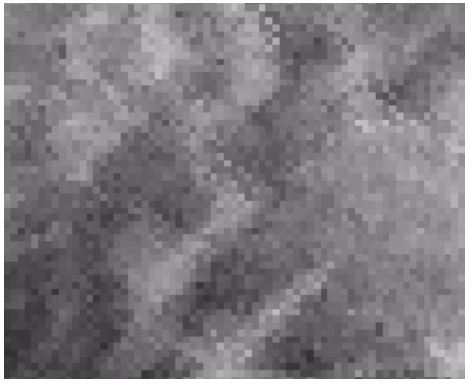
## Scan-to-Scan Alignment Calibration Issue

For Build 7.1

- A mis-alignment between adjacent Line Scan (segments) has been observed.
  - Each Scan Segment is 128 lines by 5400 samples and overlaps with it's adjacent segment by 15-30 lines depending upon ISS altitude.
  - The observed Offset appears to vary from 0 to 4 pixels, with larger offsets near the ends of the mirror scan.
  - The offset *may* be compounded in scan overlap areas by the L2 interpolation algorithm, manifesting as a "checkerboard" or blurring pattern.



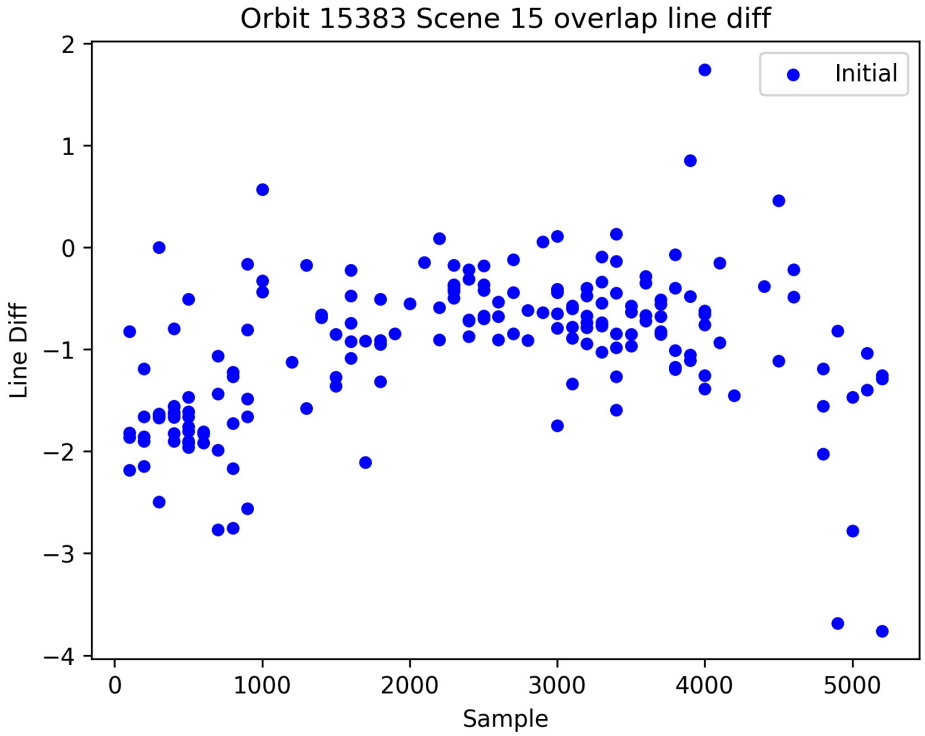
Scan Line Offsets in L1B Data



"Checkerboard" Pattern in L2/L3 Data

# Scan Line Offset Issue

## Observed Scan Alignment Offset




- Average line offsets appear to be about -1 pixel*
- Larger offsets appear to occur at the Beginning and Ending of the scan lines.

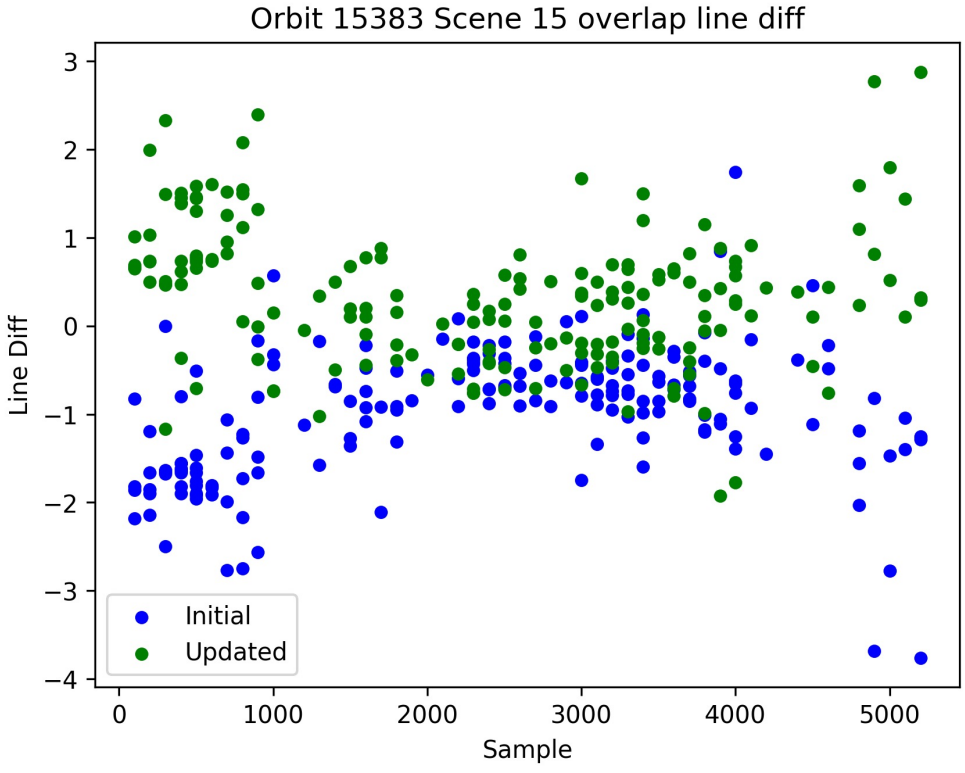
*Note: The very small 15x15 FFTs used to create this plot are prone to matching error, and probably overstate the actual error.

## Scan Alignment Correction Options

- Scan Segment calibration is a component of the mirror alignment.
  - The initial offset/fit was calculated during IOC (July 2018) and assumed to be constant.
  - Test-adjustments of this parameter did not resolve the offsets.
- Adjusting the Pointing Model (“R_camera_to_scan_mirror”) also did not explain the observed offsets.
- Another possibility is that the Center Boresight of the camera is slightly mis-aligned relative to the Mirror Axis.
  - We don’t have a tool for adjusting the Boresight, but we can approximate an adjustment by slightly moving the camera’s Principal Point.
- Testing Status:
  - An initial test of moving the Principal Point successfully improved the offset error to an average around 0 (zero) pixels.

# Scan Line Offset Issue

## Principal Point Adjustment Test




### Corrected Scan Segments

- Corrected line offsets appear to average about around 0 pixels* (Green).
- Slightly larger offsets still appear to occur at the Beginning and Ending of the scan lines.

*Note: The very small 15x15 FFTs used to create this plot are prone to matching error, and probably overstate the actual error.

## Scan Alignment Correction Plans

- Scan Segment Alignment Solution:
  - We propose to implement new code (not the Principal Point surrogate) that provides a parameter for adjusting the camera's center boresight relative to the scan mirror axis.
- Investigate and Mitigate the "Checkerboard" pattern:
  - We currently suspect the Scan Segment offset error is not a significant component of the observed Checkerboard pattern.
  - We propose to investigate the L2 tools used for merging data in the Scan Segment overlap areas.

# Backup

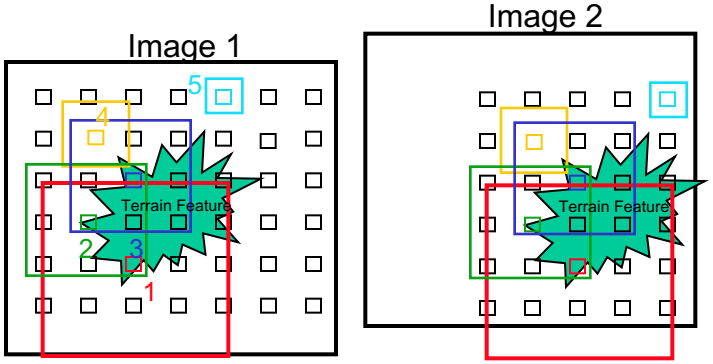
# AFIDS FFT Image Registration Process

## FFT Co-Registration Approach

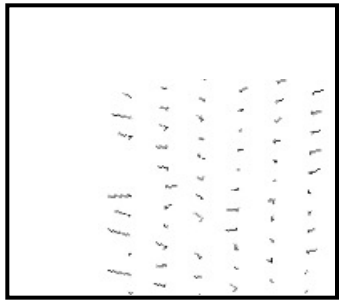
- AFIDS FFT Approach
  - Uses a grid of 2-D Fast Fourier Transforms (FFTs*) to produce tie points between images.
  - The FFT's Size initially starts out big (to cover large geographic areas) in order to catch the offset between two images, then reduces in size as the ability to predict the next tie point location improves.
  - A list of tie point matches with correlation and offset values is produced and processed to remove outliers.
  - The remaining best correlation points are used to create a polynomial fit between the two images and generate an ultra fine resolution correction grid.
  - A triangular interpolation between points in the correction grid is used to war/register the two images together.

*C.D. Kuglin and D.C. Hines, "The Phase Correlation Image Alignment Method," Proc. Int. Conference on Cybernetics & Society, pp. 163-165., 1975.

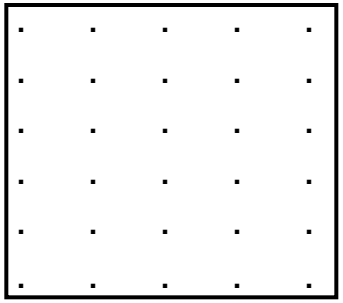
# AFIDS FFT Tiepoint Interpolation Approach



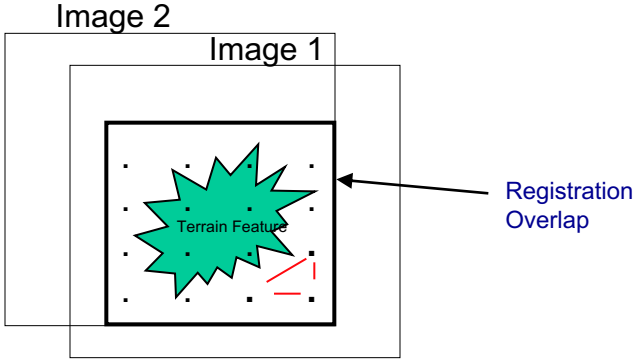

A grid of FFT tiepoints is used to match two images. FFT size starts large then decreases as matching becomes reliable. Tie point matching location order is randomly controlled by a "seed" value.



A subset of tiepoints are selected based on correlation score and offsets. Outliers are discarded. The maximum number of FFTs is 4096.



A polynomial fit is applied to the tiepoints to create an Ultra Fine grid of registration correction points. Fit options include Quad, Cubic, Linear, Keystone, and Thiessen.




A triangular interpolation is performed between points in the correction grid to produced the final registered image.