# Surface Biology and Geology (SBG)

## SBG TIR OTTER Level-1 Processing

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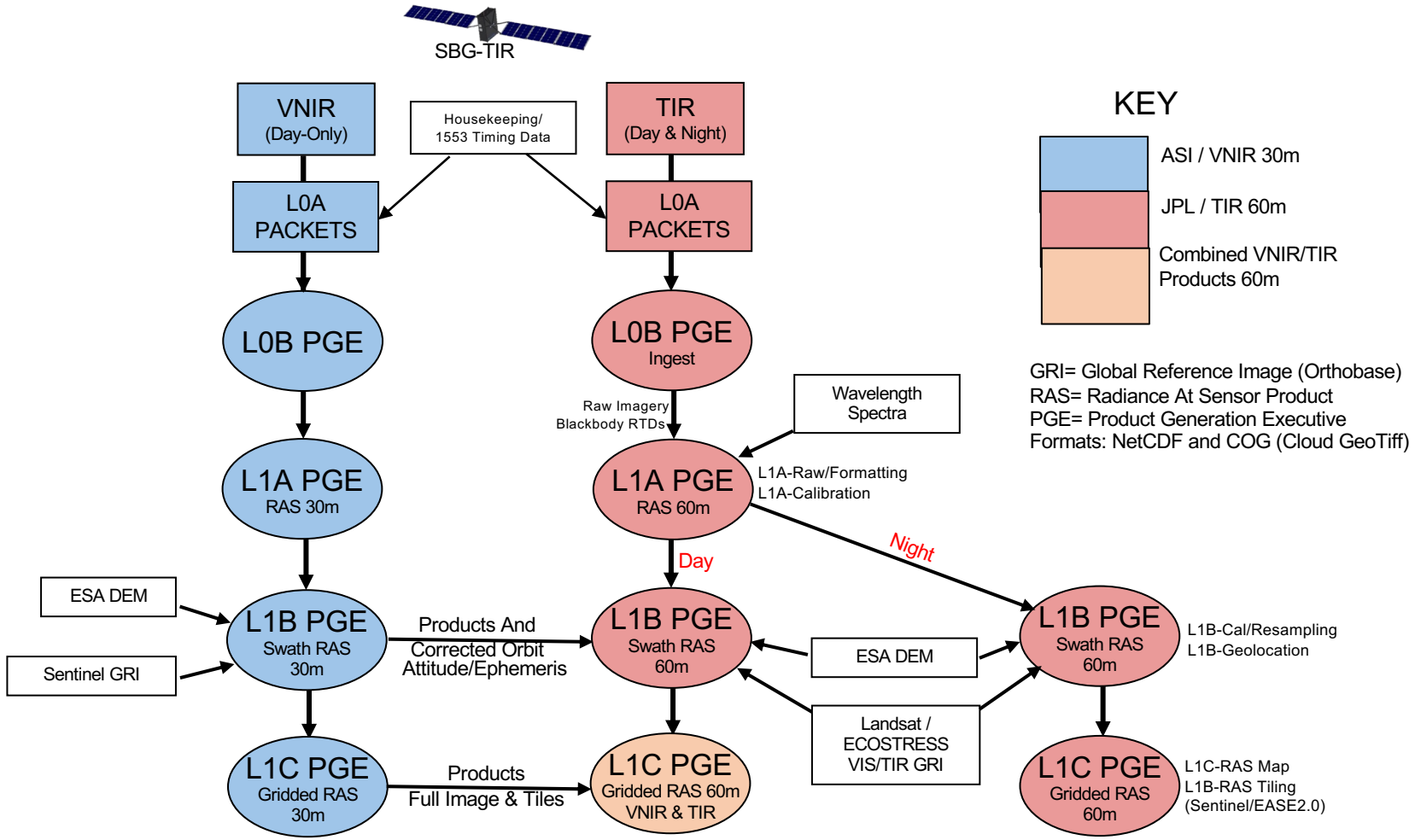
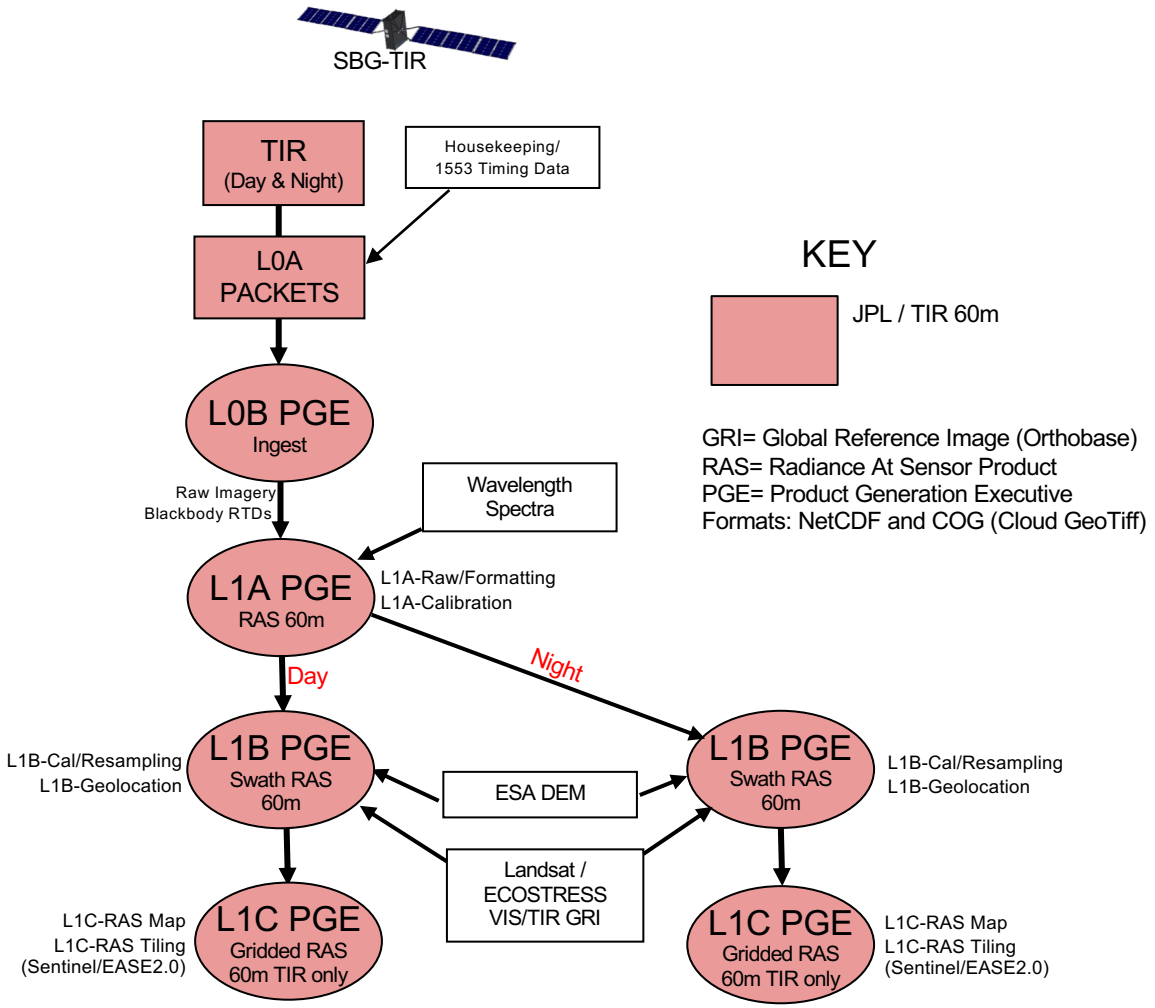
# OTTER Level 1 Overview

- L1 Purpose:
    - Calibrate raw TIR DNs to TOA Radiance
    - Geolocate/geotag TIR pixels and Map Project Radiance
    - Provide 60m/pixel GSD Products
        - Day time: With VNIR Bands and VNIR Geolocation
        - Night and Low Latency: TIR Only and TIR Geolocation
- Discussion Overview
    - Data Flow Diagrams
    - Product Descriptions
    - Radiometric Calibration
    - Geolocation Calibration

# OTTER Level 1 Day & Night Processing Flow



# OTTER Level 1 Low Latency Processing Flow



# Summary of Day/Night & Low Latency Products

- L1B TIR products (day/night/low latency) *do not* contain VNIR images.
- L1C Daytime TIR products *do* contain VNIR data, but not L1C Night or Low Latency products).
- L1B contains (and L1C inherits) orbital correction metadata from ASI for Standard Daytime products, but not for Night or Low Latency products.
- 60m TIR products use the Landsat TIR Orthobase/GRI for geolocation image matching. ASI 30-50m VNIR Daytime products use the Sentinel red-band GRI.

| Product | Coverage | Resol (m) | Joint | Level | Gridded | Requires TIR and VNIR | Day/Night | Format |
|---|---|---|---|---|---|---|---|---|
| **Standard Products** | | | | | | | | |
| L1B_RAD Radiance at Sensor | Global | 60 | N | L1B | N (Swath) | N | D and N | NetCDF |
| L1B Geolocation | Global | 60 | N | L1B | N (Swath) | N | D and N | NetCDF |
| L1C Radiance at sensor (rectified) | Global | 60 | Y | L1C | Y | Y | TIR: D and N<br>VNIR: D only | COG |
| **Low Latency Products** | | | | | | | | |
| L1B_RAD Radiance at Sensor | Global | 60 | N | L1B | N (Swath) | N | D and N | NetCDF |
| L1B Geolocation | Global | 60 | N | L1B | N (Swath) | N | D and N | NetCDF |
| L1C Radiance at Sensor (rectified) | Global | 60 | N | L1C | Y | N | TIR: D and N<br>VNIR: None | COG |

TIR Spectral Bands

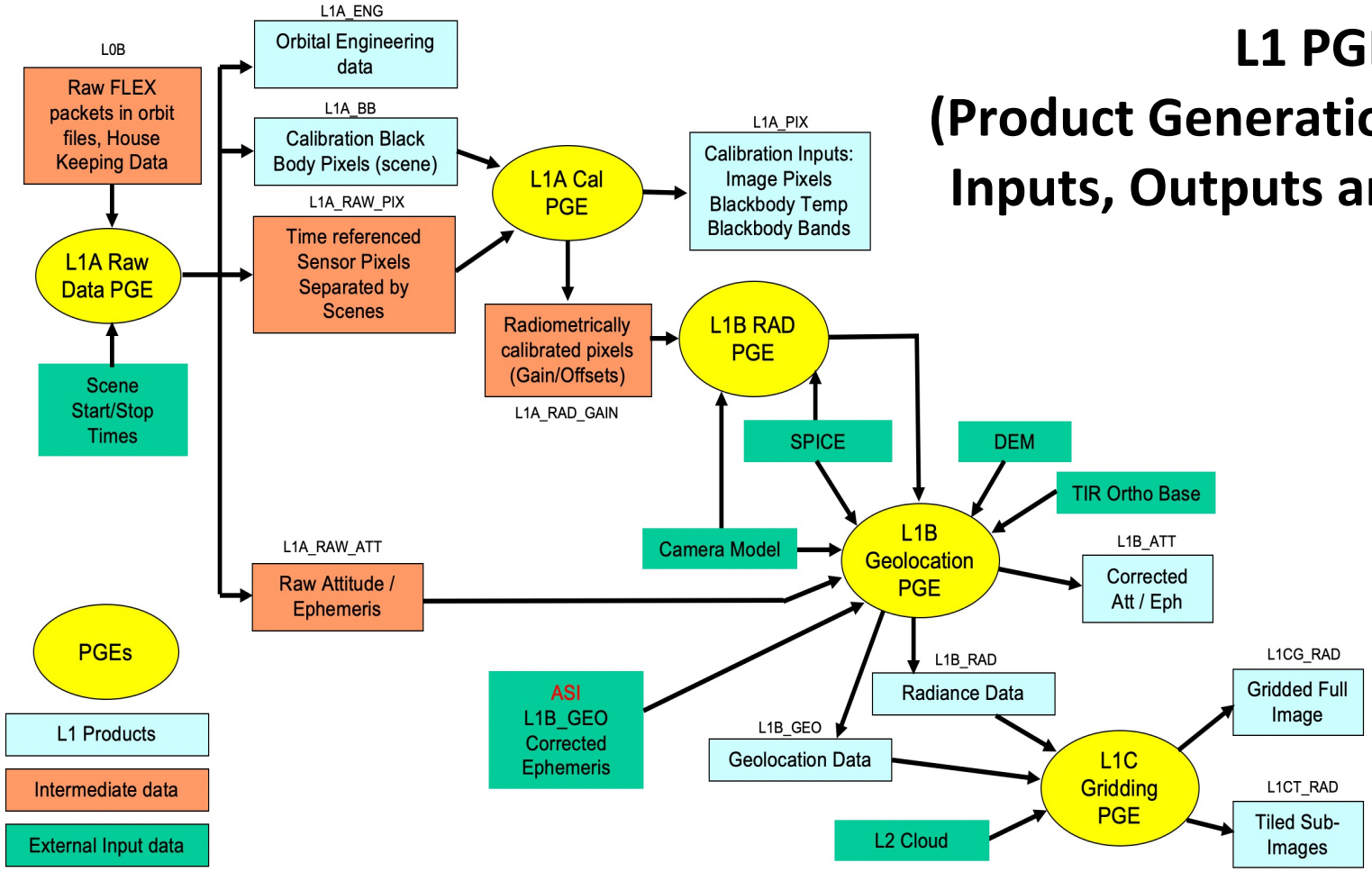
| Band Number | Center Wavelength (microns) | Bandwidth (microns) |
|---|---|---|
| 4 | 3.98 | 0.3 |
| 5 | 4.81 | 0.15 |
| 6 | 8.32 | 0.3 |
| 7 | 8.63 | 0.3 |
| 8 | 9.07 | 0.3 |
| 9 | 10.30 | 0.3 |
| 10 | 11.35 | 0.5 |
| 11 | 12.05 | 0.5 |

**Pixel GSD (Nadir):**
60 x 60m

**Earth Coverage Image:**
910 x 1060km

**Dynamic Range:**
14bit Integer

# L1 PGE Flow Diagram Detail



# L1 Inputs and Outputs

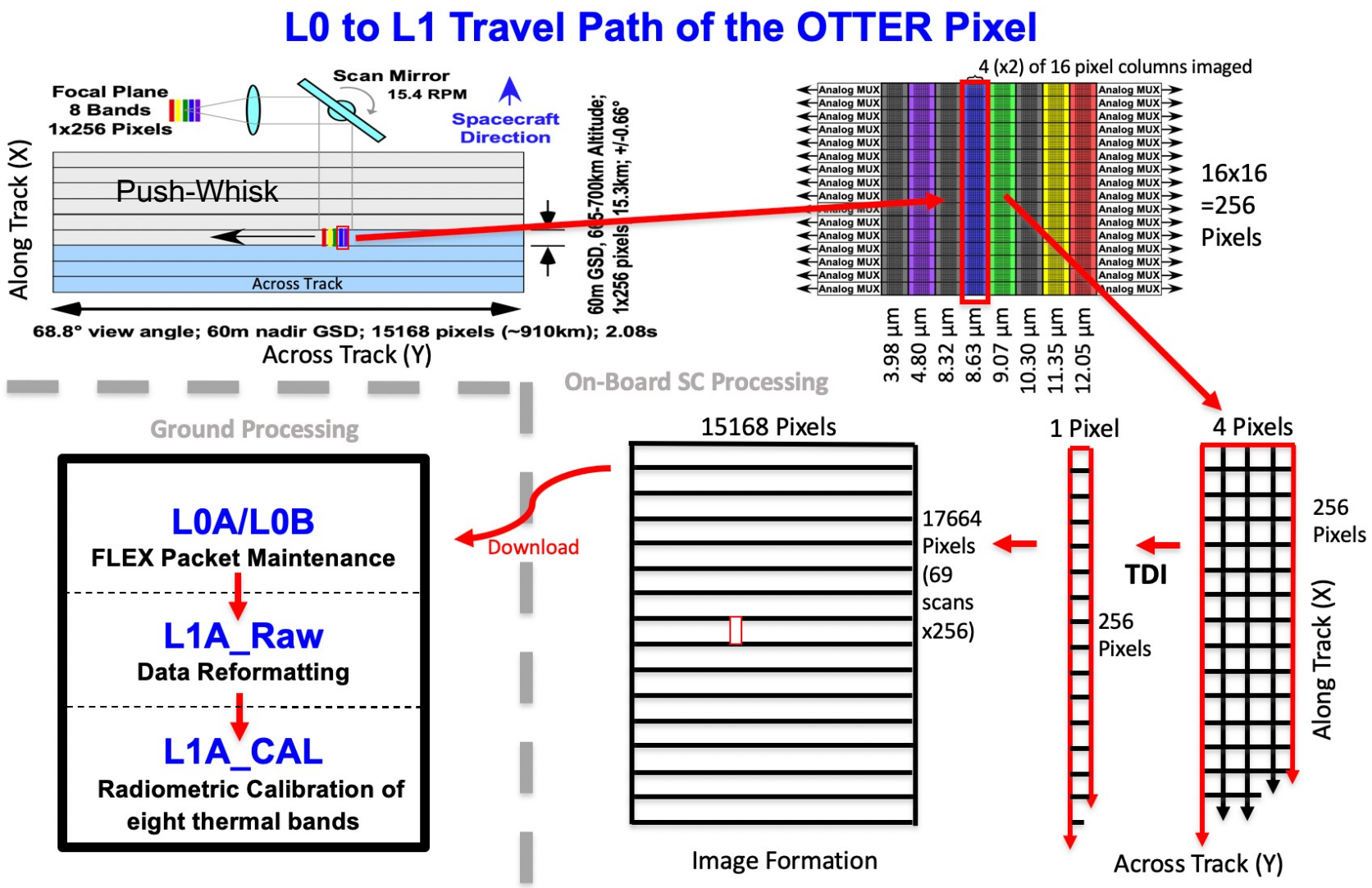
## Level 1 Required Inputs

| Product type | Description |
|---|---|
| TIR Platform Ephemeris and Attitude | -Platform Uncorrected (Day and Night)<br>-VNIR Corrected and Uncorrected (Day) |
| VNIR L1B | -Geolocated Radiance in Swath format (30-50m)<br>-3 TOA Bands plus Lat/long/Height files |
| VNIR L1C | -Geolocated Radiance in Gridded and Tiled formats (30-50m)<br>-3 TOA Bands |
| Copernicus DEM | -Copernicus GLO-30F global DEM (elevation) and LWM (ocean mask) |
| Sentinel GRI | -Sentinel Global Reference Image |
| Landsat7 TIR Orthobase | -Global brightness-corrected mosaic |
| TIR Band Wavelength Spectra | -Band Wavelength descriptions |
| NAIF/SPICE kernels | -ECI-to-ECR UTC conversions and leap-second adjustments |
| Camera Model | -FPA Description |
| Cloud Mask from L2 | -Gridded Level 2 cloud mask |

## Level 1 Intermediate and Distributable Products

| Product type | Description |
|---|---|
| L1A_ENG | Spacecraft orbital and instrument engineering data, including blackbody gradient coefficients and orbital timing |
| L1A_BB | Scene-specific instrument blackbody calibration pixels and timing |
| L1A_RAW_PIX | Scene-specific raw pixel spectral band data |
| L1A_PIX | Archive of all scene-specific inputs pre-processed as required for radiometric calibration, including raw pixel spectral band data, matching high/low blackbody pixels and temperature (Kelvin) values |
| L1A_RAW_ATT | Scene-specific raw attitude and ephemeris data |
| L1A_RAD_GAIN | Radiance gain and offset coefficients for each band |
| L1B_GEO | Swath image geolocation-tagged files, including latitude, longitude, height, sun angles, look angles, and related ancillary data. |
| L1B_RAD | Swath image radiometrically corrected radiance pixels, matched with L1B_GEO geolocation tags; 7-8 Radiance and data quality bands |
| L1B_ATT | Corrected spacecraft ephemeris and attitude data |
| L1CG_GRID | Gridded L1B radiance full image at 60m/pixel in lat/long projection; 7-8 Radiance and data quality bands |
| L1CT_TILE | Tiled L1B radiance imagery at 60m/pixel according to Sentinel UTM grid/tiling system; 7-8 Radiance and data quality bands |

# Sensor-to-Image Pixel Travel Path



# L1A Radiometric Calibration

## L1A Radiometric Calibration Steps

- Purpose: Convert TIR Image DNs to TOA Radiance.
  - Procedure for each pixel scan:
    - Read temperatures from Sensor's Cold (278K) and Hot (328K) Blackbodies.
    - Create synthetic FPA temperature images of Cold and Hot Blackbodies and convert them to Radiance (Watt/m2/sr/um) using the center wavelength of each TIR band and the Planck function.
    - Collect Push-Whisk FPA Digital Number (DN) scans of the Cold and Hot Blackbodies and Ground for all wavelengths.
    - Using the FPA Radiance values and corresponding FPA DNs, use a **two-point affine** transformation (creating gain/offset coefficients) to convert each Ground pixel's DN to Radiance.

- Accuracy should be much better than <1.0 Kelvin. The Science Team can also choose between two Planck algorithms and linearly fine tune each TIR band radiance.

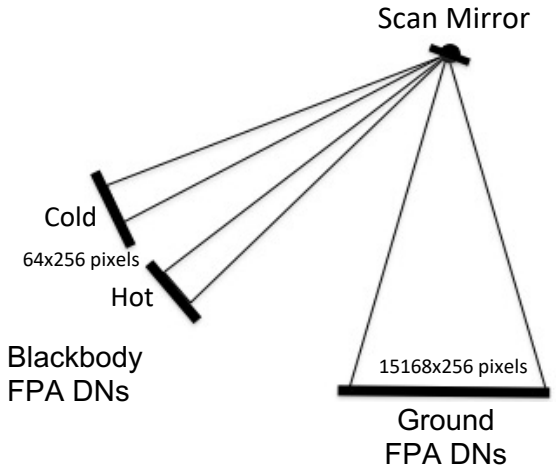
- TOA Radiance and Temperature images can be generated for Validation and Verification purposes as appropriate.

# L1A Two-Point Calibration

## L1A Radiometric Two-Point Calibration

**Approach**

- Read BB Temperatures.
- Create synthetic FPA 256x1 Blackbody Temperature Images.
- Convert FPA BB Images to Radiances using Planck Function.
- Collect FPA Blackbody and Ground DNs.
- Apply 2pt Algorithm →




*Two-Point Calibration Formula*

$$R_\lambda = a + bD_\lambda$$

$$a = \frac{R_h D_c - R_c D_h}{D_c - D_h} \qquad b = \frac{R_c - R_h}{D_c - D_h}$$

*Where:*

$R$ = *Calculated Radiance of an input Digital Number (DN)*

$a$ = *Offset Term*

$b$ = *Gain Term*

$D$ = *Input Earth Digital Number (DN)*

$R_c$ = *Radiance of the Cold Blackbody*

$R_h$ = *Radiance of the Hot Blackbody*

$D_c$ = *Digital Number (DN) from the Cold Blackbody Calibration File*

$D_h$ = *Digital Number (DN) from the Hot Blackbody Calibration File*

# L1B Geolocation Calibration – Day Time

## L1B Geolocation (Day)

- Purpose: Calculate the Latitude and Longitude of each image pixel.
  - Latitude and Longitude are calculated from Spacecraft Ephemeris/Attitude alone, or Ephemeris/Attitude corrected by an Orthobase/GRI (i.e., Earth Map Image).
- L1B Standard Daytime Approach
  - Use Corrected VNIR/Platform Ephemeris/Attitude from ASI.
    - "Corrected" by ASI using Sentinel GRI and Copernicus DEM.
    - VNIR 30m/50m bands are aligned.
    - Provided as Euler Angles or Quaternions.
  - Align TIR bands
    - Convert DN to radiance (using L1A-supplied coefficients) for easier band matching.
    - Correct individual band offsets to the middle band.
  - Camera Model is used with TIR pointing model to generate Lat/Lon positions for alignment with VNIR.
  - Latitude and Longitude coordinates are extracted for each pixel and supplied with the L1B swath product as metadata.
  - Calculate Solar Angles, View Angles, and Range metadata per pixel.

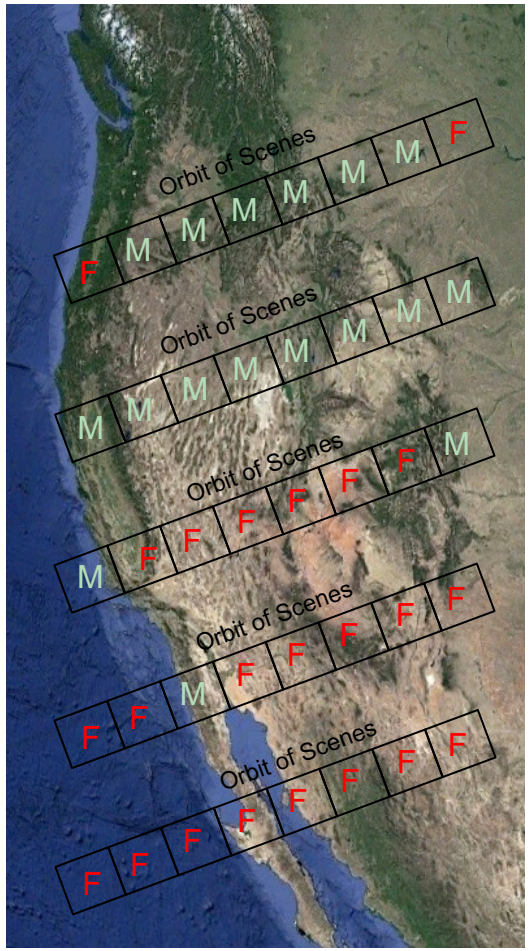
# L1B Geolocation Calibration – Nighttime

## L1B Geolocation (Night/LL)

- L1B Night time and Low Latency Approach
  - Use Un-Corrected Platform Ephemeris/Attitude from ASI.
  - Camera Model (for each band) is used with TIR pointing model to generate Lat/Lon positions.
    - Un-corrected Geolocation accuracy is ~120m.
  - Tiepoint/match Orbital Swath with TIR Orthobase.
    - Convert DN to radiance (using L1A-supplied coefficients) for easier image matching.
    - Correct individual band offsets to the middle band.
    - Create intermediate gridded orbital swath for tiepoint matching.
    - Tiepoints are collected across the entire orbit to improve geolocation by Simultaneous Bundle Adjustment (SBA).
    - Individual scene quaternions are extrapolated from the orbital quaternions.
      - Cloud/water-covered scenes can be geolocated if tiepoints are found in adjacent scenes. See next slide.
      - Corrected Geolocation accuracy should be better than 57m 1-sigma.
  - Latitude and Longitude coordinates are extracted for each pixel and supplied with the L1B swath product as metadata.
  - Calculate Solar Angles, View Angles, and Range metadata per pixel.

# Orbital Scene Matching

## Scene Geolocation from Orbital Matching




Entire Orbital Attitude Geolocation extrapolated from Matched Scenes.

Every Scene Matched and contributes to Orbital Attitude.

Orbital Attitude for Failed Scenes interpolated from Between Matched Scenes.

Entire Orbital Attitude extrapolated from Single Matched Scene.

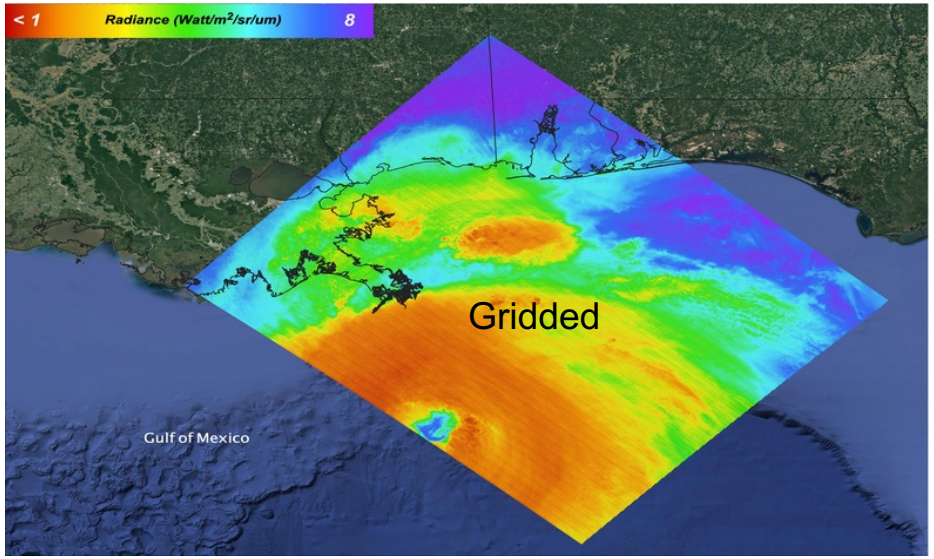
Geolocation Failed; Using Uncorrected Ephemeris/Attitude information.

Matched Scene from orthobase contributes to corrected ephemeris.
Failed Scene Matching due to Water, Clouds, Poor Terrain Definition, etc.

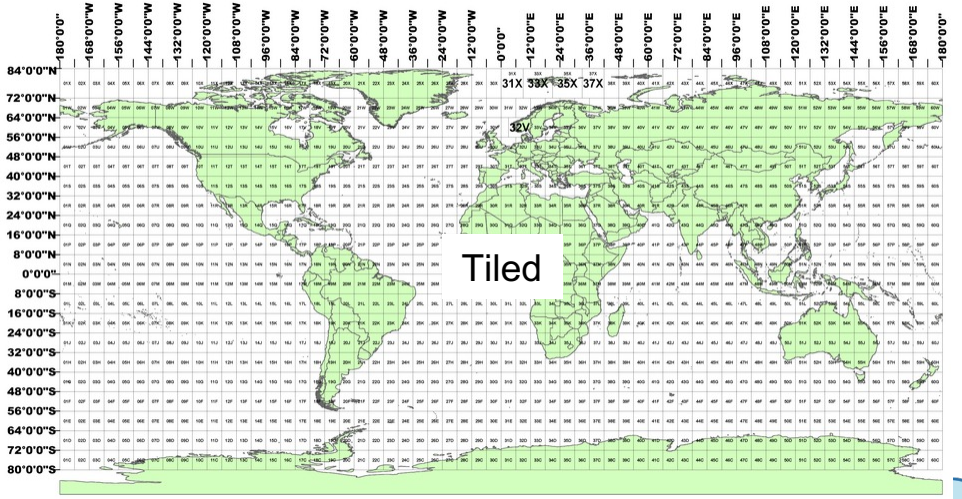
# L1C Gridding and Tiling

## L1C Geolocation

- L1C Gridded TOA Radiance at 60m/pixel.
  - TIR L1B swath pixels are resampled to a fixed (gridded) resolution of 60m/pixel.
  - VNIR bands are resampled to 60m/pixel from the ASI-provided L1C 30-50m products.
  - L1 provides the only OTTER full scene gridded products (all other L2+ products are tiled).




- L1C Tiled TOA Radiance at 60m/pixel.
  - Using the Sentinel UTM Tiling Grid.
    - Based on a slightly modified version of the Military Grid Reference System (MGRS).
    - Grid tiles are 109.8km x 109.8km.
    - 60 UTM zones overlap tiles with adjacent zones.
    - No Polar tiling.



# Level 1 Products Flow to Level 2+

**Level 1 Products Provide the Foundation for Level 2+ Processing**