Landsat 8 TIRS and OLI

highlight shows info to be input into instrument specs json file

Landsat8 TIRS

[1] Reference: The Thermal Infrared Sensor (TIRS) on Landsat 8: Design Overview and Pre-Launch Characterization

- Launch 11 Feb 2013
- Side slither mode, where FOV is rotated 90 deg!
- Simultaneous imaging with OLI, except at night
- 185 km swath width, 1850 pixels on each row of a channel
- 708 km altitude, 185 km swath gives 15 deg cross-track fov
- ifov per detector is 15/1850 deg ~ 141 urad
- pushbroom scanning first time in Landsat
- 100 m resolution => allows for less number of cross-track detectors
- **2-channel,** thermal imager
- focal-plane consists of **three** quantum well infrared photodetector arrays (QWIP) arrays. Segmented filter on array to provide spectral bandpass.
- 7 km/s ground speed, 0.014s to move 100m, 70 frames taken each second for each channel. Say 1 frame every 0.014s => 1/0.014 ~ 70 frames in 1 second, hence frame-rate of 70 fps
- *"TIRS uses a 3.49-millisecond integration time, and the resultant 25-m image motion"*, note that 3.49 ms corresponds to 25 m movement in along-track direction 0.014 / 3.49e-3 = 4.
- 3.49 millisecond integration time,
- ~~3.49 millisecond integration time, means along-track fov must be 7 km/s x 3.49 ms / 708 km = 34.50565 u rad~~
- 12 bit digitization to produce temperature measurements in range 240Kto 360K
- 25 um x 25 um detectors
- QE < 1% (**Phil:** This is of detector only, detector plus multiplier is higher)

- 3, 640 x 512 arrays arranged in staggered fashion. 640 x 3 columns is reduced to 1850 columns due to overlap in the staggered arrangement.
- See focal-plane layout in reference
- In each of the 70 samples produced per second, 6 rows read out from each array (2 illuminated rows under ***each*** filter, and 2 dark rows)
- f/1.64, 178 mm focal length TIRS telescope

[2] Reference: https://earth.esa.int/web/eoportal/satellite-missions/l/landsat-8-ldcm

- 10.8 um (10.3 - 11.3) um band. 12.0 um (11.5, 12.5) um band
- Mass: 236 kg, 80cm x 76 cm x 43 cm, 380 W
- pixel size 25 um,
- ifov = 142 urad
- f-number = /1.64
- 12 bit quantization
- 4-element refractive lens system, pooled to 185 K
- focal-lane consists of 3, 640 x 512 QWIP GaAs arrays.
- see focal-plane layout diagram in reference
- Although each array consists of 512 rows, only 32 rows are available under each band. They are separated by 76 rows of occluded pixels. OF the eligible rows (per filter band), atleast two-perfect rows must be present or three rows which can be combined to give two perfect rows. Perfect rows meeting the TRL requirements.
- In-track fov < 5.4 deg
- 12 bit quantization

[3] Reference: NASA NTRS Landsat and Thermal Infrared Imaging

- In which rows of detectors for each channel are swept in the along-track direction by spacecraft motion. For each channel, an image is built-up by concatenating successive single-row measurements.
- TIRS has 100 m spatial resolution
- 185 km swath width of TIRS, 1850 pixels are required for each row in each channel. At a ground speed of 7 km/sec, it requires approximately 0.014 seconds

to move 100 meters and 70 effective rows of pixels are produced in each second for each channel. TIRS uses a 3.4 millisecond integration time and the resultant 25 meter image motion, when convolved with the instrument spatial function, does not excessively broaden the spatial resolution.

- 12-bit digitized output data
- In each of the 70 samples produced per second, six rows are read out from each hybrid: two illuminated rows from the unvignetted region under each filter (four rows altogether) and two dark rows from an area on the hybrid that is far removed
- Capturing two rows from each infrared channel on each hybrid allows the ground processing software to combine the two rows into a single “effective” 1850-pixel row that has no inoperable pixels and covers the entire 185-km swath.

Determined TIRS specs (highlight are “guessed-values”):

```
{"@type": "Passive Optical Scanner",
    "name": "Landsat 8 TIRS Band1",
    "mass": 236,
    "volume": 0.261,
    "power": 380,
    "fieldOfView": {
        "sensorGeometry": "RECTANGULAR",
        "alongTrackFieldOfView": 0.0081,
        "crossTrackFieldOfView": 15
    },
    "scanTechnique": "PUSHBROOM",
    "orientation": {
        "convention": "SIDE_LOOK",
        "sideLookAngle": 0
    },
    "dataRate":  384,
    "numberOfDetectorsRowsAlongTrack": 1,
    "numberOfDetectorsColsCrossTrack": 1850,
```

```
    "detectorWidth": 25e-6,
    "focalLength": 0.178,
    "operatingWavelength": 10.9e-6,
    "bandwidth": 0.6e-6,
    "quantumEff": 0.025,
    "targetBlackBodyTemp": 290,
    "bitsPerPixel": 12,
    "opticsSysEff": 0.60 ,
    "numOfReadOutE":  20,
    "apertureDia":  0.1085366,
    "Fnum":  1.64,
    "maxDetectorExposureTime": 3.49e-3,
    "snrThreshold":  25,
    "_comments": "Above is Total payload data-rate not just of
f the TIRS.
                 numReadOutE and snrThreshold are guessed."
}
```

Landsat 8 OLI

[1] Reference: R. Morfitt et al., “Landsat-8 Operational Land Imager (OLI) Radiometric Performance On-Orbit,” Remote Sensing, vol. 7, no. 2, pp. 2208–2237, Feb. 2015.

- 69,160 detectors (previous Landsats had 136 detectors, whiskbrrom)
- 9 spectral bands, from Blue to SWIR
- 14 FPMs in staggered pattern, each FPM 494 detectors per band

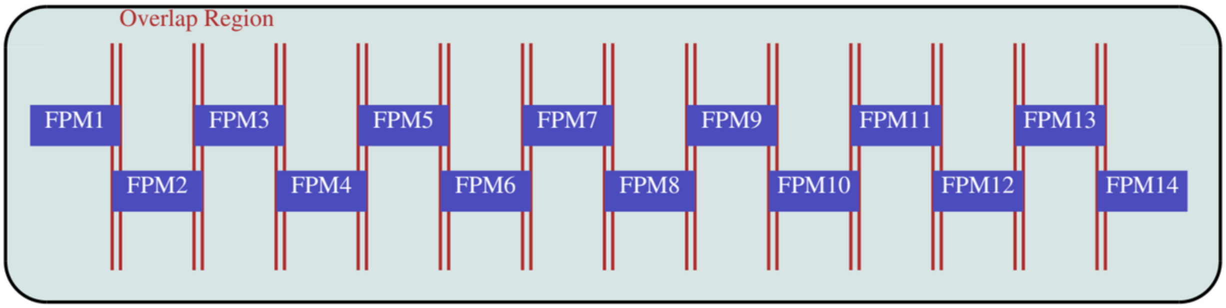

Figure 1. Operational Land Imager focal plane layout.

- 14 bits radiometric prevision acquisition, 12 bits transmitted to ground
- For blue band Ltypical is 40, Lhigh is 190
- “side slither” mode (yawed 90 deg) for calibration

[2] Reference: https://earth.esa.int/web/eoportal/satellite-missions/l/landsat-8-ldcm

- longer detector dwell time (~4 ms for OLI vs. 9.6 μs for ETM+),

[3] Reference: E. Knight and G. Kvaran, “Landsat-8 Operational Land Imager Design, Characterization and Performance,” Remote Sensing, vol. 6, no. 11, pp. 10286–10305, Oct. 2014.

- Each multispectral band has 494 detectors per module, with the PAN band having twice as many. Each detector is also redundant. One of two detectors can be selected for readout for the silicon bands (1–5, 8), and one of three detectors can be selected for the HgCdTe bands (6–7, 9).
- Focal plane integration time commandable from 90us to 3600us
- The telescope is a front-aperture four mirror anastigmat design with an effective focal length of 886 mm at the center of the field of view (FOV).
- The focal plane array consists of fourteen individual focal plane modules aligned in a staggered line, so that they overlap each other. Each module consists of nine rows of detectors with individual spectral filters over them for spectral band separation and a tenth masked row for looking at the offset behavior of the HgCdTe bands.

-

Determined OLI specs (Blue band) (highlight are "guessed-values"):

- number of detectors in cross-track = 5/(42.6e-6*180/pi) = 6146
- Effective Focal length: 36e-6/42.6e-6 = 0.8451 (against the 886mm in reference)
- Aperture diameter = 0.8451/6.4 = 0.1320


```
{"@type": "Passive Optical Scanner",
    "name": "Landsat 8 OLI Blue band",
    "mass": 1,
    "volume": 1,
    "power": 1,
    "fieldOfView": {
        "sensorGeometry": "RECTANGULAR",
        "alongTrackFieldOfView": 0.00244080020725731,
        "crossTrackFieldOfView": 15
    },
    "scanTechnique": "PUSHBROOM",
    "orientation": {
        "convention": "SIDE_LOOK",
        "sideLookAngle": 0
    },
    "dataRate":  384,
    "numberOfDetectorsRowsAlongTrack": 1,
    "numberOfDetectorsColsCrossTrack": 6146,
    "detectorWidth": 36e-6,
    "focalLength": 845.1e-3,
    "operatingWavelength": 482e-9,
    "bandwidth": 65e-9,
```

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    "quantumEff": 0.9,
    "targetBlackBodyTemp": 290,
    "bitsPerPixel": 12,
    "opticsSysEff": 0.90 ,
    "numOfReadOutE":  20,
    "apertureDia": 0.1320,
    "Fnum":  6.4,
    "maxDetectorExposureTime": 3.6e-3,
    "snrThreshold":  25,
    "_comments": "Above is Total payload data-rate not just of
f the TIRS.
                 mass, power and volume are simply wrong.
                 numReadOutE and snrThreshold are guessed."
}
```

Others Links:

https://landsat.usgs.gov/solar-illumination-and-sensor-viewing-angle-coefficient-file

Email from Phil Dabney on Landsat 8

From: Dabney, Philip W. (GSFC-6180) <philip.w.dabney@nasa.gov>
Sent: Friday, April 19, 2019 1:16 PM
To: Verville, Jonathan P. (GSFC-5850) <jonathan.p.verville@nasa.gov>
Cc: Masek, Jeffrey G. (GSFC-6180) <jeffrey.g.masek@nasa.gov>
Subject: Landsat 8/9 parameters for TAT-C and a new and different orbital coverage analysis for SLI Inter-satellite calibration

Good afternoon Jonathan and Vinay,

(Jonathan, please forward a copy to Vinay. I cannot locate his email address.)

I was going to wait until Monday afternoon's TAT-C meeting to talk about these 2 items, but we think it is best to get started and to let you consider what you need next.

Landsat-8 Parameters:

I was informed that you were looking for the Landsat 8/9 imager parameters for the TAT-C observatory/instrument characteristics.   I was surprised because in the first versions of TAT-C we tested it using Landsat's parameters and the initialization file used to start up with these parameters as the default or example.

But I am sure in the major redesign and changing of the guards, this aspect did not get conveyed well and perhaps got lost in the initialization parameter files. So here it goes:

There were four specific parameters they were looking for:

- Along-track FOV (instantaneous view angle) for OLI and TIRS

·   Both OLI and TIRS are push broom instruments whose focal planes are arranged in a staggered array of detector arrays. To accommodate this the telescopes have to prove and un-vignetted near diffraction limited in-track FOV of ~3-4 degrees.   The active pixel within a spectral band is much smaller than that.

·   The instantaneous IFOV of a single pixel in the pushbroom "linear" array are:

o   OLI Multi-spectral bands :   42.6 micro-radians   (30/705E3)

o   TIRS: 142 micro-radians   (100/705E3)

o

- The "lens specifications" for OLI. When I told him OLI was reflective, he asked if the "equivalent refractive" lens specs could be given.
  - OLI: f/6.4 (FMA – four mirror anastigmatic)   Effl: 0.85 m   (36E-6 * 705E3/30) 36 micron detector pitch
  - TIRS: f/1.6 (refractive)   Effl: 0.176 m   (25E-6 * 705E3/100) 25 micron detector pitch
- Detector efficiencies for OLI and TIRS. He found a reference quoting 1% overall efficiency (aperture to read out?) for TIRS.
  - Do you mean including optical losses/efficiencies or only the detector QE or CE (conversion efficiency). If you want the effective conversion efficiency of

the system we will need to convert it from the calibration coefficients and the knowledge of the focal plane electronics gain.
  - The number I can get you easily is the DN/L.lambda   or digital counts per unit of spectral radiance at aperture.
  - The QWIP is somewhat of an electron amplification device so the QE (conversion to the initial photoelectron is very low) but then the photo-electron is multiplied in the detector gain. The conversion of the photon to electrons collecting in the ROIC is called the conversion efficiency by the ones who created it.
  - Array detectors only:

§ OLI: >90% VNIR and >85% SWIR

§ TIRS CE: ~2.5%

- Overall system losses

This is somewhat coupled to the Overall aperture photons to digital counts implied above.

Depends on where you want the loss calculated from and to. Photons leaving the ground to photons arriving at the associated detector element on the array?

If you are only talking about optical transmission and throughput in the middle of the passbands, then they are approximately:

§ OLI: 90%

§ TIRS: 60%