JPSS-1 VIIRS
at-launch geometric performance

NASA VIIRS Characterization Support Team (VCST)
Geometric Calibration Group

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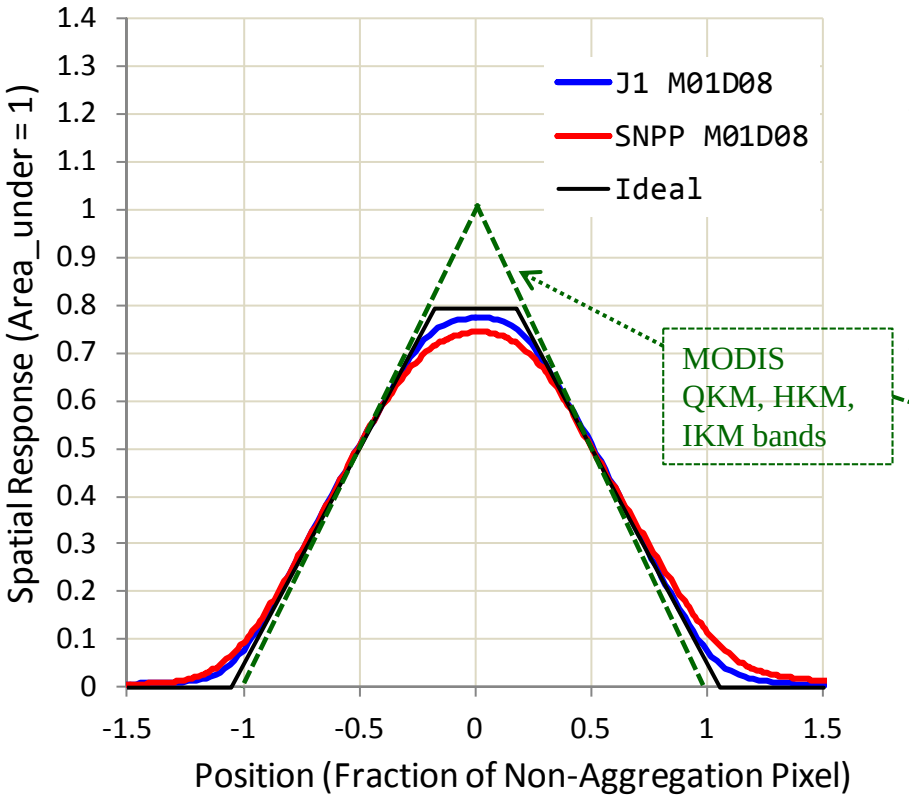
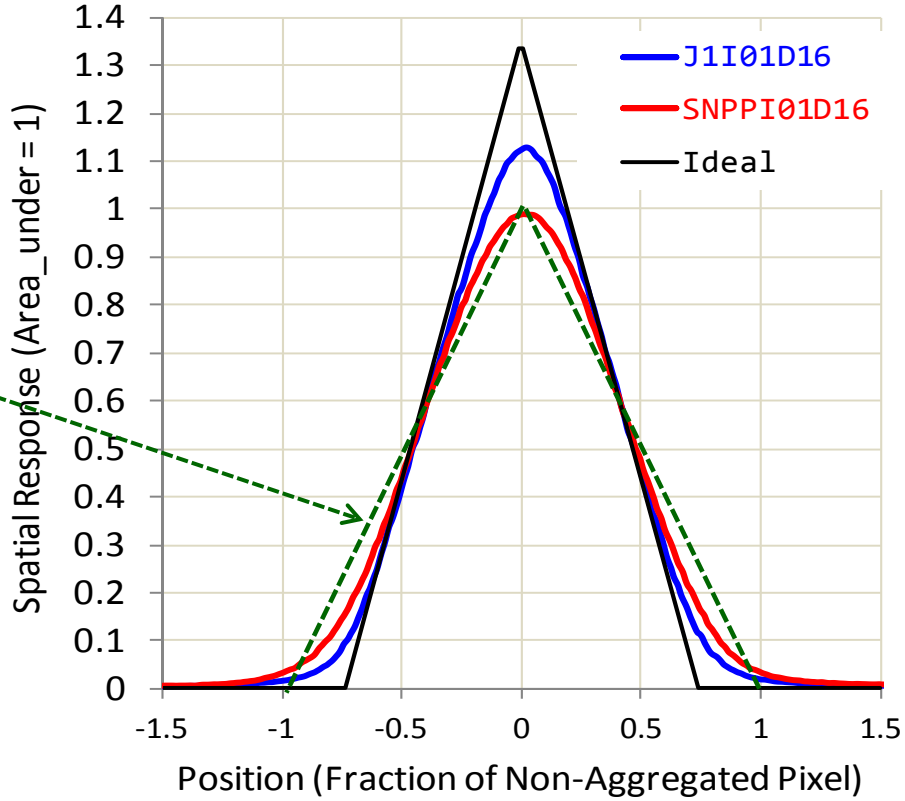
Outline

- Spatial Responses, LSF, DFOV, MTF
- Band-to-Band Co-registration (BBR)
- Pointing (for geolocation)
- DNB Geometric Performance
- Concluding Remarks

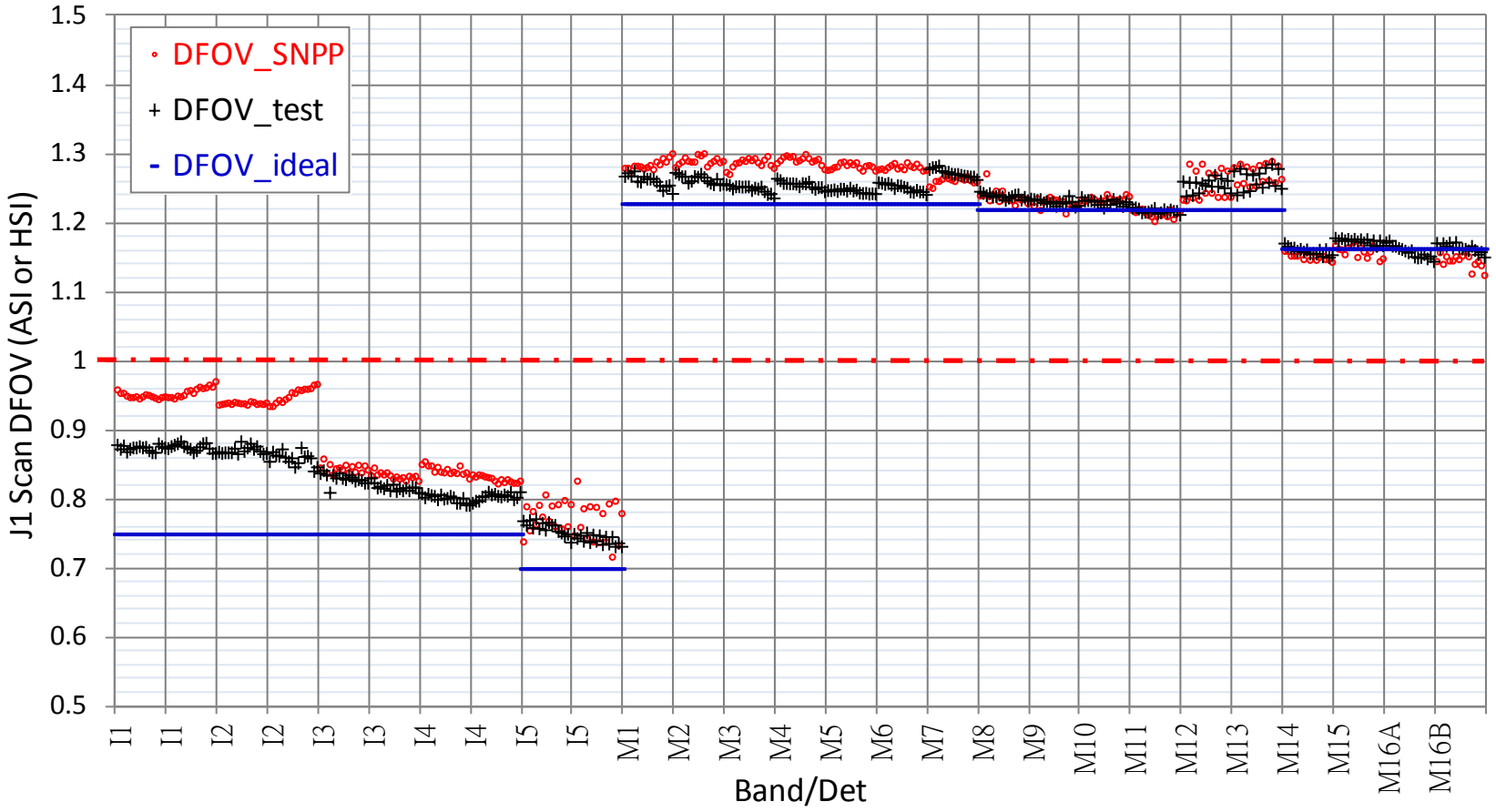
Optical calibration





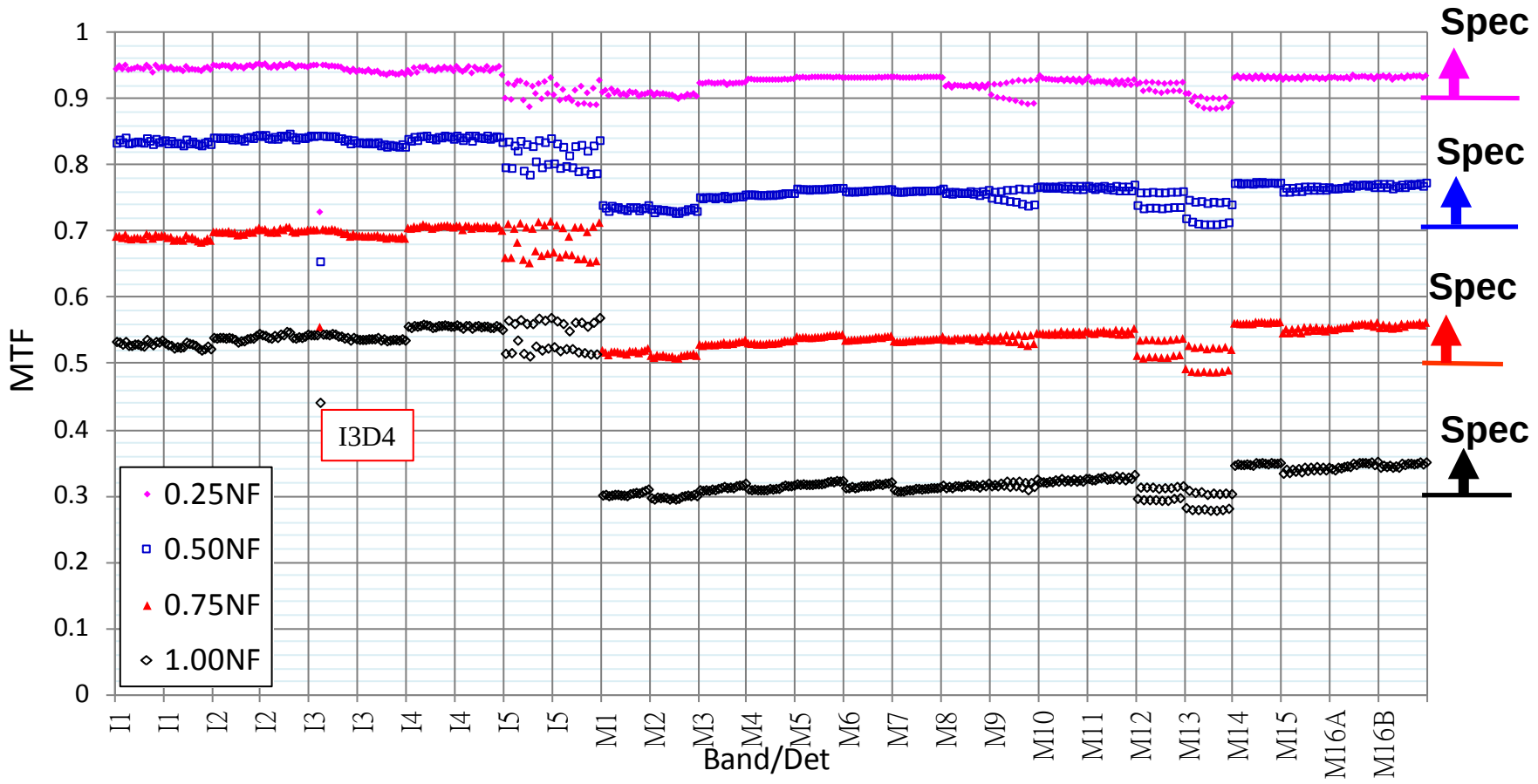
- J1 VIIRS has improved optical system over SNPP – efforts were made to improve the mirrors and the coating for the RTA

Scan LSF -- DFOV



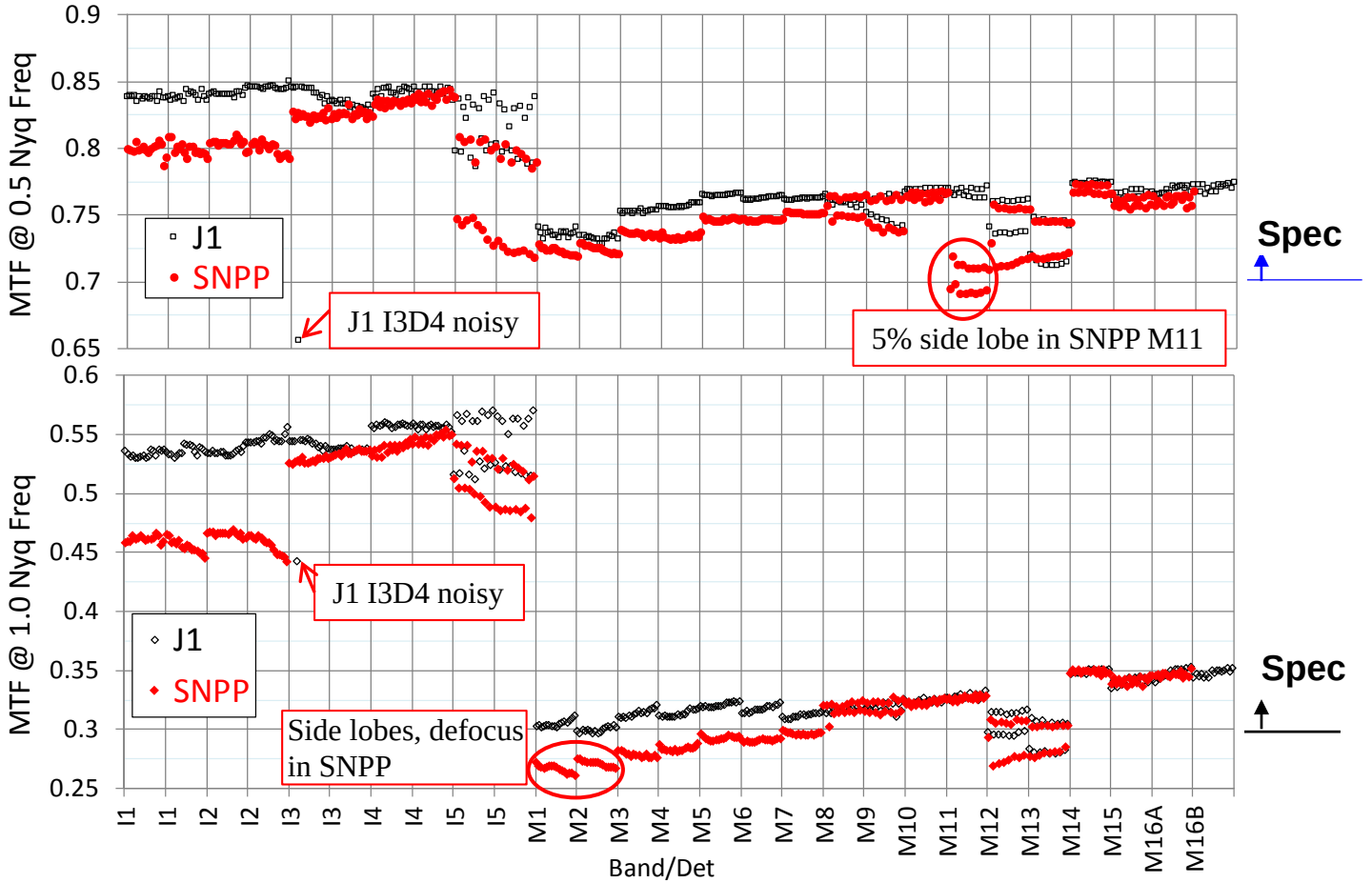
- J1 F2 optical performance is good (better than SNPP F1)
- M-Bands over-sample the earth, in the un-aggregated zones
- I-bands under-sample the earth (TOA), mostly in the un-aggregated zones
- Track direction LSFs are mostly square, IFOV ~= 1.0 ASI (or HSI on the ground)

Scan LSF -- MTF



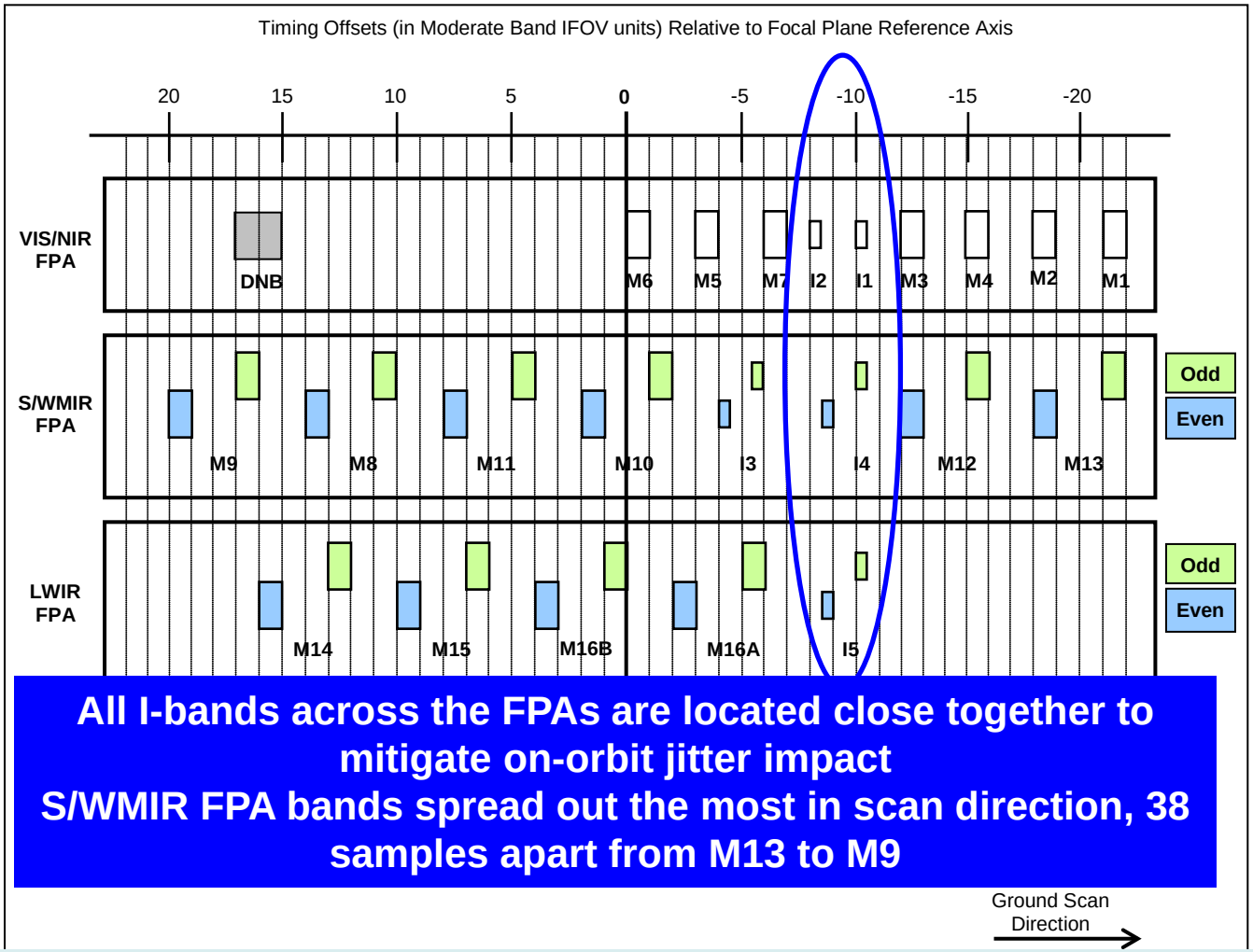
- MTF for M-bands mostly meets specification
- I-bands images are very sharp, at least at TOA (I3D4 under-performs but is still good in MTF)
- Track direction LSFs are mostly square, MTF ~= 0.63 at 1.00NF (Nyquist Frequency)

Scan LSF → MTF w/SNPP



- J1 MTF performs better than SNPP
- Side-lobes of M11 in SNPP disappear in J1
- Right focus for VisNIR FPA/bands in J1, while defocused/shorter EFL in SNPP

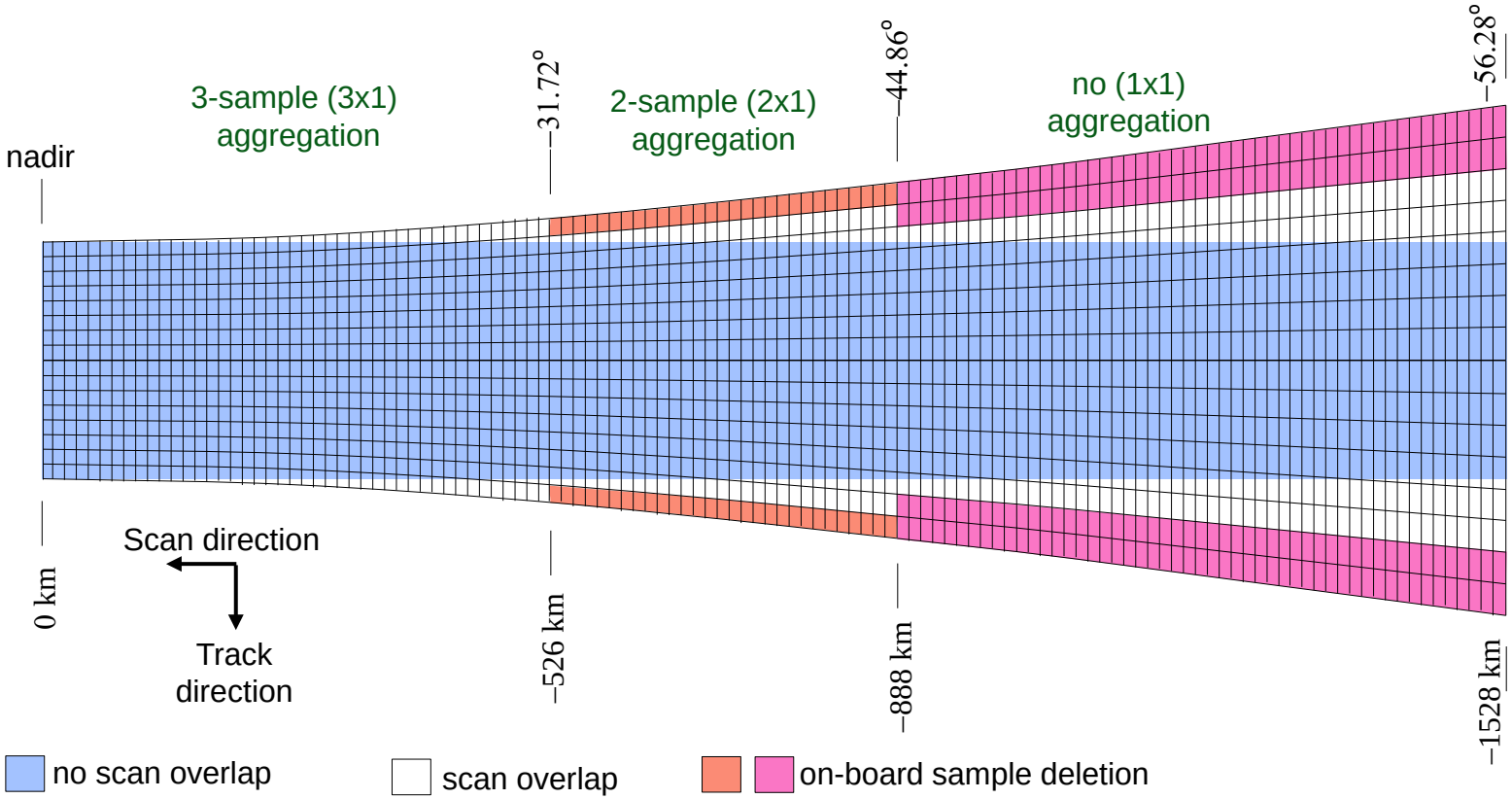
VIIRS Band/Detector Physical Layout



3 focal planes: VisNIR, SWMIR, LWIR; + 1 DNB (no BBR Spec)
21 bands (16 M-bands (M16A, M16B merged in space or just sent down one), 5 I-bands)
16 detectors in each M-band; 32 detectors in each I-band

M-band Sample Aggregation Sample Numbers Pixel Size

Sample No.	1600(3152)	1009(1377)	1008(1376)	641(641)	640(640)	1(1)
HSI Scan (m)	774(258)	1161(387)	774(387)	1295(648)	648(648)	1658(1658)
HSI Track (m)	741	893		1123		1627

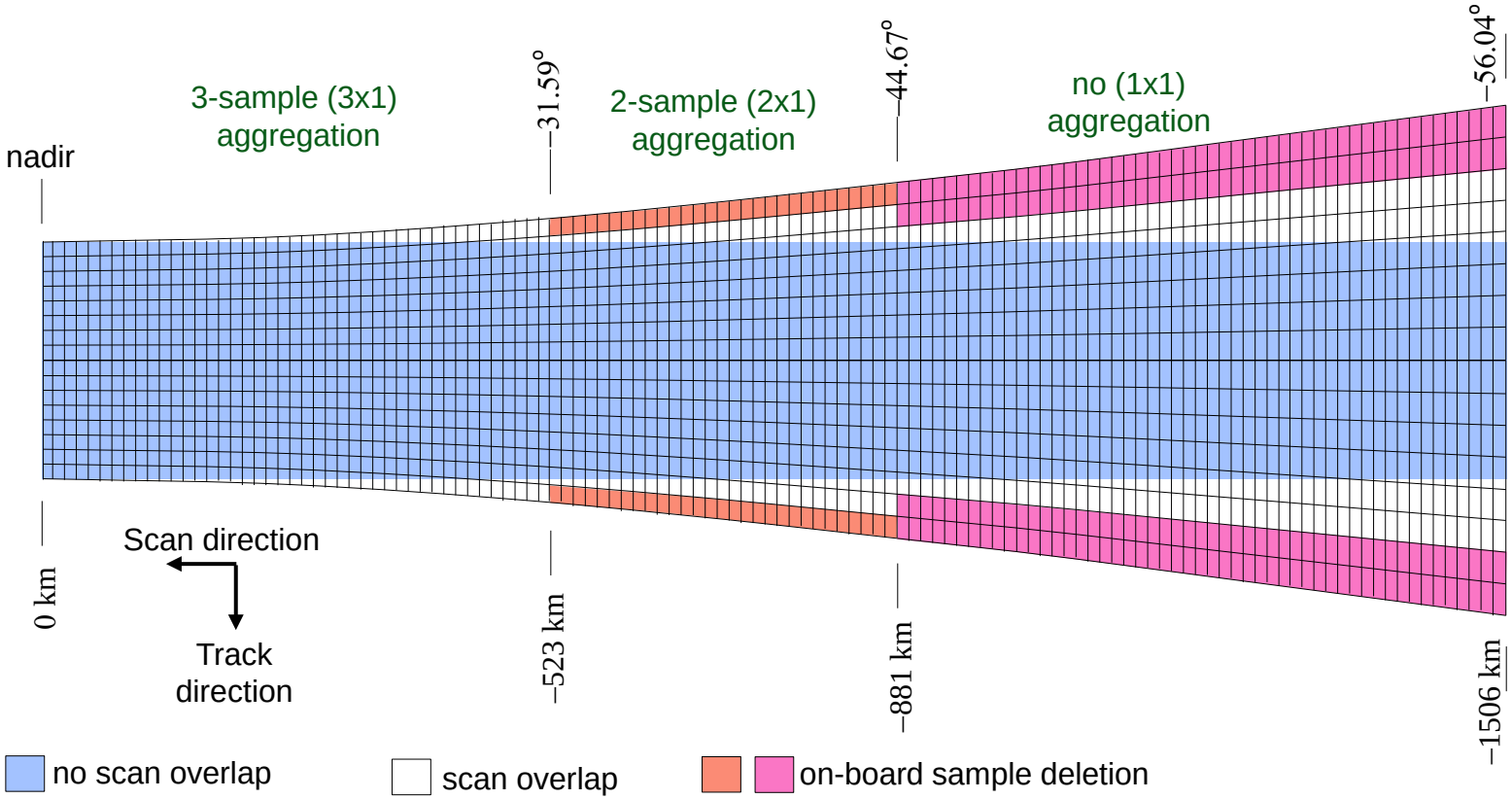


On-board sample deletion deletes 2 M-band (4 I-band) detectors in the 2 sample aggregation zone and 4 M-band (8 I-band) detectors in the no-aggregation zone. The numbers in in parentheses for the “Sample no.” and “HSI Scan (m)” are for dual-gain M-bands before aggregation, SDR of which are available to the ground as intermediate products.

Using altitude 828 km over the equator. EFL decreased by 0.4%, scan rate up 0.4% →**SNPP**

M-band Sample Aggregation Sample Numbers Pixel Size

Sample No.	1600(3152)	1009(1377)	1008(1376)	641(641)	640(640)	1(1)
HSI Scan (m)	774(258)	1152(384)	768(384)	1277(638)	638(638)	1600(1600)
HSI Track (m)	741	888		1113		1603



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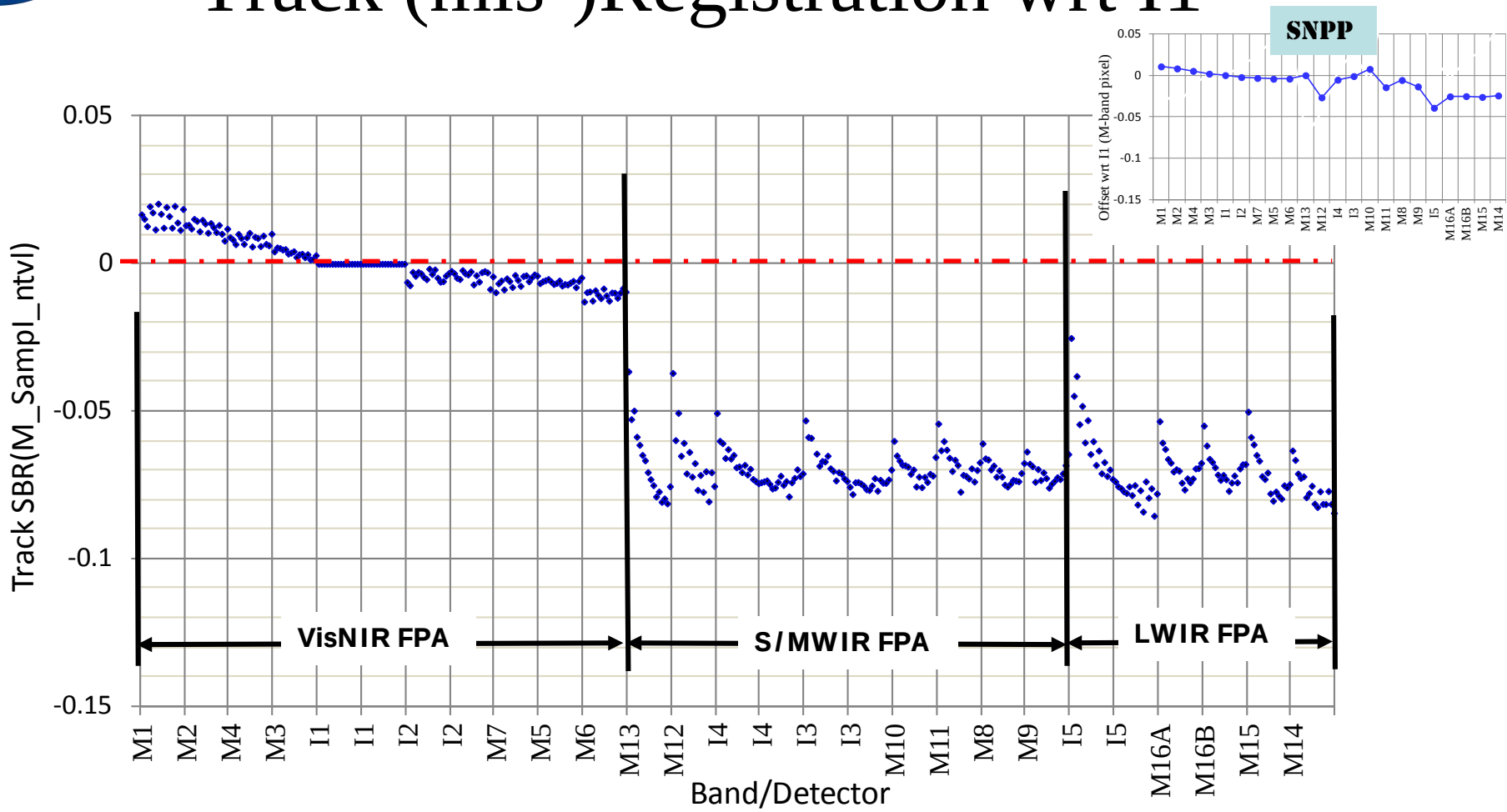
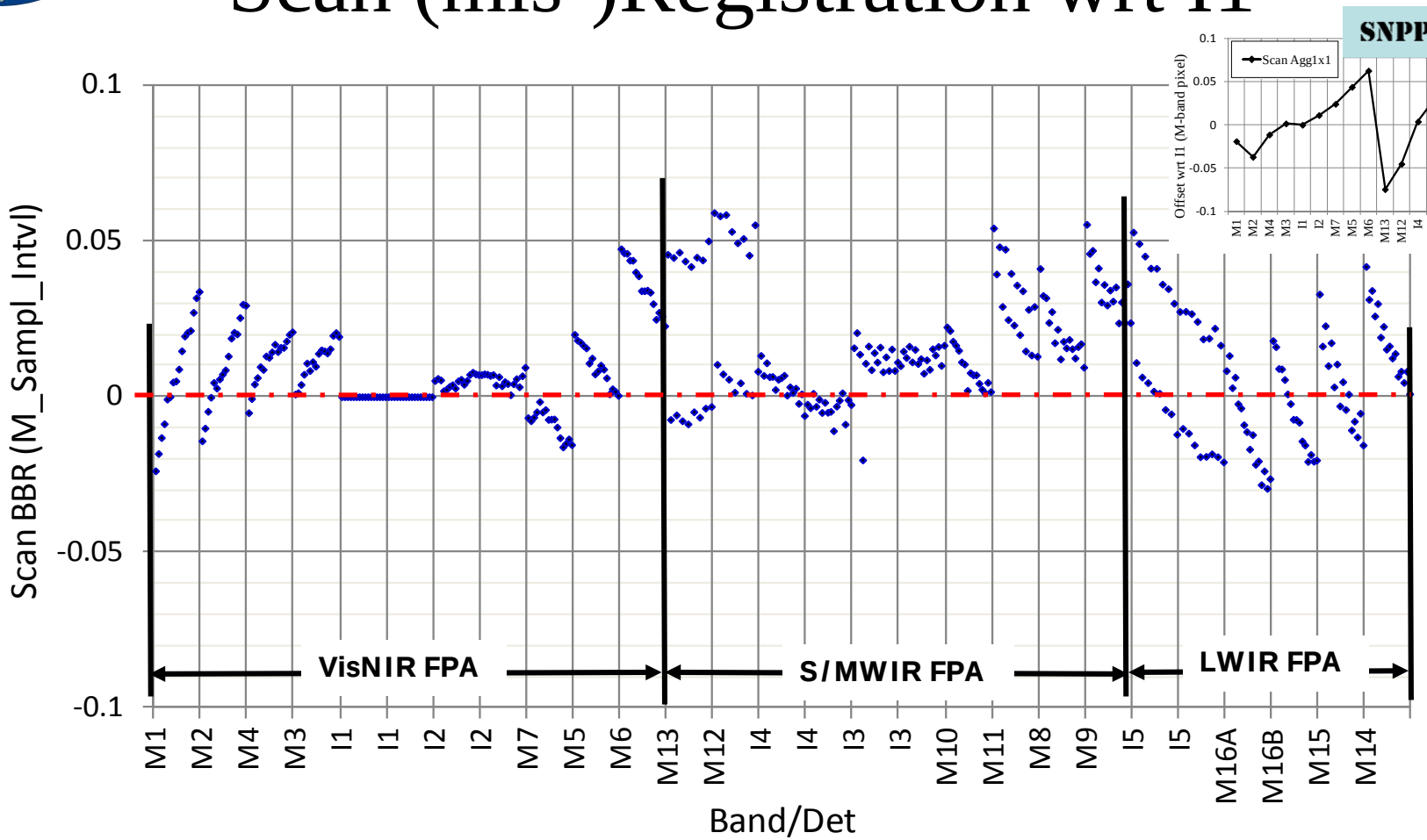
Track (mis-)Registration wrt I1



- Results obtained from tests at the nominal temperature performance plateau
- Track direction bands co-register well within each FPA
- Bands on SWMWIR and LWIR FPAs shifted from bands on VisNIR FPA, ~ 7% for M-bands and ~ 14% for I-bands. Mapping uncertainties are also affected $RMSE = \sqrt{\sigma^2 + \mu^2}$

Scan (mis-)Registration wrt I1



- Results obtained from tests at the nominal temperature performance plateau
- The scan rate is nominal @1.786 sec/scan or 3.517 rad/sec (0.4% slower than SNPP)
- Data shows for un-aggregated zones. Mis-reg in Agg2x1 and 3x1 zones is ½ and 1/3
- Mis-reg is < ~5% for M-band and < ~10% for I-bands

BBR matrix– non-agg zones

Band	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	M15	M16A	M16B	I1	I2	I3	I4	I5
M1		0.99	0.97	0.98	0.95	0.92	0.93	0.88	0.86	0.89	0.87	0.86	0.87	0.87	0.87	0.86	0.86	0.95	0.95	0.89	0.88	0.88
M2	0.64		0.98	0.98	0.95	0.93	0.94	0.89	0.87	0.89	0.88	0.87	0.88	0.88	0.87	0.87	0.87	0.96	0.96	0.90	0.88	0.88
M3	0.64	0.64		0.99	0.97	0.94	0.96	0.90	0.88	0.91	0.89	0.89	0.89	0.89	0.89	0.88	0.89	0.97	0.97	0.91	0.90	0.90
M4	0.64	0.64	0.64		0.97	0.94	0.95	0.90	0.88	0.90	0.89	0.88	0.88	0.89	0.89	0.88	0.88	0.97	0.97	0.91	0.89	0.89
M5	0.64	0.64	0.70	0.64		0.96	0.97	0.92	0.90	0.93	0.90	0.89	0.88	0.92	0.91	0.91	0.91	0.98	0.98	0.92	0.92	0.92
M6	0.64	0.64	0.64	0.64	0.64		0.94	0.91	0.93	0.91	0.92	0.90	0.90	0.91	0.89	0.88	0.89	0.94	0.95	0.91	0.90	0.91
M7	0.64	0.64	0.64	0.64	0.80	0.64		0.90	0.88	0.91	0.89	0.87	0.87	0.89	0.92	0.92	0.92	0.98	0.98	0.90	0.91	0.91
M8	0.64	0.64	0.64	0.64	0.64	0.64	0.64		0.98	0.98	0.98	0.96	0.96	0.98	0.97	0.95	0.96	0.90	0.91	0.98	0.97	0.98
M9	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64		0.97	0.98	0.96	0.94	0.97	0.95	0.94	0.95	0.88	0.89	0.96	0.95	0.96
M10	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64		0.96	0.94	0.95	0.98	0.98	0.97	0.98	0.92	0.92	0.99	0.98	0.98
M11	0.64	0.64	0.70	0.64	0.70	0.64	0.64	0.64	0.64	0.64		0.97	0.96	0.97	0.95	0.94	0.95	0.89	0.90	0.96	0.95	0.96
M12	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.80	0.64	0.64		0.98	0.95	0.94	0.92	0.93	0.88	0.89	0.94	0.93	0.94
M13	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.80	0.64	0.64	0.80		0.95	0.95	0.92	0.93	0.88	0.89	0.95	0.94	0.95
M14	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.80	0.64	0.64	0.80	0.80		0.98	0.95	0.96	0.89	0.90	0.97	0.96	0.97
M15	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.80	0.64	0.64	0.80	0.80	0.80		0.97	0.98	0.91	0.91	0.97	0.98	0.98
M16A	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.80	0.64	0.64	0.80	0.80	0.80	0.80		0.99	0.90	0.90	0.96	0.97	0.96
M16B	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.80	0.64	0.64	0.80	0.80	0.80	0.80	0.80		0.91	0.91	0.96	0.98	0.97
I1	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64		0.97	0.82	0.83	0.80
I2	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.80		0.84	0.83	0.81
I3	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.80	0.80		0.95	0.90
I4	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.80	0.80	0.80		0.89
I5	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.80	0.80	0.80	0.80	

Barely made it

- None out of spec at the ground test level
- On-orbit jitter should have little impact since I-bands are located close together with very short time delay for co-reg.

BBR matrix– 2x1-agg zones

Band	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	M15	M16A	M16B	I1	I2	I3	I4	I5
M1		0.99	0.98	0.98	0.96	0.94	0.95	0.90	0.89	0.90	0.89	0.89	0.89	0.89	0.89	0.88	0.89	0.97	0.96	0.90	0.89	0.89
M2	0.64		0.99	0.99	0.97	0.95	0.96	0.90	0.89	0.90	0.90	0.89	0.89	0.90	0.89	0.89	0.89	0.97	0.97	0.91	0.90	0.90
M3	0.64	0.64		0.99	0.98	0.96	0.97	0.91	0.91	0.92	0.91	0.91	0.90	0.91	0.91	0.90	0.90	0.99	0.98	0.92	0.91	0.91
M4	0.64	0.64	0.64		0.98	0.96	0.97	0.91	0.90	0.91	0.91	0.90	0.90	0.91	0.90	0.90	0.90	0.98	0.98	0.91	0.91	0.90
M5	0.64	0.64	0.70	0.64		0.98	0.99	0.93	0.92	0.93	0.92	0.91	0.90	0.92	0.92	0.92	0.92	0.98	0.99	0.93	0.93	0.93
M6	0.64	0.64	0.64	0.64	0.64		0.97	0.93	0.93	0.92	0.93	0.92	0.91	0.92	0.91	0.91	0.91	0.96	0.97	0.92	0.92	0.92
M7	0.64	0.64	0.64	0.64	0.8	0.64		0.91	0.91	0.92	0.91	0.90	0.89	0.91	0.92	0.93	0.93	0.99	0.99	0.92	0.92	0.92
M8	0.64	0.64	0.64	0.64	0.64	0.64	0.64		0.99	0.99	0.99	0.97	0.97	0.98	0.98	0.97	0.98	0.92	0.92	0.99	0.98	0.98
M9	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64		0.98	0.98	0.97	0.96	0.97	0.97	0.97	0.97	0.91	0.91	0.98	0.97	0.97
M10	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64		0.98	0.96	0.97	0.98	0.99	0.98	0.98	0.92	0.93	0.99	0.99	0.98
M11	0.64	0.64	0.70	0.64	0.70	0.64	0.64	0.64	0.64	0.64		0.98	0.97	0.98	0.97	0.97	0.97	0.91	0.91	0.98	0.97	0.98
M12	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.80	0.64	0.64		0.98	0.96	0.96	0.96	0.96	0.90	0.91	0.96	0.96	0.97
M13	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.80	0.64	0.64	0.80		0.97	0.97	0.95	0.95	0.90	0.90	0.97	0.96	0.97
M14	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.80	0.64	0.64	0.80	0.80		0.98	0.97	0.97	0.91	0.92	0.98	0.98	0.98
M15	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.80	0.64	0.64	0.80	0.80	0.80		0.98	0.98	0.92	0.92	0.98	0.99	0.98
M16A	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.80	0.64	0.64	0.80	0.80	0.80	0.80		0.99	0.91	0.92	0.97	0.98	0.98
M16B	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.80	0.64	0.64	0.80	0.80	0.80	0.80	0.80		0.92	0.92	0.98	0.98	0.98
I1	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64		0.98	0.83	0.84	0.81
I2	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.80		0.84	0.84	0.83
I3	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.80	0.80		0.97	0.92
I4	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.80	0.80	0.80		0.92
I5	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.80	0.80	0.80	0.80	

Improved a little, but not much

- None out of spec at the ground test level
- On-orbit jitter should have little impact since I-bands are located close together with very short time delay for co-reg.

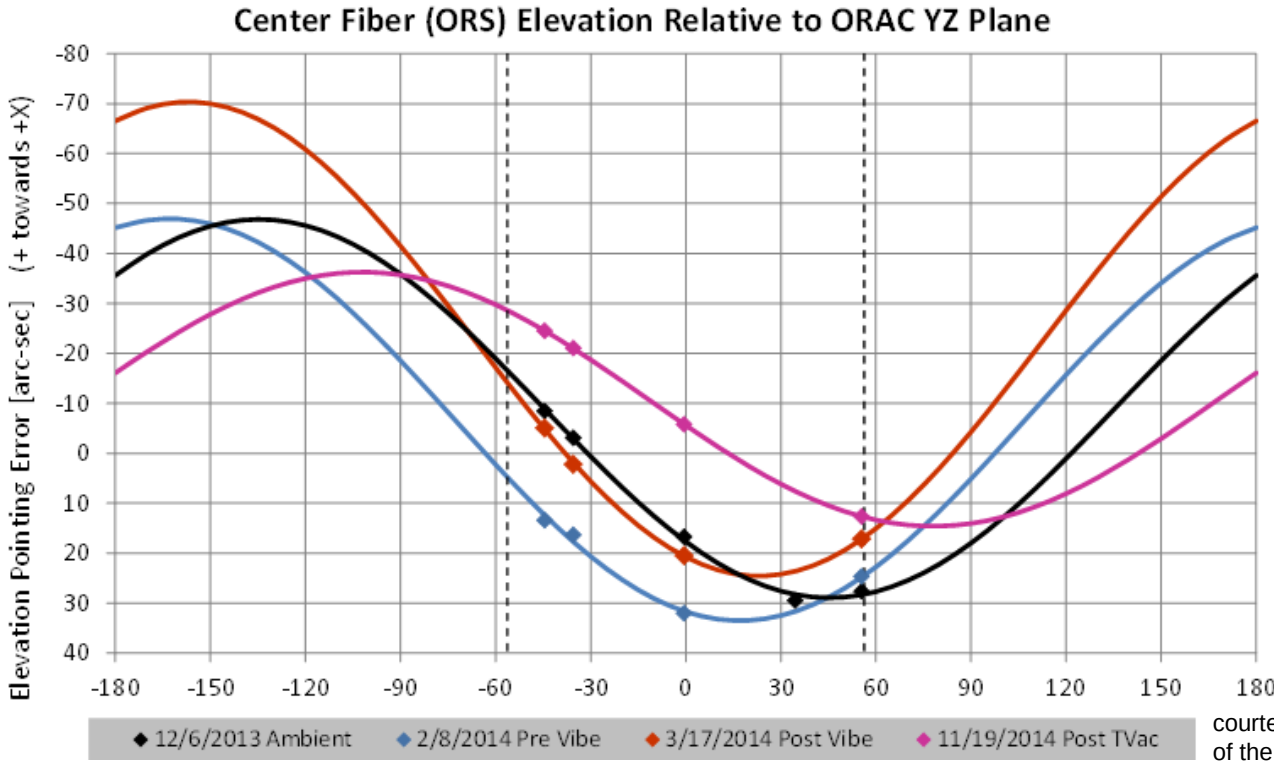
BBR matrix– 3x1-agg zones

Band	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	M15	M16A	M16B	I1	I2	I3	I4	I5
M1		0.99	0.98	0.99	0.96	0.95	0.96	0.9	0.89	0.90	0.90	0.90	0.89	0.89	0.89	0.89	0.89	0.97	0.97	0.90	0.90	0.89
M2	0.64		0.99	0.99	0.97	0.95	0.97	0.91	0.90	0.91	0.90	0.90	0.90	0.89	0.90	0.90	0.90	0.98	0.97	0.91	0.90	0.90
M3	0.64	0.64		0.99	0.98	0.97	0.98	0.92	0.91	0.92	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.99	0.99	0.92	0.91	0.91
M4	0.64	0.64	0.64		0.98	0.96	0.97	0.91	0.91	0.91	0.91	0.91	0.90	0.90	0.90	0.90	0.91	0.98	0.98	0.91	0.91	0.90
M5	0.64	0.64	0.70	0.64		0.98	0.99	0.93	0.92	0.93	0.92	0.92	0.91	0.92	0.92	0.92	0.92	0.99	0.99	0.93	0.93	0.92
M6	0.64	0.64	0.64	0.64	0.64		0.98	0.93	0.93	0.92	0.93	0.92	0.92	0.92	0.92	0.92	0.92	0.97	0.98	0.93	0.92	0.92
M7	0.64	0.64	0.64	0.64	0.80	0.64		0.92	0.92	0.92	0.91	0.91	0.90	0.91	0.92	0.93	0.93	0.99	0.99	0.92	0.92	0.92
M8	0.64	0.64	0.64	0.64	0.64	0.64	0.64		0.99	0.99	0.99	0.97	0.97	0.98	0.98	0.98	0.98	0.92	0.92	0.99	0.98	0.97
M9	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64		0.98	0.99	0.97	0.97	0.97	0.98	0.97	0.98	0.91	0.92	0.98	0.98	0.96
M10	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64		0.98	0.96	0.97	0.98	0.98	0.99	0.99	0.92	0.93	0.99	0.99	0.97
M11	0.64	0.64	0.70	0.64	0.70	0.64	0.64	0.64	0.64	0.64		0.98	0.97	0.98	0.98	0.98	0.98	0.91	0.92	0.98	0.98	0.97
M12	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.80	0.64	0.64		0.99	0.97	0.97	0.97	0.97	0.91	0.92	0.97	0.97	0.97
M13	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.80	0.64	0.64	0.80		0.97	0.98	0.96	0.96	0.90	0.91	0.97	0.97	0.98
M14	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.80	0.64	0.64	0.80	0.80		0.98	0.97	0.98	0.91	0.92	0.98	0.98	0.97
M15	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.80	0.64	0.64	0.80	0.80	0.80		0.99	0.99	0.92	0.92	0.99	0.99	0.98
M16A	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.80	0.64	0.64	0.80	0.80	0.80	0.80		0.99	0.92	0.92	0.98	0.99	0.97
M16B	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.80	0.64	0.64	0.80	0.80	0.80	0.80	0.80		0.92	0.92	0.98	0.99	0.98
I1	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64		0.98	0.84	0.84	0.82
I2	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.80		0.85	0.85	0.83
I3	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.80	0.80		0.97	0.92
I4	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.80	0.80	0.80		0.92
I5	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.80	0.80	0.80	0.80	

Improved a little, but not much

- None out of spec at the ground test level
- On-orbit jitter should have little impact since I-bands are located close together with very short time delay for co-reg.

Pointing (for geolocation)



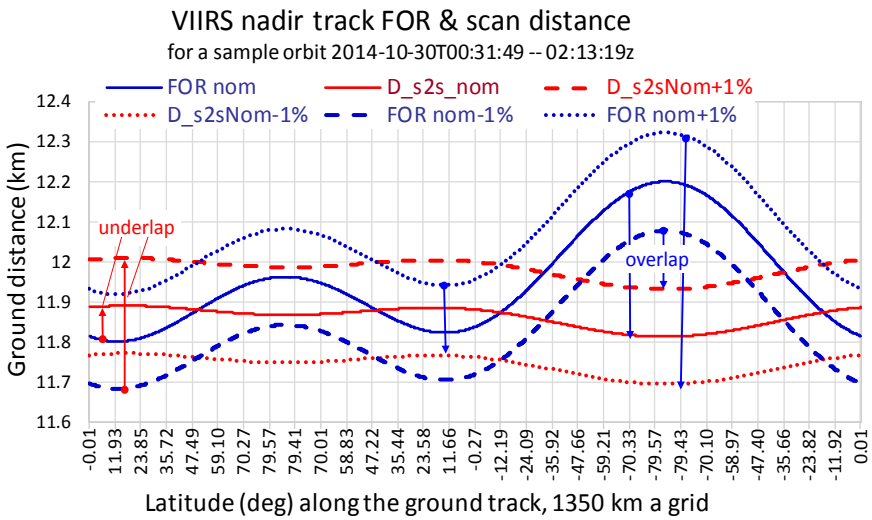
courtesy of the instrument vendor

- Scan plane was measured to within 1 arcmin
- Instrument mounting (within 1 arcmin post-vibe), launch will add to the variation
- On-orbit geolocation CalVal will remove biases and sub-pixel accuracy is expected for M- & I-bands

Geolocation/orbit geometry related

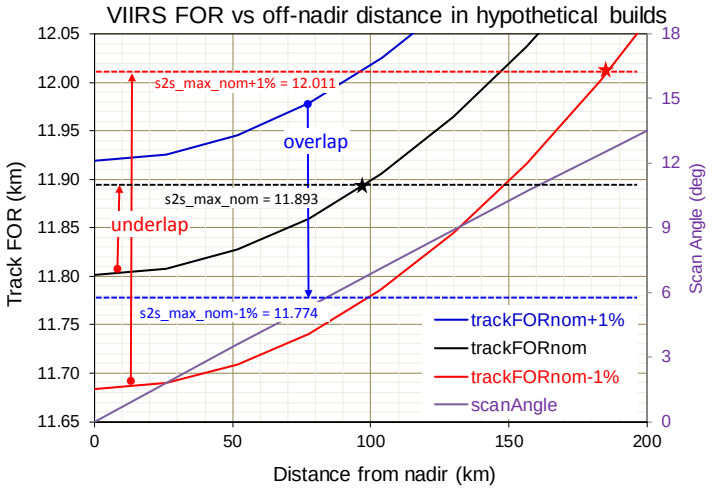
VIIRS potential underlap at nadir over Equator

VIIRS nadir overlap/underlap potential



- For nominal ground track Field of Regard (FOR) with nominal detector pitch in the track direction at nominal scan rate, underlap will occur at low latitude regions

VIIRS overlap/underlap vs off-nadir distance

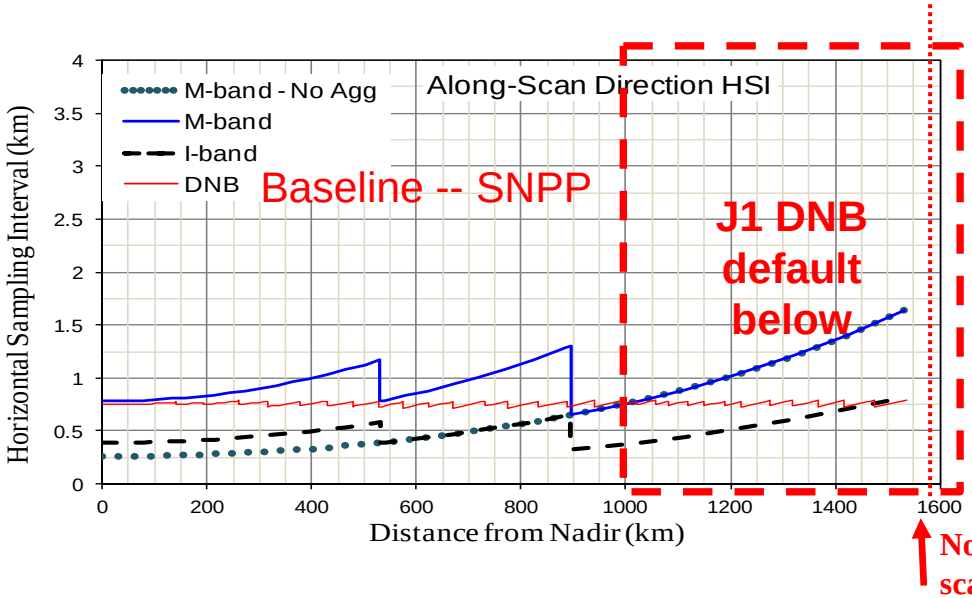


- Scan-to-scan overlaps / underlaps are very sensitive to changes in orbit/instrument parameters
- The scan to scan (s2s_max) distance is based on max speed of 6656 m/s from SNPP experience.
- Assuming the scan rate is tied to FOR through focal length via exact BBR requirement.

Lin et. al., 1 Sept 2016 VCST/GEO 18 Lin et. al., 1 Sept 2016 VCST/GEO 20

- Tight requirements in orbit parameters (e.g., altitude, inclination, repeat ground tracks) and instruments parameters (e.g., DFOV, MTF, BBR) leave little room for adjustments
- A “small” change of tolerance during instrument fabrication (e.g., focal length) makes significant impact in scan-to-scan overlaps or underlaps

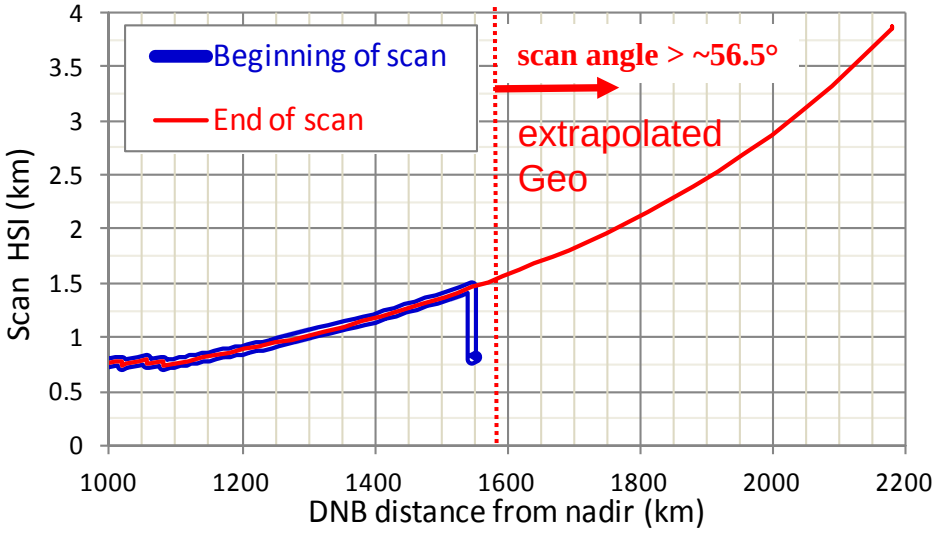
SNPP & J1 DNB cell sizes in scan direction



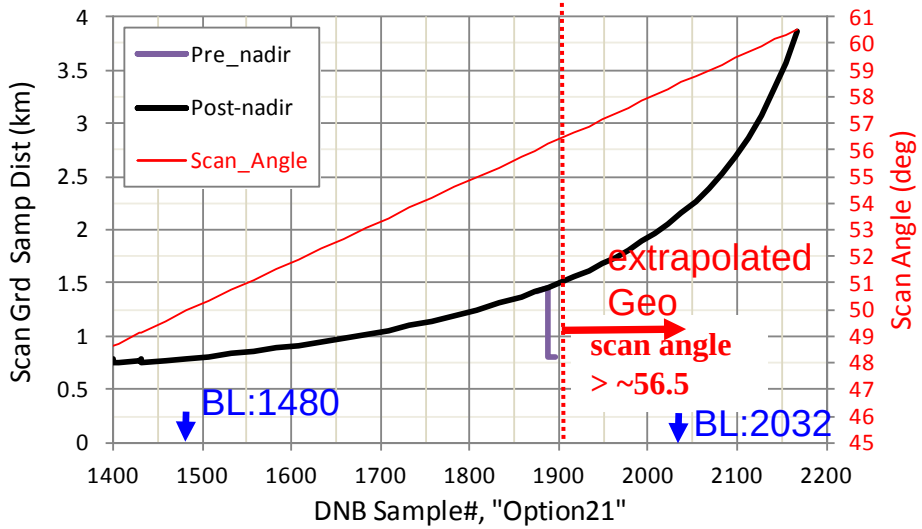
Nominal maximum scan angle (~56.5°)

- DNB LSFs are mostly square
- Baselined pixel size is ~ 750 m
- "Option21" has pixel size up to 1.6 km within 56.5°
- Geolocation is extrapolated post-nadir for scan angle > ~56.5° (pixel size up to 3.9 km @60.5°)

- J1 DNB cell sizes are not constant as SNPP VIIRS are



"Option21" – default, in km



"Option21" – default, in Samp#

Concluding Remarks

- J1 VIIRS has good optical performance (better than SNPP)
- J1 VIIRS scan rate is nominal @1.786 sec/scan or 3.517 rad/sec (SNPP VIIRS is @ 1.779 sec/scan or 3.531 rad/sec)
- J1 VIIRS BBR aligns well in scan direction
  - However, in the track direction, bands (**I3-5, M8-16**) on the CFPAs are shifted from bands (**I1-2, M1-7**) on VisNIR FPA, ~ 7% for M-bands and ~ 14% for I-bands. Mapping uncertainties will be affected
- J1 VIIRS pointing was measured. On-orbit geolocation CalVal will remove biases and sub-pixel accuracy is expected for M- & I-bands, as was done for that of SNPP VIIRS
- J1 DNB geometry is different than that of SNPP VIIRS

Backup

Image Resolution Specifications – FOVs

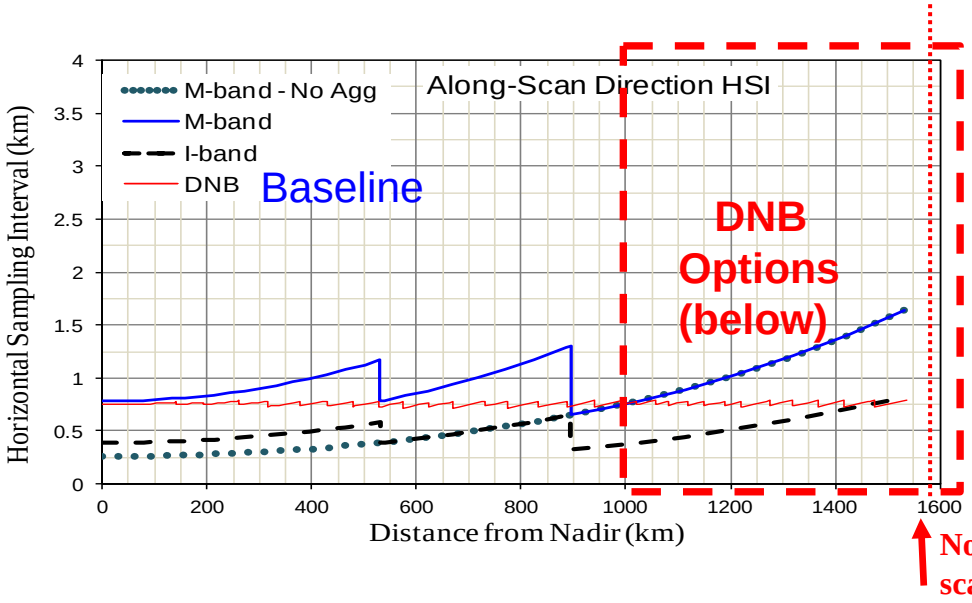
- Scan Dynamic Field of View (DFOV), including integration drag
  - = Full Width Half Maximum (FWHM) of Line Spread Function (LSF)
  - I-bands, original Spec (actual dominant by integration_drag & EFL)
    - I1, I2: 114 (116) μrad
    - I3: 108 (116) μrad
    - I4: 109 (116) μrad
    - I5: 102 (109) μrad

    ±10% for spec
  - M-bands: original Spec (actual dominant by detector_size & EFL)
    - M1 to M11: 382 (381) μrad
    - M12, M13: 379 (378) μrad
    - M14, M15: 362 (361) μrad
    - M16: 364 (361) μrad

    ±5% for spec
- Track IFOV, without integration drag
  - Given by FWHM of LSF curve, mostly square
  - I-bands: IFOV = 445.5 μrad ±5%
  - M-bands: IFOV = 891 μrad ±5%

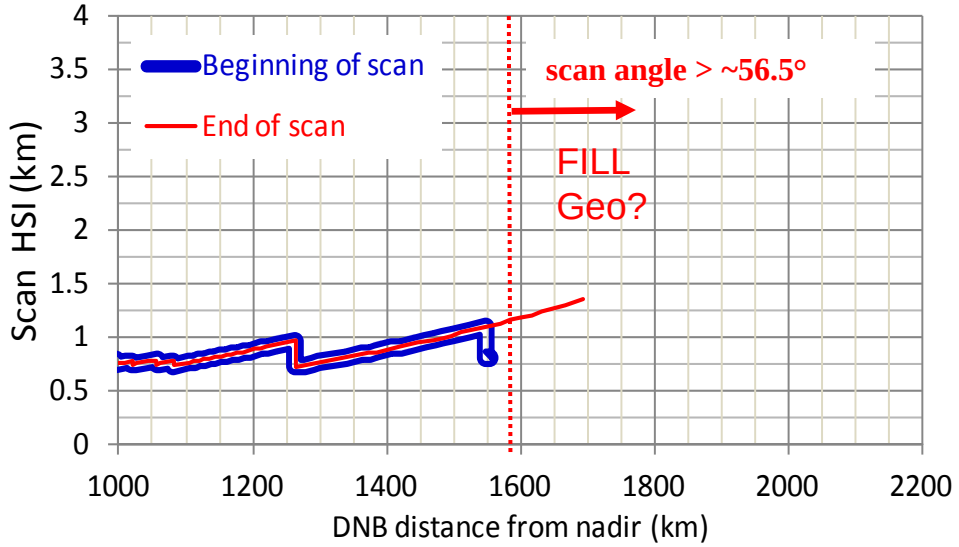
- Note: angular sampling interval (ASI) (and horizontal sampIntvl (HSI)) at nadir w/ avg Alt=838.8 km
  - I-bands scan ASI = 155.21 μrad (130 m @ nadir) ->3 ASIs = 465.6 μrad (391 m @ nadir)
  - I-bands track ASI = 445.5 μrad (381 m @ nadir)
  - M-bands scan ASI = 310.42 μrad (260 m @ nadir) ->3 ASIs = 931.3 μrad (790 m @ nadir)
  - M-bands track ASI = 891 μrad (762 m @ nadir)

DNB Geometric Performance

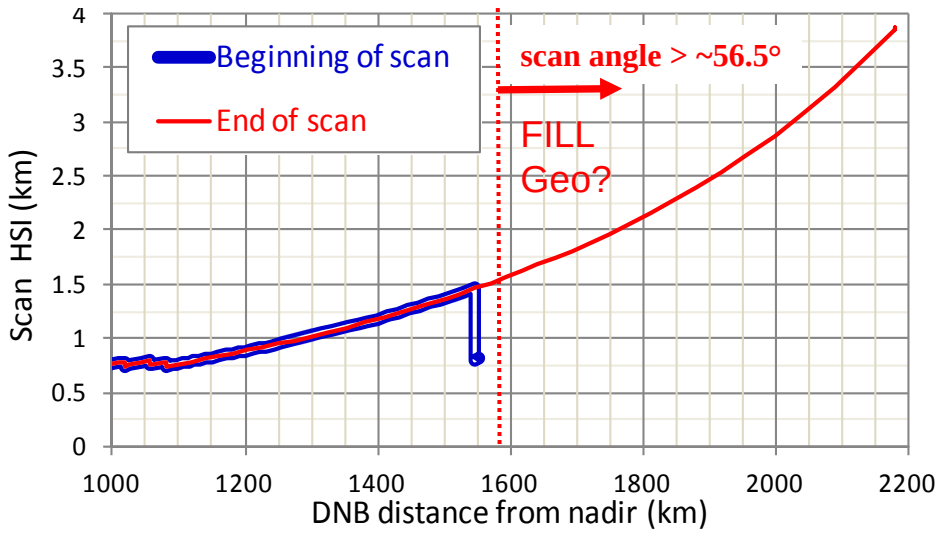


Nominal maximum scan angle (~56.5°)

- DNB LSFs are mostly square
- Baselined HSI is ~ 750 m
- "Option21-26" has HSI max of 1.1 km within 56.5° (up to 1.4 km @57.6°)
- "Option21" has HSI max of 1.6 km within 56.5° (up to 3.9 km @60.5°)
- Geolocation may be FILL post-nadir for scan angle > ~56.5°



"Option21-26"



"Option21"