NPP and J1 CrIS Instruments Noise Performance

STAR JPSS Science Team Meeting SDL, Exelis, NOAA STAR results

Deron Scott presenting

May 12-16, 2014

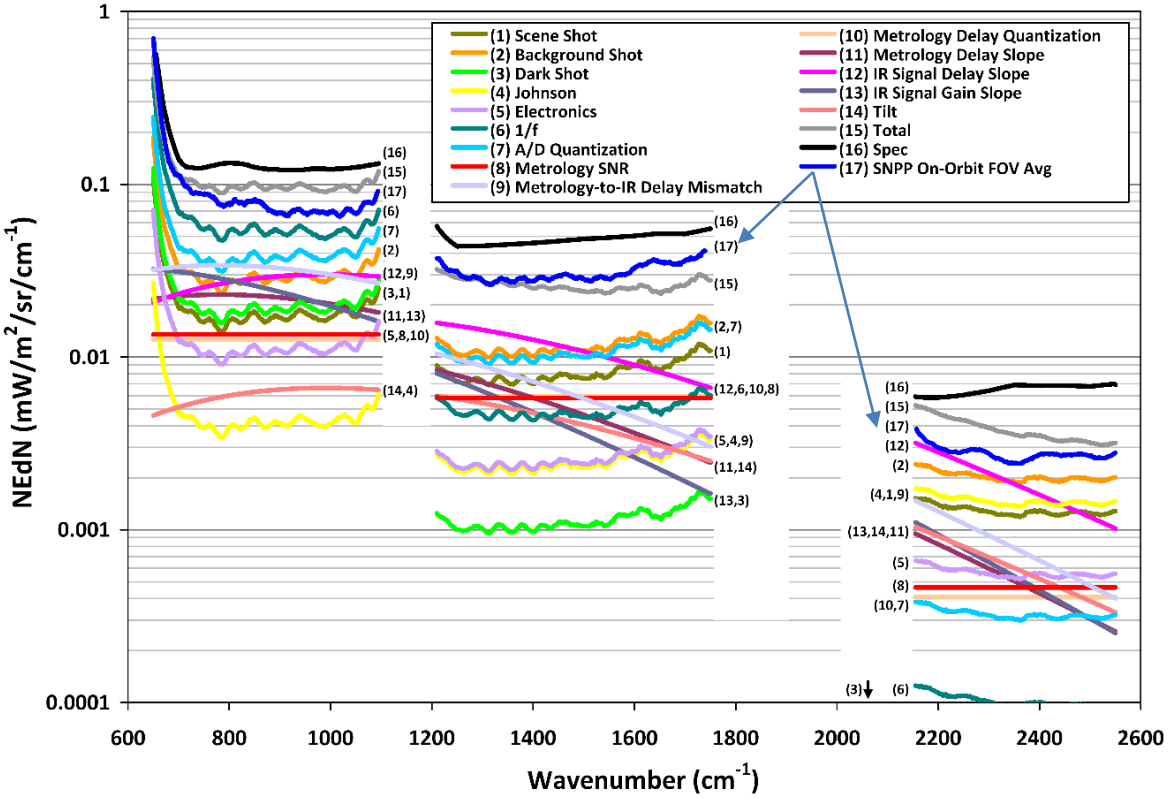
Outline

1. Noise sources and NPP on-orbit real spectra NEdN
2. NPP CrIS on-orbit noise performance as compared to TVAC ground test and heritage AIRS and IASI instruments
3. NPP on-orbit NEdN trend. NEdN stability over different orbital positions (North Pole, Tropics, and South Pole)
4. Small seasonal, spatial, and orbital NEdN variations.
5. Imaginary spectra NEdN as a diagnostic tool to monitor instrument health
6. J1 CrIS instrument NEdN performance (bench and RRTVAC tests)
7. Conclusion.

- Total NEdN is calculated using standard technique (standard deviation)
- PCA technique is used to estimate random NEdN component
- Correlated noise contribution is estimated as:

$$NEdN_{cor} = \sqrt{NEdN_{total}^2 - NEdN_{random}^2}$$

CrIS Instrument Noise Sources

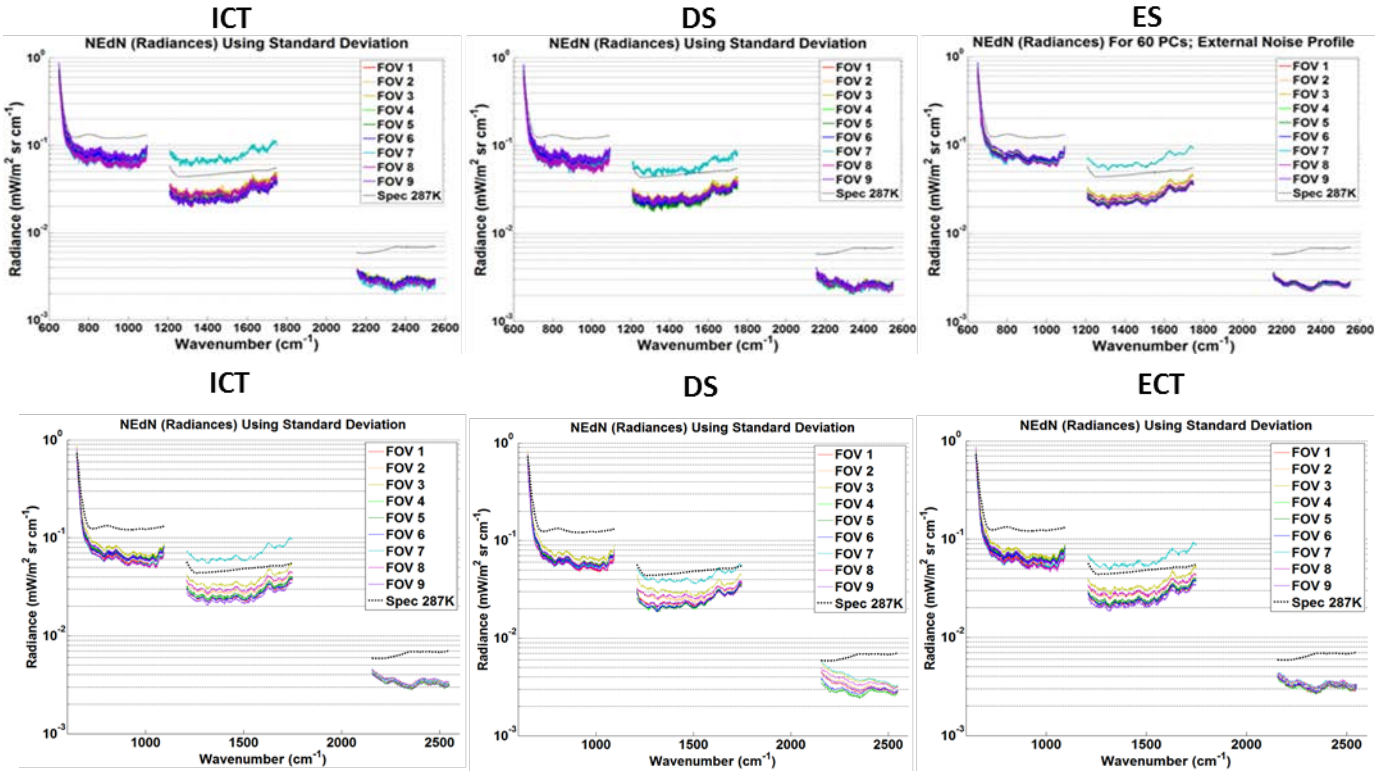


- **Exelis** CrIS NEdN model and simulations: 1-7 detector and electronics noise (random); 8-14 interferogram distortion noise (may lead to spectrally correlated noise component)
- Major contributors: LWIR- 1/f noise; MWIR and SWIR - background shot and IR signal delay slope noise
- Background shot noise dominates in MWIR and SWIR spectral bands in both NPP and J1 sensors.
- Note, under external vibration interferometer induced noise dominates – characteristic slope (12)

NPP: On-orbit NEdN vs TVAC4

On-orbit
January 10, 2013

TVAC 4, MN
T_{ECT}=287K



- NEdN in all spectral channels and FOVs (except MWIR FOV7) is well within spec
- On orbit NEdN is practically the same as during TVAC4 ground test
- MWIR FOV7 is slightly out of spec from TVAC4 test probably due to migrating impurities in the IR detector interface (may change after warm-up/cool-down cycle).

NPP: Correlated noise contribution. SWIR DS-worse case

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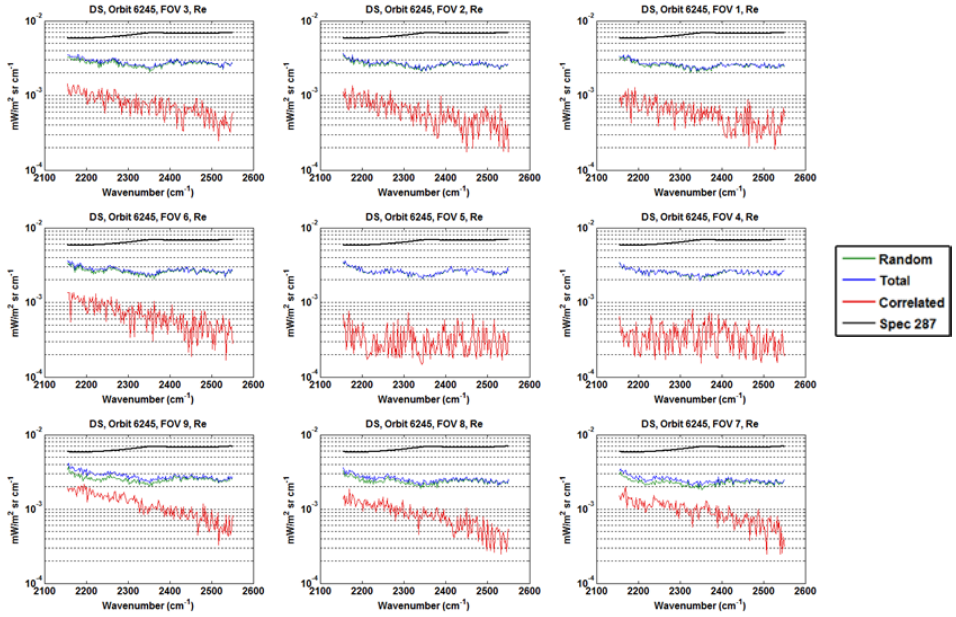
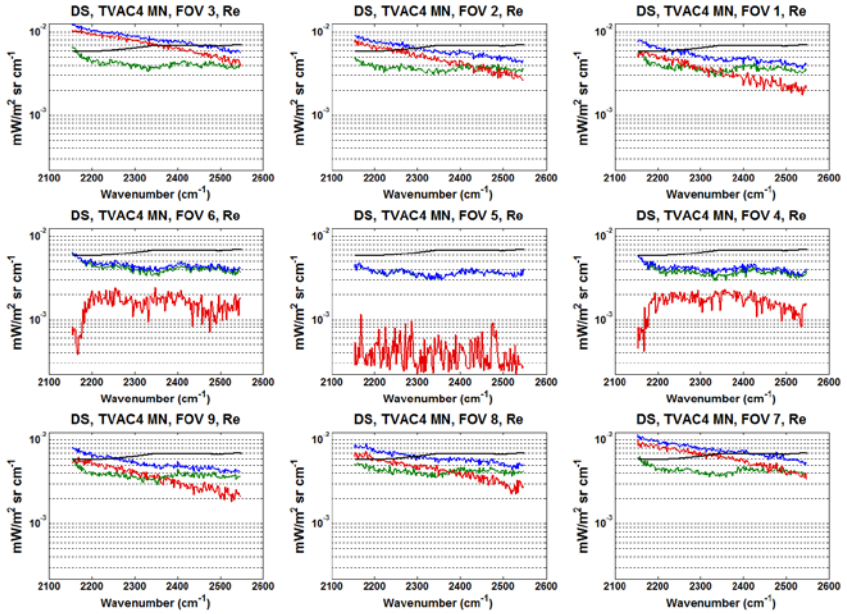
SWIR DS:
Orbit #6245 January 10, 2013

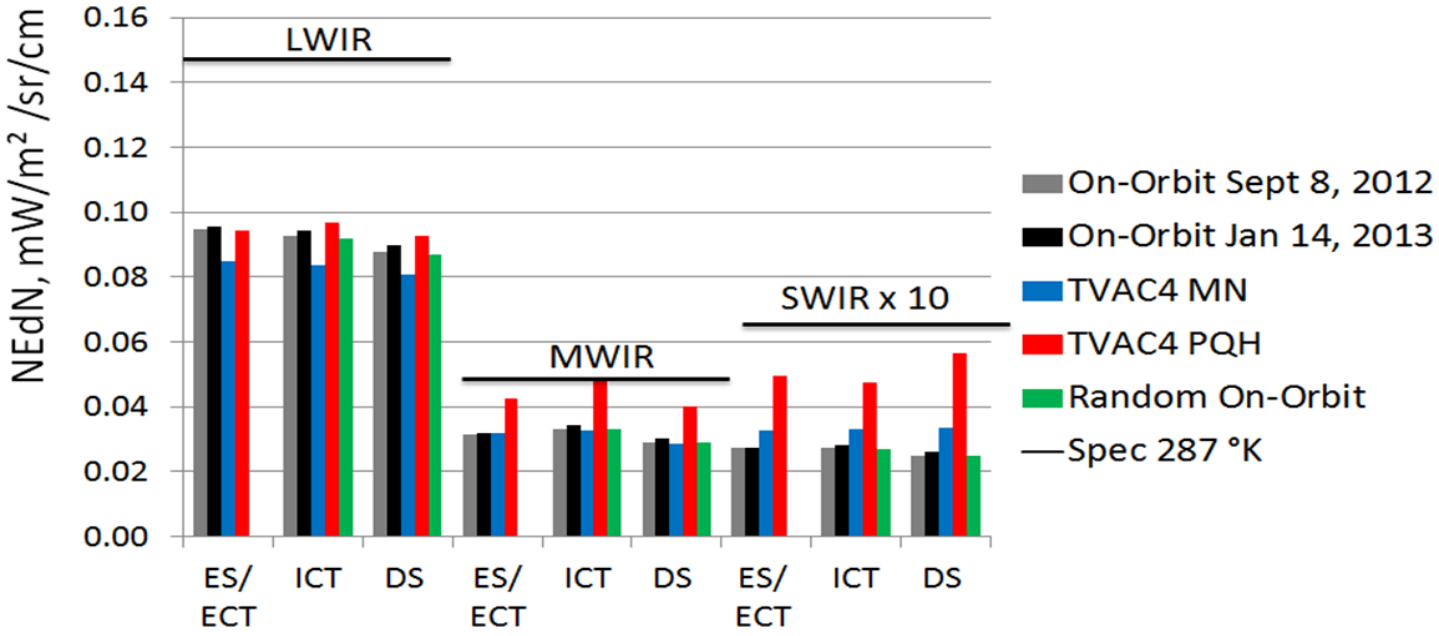


SWIR DS: TVAC4 MN



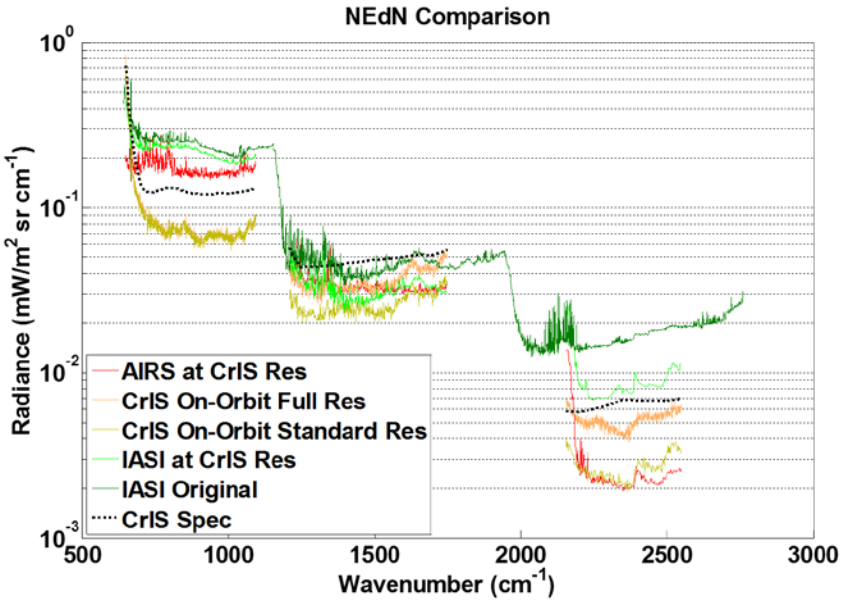
- On-orbit NEdN exhibit significantly lower correlated noise contribution. During TVAC4 test additional vibration from the test equipment was present
- Vibration test and NEdN simulations conclusions:
  - SWIR NEdN is most sensitive to the external vibration
  - DS is most sensitive to the external vibration as compared to the ICT and ECT
  - Corner FOVs (1,3,7,9) are most susceptible to the vibration

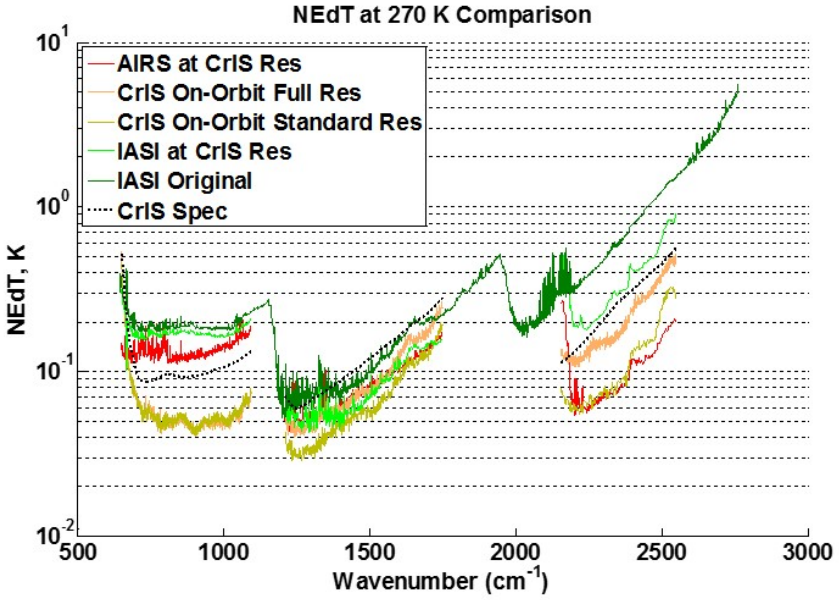
NPP: Average real spectra total NEdN On-orbit vs TVAC4



- Change in the on-orbit NEdN as compared to TVAC4 MN is mostly due to a random noise component (intrinsic detector noise):
  - LWIR: on-orbit random NEdN higher by ~10-12% then TVAC4 MN level
  - MWIR: on-orbit NEdN is at the same level as TVAC4 MN NEdN
  - SWIR: on-orbit random NEdN is smaller by ~15-20% then TVAC MN NEdN
- NEdN is averaged over each spectral band and all FOVs
- 220 spectra were used for each on-orbit and TVAC4 data analysis

NPP: NEdN and NEdT (at 270^{0}K) comparison with AIRS and IASI





- NEdN is estimated from Earth scene radiances using SDL PCA approach (60 PCs retained)
- CrIS exhibits smaller noise level in LWIR (~x3) and SWIR (~x3) spectral bands than noise estimated from IASI observations reduced to CrIS spectral resolution
- As expected, CrIS full spectral resolution noise in MWIR and SWIR bands is higher by ~x1.4 and ~x2, respectively, as compared to the CrIS standard spectral resolution

NPP: NEdN on-orbit trend over Equator region

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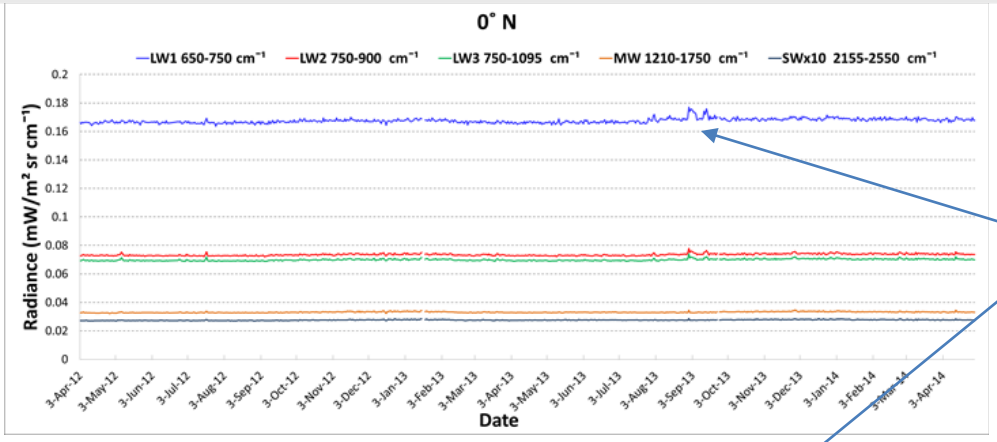
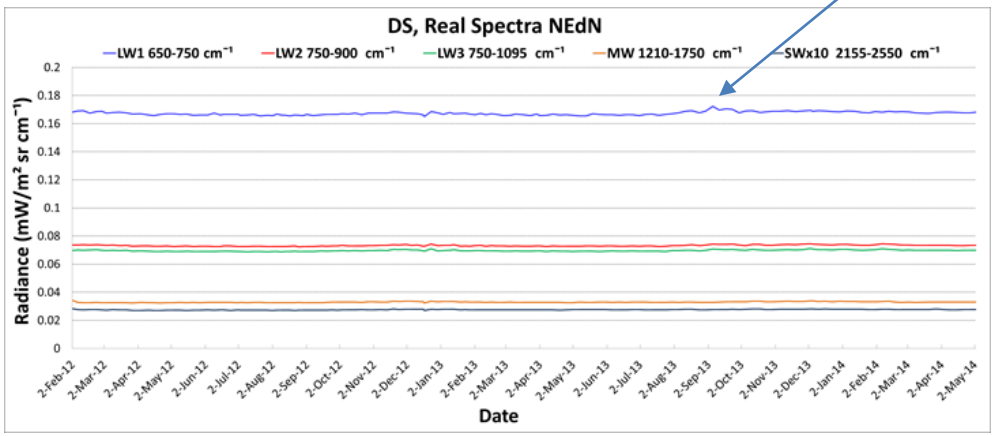
ICT
IDPS NEdN SDR
once a day
04/03/2012-
05/05/2014

DS
SDL monitoring
once a week
01/21/2012-
05/05/2014



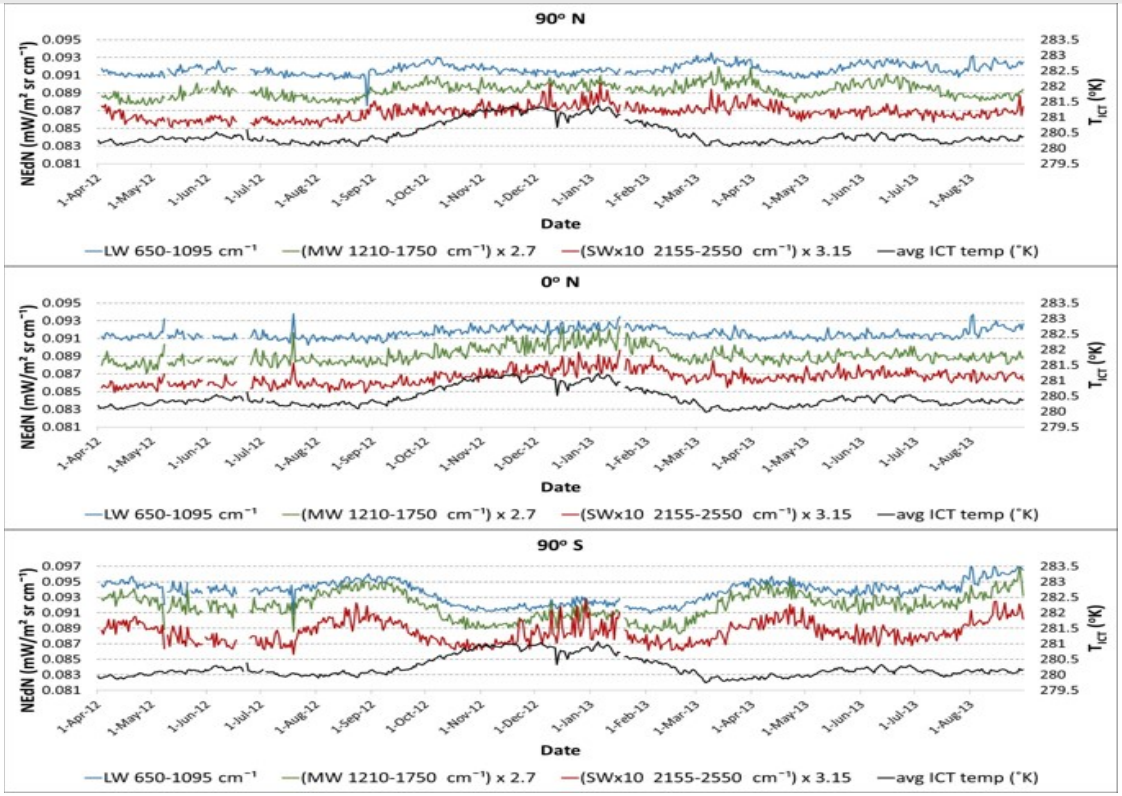


LWIR FOV1 anomaly observed in July-September 2013.
No new anomalies were observed since.

- NEdN remains stable during orbital operations
- LWIR FOV1 NEdN variations of ~(25-50)% were observed in July-September 2013
- NEdN was averaged over all FOVs and over spectral regions:

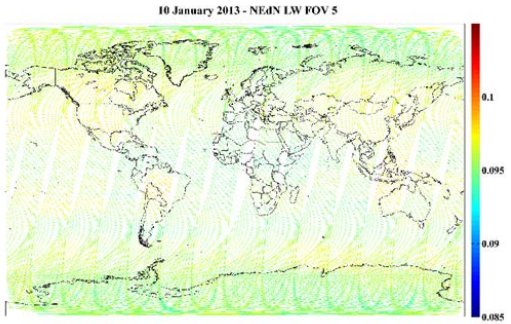
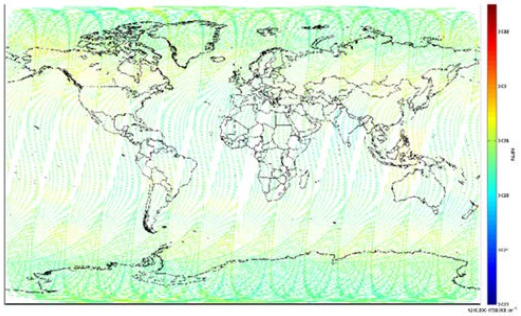
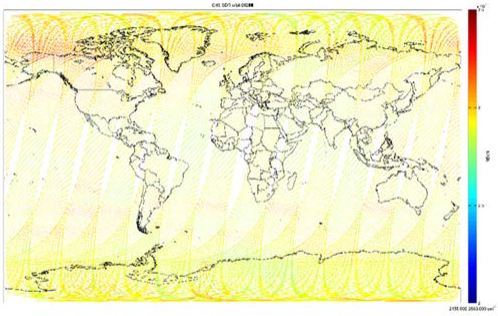
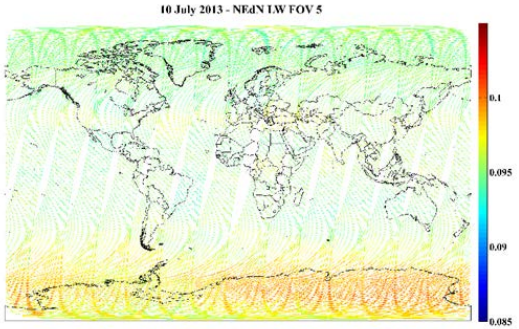
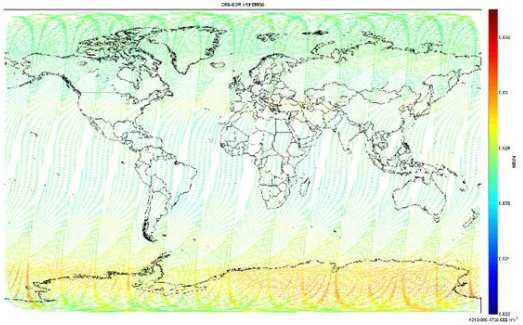
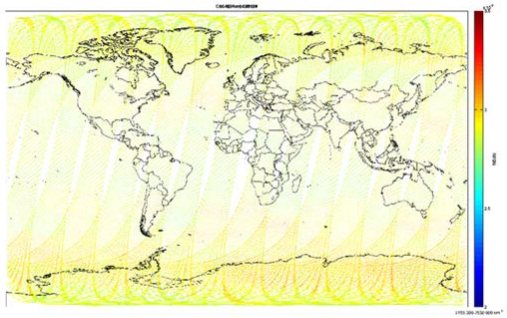
LWIR: 650-750 (beam-splitter transmittance); 750-900 (possible icing); and 750-195 cm^{-1}
MWIR: Entire band 1210-175 cm^{-1}
SWIR: Entire band 2155-2550 cm^{-1}

NPP: Seasonal NEdN variations over NP, Equator, and SP regions



- IDPS SDR NEdN and ICT temperature acquired once a day over NP (90^0N), Equator (0^0N), and SP (90^0S) regions
- At low latitude (~ 65^0 North to -65^0 South) the NEdN seasonal variations do not exceed 2-3% and follow the seasonal variations of the ICT temperature
- larger variations ~ 4-6% are observed over the South Pole. NEdN over both North and South Pole regions exhibit additional seasonal variations during spring and fall.

NPP: Orbital NEdN variations. FOV5

	LWIR	MWIR	SWIR
January 10, 2013			
July 10 , 2013			

- Descending (night time) orbits are shown
- Color scale is chosen +/- 10% of NEdN nominal values
- Small orbital NEdN variations <10% are typical for each FOV
- No NEdN anomalies are observed over the South Atlantic Anomaly region
- Relatively large area of PV HgCdTe detectors and radiation shielding provide reliable protection of the detector array from high energy particles

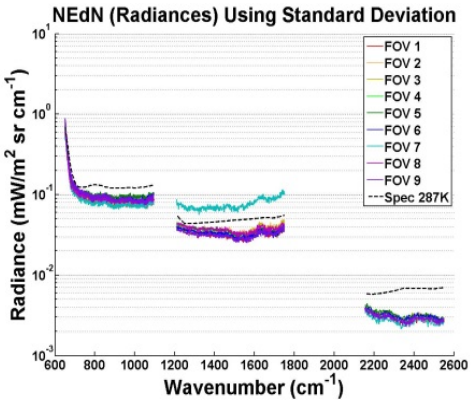
NPP: Total Imaginary NEdN
On-orbit vs TVAC4 MN

Orbit 6245

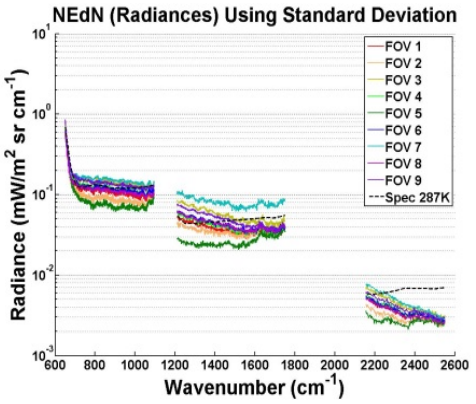
January 10, 2013

TVAC4 MN

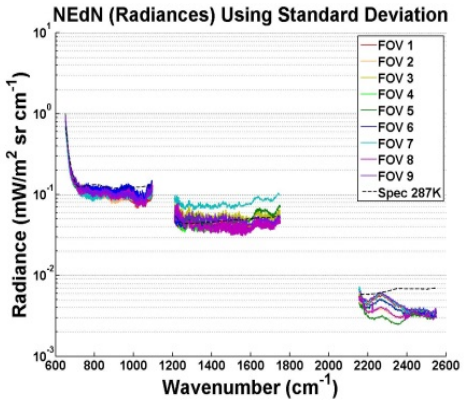
ICT



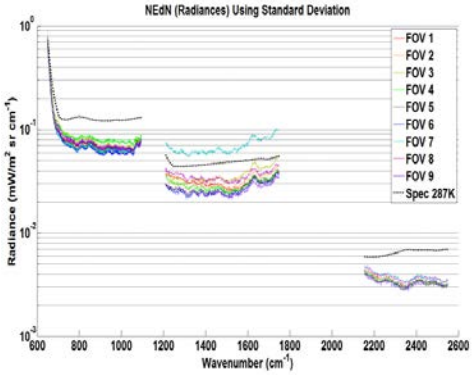
DS



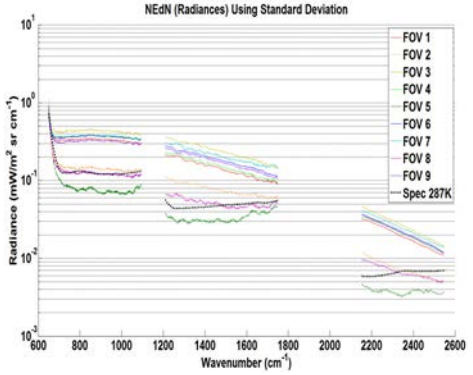
ES



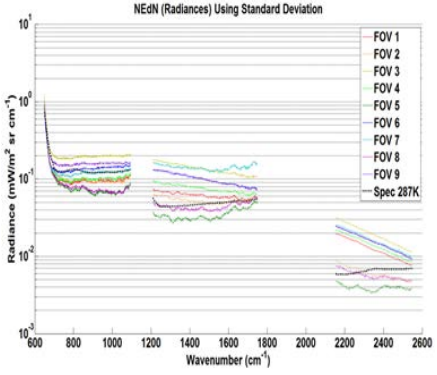
ICT



DS



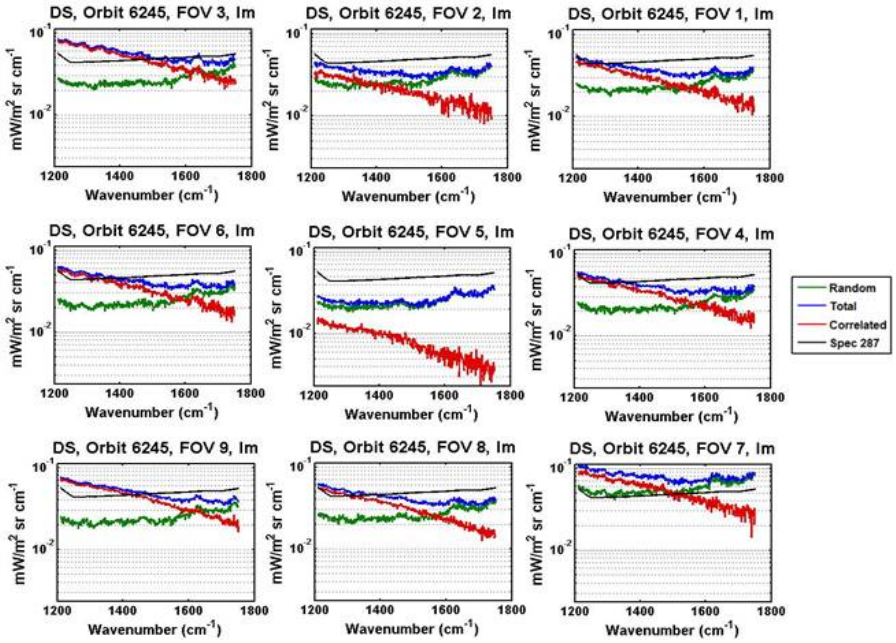
ECT



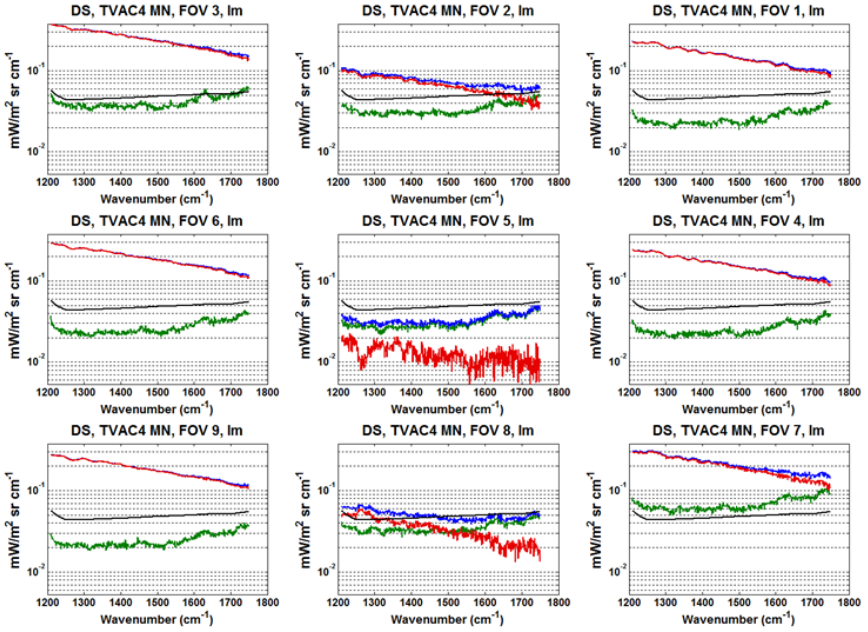
- Imaginary NEdN exhibits elevated level due to the spectrally correlated noise component
- Random noise is dominated by the intrinsic detector noise like in real NEdN
- On-orbit imaginary NEdN is lower than during TVAC4 especially for DS derived NEdN
- Negligible contribution of the correlated noise is observed in real NEdN shown previously

NPP: Correlated noise contribution
DS Imaginary NEdN

DS: **Orbit 6245**, January 10, 2013

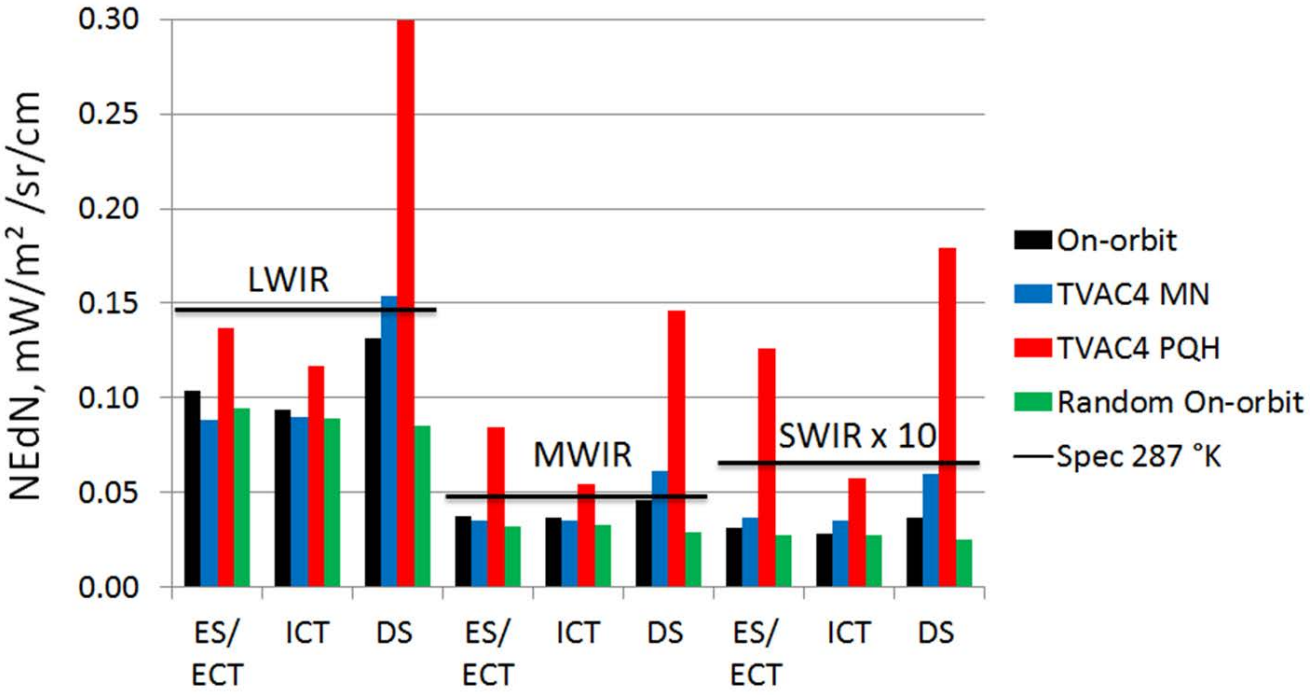


DS: **TVAC4 MN**



- Imaginary NEdN is extremely sensitive to any instrument artifacts and external vibration as compared to real NEdN.
- Corner FOVs are more susceptible to the tilt-induced OPD sample jitter
- DS derived imaginary NEdN has largest vibration sensitivity while ICT target exhibits the smallest vibration susceptibility.
- On-orbit correlated imaginary NEdN significantly lower than during TVAC4

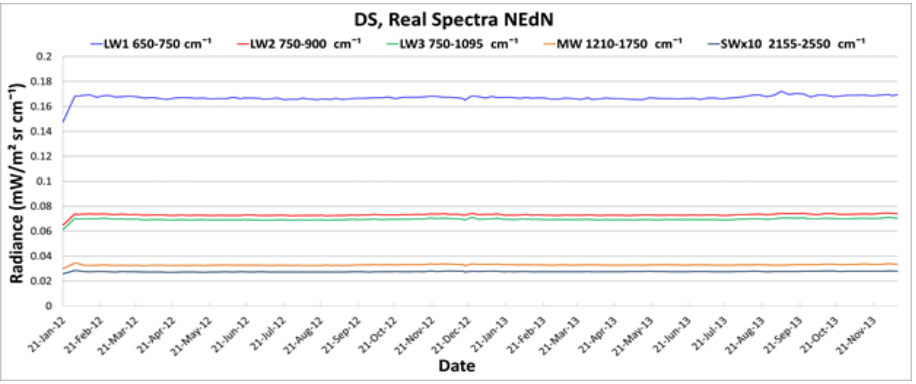
NPP: Average imaginary total NEdN. On-orbit vs. TVAC4



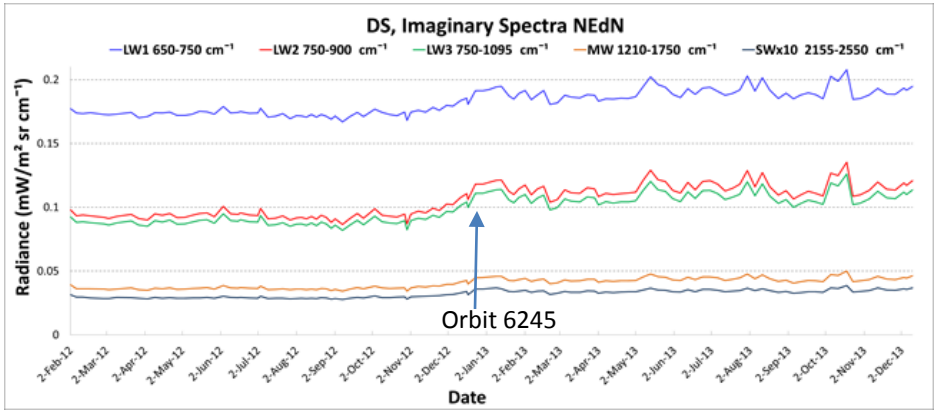
- On-orbit data : orbit # 6245 at January10, 2013 (max increase in the imaginary NEdN)
- During TVAC4 PQH test additional vibration from the test equipment was present
- On-orbit imaginary NEdN is comparable or smaller than TVAC4 MN value
- Only random NEdN component can be estimated on-orbit from ES view using PCA
- NEdN is averaged over each spectral band and all FOVs

NPP: DS derived average imaginary NEdN

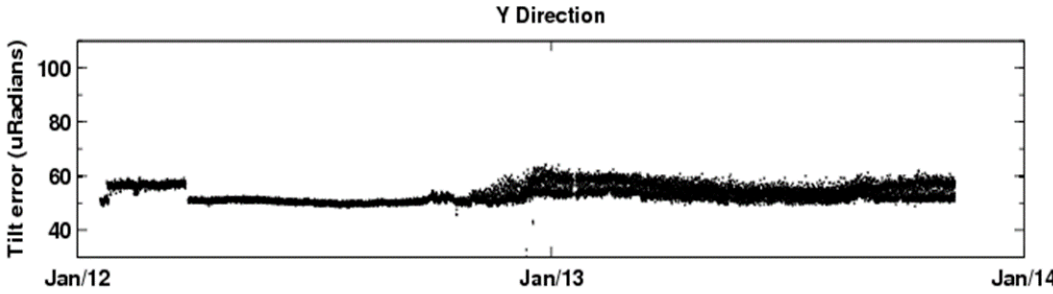
Real spectra NEdN



Imaginary spectra NEdN

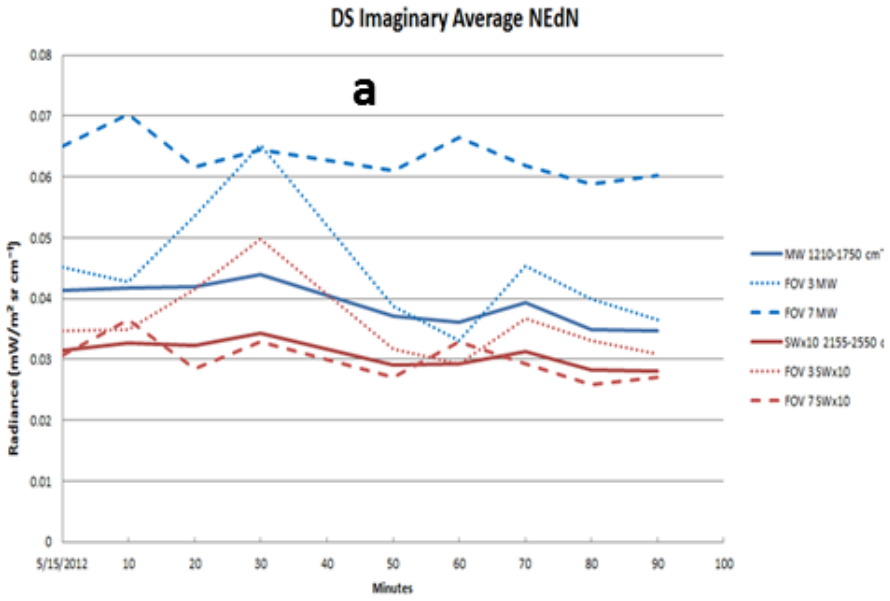


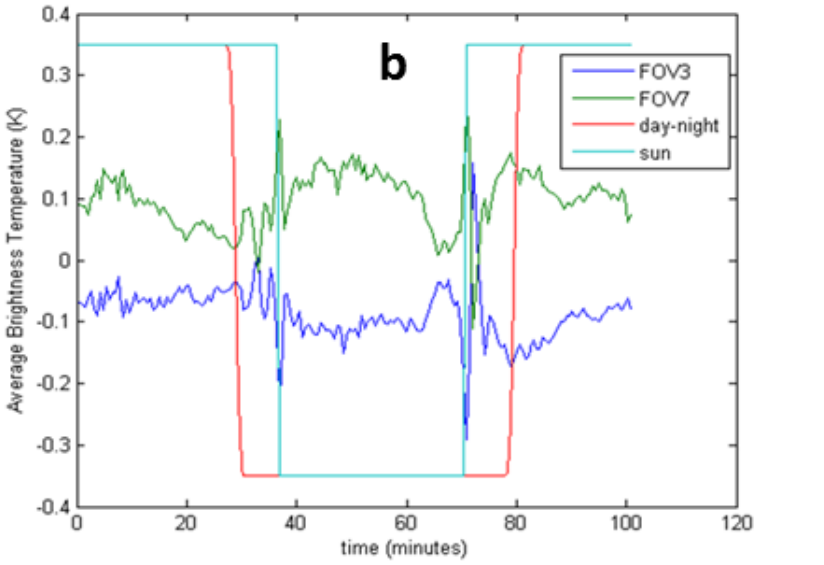
STAR NPP CrIS Housekeeping
DA tilt error in Y-direction,
hourly averaged



- NEdN has increased in the imaginary part of the DS spectra in all spectral bands (~30-40%)
- Increase in the imaginary DS NEdN correlates with DA tilt error in Y-direction
- Practically no change in real spectra NEdN is observed
- Possible source of small additional S/C vibration: ATMS scanning assembly

NPP: Orbital fluctuations in the DS imaginary NEdN





- DS imaginary NEdN exhibit slightly larger fluctuations ~10-30% over time as compared to the real NEdN and ICT derived NEdN (a)
- Variation are due to correlated noise component
- Larger noise occurs near North and South poles when the Sun light hit the Suomi NPP spacecraft during day/night transition (flight time of ~25 and ~80 minutes respectively)
- These variations in the imaginary NEdN correlate with FOV-to-FOV responsivity and small variations in BT of FOV3 and FOV7 (b)

J1 Bench test:
ECT Real NEdN, Standard resolution

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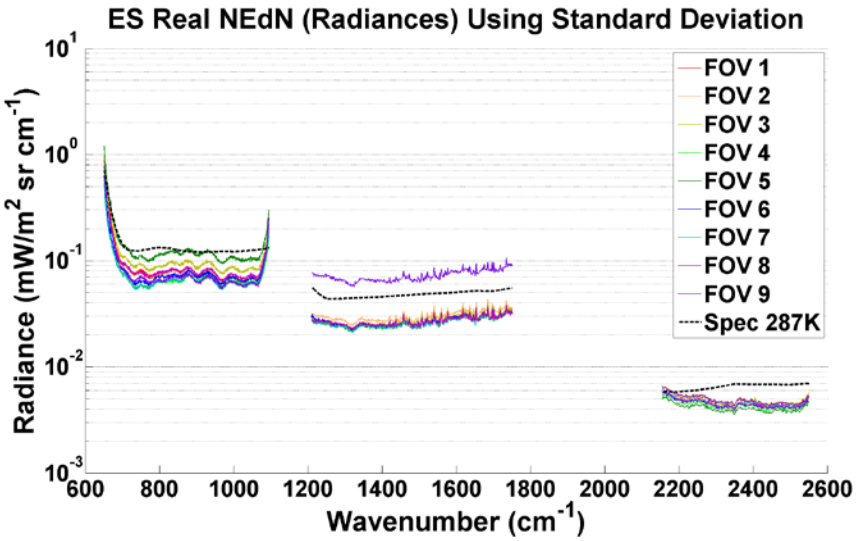
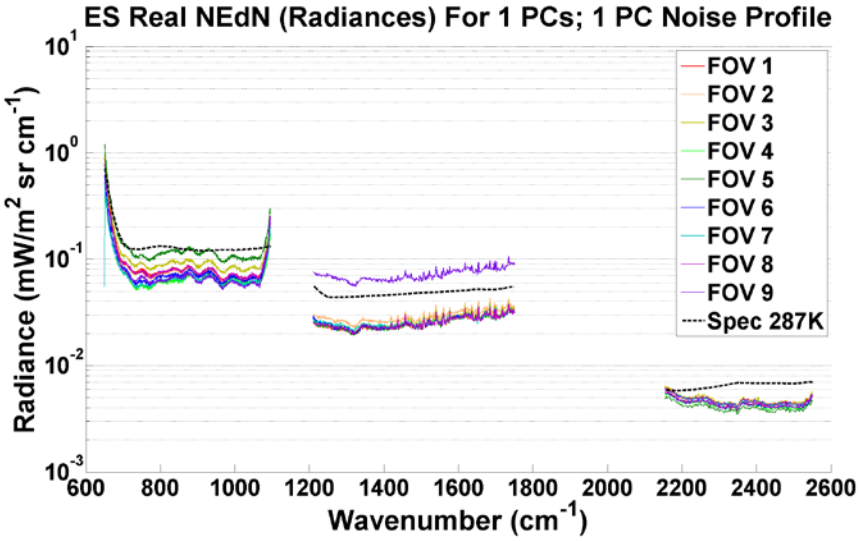
Total NEdN



Random NEdN component



- No contribution of correlated noise is observed
- Additional LWIR short wavelength tail is observed. It is probably due to combination of transmission and digital filter.
- MWIR FOV 9 is out of family as FOV7 for NPP CrIS

J1 Bench test:
ECT Real NEdN, Full spectral resolution

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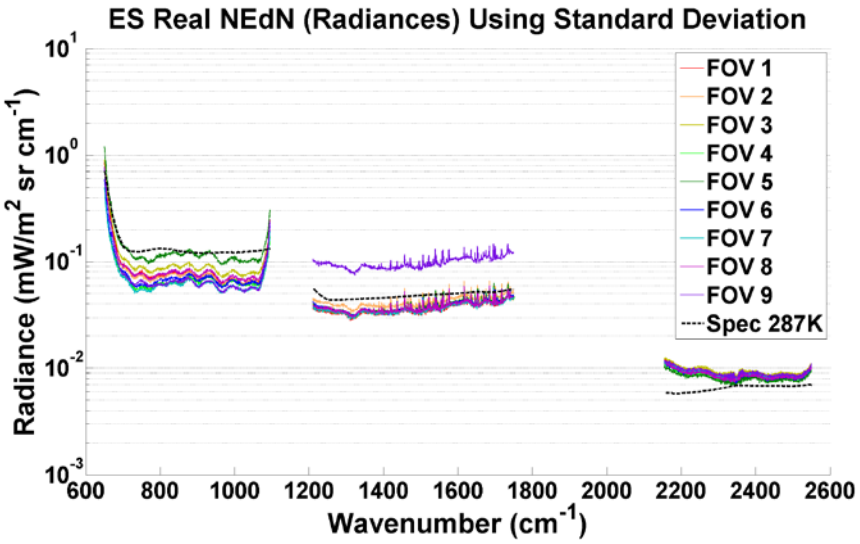
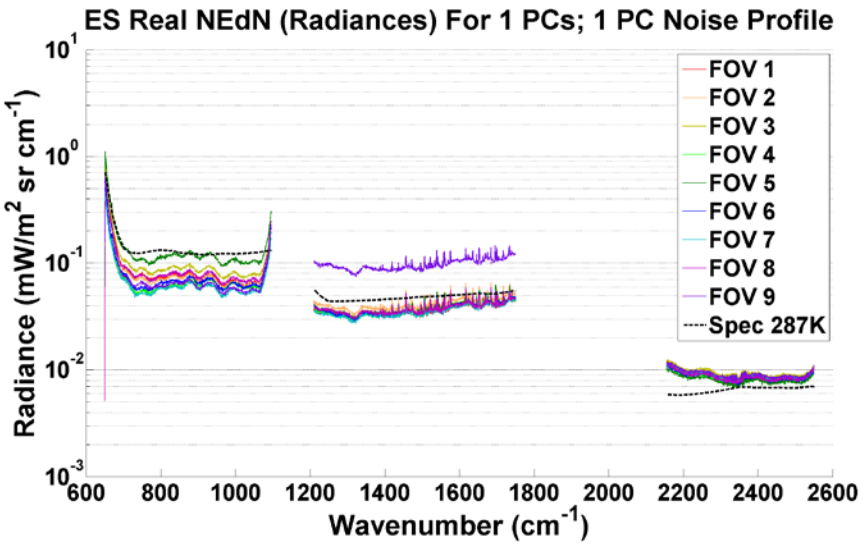
Total NEdN



Random NEdN component



- CrIS full spectral resolution noise in MWIR and SWIR bands is higher by ~x1.4 and ~x2, respectively, as compared to the CrIS standard spectral resolution
- Other features are the same as for standard spectral resolution

RRTVAC: ECT Real NEdN
Standard resolution

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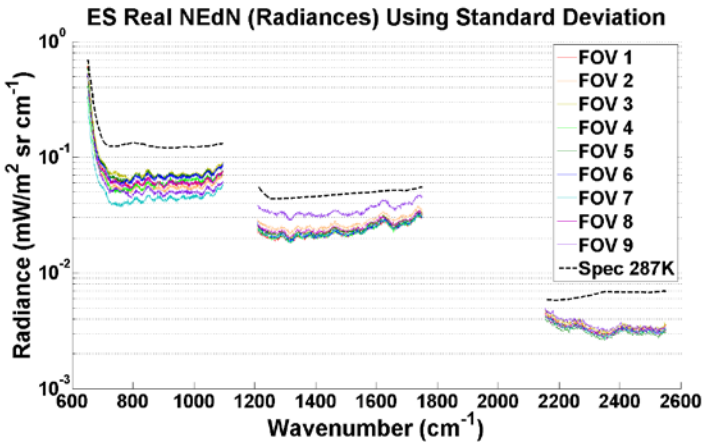
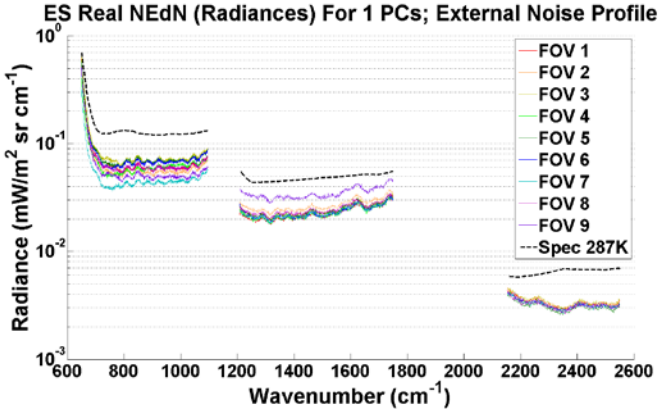
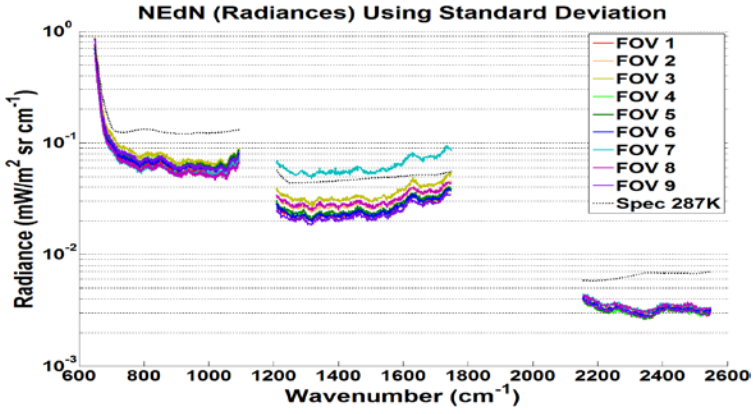
J1 RRTVAC: Total NEdN



J1 RRTVAC: Random NEdN component



NPP TVAC4 MN: Total NEdN



- No contribution of correlated noise is observed
- LWIR short wavelength tail seen in bench not observed
- MWIR FOV 9 is still out of family but is within specification
- J1 has comparable or smaller NEdN than NPP

RRTVAC: ECT Imaginary NEdN
Standard resolution

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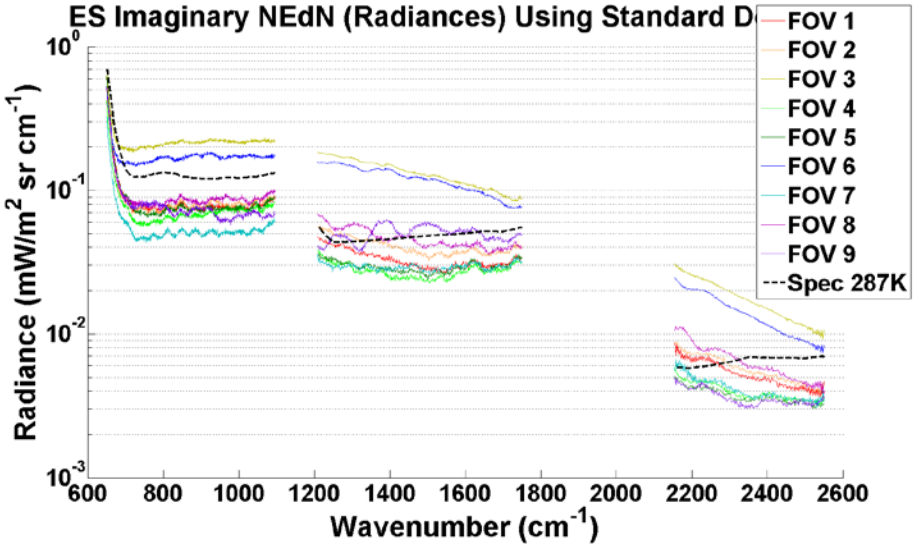
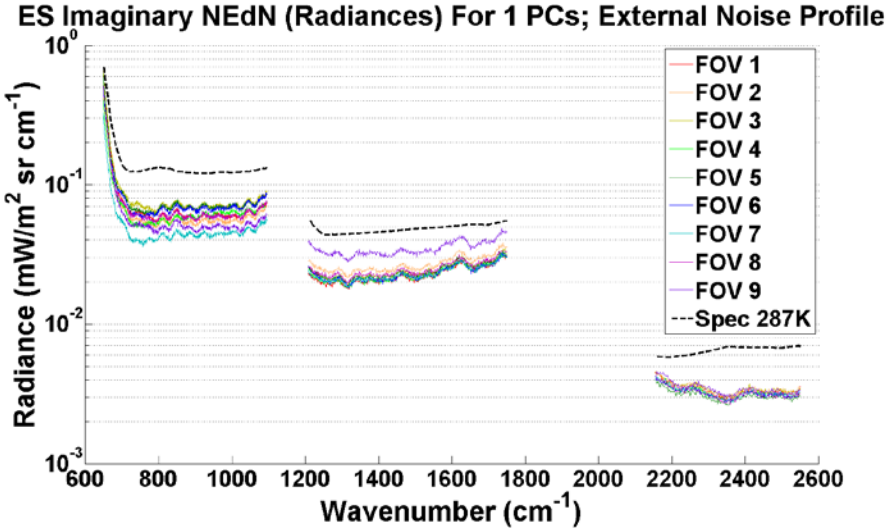
Total NEdN



Random NEdN component



- Contribution of correlated noise is observed
- Likely an ECT target alignment issue (FOVs 3 &6 higher for all bands)
- Significant FOV 2 FOV calibrated radiances difference also indicative of target alignment issue
- No impact on the real NEdN is observed

Conclusion

1. NEdN level meets mission requirements for both NPP and J1 instruments with a margin of typically 100% (except MWIR FOV 7 NPP instrument).
2. The intrinsic detector noise randomly distributed in spectral domain dominates total instrument NEdN. Negligible contribution of correlated noise is observed.
3. CrIS has comparable or smaller noise levels than AIRS and IASI heritage instruments (~2-3 times smaller in LWIR spectral band)
4. NEdN has remained extremely stable during on-orbit operations. Only small seasonal, orbital and spatial NEdN variations (<10%) are observe on-orbit.
5. Small anomaly ($\lesssim$50%) in LWIR FOR1 NEdN was observed on July 07 and September 10 and 12,2013. Remains stable on slightly elevated level (<10%)
6. As expected, for both instruments full spectral resolution noise in MWIR and SWIR bands is higher by ~x1.4 and ~x2, respectively, as compared to the CrIS standard spectral resolution.
7. Imaginary NEdN is extremely sensitive to any instrument artifacts and external vibration as compared to the real NEdN and may serve as an important tool to monitor on-orbit performance of CrIS

J1 RRTVAC test (Exelis): Excellent NEdN Performance

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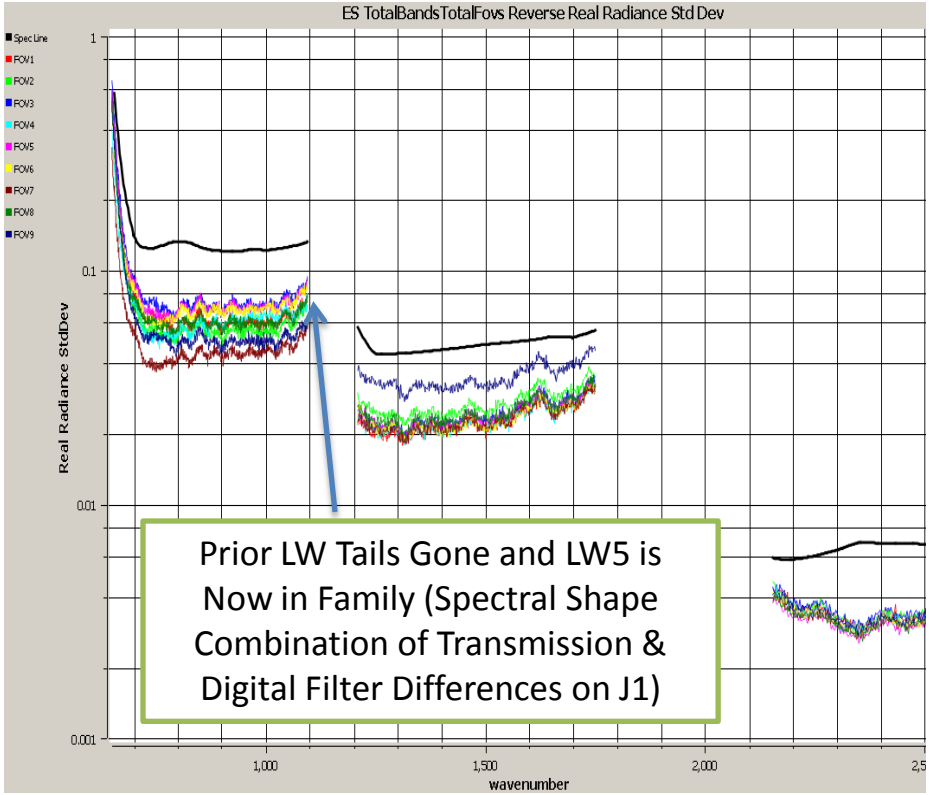
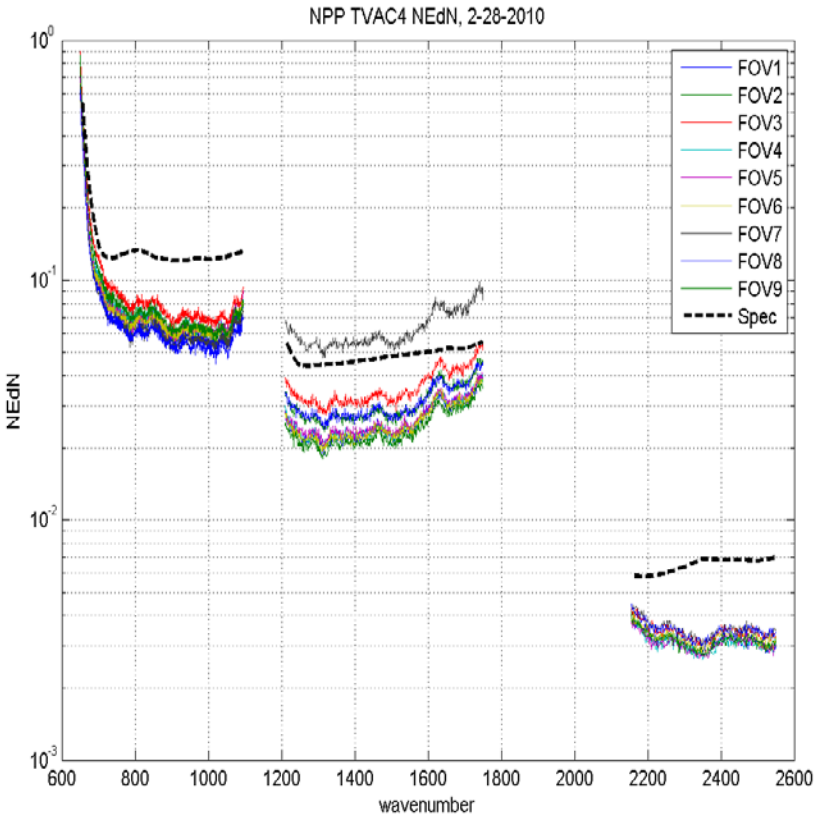
J1 RRTVAC2



Prior LW Tails Gone and LW5 is Now in Family (Spectral Shape Combination of Transmission & Digital Filter Differences on J1)

NPP

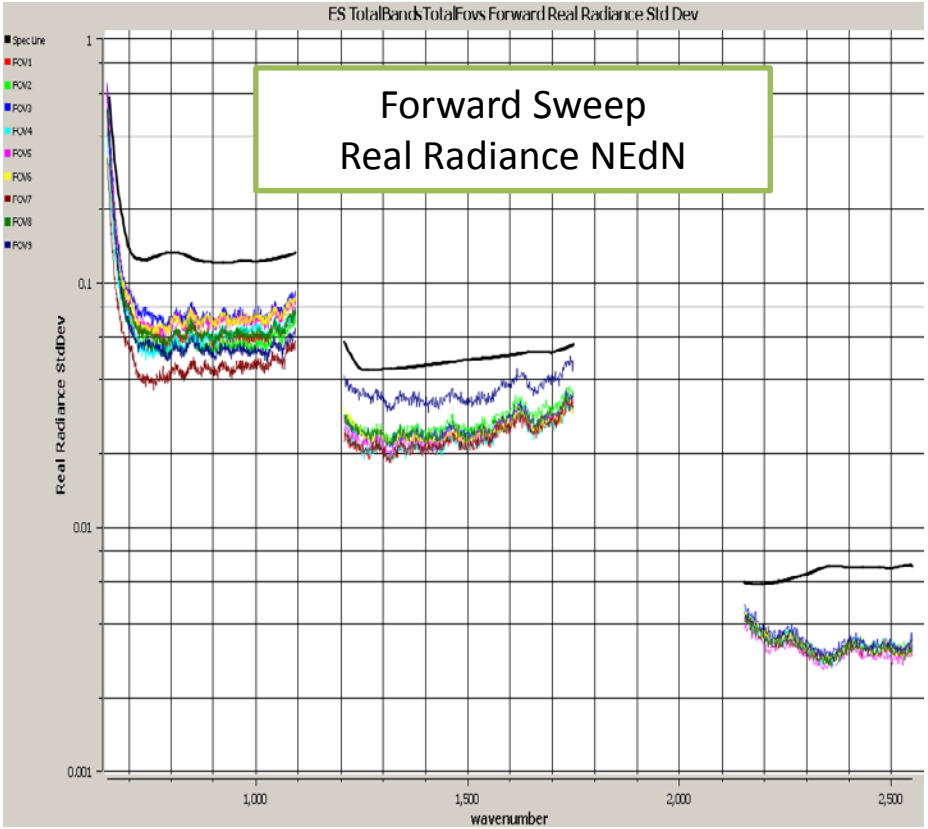


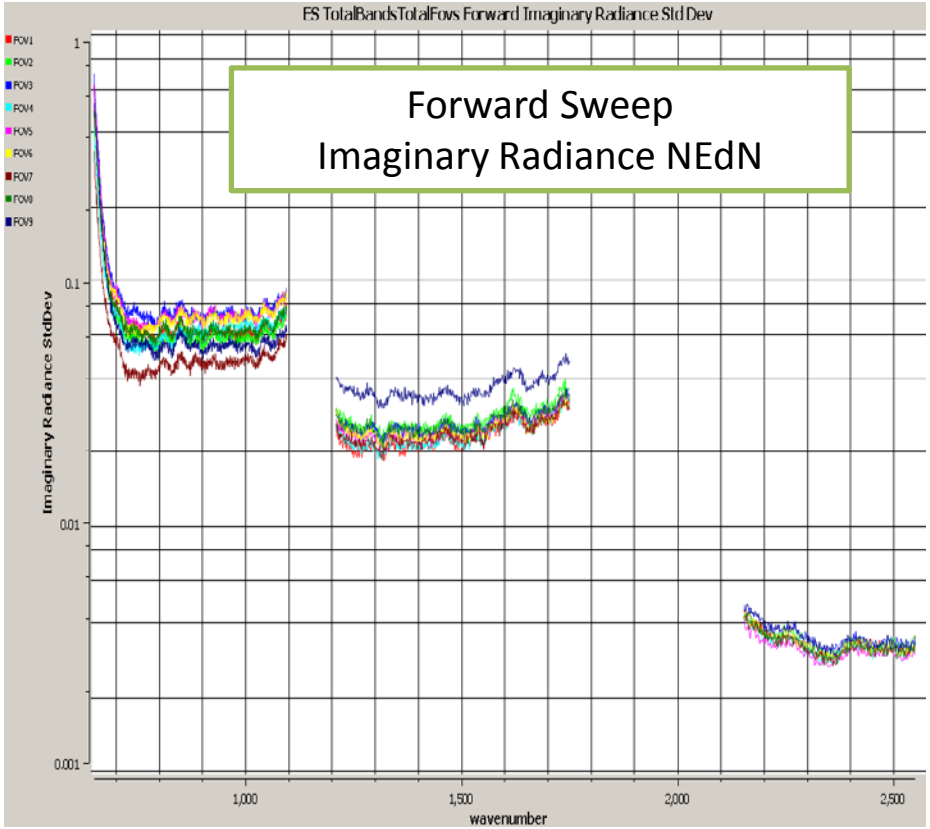
- J1 NEdN Spec Applies Only to MN
- RRTVAC Results Predict Full Compliance (MW9 may still change with cool-downs)

RRTVAC NEdN Performance is Similar or Better than NPP

J1 RRTVAC test (Exelis): Real NEdN vs Imaginary NEdN

Space Dynamics Laboratory
Utah State University Research Foundation





- Small increase in the imaginary noise is observed (the same was observed for NPP sensor). No impact on the real NEdN is observed.
- Most probably it is due to correlated noise component (analysis is underway)
- This is typical for normal FTS instrument performance