Focal Plane Development

US Army RDECOM CERDEC
Night Vision and Electronic Sensors Directorate (NVESD)

Dr. A. Fenner Milton
Director
NVESD

What I Told You in 2004

- NEΔT (vs. T) measurements with low fno and big pixels are indicative but of little practical interest
- InSb is the true competition for tactical systems (the gold standard)
- MWIR arrays with η_p < 50% are of no interest (need to cover high fno cold weather conditions)
- Dual Band MWIR/LWIR is the future.
- Dual fno with good cold shielding is needed to take full advantage of dual band.

What I Will Tell You in 2006

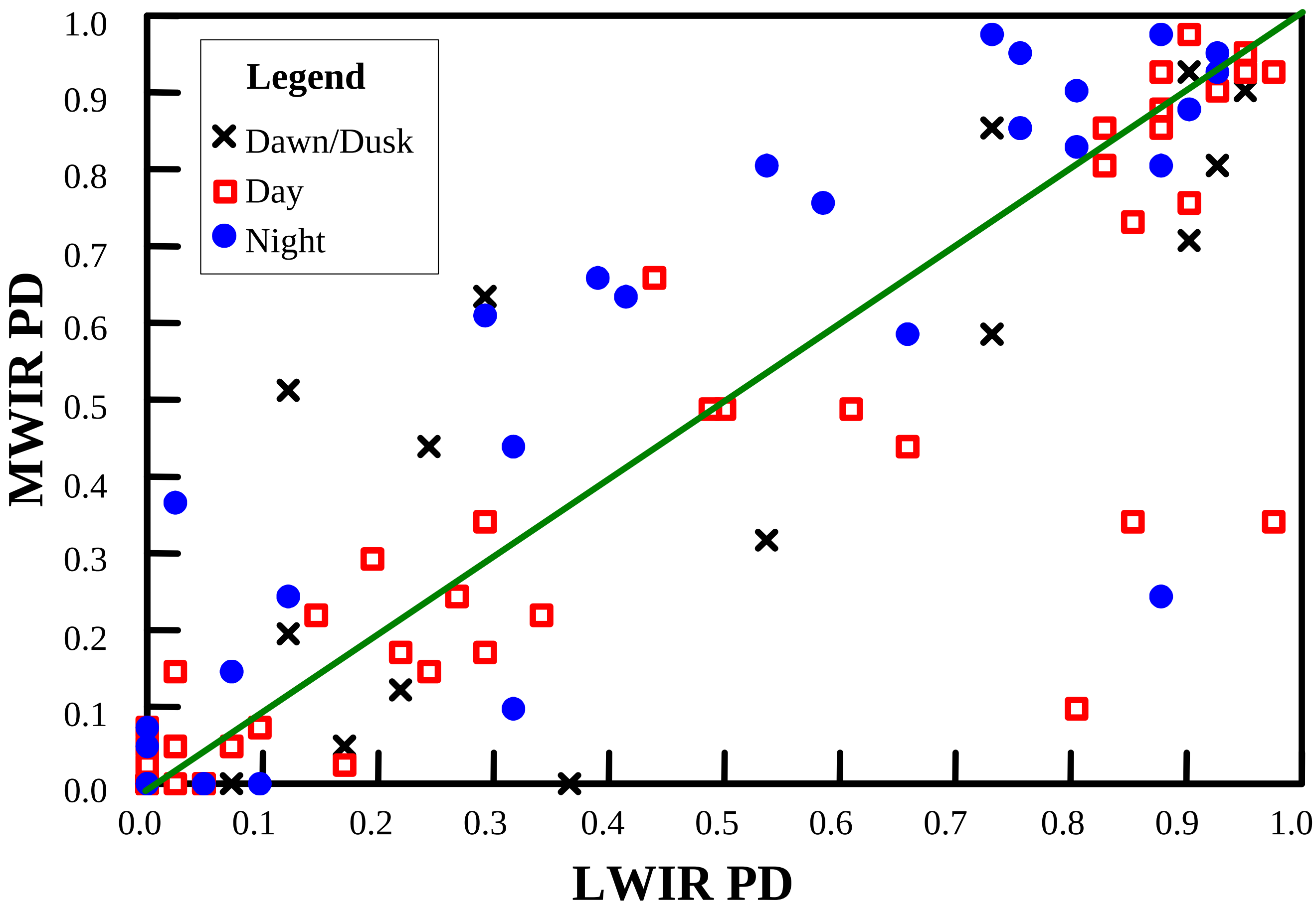
- NVESD still committed to Dual Band
  - Preferred band depends on environmental condition
  - Turbulence often limits usefulness of superior MWIR Optical MTF (LWIR superior otherwise)
  - Dual fno Dewar technology (low fno for search, high fno for ID) maturing on schedule
- NVESD embarking on measurement program to compare:

InSb, MCT, QWIP, Type 2 Superlattice

More than just NEΔT

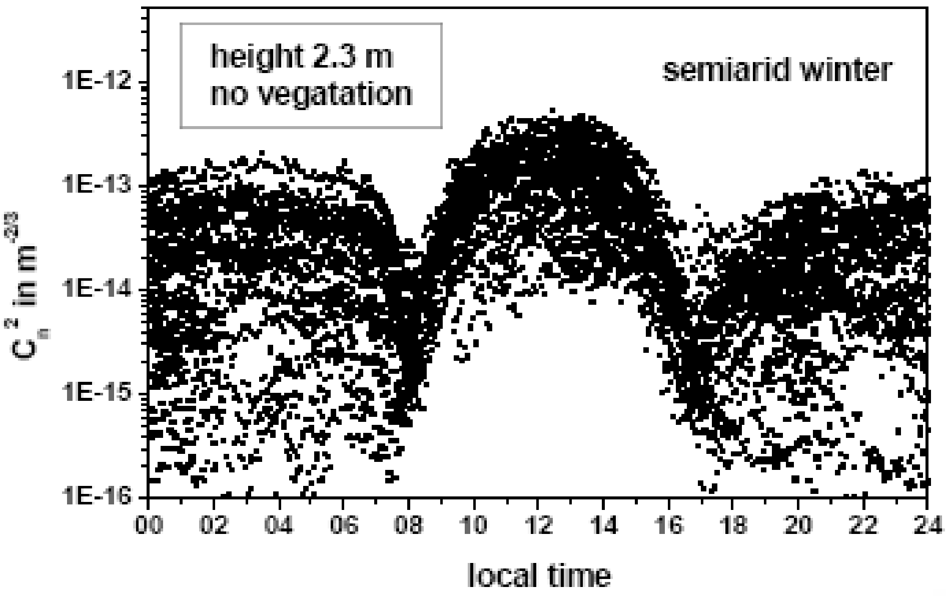
Comparison of MWIR and LWIR Probability of Detection

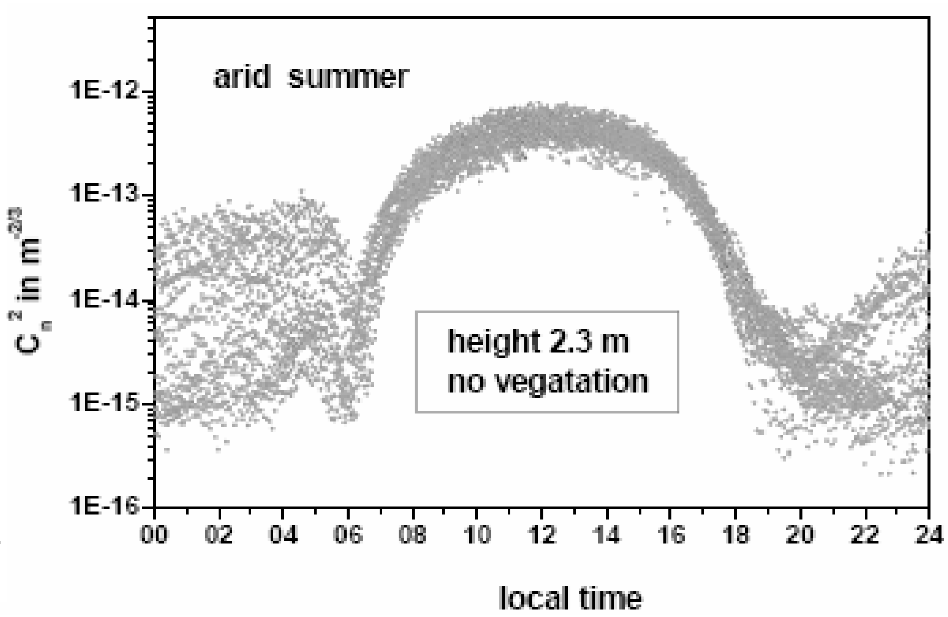
LWIR vs. MWIR PD



Turbulence Cn² Frequency of Occurrence Data

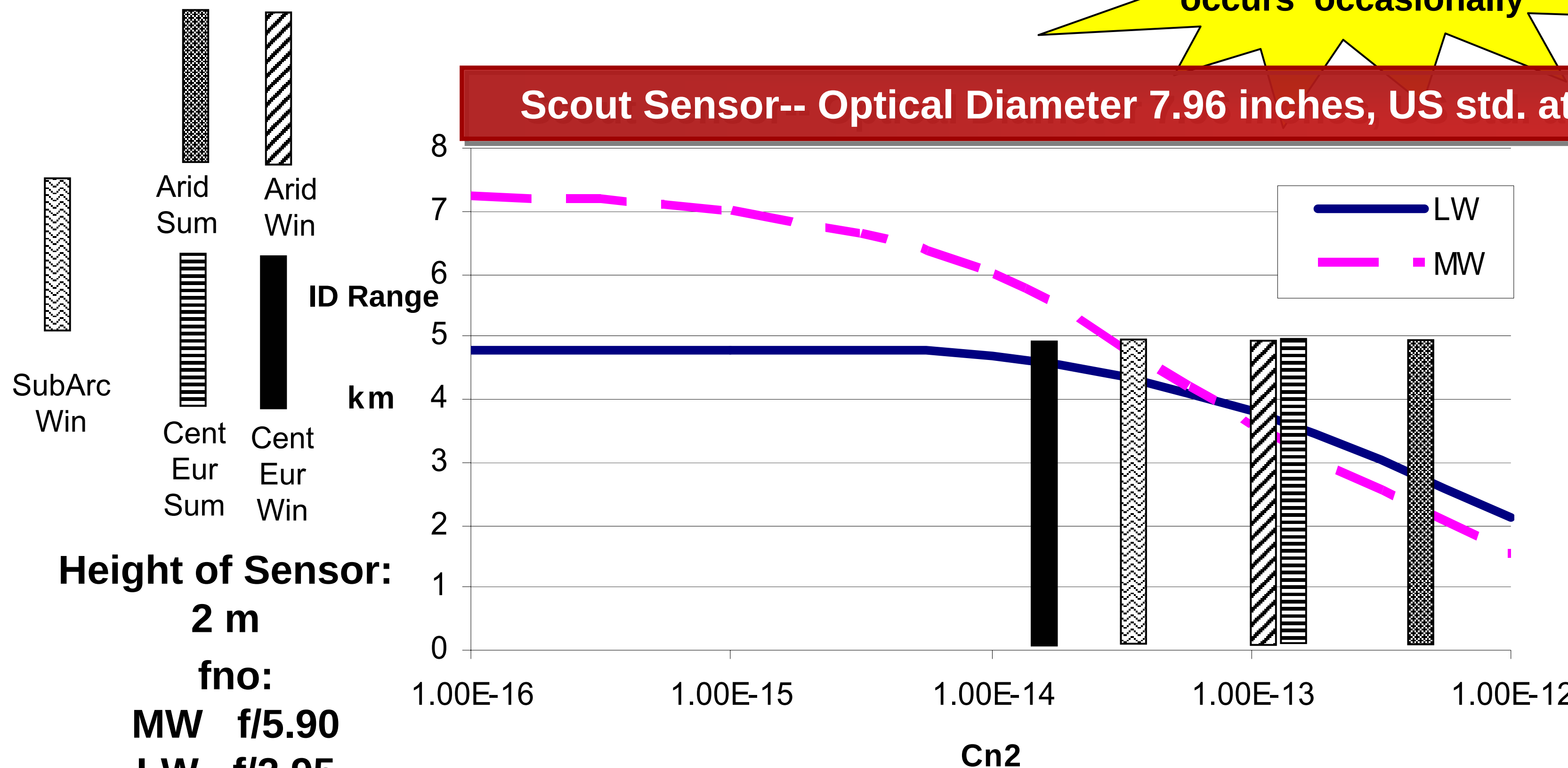
- Weiss-Wrana's data showed a characteristic day/night variation in the arid/semi-arid climate:
- Cn^2 decreases with height above the ground





50% Cumulative Probability Values of Cn^2 (day and night averaged) per climate and season vs. ID Range

MWIR advantage only occurs occasionally



Height of Sensor: 2 m

fno:

MW f/5.90

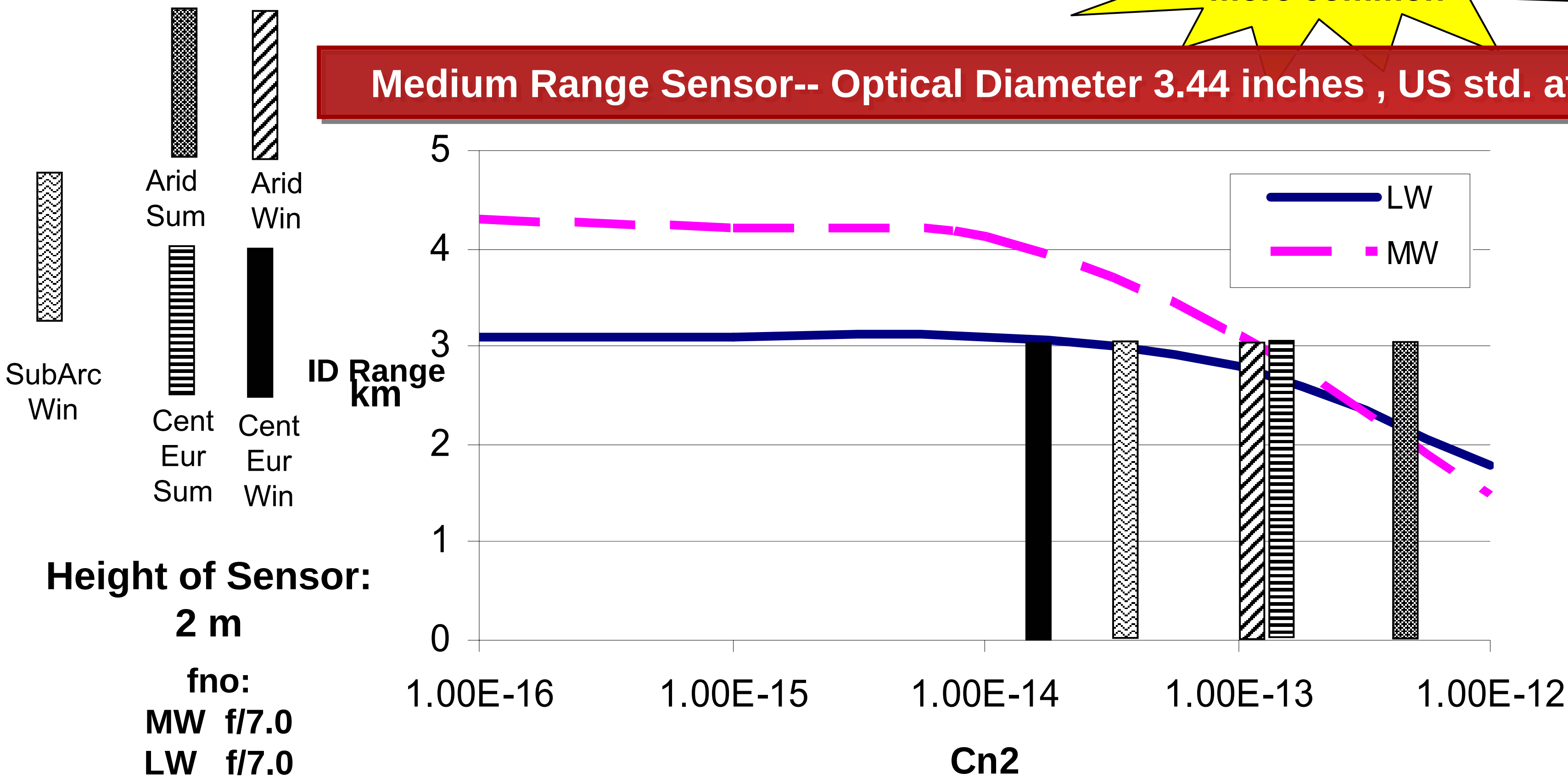
LW f/2.95

For large aperture systems- ground to ground medium-to-high turbulence conditions (where LWIR and MWIR perform similarly) are much more common than low turbulence conditions (where MWIR performs better than LWIR)

50% Cumulative Probability Values of Cn2 (day and night averaged) per climate and season vs. ID Range

MWIR advantages more common

Medium Range Sensor-- Optical Diameter 3.44 inches , US std. atm.



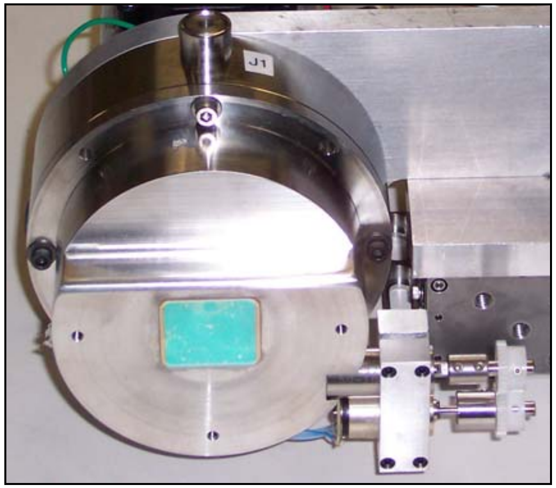
Height of Sensor: 2 m

fno:
MW f/7.0
LW f/7.0

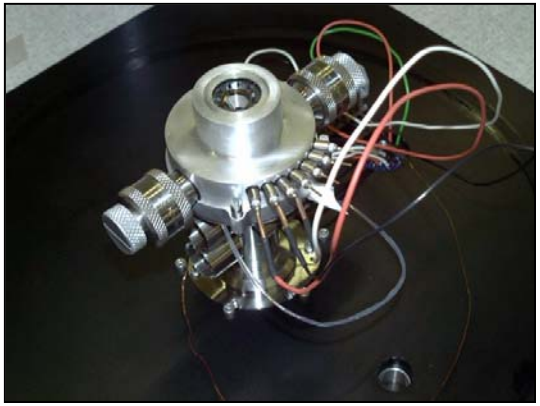
For small aperture systems- ground to ground medium-to-high turbulence conditions (where LWIR and MWIR perform similarly) are less common than low turbulence conditions (where MWIR performs better than LWIR)

Dual F# Dewars with High Cold Shield Efficiency

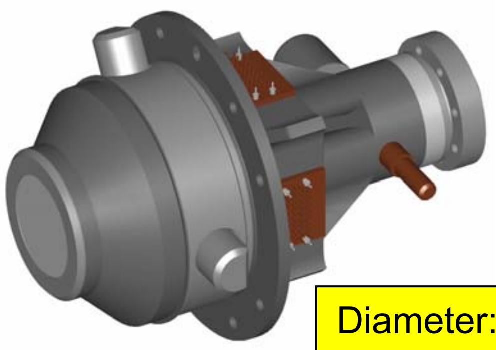
OKSI Pour-fill Prototype
(June 2002)



OKSI 3rd Gen Plate FLIR
(July 2004)

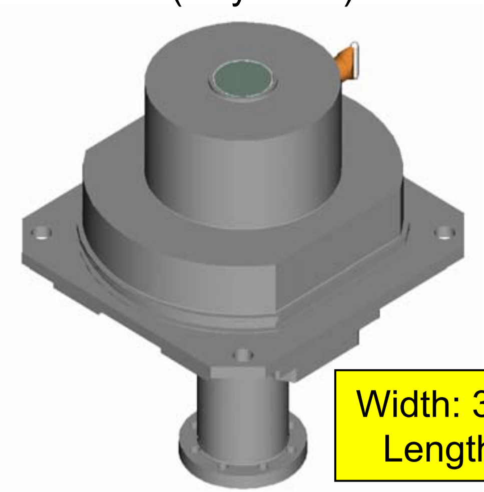


OKSI SADA II Demo
(December 2004)



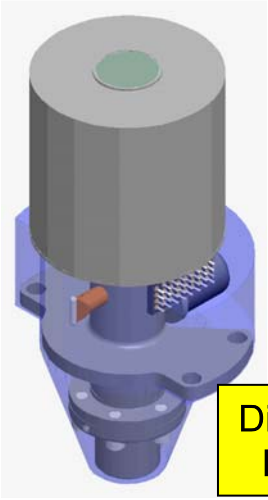
Diameter: 3.175”
Length: 4.58”

L3/CMC 3rd Gen Prototype
(July 2005)



Width: 3.0” x 3.4”
Length: 4.55”

RVS 3rd Gen Prototype
(Jan 2006)



Diameter: 1.65”
Length: 4.0”

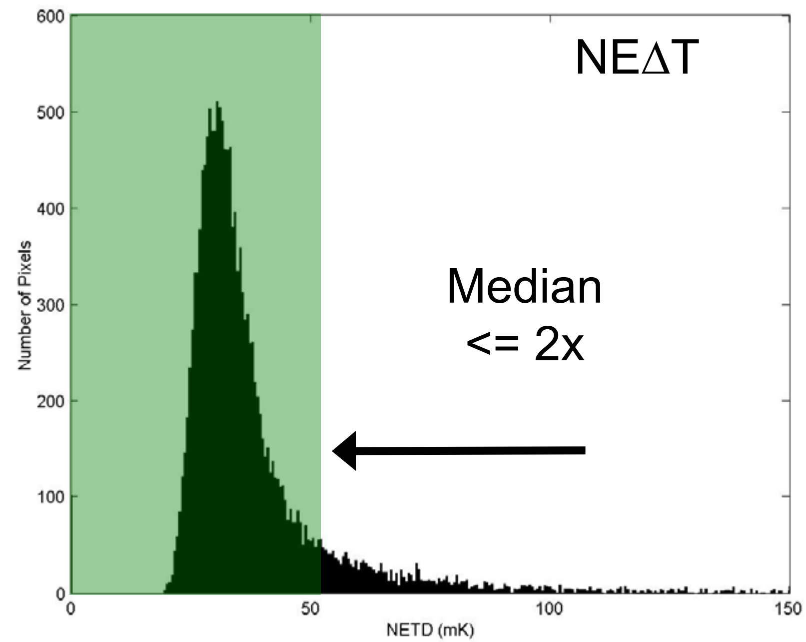
3rd Gen 640x480 “Slim-line” Concept
(Jan 2007)

Low F# for search – High F# for ID

NVESD Operability Criteria

NVESD Definition for Operability:

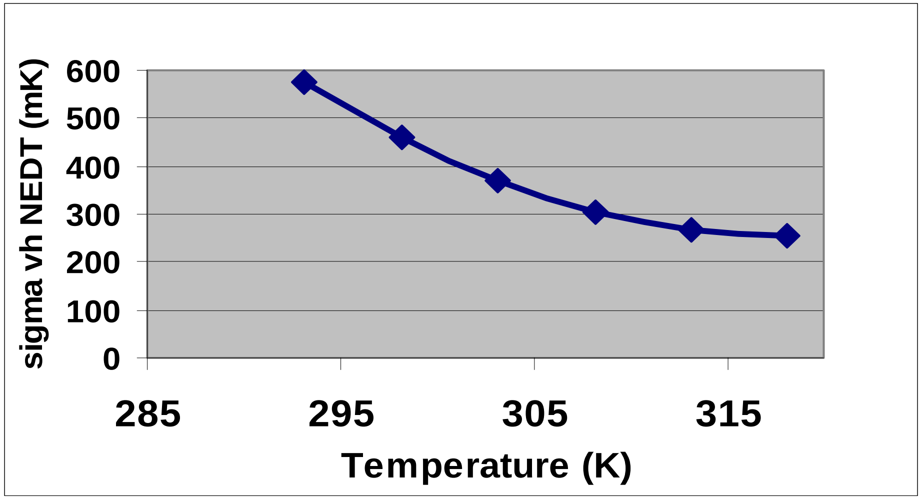
- 0.5x median ≤ Response ≤ 1.5 x median
- NEΔT ≤ 2 x median NEΔT
- Any pixel that meets both NEΔT and responsivity is considered operable.



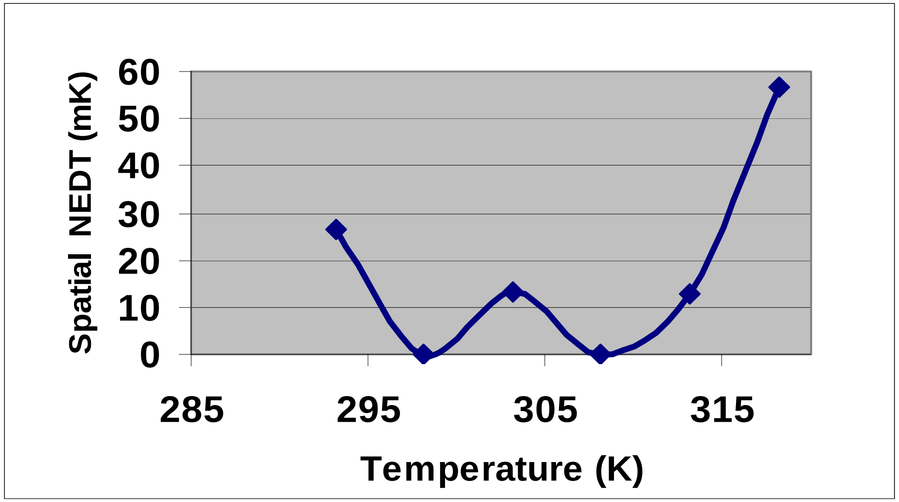
NVESD Non-Uniformity Criteria

- Non-Uniformity (NU) is defined as the uncorrelated spatial noise of an FPA divided by the mean signal at 300K
- Pre-correction signifies that the NU is before correction (raw data)
- Post-correction NU or Residual Non-Uniformity is the NU at a mid-point between the NUC points after 2-point NUC; here we selected 295K and 305K as the NUC points. Multiple correction points will be required to accommodate adequate dynamic range.

Merlin InSb - Uncorrected

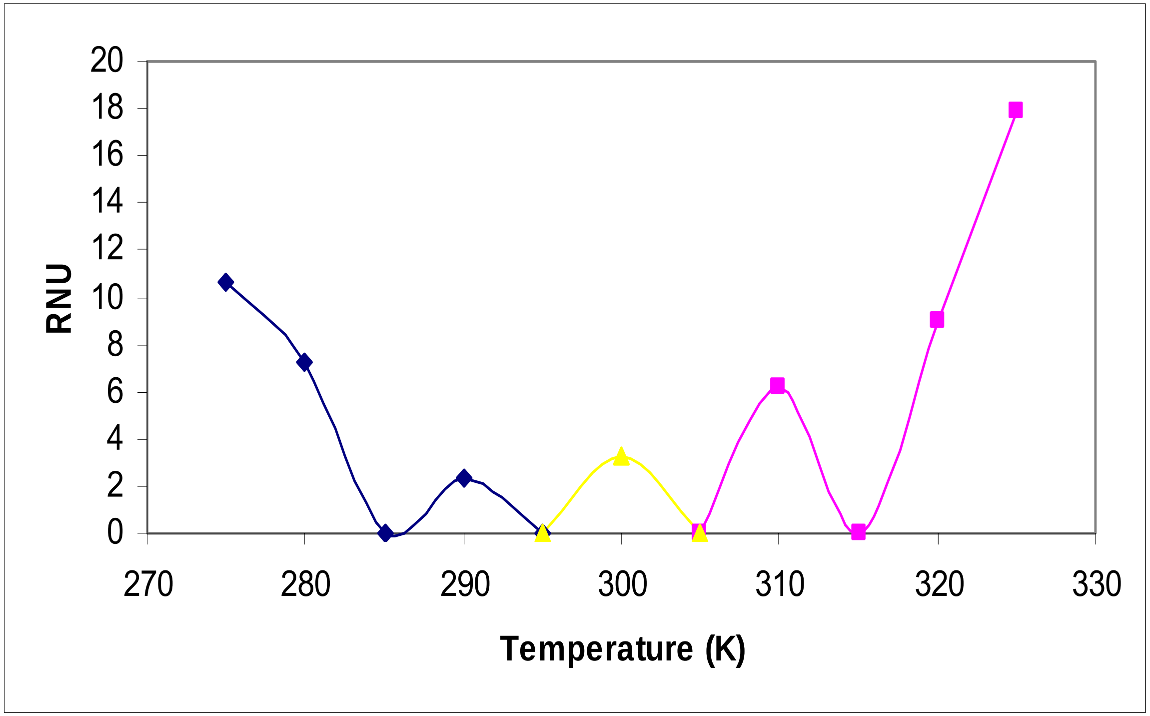


Merlin InSb Corrected



Smaller non-uniformity is better, but it is residual non-uniformity that is important.

Multipoint Linear NUC Correction $\Delta T = 10^o$



Adequate dynamic range can be accommodated

Stability

- Using a single set of NUC coefficients, we examined the RNU as a function of time
- Stability after 24 hours is defined as

$$\frac{RNU_{TIME=24HRS}}{RNU_{t0}}$$

where t0 could be the factory settings or the first NUC after turn-on.

- Stability after thermal cycling is defined as

$$\frac{RNU_{after\ thermal\ cycle}}{RNU_{t0}}$$

The optimum value of stability is 1

Comparison of FPAs

Description	NEΔT (mK)	Operability	Pre-correction Non-Uniformity	Post-correction Non-Uniformity	Spatial NEDT of the detector material (mK)	Spatial NEDT (mK) (Includ. ROIC)	Stability @ 1 day	Stability after thermal cycle
InSb 320x240	15.8	99.5%	0.0074	0.00088	25.9	26.6	1.4	2.4
InSb 640x512 *	15	99.93%		0.00063	18.5			
3rd Gen MWIR HgCdTe/CdZnTe 640x480	18.6	99.85%	0.014	0.00032	9.41	19.6	1.93	19.01
3rd Gen LWIR HgCdTe/CdZnTe 640x480	21.7	99.16%	0.012	0.00024	14.1	28.7	1.22	4.75
MOVPE LWIR HgCdTe/GaAs 256x256	20.6	99.32%	0.033	0.0024	141	135	1.03	7.66
MBE LWIR HgCdTe/Si 256x256	24.3	93.6%	0.0822 0.0795 0.0837	0.00609 0.00463 0.00751	358 272 442	180.9 146.4 241.0	1.233 5.054 0.93	3.093 8.827 3.83
LWIR QWIP 640x512	28.3	99.98%	0.00044	0.00037	21.7	22.4	1.07	0.97

*Vendor Data- The vendor definition of operability contains several parameters including any pixel whose correction coefficient for gain is >1.4 or less than 0.75 or any pixel whose NEΔT>75mK is considered inoperable. The RNU is defined by any pixel whose corrected value deviates by more than 25mK. Corrected over a span of 10^{o}-40^{o} C ($\Delta T=30^{o}$).

QWIP Delivery Dates

Company	Description	Order Date	Delivery Date
JPL	MWIR/LWIR QWIP	August 2002	Due 1-2 months
QWIPTECH	LWIR/LWIR QWIP	October 2002	30 September 2006
Sofradir	MWIR QWIP	November 2004	Due ~1.5 months
AIM	MWIR T2SL	2005	Due ~ 1 month
Indigo/QmagiQ	LWIR QWIP	9 June 2005	September 2005

Conclusions

Of the FPAs examined

- InSb shows excellent operability with very good raw non-uniformity and residual non-uniformity.
- All FPAs show adequate operability (>99%) except MBE LWIR HgCdTe/Si.
- HgCdTe on CdZnTe is more uniform than HgCdTe on alternate substrates in both raw and residual non-uniformity.
- The LWIR QWIP has the highest operability and lowest raw non-uniformity of the measured devices. Its residual non-uniformity is only slightly better than its raw value.
- However, post-correction non-uniformity was not a problem with the FPAs, except HgCdTe on alternate substrates, as long as multipoint correction was used with a ΔT between points of 10^{o}.
- Stability at one day seems adequate for all FPAs however there are uncertainties for MBE LWIR in that the data was not repeatable.
- Stability after a thermal cycle is inadequate in all cases except QWIP. The NUC for other FPAs must be recalibrated after each cool down.

Acknowledgements

- For analysis of environment and turbulence
  - Phil Richardson
- For measurement and analysis of FPAs
  - Dr. Whitney Mason
  - Tomas Cincotta
  - Khoa Dang
  - Mike Fields
  - Patrick Maloney
  - Tim Mikulski
  - John O'Neill
  - Dr. Jason Zeibel
  - Nicole Devitt
  - John Devitt of L-3 Cincinnati Electronics for InSb data