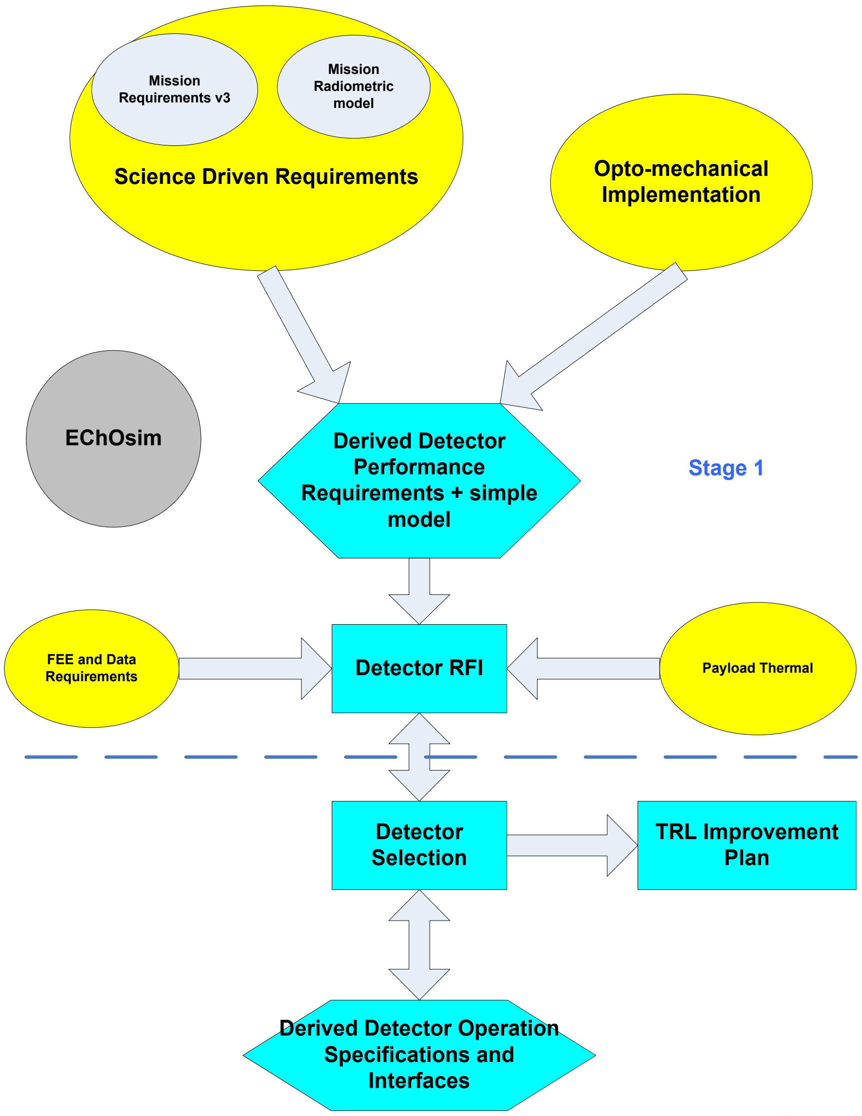
Thanks to the group

- Ian Bryson (UK ATC) – WG coordinator, Selex PoC
- Naidu Bezawada, Alistair Glasse (UK ATC) – Detector & SiAs experts
- Ranah Irshad , Tanya Lim (RAL) – systems engineering, Ground Segment
- Enzo Pascale (Cardiff Uni) – Raytheon & Teledyne PoC, LWIR arrays specialist
- Frederic Pinsard, Christophe Cara (CEA) – Sofradir PoC, MWIR arrays and module
- Giancarlo Bellucci (Italy) – VNIR module representative(s)
- (+ Gianluca Morgante – Thermal)
- Neil Bowles (Oxford) – LWIR Module Lead
- Ana Belen, Mirek Rataj (Spain / Poland) – SWIR module representative(s)
- Paul Hartogh/ Peter Börner (MPS) – AIM PoC, detector electronics expertise
- Mauro Focardi (Florence) – FEE expertise, Interface to Electronics WG
- Jan-Rutger Schrader, (SRON) – FAIR (European SideCar ASIC programme) representative
- Roland Ottensamer (Vienna) – Austrian contribution to electronics (TBC)
- Marc Ollivier (Paris) Bruce Swinyard (UCL) Science Team
- Pierre-Elie Crouzet, Martin Linder - ESA representatives

Aims of this working group

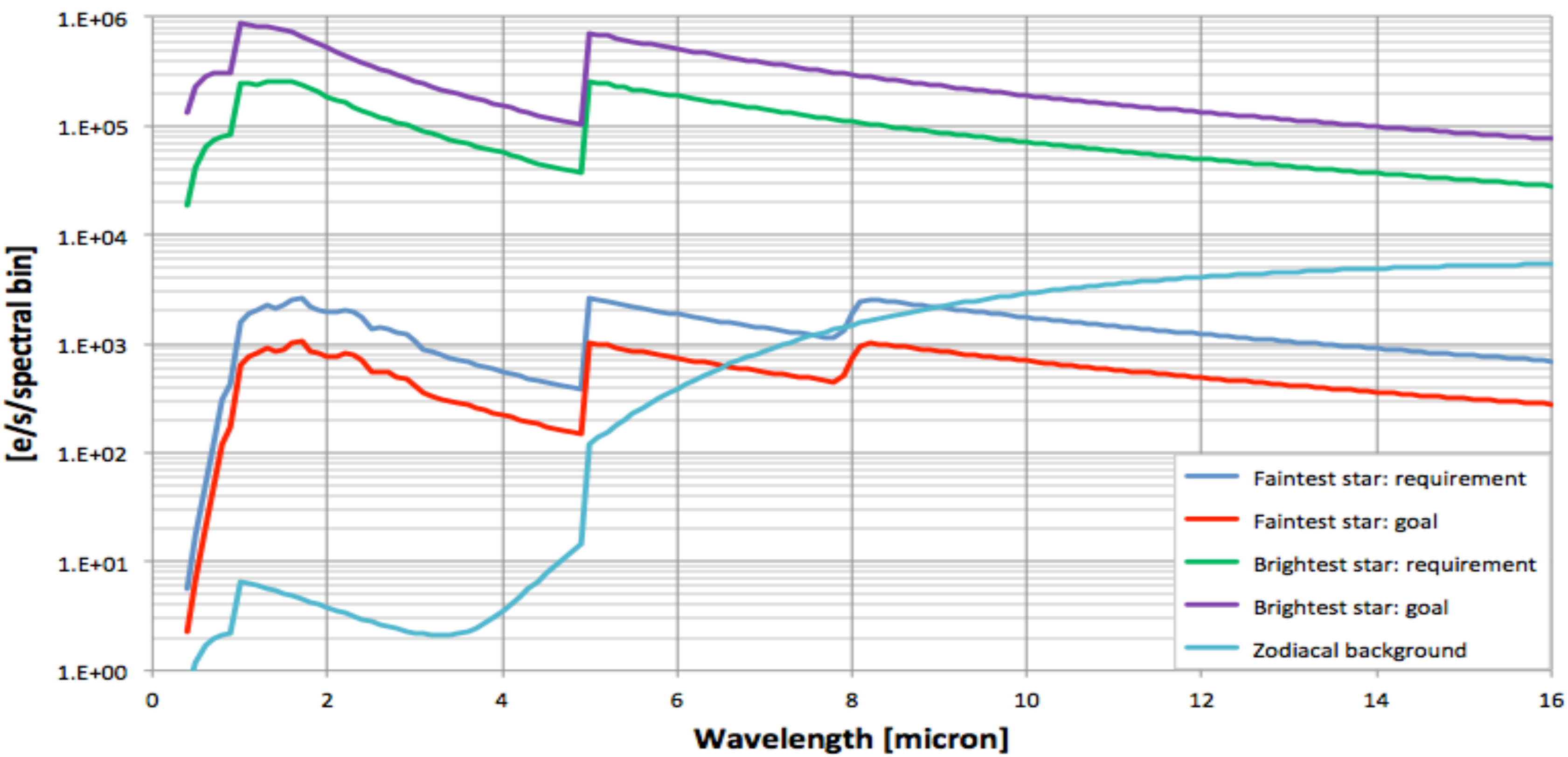
- Stage 1: Establish the current status of detectors
- Stage 2: Develop the detector system requirements for all channels in a consistent way
- Stage 3: Make recommendation on detector choice with necessary development plans to meet the required TRL levels next year



Input data

Key requirement to meet is R-PERF-350:

$$Noise_{Total} \leq \sqrt{(N_0(\lambda, \Delta\lambda) + zodi) \times (1 + X)}$$

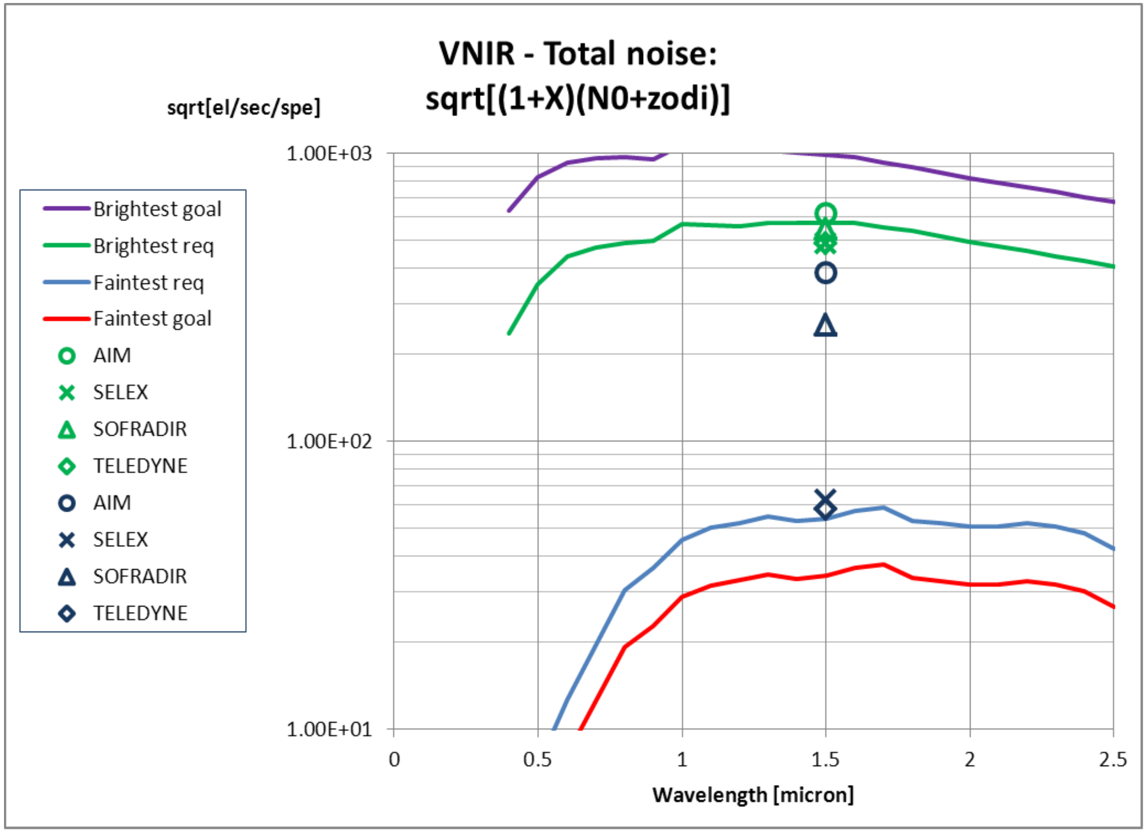


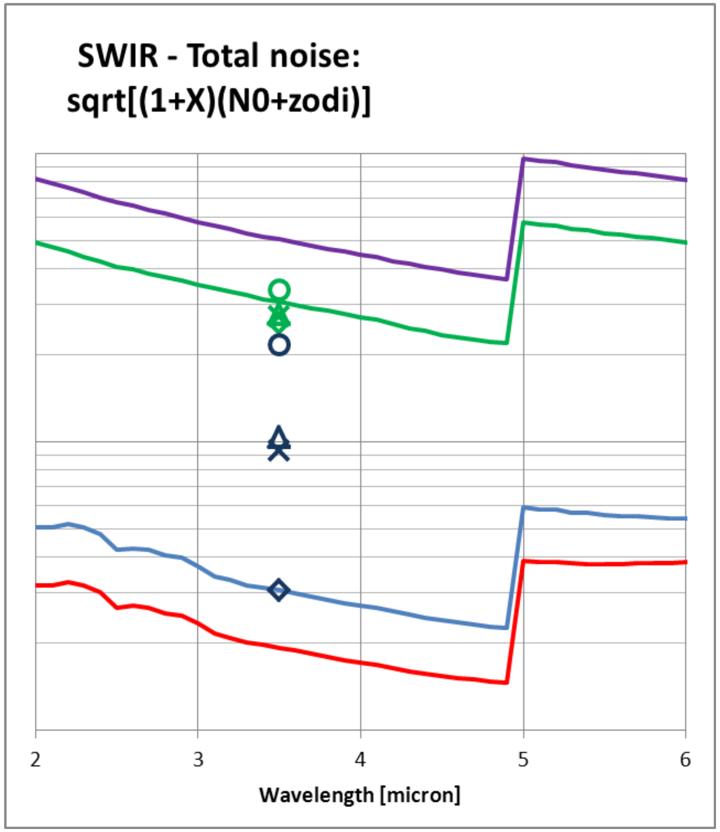
Comparison against existing systems

- Simple Performance Model
  - MRD based spread-sheet model from radiometric model.
  - Cross-checked model against EChOSIM.
  - Inserted performance from either existing detectors and/or current estimates of possible performances.

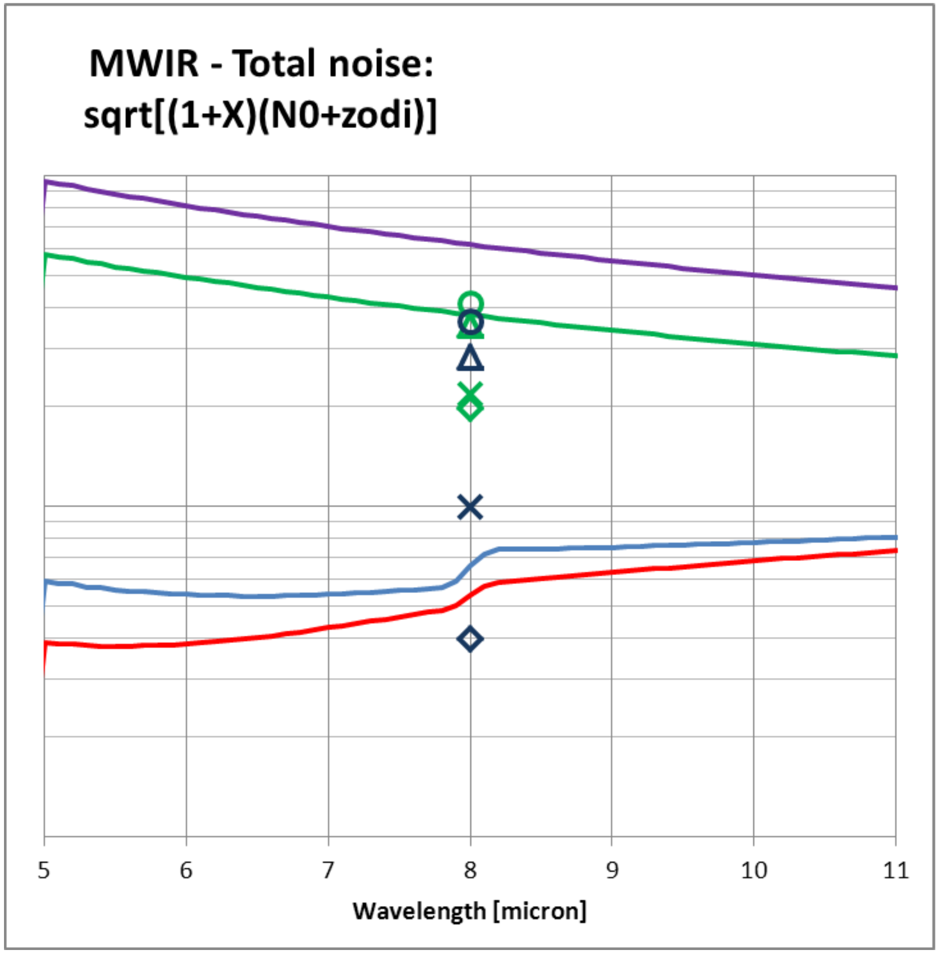
  - Current detectors show good performance for bright sources but are generally out of spec for faint targets.

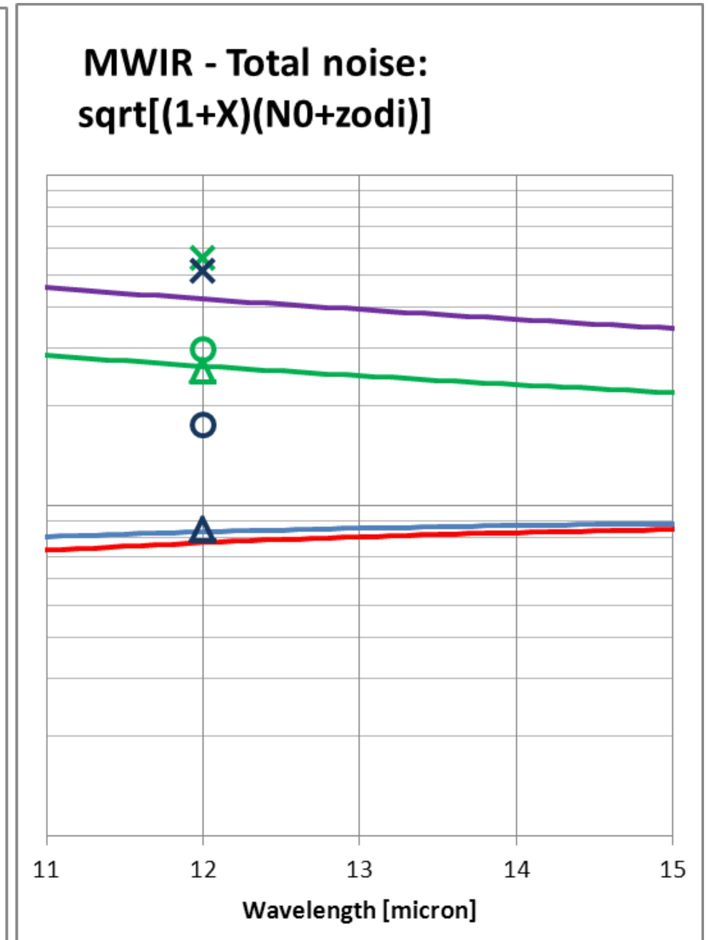
Simple Model Comparison





Simple Model Comparison





Deriving Detector Performance Requirements

Over 30 requirements are used to describe the performance of the detector these include:

- Well Depth
- Dark Current
- Read Noise (for correlated double samples)
- Total Noise performance
- Quantum efficiency
- Modes
- Operability - persistence
- Acceptable characteristics – linearity, uniformity,

Deriving Detector Performance Requirements

Expanding the Simple Performance Model

- Calculated signal levels per pixel for bright and faint sources at several wavelengths
- Applied various pixel sizes based on likely detectors
- Included opto-mechanical inputs:
  - Sampling in spatial and spectral directions (focal plane size)
  - Actual resolving power across array
  - Throughput
- Quantum efficiency variations
- Cosmic ray deglitching, considered to determine read rates
- Applied more of a 'typical integration approach' rather than 'per second'

Observational strategies

Must consider 'real' observations to handle read errors

- Bright sources:
  - Time taken to fill well depth to 80% with limit of 3s.
  - 10 reads per second

- Faint sources:
  - Time taken to fill well depth to 80% with limit of 600s.
  - 150 reads up the ramp (so ~4s)

Request For Information (RFI)

For each channel requirements were different for different options to allow for different pixel sizes.

RFI sent to:

- Teledyne (US)
- Raytheon (US)
- Selex (UK)
- Aim (Germany)
- Sofradir (France)

Pixel Size (μm)	Option 1	Option 2	Option 3
VNIR	30	15	18
SWIR	18	15	
MWIR	25	18	TBD (30)
LWIR	25	TBD (40)	

The RFI Numbers – Well Depth

For the different options the minimum and maximum flux per second per pixel was calculated…

	Option 1		Option 2		Option 3	
	Max	Min	Max	Min	Max	Min
Signals (el/s/pixel)						
VNIR 0.5	2250	1	562	0.3	810	0.4
VNIR	27236	173	6809	43	9805	62
SWIR	16821	28	11681	19		
MWIR	38078	455	19739	236	54832	655
LWIR	16347	1615	41848	4135		

Considering a 3 second exposure but also the realistic limits of a possible detector, the requirements listed in the RFI were…

Required well depth [el]			
VNIR	75000	50000	50000
SWIR	75000	75000	
MWIR	100000	100000	100000
LWIR	75000	100000	

The RFI Numbers – Dark Current

- The maximum dark current was calculated to be either 1/10th of the background, i.e. the zodiacal contribution, or 1/10th faint signal, whichever is lower.
- Required values have been set considering the realistic possible performance of detectors in these wavebands.

	Option 1	Option 2	Option 3
Ideal dark current [el/pixel/s]			
VNIR 0.5	0.003	0.001	0.001
VNIR	0.07	0.02	0.16
SWIR	0.03	0.02	
MWIR	2.4	1.2	3.5
LWIR	109.2	279.6	
Required dark current [el/pixel/s]			
VNIR 0.5	0.01	0.01	0.01
VNIR	0.01	0.01	0.01
SWIR	0.1	0.1	
MWIR	75	75	75
LWIR	200	200	

The RFI Numbers – Read Noise

- The required read noise for correlated double sampling (CDS) of a signal *S* can be calculated by:

$$Read\,Noise = \sqrt{2S(\frac{1}{X^2} - 1)}$$

where X is scaling factor between the optimum performance and the expected. We used *X=0.8*

	Option 1	Option 2	Option 3
Ideal CDS read noise [sqrt(el/pixel)]			
VNIR 0.5	2	1	1
VNIR	19	14	17
SWIR	11	9	
MWIR	27	27	27
LWIR	24	24	
Required CDS read noise [sqrt(el/pixel)]			
VNIR 0.5			
VNIR	18	15	15
SWIR	18	18	
MWIR	25	25	25
LWIR	30	30	

The RFI Numbers – Total Noise

- Also provide a 'total noise budget' as a requirement. We did this for a typical 600s exposure:

$$Noise\,budget = X\sqrt{t.D_{current} + \frac{6R^2}{N}}$$

where t is the exposure time, R the read noise and N the number of reads. Again X is a scaling factor, we used X=1.1

Total dark noise [sqrt(el/pixel)]	Integration time (s)	Performance ratio	Option 1	Option 2	Option 3
VNIR	600	1.2	5	5	5
SWIR	600	1.2	10	10	
MWIR	600	1.2	255	255	255
LWIR	300	1.2	294	294	

Performance assessment (with N_{min})

- Once all feedback from suppliers is received we will assess performance against R-PERF 350.
- If we do this now, assuming suppliers exactly meet the requirements, then clearly we should meet R-PERF 350: with the new inclusion of N_{min} we generally do.

MWIR

Performance for a typical faint object (i.e. ~600s)	Option 1 (25µm)		Option 2 – (18µm)		Option 3 – (30µm)	
	6µm	10µm	6µm	10µm	6µm	10µm
Total dark noise contribution to faint signal (el/spaxel)	335	415	646	768	232	288
Total faint noise (el/spaxel)	765	804	1104	1197	618	642
Total allowed faint noise (no Nmin) (el/spaxel)	783	783	1088	1043	653	653
Total allowed faint noise (with Nmin) (el/spaxel)	811	825	1126	1099	676	688
Meet requirement without Nmin?	Yes	No	No	No	Yes	Yes
Meet requirement with Nmin?	Yes	Yes	Yes	No	Yes	Yes

Outstanding concerns

- Extend model to treat all wavelengths, rather than simply discrete chosen wavelengths.
- Resolution of longer wavelengths for MWIR might make it difficult to achieve the required signal if the pixels are small.
- Decision to baseline with MCT detectors may have an impact on performance at longest wavelengths (>14.5μm), but otherwise we will need to cool to lower temperatures (below 30K).
- How do we rank the different detectors when comparing predicted values and performances?

Current Status and Conclusions

- All major EU and US manufacturers have been issued with RFI against the derived detector requirements
- Waiting on response from some suppliers
- Recommendation from working group to consortium management in mid/late July (providing responses are received)
- Feedback to suppliers baseline choice in August
- Will work with potential suppliers to understand their development needs and implement a plan to reach required TRL
- In general we expect the detectors to meet the MRD requirements across most, but not all, of the wavelength range.