National Aeronautics and Space Administration
Jet Propulsion Laboratory
California Institute of Technology

Selecting the NIR detectors for Euclid

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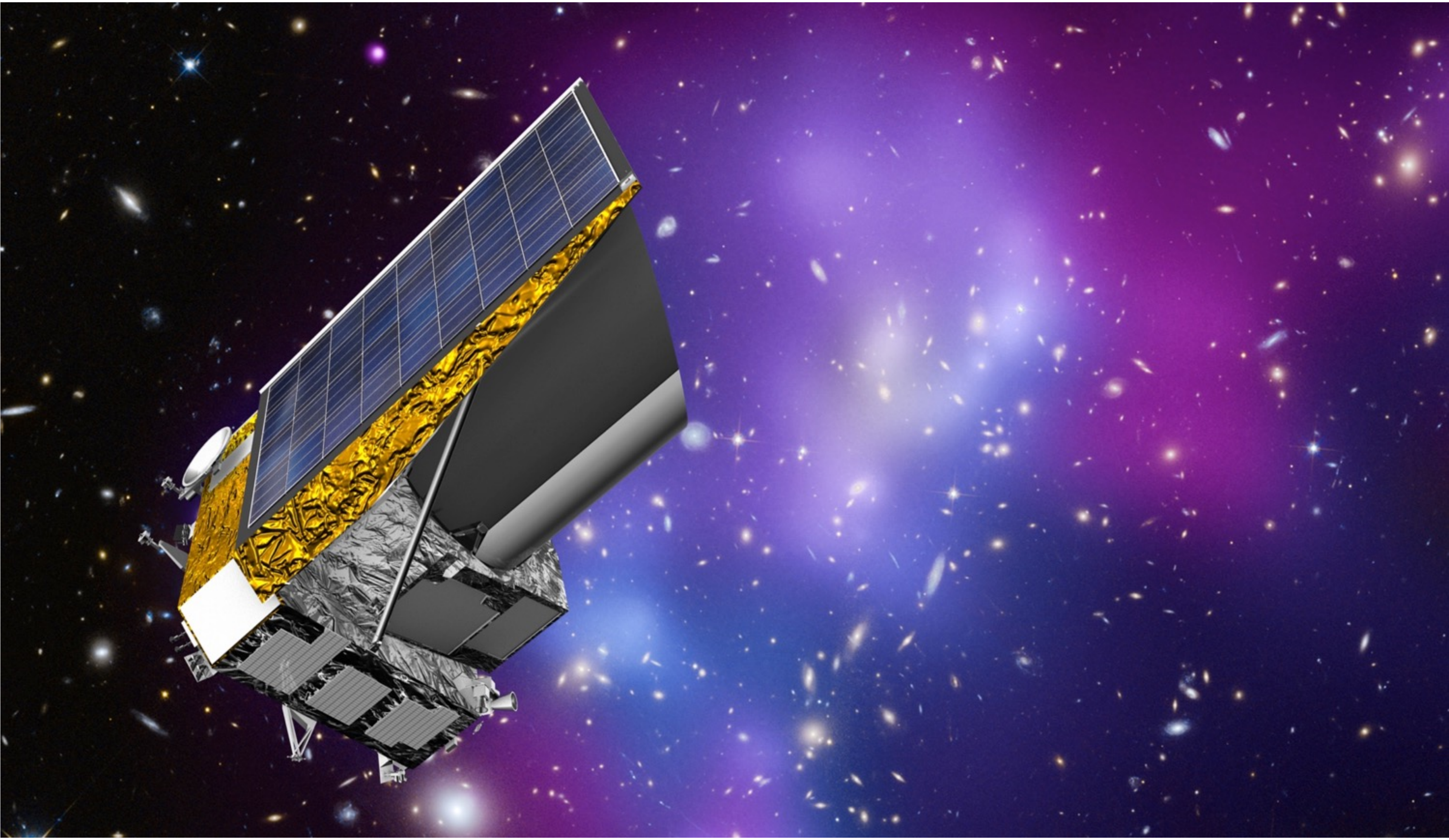
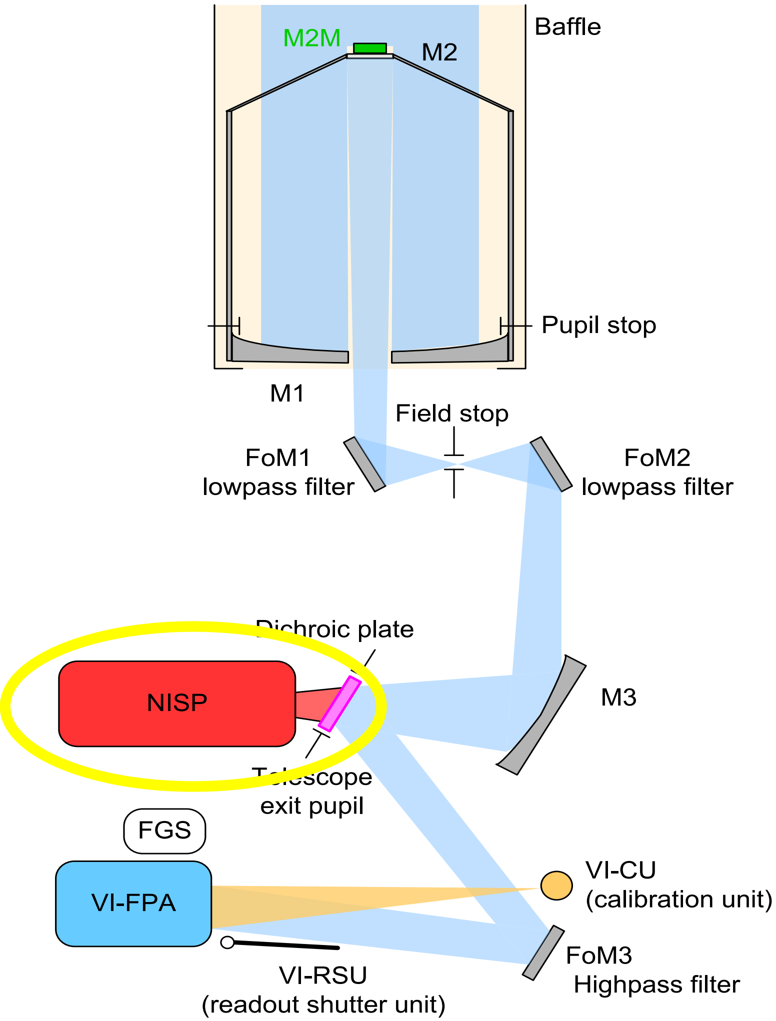
On behalf of the Euclid Near-IR Detector Working Group
and the
Euclid Consortium

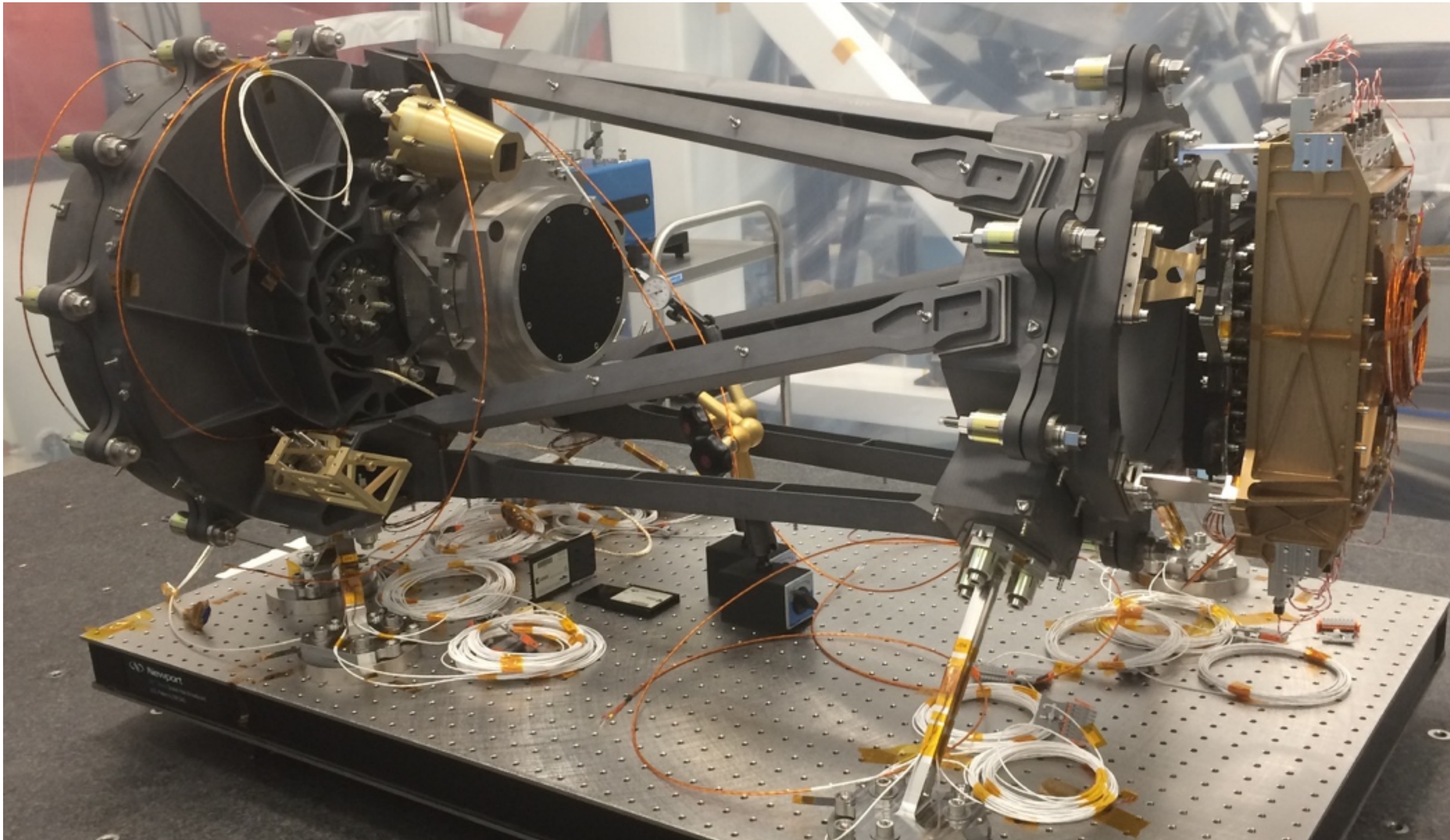
Euclid is an ESA mission to map the geometry of the dark universe



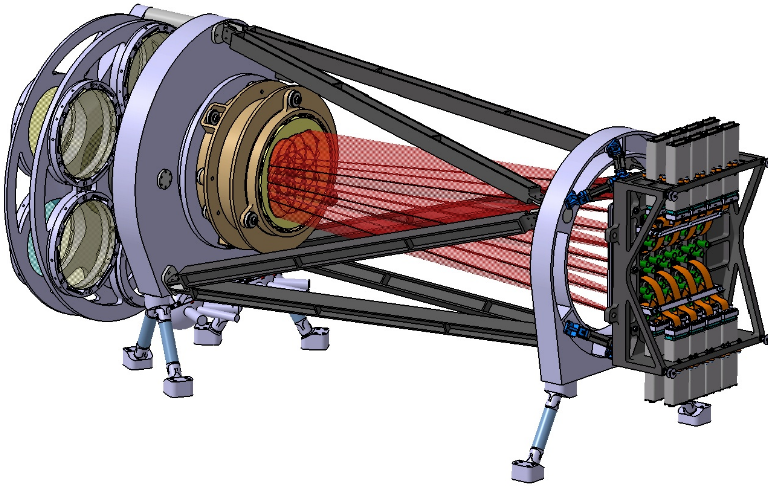
Euclid Telescope feeds two instruments



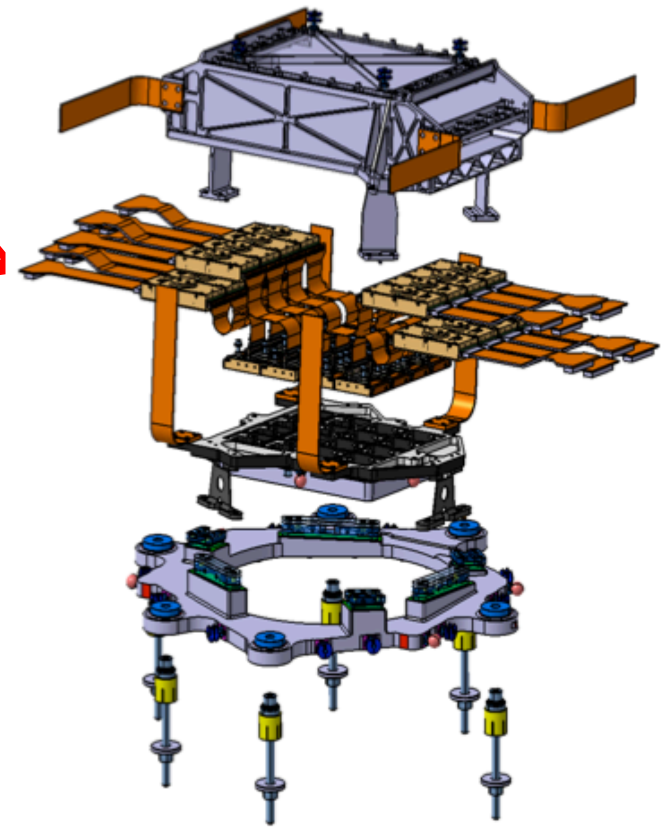
Structural – Thermal Model of NISP (Near-IR Spectrometer – Photometer)



NISP Instrument Detector System

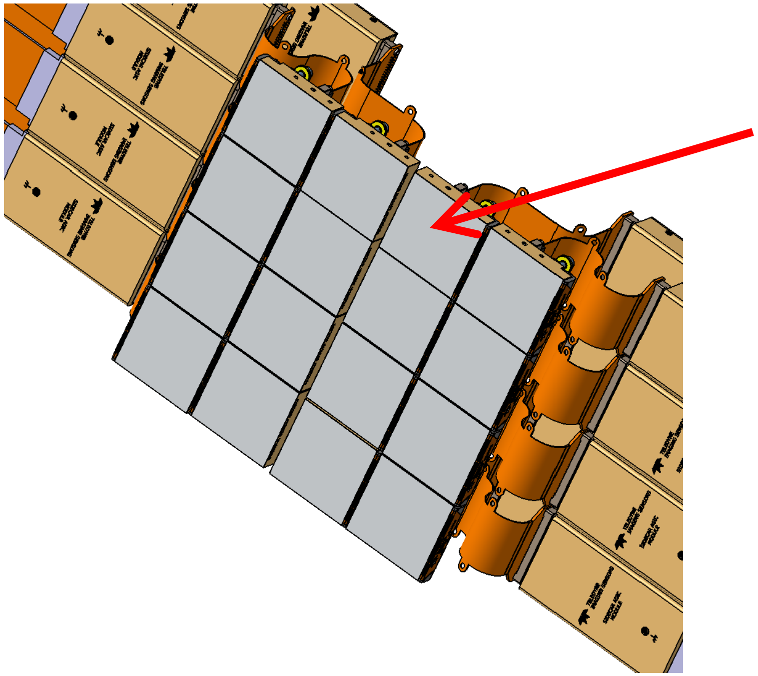


NISP Instrument



NISP Detector System (Focal Plane)

Euclid NISP Detector System



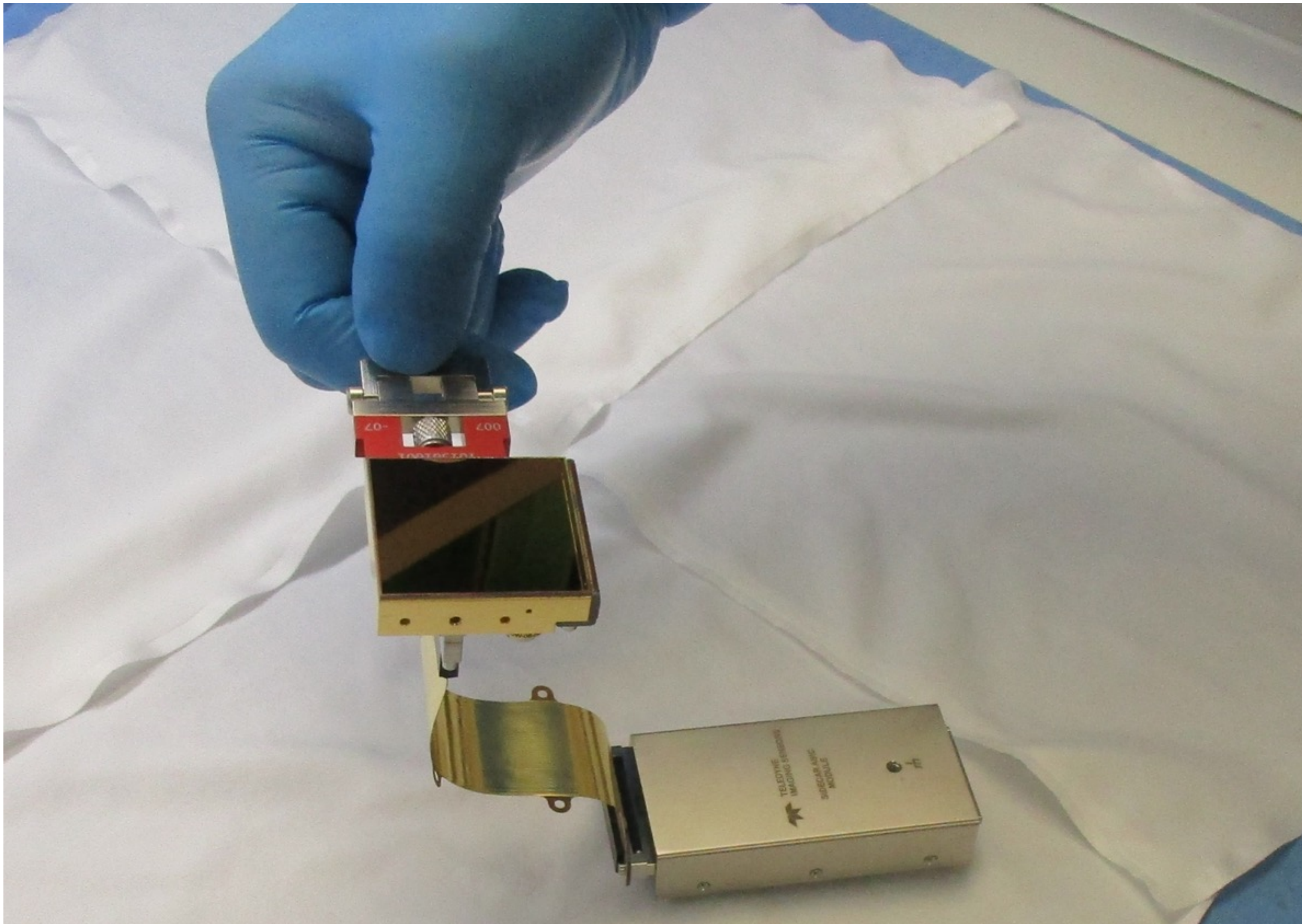
Each element in the 4x4 focal plane mosaic consists of

- detector chip (H2RG, 2kx2k, 2.3 um)
- cold interface cable
- cold electronics assembly

NASA is responsible for delivering fully characterized units :

- 16 flight units
- 4 flight spares

One element in the NISP focal plane



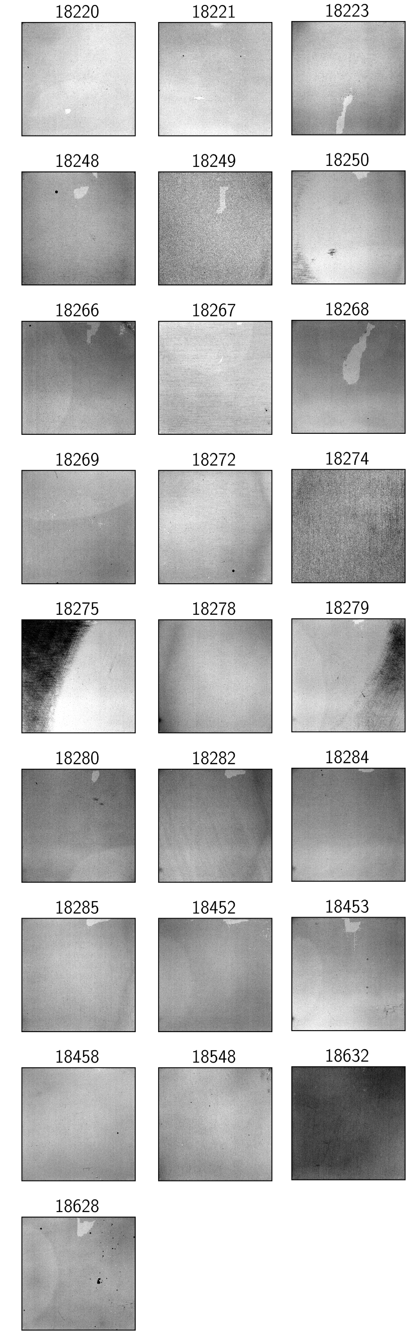
Detector Selection

We have detailed characterization data on 25 detectors. Need to choose 16 flight units plus flight spares.

We have used a figure-of-merit (***FoM***) approach for selection.

- Assigns a scalar number to each Euclid NIR flight candidate detector:
  - 0 represents a dead detector
  - 1 represents an ideal, perfect detector (i.e., no dead pixels, no noise, QE=1, no other issues)
- The FoM is intended to represent the scientific performance of the detector in the Euclid Survey

Data from the GSFC Detector Characterization Lab on flight candidates detectors form basis for ranking.



Detector figure-of-merit (FoM)

So, how to define the FoM?

- Estimated survey efficiency (e.g. survey speed to given depth) – include full survey strategy, observing modes, dither strategy, simulated zodi, and focal plane layout along with detector properties
  - Too complex to be ready in time
  - Unknown sensitivity to observing details that might change

- Consensus choice –Cumulative quantum efficiency over noise.

Practical issues:

- How to define bad pixels
- How to treat persistence
- Suspected intrapixel variation

Cumulative QE over noise

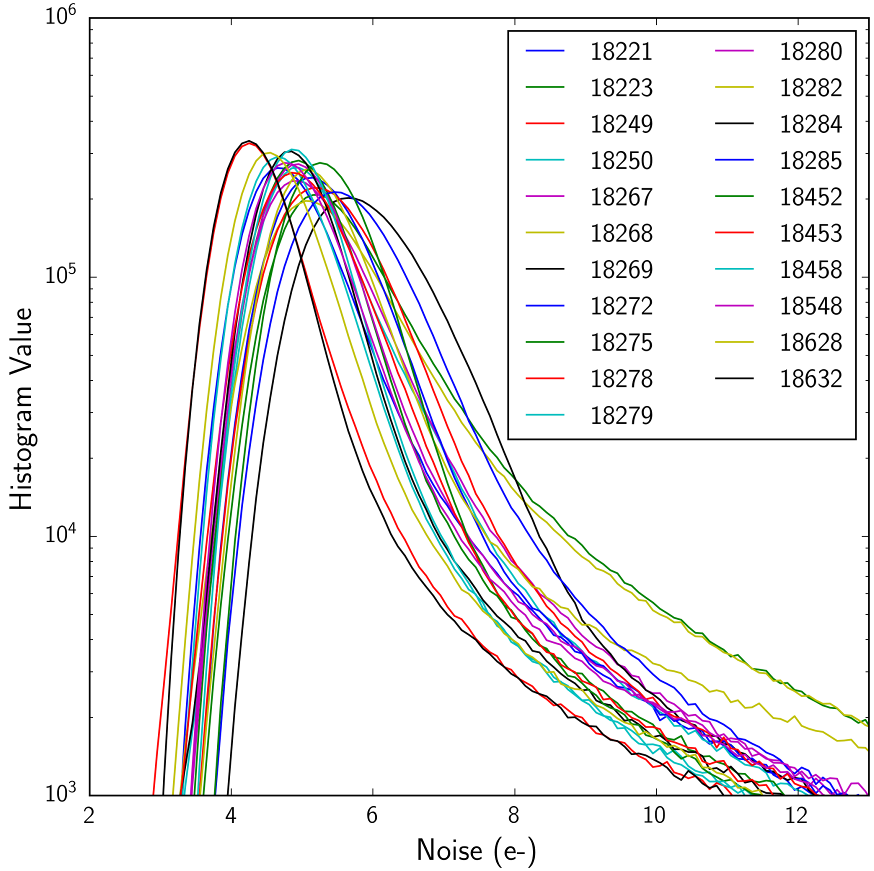
For the cumulative quantum efficiency over noise FoM, we use the following formula:

- For each pixel in the detector, calculate the mean QE in the wavelength range of a photometry filter.
- Divide each of these values by a pixel noise estimate. Noise is taken to be the quadrature sum of the detector noise in photometry mode and a nominal value for the background.
- Sum this value over all good pixels. Bad pixels contribute zero.
- Normalize by an ideal detector. Ideal detector is QE=1, detector noise=0, all pixels good, zodi background still present.
- Average over the 3 photometry bands
- Repeat the exercise for the red grism spectroscopy channel. Average spectrometry mode and photometry mode results (equal weighting to two observation modes)

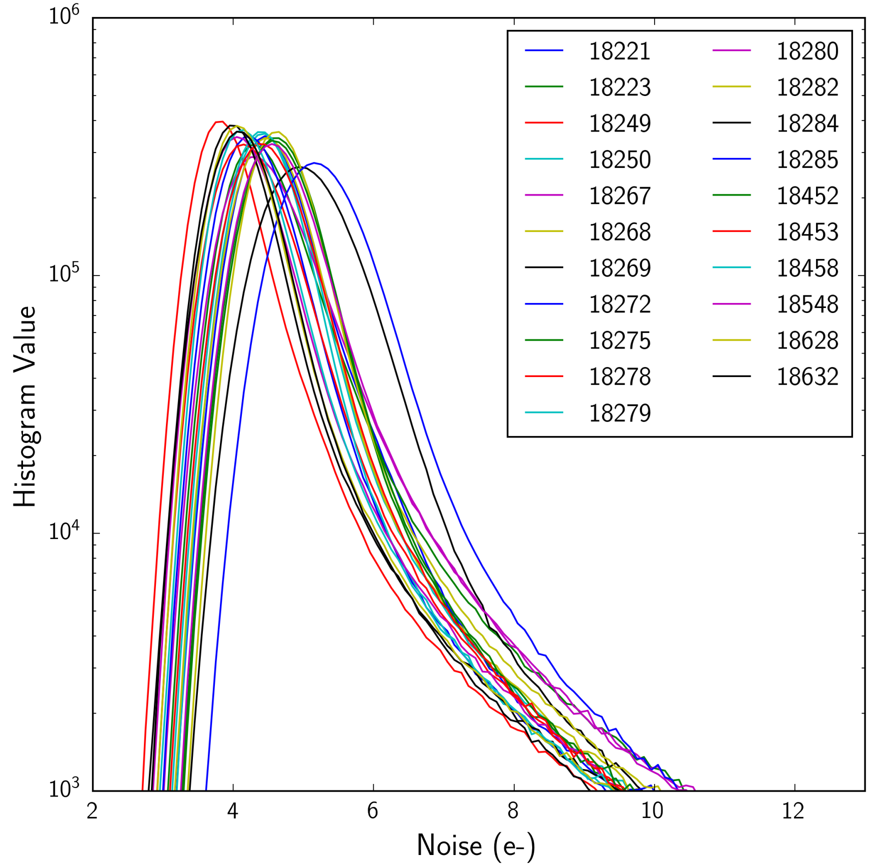
Cosmetic arrangement of bad pixels do not enter the calculation. Persistence will be contribute to the bad pixel fraction. Choose typical zodi level.

Noise Histograms

Spectroscopy mode



Photometry mode

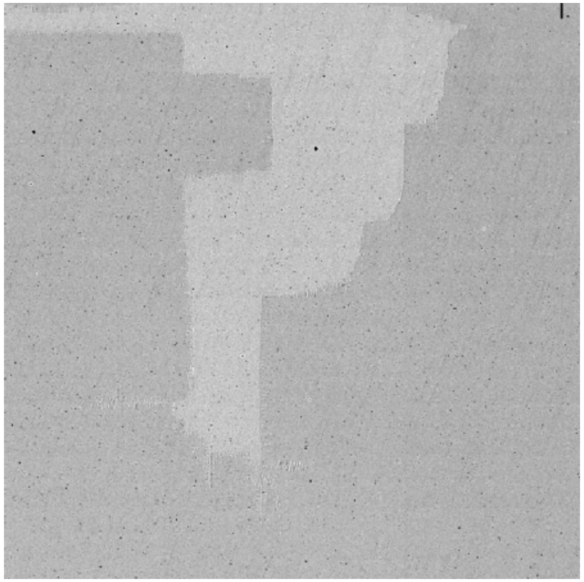


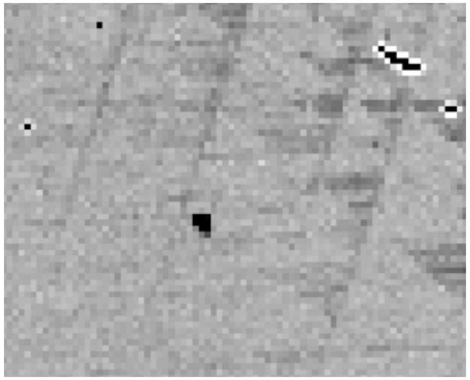
Readout mode for spectroscopy: multiaccum [15x16, 13] (540 sec)
Readout mode for photometry: multiaccum [3x16,4] (60 sec)
Baseline reference pixel subtraction scheme

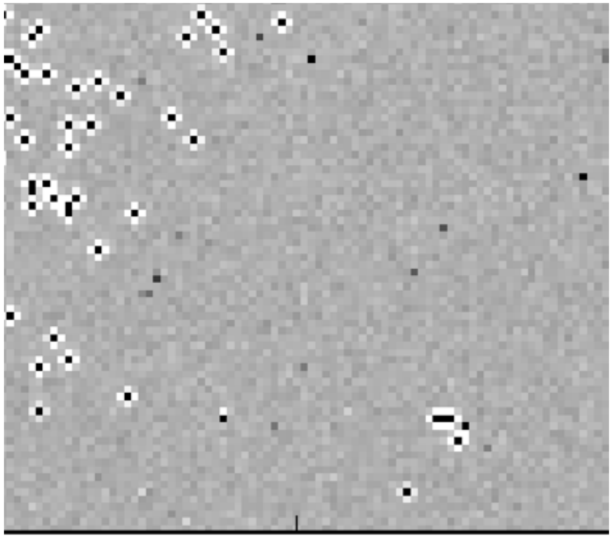
Bad Pixel Flavors

There are many flavors of bad pixels:

- Disconnected pixels
- Pixel defects
- Void boundary
- QE variation
- Bad column
- Bad ref pixel (row)
- Photo emissive
- Cross hatching







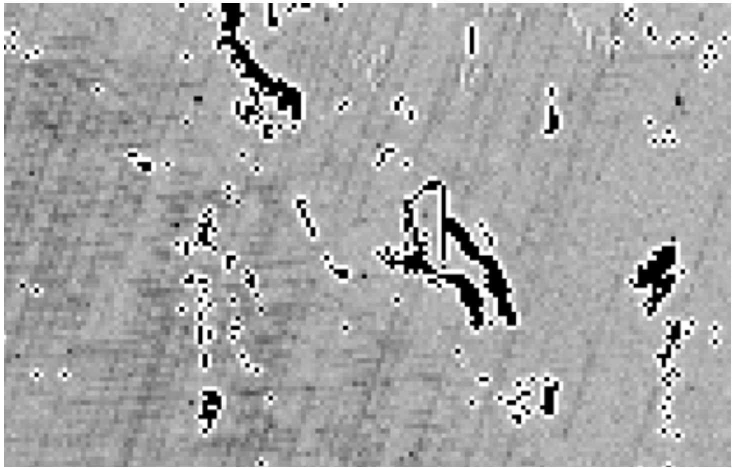
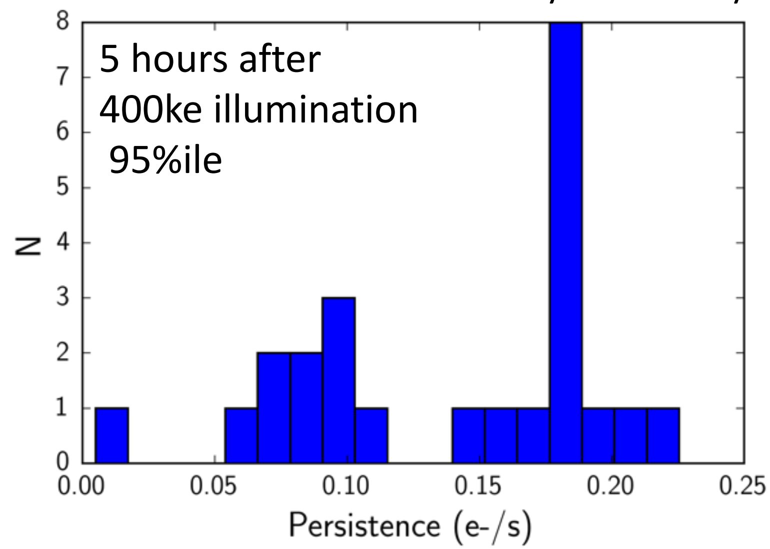


Image Persistence

Nominal impact: a detector at the level of the persistence goal will have a given pixel unusable ~ 3-4 % of the time due to recent exposure to a bright star. Work continues on better modeling and simulations.

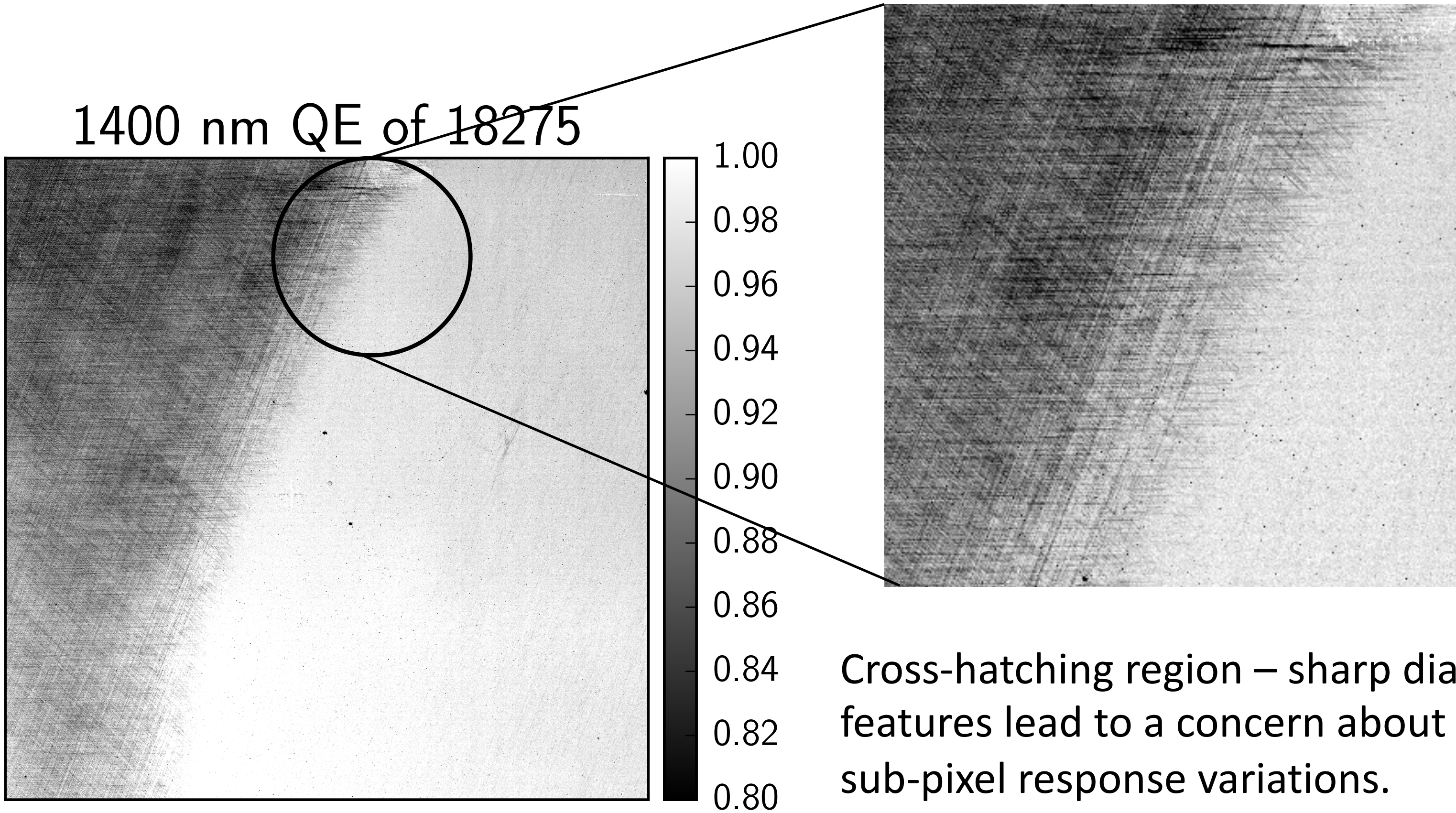
Persistence shows distribution of behavior across detectors

Data from GSFC-DCL courtesy of A. Waczynski.



Editorial comment: there is still considerable work to do to understand the full details of the effect including ***stability***, ability to model and regress, sensitivity to background zodiacal level, temperature, and other effects

Cross-hatching



Cross-hatching region – sharp diagonal features lead to a concern about significant sub-pixel response variations.

Sub-pixel variations can potentially affect photometric accuracy.

- For FoM, de-weight areas of rapid variation

Final Figure-of-merit (FoM) detector ranking

SCA	FOM
999	1.000
18220	0.817
18284	0.811
18628	0.801
18458	0.799
18249	0.788
18632	0.787
18278	0.785
18452	0.783
18453	0.773
18269	0.770
18280	0.765
18282	0.763
18548	0.761
18268	0.760
18250	0.753
18221	0.751
18285	0.751
18267	0.748
18272	0.740
18223	0.740
18279	0.719
18248	0.714
18266	0.701
18274	0.693
18275	0.538
0	0.508

Fictitious ideal detector

Selected flight detectors

Fictitious uniform detector at level of requirements

Relatively close spacing of good detectors in the FoM, with a few clunkers at the bottom end.

Couldn't use 18220 for a quality assurance concern

Summary

- Flight detectors have been shipped to ESA
  - Avoided the worst detectors with respect to cross-hatching and image persistence
  - Detectors pretty closely grouped in FoM. Variations are mostly due to bad pixel fraction.
  - It is clear that bad pixel definition influences the figure of merit. In flight, bad pixels partially mitigated by multiple dithers.
  - persistence treated as separable variable affecting pixel operability. Our approach is perhaps overly simplistic – but it is available immediately.
- Despite the focus on all the non-ideal behavior in the detectors: *Figure of Merit for flight units much better than a uniform detector at the level of the requirement!*