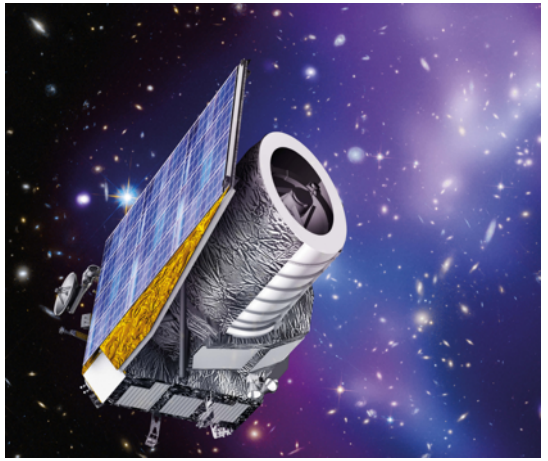
Characterising detectors @ ESA

Thibaut Prod'homme (SCI-FIV), Toncho Ivanov (TEC-MME)

EIROforum detector development workshop

17/02/2022

Two laboratories @ ESTEC, NL



SCI-FIV lab

Science Directorate / Future Missions Dept / Instrumentation Div. / Payload Validation Section

- **Application:** Science programme technology development and mission support in all phases
- **Test benches:** 4x VIS (CCD), 3x SWIR (MCT-Hybridised), 1x MWIR, UV-beam line,
- **Wavelength range:** from X-rays to long-wave infrared
- **Additional equipment/lab:** Elec. and optics lab, mechanics workshop, clean rooms, plasma and TVAC chamber, Pyxel!

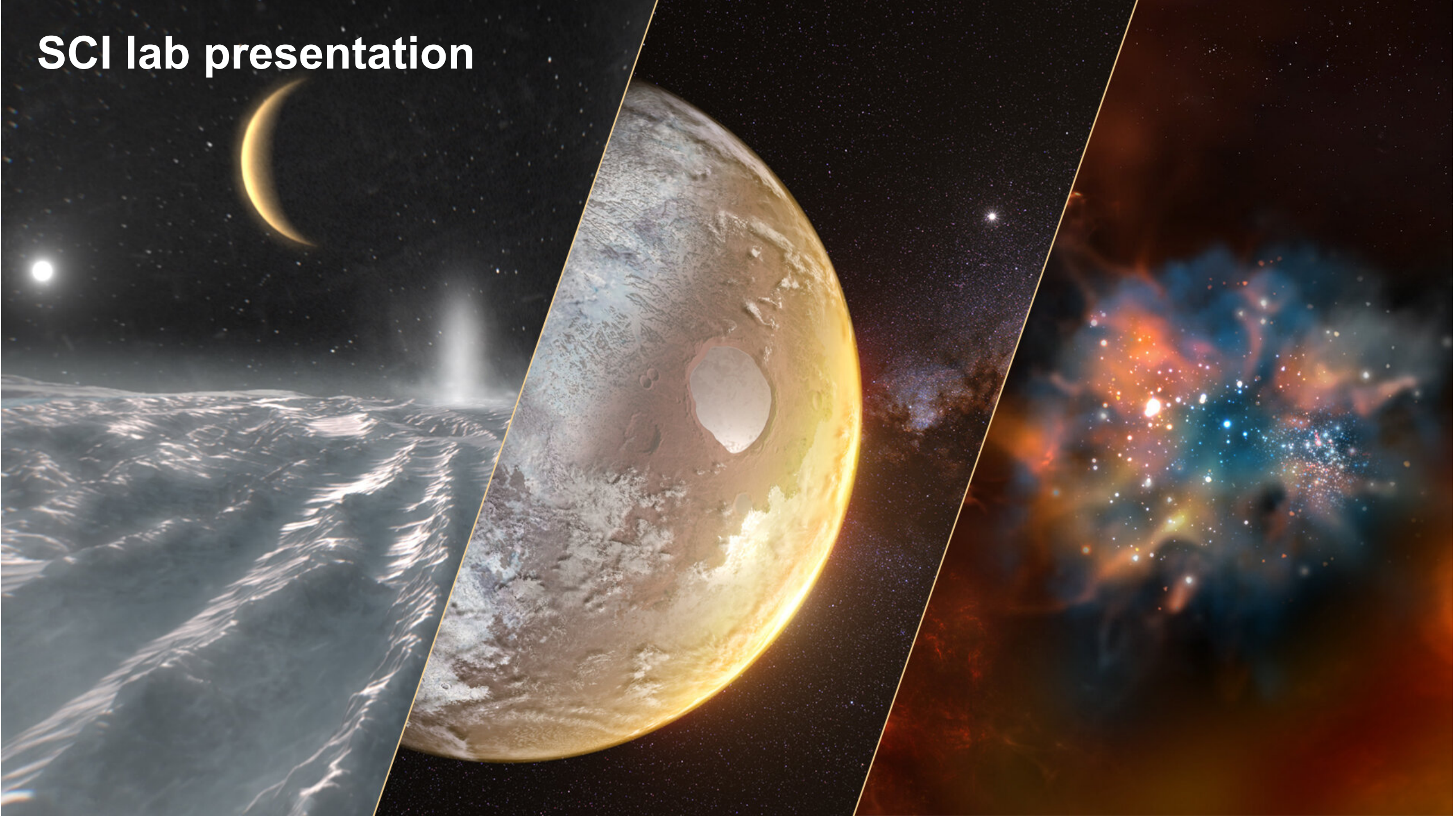
TEC-MME lab

Technology, Engineering and Quality Dir. / Mechanical Dept / Mechatronics & Optics Div. / Opto-Electronics Section

- **Application:** Earth Observation & telecom missions support and generic technology development
- **Test benches:** VIS (CCD, CMOS), SWIR
- **Wavelength range:** Visible to SWIR
- **Additional equipment/lab:** Laser lab

Both labs have greater scope and capabilities than detector characterisation, we focus in the following only on their detector characterisation capabilities.

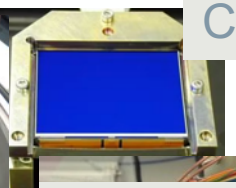
SCI lab presentation

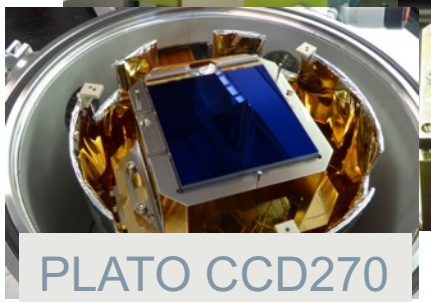


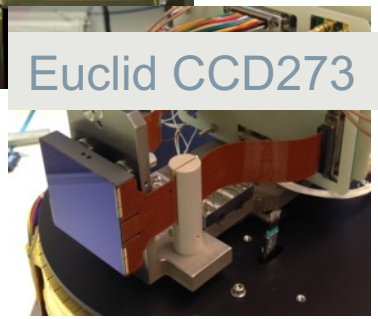
SCI lab: detectors tested in the last 5 years

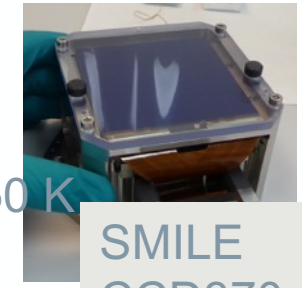

SO EUI CIS

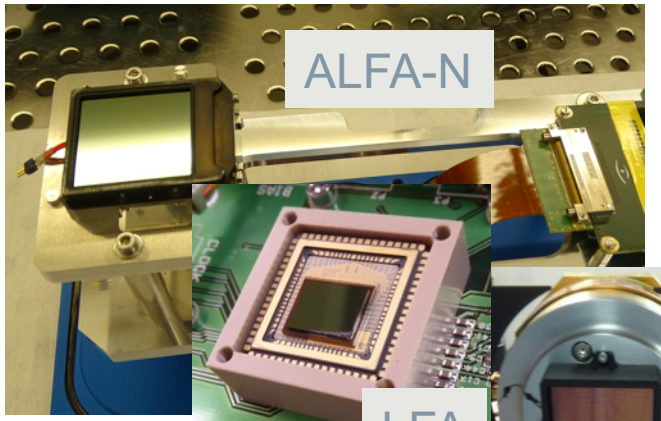

CHEOPS CCD47-20


Gaia CCD91-72

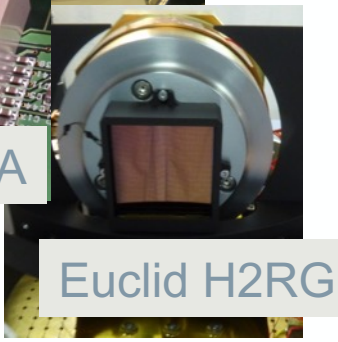

PLATO CCD270

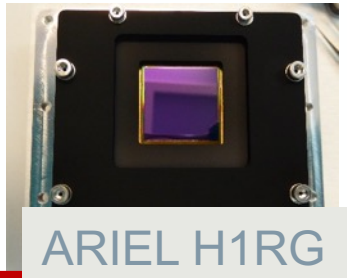

Euclid CCD273


SMILE CCD370


ALFA-N

LFA


Euclid H2RG


ARIEL H1RG

Temperature

240 K

200 K

150 K

80 K

20 K

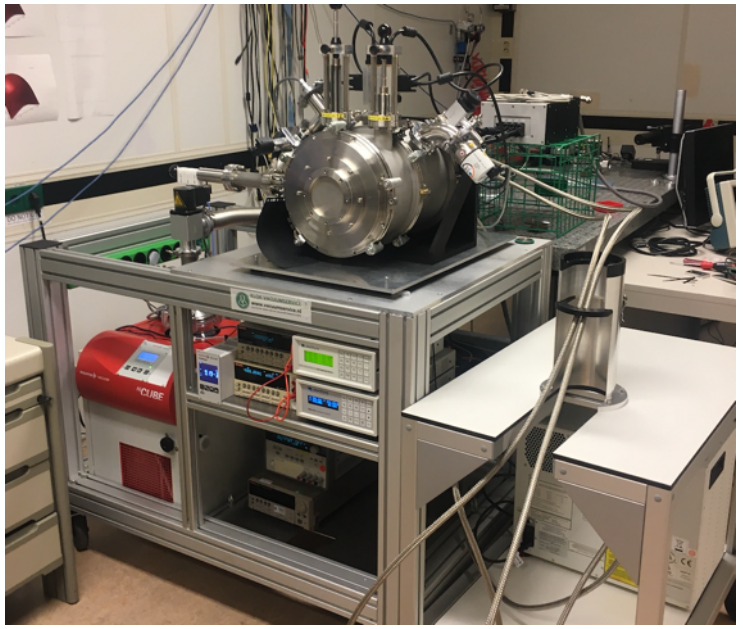
Wavelength

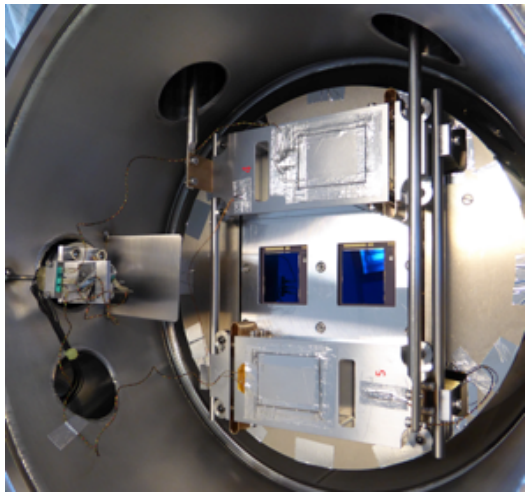
X-rays 20-100 nm 800 nm 2.1 um 2.3 um 8 um

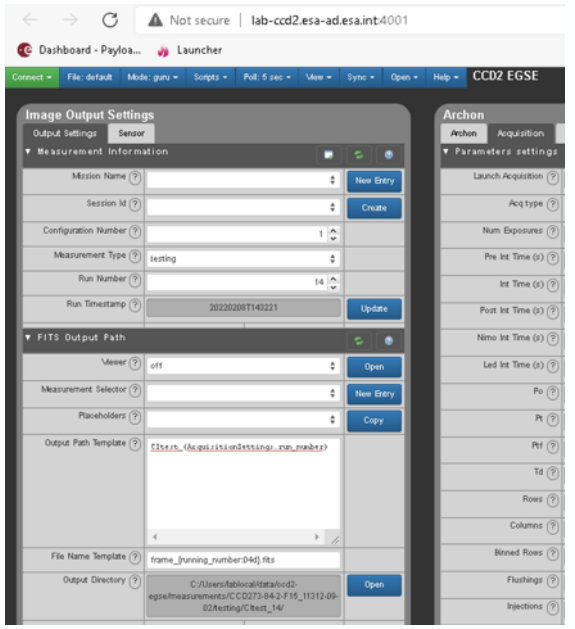
SCI lab: overview of test benches

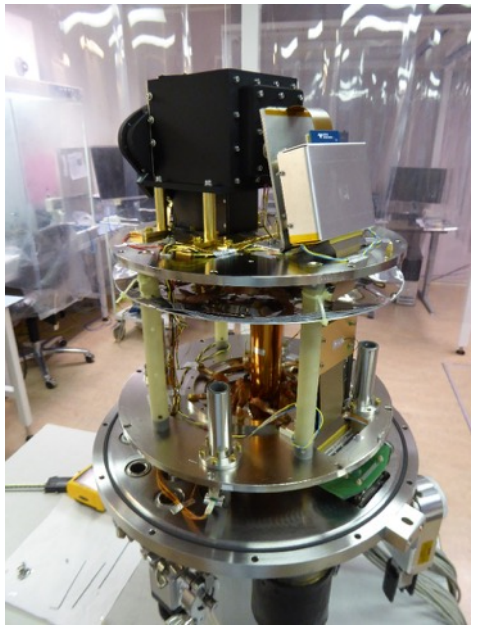
Bench name	Gaia	CCD1	VIS1, VIS2	NIR1-bumblebee NIR1-R2D2	(NIR2), MWIR
Detector type	CCD		CCD (CMOS)	MCT-Hybridised	
Cooling system	IN2		Compressor: Cryotiger	IN2	Cryocoolers: (Leybold), Cryomech
Temperature range	80 - 240 K		120 - 260 K	80 - 150 K	20 - 120 K
Wavelength range	Vis: 300-1000 nm UV: 20-100 nm (X-ray 0.6-15.8 keV) Fe55 5.9 keV			NIR: < 3 um	MWIR: < (4), 8 um
Light source	Red LED array	QTH lamp + monochromator, LEDs, smartphone projector, X-ray source		Black body, QTH lamp + monochromator, LEDs	
Controller	Flight electronics	XCAM	STA ARCHON	Flight electronics, ARC, NGC, (in-house development)	
SW EGSE	Mistral: in-house developed Python server framework communicate with hardware, dynamically render a user interface, run parameterized scripts, and construct reusable modules				
Generic measurements	Dark current & DSNU, Non-linearity, Photon transfer curve, Quantum efficiency, Photo response non-uniformity, Point Spread Function, etc.				
Specific experiments	TDI/moving scene projection	Scene projection (smartphone & masks), Subpixel spot projector, Cold irradiation, EMC		Subpixel spot projector, Persistence, Cold irradiation	(Subpixel + Scene projection), Persistence, Cold irradiation

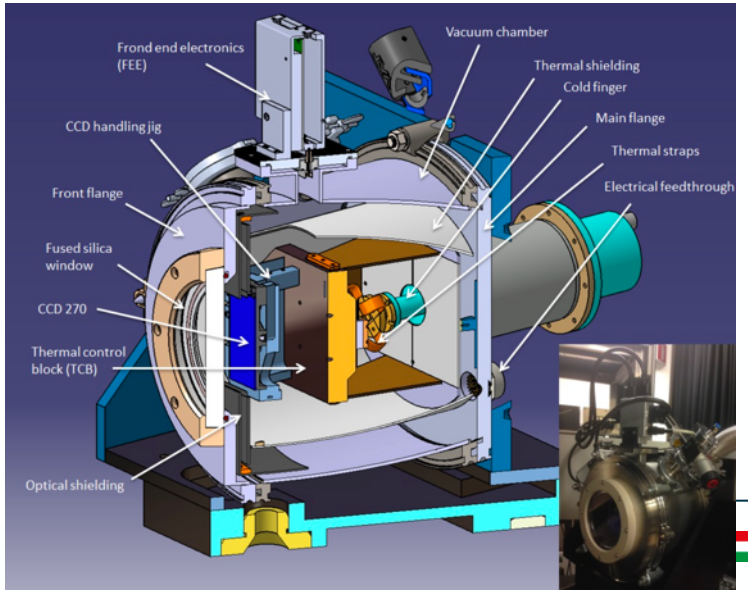
SCI lab: overview of test benches

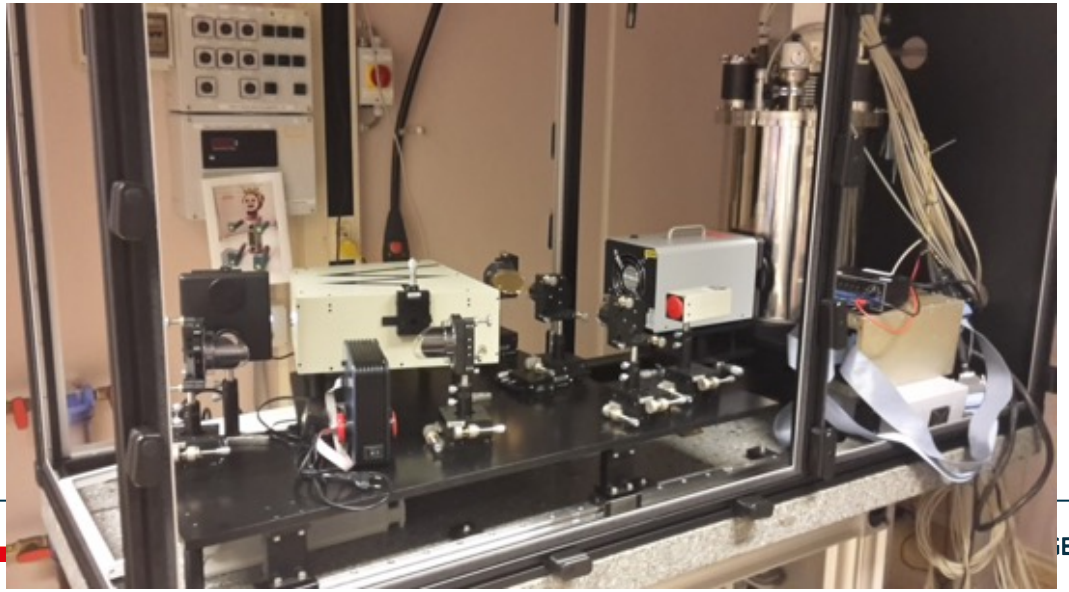












SCI lab: mission-specific experiments

- **Cold irradiations:** CHEOPS CCD47-20*, ARIEL H1RG**, PLATO CCD270***

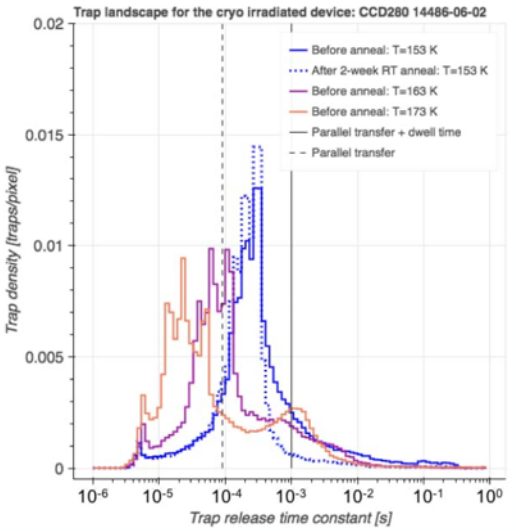
**P. Verhoeve et al, SPIE Proc. 2022?*

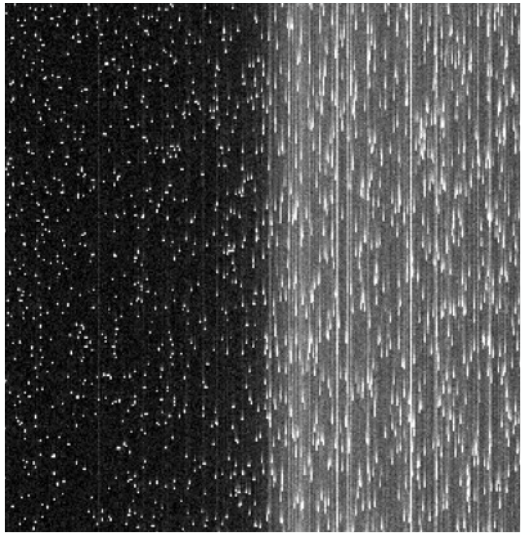
***Impact of proton radiation on the Ariel AIRS CH1 HAWAII-1RG MWIR detector, P.-E. Crouzet et al, SPIE Proc. 2020*

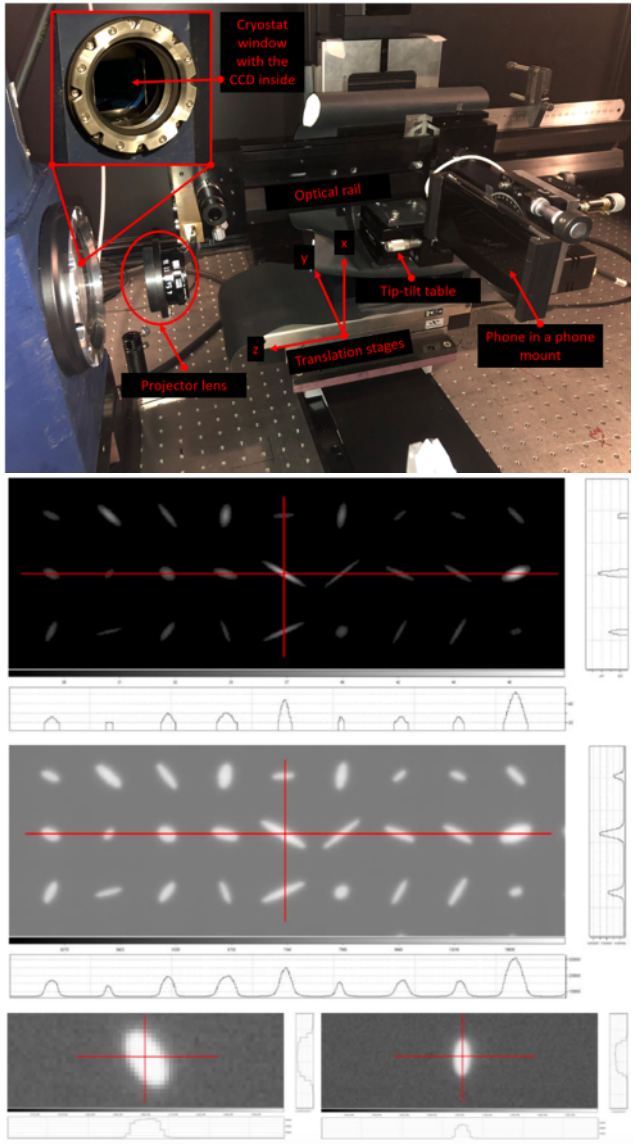
****Comparative Study of Cryogenic Versus Room-Temperature Proton Irradiation of N-Channel CCDs and Subsequent Annealing, T. Prod'homme et al. IEEE Nucl., Trans. 2019*

- Representative scene projections on irradiated Euclid CCD273

A smartphone-based arbitrary scene projector for detector testing and instrument performance evaluation, T. Prod'homme et al. SPIE proc. 2020







SCI lab: other capabilities

- Intrapixel response measurement (subpixel spot projector)

Optical and dark characterization of the PLATO CCD at ESA, P. Verhoeve et al. SPIE proc. 2016

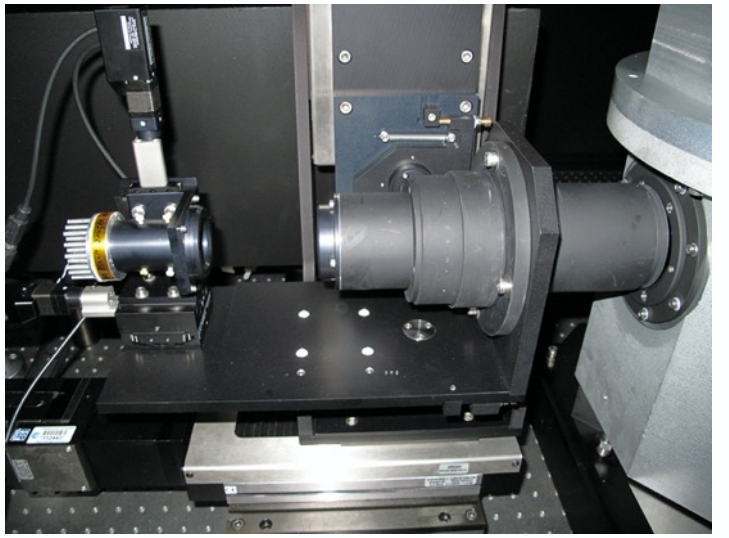
- QE validation and comparison: e.g. NIR-LFA vs. HxRG

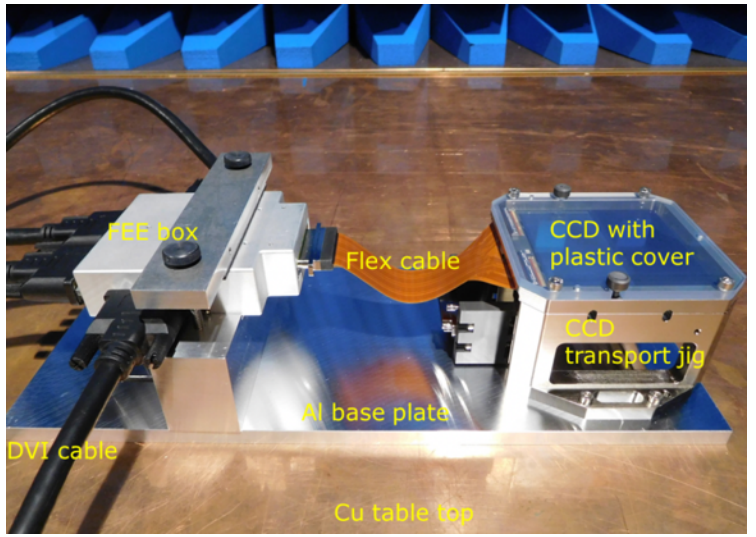
Quantum efficiency performances of the NIR European Large Format Array detectors tested at ESTEC, P.-E. Crouzet et al, SPIE Proc. 2015

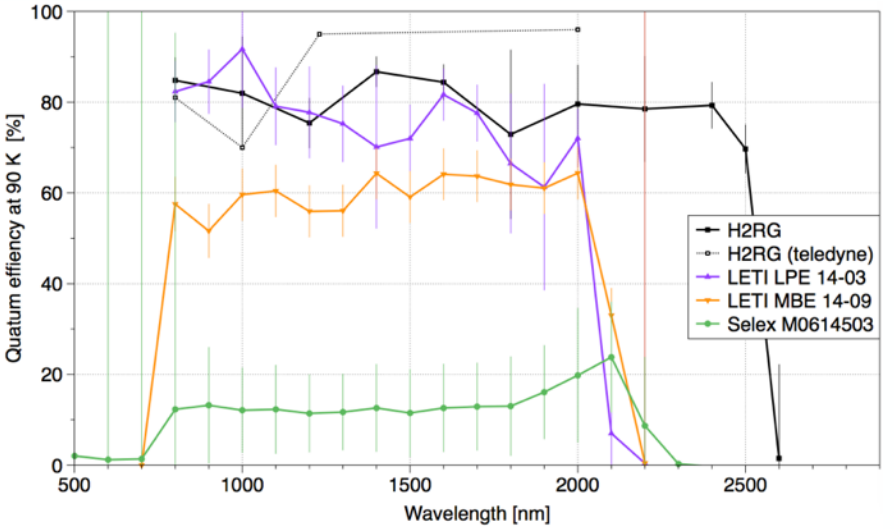
- Persistence measurements: e.g. Euclid H2RG

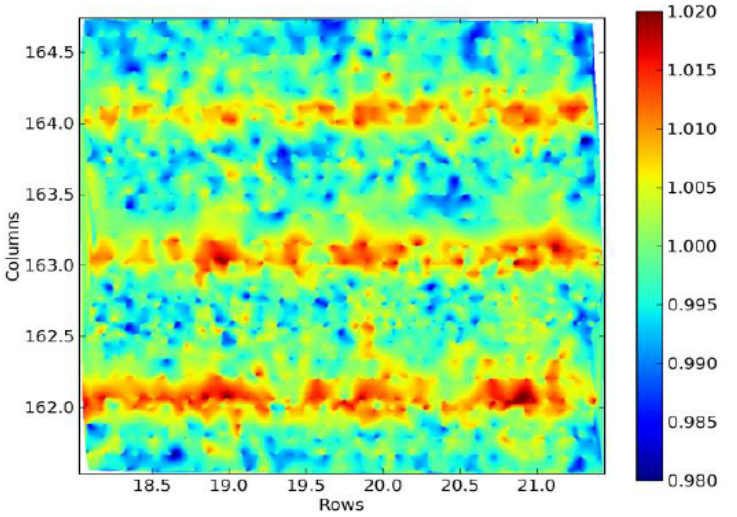
Comparison of persistence in spot versus flat field illumination and single pixel response on a Euclid HAWAII-2RG at ESTEC, P.-E. Crouzet et al, SPIE Proc. 2016

- And more: EMC testing, cross-hatch investigation etc.

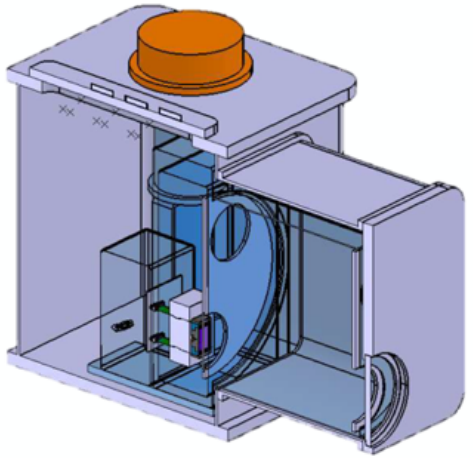








SCI lab: on-going developments

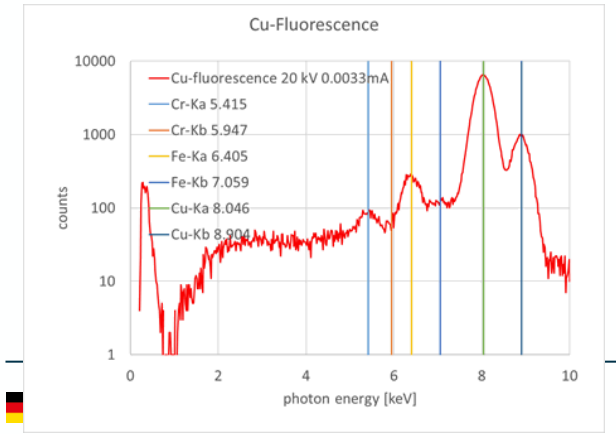


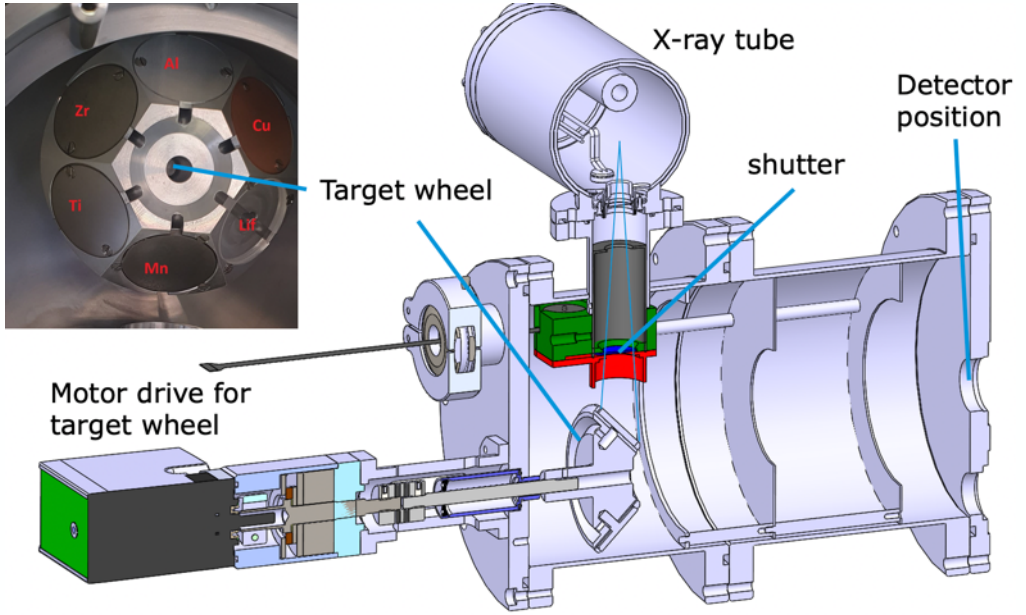
NIR2/LAPD bench: future lab workhorse for large (4kx4k) NIR (< 4um) detector charac.

- First detector to be characterised is Leonardo LAPD detector
- Successful phase 0 (in collaboration with ESO)
- Currently in preliminary design phase (LAPD package and flex PCB under manufacture)

Electrical X-ray source: in commissioning

- based on Ofxord instrument XTF5011 source
- fluorescence of target materials (0.5, 15 keV)

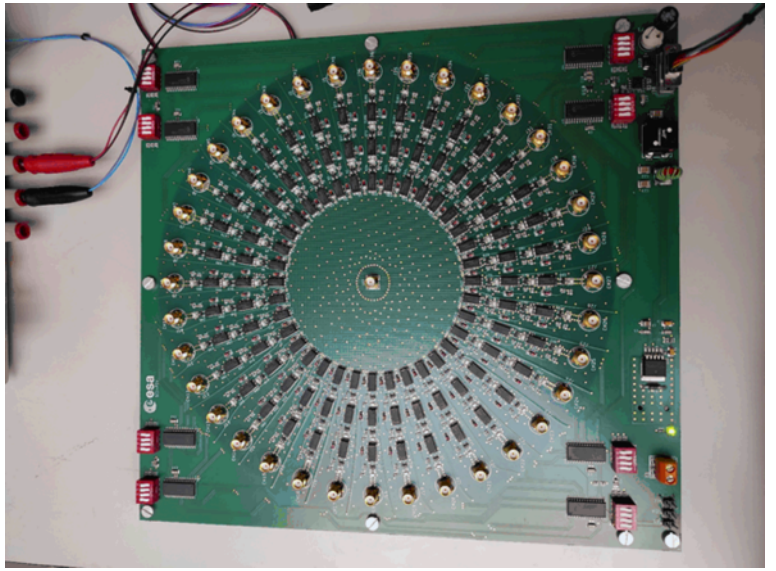


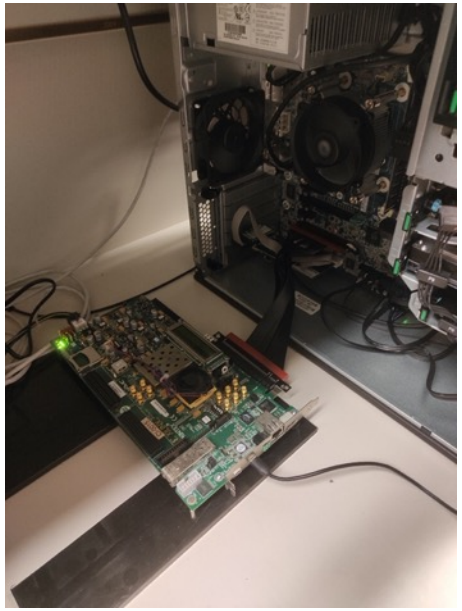


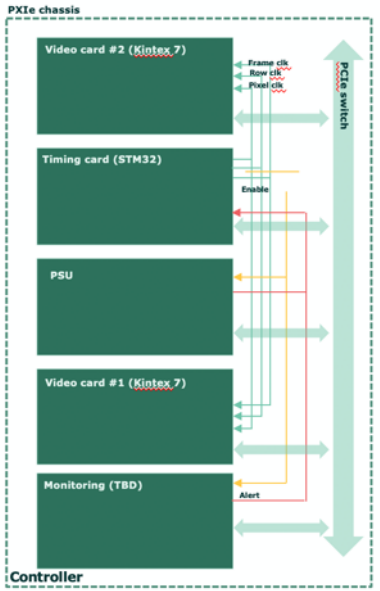
SCI lab: on-going developments

ALFA-C ASIC bench: to characterise in detail the newly developed ALFA controller ASIC (Caeleste)

- PXIe standard-based system with COTS and custom designed modules
- low crosstalk video signal switching to characterise the ASICs 36 channels
- characterisation of ASICs LDO and reference performance
- characterisation of ASICs state machine and the universal digital detector interface







CMOS readout controller:

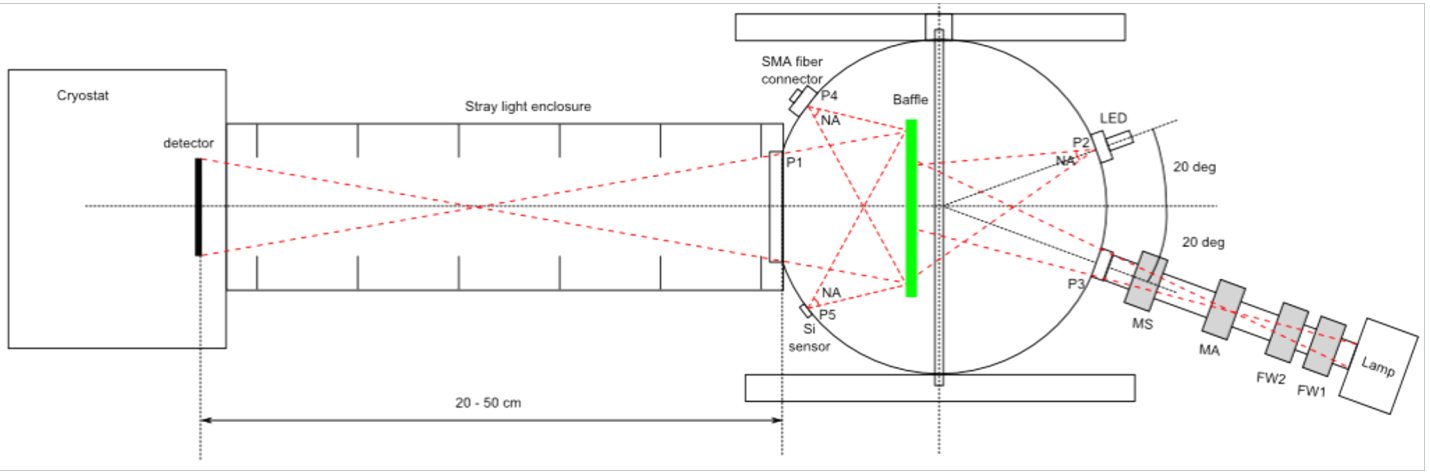
- System based on cPCIe/PXIe standard
- ARM based timing card programmable in a high level programming language
- PSU and bias cards with user configurable voltage and current
- FPGA based video back-end card. The detector-dependent front-end is hosted on a FMC module. The FPGA will reconfigure the front-end part according to the FMC module installed

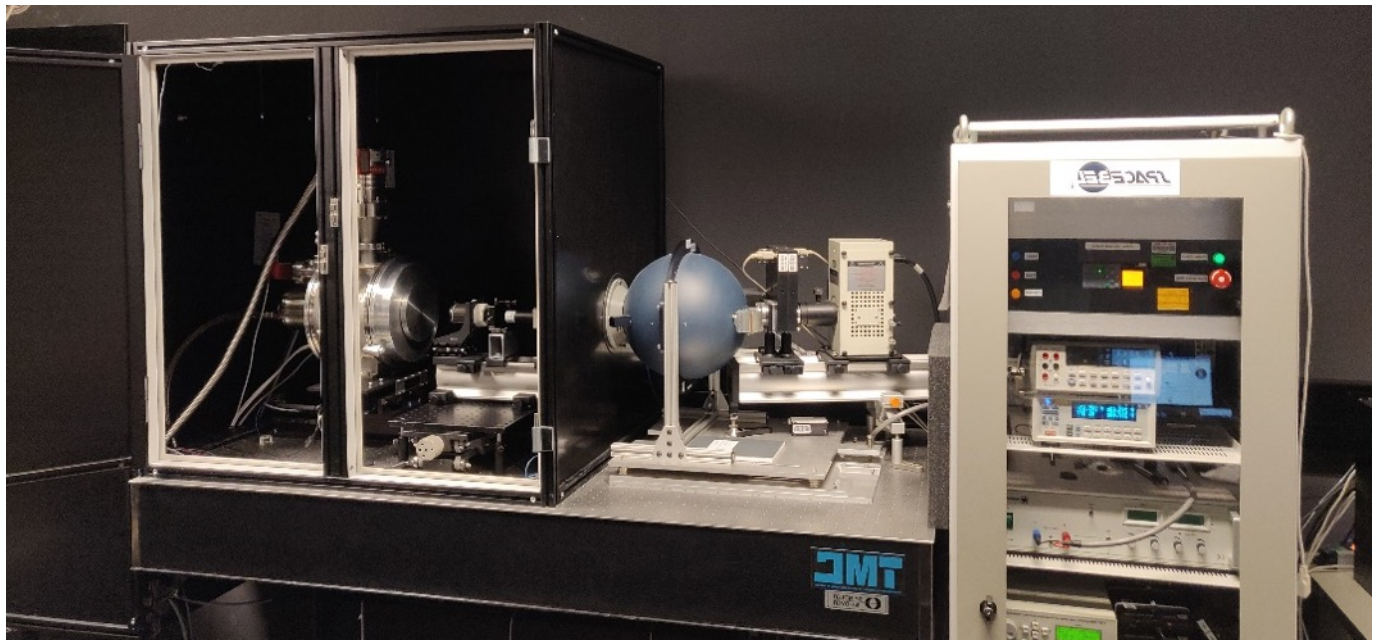
Sci virtual lab = Pyxel

- Collaborative detector simulation framework
- Python library, open source project, hosted on Gitlab
- Simulate instrument and detector effects on images from optics down to readout electronics
- Joint collaboration between ESA and ESO
- Easy to use, easy to implement new models, and pipeline different models
- Main objectives are: reusability, knowledge transfer, reliability
- v1.0.0 is out! Launch event in March ==========>
- more about Pyxel? https://esa.gitlab.io/pyxel/

TEC lab presentation

TEC lab: VIS detector characterization facility



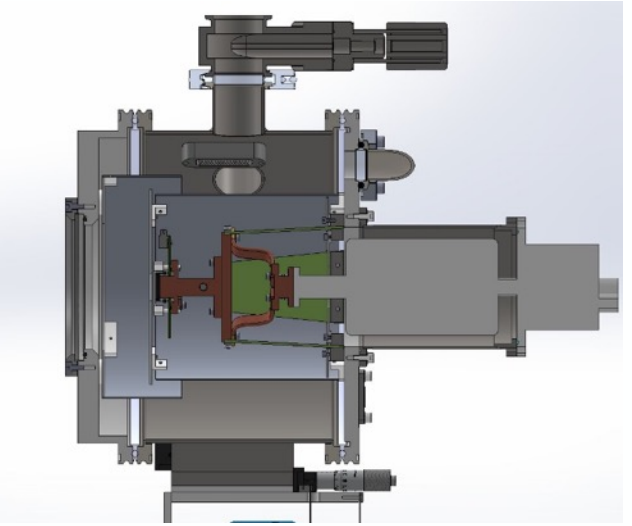


FEATURES:

- Detector testing: CCD, CMOS
- Cryostat temperature capability down to 120K
- Setup automation and detector safety control
- High dynamic range of illumination levels

ILLUMINATION:

- QTH Lamp, filters and variable Aperture
- Various LEDs, CW or pulsed
- Spot Projector



TEC lab: VIS detector characterization facility

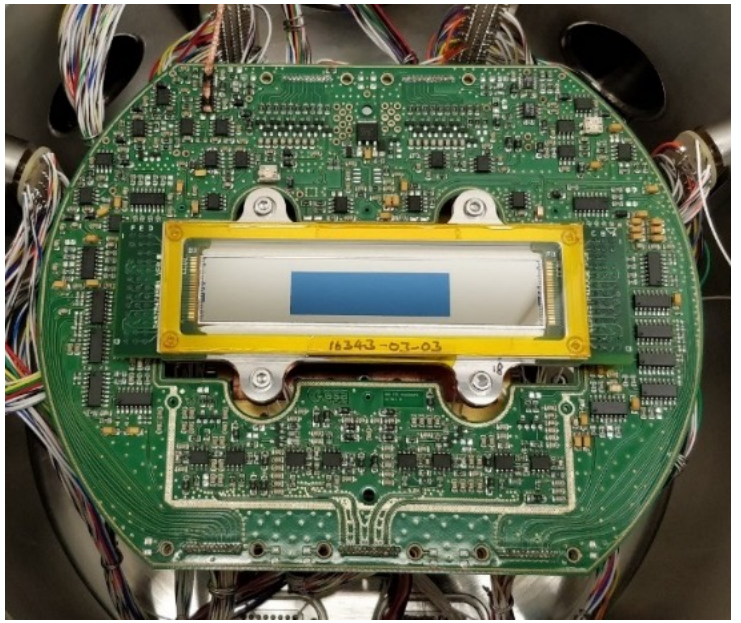
DETECTOR DRIVE ELECTRONICS

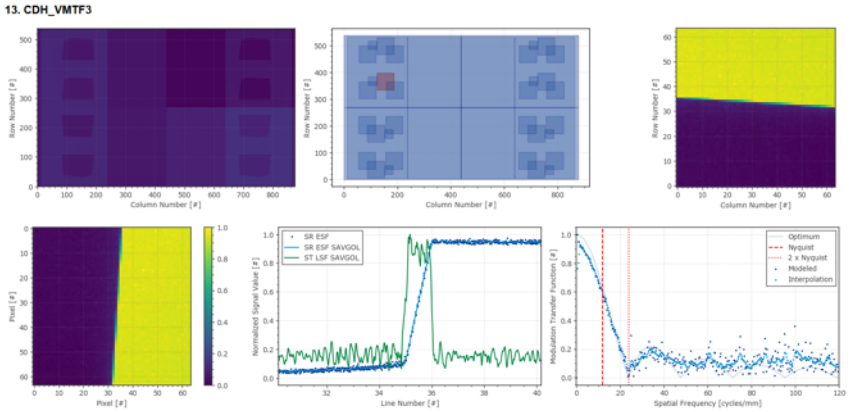
- Archon commercial drive electronics
- Modular chassis-based design
- Standard interchangeable modules
- Flexible high-level programming
- Standard gigabit network interface
- Standard stock software
- Custom automation software (Mistral)

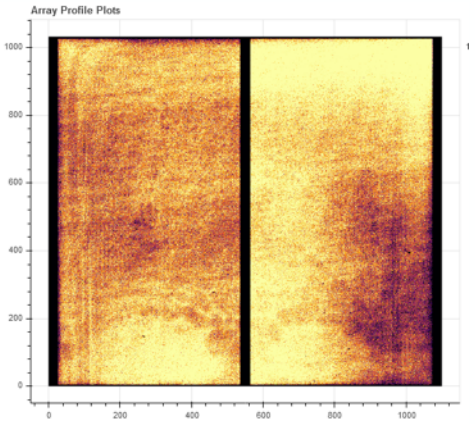
ARCHON
A HIGH PERFORMANCE MODULAR CCD CONTROLLER

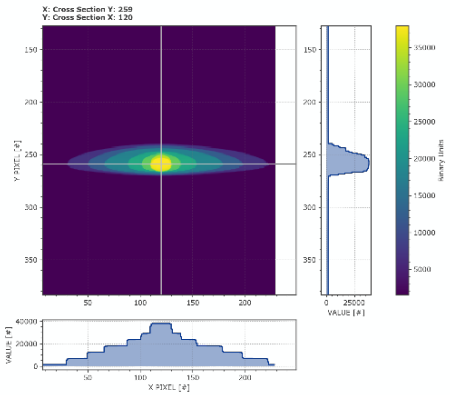
MEASUREMENT CAPABILITIES

- Optimization of detector operation and data validation
- Standard characteristic evaluation
  - Dark current and DSNU
  - Non-linearity
  - Photon transfer curve
  - Charge transfer efficiency
  - Quantum efficiency
  - Photo response non-uniformity
  - Modulation Transfer Function
- Custom measurements upon request

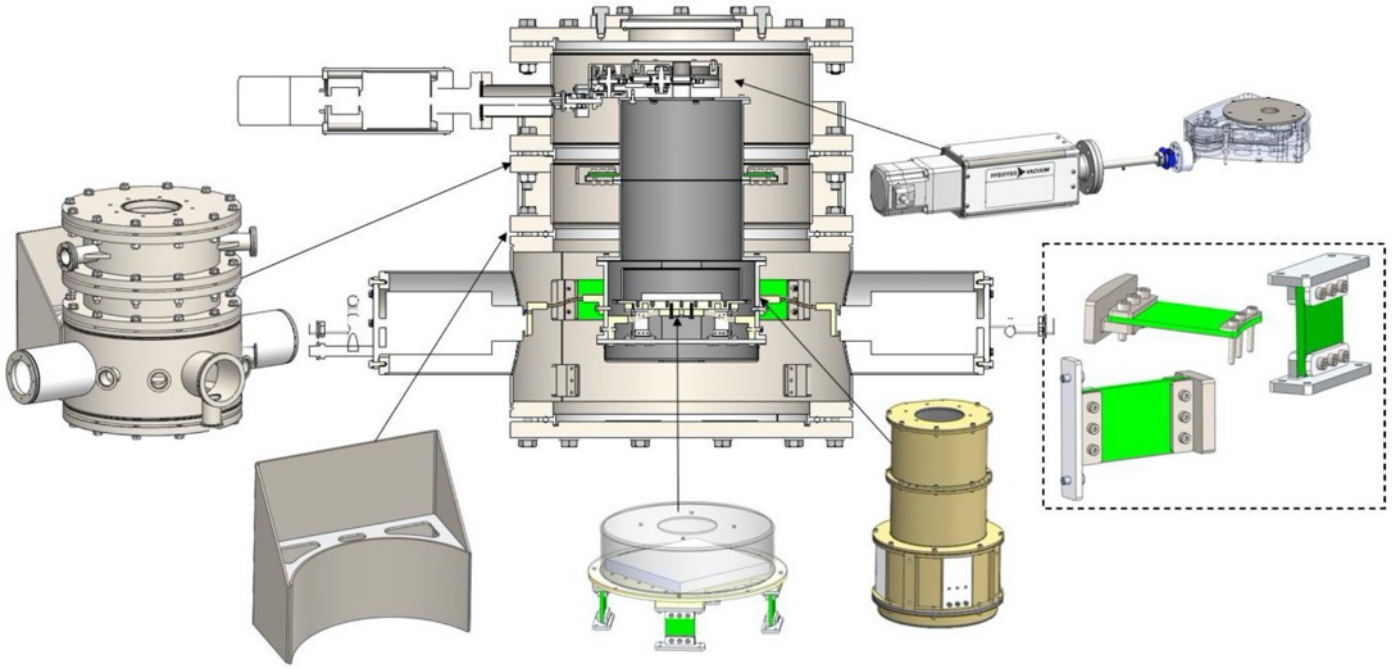


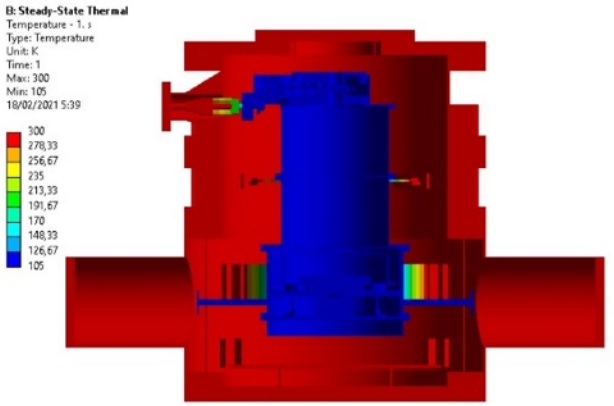


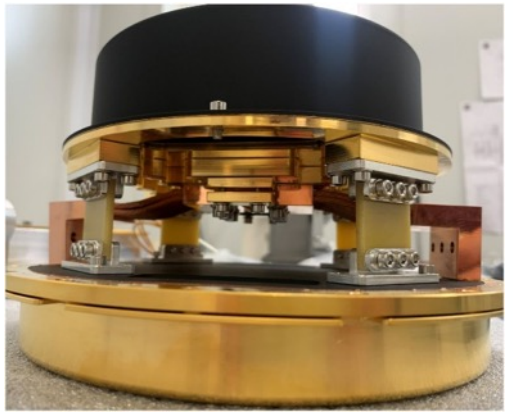




TEC lab: SWIR detector characterization facility







- Targeted detector spectral range 0.4 – 2.5 µm
- Detector temperatures down to 120 K
- Cold filter wheel
- Modulus design for improved flexibility
  - Low thermal background (closed) configuration for sensitive measurements
  - High thermal background (open) configuration for imaging applications

ILLUMINATION:

- LDLS + spectrometer
- QTH + Integrating sphere
- LEDs

MEASUREMENT CAPABILITIES:

- Dark current and DSNU
- Non-linearity
- Gain
- Detector Lag
- Photo Response Non-Uniformity
- Quantum Efficiency
- MTF

TEC lab: SWIR detector characterization facility

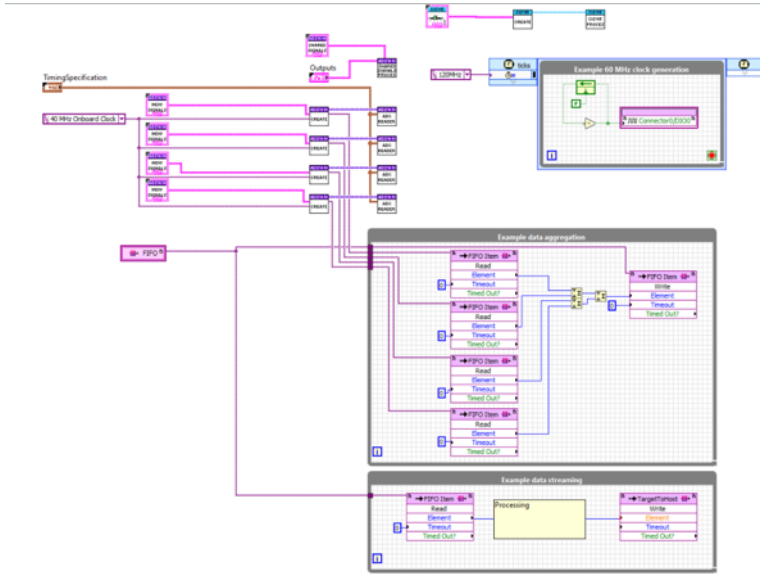
SAFETY AND CONTROL

- System control via HMI
- RestAPI access
- Power distribution and control
- UPS
- Housekeeping log
- Failure detection
- SMS notifications

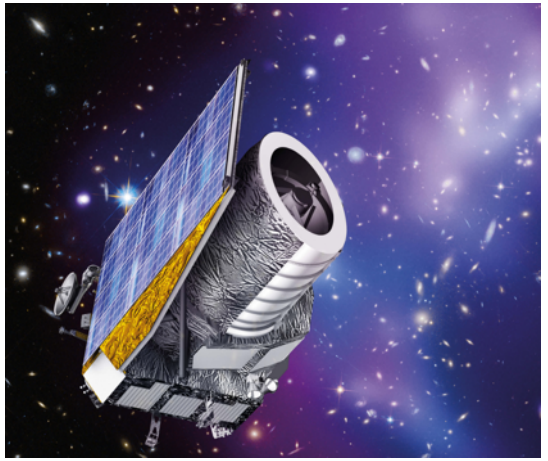
DETECTOR DRIVE ELECTRONICS

(in development)

- PXI based system
- Standard off-the-shelf modules
- Firmware “blocks” configurable on the go without resynthesis of bit files
- Primitives to develop the firmware for purely clocked sensors, SPI configurable, analog (16bit 125Msps) and digital output (LVDS 1.2Gbps)
- Feasible MCLK freq. up to 200MHz



Many thanks for your attention



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- **Application:** Science programme technology development and mission support in all phases
- **Test benches:** 4x VIS (CCD), 3x SWIR (MCT-Hybridised), 1x MWIR, UV-beam line,
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- **Application:** Earth Observation & telecom missions support and generic technology development
- **Test benches:** VIS (CCD, CMOS), SWIR
- **Wavelength range:** Visible to SWIR
- **Additional equipment/lab:** Laser lab

Let us know if you have any questions, remarks!

Back-up slides

SCI lab: EUV bench

Extreme UV beam line:

- hollow cathode discharge, using He gas, with a grating monochromator
- Wavelength range of ~20-100nm