

# Detector developments supported by the European Space Agency

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Infrared Detectors in Space (IRIS 2026) Workshop, 10 March 2026

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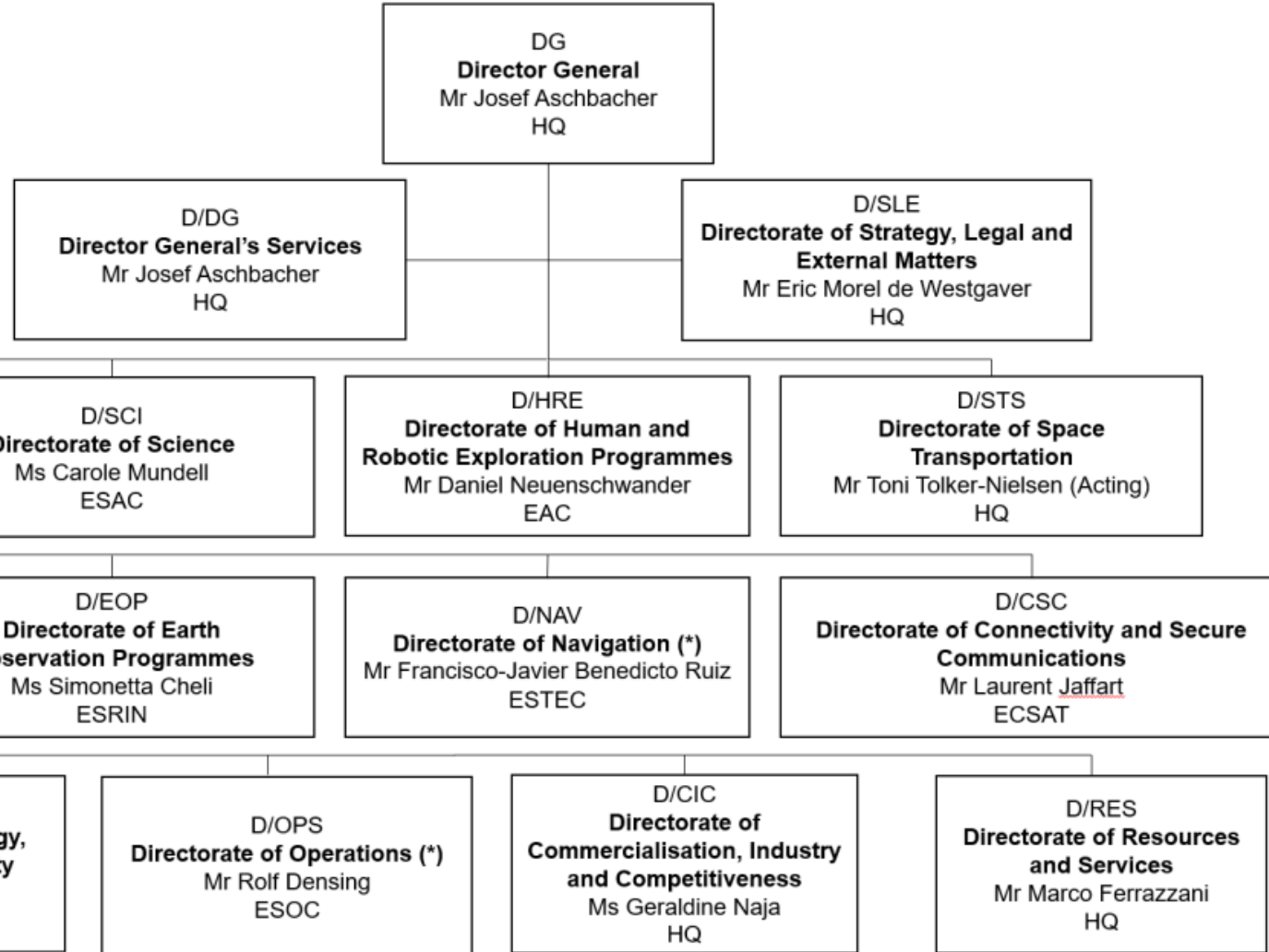
The European Space Agency is an international organisation with 23 Member States.

*... to provide for, and to promote, for exclusively peaceful purposes, cooperation among its Member States in space research and technology and their space applications, with a view to their being used for scientific purposes and for operational space applications systems ...*



ESTEC, in the Netherlands, is the largest ESA facility and centre of technical activity.

# 'Us' at ESA



Ralf Kohley  
*Science Operations*

Eloy Hernandez  
Frédéric Lemmel  
Vincent Affatato  
*Science Payload Validation*

Matthew Soman  
*Optoelectronics*





Limitations can be:

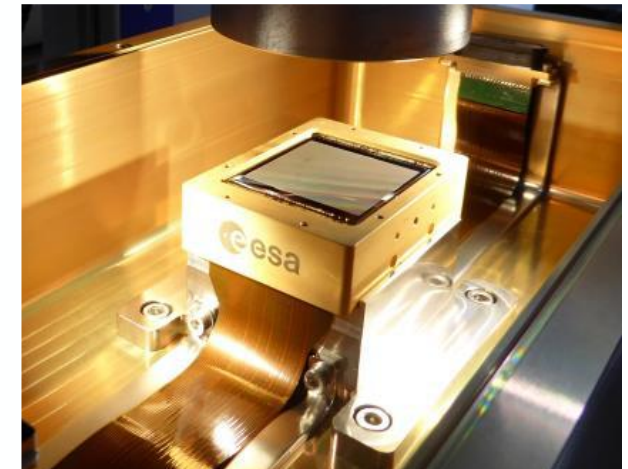
Physical parameters	... pixel size, detector size and shape
Electro-optical performance	... quantum efficiency, dark current, SNR, MTF
Dynamic operation	... frame rate, rolling/global shutter, integration time

State-of-the-art missions require state-of-the-art performance, so there is a strong argument for continuous detector development

- ESA pursues a challenging program of generic and custom detector development

# How does ESA decide what detectors to develop?

- From basic principles (TRL3-) 💡 to flight preparation (TRL6+) 🚀
- From VLWIR (17  $\mu\text{m}$ ) to gamma-ray 🌈
- From earth observation to optical communications to LIDAR to X-ray astronomy ... 📷
- Technologies including:
  - CCDs & CMOS image sensors and ROICs
  - Infrared materials such as MCT, T2SL (III-V) and InGaAs
  - High energy detection materials
  - Specific applications, processes, materials and technologies closely linked to the Focal Plane Architecture:
    - Filters and surface processing
    - Control ASICs and detector Front End Electronics
    - Curved-silicon
    - Packaging and flex-circuits



# ESA Detector Development Roadmap



## MAPPING

Review the state-of-the-art and identify the existing capabilities and future development needs in Europe

- Tech. Status
- Competition
- Mission Needs
- Products
- Market
- Strategic Interests
- Funding
- Organisations
- Competences

## ROADMAPPING

Consolidate and agree on Technology Roadmaps with a common vision to answer those needs in an optimal manner

- What
- When
- Who
- Cost
- TRL
- Priority

## ESA Technology Harmonisation

- ESA/Industry approved roadmap of Technologies for Optical Detectors (ESA/IPC/THAG(2022)5) Revision 4.2
- Optical Detectors topic is next planned for the 1<sup>st</sup> cycle of 2027

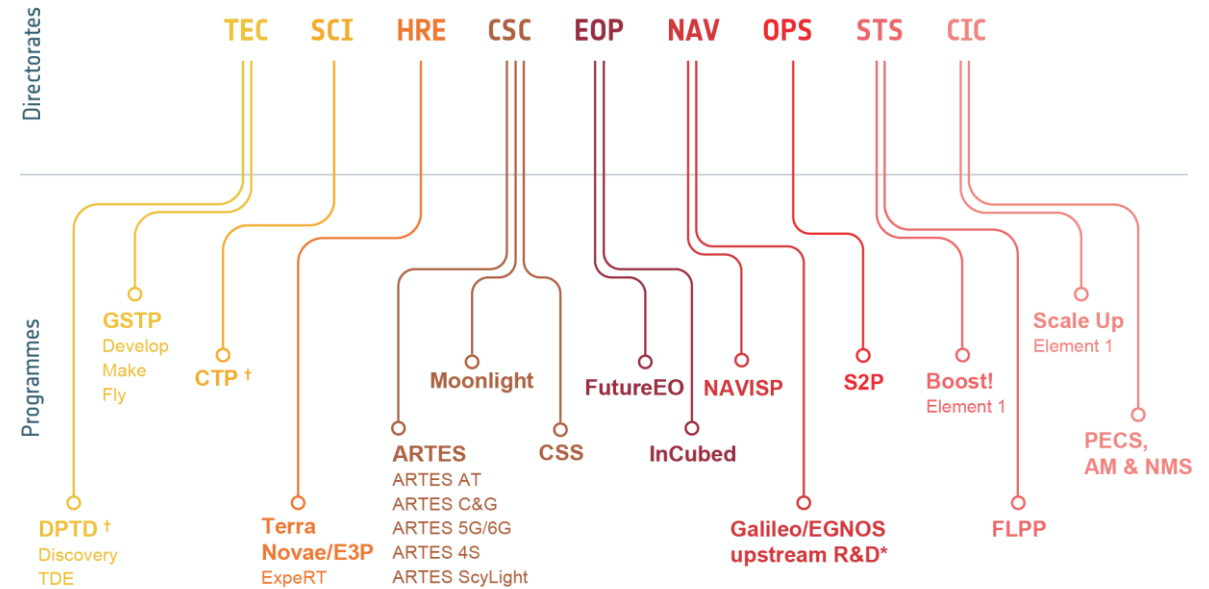
## Detector Working Group

- Endorsed by Component Technology Board, under European Cooperation for Space Standardization (ECSS)



- ❑ Discovery on OSIP (including support for PhD and post-doctoral researchers)
  
- ❑ Technology Development Element (TDE)
- ❑ Science Core Technology Programme (CTP)
  
- ❑ General Support Technology Programme (GSTP)
  
- ❑ Future Earth Observation Programme (FutureEO)
  
- ❑ ARTES Secure and Laser communication technology Program (ScyLight)
  
- ❑ Project-specific pre-developments

## ESA DIRECTORATES AND TECHNOLOGY R&D PROGRAMMES

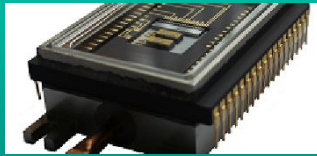


\* EU programme implemented by ESA through delegation and cooperation agreements.

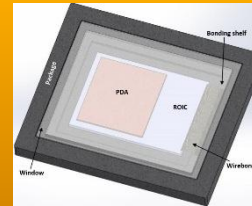
**TEC** Technology, Engineering and Quality | **SCI** Science | **HRE** Human and Robotic Exploration | **CSC** Connectivity and Secure Communications | **EOP** Earth Observation Programmes | **NAV** Navigation | **OPS** Operations | **STS** Space Transportation | **CIC** Commercialisation, Industry and Competitiveness. † Indicates programmes that are part of ESA's mandatory activities.

## CCD and CMOS

Aeolus 2: CCD for doppler wind lidar

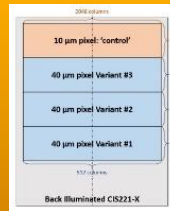


Hybrid Visible Image Sensors

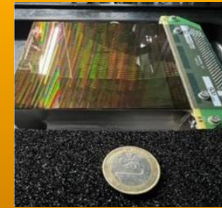


High Dynamic Range Panchromatic Detector  
Pre-development

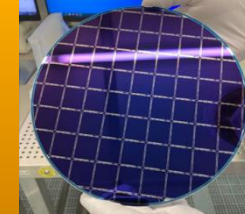
Monolithic CMOS sensor for 0.1 to 5 keV X-rays



CIS304 Radiation & Performance Testing



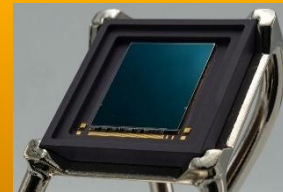
FLAMES  
Flash-LiDAR Image



S2NG: VIS multispectral focal plane



CIS220 High-rho CMOS demonstrator product



ELFIS II: Low flux CMOS sensor from a European supply-chain

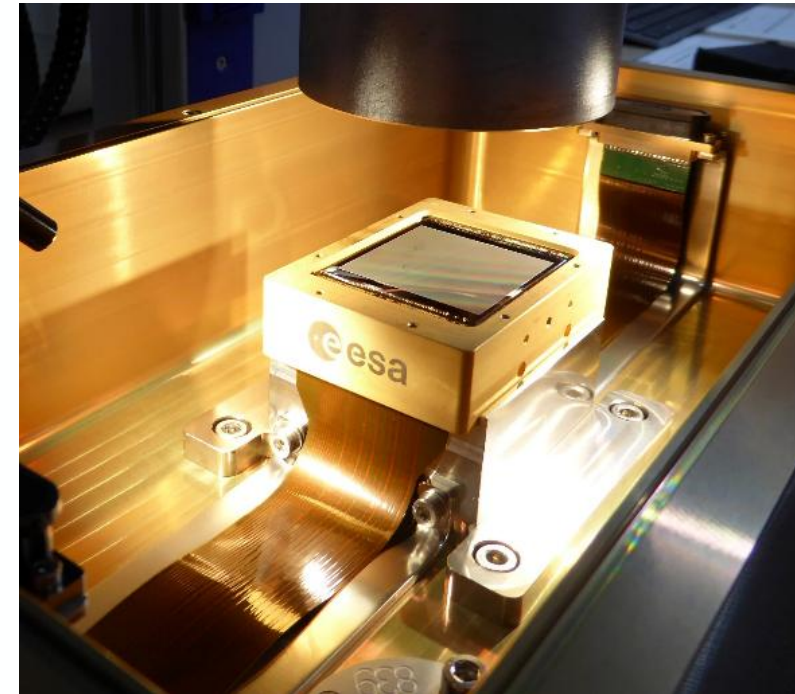


# SWIR (< 2.5 $\mu\text{m}$ ) – photon starved regime

Widespread adoption of cooled MCT detectors, as the ‘gold standard’ for performance.  
In photon-starved applications, the **HxRG** has been exemplar (e.g. Euclid, Ariel, Arrakis)

Are **linear-mode APD arrays** going to change this status quo?

- ImAPDs from Leonardo UK are now established in adaptive optics, but staring arrays must be optimised differently
- A successful 2k x 2k array development with ESA (**IBEX**) is being continued
  - Improvements to both the ROIC and the MCT avalanche structure
- On-sky demonstrations planned in 2026-27 to utilise the enhanced performance in photon starved regimes
- Radiation assessment of ESA developments are scheduled for 2026



2k x 2k IBEX detector: ImAPD array from Leonardo UK

HxRGs + MCT have dominated in MWIR and LWIR space instrumentation for photon-starved applications (JUICE, JWST, Ariel).

AIM, Leonardo UK and Lynred have focused their longer-wavelength MCT product development on dual-use and Earth Observation applications, with bespoke and high-performance products (e.g. IASI-NG, LSTM TIR, CO2M NGP, ...)

## What could change the status-quo?

- Lynred shared extremely promising performance in the MWIR-VLWIR in 2025, with a new p-on-n MCT process – it's now being productionised
- Can ImAPD technology extend to wavelengths beyond SWIR? Probably not very far

For now, Ariel (8  $\mu\text{m}$ ) and NEOMIR (11  $\mu\text{m}$ ) both baseline HxRGs.

## Can other materials compete against MCT?

- Type-II Super Lattice (T2SL) has potential advantages (uniformity, radiation tolerance, stability, sustainability and sourcing) but side by side comparisons are needed
- T2SL detectors are still being rapidly developed (also in the SWIR)

And don't forget about MKIDs or SNSPDs...



Lynred NGP



AIM detector for LSTM

## Hybridised arrays with infrared-sensitive materials: MCT, T2SL, InGaAs, Ge-on-Si

**COBRA-L**  
Large area SWIR detector



COBRA  
1840 x 1112, p20µm

NGP for SWIR hyperspectral applications

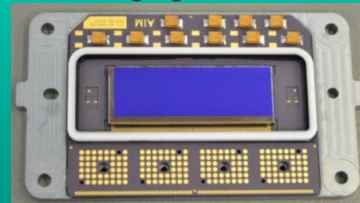


2x High frame-rate HDR ROIC for MWIR-LWIR sounders

1 MPix MWIR detectors using Type-2 Superlattice



VNIR-SWIR Hyperspectral Imaging Detector



S2NG - Pre-developments for wide-swath SWIR multispectral array



Low power digital ROIC development

MPix InGaAs Array Development



LSTM NIRSWIR Land Surface Temperature NIRSWIR channel

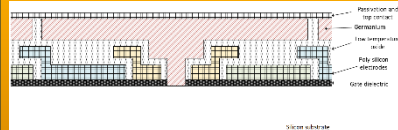


2k x 2k SWIR APD Low-flux SWIR detection

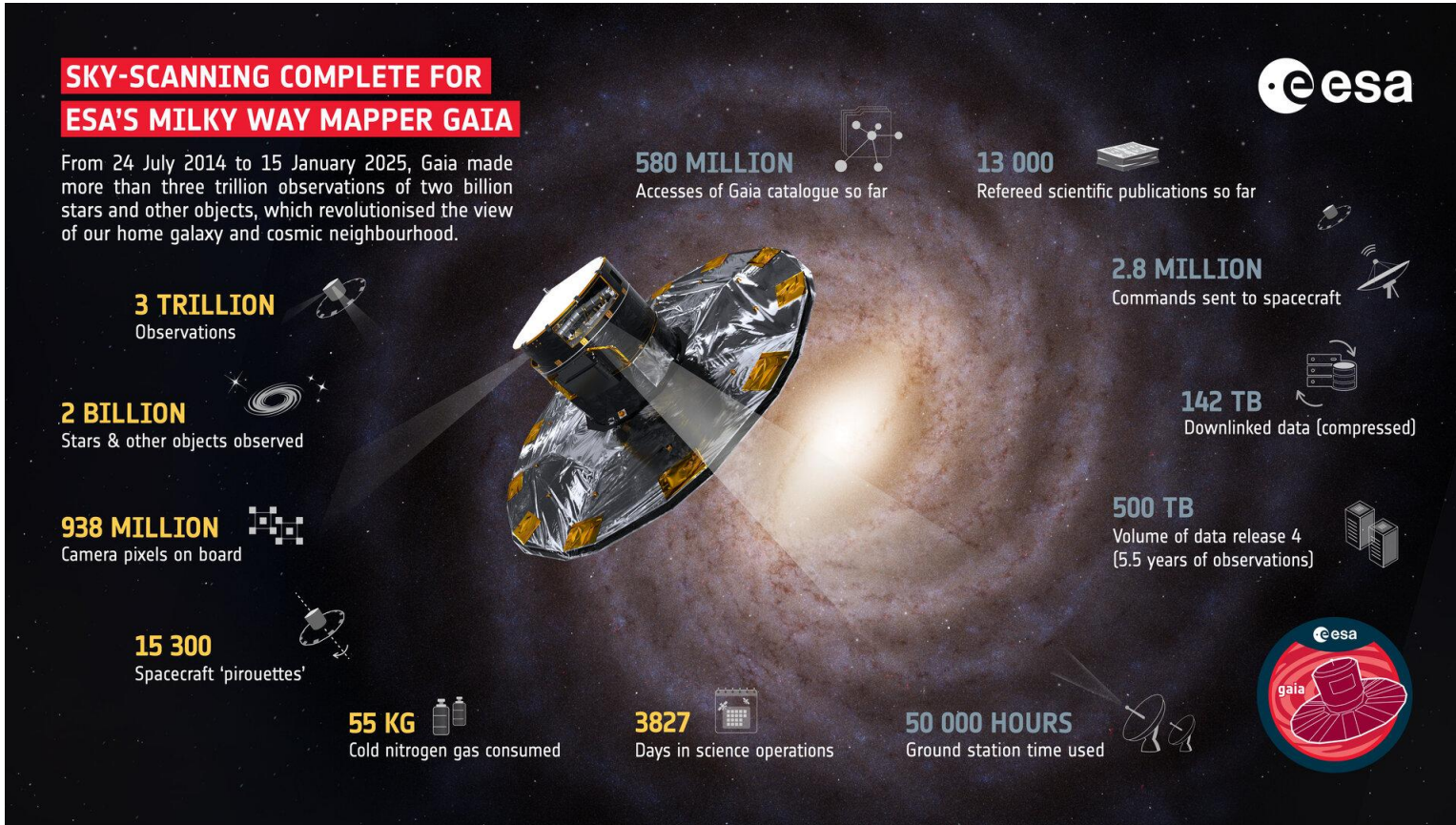


Industrialisation of eSWIR T2SL

Germanium-on-Si CCDs



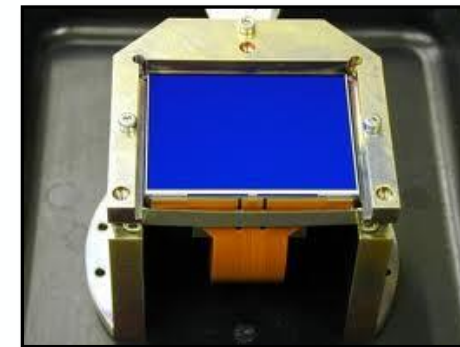
# A mission pull – example: GaiaNIR



Gaia was built on 30 years of CCD heritage

GaiaNIR would allow observations to penetrate the dust & gas of the galactic centre

Infrared detectors that meet the needs of a spinning spacecraft are not (yet!) available.



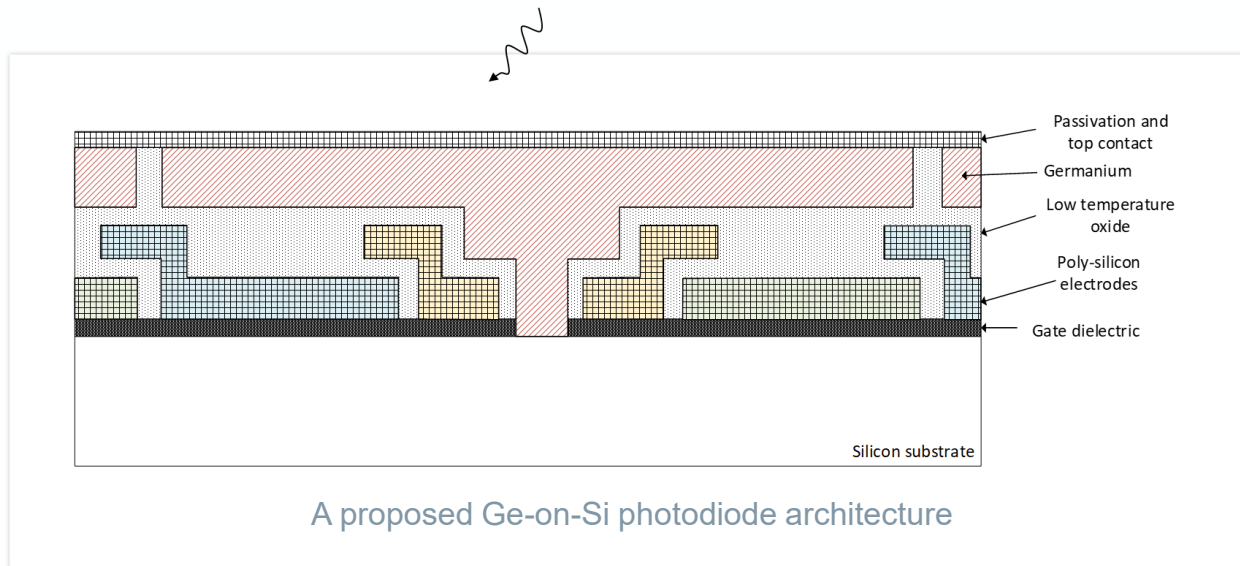
Gaia CCD from Teledyne e2v

CCDs are well-established – for UV, visible, NIR and soft X-ray detection

Well-understood and offering high performance, and there is still opportunity for further development

Teledyne-e2v (UK) is investigating the implementation of germanium photodiodes onto the CCD with the aim to extend the cut-off wavelength to  $>1.8 \mu\text{m}$

If demonstrated, this could develop new applications for CCDs and support large-scale TDI operation in the NIR/SWIR waveband



A completed feasibility study is being followed by an activity to design, manufacture and characterise representative photodiode structures prior to implementation into a full Ge-on-Si CCD development.

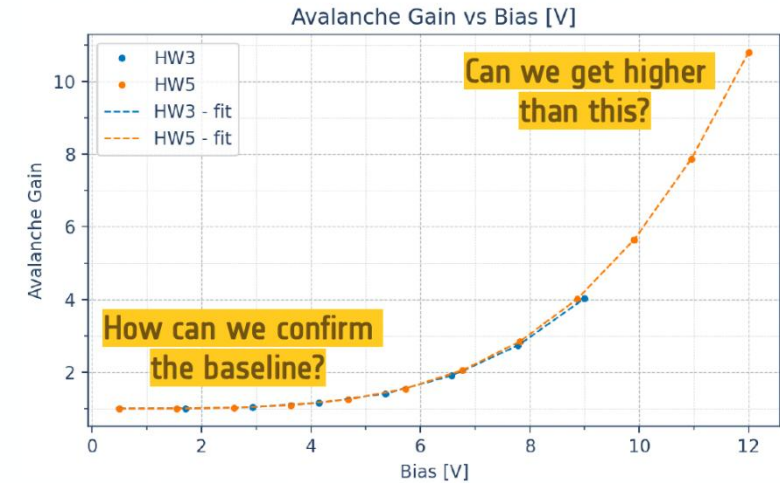
- Targets future photon-starved applications in SWIR, using a large format ROIC bonded to an APD array
- Builds on successful SAPHIRA technology with Leonardo UK

### ME1130 ROIC:

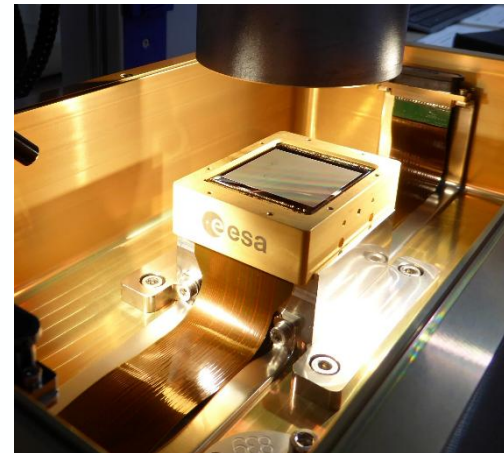
- Activity completed in 2024: 2k x 2k, 15  $\mu\text{m}$  pitch - see talk from Vincent Affatato

### ME1230 ROIC:

- Implementing improved readout chain (from Ike Pono), latest MCT (graded bandgap), hybrid detector characterisation and full radiation test.
- Recently finished manufacturing...



What happens after exposure to radiations?



More development will be needed before a high performance GaiaNIR Flight Model detector...

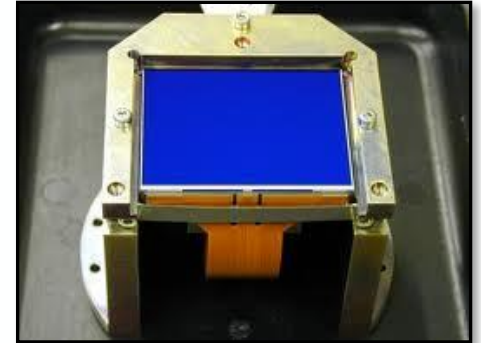
Parameter	Value	Comment
No. pixels	2048 x 2048	Plus 4 reference rows top and bottom
Pixel size	15 $\mu\text{m}$	Square pixel
Charge handling capacity	>100 ke-	
Read noise (expected)	<27 e-rms	M=1
Pixel clock	270 kHz	
No. outputs	4, 8 or 16	Selectable
Frame rate	1 Hz	16 outputs @ 270 kHz
Cut-off wavelength	2.5 $\mu\text{m}$	
Operating temperature	80 K	Typical, for 2.5 $\mu\text{m}$ cut-off

What is 'high-performance'?

- A subjective and relative term – not necessarily agreed upon by detector supplier and detector user

Instead, initial detector developments could be considered as having 'high-potential'

- Not because of risks in the development (which do exist) but rather due to the future characterisation that is necessary to realise the high-performance
- Dedicated characterisation (test as you fly) leads to an excellent understanding of the detector and enables first-class science



Gaia CCD from Teledyne e2v



NGP SWIR detector from Lynred

Consequently, a successful detector development should be seen not as the end but rather as the beginning of the development of a high-performance detector

- The European Space Agency (ESA) is an international organisation for promoting space research, technology and applications
- **Detectors are very often a performance-limiting component for space instrumentation**
- ESA pursues a challenging program of generic and custom detector development, driven by:
  - Development roadmaps prepared with stakeholders via ESA Technology Harmonisation and Detector Working Group 🤝
  - Mission-pull needs
- Various ongoing detector developments were presented

**A successful detector development is the  
beginning  
of a high-performance detector**

*Thanks to all detector colleagues across ESA directorates*

**SPACE & SCIENTIFIC CMOS IMAGE SENSORS WORKSHOP**

~~26, 27 November, 2024~~

ThalesAlenia Space | AIRBUS DEFENCE & SPACE | esa | comet | cnes | OHB | sodern ananeGROUP | isaer SUPAERO

Next visible detector workshop:

VISSA: VISible detection for Space Applications

24-25 November 2026 @ ESTEC, The Netherlands

Next infrared detector workshop:

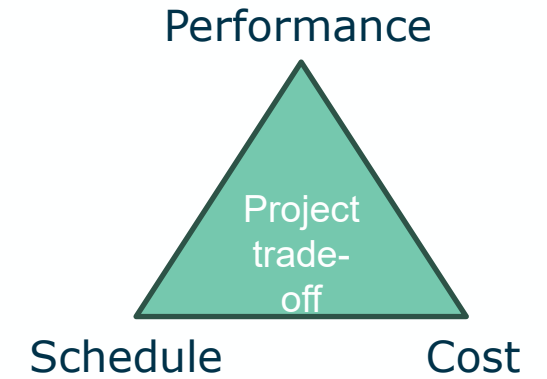
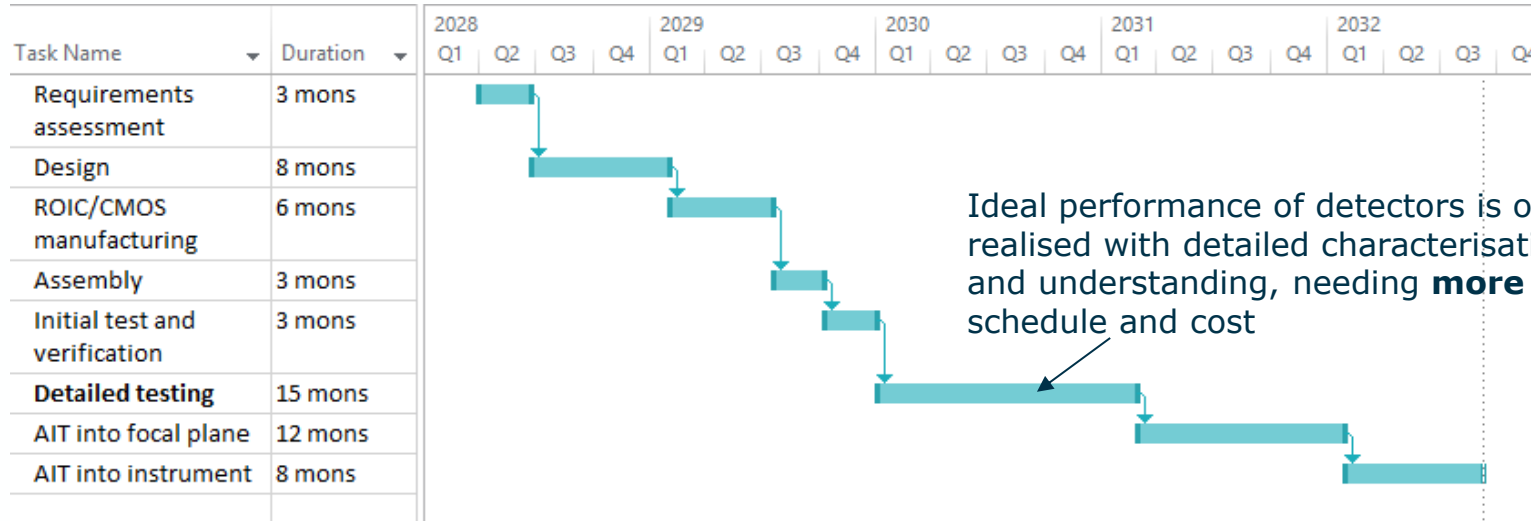
November 2027

**InfraRed detection for Space Applications IRSA 2025**

cnes | esa | isaer SUPAERO | ONERA THE FRENCH AEROSPACE LAB | AIRBUS DEFENCE & SPACE | leti | FOCUS | ThalesAlenia Space

# What timescales to consider for a CIS or ROIC?

Custom developments can maximise instrument **performance**, but the wider project must be considered – **schedule and cost**

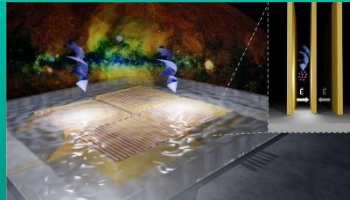


Further **risk**: CIS and ROIC development complexity can reduce the likelihood of ‘right first time’

*But still, some instruments would be impossible without bespoke developments...*

## Other specific applications, processes, materials and technologies related to focal plane architecture

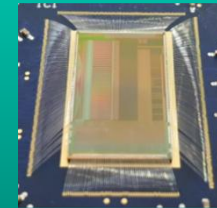
Perovskite-based  
X-ray and  $\gamma$ -ray detection



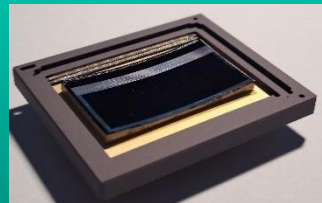
Carbon-based Filters  
Improved X-ray transmission



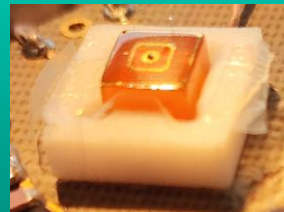
ALFA-C Optimised ASIC for  
NIR Large Format Array



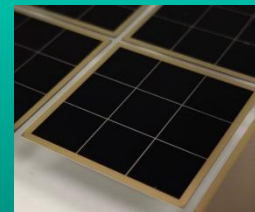
Curved CMOS sensors for  
compact optical design



Single crystal perovskite-  
based radiation detectors



Black-Silicon SDDs  
For coupling with scintillators



NIRCA MkII  
ASIC to drive detectors



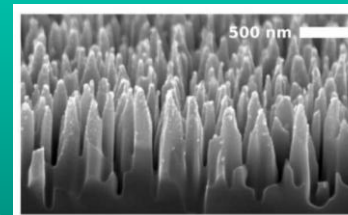
Curved-silicon 2D array  
CCD with 500 mm radius



GaAs on MiniPix TPX3 for  
high energy detection



APDs based on  
black-Silicon



Front End Electronics based  
on NIRCA MkII: breadboard  
and engineering models

