ESA Detector Development Activities

EIROForum
Topical workshop on Semiconductor Detector Developments

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TEC-MME

17 Feb 2022

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Funding Programmes

Technology Development Element (TDE)
https://www.esa.int/Enabling_Support/Space_Engineering_Technology/Shaping_the_Future/About_the_Technology_Development_Element_programme_TDE

General Support Technology Programme (GSTP)
https://www.esa.int/Enabling_Support/Space_Engineering_Technology/Shaping_the_Future/About_the_General_Support_Technology_Programme_GSTP

Science Core Technology Programme (CTP)
https://www.esa.int/About_Us/Business_with_ESA/Business_Opportunities/Science_Core_Technology_Programme

Earth Observation Envelope Programme (EOEP)
http://www.esa.int/About_Us/Business_with_ESA/Business_Opportunities/Earth_Observation_Envelope_Programme

European Component Initiative (ECI)
http://www.esa.int/Enabling_Support/Space_Engineering_Technology/European_Component_Initiative_ECI

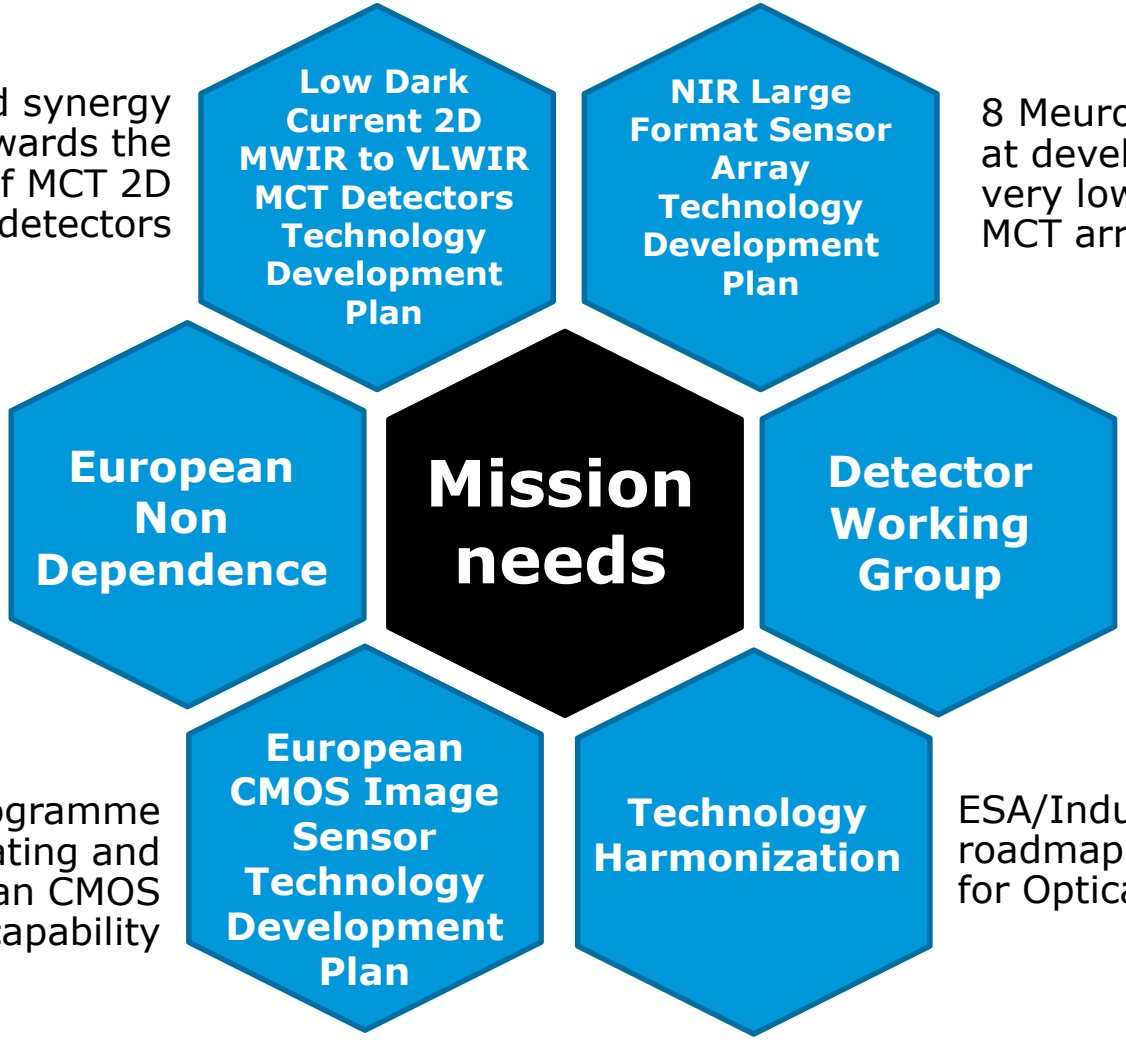
Innovation Triangle Initiative (ITI)
Network Partnering Initiative (NPI)

NPI, ITI and the GSP internal call for ideas have been discontinued and these functions are now covered by **OSIP**
https://ideas.esa.int/

Secure and Laser communication technology Program (Scylight)
https://artes.esa.int/scylight

Detector Development Roadmaps in ESA

Coordination and synergy at ESA aiming towards the next generation of MCT 2D IR detectors

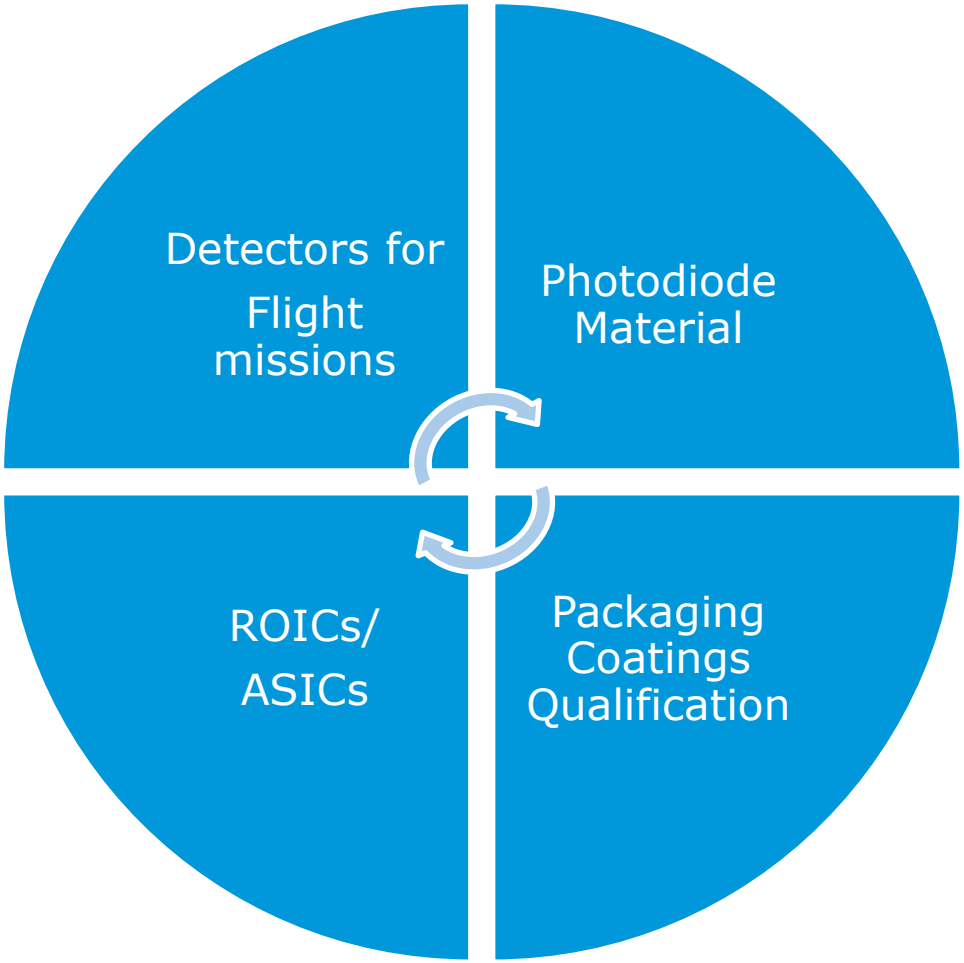


8 Meuro program aimed at developing 2K x 2K, very low noise and DC MCT array + ASIC

Two phase programme aimed at investigating and supporting European CMOS foundry capability

ESA/Industry approved roadmap of Technologies for Optical Detectors

“Detector activities” are covering…



Detector Activities

- Visible Wavelength
  - CMOS, CCD, Star Trackers…
- SWIR
- MWIR to TWIR
- High Energy Detection
- Mission pre-developments
  - CO2M, LSTM, CHIME, AEOLUS
- Other activities related to detectors
  - Detector qualification,…
- Recently started and upcoming activities

Visible

High performance CMOS Visible
Star-trackers
CCDs

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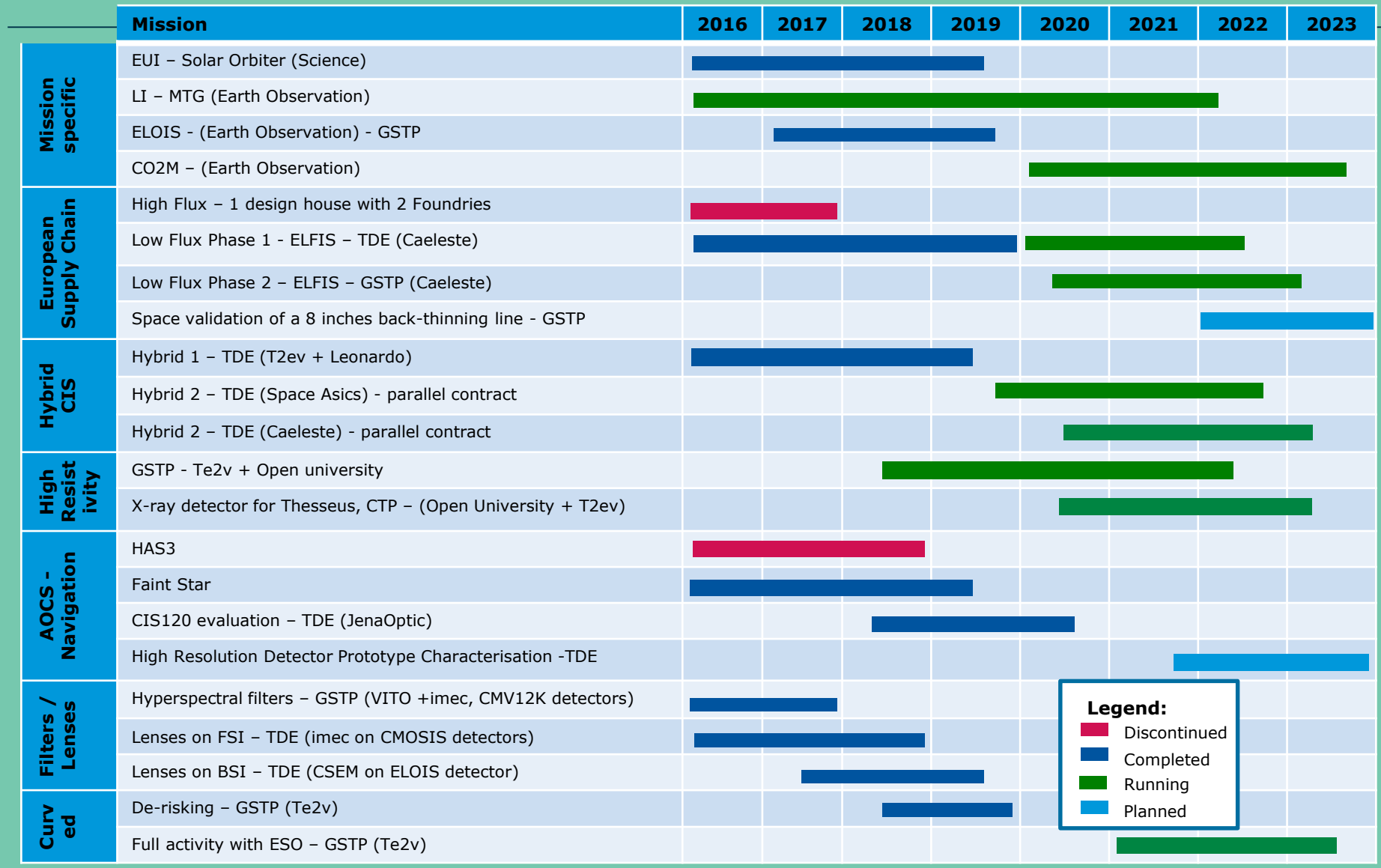
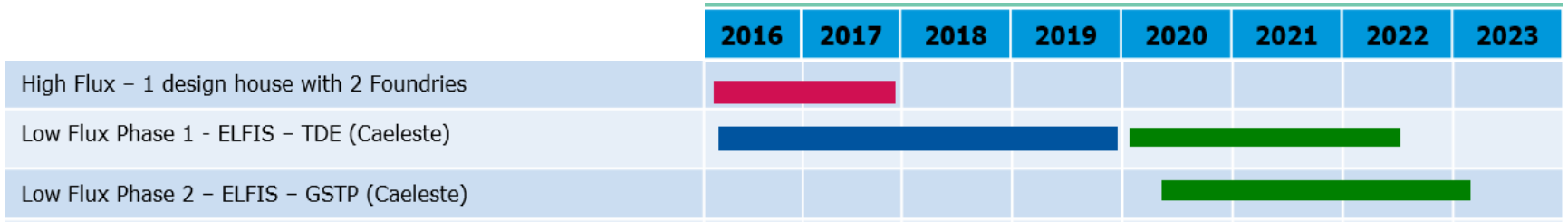
CIS activities at ESA



European CMOS visible detectors

European CMOS Image Sensor Technology Development Plan

Two phase programme aimed at investigating and supporting European CMOS foundry interest and capability for development of high performance image sensors.



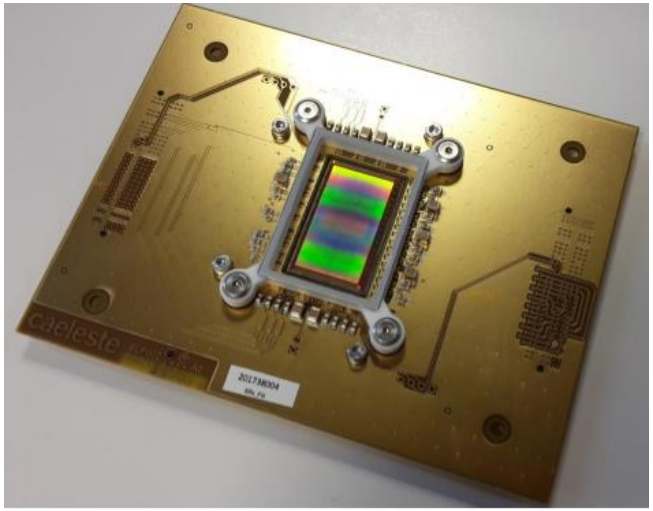
ELFIS – Phase 1

Development of European CIS for science/astronomy applications – low noise
15um pitch, 1920x1080 pixels

caeleste

LFOUNDRY
A SMIC COMPANY

AIRBUS
DEFENCE & SPACE



Completed

European Space Agency

European Low-Flux CIS (ELFIS 2)

TO: K. Minoglou

Caeleste (BE) – GSTP 1000keuro (Q1 2021 – Q1 2023)

Objective

To continue the activity started on ELFIS-CCN1/CCN2 developing a new version of Low Flux CMOS image sensor and develop a detector representative in form, fit and function of potential flight suitable device.

Same EO as ELFIS 1

and improvements in design:

Spec/property/feature	Actual ELFIS (Rev.C 7E)	Target (ELFIS2)
Geometry		
Pixel array size	1920x1080	N*512 x M*1024
Stitching	No	Yes
Binning	No	Charge domain binning
Backside shallow p-implant	No	Yes
Back bias capability	No	Yes
Test pixels	16 columns left side	Will be placed at south or north side
# outputs per segment	16 differential output for whole 2kx1k pixel array	8 differential outputs per X=1024 columns (stitch block(s))
Merging of outputs	no	8 or 4 channels per x=1024 or x-512 column segment can be merged to 1
Column FPN correction	No	Yes
Output format	Analog, fully differential	a. Analog, fully differential b. Analog, pseudo-differential (compatible with own ADC)
enhanced low-noise modes	On S&H stage, mux, colamp etc	More options, team effort, brainstorm to optimize.
ADC (Not a requirement. Extra design add-on)		
On chip	No	No
Companion ADC	No	Yes (same reticle)

Results

KO: Dec20 → CDR: Feb21

Tape Out in June

FSI completed

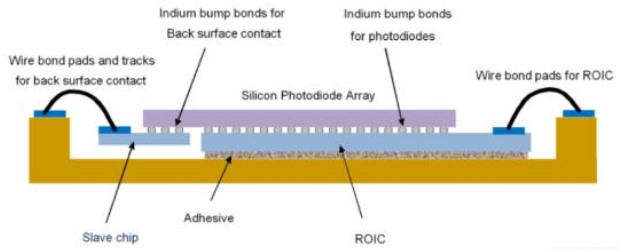
BSI in Jan and Feb 22 → TRR in April 22

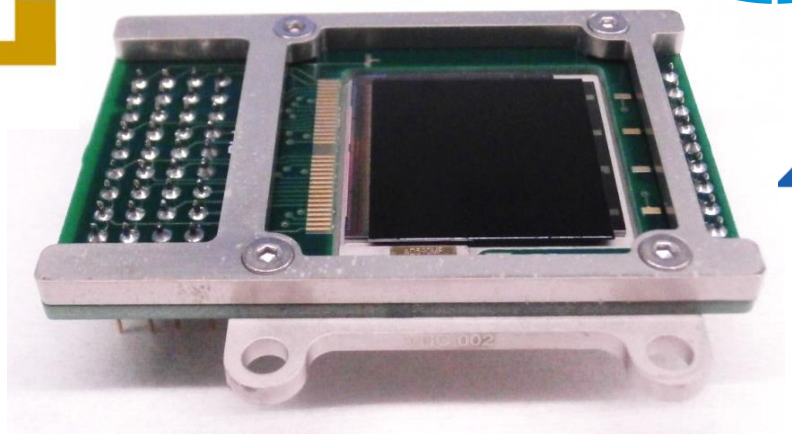
Hybrid CMOS visible detectors

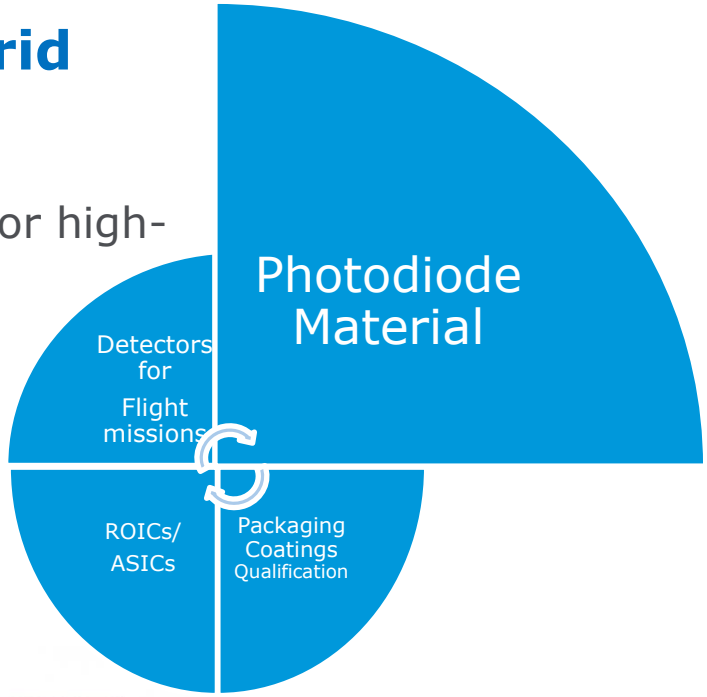
High-performance silicon visible hybrid CMOS image sensor

To demonstrate the potential of hybrid technology for high-performance silicon visible CMOS image sensors.

Si 2D photodiode array (PDA)
- Target thickness 300um, full depletion at <50V
- ROIC: Selex ME930
- 15um pitch, 1280x1024 pixels







Completed

TELEDYNE e2v
Everywhereyoulook™

LEONARDO
INGENUITY AT YOUR SERVICE

European Space Agency

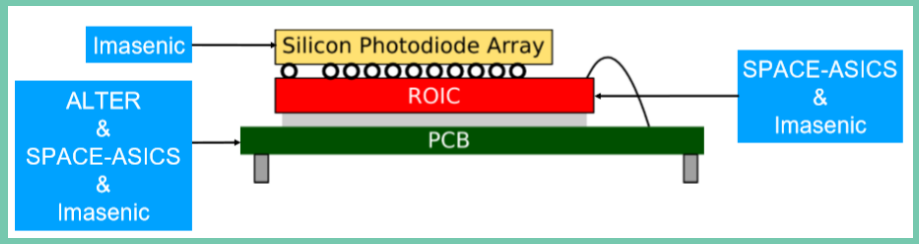
Hybrid visible image sensor (1st parallel contract)

TO: K. Minoglou

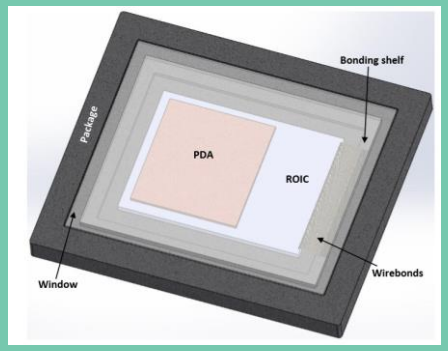
Space ASICS (GR) – TRP 1000keuro (Q1 2020 – Q4 2022)

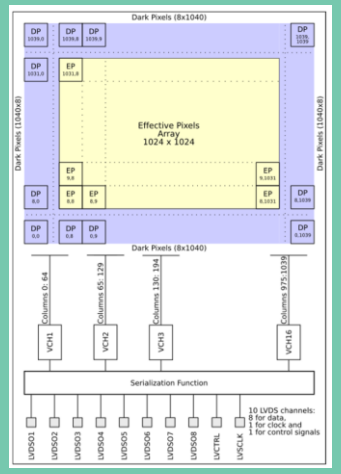
Objective

To progress further recent developments of large-format, high-performance visible hybrid detector arrays with the design and manufacture of a new ROIC and the fabrication and characterisation of a visible hybrid sensor breadboard. The usage of an existing high performance detection layer in line with the performances specified in this SOW and suitable for hybridisation on a ROIC, is assumed for this activity in order to keep development risk under control.



- Si 2D photodiode array LFoundry, LF11IS
- 1kx1k, 10-20um pitch
- ROIC: new design LFoundry
- TBD analogue or digital video outputs
- Global shutter with elements of radiation-hard design
- Hybridization @ Fraunhofer





Results

PDR: March 2020, DDR March 2021

Currently : Fabrication of the SiPDA and fabrication of the ROIC by LF

TRR planned in August 2022

Hybrid visible image sensor (2nd parallel contract)

TO: K. Minoglou

Caeleste(BE) – TRP 1000keuro (Q2 2020 – Q4 2022)

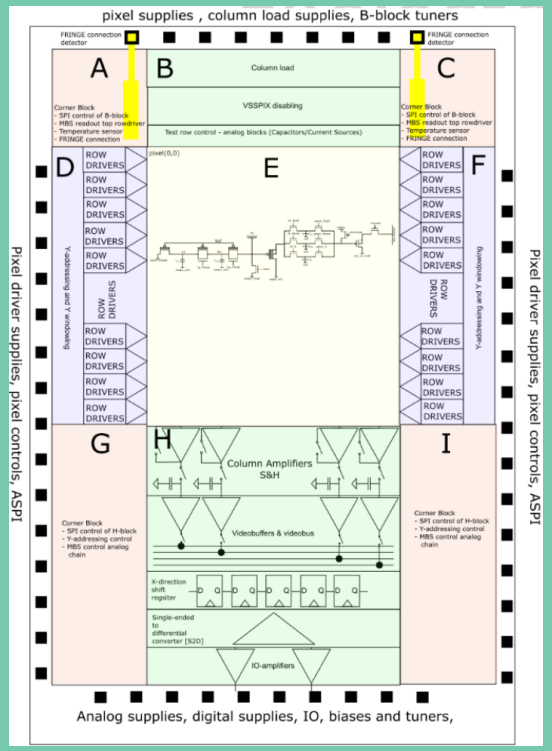
Objective

To progress further recent developments of large-format, high-performance visible hybrid detector arrays with the design and manufacture of a new ROIC and the fabrication and characterisation of a visible hybrid sensor breadboard. The usage of an existing high performance detection layer in line with the performances specified in this SOW and suitable for hybridisation on a ROIC, is assumed for this activity in order to keep development risk under control.

Caeleste → ROIC development and characterization

Advacam → Detector design, manufacturing and hybridization

- Si 2D photodiode array using SOI carrier wafer technology
- 1kx1k, 10-20um pitch
- ROIC: new design XFAB XH018
- TBD analogue or digital video outputs
- Global shutter with elements of radiation-hard design



Results

PDR June 2020 → DDR beg. Nov 2020 → FDR April 2021

Next : TRR planned in March 2022

CMOS Image Sensor Based on High-Resistivity Epitaxial Silicon

TO: K. Minoglou

T-e2v(UK) - GSTP 1000keuro **+ 313Ke CCN** (2018 – 2022)

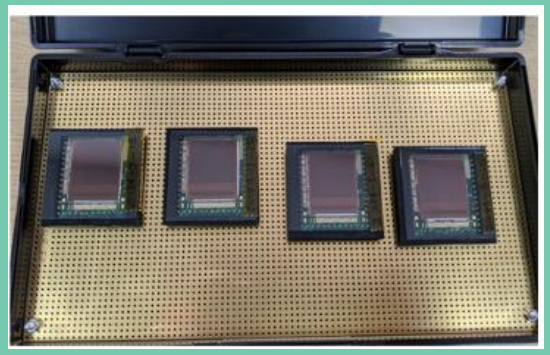
Objective

The main focus of this activity is the design, manufacturing and characterisation of a CMOS image sensor which should be: monolithic, backside illuminated, fabricated on high-resistivity thick starting material and being possible to operate in a fully depleted mode.

→ The design of the new detector **CIS220** is based on the Te2v platform CIS120.

→ Pixel special implants design and simulations by Open University, fabrication by Xfab.

- 2k*2k array, 10 - 20 um pitch
- Target substrate epi thickness: 40um
- MTF: >0.5 at Nyquist for at least 4 wavelengths
- QE x Fill Factor:
  - 400 – 800 nm > 75
  - 800 – 900 nm > 50



Front face CIS220 XFAB devices in PCB package

Results

KO Nov 2018 → PDR April 2019 → CDR Nov 2019

- FSI completed
  - 3 different implantation conditions and 2 thicknesses
  - characterization results are according to expectation / design fix is not needed
- BSI Wafer Fabrication – completed
- CCN: investigate if thicker bulk silicon can be used to improve QE at high wavelengths within existing Teledyne and CMOS wafer fab processes

Next steps → TRR April 2022 → FR July 2022

CMOS Image Sensor for X-ray Applications

TO: K. Minoglou

The Open University(UK) - TRP 1000keuro (2020 – 2022)

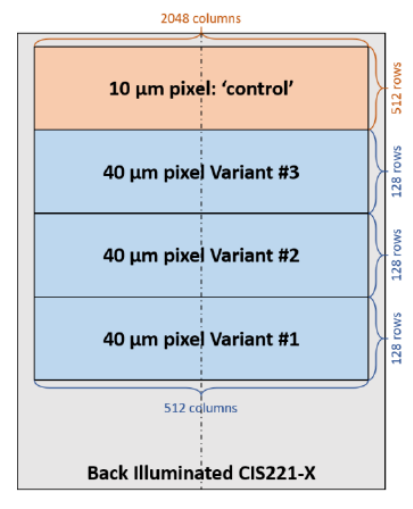
Objective

The goal of this activity is to design, manufacture and characterise a large-format CMOS image sensor optimised for soft X-ray detection.The CIS produced in this activity is intended to be used as SXI camera demonstrator devices for the THESEUS SXI instrument (one of the ESA's three Cosmic Vision M5 candidates).

→ The design of the new detector **CIS221-X** is based on the 2 other Te2v on-going developments:

(a) the CIS120 platform and (b) the High Resistivity CIS220 .

- 500x500 array, minimum active area requirement is 2x2cm2
- Scalability of the design to larger arrays, 3-sides buttable using stitching is required
- **40um pitch, target substrate epi thickness: 40um**
- **RON <5e RMS**
- With light blocking filter
- QE :0.5 -1.5keV >60
  0.3 – 5 keV >80



Results

KO Apri 2020 → RR May 2020 → PDR July 2020 → CDR Oct 2020

First results of FSI CIS220 give confidence on the implantation splits for the CIS221-x

BSI delayed, work on-going on the camera system commissioning at OU → TRR completion planned for March 2022

Second Generation APS for AOCS : Faint Star

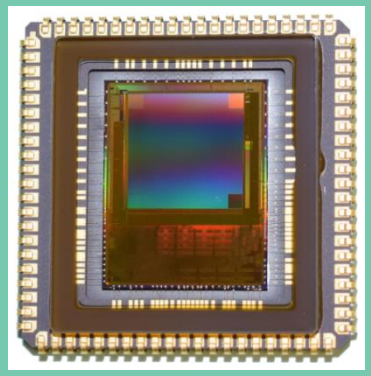
TO: S. Kowaltschek

AMS (BE) – GSTP 1750keuro (2012– 2021)

Objective

Two phase activity to prototype then qualify a detector aimed at STR remote OH, navigation, inspection and descent and landing cameras. Key drivers are the incorporation of the image pre-processing on chip for these applications.

- 1024*1024 array,
- 10 micron pitch,
- 12 bit ADC,
- JLCC package



Results

Final review successfully held.

Very significant number of Star Trackers in development or in qualification using the component as well as bespoke sensors (Navigation Cameras)

New FM batch under manufacturing.

Commercialisation transfer from **ams** to **Caeleste**

Completed

Presentation & paper on the outcome of the evaluation presented at ESA GNC 2021 (www.esagnc2021.com virtual event)

APS Detectors for Vision-Based Navigation Systems

TO: S. Kowaltschek

Jena Optronik (DE) – TRP 200 keuro (2018– 2019)

Objective

Assess and compare potential APS sensors and determine their suitability for space applications (Star Trackers, Navigation Cameras), including electro-optical characterization before after radiations tests.

Mandatory detector to be characterized : **e2v CIS120**

Results

All radiation tests have been performed.

Latch Up immunity confirmed,

No significant increase of DC or other parameters with TID.

As expected, DC/DCNU increase after TNID (protons).

Contract closure in Dec 2020, with test report availability for the community.

Completed

Development of a large format science-grade p-channel CCD

TO: A. Ciapponi

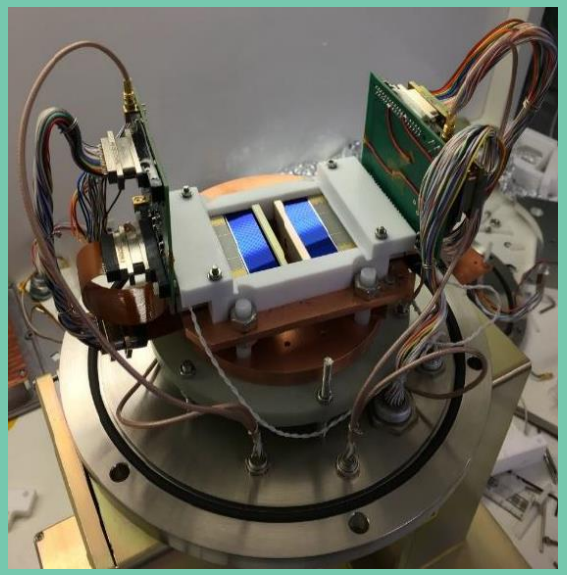
Open University + Teledyne/e2v(UK)-CCN: CTP 640 keuro (Q4 2019–Q1 2023)

Objective

The aim of the activity is to develop and characterize (including radiation tests) a new large format science-grade p-channel CCD building on the acquired know-how during the previous activities, including the investigation of several designs variants. A version of the Euclid CCD273 manufactured in P-channel materials will be used for this activity. It will be divided in 4 quadrants with design variants in each one. A side by side irradiation with the n-channel version will be performed.

Results

- DDR successfully completed June 2020
- Backthinning process delay postponed the delivery of the devices to OU by may/June 2022
- A n-channel device will be use to debug the test bench
- Vacuum chamber manufacturing is finished and validation of acquisition system is on-going
- Radiation will be performed at ULC facility in Q3 2022



Development and evaluation of curved silicon 2D array

TO: A. Ciapponi

Teledyne/e2v (UK) – GSTP + ESO 750 keuro (Q3 2021 – Q3 2023)

Objective

- to manufacture curved detectors with 500mm radius of curvature
- to further improve the process of curving and its accuracy & repeatability in line with a new production standard,
- to evaluate the repeatability of the curving process with a high number of samples,
- to assess by test the evolution of the performances due to the curving process

This activity has the aim to raise the TRL to 5.

Results

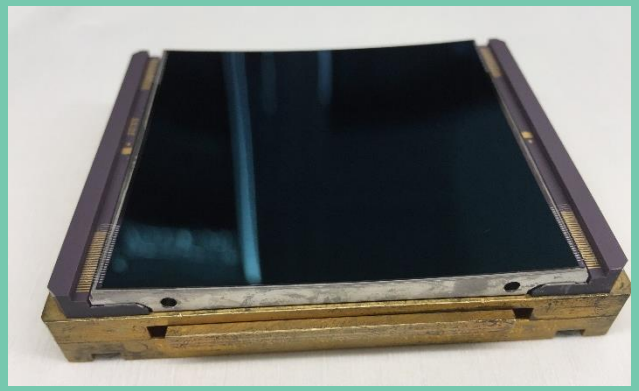
KO in June 2021

The activity is running with a small delay

Last review was in end of 2021

The aim of the review was to assess:

- Early performance on the devices manufactured during the de-risking phase
- Package robustness and way forward for production



Curved 6cmx6cm CCD with 511mm radius of curvature

SWIR

APDs

Earth Observation related developments

Astronomy (includes NIR Large Format Array TDP activities)

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Large Area SWIR Detector Array

TO: N. Nelms

Leonardo (UK) – TRP 900 + 120 keuro (Feb 2012 – Mar 2022)

Objective

Preliminary development of technology leading to large area SWIR array (2.5 um cut-off) for Earth observation missions

2k x 2k ROIC coupled to smaller area MCT

Results

Current activity completed:

2k x 2k ROIC designed, manufactured and tested – fully operational but excess leakage in pixel → ¼ area MCT hybridized and characterized

CCN for ROIC optimization:

Detector commissioning underway at UKATC.

Issue with headboard found – new headboard in manufacture.

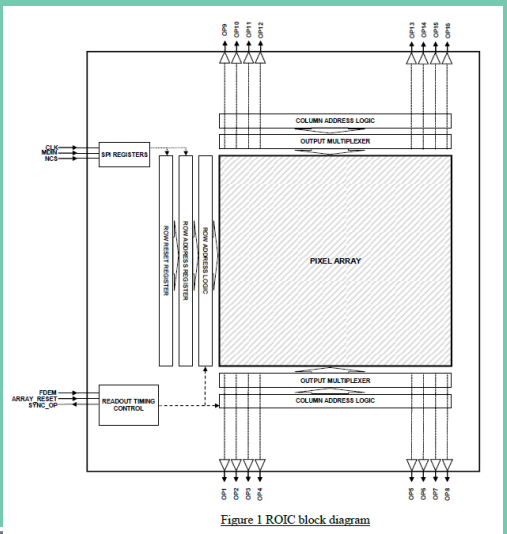
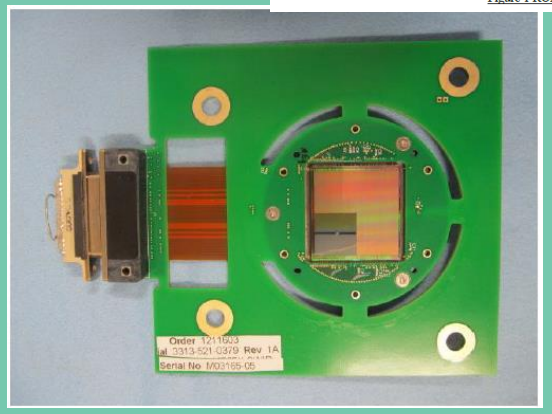


Figure 1 ROIC block diagram



Prototype NIR Large Format Sensor Array (ALFA)

TO: N. Nelms

LYNRED (FR) – TRP 2000 keuro (Nov 2016 – Feb 2022)

Objective

Design, manufacture and characterise MCT array (with 2.1 um cut-off) optimised for high QE and very low dark current – 2k x 2k pixels, 15um pitch.

On-going activity following on from NIR LFA development at CEA-LETI.

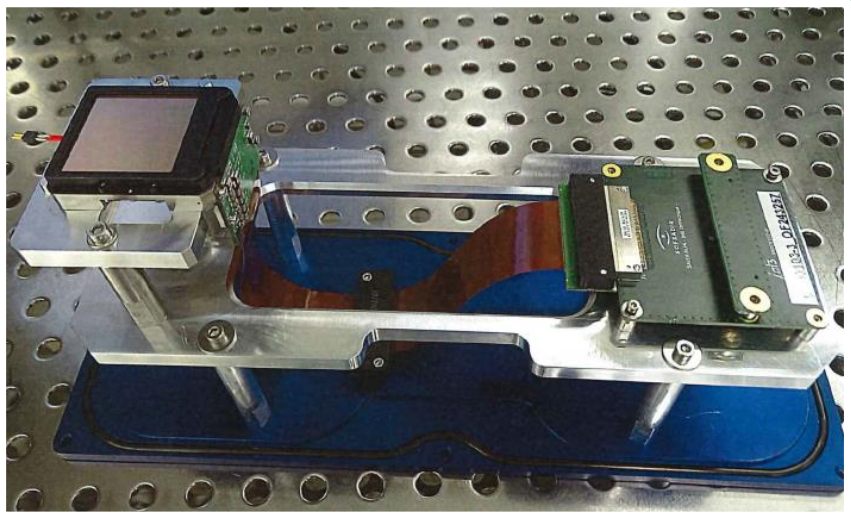
Results

Three hybrid detectors manufactured.

Characterisation underway.

QE/intrapixel capacitance test facility TRR planned for November.

Full characterisation on two detectors expected Q1 2022.



Control ASIC for EO Infrared Detector Array

TO: N. Nelms

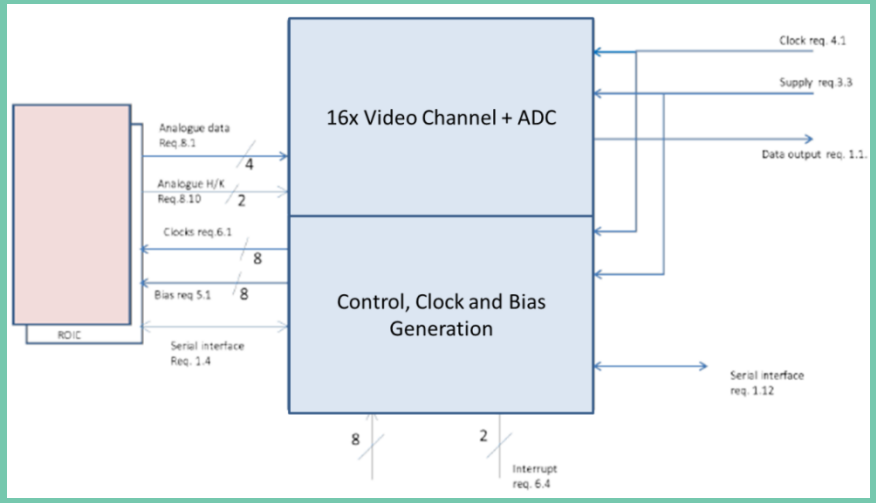
IDEAS (NO) – TRP 800 + 250 + 784 kEuro (Q1 2017 – Q4 2021)

Objective

Developing an ASIC ("NIRCA mkII") capable of providing clocks and bias voltages to operate the detector as well as providing video processing and digitisation (16 channels, 14 bit, up to 12 Msps), leading to a two-chip detection system (ASIC + detector)

The activity includes

- the design and manufacturing of the ASIC
- testing and characterization
- design of 16bit ADC up to PDR(CCN)
- environmental testing (CCN)



Results

TRB held October 2021 – ASIC operating as expected with good performance.

Some functional issues identified to be resolved in design iteration.

Radiation tests: SEE and TID tests performed end 2021.

CCN underway.

Feasibility of Ge-on-Si CCD development

TO: N. Nelms

Te2v (UK) – OSIP 69.5 kEuro (Q2 2021 – Q4 2021)

Objective

Feasibility study to investigate the potential for producing Ge-on-Si CCD detectors with extended cut-off wavelength (1.6 um) within an existing industrial process.

Results

KOM May 2021

Intermediate review held with positive outcome on feasibility.

Final Report Dec 2021

Large-format NIR APD for Scientific Imaging

TO: N. Nelms

LEONARDO (UK) – TRP 1300 keuro (Apr 2020– March 2022)

Objective

Design, manufacture and characterise MCT APD array (with 2.5 um cut-off) optimised for high QE and very low noise in low-photon applications– 2k x 2k pixels, 15um pitch.

Results

DDR successfully completed end of March.

Tape-out completed.

Silicon expected at Leonard towards end of November – probe testing to begin in December.

First MCT growths successfully completed.

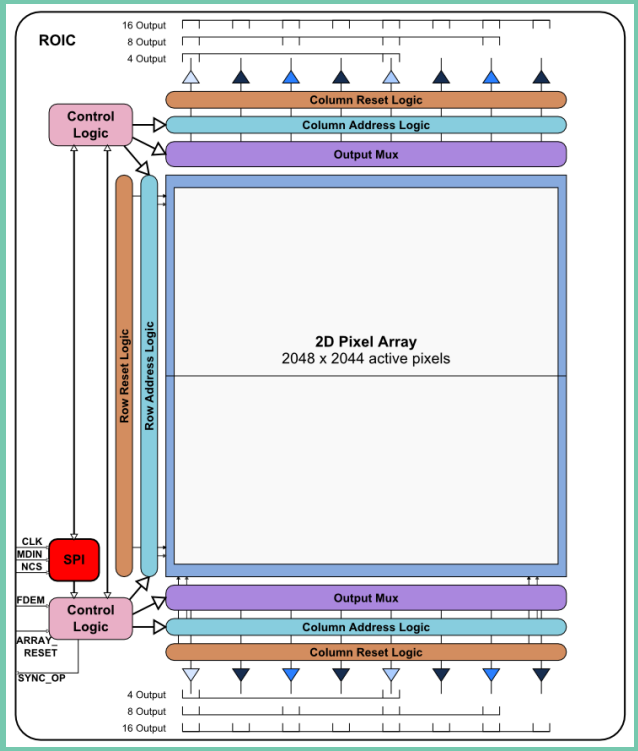


Diagram supplied by Leonardo MW

Direct Deposited opaque pixel mask for MCT detectors

TO: K. Minoglou

Leonardo (UK) – TDE 250 kEuro (Q1 2021 – Q2 2022)

Objective

To apply an opaque mask on top of an infrared imager chip in order to create true dark reference pixels, and perform some initial assessment of its suitability in a space environment. Basic reliability tests, to assess the robustness of the mask in space and related AIT environments, are to be performed.

Short loop trials to assess solution viability and develop process/ establish key parameters

Apply solution to existing Leonardo detectors over 20 columns/rows

1. Ike Pono D4120 → SWIR, Format: 1kx1k, Pitch: 15um
2. Eagle → LWIR, Format: 640x512, Pitch: 24um

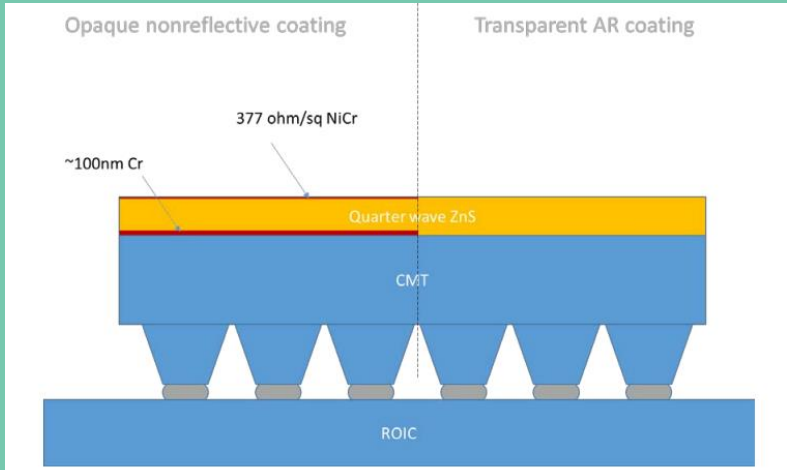


Figure 1 A schematic of a proposed non-reflective opaque mask design that is derived from Leonardo heritage designs.

Results

KOM March 2021

Identification of the MCT samples and short loop trials on-going

Successful MRR: Nov 2021

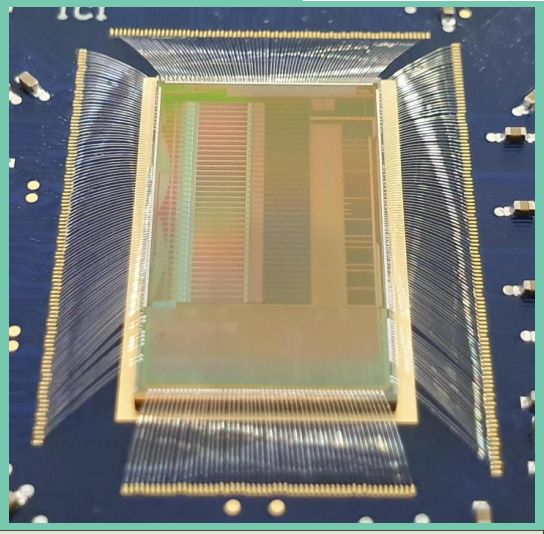
Optimised ASIC for NIR Large Format Sensor Array

TO: Jörg ter Haar

Caeleste (BE) – CTP 1000keuro (Q2 2018 – Q4 2021)

Objective

Further development of a cryogenic, control and digitisation application specific integrated circuit predominantly for optimised large area NIR/SWIR detector hybrid with 34 video channels (100 kHz, 16 bit), adjustable detector bias and power supplies, state-machine, SpaceWire interface. UMC180 process.



Results

After reissue the activity has been kicked off in June 2018

Successful SRR in July 2018

Significant design effort on improving ADC linearity and power consumption

Successful PDR in June 2019

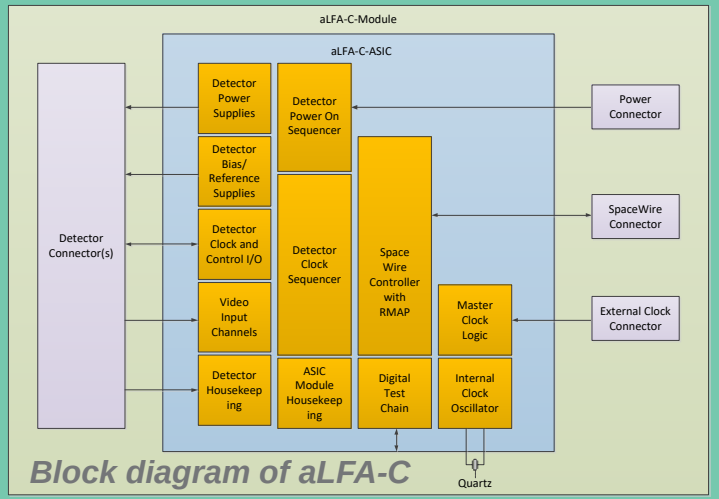
Successful DDR in June 2020

Wafer manufacturing at UMC completed in October 2020

RT tests and optimisation, cryo tests @SRON in Q1 2021

Radiation tests (heavy ion and TID) in Q2 and Q3 2021

Completed : December 2021



Block diagram of aLFA-C

Photon-counting 2D Tracking and Communications Detector Demonstrator

TO: C. Heese/S.Mejri

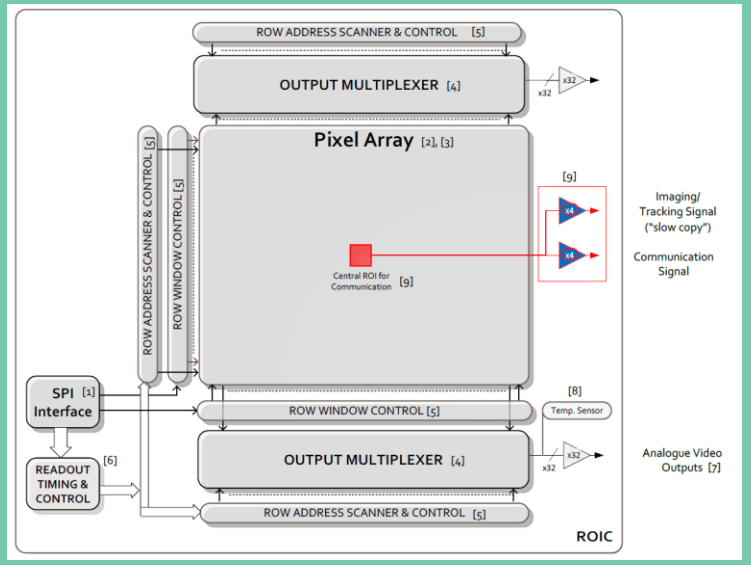
Leonardo - TRP 850keuro (Q4 2020 – Q4 2022)

Objective

The objective of this activity is to develop and characterize a near-photon-counting, 2D imaging detector array able to be read-out at near-kHz frame rate, with the additional capability of configuring the central four (super-)pixels to be read-out at near-GHz rate, thereby serving as tracking sensor and communications receiver in one device for photon-starved PPM optical links– for applications ranging from deep-space to commercial LEO-DTE links.

Demonstrator aimed specifications:

- Overall size: 512x512 pixels 20-50um pixel pitch
- Wavelength: cover 1550 nm
- Minimum signal: 5 photons (goal:1)
- Frame rate: up to 1kHz
- Response time jitter: 100 ps



ROIC block diagram

Results

- Successful PCR on the 3rd February 2021
- Test Chip Design planned for 08/2021 is rescheduled for 11/2021 due to reduction of resource availability due to overrunning work on two other contracts from the side of Leonardo.

Photon-Counting Ground-Based Optical Communications Detector

TO: C. Heese / S. Mejri

LETI (FR) – TRP 480keuro (Q3 2017 – Q4 2021)

Objective

The objective of this activity is to develop and characterize a four-quadrant detector as communications receiver for photon-starved direct-to-ground optical satellite links also capable of high-bandwidth tracking. The demonstrator to be delivered includes the detector together with its packaging, optical interface as a stand-alone functional unit suitable to be integrated behind a large telescope.

Results

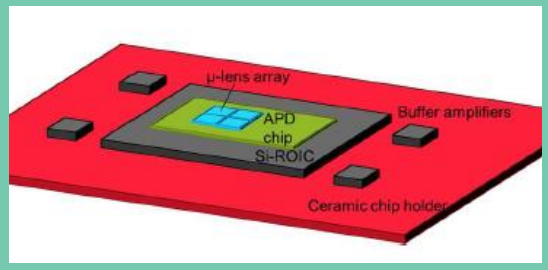
The project has encountered some technical problems. An alternative option is to resort to off-chip commercial amplifiers (TIA) offering much higher bandwidths (BW>1GHz), but whose higher noise would not allow truly single photon-counting (CCN WP6 detectors).

Scenario 1: CEA/Leti delivers a fully functional photon-counting detector, and only delivers characterization results of high BW components as a function of operating temperature together with the tested high BW device.

- TRR held successfully on the 06/10/2021
- TRB planned for 30/11/2021
- Final Review planned for 15/12/2021

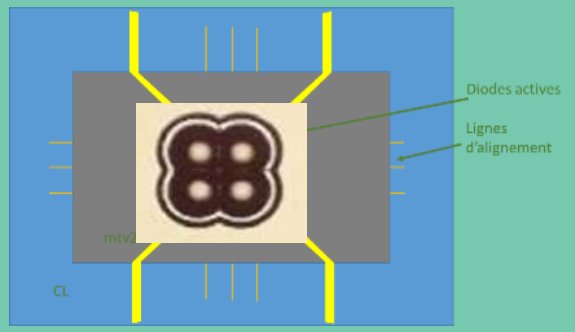
Scenario 2: CEA/Leti does not get a fully functional photon-counting detector, and, instead, delivers a high BW demonstrator packaged and tested in a LN2 cryostat.

- Final Review for CCN WP6 detectors held successfully on the 29/09/2021
- Detectors will be delivered in LN2 cryostat to ESA end of November



Photon-counter based on ROIC

(low noise, 400-500 MHz)



Back-up solution(CCN): Commercial TIA on a 4-output ceramics, high BW (>1GHz) but more noise (near photon-counting regime)

MWIR to TIR

MCT detectors (includes Low Dark Current 2D MCT Detector TDP activities)
QWIPs
Bolometers
Study on alternative technologies (QDIPs / T2SL)

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Low dark current IR detectors

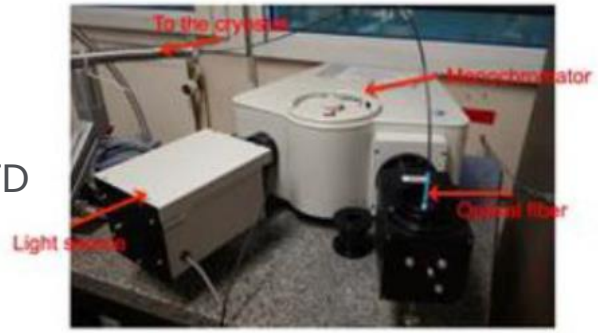
Development of Low Dark Current MWIR/LWIR detectors

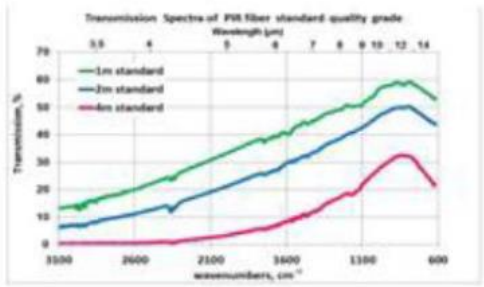
Design, manufacture and characterisation of a MCT detector array optimize for low dark current in LWIR

2 parallel contracts

Cut-off wavelength 12.5um @ 40K
Existing ROICs selected – CTIA & SFD

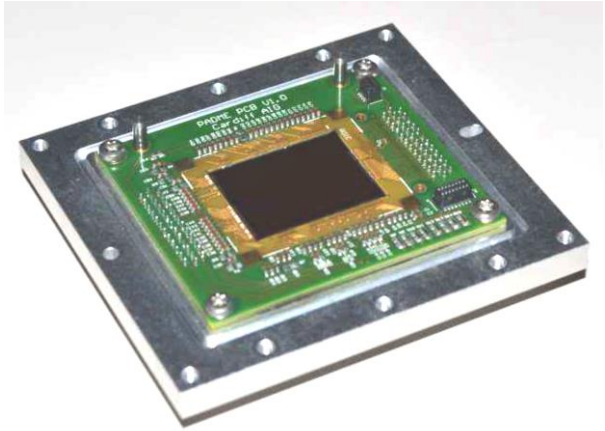
LYNRED
BY SOFRADIR & ULIS





Cryogenic QE test setup

Cut-offwavelength 12.5um
Custom test ROIC with 4 pixel types (CTIA, 7T, 5T, 5TRH, SFD)
Planar p-on-n and n-on-p photodiodes
4x320x1024pixels, 20umpitch



AIM caeleste CARDIFF UNIVERSITY

Completed

IR detectors based on non-MCT materials

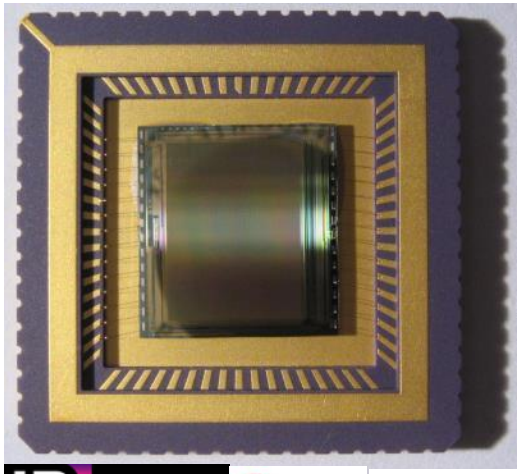
Low Dark current VLWIR T2SL Infra Red detectors

Evaluate T2SL for space applications

-Design, manufacture and test high performance, low dark current VLWIR detector array using COTS ROIC and compare with established technology

- -InAs/GaSb and InAs/InAsSb (Ga-free) T2SL options
- -COTS ROIC (FLIR Systems):
- -320 × 256 array size, 30µm pixel pitch
- -384 × 288 array size, 25µm pixel pitch

Completed

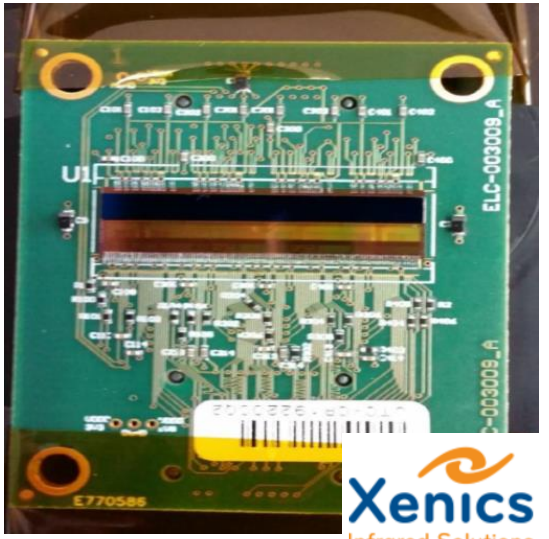


Optimisation of long, modular linear InGaAs imagers

Next generation of long-linear InGaAs arrays with improved noise performance for commercial applications.

- -Pixel : Standard SWIR InGaAs(1.7µm cut-off), 12.5 um
- -Array : 1 x 2048 pixels
- -ROIC: stitched CMOS OnSemi 0.18um
- -Configuration : 8 or 16 analog video channels @ 60 MHz

Completed



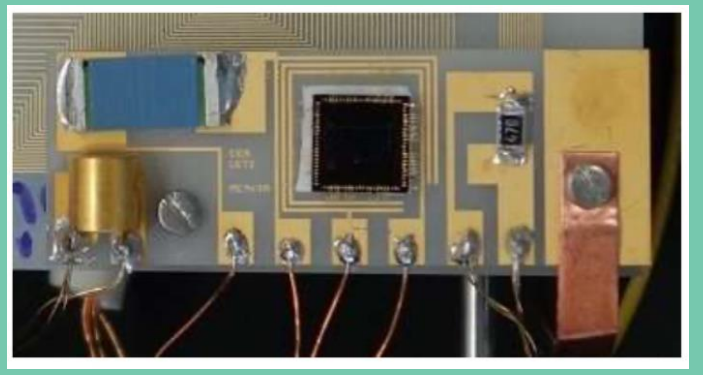
Development and cryogenic testing of MWIR detectors

TO: T. Prod'homme

CEA LETI, IRFU (FR) – CTP 1000 keuro (Q2 2017 – Q4 2022)

Objective

The main objective of the activity is to develop and characterise detectors in the Mid Wave Infrared (MWIR - 2 to 8 um) wavelength range, operating at 40 K with performance meeting the requirements of potential future science missions.



Results

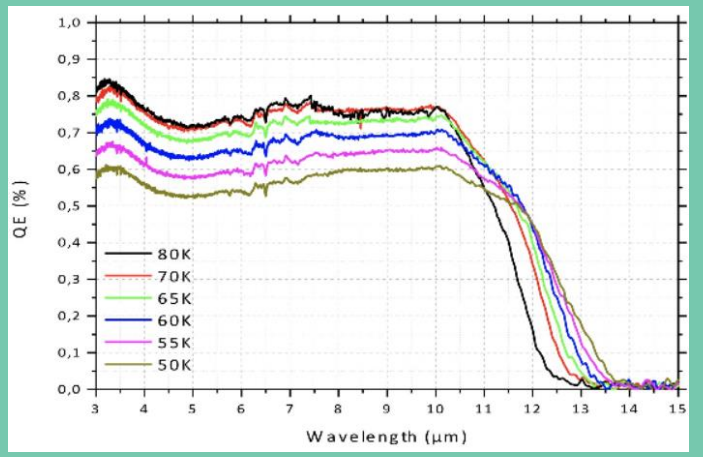
A first batch of devices has been manufactured and characterised showing promising results and enabling the use in a 2nd batch of a SFD pixel ROIC (first batch was CTIA only).

Batch#2 devices have been successfully manufactured and wafer-probe tested.

Selection and first hybridisation is on-going.

Diode dark current and QE measurements are on-going.

Completion of the activity planned for Q4 2022.



Far-infrared superconducting imaging technology

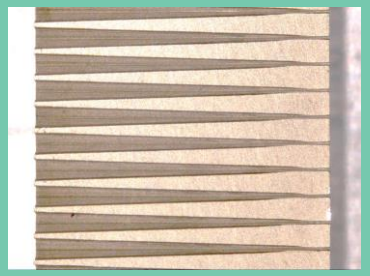
TO: A. Heske

Univ. Cambridge (UK) CTP 1400kEuro (Q2 2020 – Q2 2023)

Objective

To demonstrate a fully integrated, multiplexed detector module:

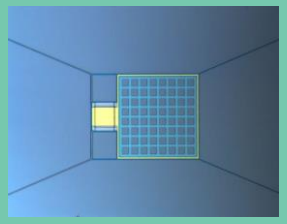
- Demonstrate multiplexed transition edge sensor (TES) modules that are fully compatible with the layout, constraints and interfaces of SPICA-SAFARI.
- Develop rugged packaging and operating techniques, including manufacture and metrology, ensuring science-grade performance in the relevant space environment (magnetic & EMI shielding, resilience to energetic particles, performance uniformity, ruggedness, space-readiness compatibility).
- Establish a 50-mK test facility for developing and verifying SAFARI detector technology and control software



Detailed view of lightpipe structure

Results

Single detector pixel with mesh absorber



- CCN (LiteBIRD application study) under completion
- Original activities under contract fully resumed:
  - Wafer fabrication and measurements in progress
  - Module design incl FDM readout finalised
  - Lightpipe design finalised; machining trials (micro mill) in progress
  - Cryo test facilities installed; awaiting characterised refrigerators
  - Contract is due to be closed out at the end of 1st phase, in Q1 2022

Mounted detector array

Polarization-sensitive submillimeter bolometer technology

TO: A. Heske

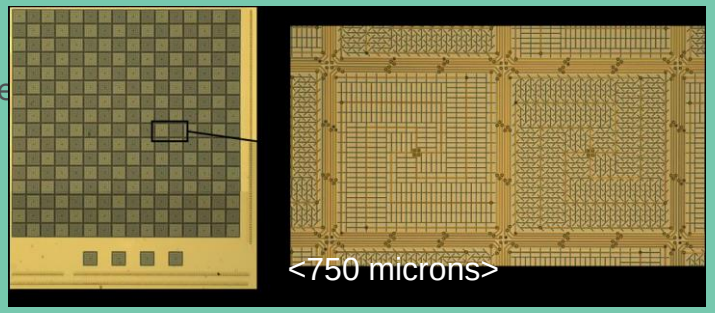
CEA/LETI/DOPT CTP 1000kEuro (Q2 2020 – Q4 2021)

Objective

The full work program for the fabrication of detector array prototypes at CEA for the B-BOP instrument in the frame of the Phase A study of the SPICA mission was aimed at the following:

- Separate funding:
  - Masks design and fabrication process definition (completed)
  - Manufacturing of detectors on interconnection network (comple
- Funded by this contract
  - Manufacturing of detectors on ROIC (completed)
  - Characterization of detectors and chip assembly

Photograph of full array and adjacent pixels



Results

- Hardware (test chips, one on ROIC one on interconnect network) delivered to ESA (Apr 2021)
- Manufacturing Review/Post Test Review successful (Sep 2021)
- Final data package received and accepted (Oct 2021)
- Contract closure in progress; end of 1st phase

Chip mounted on test assembly

High Energy Detection

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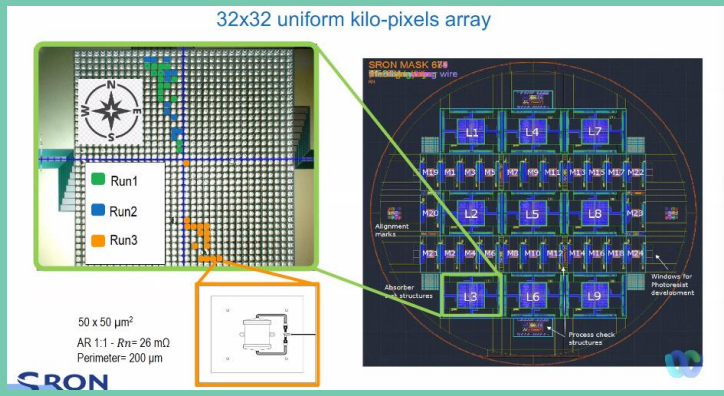
Optimization of a European Transition Edge Sensor array

TO: A. Stefanescu & E. Saenz
SRON(NL) – CTP 750 +1000(CCN)keuro (Q4 2015 – 2020)
SRON(NL) – CTP 1400keuro (Q2 2020 – 2022/23)

Objective

Design and develop Superconducting Transition-Edge Sensor microcalorimeter detectors for X-ray astronomy applications:

- Large format arrays, compatible with SQUID readout and multiplexing
- Towards drop-in replacement compatibility with GSFC detector baseline on ATHENA/XIFU
- Cryogenic anti-coincidence system based on TES pixels and compatible with large TES array



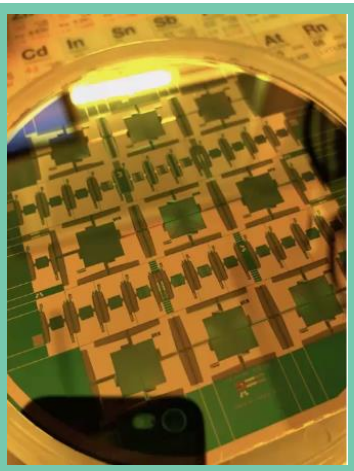
Results

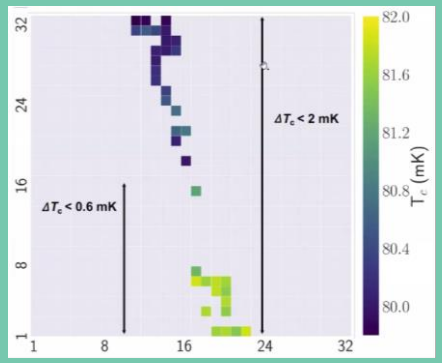
Focus on technology improvement and array homogeneity for TDM-readout TES

Iteration #1 successful Post Test Review

Iteration #2 design goals of TES array confirmed

- 8x8 mixed array:
  - TDM pixel optimization
  - Absorber coupling optimization
- 32x32 uniform kilo-pixel array: performance uniformity and characterization as a real instrument





→ THE EUROPEAN SPACE AGENCY

Large area high-performance optical filter for X-ray instrumentation

TO: A. Ciapponi

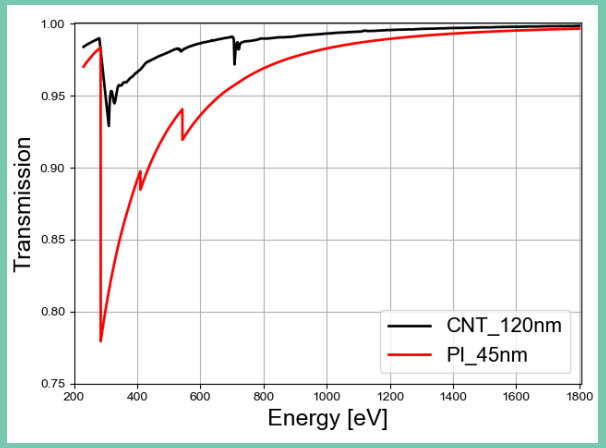
Ametek (FI) – TRP+CTP 1500keuro (Q2 2017–Q4 2020) + CCN500keuro (Q2 2022)

Objective

Design, manufacture and characterization of very large filters (185x185 mm2) for X-ray application in the context of Athena mission.

The activity shall demonstrate:

- the feasibility of the reproducible production
- the critical qualification aspects considering the relevant environments and critical process steps
- CCN is on going to demonstrate the feasibility to use Carbo-nano tube (CNT) foils as support for the filter. CNT meshes are also investigate.



Comparison between a measured x-ray transmission curve of a bare “low density” CNT, and modelled transmission of a 45 nm thick film of Polyimide.

Results

A large number of samples (around 150) have been produced and sent to University of Palermo for characterization. The first campaign at Bessy was concluded. The samples are quite transparent in the region of interest.

On-going investigation under the CCN:

- several materials for the support metallic meshes are under evaluation from two different suppliers (an European and an American one).
- CNT foils with CNT meshes under investigation (problems during vibration tests) – possible improvement under investigation for more solid meshes
- Post Test Review succesufully held in Oct 26th to assess results from vibration, thermal cycling, RF attenuation, differential pressure, X-ray transmission, …

Mission related
Detector pre-developments

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CO2M detector pre-development

TO: K. Minoglou
LYNRED (FR)

Objective

Pre-development of a detector for the Copernicus CO2M activity.

Spectral range
- NIR: 0.747-0.773 µm
- SWIR-1: 1.590-1.675 µm
- SWIR-2: 1.925-2.095 µm

Format 2000 x 1100
Pixel pitch 15-20 µm

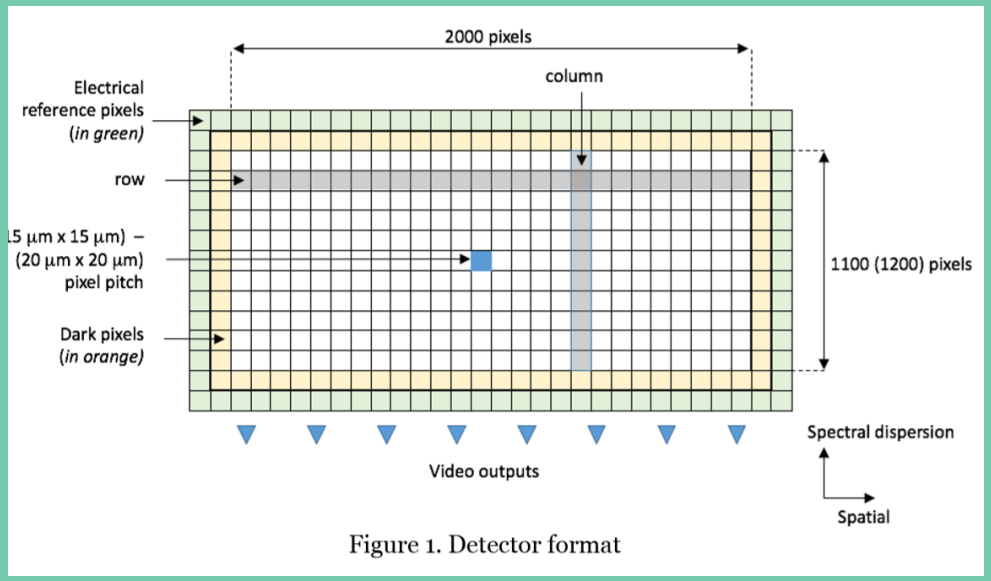
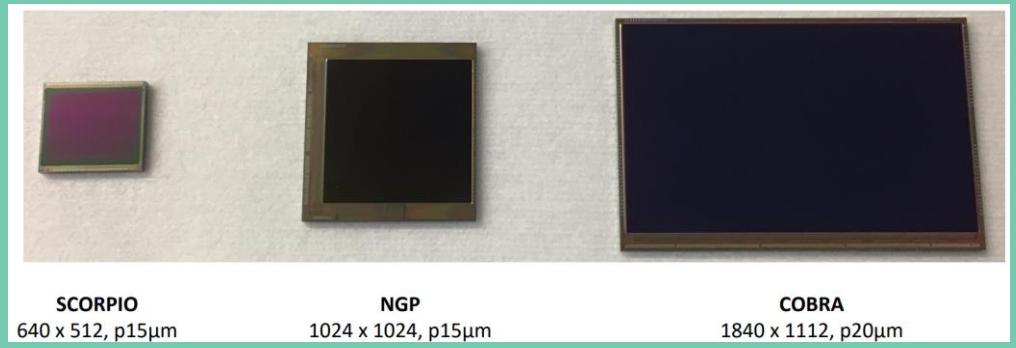


Figure 1. Detector format

Results

KO December 2018 → manufacturing start in June 2020
Successful Key point ROIC probe test Jan 2021
DDR2 Oct 2021 : First IRFPAs are available, test plans is ready, package concepts under review
Next milestones → TRR March 2022 and TRB Sept 2022



LSTM detector pre-development

TO: A. Ciapponi

AIM Infrarot-Module (DE)

Objective

Pre-development of a detector for the Copernicus LSTM (Land Surface Temperature Monitoring) activity.

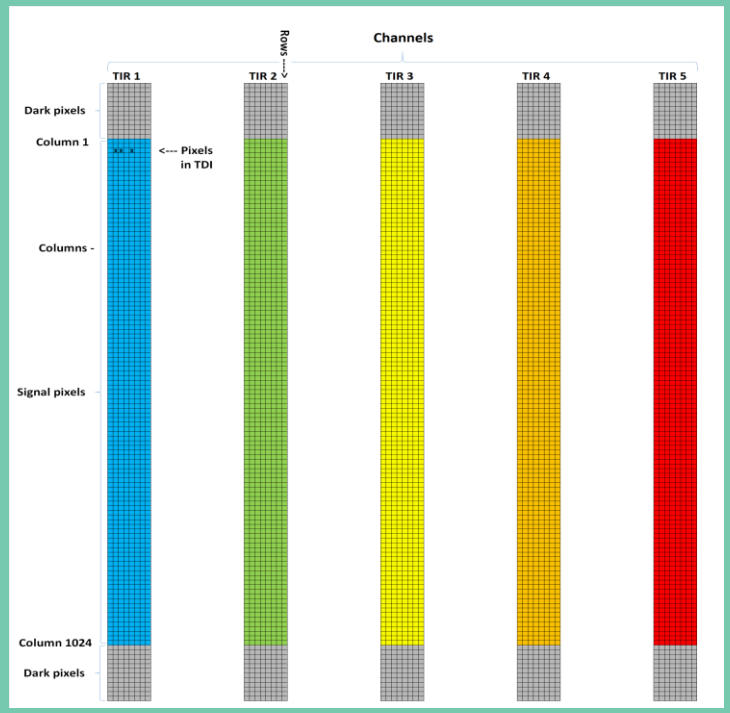
Spectral range:

- TIR1:8.6 µm
- TIR2:8.9 µm
- TIR3:9.2 µm
- TIR4:10.9 µm
- TIR5:12 µm

Format 1088 x 592 with 32 pixel for each band

Pixel pitch 25 µm

Readout frequency up to 10MHz



Schematic layout of the detector

Results

3 Hybrids are available.

Heavy ion test performed in March and July 2021.

Next MS→ TRR November 2021 – environmental / radiation evaluation will follow this MS

CHIME detector pre-development

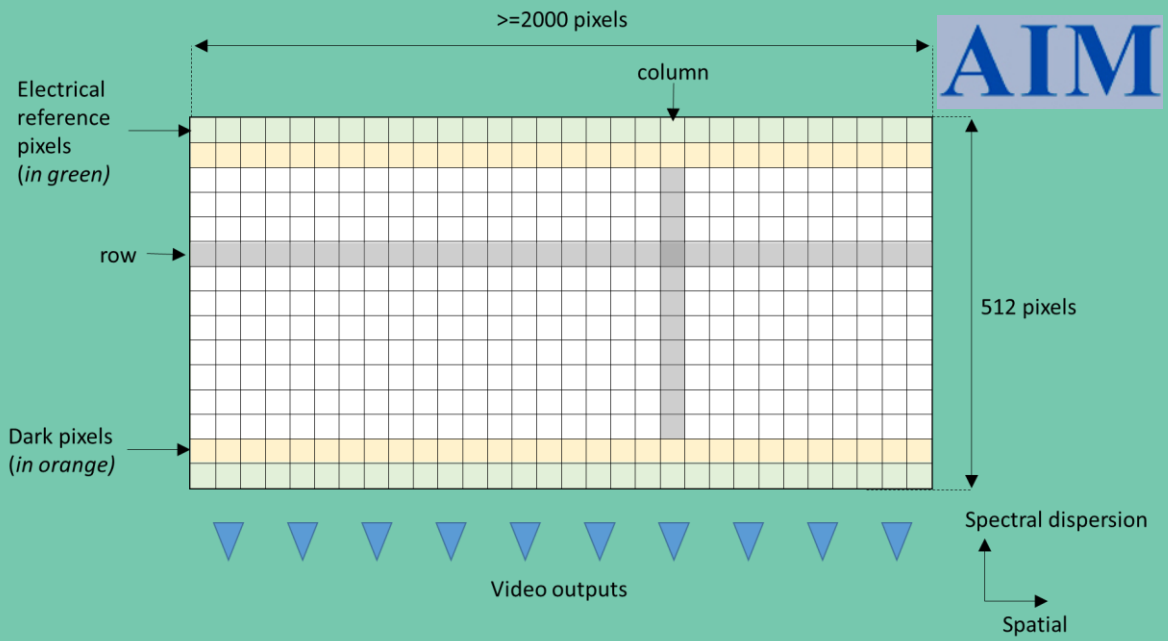
TO: M. Soman
AIM Infrarot-Module (DE)

Objective

Pre-development of a detector for the Copernicus Hyperspectral Imaging Mission for the Environment (CHIME) activity.

Key features:

- broad spectral range from 0.4 µm to 2.5 µm
- high frame rate >230 Hz
- large across-track format



Schematic layout of the detector

Results

- The basic functionalities of the ROIC have been confirmed
- Hybridization of first samples is complete
- TRR -> December 2021
- E/O test will be performed on hybrids in Q3/4 2021

Future Wind LIDAR Detector Development

TO: N. Nelms

Teledyne/e2v(UK): EOEP 2800 keuro (Q1 2021–Q2 2023)

Objective

The objective of the detector pre-development activity is to design, manufacture and test an engineering model of a CCD detector, inheriting from Aeolus Accumulation CCD but with increased vertical sample resolution.

Results

- PDR successfully completed September 2021
- DDR January 2022

Other activities

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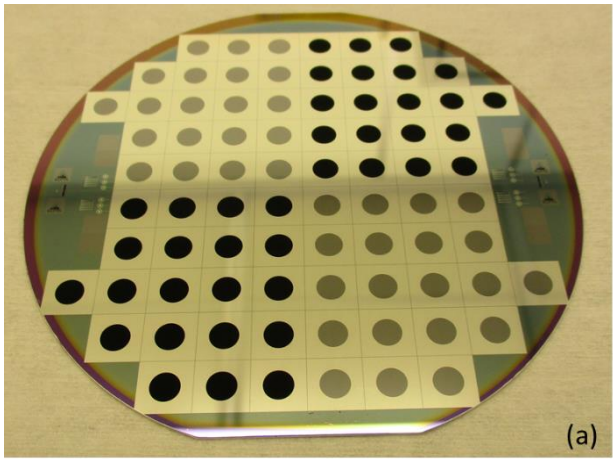
Detectors and ”coatings”…

Application of black silicon treatment on PIN diode and SDD

Characterization of PIN diode and SDD detector with and without the nanostructured surface treatment (black silicon)

ELFYS

Completed



Fully processed SDD wafer with and without Black Silicon treatment

Microlenses deposition for backside-illuminated imagers

Design, manufacture and test the application of microlenses on a back thinned and back illuminated CMOS image sensor under space environment conditions

csem

Completed

Humidity Resistance Assessment of MCT Based IR Detectors in Open Packages

TO: C. Bringer

LYNRED, LETI (FR) – TRP 400 keuro (Q3 2017-Q4 2021)

Objective

Identify and validate one or several acceleration laws applicable to MCT detector technology when tested for humidity. MWIR Scorpio is the test vehicle.

Results

- Testing terminated, waiting for a last EO test on EXP12:

	T	RH	t0	t1	t2	t3	t4	t5	t6	t7	Comments
EXP 11	85	85	0	20	50	100	200	400	-	-	Finished- VI: All samples greatly affected, EO: high increase of defects between 100/200h
EXP 12	70	85	0	20	50	100	200	*500*	*1000 ?*		VI 200h: 50% with defects in the corners and sides EO 100h: starts to degrade by the corners
EXP 13	50	85	0	50	100	200	500	700	1200	*2000*	VI 700h: 100 % samples with defects, some larger EO 700h: dark increases, defects increased
EXP 14	85	70	0	20	*50*	*100*	*200*	500	*1000*		VI 200h: defects reaching the center EO 100h: 30% affected on the corners
EXP 15	85	55	0	200	350	500	700	*1200*	*(2000)*		VI 700h: defects all around the periphery EO 500 h: defects reaching center from 350 h
EXP 16	70	70	0	50	100	200	500	700	1200	*2000*	VI 1200h: increase of size and density of defects EO 700h: defects reaching center from 500 h

- TRB in November 2021
- Acceleration model was presented
- Waiting for final documentation to be delivered

Investigation of additive manufacturing of improved ceramic packages for detectors

TO: C. Bringer

RHP, FACT, TECHNALIA, EGIDE - TRP 400 keuro (Q3 2019-Q1 2022)

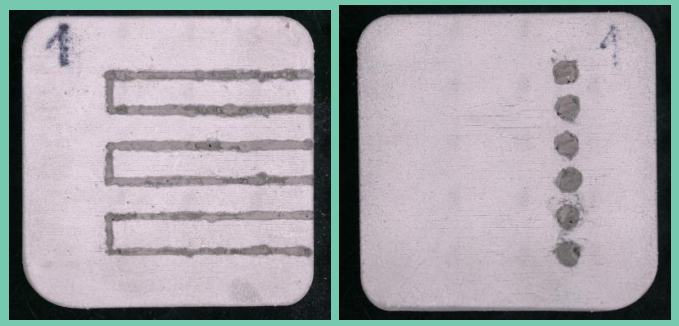
Objective

To manufacture a complete SiC package having internal routing, brazed pins and plated pads.

Results

6 additive manufacturing methods for processing of SiC are investigated:

- Selective laser melting (FACT)
- Lithography (FACT)
- Binder jetting technology (Tecnalia)
- Laminate object manufacturing (RHP)
- Filament printing - fused deposition modelling (RHP)
- Feedstock printing - composite extrusion modelling (RHP)



Paste filling of SLA parts (top and bottom)

Manufacturing trials:

- Challenges: flowability, printability, densification, sintering, and optimisation of the CTE and electrical properties.
- Lots of delays due to challenging technology, including many trials.
- TRB in November, close-out in December
- Next step : manufacture a complete package vehicle

Recently started and upcoming activities

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Activities under preparation

		Budget	Duration	Program	KO date	Current Status
1	Black Silicon induced junction photodiode applied to scintillators-based detectors for hard X-ray and Gamma-ray detectors	350	18	GSTP	Q1 2022	**ITT published**
2	Flash-LIDAR image sensor	1900	24	GSTP	Q4 2021	**Under evaluation**
3	Minimum Viable Payload (MVP) for the MultiSpectral Companion Mission (MSCM) In Orbit Demonstration	2350	12	GSTP Element 3	Q4 2021	**In negotiation**
4	High Performance Type-2 Super Lattice (T2SL) Infra Red detectors	1850	24	GSTP	Q4 2021	**In negotiation**
5	Thermal infrared imaging camera for small satellites (SATIRIM 2)	1000	12	GSTP	Q4 2021	**Kick-off planned**

Upcoming activities: TDE

TDEs approved in the Work Plan 2021-2022
(approved by IPC)

		Budget	Duration	Program	Expected start	Current Status
1	Megapixel InGaAs Detector Array Development	1150	24	TDE	2021	**In negotiation**
2	High-performance microbolometer array	1000	24	TDE	2022	**ITT under preparation**
3	Curved CMOS sensors for compact optical designs	450	18	TDE	2022	**ITT published**
4	High Resolution Detector Prototype Characterisation for Star Trackers	500	15	TDE	2022	**ITT under preparation**

Potential future GSTP activities from Compendia

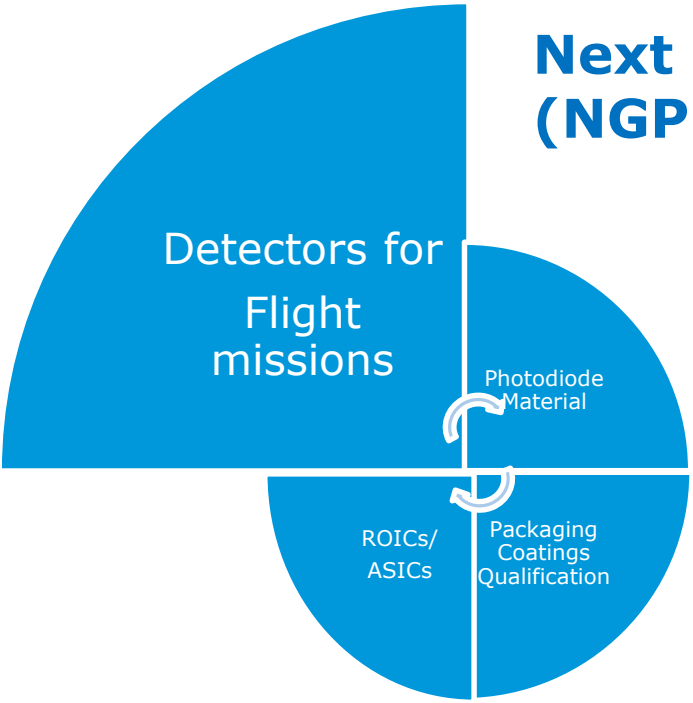
		Budget	Duration	Program	Expected start	Current Status
1	Radiation Testing of a COTS General Purpose CMOS Image Sensor	400	12	GSTP E1 Develop Compendium 2017	-	Pending expression of interest
2	Demonstration of high-performance CMOS image sensor pixels for space applications using advanced technology nodes	1000	24	GSTP E1 Develop Compendium 2017	-	Pending expression of interest
3	3D Stacked Hybrid Visible Image Sensor	1000	24	GSTP E1 Develop Compendium 2019	-	Technical discussions on-going
4	Space validation of a 8 inches back-thinning manufacturing line	500	18	GSTP E1 Develop Compendium 2019	-	**Potential re-issue**

Upcoming activities: Scylight

Activities approved in the ARTES SPL Optical Communications Work Plan 2022 (approved by IPC)

		Budget	Run by	Program Ref	Expected ITT	Current Status
1	Four-quadrant InGaAs avalanche photodiodes for LEO direct-to-Earth optical ground station		TEC-MME	SPL 6C.016	Q1/2022	**ITT under preparation**
2	Large area nano-wire detector for quantum and optical communication applications		TEC-MME	SPL 6C.021	Q1/2022	**ITT under preparation**
3	Quantum Key Distribution high rate detector predevelopment (4S SAGA)		TIA-TO	E/0533-16A - 4S-SAGA		**Intended**

Example of "success" story: from low TRL to flight model

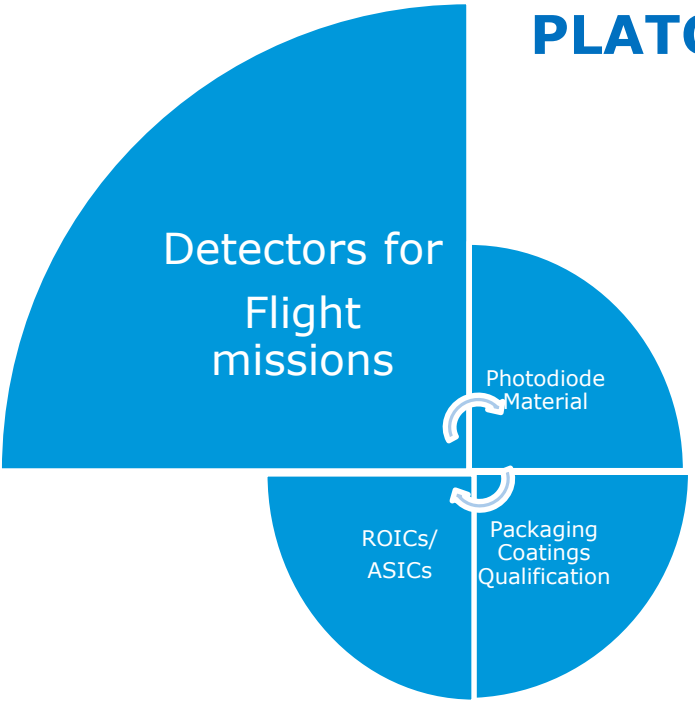


Next Generation Panchromatic Detector (NGP)

Successful design, development and characterization of:
Radiation hard, 1024 x 1024, 15um pixel ROIC
Thinned MCT diode layer to extend sensitivity into the visible waveband
Multi-layer anti-reflection coating for wideband sensitivity

Selected as baseline for
Sentinel-5
CNES MicroCarb Mission
CO2M mission

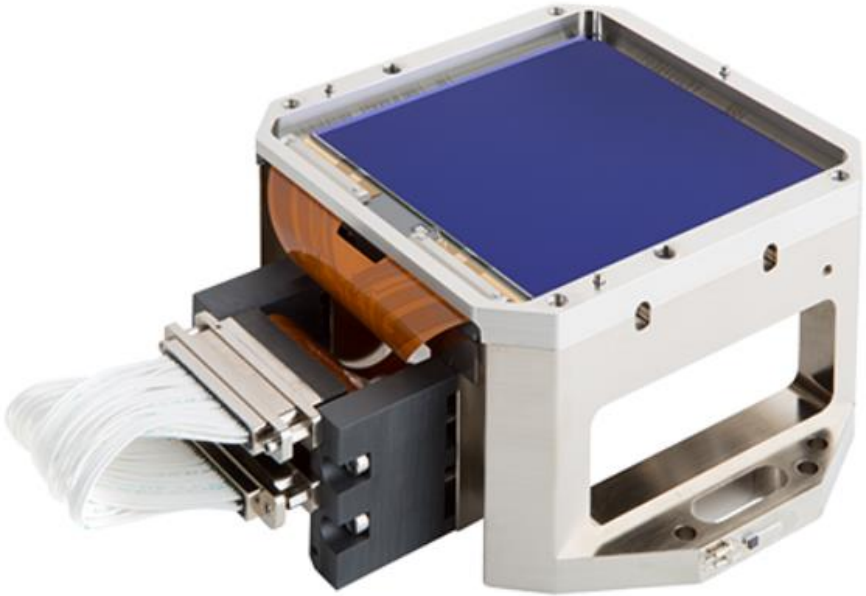
Example of "success" story: challenging developments



PLATO CCD

Exo-planet detection

- 4510 x 4510 pixels, 18 um pitch
- Back-illuminated
- Full-frame and frame-transfer variants
- CHC 1.0 Me-, 20 e-rms read-noise



Some numbers….!

26 telescopes (cameras)
112 flight grade CCDs
€42 M contract

TELEDYNE e2v
Everywhereyoulook™

Charge Coupled Device renamed as CCD Bruyéres for PLATO Exoplanet Space Telescope

European Space Agency

Take home message

- ESA is aiming on high performance detectors
- CCDs, CMOS, IR and novel technologies and materials are of high interest
- Numerous R&D activities are on-going, more are part of ESA Roadmap

The Agency recognizes the importance of not only improving and optimizing the performance of detectors but also in supporting their continued availability

Proof of concept → Maturity increase (TRL) → Industrialization

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