The status of European Space Agency supported infrared detector developments

Infrared detection for space applications workshop
Toulouse 7-9 June 2023

Presented by Nick Nelms on behalf of ESA Technical Officers

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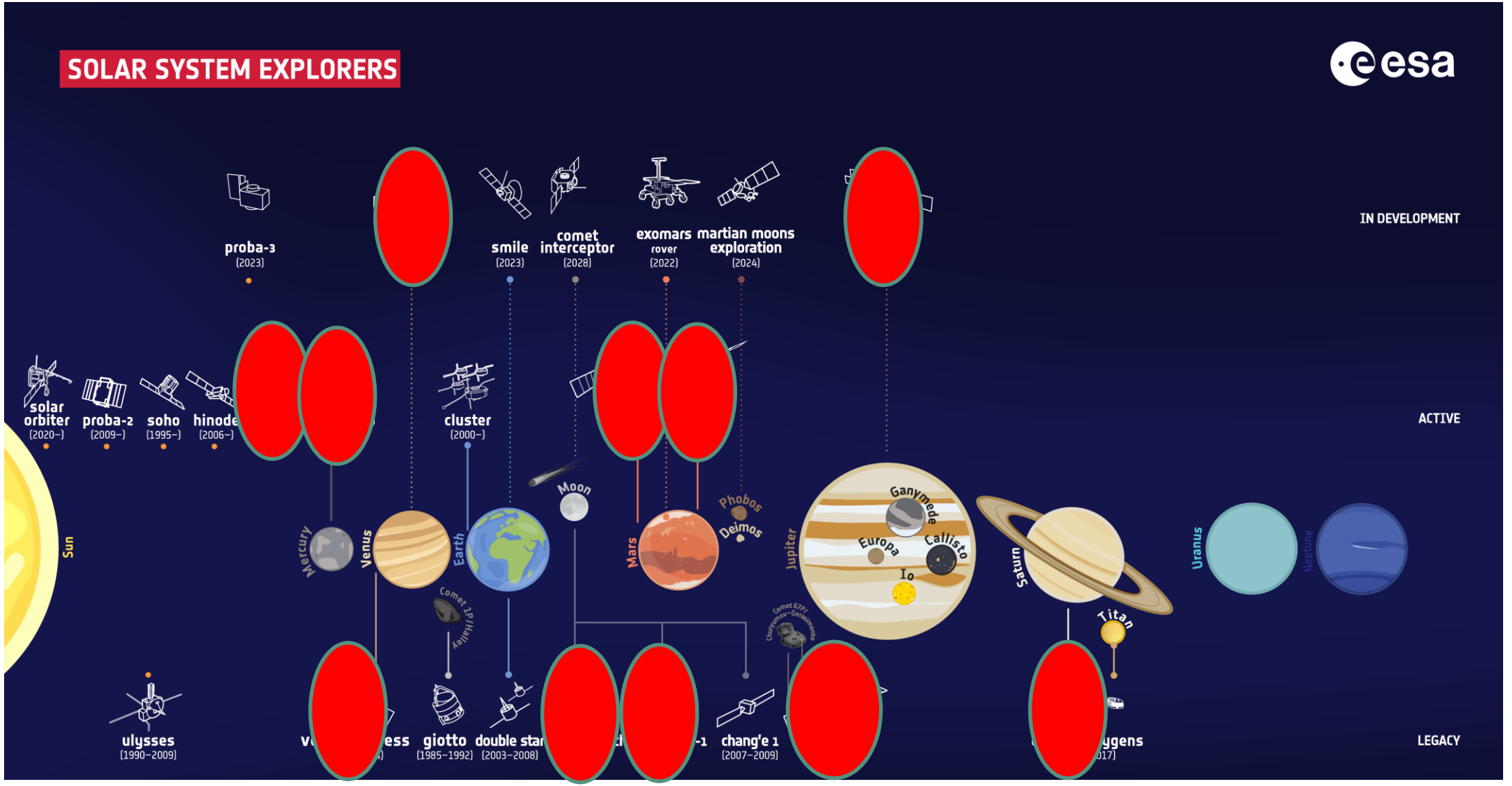
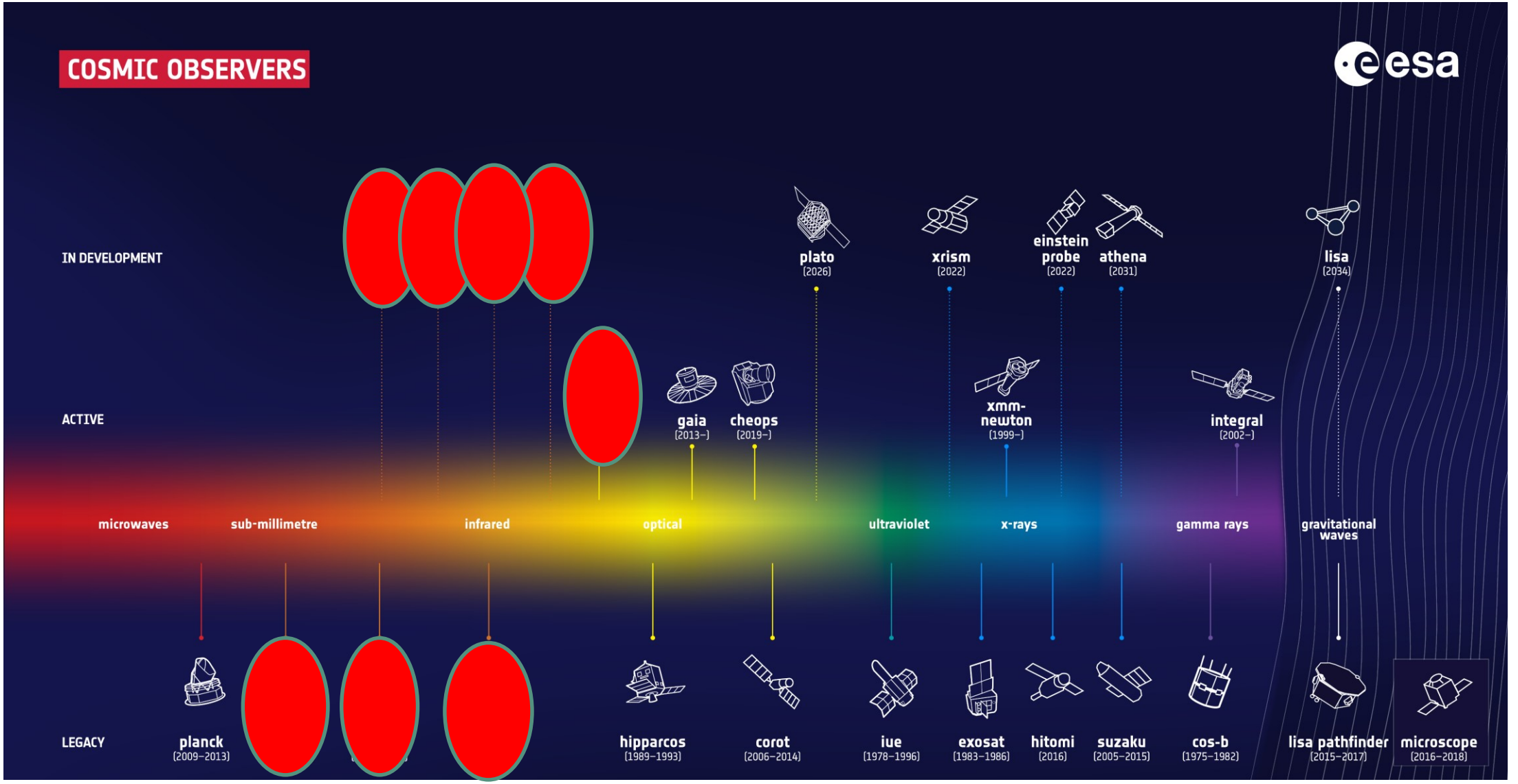
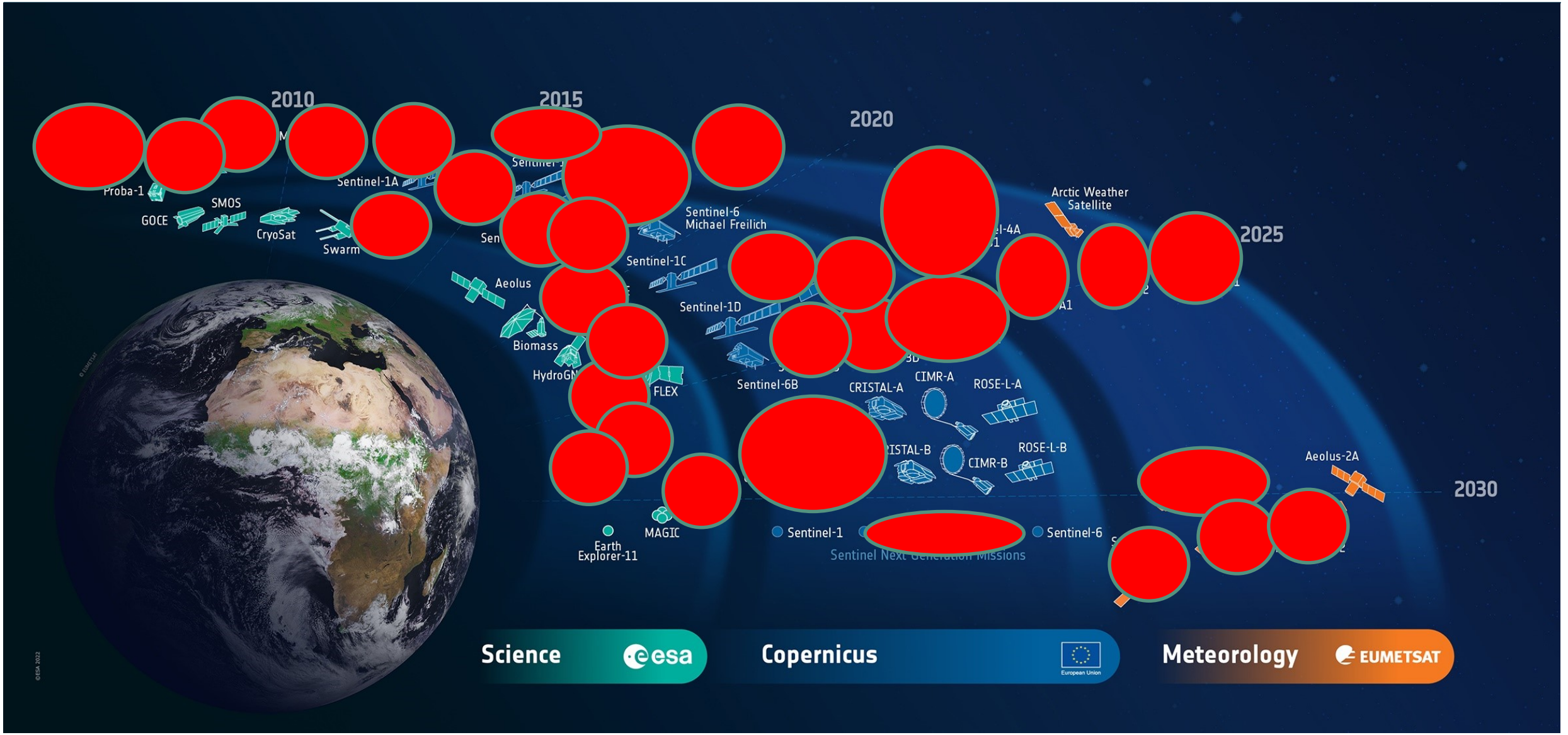
ESA planetary missions using infrared



ESA cosmology missions using infrared



ESA Earth Observation missions using infrared



Detection requirements

- Clearly, the infrared waveband is very important for space instrumentation
- Consequently, the European Space Agency undertakes a comprehensive technology development program in support of on-going and future missions
- The development program is determined in coordination with European primes, member state space agencies and industrial input via the ESA technology harmonisation activities, along with key technologies identified as part of selected missions – a combination of technology pull and technology push
- In this paper, we present details of on-going and recent infrared detector developments and applications supported by the Agency

Overview

The detector development activities are presented in terms of waveband

NIR-SWIR

MWIR-TIR

And an introduction to developments for

Optical Communications

The slides are intended to act as a reference which can be followed up with the Agency for further information.

Some of the developments are also the subject of separate presentations during the Workshop, as indicated.

For further information on any of the presented activities, please contact either

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NIR – SWIR

Large-format NIR Avalanche Photodiode array

Prime contractor – Leonardo MW (UK)

Objectives

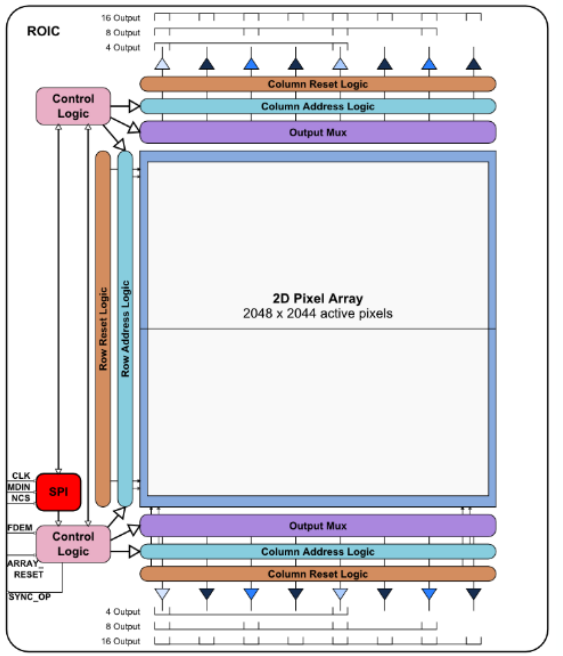
Development of large-format 2k x 2k pixel, 15um pitch avalanche photodiode detector array for low photon applications

Absorber cut-off wavelength 2.5um

16 outputs @ 500 kHz

2 frames per second maximum

Maximum CHC 100 ke-



Status

First arrays under test – already a TRL enhancement activity planned

See Leonardo (D. Owton) presentation in Session 1 for latest results

NIR – SWIR

Astronomy Large Format Array (ALFA-N)

Prime contractor – Lynred (F)

Objectives

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

32 outputs @ 100 kHz

CHC 80 ke-

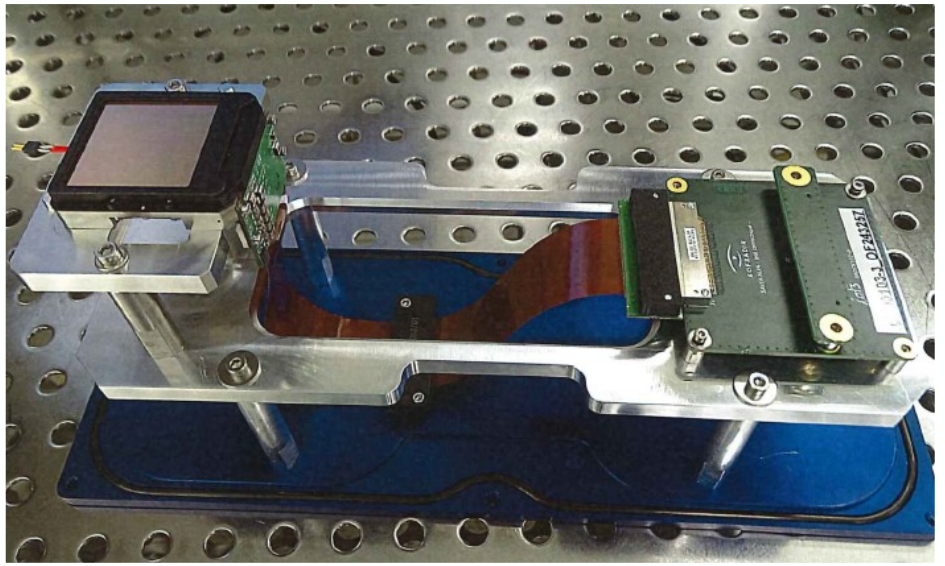
Status

Successful development of array, package and flex circuit.

One array on loan to Colibri/Cagire ground based instrument for GRB follow-up.

ROIC design iteration required to correct design issues.

Further development suspended.



NIR – SWIR

Hyperspectral 2d Array development

Prime contractor – AIM (D)

Objectives

Development of high-frame rate, broadband SWIR detector for hyperspectral applications

2048 x 512 pixels, 20um pitch

Waveband 0.4 – 2.5 um

CHC 700, 1400 or 2100 Ke- configurable gain

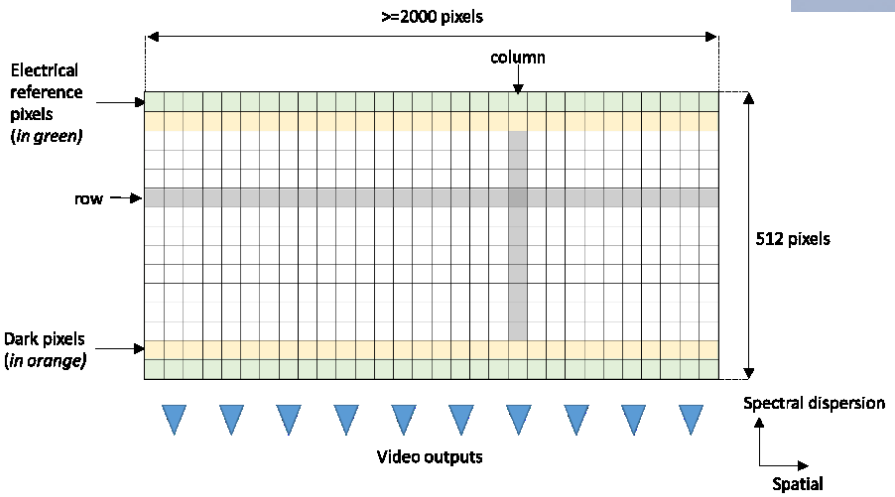
32 Outputs at 10 Mhz -> frame rate up to 290 Hz

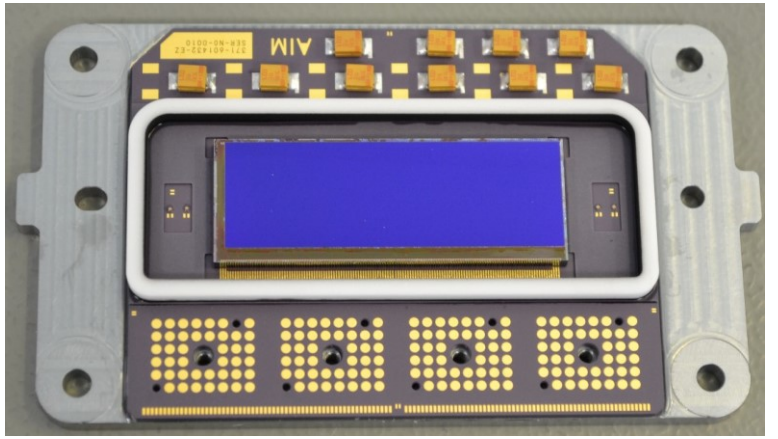
Status

ROIC characterisation performed along with EO testing on multiple hybrid arrays.

ROIC design iteration planned to correct identified issues.

New devices expected Q2 2024.





NIR – SWIR

NIR-SWIR Large-format 2D array - COBRA

Prime contractor – Lynred (F)

Objectives

Development of large format SWIR detector with 1840 x 1112 pixels, 20um pitch

N-on-P MCT with cut-off wavelength 2.5um.

Close-butting on three sides

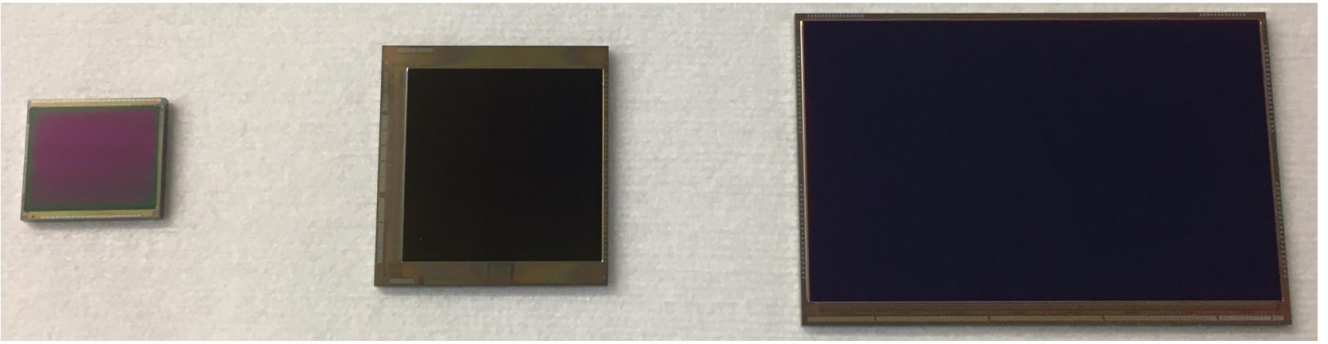
Row selectable gain – CHC ~150 ke-/1000 ke-

16 outputs at 12 MHz max -> frame rate 90 Hz

Status

EO testing in progress

Environmental testing planned for 2023 Q3



SCORPIO
640 x 512, p15µm

NGP
1024 x 1024, p15µm

COBRA
1840 x 1112, p20µm

NIR - SWIR

Large-area SWIR detector development

Prime contractor – Leonardo MW (UK)

Objectives

Development of large-format 2k x 2k pixel, 17um pitch detector array

Sensitivity 0.8 – 2.5 um

ROIC architecture includes multiple pixel designs

16 outputs @ 10 MHz

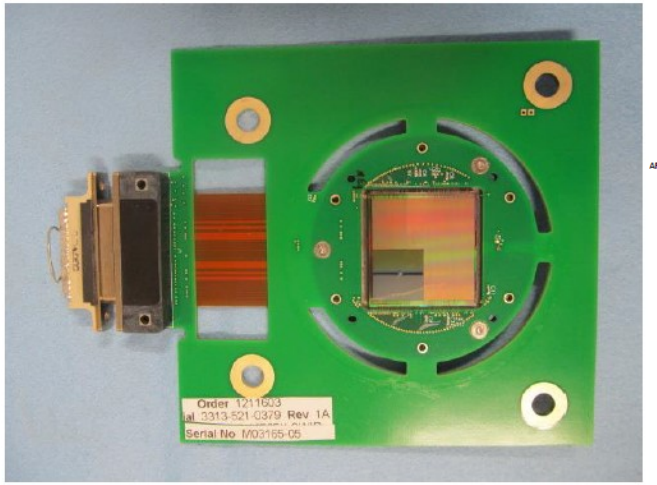
40 frames per second maximum

CHC 1 Me-

Status

Pixel design fault.

ROIC design iteration under consideration.



ROIC on test PCB

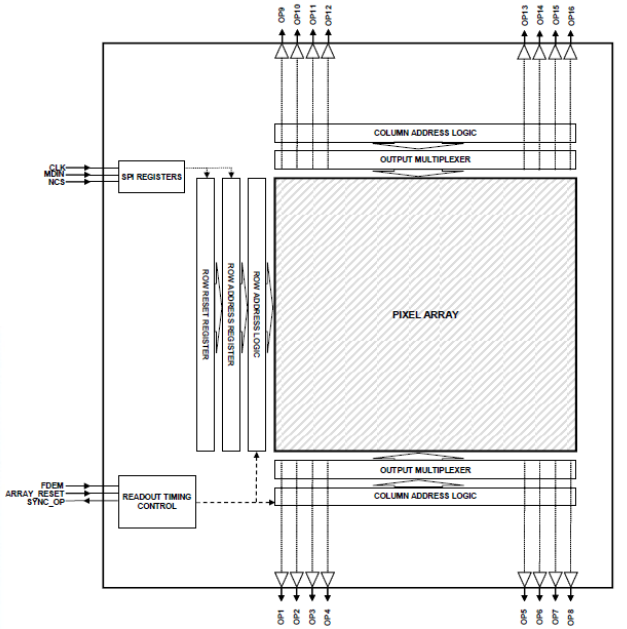


Figure 1 ROIC block diagram

NIR – SWIR

Mega-pixel InGaAs Array development

Prime contractor – Xenics (B)

Objectives

Development of an hybrid InGaAs 2D array with 2k x 1K pixels and a pitch of 12um.

ROIC compatible with dual polarity inputs.

Cut-off wavelength 1.7um (extended waveband also considered) @ 253K

2x1, 1x2 and 2x2 binning

16 outputs @ 32MHz -> 240 frames per second maximum

CHC 25 ke-, 250 ke-, 1.5 Me-

Analogue and digital output

Status

PDR held in April 2023.

Tape-out planned for Q2 2024

NIRCA MkII – Near-infrared detector control ASIC

Prime contractor – Ideas (N)

Objectives

Development of a control ASIC to provide clocks, bias and video channel processing for infrared and CMOS image sensors .

Programmable bias voltages and clock sequencer

16x 16-bit video channels at 12 Msps/channel

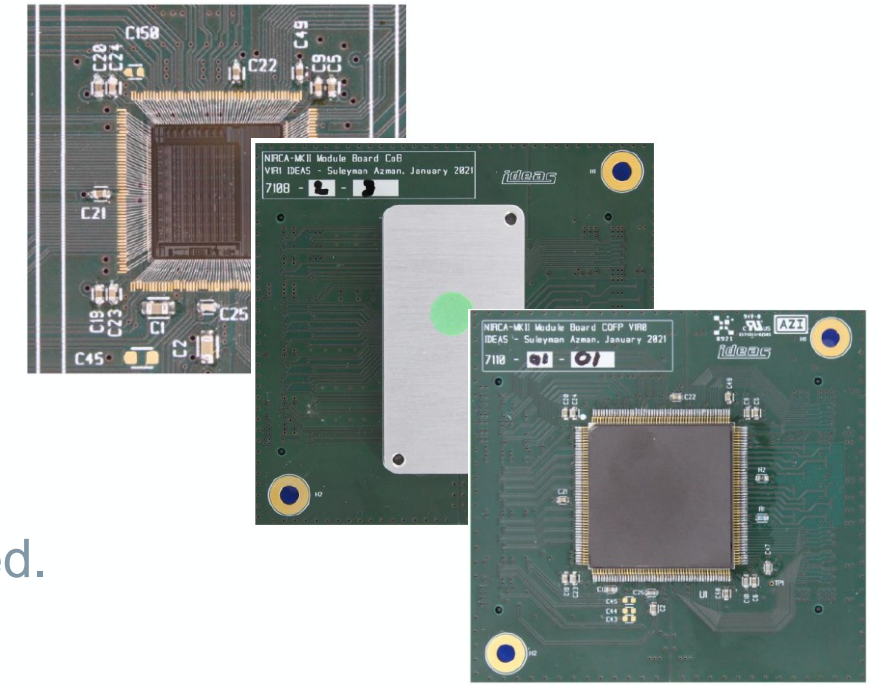
Status

ASIC fully functional and tested, including radiation tests

Some corrections needed – ASIC design iteration in progress.

Flight package development and ASIC validation program initiated.

See Ideas presentation (T. Ostmoe) in Session 7 for full details



All images © Ideas

NIR – SWIR

ASIC for NIR Large Format Array

Prime contractor – Caeleste (B)

Objectives

Development of a control ASIC to provide clocks, bias and video channel processing for infrared and CMOS image sensors – slow scan, low noise

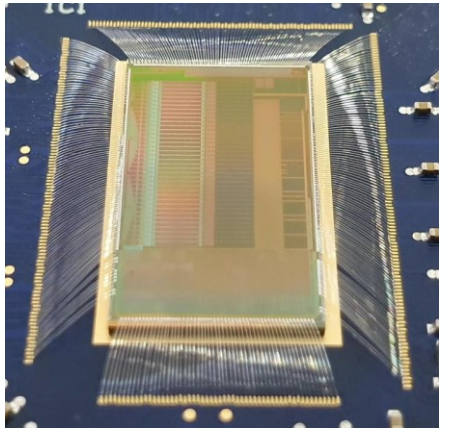
Programmable bias voltages and clock sequencer

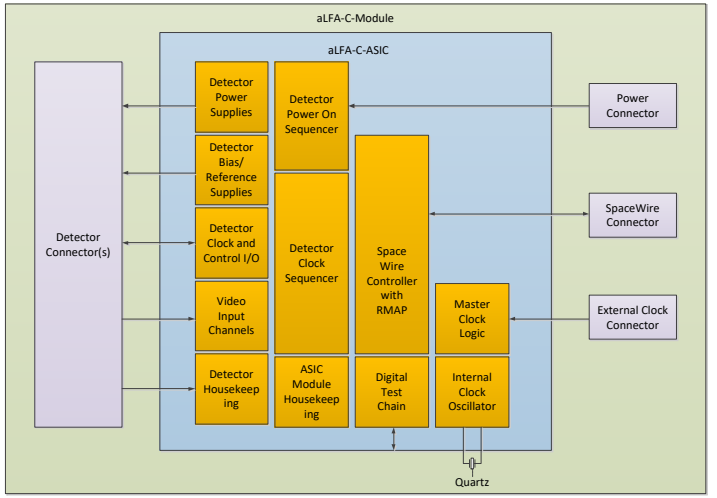
32x 16-bit video channels at 100 kHz/channel

Status

ASIC fully functional and tested

Some corrections needed – metal fix design iteration in progress





NIR – SWIR

Feasibility of Ge-on-Si CCD development

Prime contractor – Teledyne e2v (UK)

Objectives

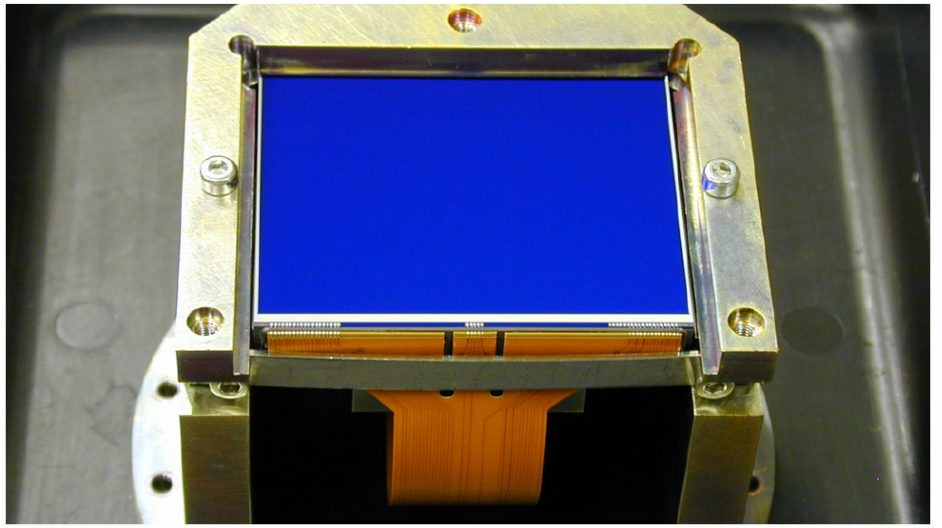
Feasibility study to investigate the potential for producing Ge-on-Si CCD detectors with extended cut-off wavelength (1.6 um) within an existing industrial process.

Could allow true charge-level TDI into NIR.

Status

Study complete with positive outcome.

Follow-on activity planned, to investigate critical performance parameters of Ge-on-Si structure.



NIR – SWIR

Direct Deposited opaque pixel mask for MCT detectors

Prime contractor – Leonardo MW (UK)

Objectives

Process development of opaque pixel mask structure suitable for space applications providing true dark reference elements for hybrid infrared detectors

Status

Development to be applied to existing detector arrays -

1k x 1k pixel, 15um pitch

640 x 512 pixel, 24 um

Samples in production – TRR planned for September 2023

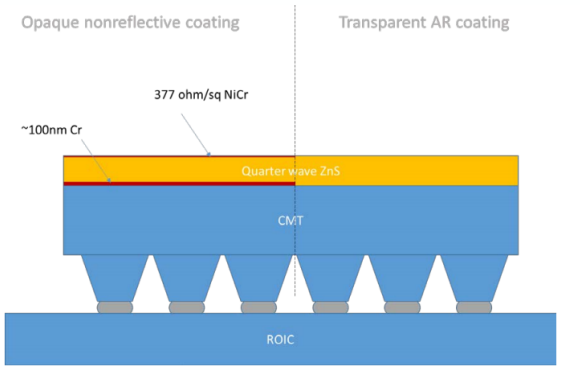
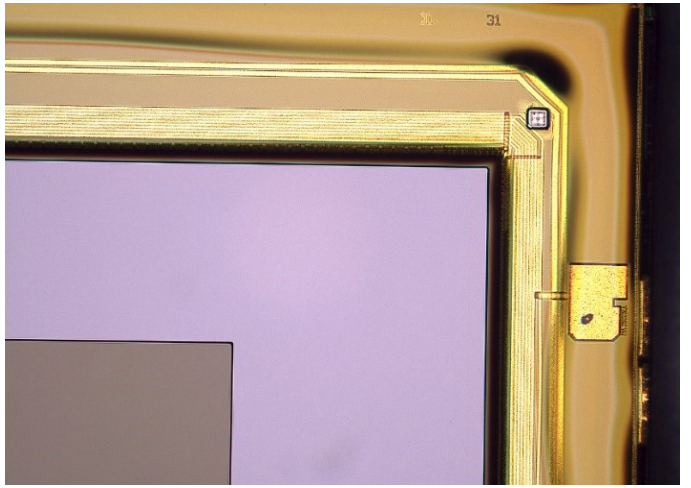


Figure 1 A schematic of a proposed non-reflective opaque mask design that is derived from Leonardo heritage designs.



MWIR - TIR

High-performance T2SL Infrared Detector Development

Prime contractor – IRNova (S)

Objectives

Development of a 1280 x 1024 pixel, 10um pitch Type-II superlattice infrared detector

Waveband MWIR (cut-off ~5 um @ 110K), VLWIR (cut-off

CHC 1.6 Me- or 5.5 Me-, configurable gain

4 Outputs at 20 Mhz -> frame rate up to 60 Hz – higher frame rates with 2x2 binning

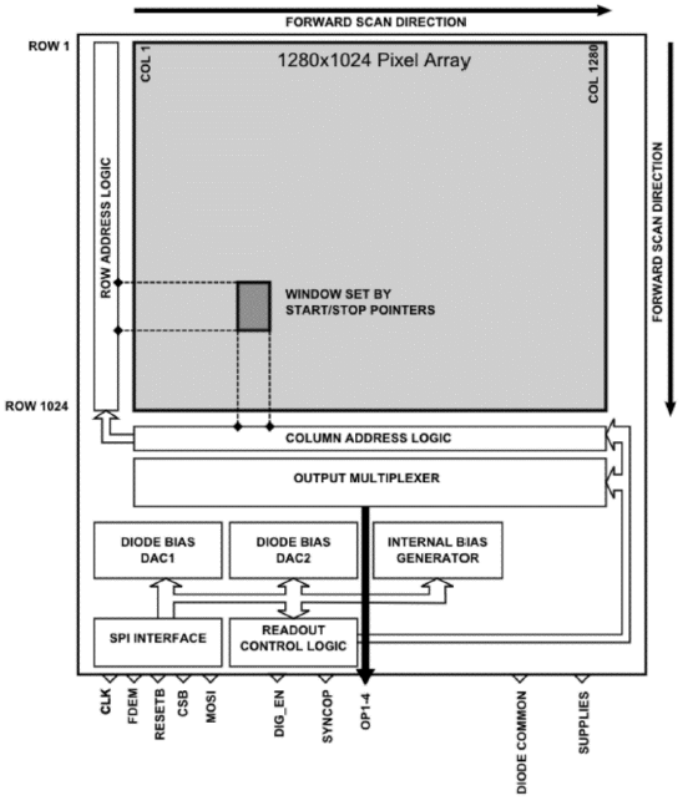
Status

PDR completed, CDR expected Q3 2023

T2SL detection layer fabricated and cut-off verified.

Detector processing in progress.

See IRNova presentation (M. Delmas) in Session 2 for further details



MWIR - TIR

LSTM Detector pre-development

Prime contractor – AIM (D)

Objectives

Development of custom LWIR-VLWIR detector for Copernicus LSTM instrument.

Single ROIC 1088 x 592 pixels with pixel pitch 25um

Five 1088x32 pixel active regions

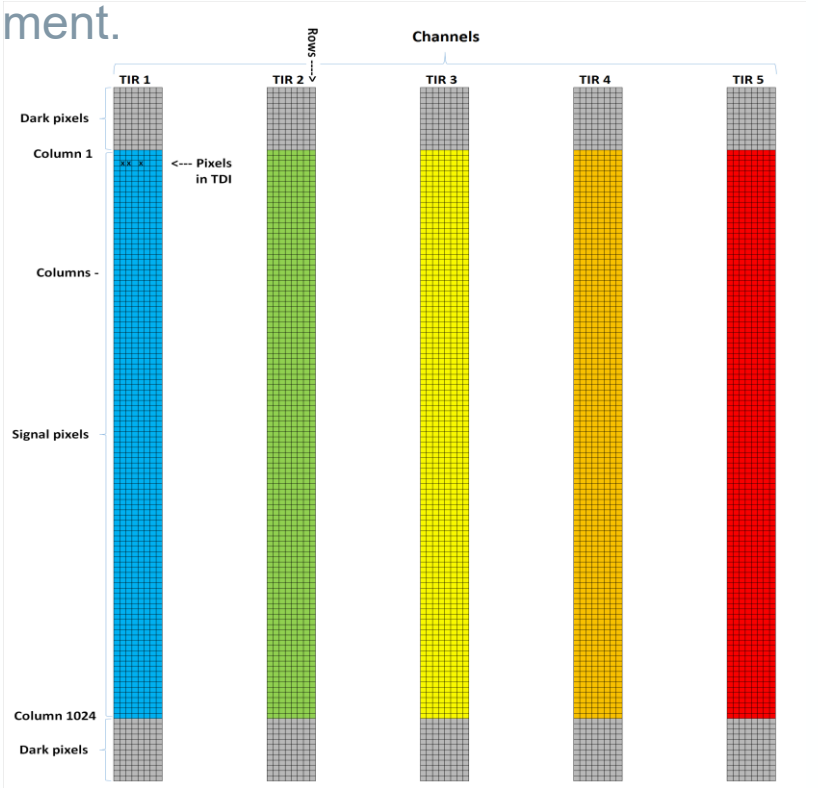
TIR-1	8.6 um
TIR-2	8.9 um
TIR-3	9.2 um
TIR-4	10.9 um
TIR-5	12 um

16 outputs at up to 10 MHz per channel – target frame rate ~4 kHz

Status

TRR complete, E/O characterisation in progress

See AIM presentation (H. Hohnemann) in Session 2 for more details



Optical Communications

Photon counting 2D tracking and communications demonstrator

Prime contractor – Leonardo MW (UK)

Objectives

Development of a NIR detector for optical comms station, combining tracking and receiver in a single unit.

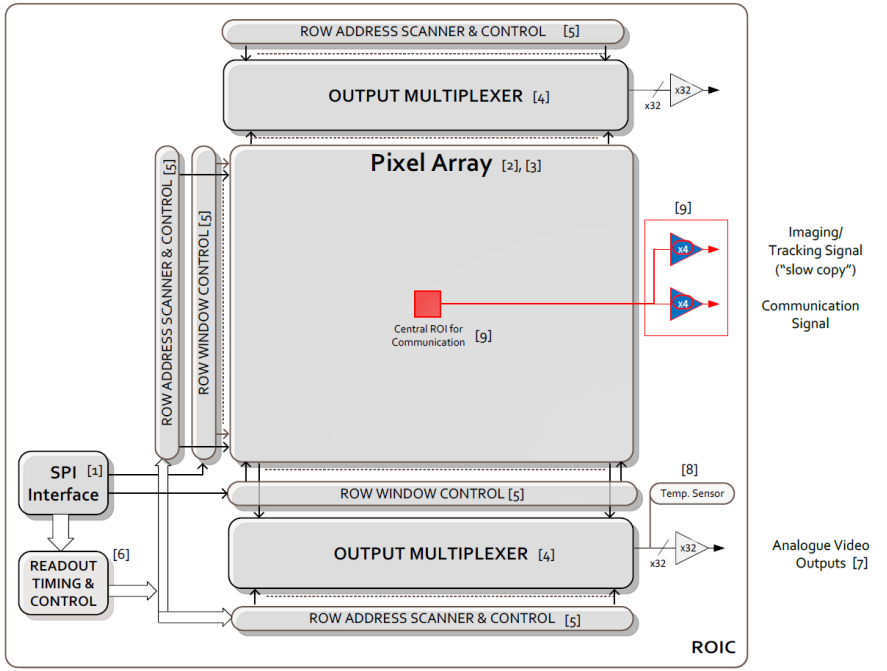
512 x 512 pixels, 12-20 um pitch

Image area 1 kHz frame rate

Central super pixels for tracking up to 1 GHz

Status

ROIC design completed – tape-out planned for Q3 2023



Optical Communications

Four-quadrant APD for LEO communications and tracking

Prime contractor – Albis (CH)

Objectives

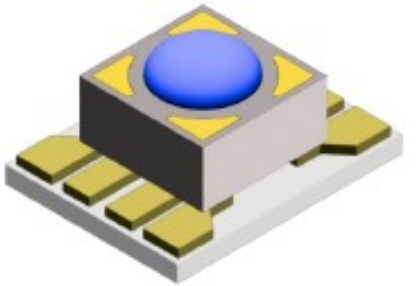
Development of a large-area (200 um diameter) multi-quadrant APD detector for detector for optical comms station, combining tracking and receiver in a single unit.

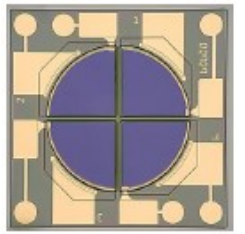
III-V APD for operation at 1550 nm @ RT

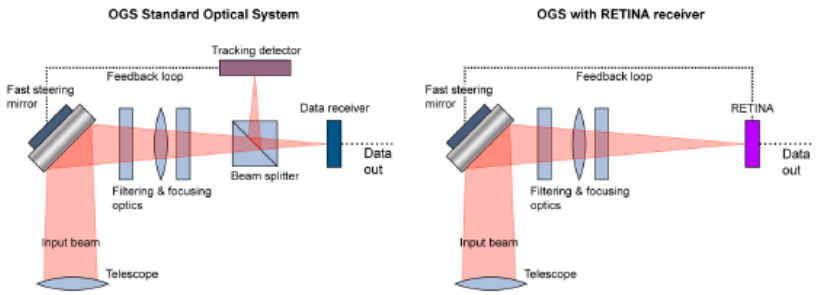
>10 Gbps data rate

Status

Activity kick-off meeting held in May 2023







Summary

- ESA has in excess of 15 infrared detector development activities in progress at any one time
- Total running budget for activities ~20 Meuro
- Significant development in SWIR waveband
- But increased interest in MWIR and especially LWIR
- Associated development also important

  -> ASICs for control and readout, pixel masking, detector hybridisation
- Increasing interest in optical communication detector developments

For further information on any of the presented activities, please contact either

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