

ATELIER DÉTECTEUR OPTOELECTRONIQUES POUR APPLICATIONS SCIENTIFIQUES SPATIALES

CNES OPTO-ELECTRONIC
DETECTION ACTIVITIES

Cedric Virmontois et al.
CNES
DTN/TPI/OED

13/06/2024

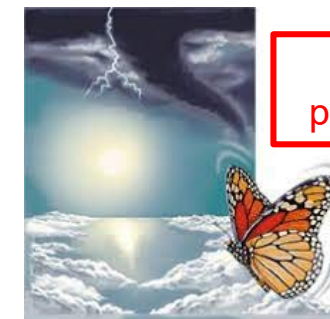


Le service Opto-Electronique de détection – DTN/TPI/OED

Le rôle du service

- Garantir la **performance** de la **chaîne de detection opto-électronique**
- Etudier et développer les **nouveaux concepts** de détection et de traitement du signal
- Evaluer et caractérisation des **critères de performances** de la chaîne de détection

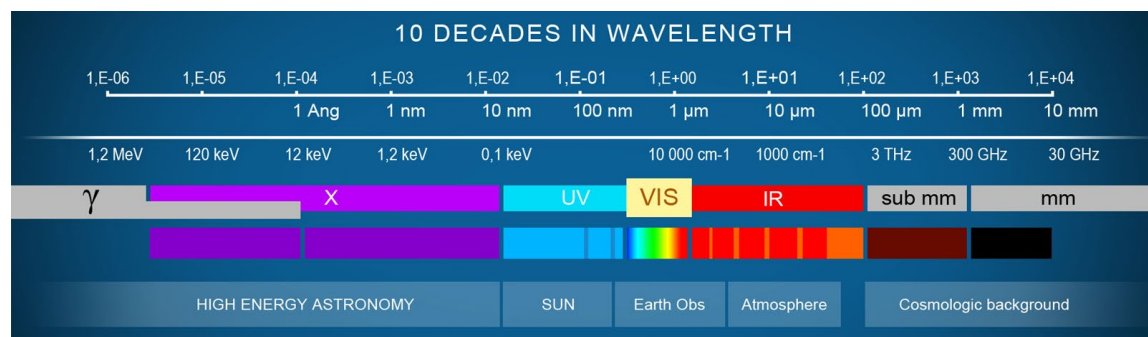
Le **Détecteur** est au **Cœur** des **Systèmes d'observation optique**



Effet papillon

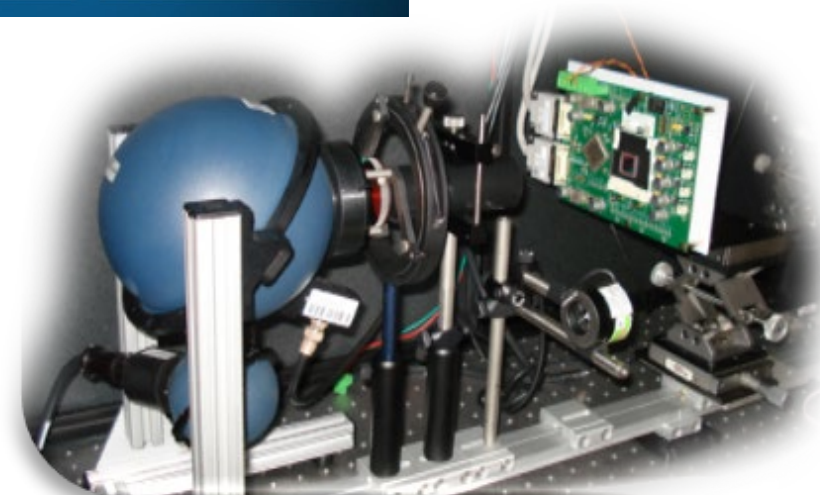
Les Domaines du service

- Visible
- Infrarouge
- Science / Comptage de photon
- Electronique Analogique et Numérique



Laboratoire → Mesure du prototype au modèle de vol

- 5 Bancs visible
- 3 Bancs IR
- 1 nouveau labo comptage de photon
- 10 Zones de mise en place électronique analogique et numérique





C. Virmontois
CdS



V. Lallucaa
Spécialiste
SC, MS



C. Robert
Assistante



JM. Biffi
Expert
CD, EL



A. Materne
Expert Senior
CD, EL



V. Bernard
Spécialiste
MS, EL



JM. Belloir
Spécialiste
SC



A. Panglosse
Spécialiste
EL, Mesure



S. Beaumont
Spécialiste
CD, EL



A. Rouvié
Expert
CD, SC



H. Geoffray
Expert
CD, SC



C. Durnez
Spécialiste
SC

ELECTRONIQUE

VISIBLE

INFRAROUGE

10 Agents CNES (Hors CdS et Sec.)
+ 1 apprenti

10 Sous-traitants

Astek/Expleo/Sophia/CapGemini

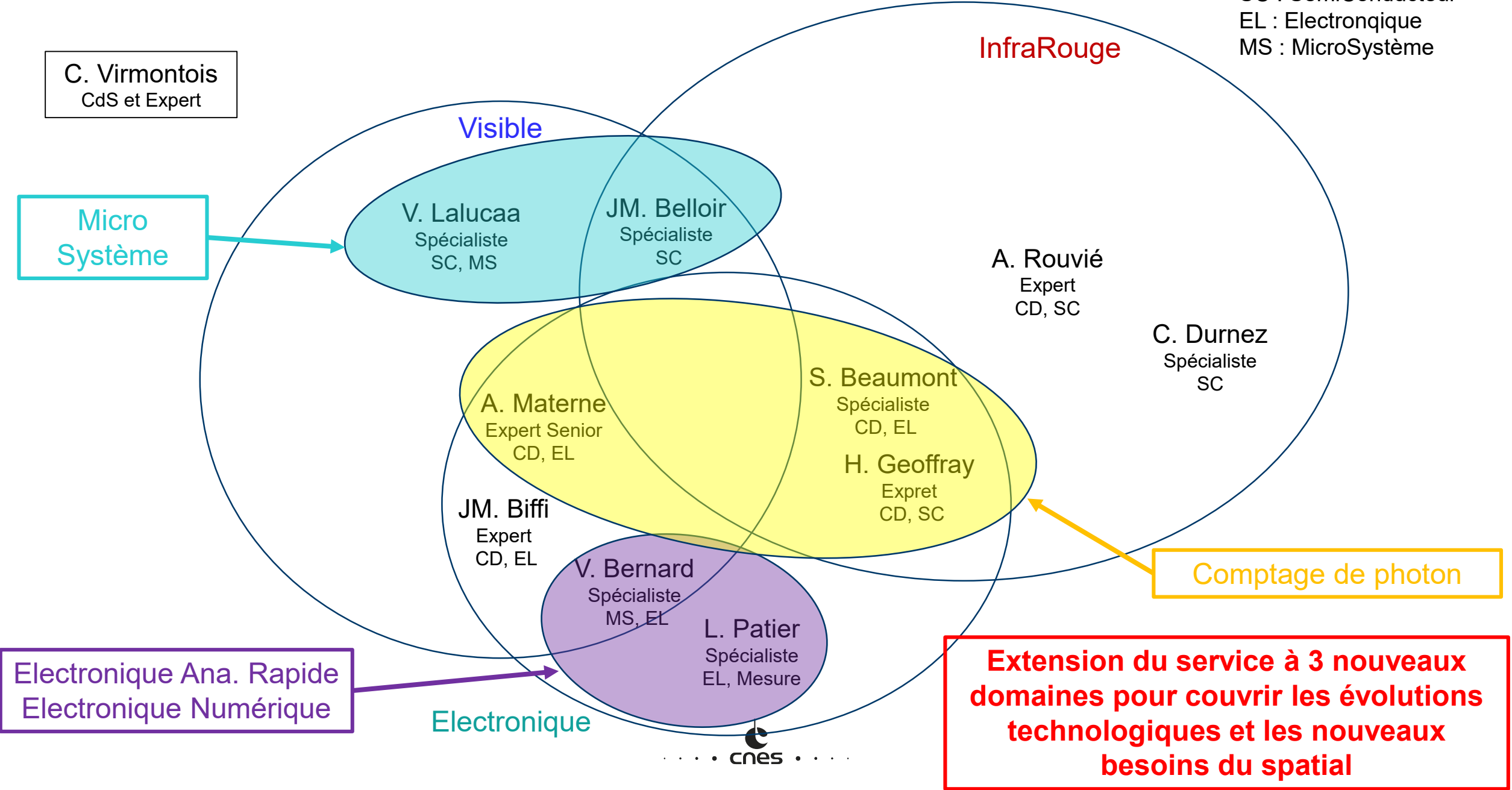
6-7 Doctorants/Post-doc :

ISAE, CEA, TAS, STM, ADS, NASA...

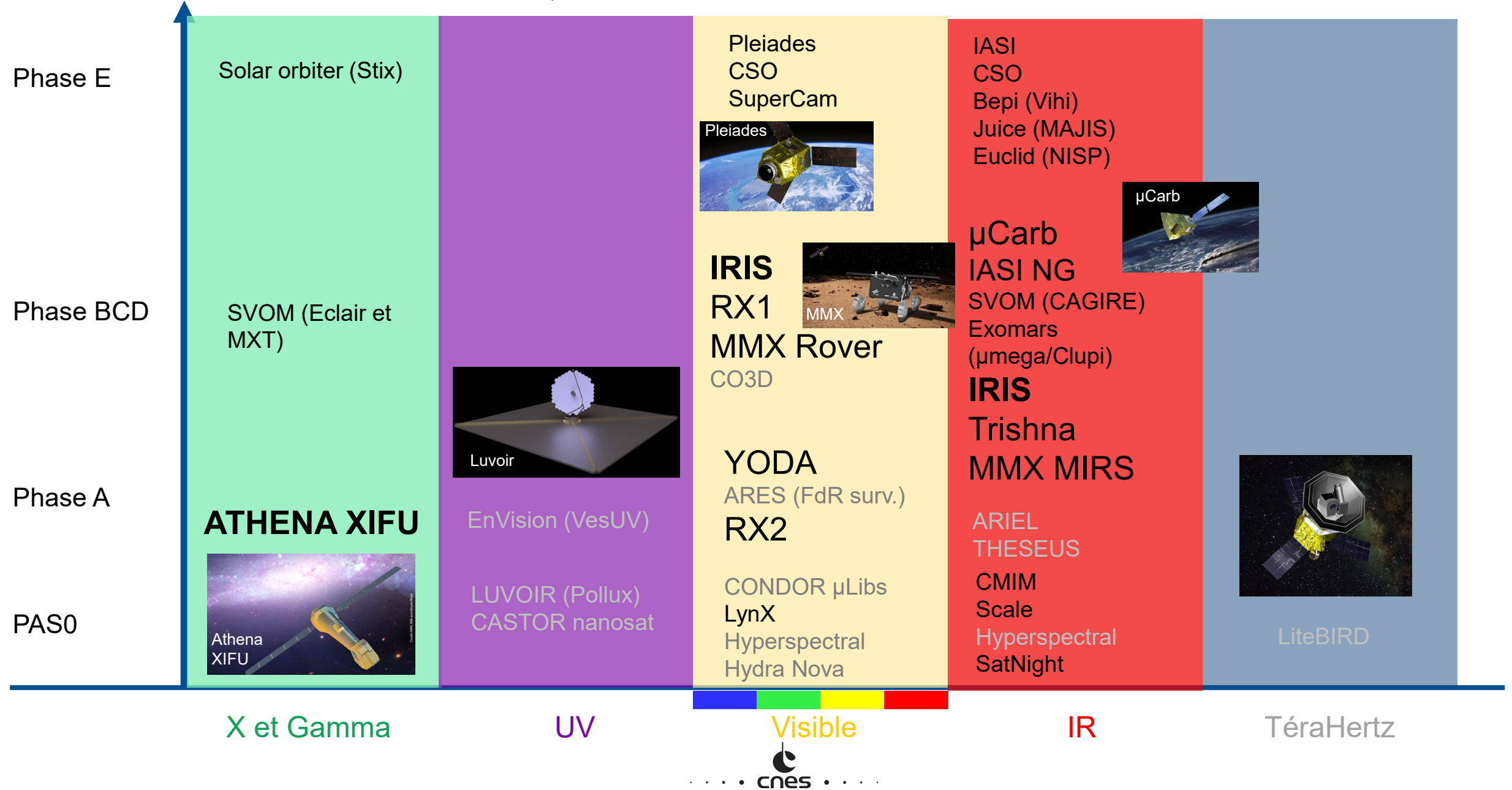


COMPÉTENCE SERVICE CHAÎNE DE DÉTECTION – NOUVEAUX DOMAINES

CD : Chaîne de Détection
SC : SemiConducteur
EL : Electronique
MS : MicroSystème



ACTIVITÉS SERVICE OPTO-ELECTRONIQUE DETECTION DTN/TPI/OED : IMPLICATION PROJET



Outline

 **CNES R&T**

 **R&T Activities**

 **PHD thesis**

 **COMET OOE Workshops**

Outline

 **CNES R&T**

 **R&T Activities**

 **PHD thesis**

 **COMET OOE Workshops**

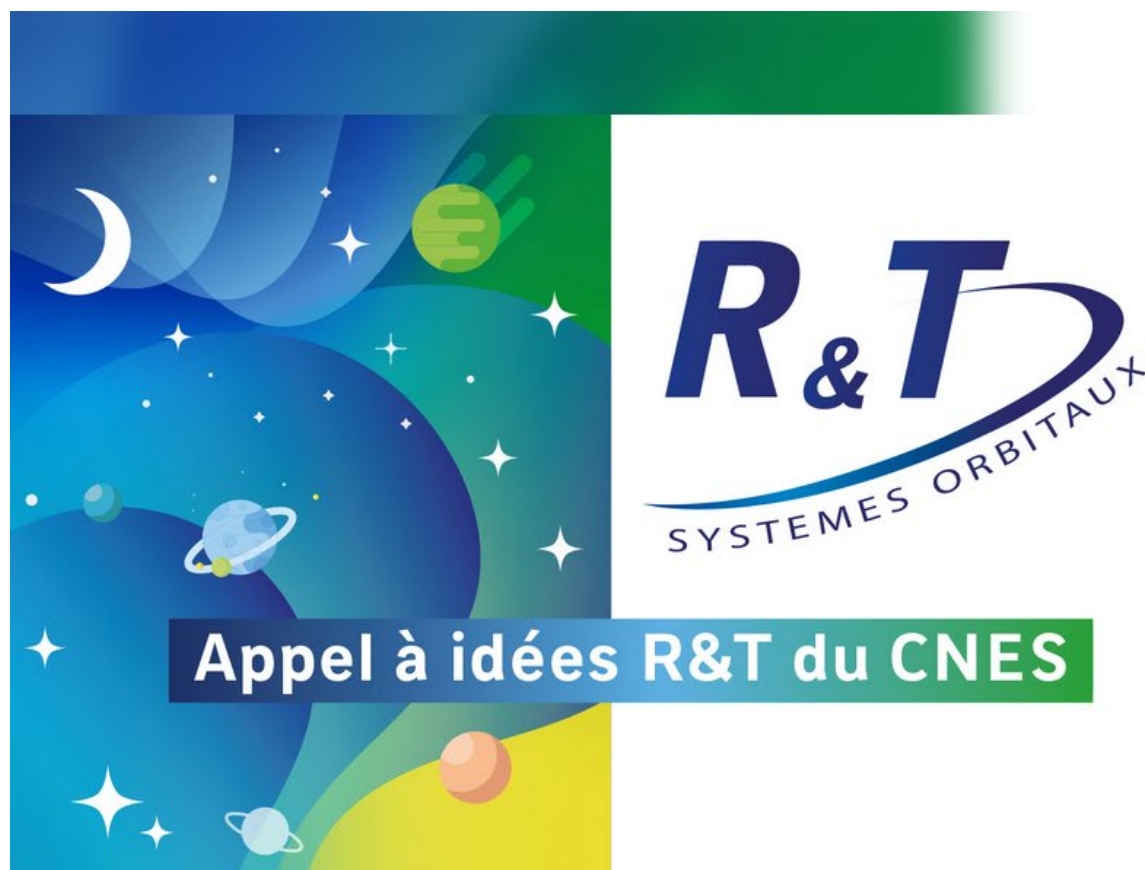
CNES R & T

Call for R&T ideas always open on:

<https://rd-cnes.wiin.io/fr/applications/aai-2022/>

3 checks per year

3 months from the idea to the kickoff



RD-CNES

AAI R&T

Le programme de R&T systèmes orbitaux du CNES fait l'objet d'un appel à idées vers les industriels et les organismes de recherche institutionnels. Une fois acceptées, ces propositions sont intégrées dans le programme pluriannuel d'actions de R&T. Les critères d'éligibilité sont décrits dans la page "La R&T au CNES"

Outline

- 🪐 **CNES R&T schedule**
- 🪐 **R&T Activities**
- 🪐 **PHD thesis**
- 🪐 **COMET OOE Workshops**

R & T Activities: Visible

New generation of visible Microcamera cube CASPEX 12M

TO: V. Lалуcaa

3DPLUS (France)



Objective

To develop the next generation of CASPEX (flying on PERSEVERANCE, ONEWEB STR...) with higher performances (Nb. Of Pxl, SNR, and function as compression) using Sony IMX253 (selected over 8 CIS) & FPGA Xilinx KU40 (selected against NanoXplore Medium) For multi-purpose

Duration

Q2 2018 → Q3 2024

Delivery

EM (Q1 2023) : On going caracterizion

PFM (Q3 2023): already selected on CNES internal mission

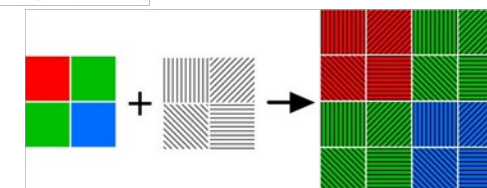
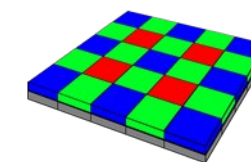
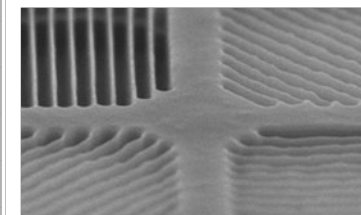
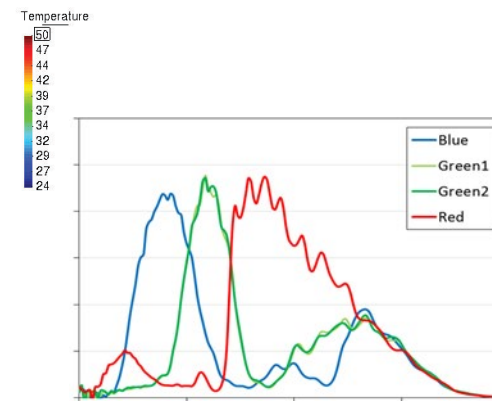
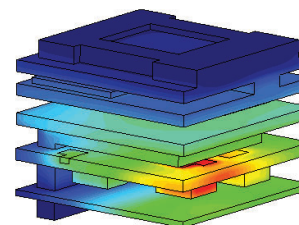
end of qualification : Dec 2024

Results

2D breadboard fully characterized using spacewire and Cameralink output

3D CDR passed with **specific thermal architecture**

First FM batch produced for qualification and projects, Qualification TRR passed



R & T Activities: Visible

New generation of visible Microcamera cube CASPEX

TO: V. Bernard

Ingespace

Objective

To develop wireless microcamera cube

Duration

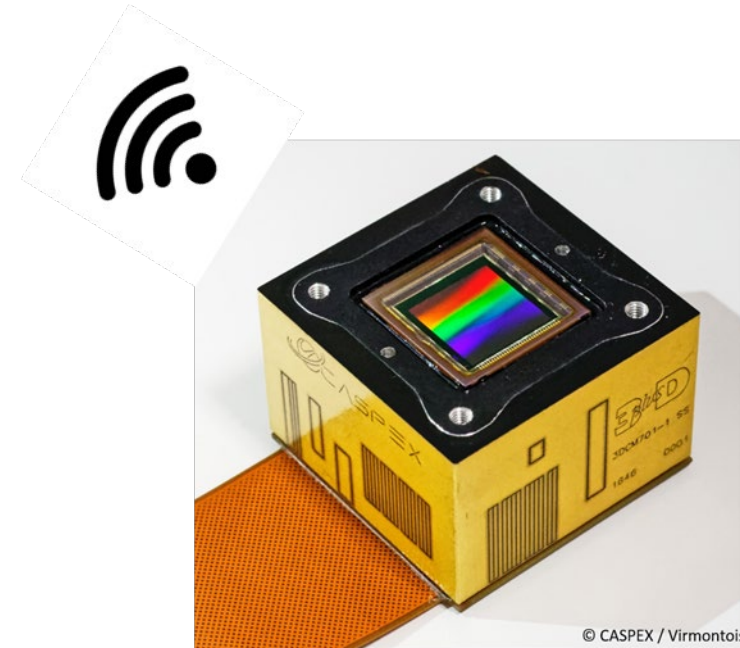
Q2 2022 → Q3 2024

Delivery

Reports and 2D breadboard

Results

Architecture of RF link



R & T Activities: Visible

CASPEX 10X (Thrid Generation)

TO: C. Durnez

3D+

Objective

To develop a miniaturized microcamera module that can be easily embedded, without weight or size constraints.

Duration

Q2 2024 → Q4 2025 (18 months)

Delivery

Reports and 2D breadboard

Results

Prototype characterization with the breadboard

Current generations	New generation
35 x 35 x 23 mm ³ (gen1) / 40 x 40 x 39 mm ³ (gen2)	10x smaller
64g (gen1) / 120g (gen2)	10x lighter
60 k€ (gen1) / 100k€ (gen2)	Target price below 20 k€

R & T Activities: Visible

COTS CIS characterization and radiation test

TO: A. Materne

Internal CNES

Objective

To evaluate COTS CIS: GigaPyx from Pyxalis
46 Mpxl, Rolling shutter, 4.4 μ m pixel pitch

Duration

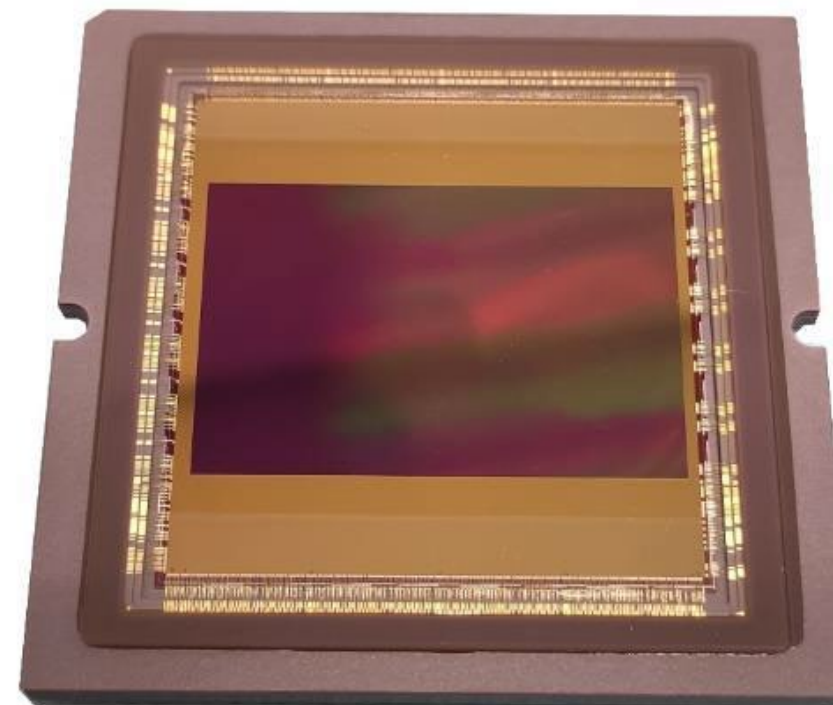
Q4 2022 → Q4 2023

Delivery

Publications at RADECS + ICSO 2024 + Workshop CIS 2024

Results

Proton and heavy ion tests reports



R & T Activities: Visible

Improvement of radiation hardness of SiPM detectors

TO: A. Materne

CNES Lab

Objective

Follow-up of the FBK R&T focused on on-flight annealing feasibility based on forward annealing of the SiPM

Duration

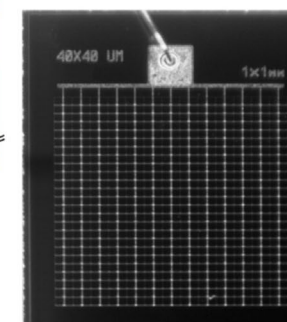
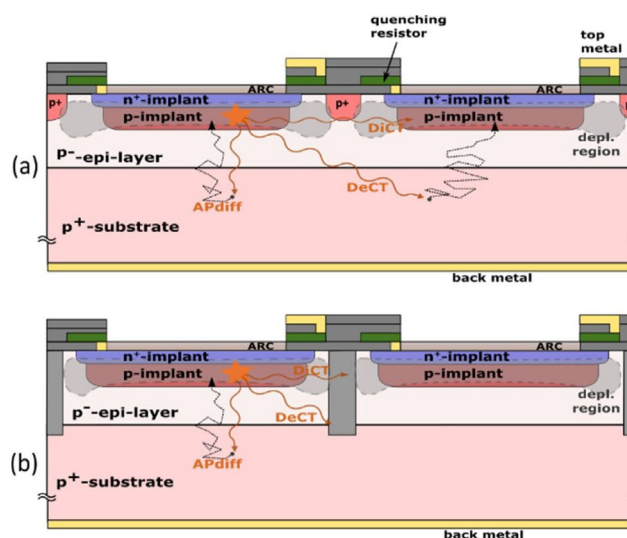
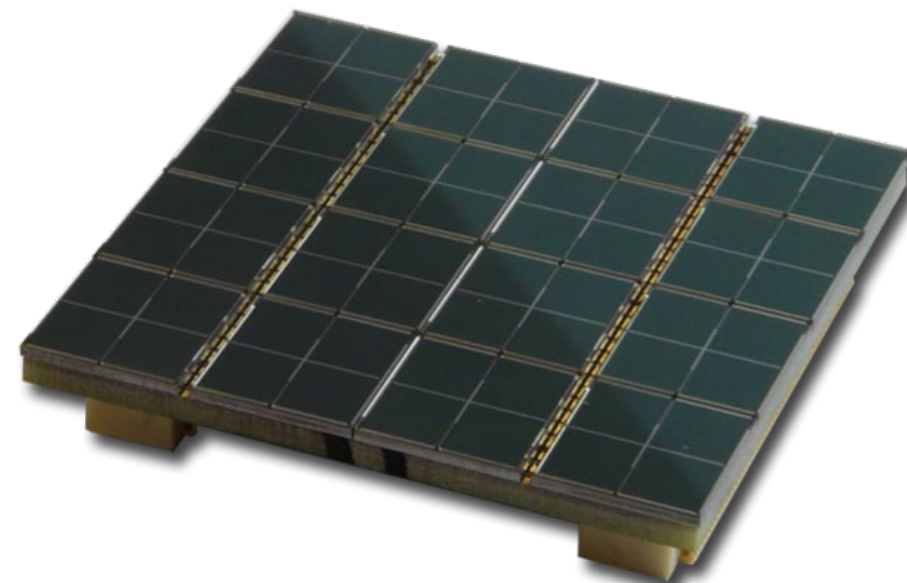
Q1 2024 → Q1 2025

Delivery

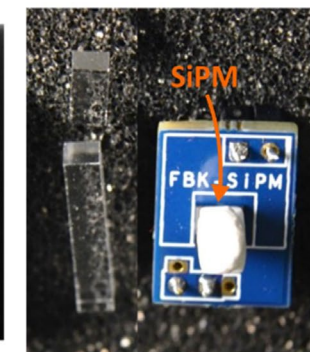
Test vehicle. Radiation report.
Annealing test report
Recommendations for SiPM.

Results

2025



(c)



(d)

R & T Activities: Visible

Detection Head for Gamma-Ray based on SiPM

TO: A. Materne

IRAP

Objective

Development and test of a detection head for High Energy Photon detection on space programme 3U Transat = cubesat for exploration of electromagnetic counterparts of gravitational waves.

Radiation tests

Duration

Q4 2023 → Q2 2025

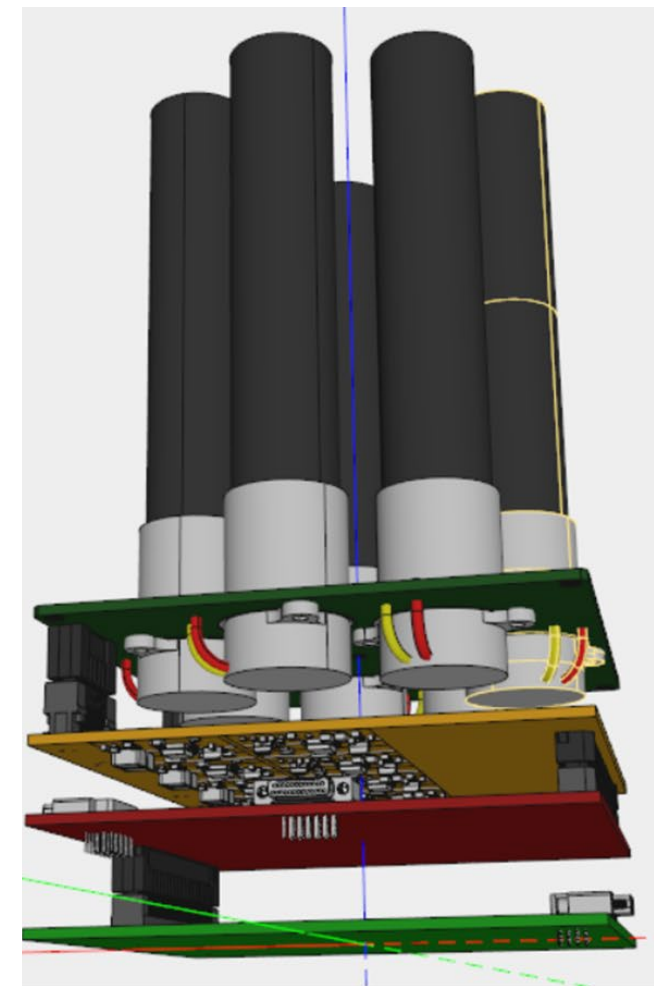
Delivery

Detection Head definition

Radiation test report

Results

2025



R & T Activities: Visible

Quanta image sensor: low flux application in integration mode

TO: V. Bernard

ONERA / ADS

Objective

Characterize quanta image sensor technology

Integration mode CIS

Evaluation of radiation tolerance

Duration

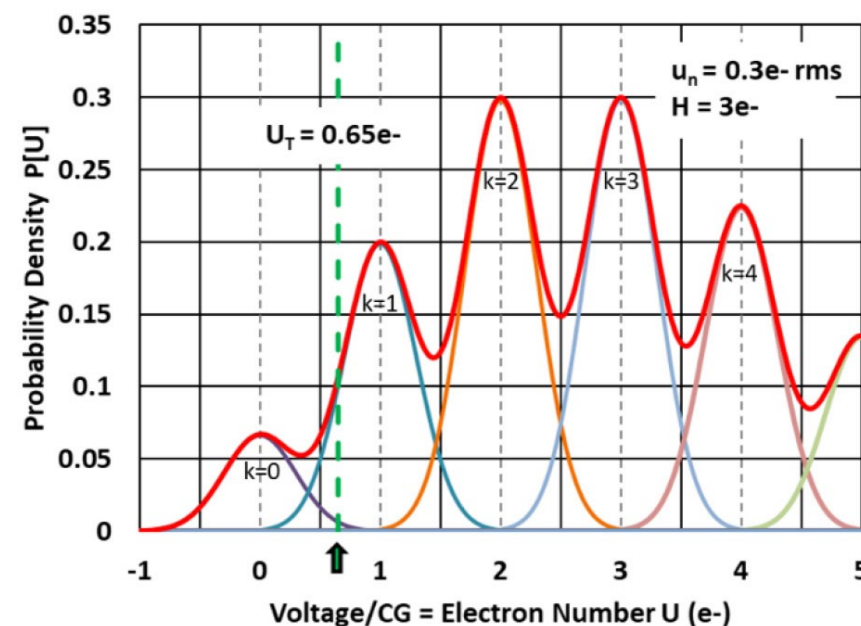
Q3 2022 → Q3 2024 (followed by internal PhD, Joanna Krynski)

Delivery

Test reports, Radiation report.

Results

2024



R & T Activities: Visible

CDTI CCD on CMOS Avalanche mechanism within image sensors

TO: A. Rouvié

ISAE SUPAERO, Thales Alenia Space

Objective

Avalanche implementation for low light level image sensors development

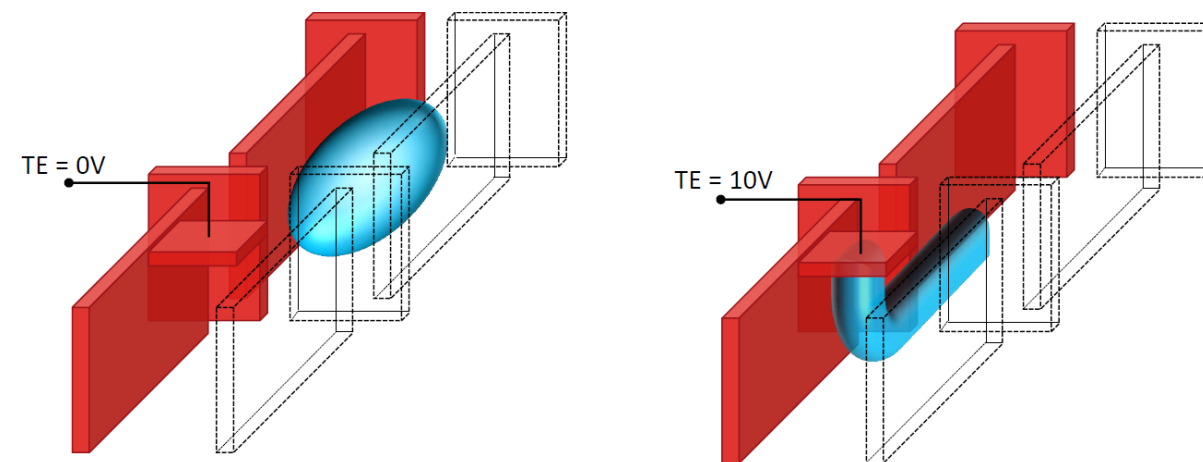
Duration

#1 Q4 2022 → Q4 2023 (ended)

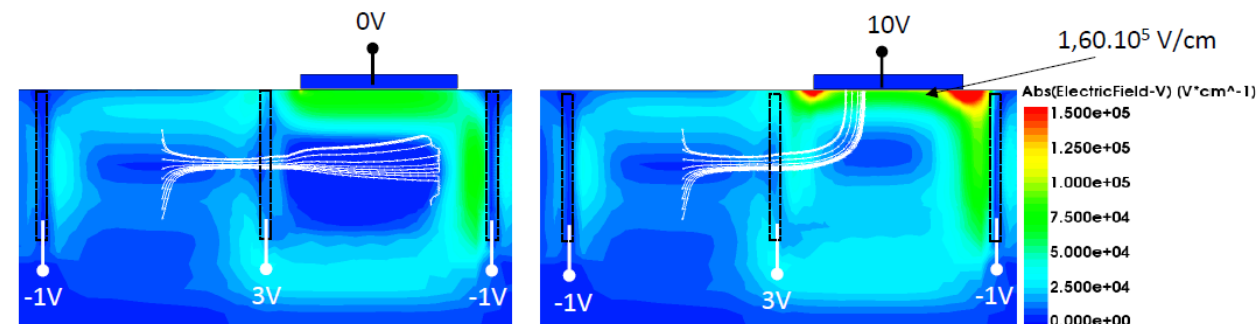
#2 Q1 2024 → Q3 2025

Delivery

Characterization of designed structures
Radiation hardness



- Electric Field cross-section with electron streamlines



R & T Activities: Visible

Evaluation of radiation effects on COTS detectors

TO: C.DURNEZ

Internal CNES

Objective

Evaluate the radiation hardness (TID, DDD, SEE) of two COTS detectors from Sony and TE2V

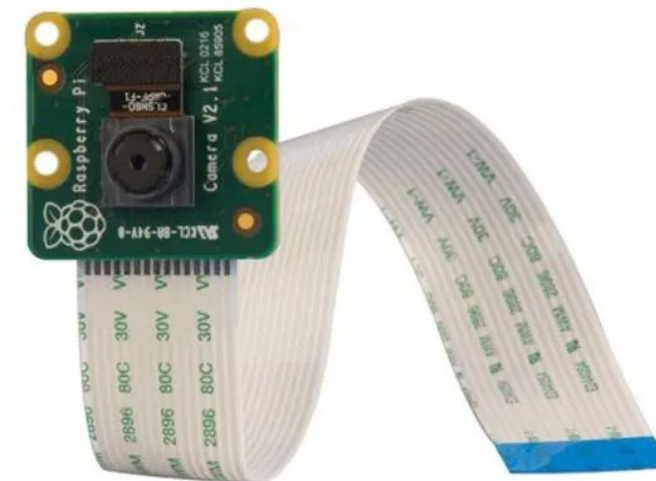
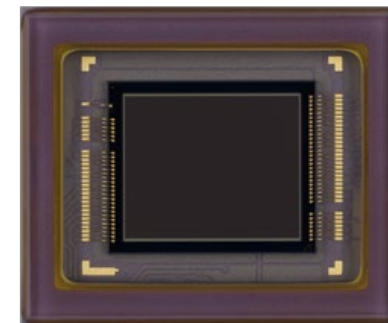
- one with the new stacked technology
- one very small detector (smartphone like)

Duration

Q1 2024 → Q3 2025

Delivery

Report and synthesis



R & T Activities: Visible

RTS software

TO: C.DURNEZ

Thales services

Objective

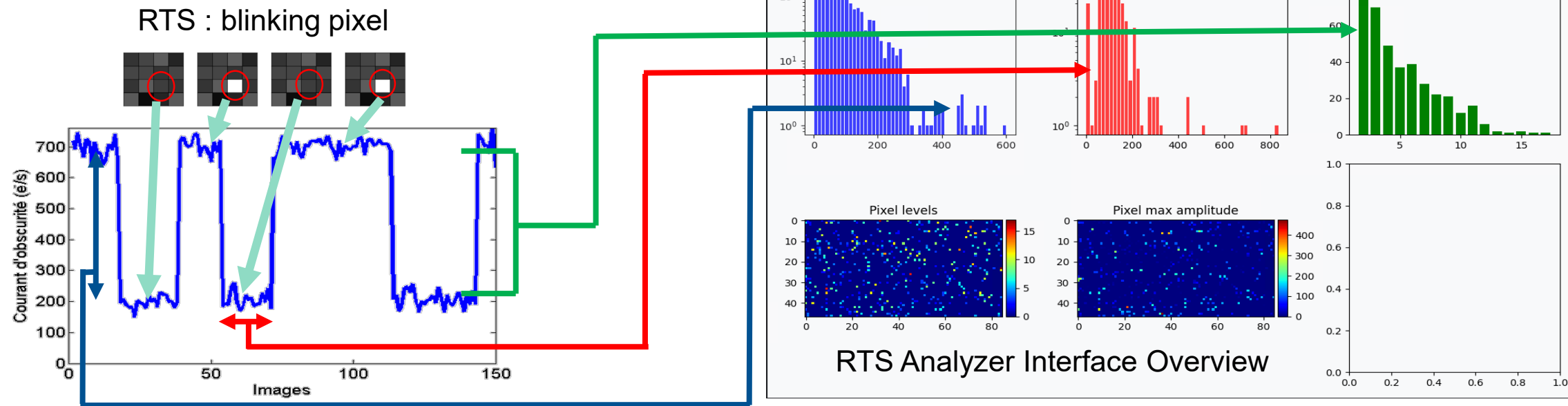
- Improve RTS detection software :
- Based on Python code, with a user friendly IHM
- Improved methods, such as comparison of several measurements to obtain deeper analyses

Duration

Q2 2024 → Q4 2024

Delivery

Software and user manual



R & T Activities: Infrared

New generation of Infrared Microcamera cube CASPEX IR

TO: J-M. Belloir
3DPLUS

Objective

To develop the next generation of CASPEX for SWIR
with higher performances (Nb. Of Pxl, SNR, and function as compression)
using Sony IMX990 & FPGA Xilinx KU40
For multi-purpose

Duration

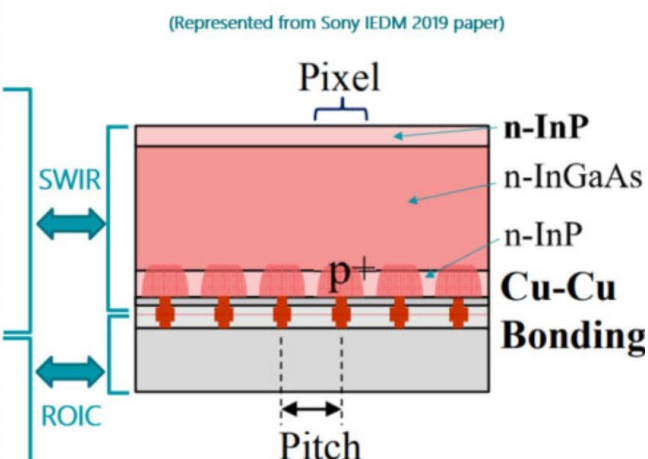
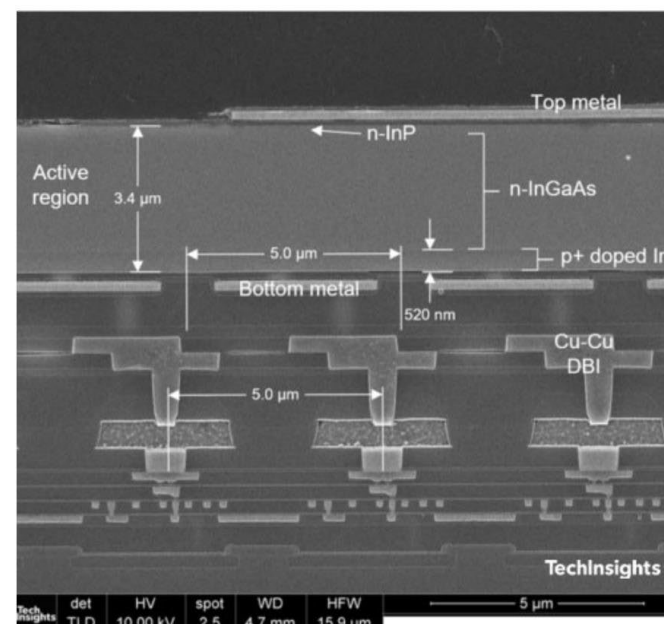
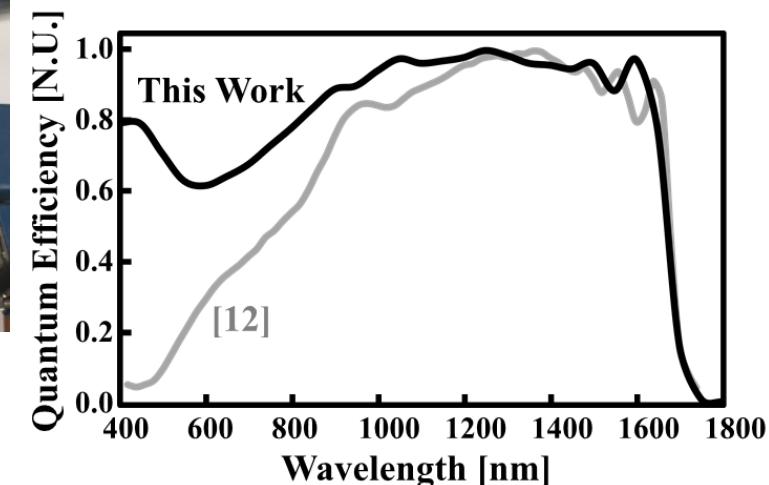
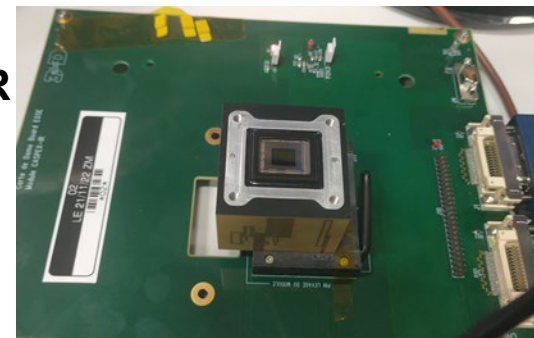
Q1 2020 → Q4 2024

Delivery

DJD, ICD, Prototype (Q2 2024) and PFM (Q4 2024)

Results

2D breadboard and 3D prototype delivered at CNES
PFM to be delivered before end of year



High-definition Visible-SWIR InGaAs Image Sensor
using Cu-Cu Bonding of III-V to Silicon Wafer.

S. Manda, R. Matsumoto, S. Saito, S. Maruyama, H. Minari, T. Hirano, T. Takachi, N. Fujii,
Y. Yamamoto, Y. Zaiten, T. Hirano, and H. Iwamoto
Sony Semiconductor Solutions Corporation
email: Shuji.Manda@sony.com

R & T Activities: Infrared

MCT detector persistence test

TO: J-M. Belloir

CEA/LETI

Objective

To test persistence performance for different MCT detectors configurations
For atmosphere probing and astronomy

Duration

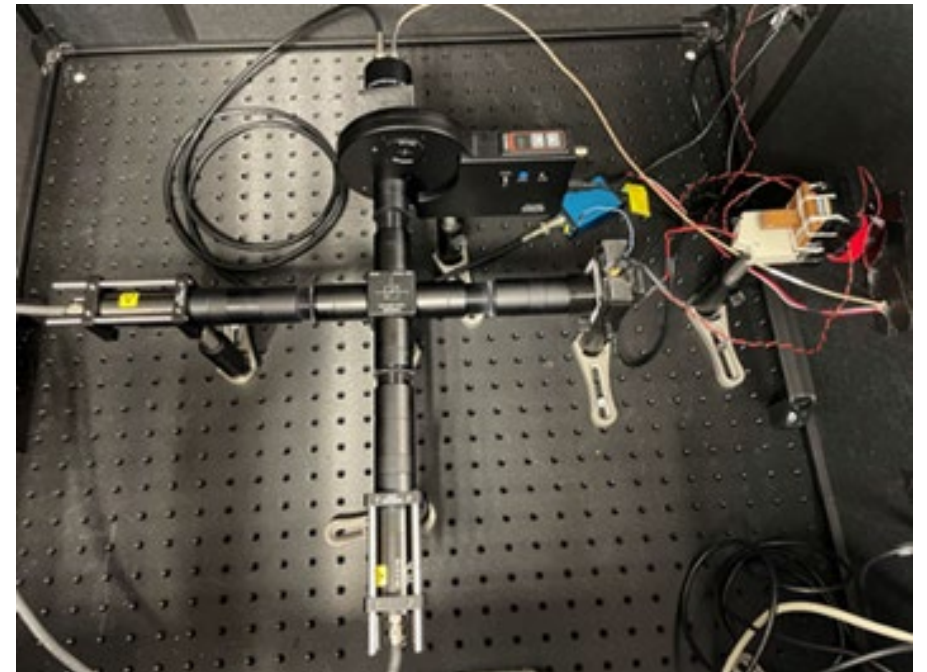
Q2 2024 → Q2 2025

Delivery

Reports

Results

Test bench set up and validation
Characterization of specific test vehicle with optimized interface



R & T Activities: Infrared

VLWIR p/n technology up to 15.5 μm

TO: A. Rouvié

Lynred

Objective

To evaluate Lynred p/n technology ($\lambda_c \sim 15.5\mu\text{m}$ at 60K)
with a pixel pitch 15 μm

For meteo applications

Duration

#1 Q4 2022 \rightarrow Q1 2024

#2 Q4 2023 \rightarrow Q1 2025

Delivery

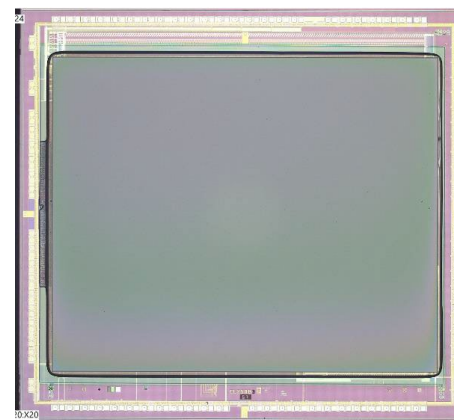
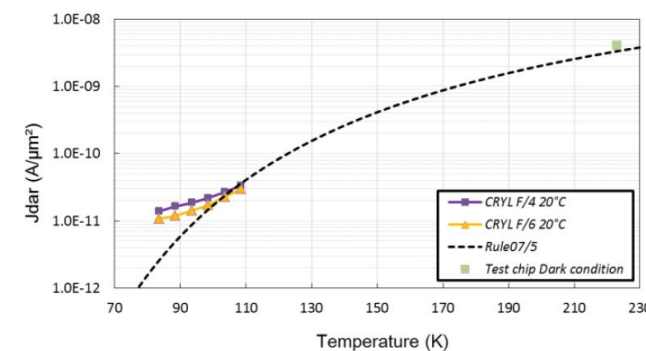
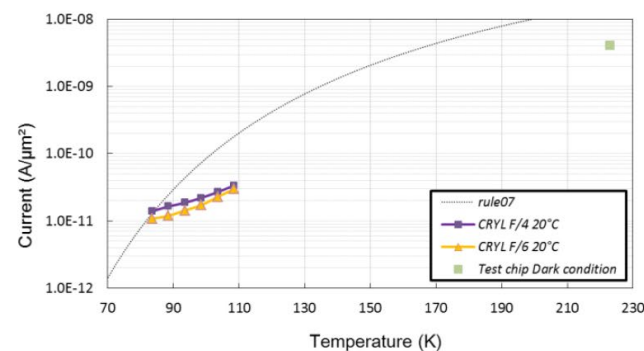
Breadboard

Results

Detection layer hybridized on ROIC and
characterization

Results obtained in the frame of the
previous R&T P/N 13 μm

Figure 14: Sensor current levels measured on sensor #304763 under different electro-optical conditions and compared with the Rule'07 trend (left). Dark current levels as a function of temperature for sensor #304763 and comparison with Rule'07 /5 trend for dark current (right).



1st retina with
VLWIR P/N technology
(measurements on going)

R & T Activities: Infrared

Evaluation of SWIR sensor from NIT

TO: S. Beaumont

NIT + TAS

Objective

To evaluate the tolerance of NIT sensor (Visible + SWIR)

Duration

Q3 2023 → Q2 2024

Delivery

Reports

Results

Publications



R & T Activities: Infrared

Radiation test on T2SL matrices

TO: C. Durnez

ADS - ONERA

Objective

To test radiation behavior of IRNOVA T2SL detectors:
ODEN product
For MWIR

Duration

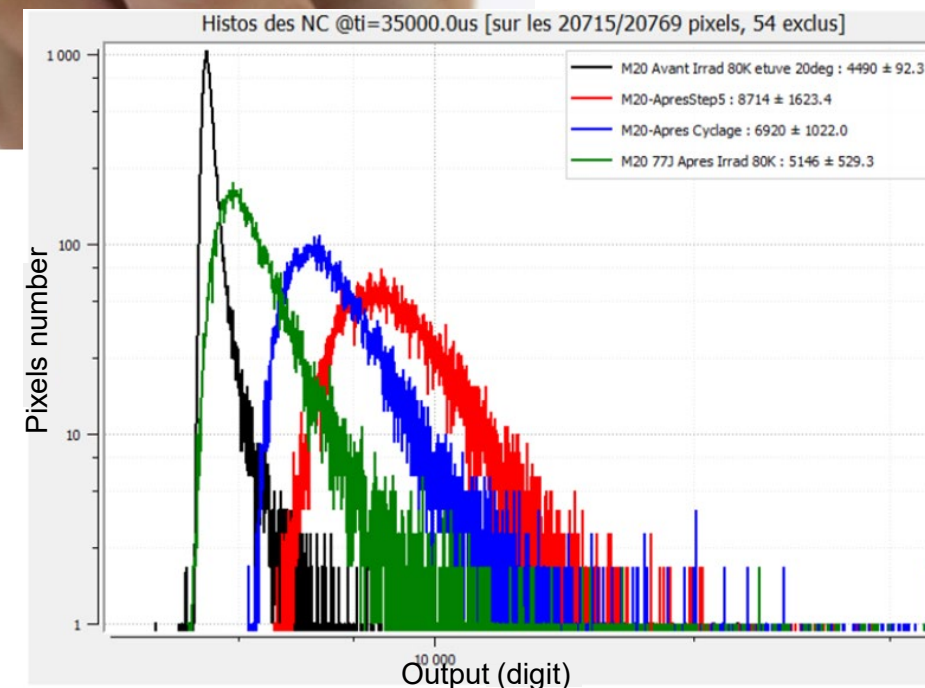
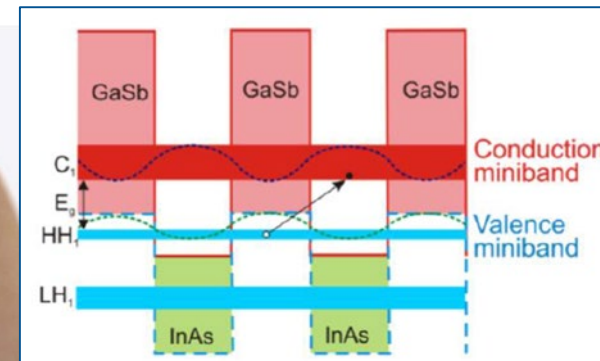
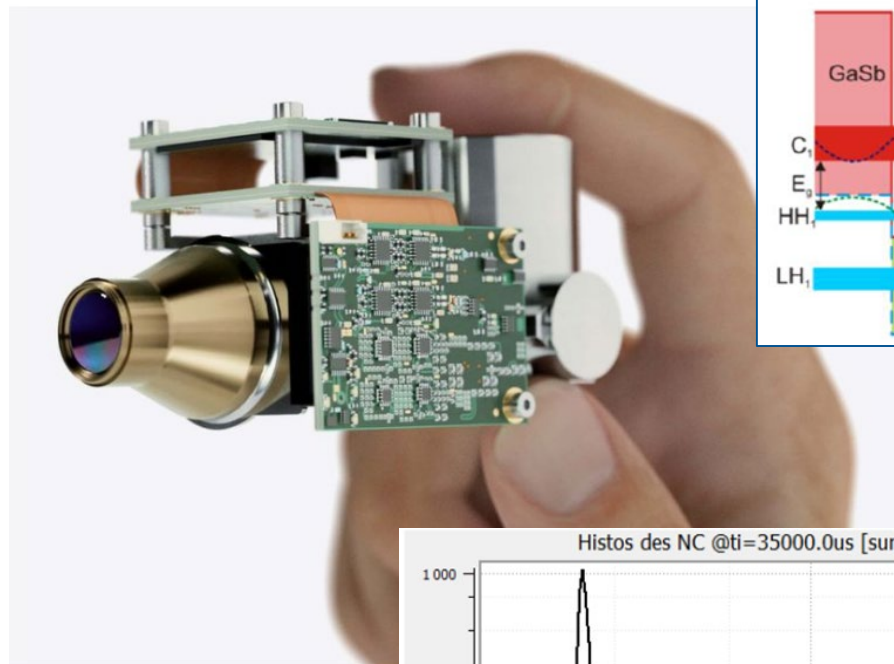
Q2 2024 → Q2 2025

Delivery

EO performance and Radiation tests

Results

Presentation during 2025 IR Workshop



R & T Activities: Infrared

SiGeBiCMOS pre-amplifier for MCT APD

TO: A. Rouvié

CEA/LETI

Objective

Evaluation of SiGeBiCMOS technology to improve the readout circuit bandwidth ($>1\text{GHz}$)

SiGeBiCMOS readout circuit layout design

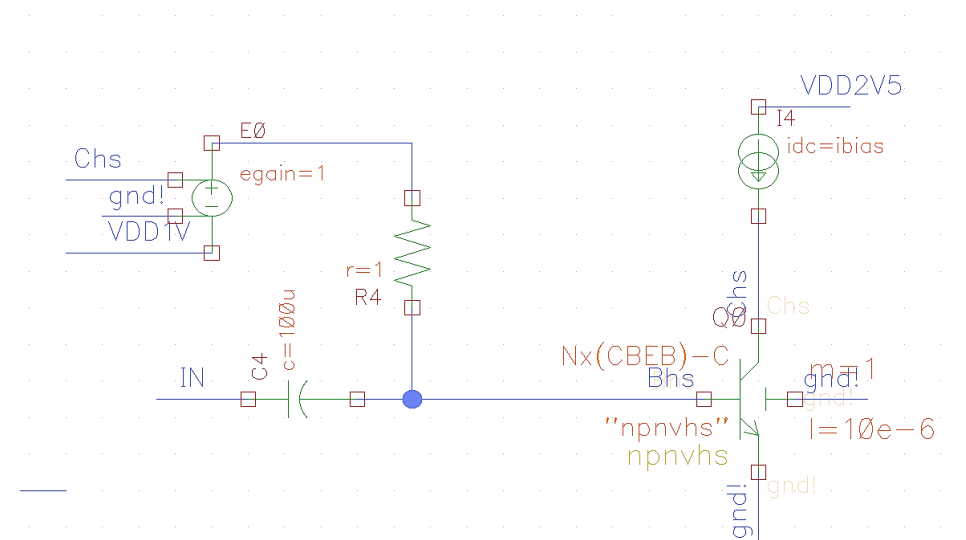
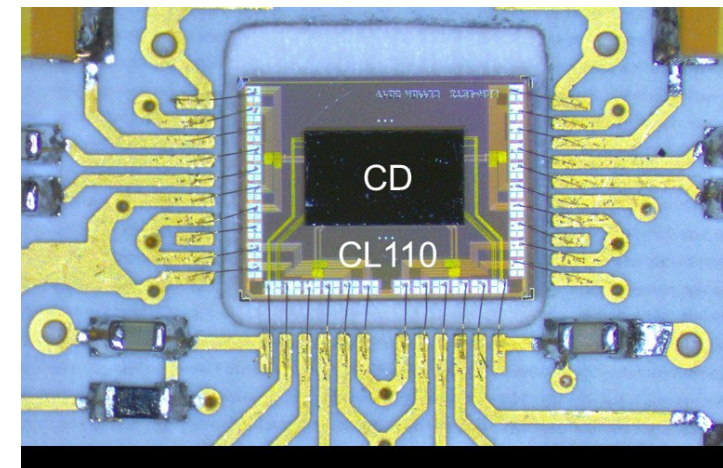
Duration

Q3 2023 \rightarrow Q3 2024

Delivery

Reports

Readout circuit layout



R & T Activities: Infrared

Compact IDDCA for space applications (Cryos XS)

TO: A. Rouvié

Lynred

Objective

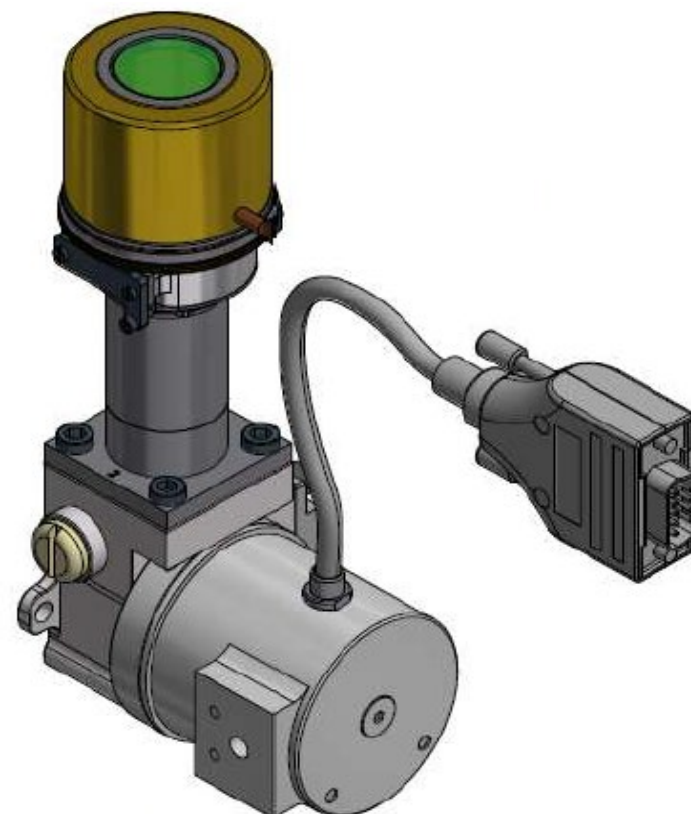
To develop the Neptune IDDCA successor for science and hyperspectral missions

Duration

Q3 2024 → Q2 2026

Delivery

IDDCA with Cobra S



LYNRED Staring Array
COBRA
1840x1112 (COBRA-L)
1380x640 (COBRA-S)
20μm
MCT - SWIR

R & T Activities: Infrared

IRS-NG

TO: C. Durnez

Lynred

Objective

In addition to ESA activity : ESA AO/1-11852/23/NL/AR

Work on the prototype of a readout circuit that can be suitable for future meteorology applications (high frame rate, p/n technology, up to VLWIR)

Duration

Q2 2024 → Q4 2025

Delivery

Test reports from MER0



R & T Activities: X detector

Highly integrated X detector

TO: S. Beaumont

CEA

Objective

To develop an assembly technology of ASICs for the manufacturing of highly integrated X ray detector in the perspective of large focal planes at ambient temperature (CdTe) → Compression molding and RDL

Typical targeted module

64x64 pixels

250µm pitch

digital outputs

For astronomy

Duration

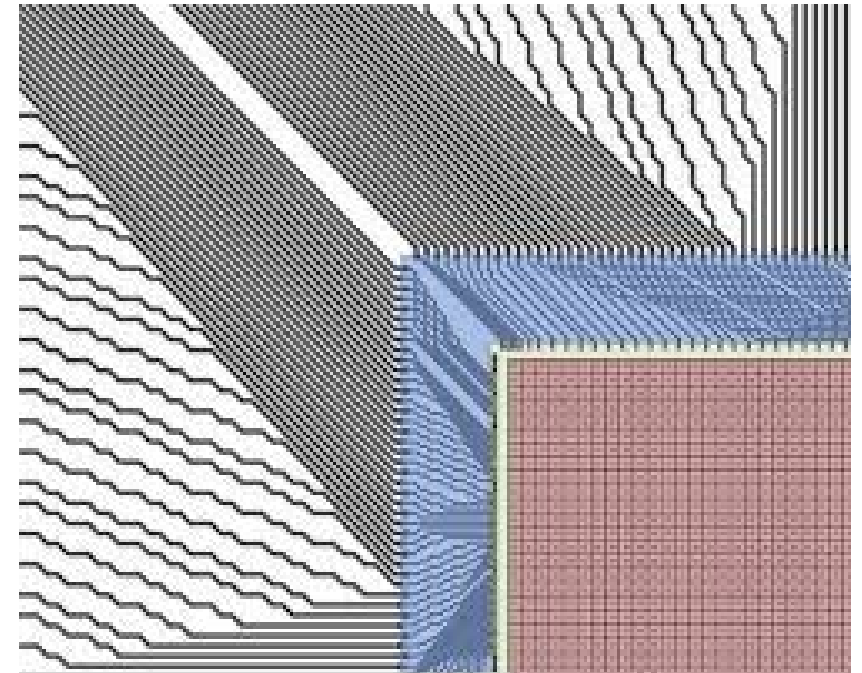
Q3 2022 → Q2 2024

Delivery

4 ASICs report on the same compression molded plan and CdTe report

Results

Reports



R & T Activities: Electronic

Development of a readout ASIC for "Search-coil" magnetometer in 180 nm CMOS technology

TO: A. Panglosse

LPP – Plasma Physics Laboratory

Objective

Design and develop a new readout ASIC for a search-coil type magnetometer in 180 nm CMOS technology for 2 reasons:

- AMS's planned cessation of 350 nm technology within two years and the uncertain support from Euro-Practice.
- LPP's long-term goal is to integrate functions for digitizing and pre-processing signals near the magnetic sensor to optimize signal-to-noise ratio and transmit them digitally.

Duration

2020 → Q4 2023

Delivery

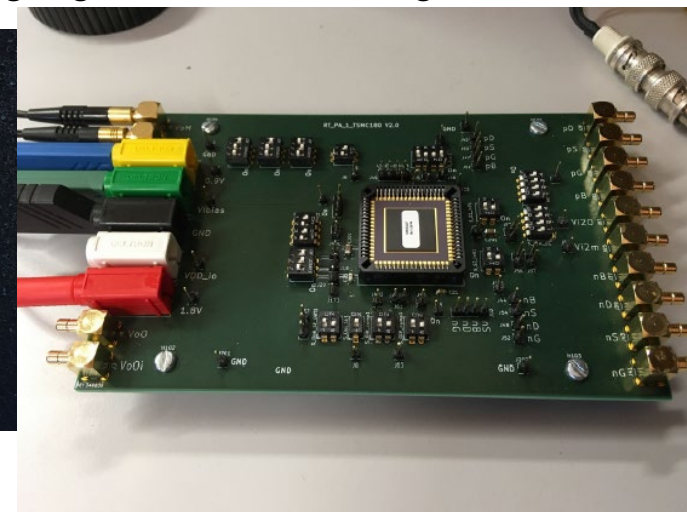
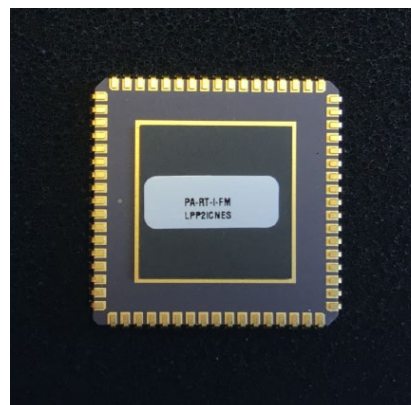
Reports

Results

An ASIC was designed and made using TSMC 180 nm technology.

However, due to the semiconductor material shortage and TSMC's decision to stop their 180 nm technology, LPP is testing other technologies to find a sustainable alternative.

A study is currently being done on three identified technologies.



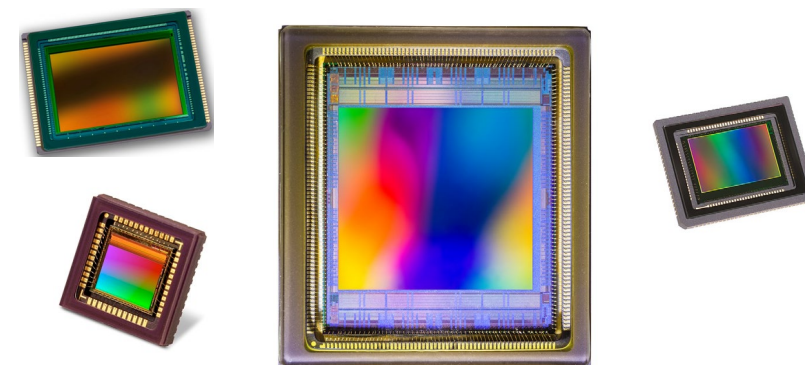
Outline

- 🪐 **CNES R&T schedule**
- 🪐 **R&T Activities**
- 🪐 **PHD thesis and Post-doc**
- 🪐 **COMET OOE Workshops**

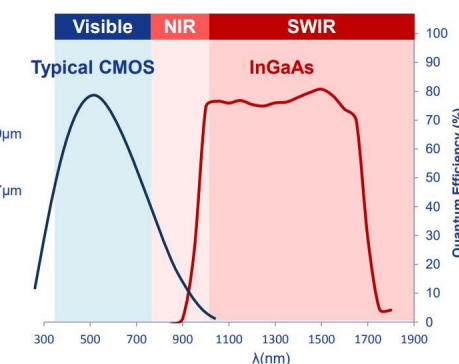
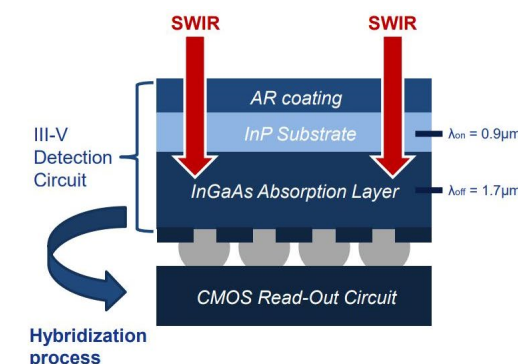
PhD Thesis with CNES

🪐 Ongoing defenses

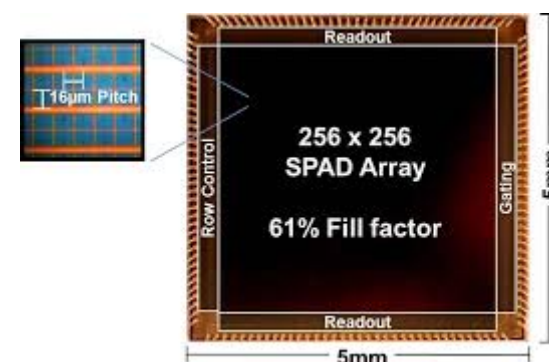
- 🪐 Aubin Antonsanti, ISAE Supaéro, NASA
- 🪐 Radiation effects on CMOS image sensors



- 🪐 Marco Benfante, ISAE Supaéro, III/V Lab, Thales
- 🪐 Radiation effects on InGaAs sensors



- 🪐 Ali Jouni, ISAE Supaéro, STMicroelectronics
- 🪐 Radiation effects on SPADs
- 🪐 Defense on September 4th

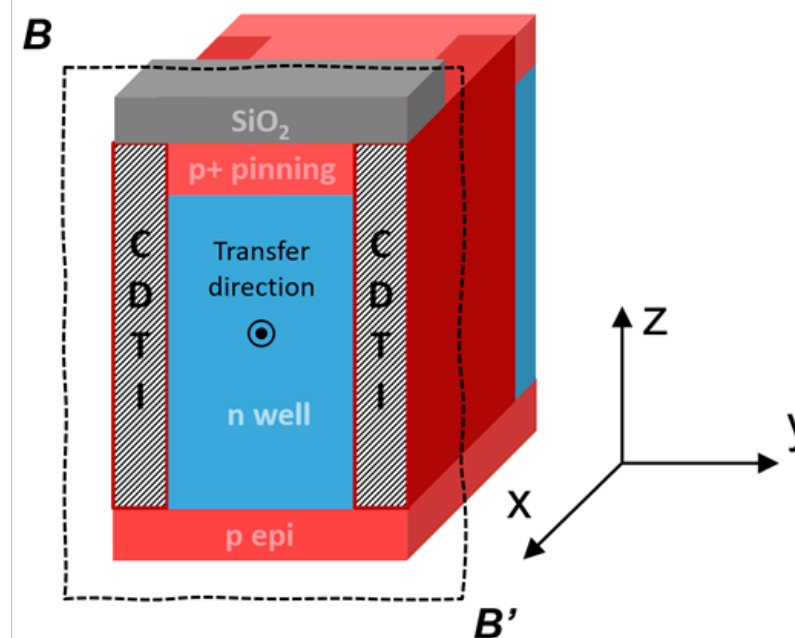
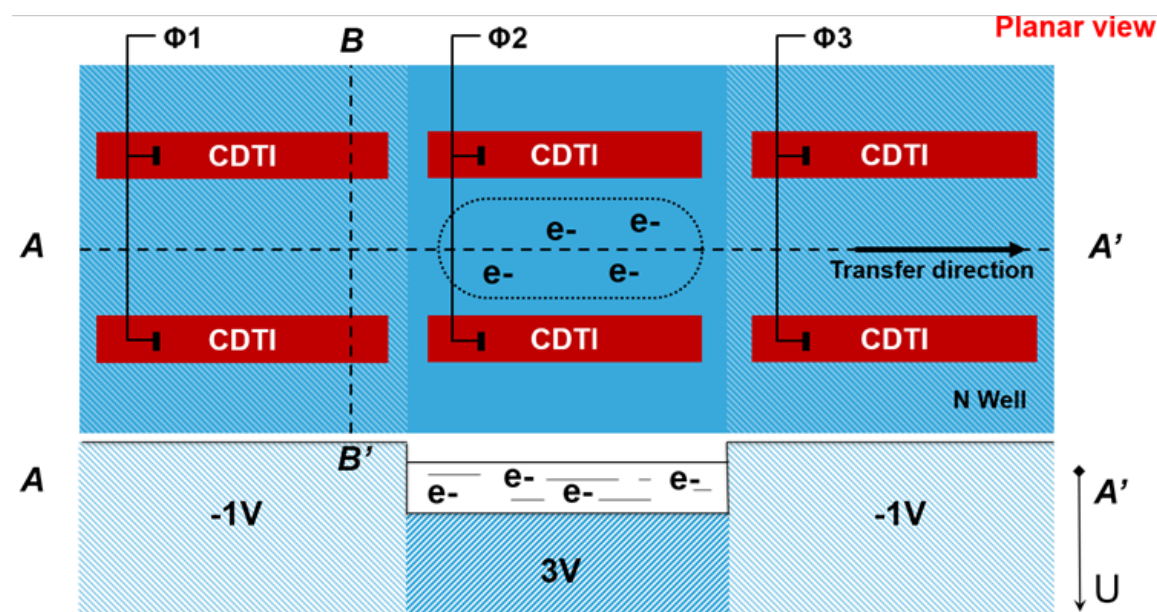


PhD Thesis with CNES

🌐 3rd year

🌐 Antoine Salih Alj, ISAE Supaero, STMicroelectronics, TAS

🌐 Radiation effects on CCD on CMOS based on CDTI



PhD Thesis with CNES

🪐 2nd year

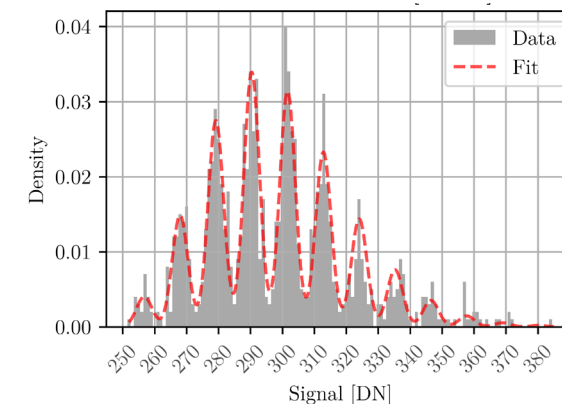
- 🪐 Thibaud Friess, ISAE Supaero, CEA LETI, ADS
 - 🪐 Radiation effects on LWIR detector

🪐 1st year

- 🪐 Pierre Arrondeau (ONERA): MTF characterization for IR detector
- 🪐 Sarah Holloway, ISAE / TAS / Pyxalis : Development of QIS
- 🪐 Joanna Krynski, ISAE CNES internal : Evaluation of QIS and SPAD/SiPM
- 🪐 Alexandre Neyret, ISAE / TAS / NIT : Evaluation of QCD
- 🪐 APC : Flicker noise impact and design methodology in SiGe integrated circuit

🪐 Will start in S2 2024

- 🪐 Pierre (ISAE/NASA): Irradiation of CIS and ROIC at cryogenic temperature



Outline

- 🪐 **CNES R&T schedule**
- 🪐 **R&T Activities**
- 🪐 **PHD thesis**
- 🪐 **COMET OOE Workshops**

COMET OOE Workshops

<https://www.comet-cnes.fr/>



2024

November 26th & 27th, 2024 → CMOS Image Sensors Workshop

September 5th, 2024 → Support to Photonic day organized by Minalogic
(French speaking event)

2025

To be planned → Infrared detection Worskhop

Thank you

These slides were prepared with all CNES optoelectronic detection department