

# Airbus Defence and Space au forum UTIAS<sup>2</sup> 2024

**UTIAS<sup>2</sup> 2024** 4 / 5 Avril  
**Optimisation des lois d'alimentation de réseaux d'antennes** Airbus Defence & Space / CNES  
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← Optimisation des lois d'alimentation des réseaux d'antennes

**Modèles de réseaux de neurones appliqués à l'optimisation de lois d'alimentation de réseaux d'antennes**

**Abstract**  
 L'obtention des lois d'alimentation d'un réseau d'antennes peut être coûteux en temps et en ressources de calculs. Il est proposé d'étudier des modèles à base de réseaux de neurones en substitution.

**Applications**

- ✓ Formation de faisceaux scènes dynamiques HTS LEO
- ✓ Formation de faisceaux larges couvertures DTH GEO

**Méthodologie**

Résumé sur de nombreuses années / années (travaux antérieurs)

Entrée: Interfèrent, Utilisateur, Modèle NN, Poids complexes, Directivité, Masques

Processus: Apprentissage supervisé, Solution analytique, Optimisation directe

**Résultats**

**CDF Directivité HTS**

**Directivité DTH**

Masque utilisateur, Directivité - dBi

**Contributions**

- ✓ Modèles de substitution supervisés
- ✓ Modèles d'optimisation directe
- ✓ Application aux scènes dynamiques et statiques

**Perspectives**

- Encodage de contraintes plus fines (niveau de réjection, contrôle du C/I).
- Approfondir les capacités de formation de formes complexes (cas DTH)
- Etudier la faisabilité d'implémentation sur Versal

Assistance par *machine learning* d'algorithmes d'aide à la décision (application à la planification de satellites) → + poster Jolibrain : étude jointe sur l'apprentissage par renforcement sur ce sujet.

**Machine Learning assistance to satellite mission critical decision making algorithms**

Historical experience in mission critical decision making algorithms for Earth Observation

**History:** Decision Making algorithms for Earth Observation satellite mission planning

- Frequent execution
- Time constrained
- Highly combinatorial
- Performance guaranteed

**Machine Learning for Decision Making**

3 main ways to use ML for Decision Making:

- Offline ML assistance (Learning, modeling, ML-based optimization)
- Mission critical operational software (Frequent execution, time constrained, performance guaranteed)
- Online ML assistance (ML models to help decisions)

**Online ML Assistance applications**

ML to tackle a subpart of the problem (assistance to the complete DM process).

**Examples:**

- Optical based Geostationary telecom satellite Ground station operation
- VHTS problem (Neuroevolution for EO mission planning (order & sees presentation) → Allows for uncertainty quantification in planning! → Uncertainty prediction using NN)

**Offline ML Assistance applications**

Design of a DM algorithm can require an intensive amount of simulations → ML used to approach those models and/or to choose the parameters of the automatic DM algorithms.

**Examples:**

- Optimization criteria of the DM algorithm on long term simulations. → Long term behavior is hardly assessable → ML assisted optimization can help!
- ECNDS: Surrogate models of error contributor estimation → Time consuming model → Limiting for system design analysis.

**Fully ML Decision Making (Reinforcement Learning)**

**Examples:**

- EO mission planning using RL (see VHTS paper)
- VHTS (Very High Throughput Satellite) operation using RL: Some problem as in Online ML, but an agent has to continually decide which OGS to use. Example of an instance in table.

**Perspectives**

Knowledge on the Machine Learning assistance to mission critical Decision Making algorithms built on top of operational research applications. However, it remains challenging to have operational use of ML for critical software for mission operation. Current work with Jolibrain to move towards more operational use of those techniques (in particular for fully ML decision making, less risk for offline).

**AIRBUS** Contact us! jonathan.guerra@airbus.com



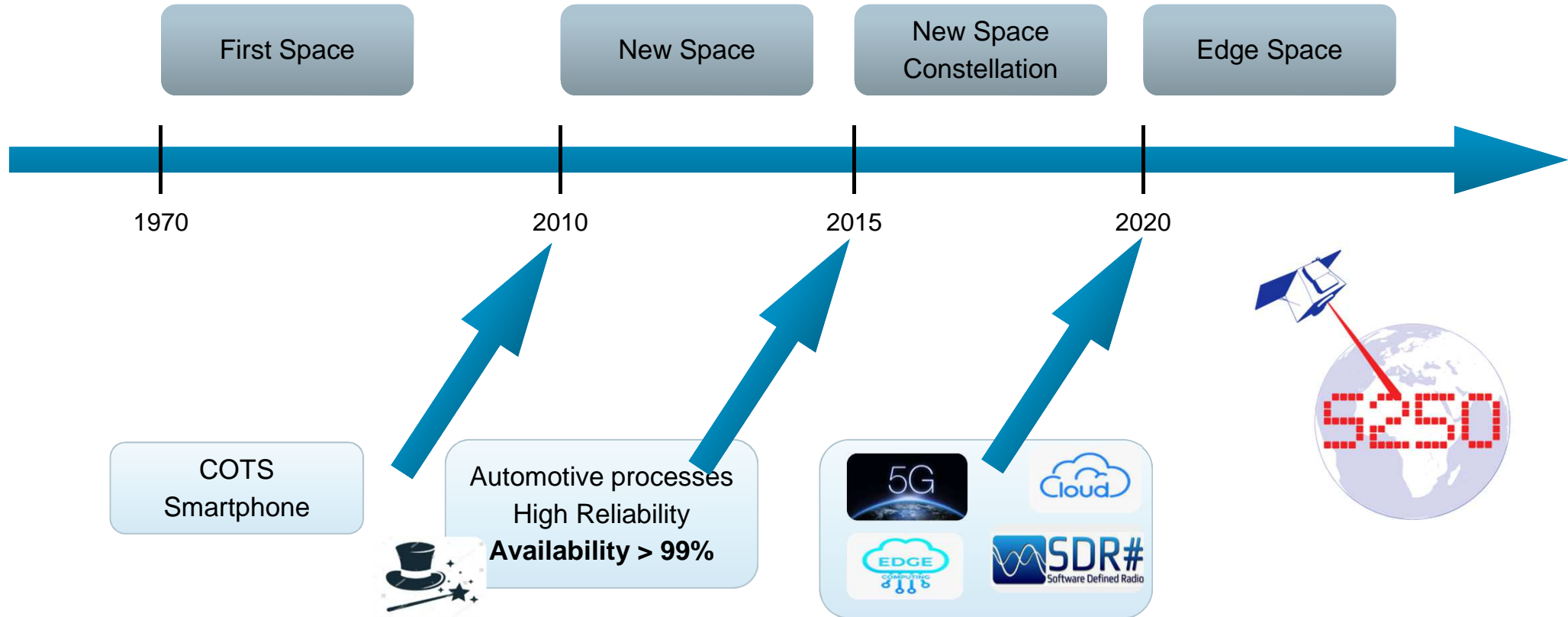



# COMET – AI uses cases on EO satellites

Olivier CAMBON, Clement COGGIOLA, Fanny MOREL

# History

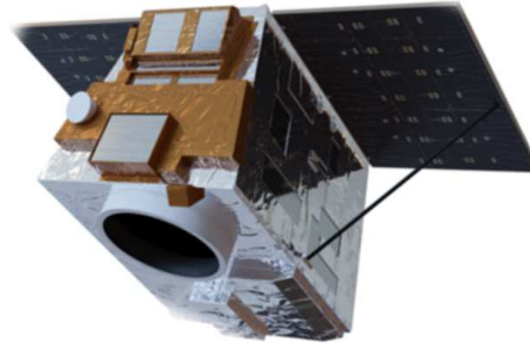
Edge computing is a distributed computing paradigm that brings **computation and data storage closer to the sources of data**



# S250 product



Product

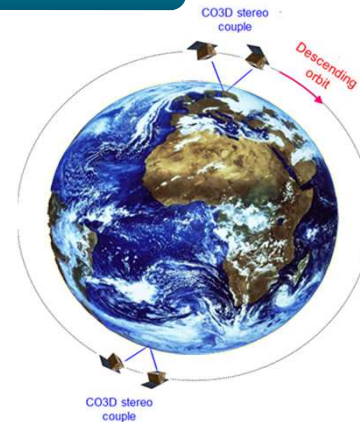


Optical option



Radar option

- Alt: SSO 500km
- GSD: 50cm -> 40cm
- 7000 RGB img / day / Sat
- 7000 NIR img / day / Sat
- 250 000 km<sup>2</sup> / day / Sat
- Life time: 8 years



Project

# S250 concept

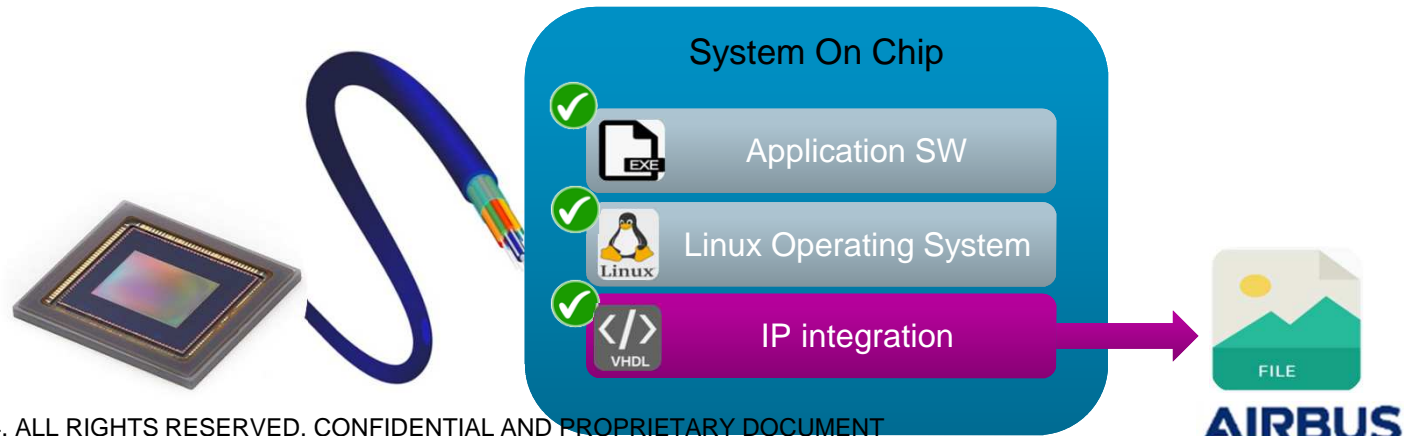
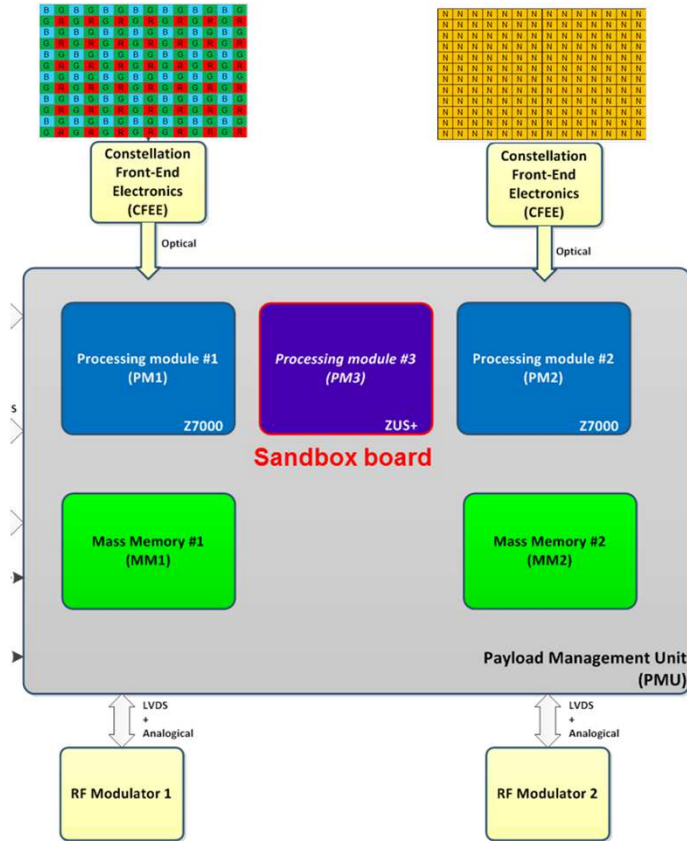
- Home made solutions HW and SW
- Custom data format
- Payload TC and TM
- Space only standard
  - Packet store
  - SpaceWire
- OBMP / OBCP
- Monolithic SW
- Some parts reprogrammable
- On-board computer
- Real-time OS
- Embedded SW developer



THE KISS PRINCIPLE  
**KEEP  
 IT  
 SIMPLE,  
 STUPID**

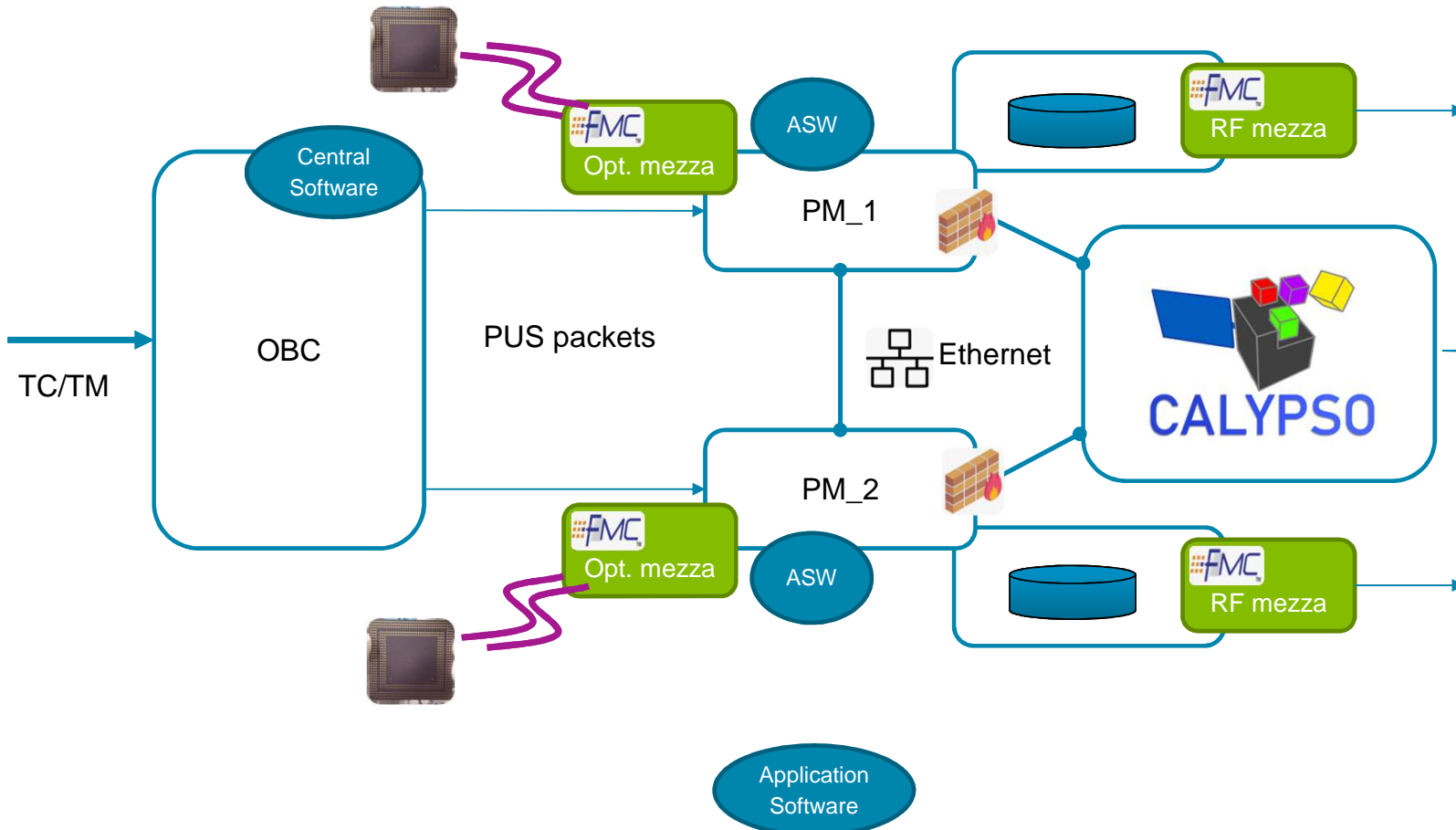
- Industry proven solutions
- Standard format
  - Command line, logs, timeseries DB
- Mainstream standards and tools
  - **Files (File based operations)**
  - Ethernet
  - Shell script
- Multi-applications, software center / smartphone
- All reprogrammable**
- Standard PC**
- Standard OS
- Industry SW developer










# Payload focus





# Airbus S250 Data Handling architecture (File based)



- Mainstream standards and tools
  - **Files (File based operations)**
  - Ethernet 
  - Shell script
- Standard format
  - Command line 
  - Logs 
  - Timeseries DB 
- Multi-applications
- Software center / smartphone 
- Containers  
- Off the shelf libs  
- All reprogrammable (including FPGA partial reprog.)

# CALYPSO : Sandbox Objectives

**Test applications** and new functions on-board of the satellite...and become operational

**Shorten time to market** from app development

**Light application validation**

Dev. env. as PC: Linux, Python, Libs...  
**Easy portability**

Downlink of only **useful information** (higher value information with lower data rate and short reaction times)

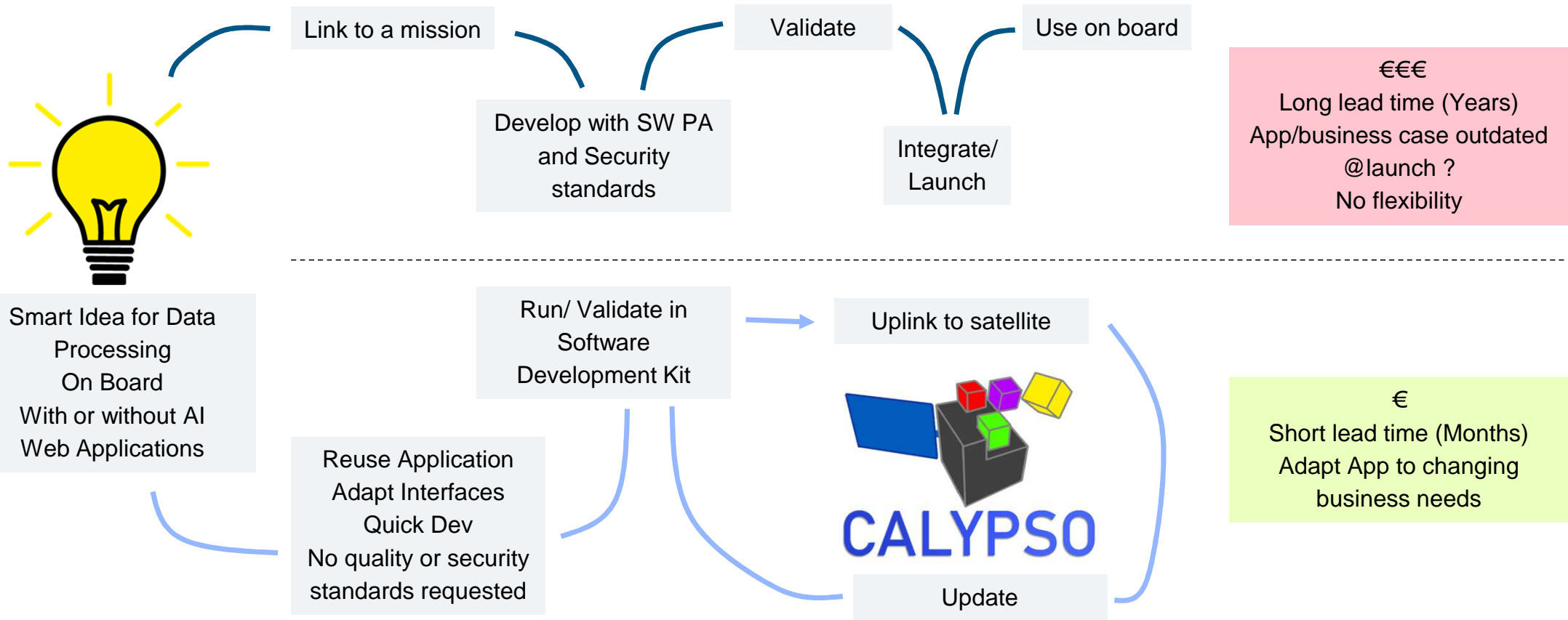
Bring non space labs to space



# CALYPSO – Sandbox

## Software Defined Satellite

**CALYPSO**  
- Custom AppLYcation  
Processing Service in Orbit





# Software Development Kit for Flight-Application

**Develop on Evaluation Bord**



**Package**



**Upload**



**SW + HW accelerator**

like

**ANDROID  
STUDIO**



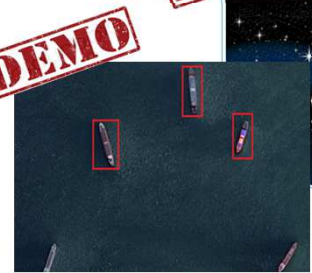
**Designed for our Smart Payloads**

**Bringing the smartphone revolution  
to our satellites**

# Use Cases



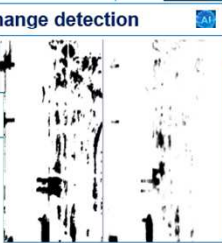
DEMO



Instrument as StarTracker



Cloud detection



Change detection



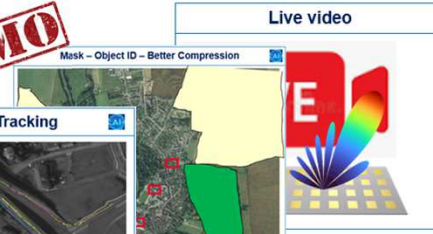
Autonomous Collision Avoidance



Forest Fire Detection



Mobile Tracking



Mask - Object ID - Better Compression



Live video



# V2

# V1

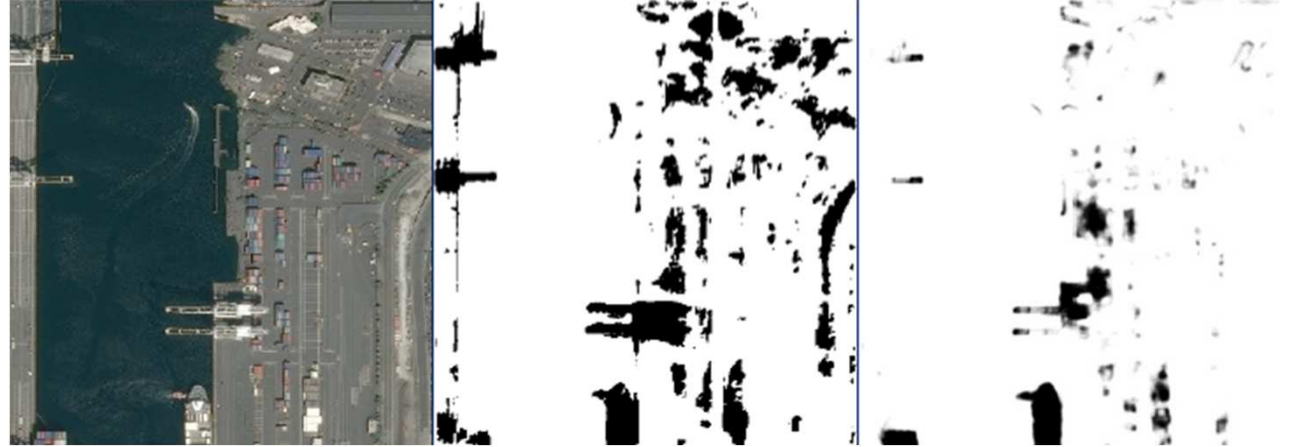
- ✓ Linux Operating System
- ✓ VHDL Framework
- ✓ Sandbox (CALYPSO)
- ✓ AI hardware

- ✓ EXE Multi process SW
- TIFF File Based Payload
- Std Ethernet Network
- ✓ FMC Mezza std form factor
- High processing power

- OpenCV TensorFlow Std libraries
- SW Center
- Software Defined Radio
- IOT Low bitrate coms

# Activity Monitoring

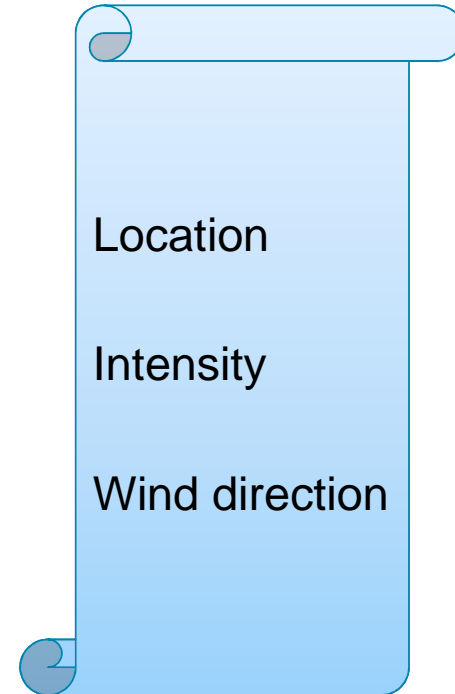
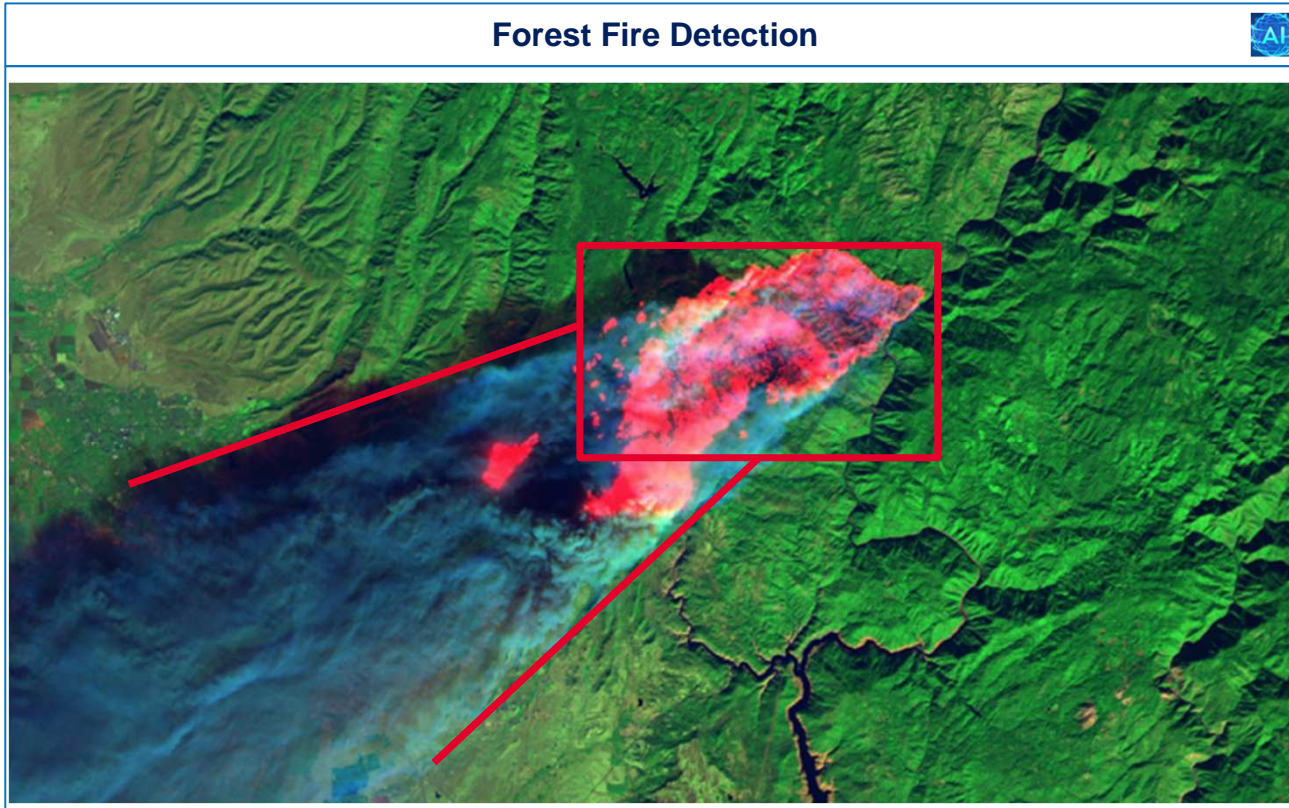
- Ship detection (CNES)
- Traffic measurement



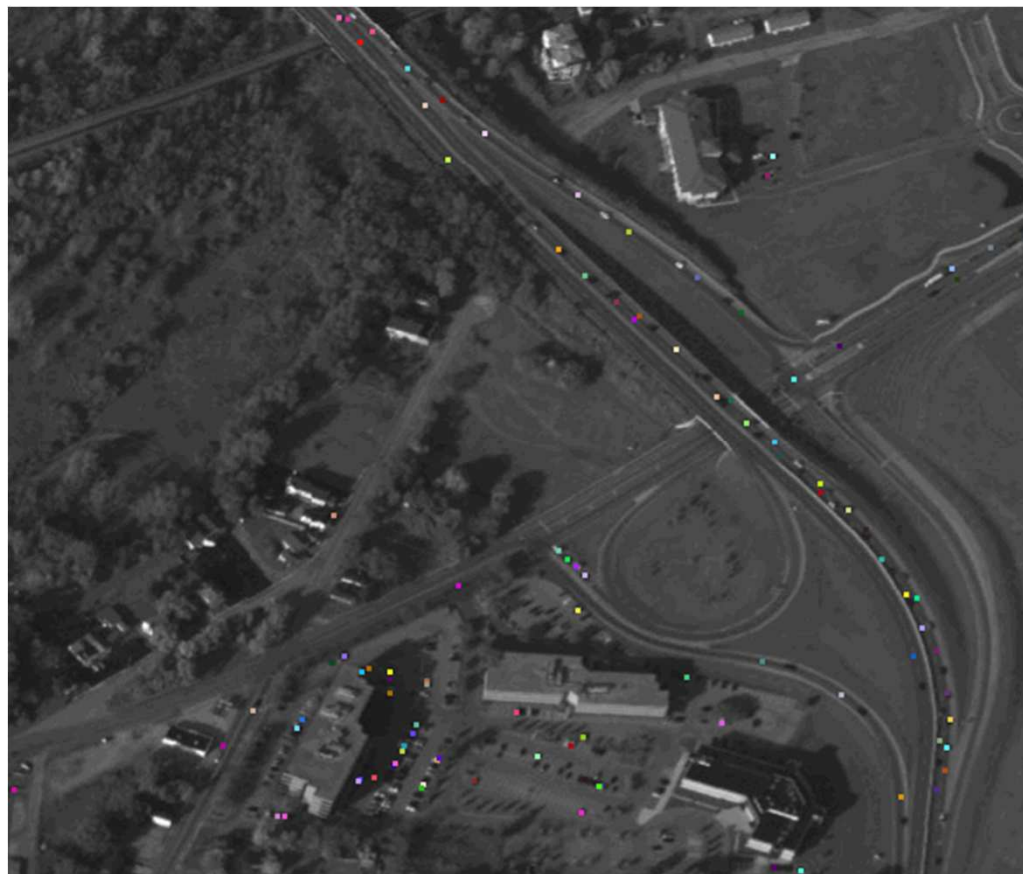
- Change detection with alert
- Object counting



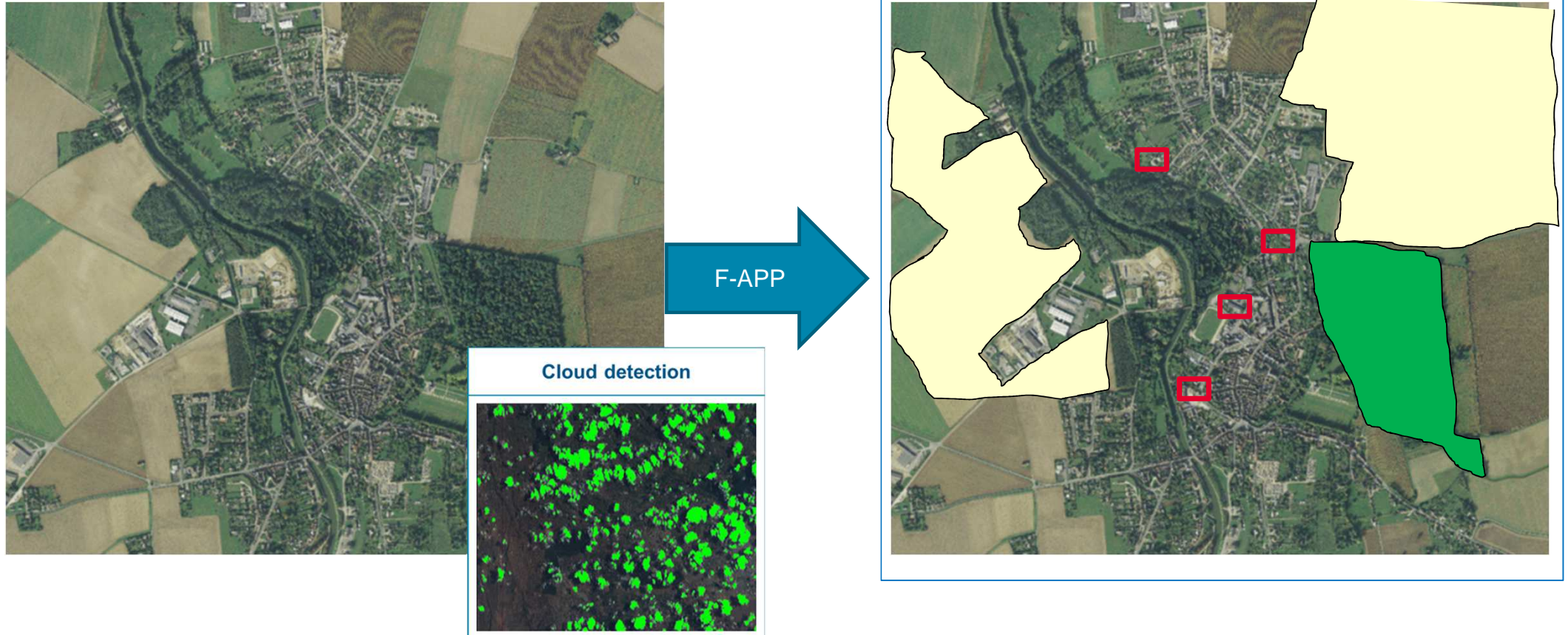
# Forest fires



# Vehicle Tracking



# Details extraction, higher compression



Applications on CO3D Satellite (1/2)  
Application by CNES : Ship detection  
Clément Coggiola



# CNES demo application on CO3D

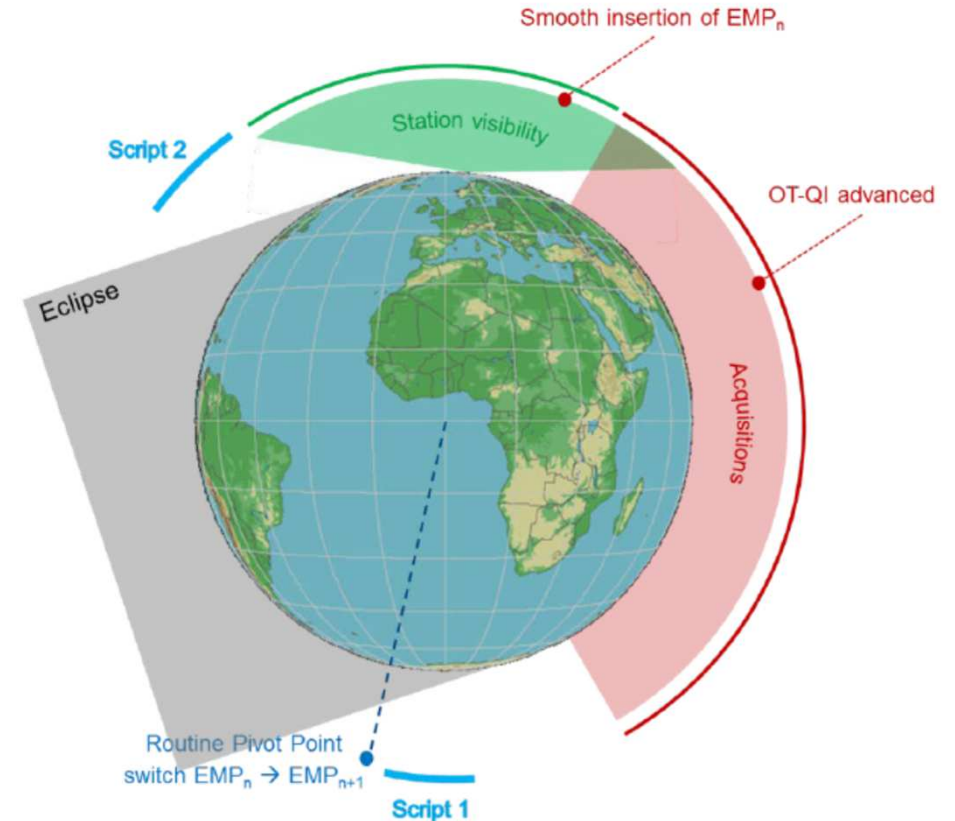


## Objectives

- CNNs training, distillation and on-board implementation
- Semantic segmentation: targets of interest in **very-high resolution images**
- PoC: a client provides an algorithm

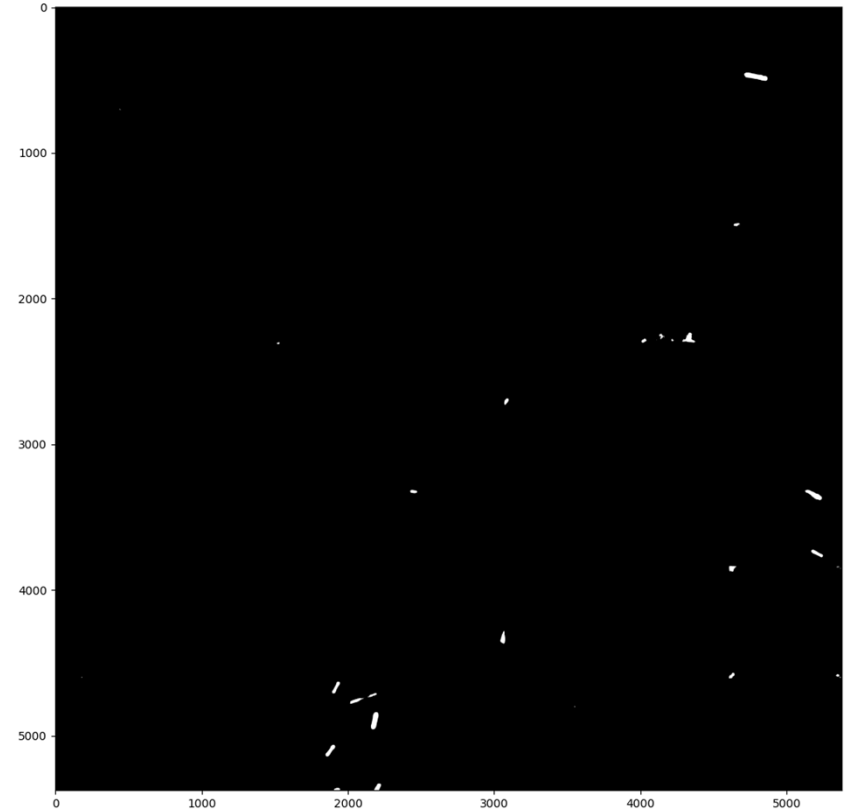
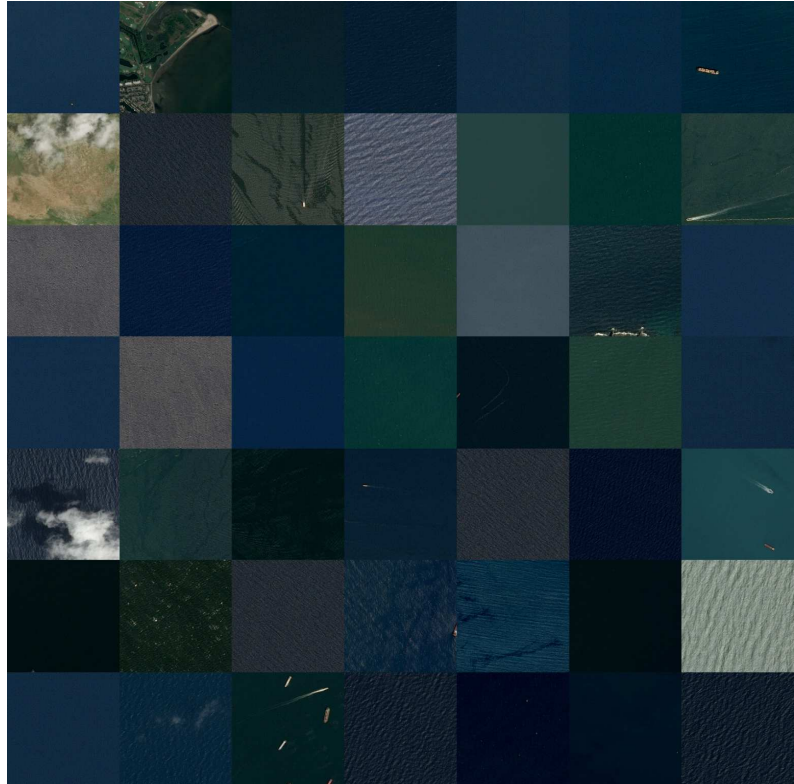
## Why?

- New space system capabilities
- Optimized downlink: data reduction as compression
- Reactivity (which needs constellations)



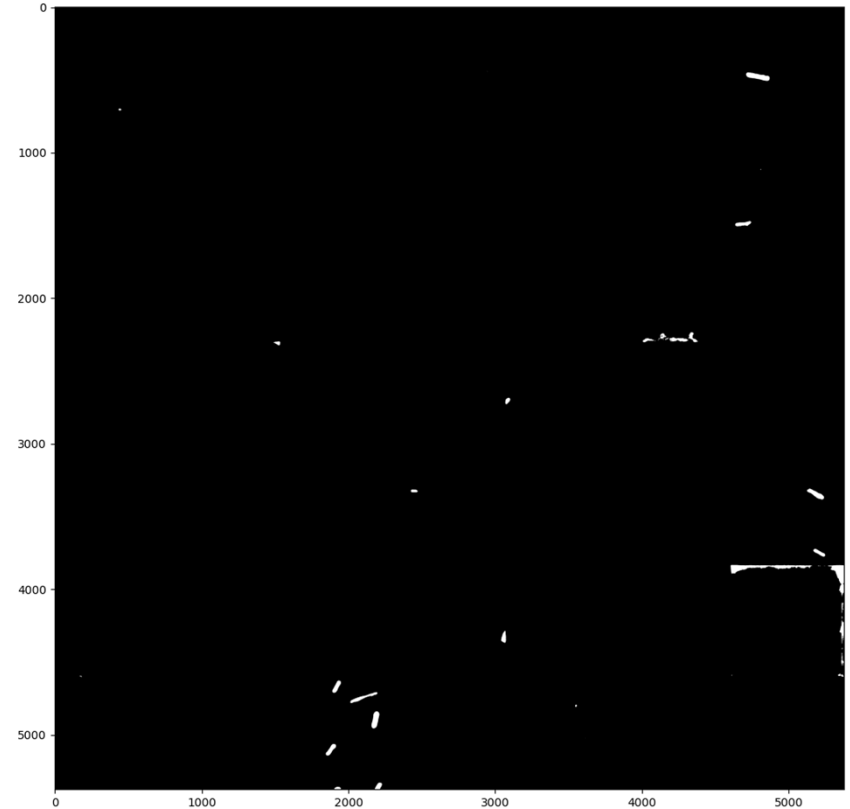
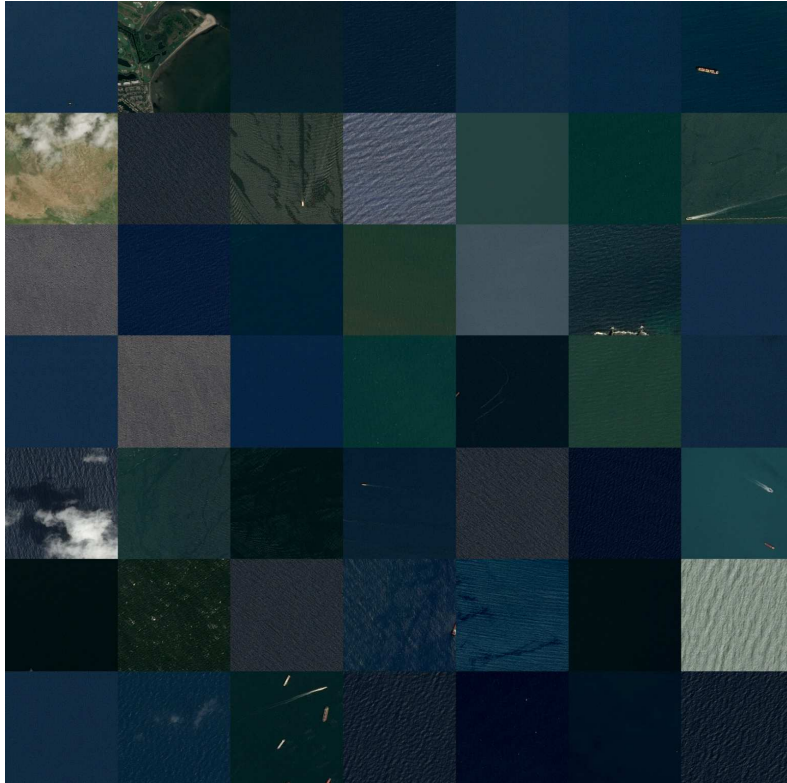
# CNES demo app: results (*work in progress*)

Ship detection (200k parameters, run on hardware)



# CNES demo app: results (*work in progress*)

Ship detection (100k parameters, run on hardware)



Demonstration on CO3D Satellite (2/2)  
Application by ADS : MobIA 1 et 2  
Fanny Morel

# Application de demonstration Airbus Defence and Space sur CO3D - MobIA1&2

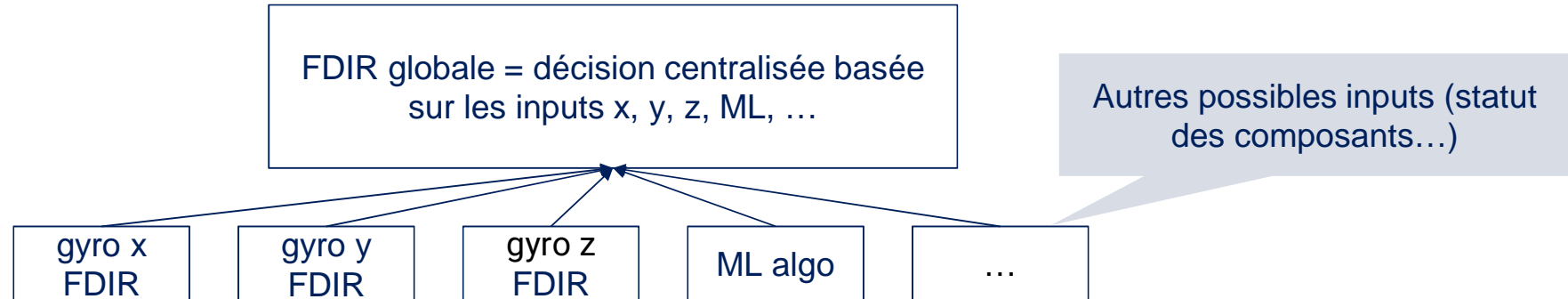
En collaboration avec le CNES depuis 2020

## Objectifs :

- MobIA 1 : Prouver l'intérêt de l'utilisation d'IA embarquée pour la détection automatique de pannes, en complément de la FDIR
- MobIA 2 : Une fois cet intérêt confirmé, prouver la possible industrialisation de cette IA embarquée, via la Sandbox Calyspo.

## Intérêts identifiés :

- Optimisation de la FDIR (Failure Detection, Isolation and Recovery) via IA à bord, pour des pannes ciblées
- Meilleure réactivité de l'IA embarquée (vis à vis d'une solution IA au sol)



# Application de demonstration Airbus Defence and Space sur CO3D - MobIA1&2

En collaboration avec le CNES depuis 2020

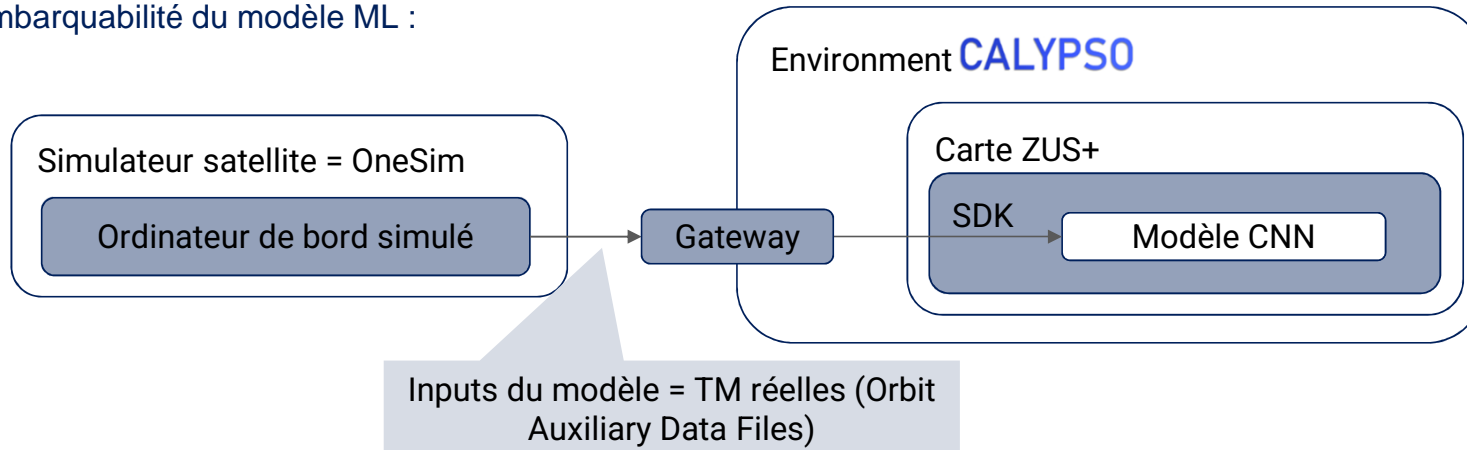
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- Optimisation de la FDIR (Failure Detection, Isolation and Recovery) via IA à bord, pour des pannes ciblées
- Meilleure réactivité de l'IA embarquée (vis à vis d'une solution IA au sol)

Opportunité d'utilisation de la **Sandbox Calypso** pour démontrer l'embarquabilité du modèle ML :



# Application de demonstration Airbus Defence and Space sur CO3D - MobIA1&2

En collaboration avec le CNES depuis 2020

Pour en savoir plus => venez nous rencontrer devant notre poster !

UTIAS<sup>®</sup>**On-board IA-based Monitoring**AIRBUS

MobIA 1&2 - ADAP

In collaboration with and since 2020

**Three interdependent projects**

Thanks to MobIA 1 and ADAP via input ML techniques - in particular CNN models - are efficient and useful to complement FDIR systems (Failure Detection Isolation & Recovery) for automated on-board fault detection. From this statement, MobIA 2 has a simple objective:

How do I get my ML model to come out of its Notebook? I want to take it on board and industrialize it!

**MobIA 1 logic and results** Project name: 2020 - 2023

Frozen gyroscope failures are quite difficult to detect via standard FDIR - Reliance of AI usage in order to increase the FDIR detection performances.

Three ML models tested:

1. CNN (Augmented)
2. LSTM (Self-supervised)
3. LSTM (Augmented)

Criteria / Method	CNN	ASSTC	LBP
FDIR Performance	++	++	++
Application ease	++	++	++
Complexity of implementation	++	++	++
Learning time	++	++	++
Resource time	++	++	++
Ease of adjustment	++	++	++

Convolutional Neural Networks (CNN) are the most promising Machine Learning models for on-board implementation:

- Good performance: coupled with FDIR, significant increase of frozen gyroscope fault detection rate
- Good generality: can adapt to other failure types
- Low complexity & execution time useful for on-board implementation

Conclusion:  
ML algorithms are relevant to complement FDIR for on-board fault detection

Core FDIR = receive on-board data (input:  $s, \dot{s}, \ddot{s}$ ) -> FDIR systems (output:  $u, v, w$ )

**ADAP (Anomaly Detection - Anomaly Prognosis)** Project name: 2021 - 2023

JCS had project in collaboration with ESA since 2021. R&D objectives: develop an AI-based FDIR system in order to increase satellite failure detection capabilities.

Technical objectives and logic:

1. Design and develop neural network models for unexplained anomaly detection, using JCS on the Airbus public cloud (JCS-PCP)
2. Find the optimal combination of hyperparameters for the designed model architectures
3. Perform extensive testing of the best-performing models on various data scenarios
4. Port the best-performing models onto space representative hardware (Orin ZCU104)

Three failures relevant for FDIR are selected..

- JCS subsystem failures
- Thermal subsystem failures
- Power subsystem failures

- and few ML (Machine Learning) models are developed to automatically detect anomalies on these use-cases:

- CNN (Convolutional Neural Network) for JCS and power failures
- LSTM (Long Short Term Memory)-based network for thermal failures.

Conclusion:  
ML performance (judged excellent) in all use cases. In particular, the JCS-PCP system detects the JCS equipment anomaly several time steps before classical FDIR.

**MobIA 2 strategy** Project start: 2023 - Currently ongoing

Anticipate flight implementation tests via...

- a targeted platform: CO3D satellites
- the CO3D on-board testing platform: Calypso

→ Embedded hardware  
→ QEC (On-board Computer) communication  
→ Isolation from the rest of the satellite

Ground testing phase should be determined by the Calypso platform target

BDC = Software Development Kit  
DUB = Flight Hardware

# Welcome to Edge Space !

## Questions and Answers

