PRELIMINARY ON-BOARD IMAGE PROCESSING SOLUTION FOR THE H2020 EO-ALERT PROJECT

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European Workshop on On-Board Data Processing

26 February 2019, ESTEC, Noordwijk, The Netherlands

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 776311

Acknowldgements

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Call: COMPET-3 2017 Call on "High speed data chain"

Title: Next Generation Satellite Processing Chain for Rapid Civil Alerts

Funding: ~5M€

Overview

Started in January 2018

Duration three years (2019 – 2021)

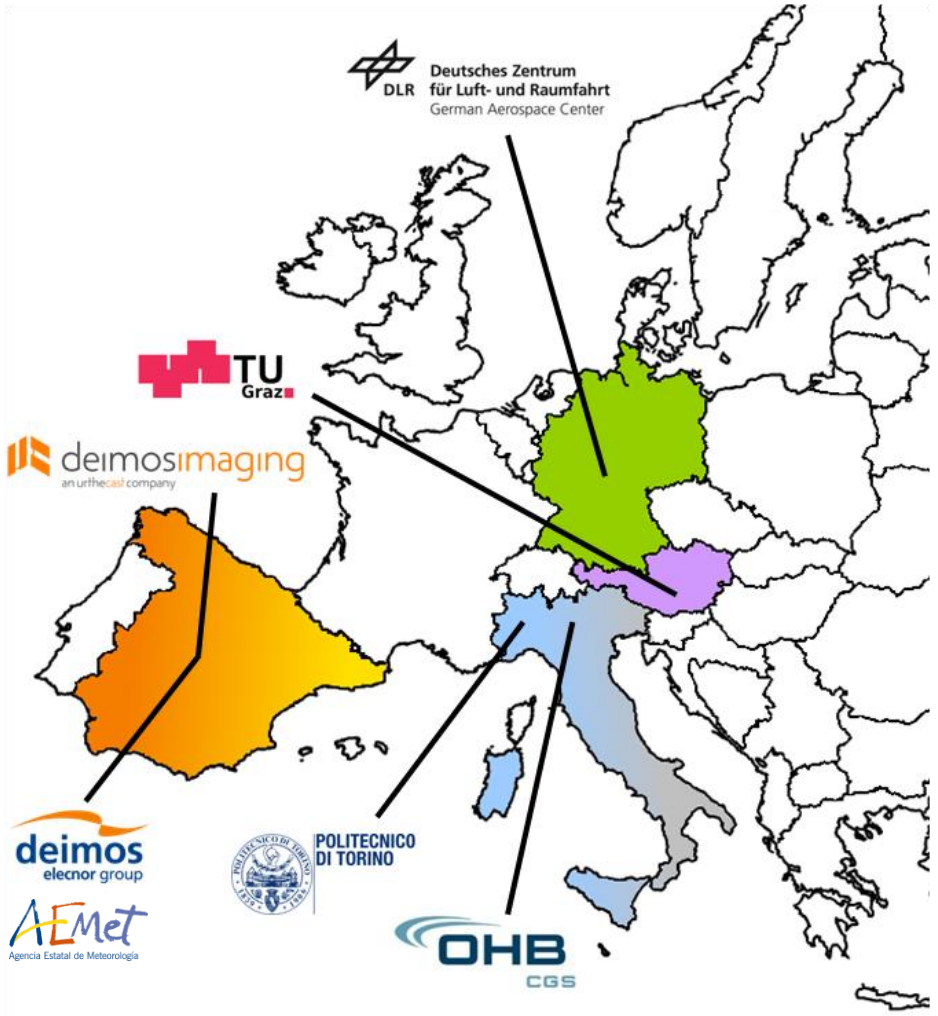
6 partners:

- Deimos Space (Spain) – coordinator
- DLR (Germany)
- Technische Universitaet Graz (Austria)
- Politecnico di Torino (Italy)
- OHB Italia (Italy)
- Deimos Imaging (Spain)

One consultant:

- AEMET

Cover full FS to GS chain



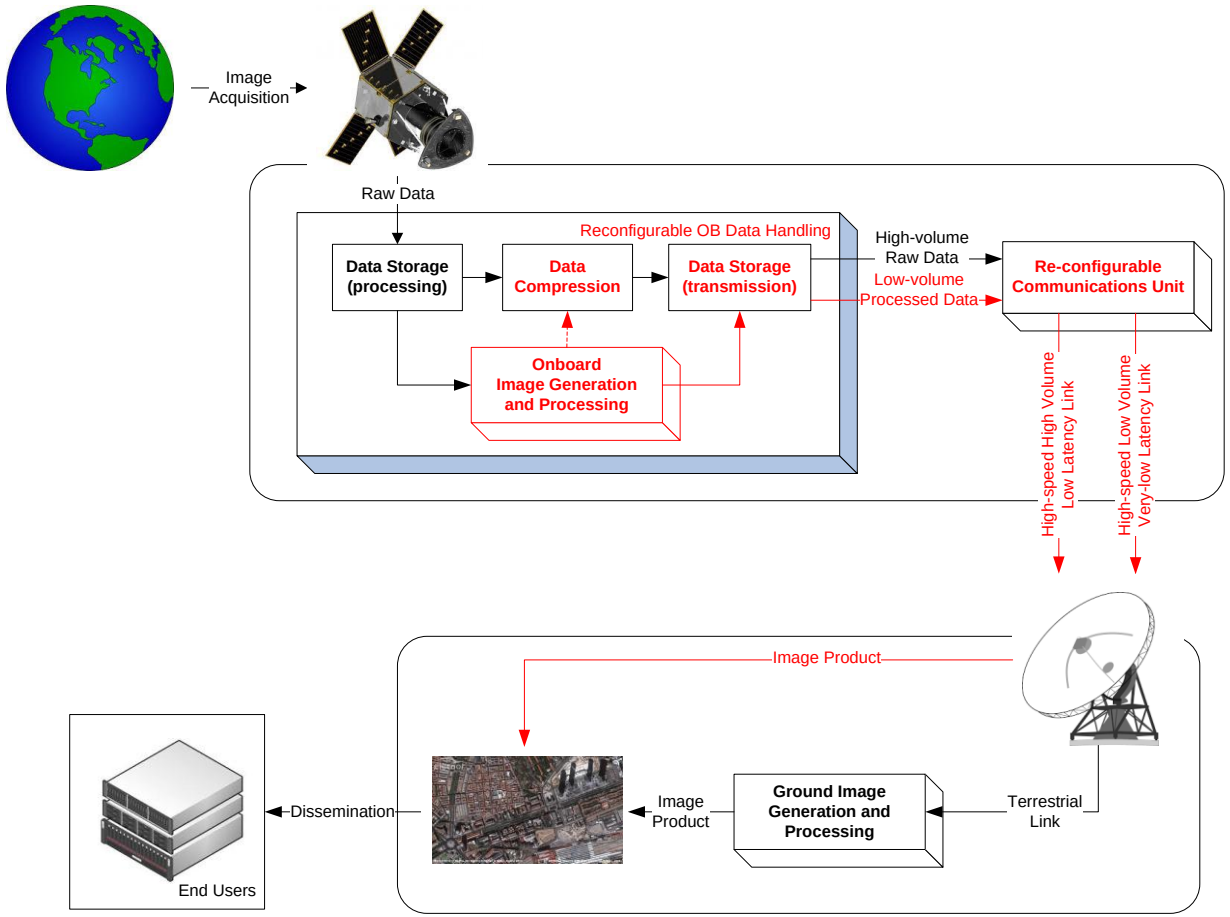
Project Goal and Idea

Goal: develop a new approach for the provision of very low latency EO data products, exploiting the flight segment processing capabilities

- ✓ Goal latency: **< 1 minute**
- ✓ Requirement latency: **< 5 minutes**

Idea: focus on the image product and what is needed with very low latency

- Move key EO data processing elements from the ground segment to the satellite
- Improve general target and situational awareness
- Applicable generally to scenarios that require near real time information: surveillance, monitoring, etc
- Prove this to TRL 6 via avionics HW testing
- Focused on the **overall capability** (not technology)
- Consider the **full and real problem**
- Prove this for Optical and SAR



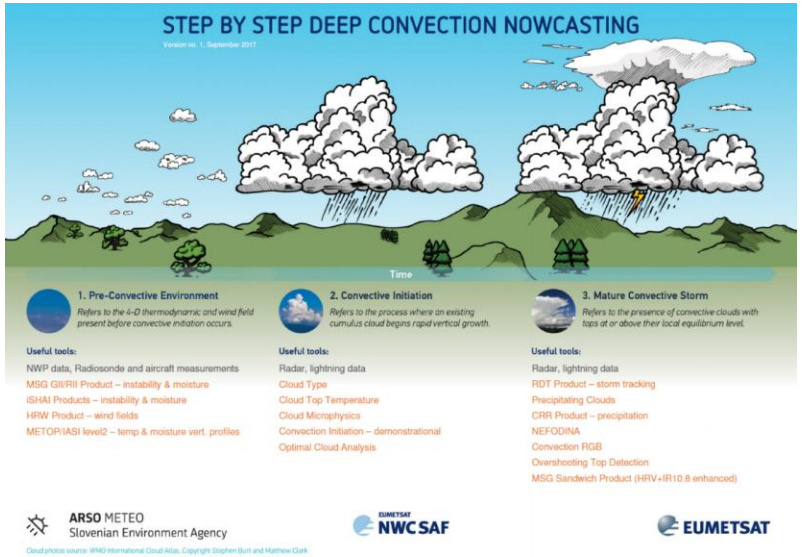
EO scenarios

Two EO scenarios are used to drive the developments and prove development in **operationally relevant scenarios**

- Maritime surveillance (ship detection)
- Extreme weather (convective storms, maritime wind and waves)

Requirements derived from End users

- Maritime surveillance (ship detection)
  - DMI as provider of service
  - Requirements from EMSA VDS
- Extreme weather (storms, wind, waves)
  - AEMET has provider of service and end user
  - Covers both convective storms service and maritime weather service



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Ship detection scenario

Alert Information Description – Operational Scenario

- EMSA VDS
- The expected output will be a text file, plus possible image thumbnail, easy to integrate in the end users systems and containing at least the following information

Product Name	Operational Details
Ship Detection	-Position information: Latitude, longitude coordinates -Time Stamp: Date/Time of acquisition -Heading: Route direction -Length and width: in meters -Speed: Over Ground expressed in meters per second -Ship classification: ID data -Confidence level: three different confidence levels for Ship classification, detection and identification from 0 to 100%

EO testing

Experiment will be used to test both EO scenarios

- Experiment planned for early-mid 2020
- Maritime surveillance: ship positioning in Mediterranean
  - Uses DEIMOS-2 and TSX satellites performing close observations
  - Uses a ship and in-situ measurements for the ground truth
- Extreme weather: extreme summer storm in Mediterranean
  - Uses MSG-1 and TSX satellites
  - Uses a ship and in-situ measurements for the ground truth

EO-ALERT Functional Architecture

Preliminary functional architecture

- **Data handling is key**
- Allows raw data and EO-product (alert) transfer to ground
- Prioritises product over raw data via reconfiguration
  - Compression and encryption applied depending on the data
  - TX chain data dependent
- Allows functional reconfiguration
  - swap SAR and Optical
  - swap IP approach
- Leads to multiple functional chains that can be (re-)configured as needed

Physical Architecture (FS) Avionics

Preliminary physical architecture

- FPGA based
  - Xilinx Zynq UltraScale+
- Two system boards
- Two compression, encryption, storage boards
- Five SAR and optical processing boards
- Additional communication HW and the GS

Ship Detection
Onboard Image Generation and Processing

Image Generation – L1B

- Radiometric Calibration
- Denoising
- Deconvolution
- Geolocation

Image Processing

- Ship candidates extraction
  - Remove land and identify possible ships
- Ship Detection
  - Extract visual features from the candidates
  - Ship/no-ship inference

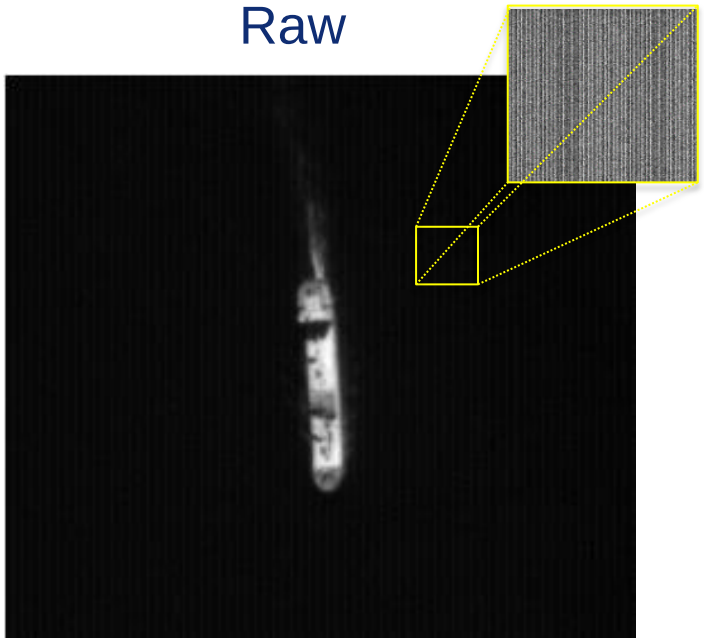
Processes tailored for parallel and distributed execution on FPGA

Ship Detection
Onboard L1B Image Generation

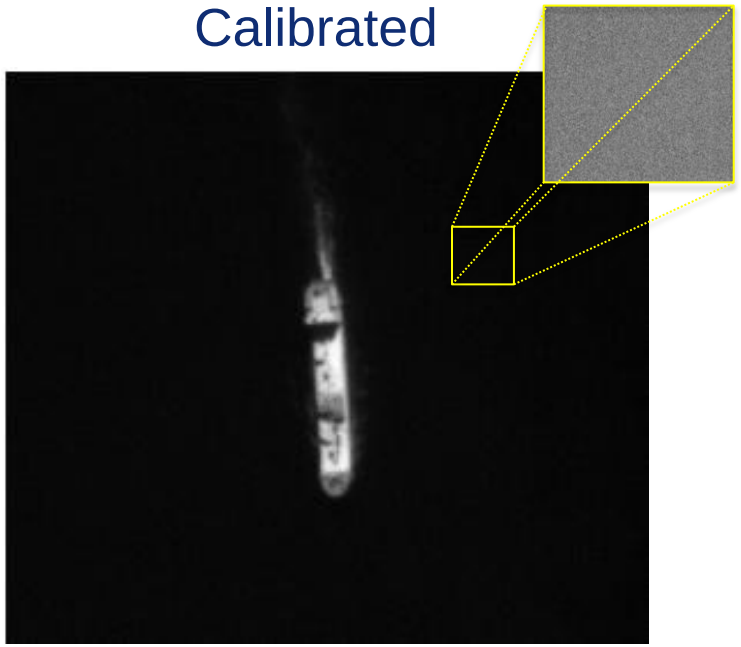
Image Generation – **Radiometric Calibration**

- Convert digital counts to radiances
- Remove inconsistencies from the image
- Peak error less than 5% wrt GS in testing

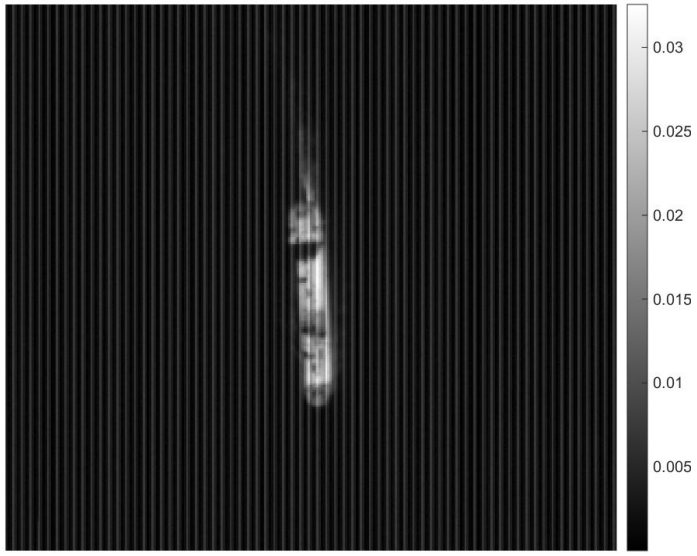
Raw



Calibrated



GS - Absolute Error



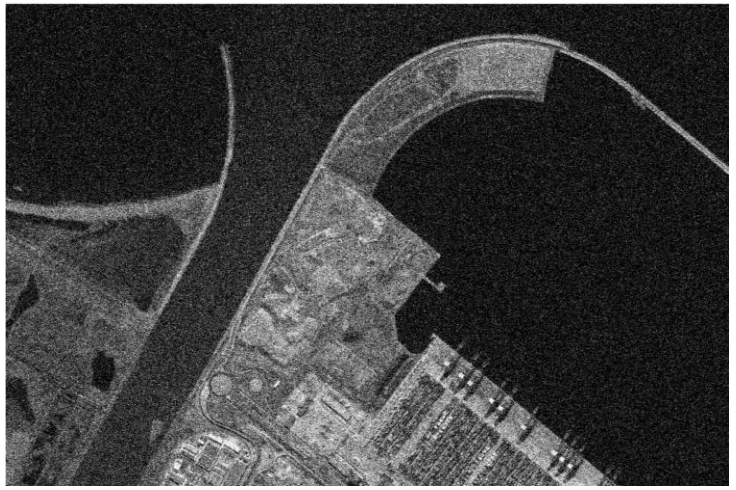
Ship Detection
Onboard L1B Image Generation

Image Generation – **Denoising**

- Based on efficient convolutional schemas suited for FPGA
- Edge preserving algorithm
- Exact linear-time complexity, independent from denoising parameters

Calibrated Input

Added Noise

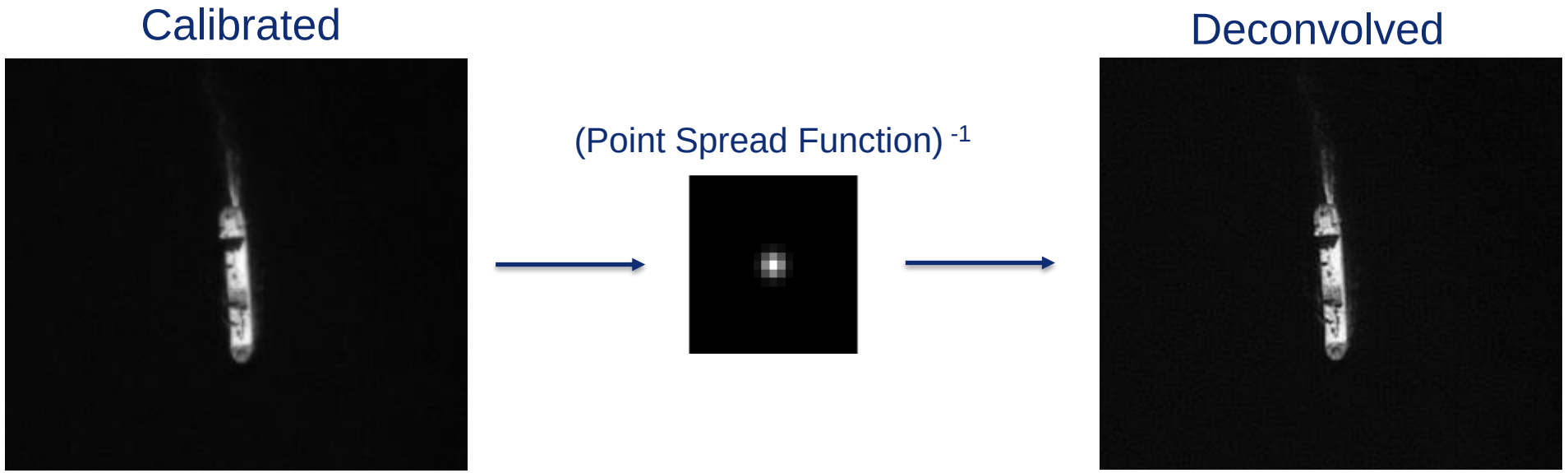


Recovered

Ship Detection
Onboard L1B Image Generation

Image Generation – **Deconvolution**

- Mitigate the "blurriness" introduced by the optical system
  - Inverse the process
- Regularised FFT based processing
  - Suitable for FPGA implementation



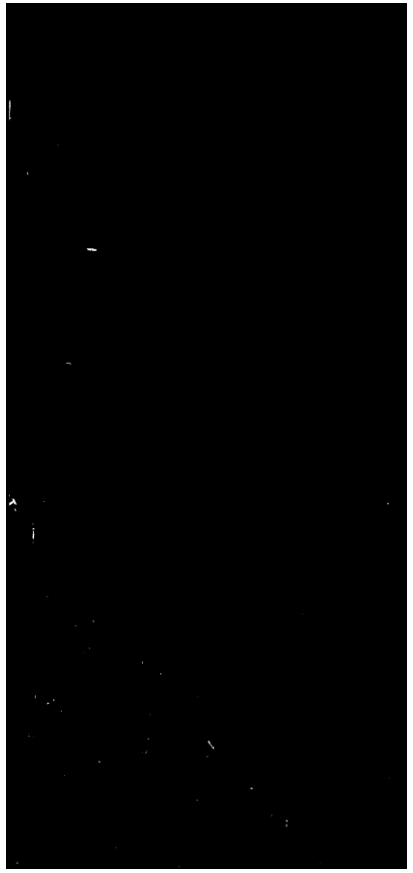
Ship Detection
Onboard Image Processing

Image Processing – **Coarse Detection**

- Based on saliency models and adaptive thresholding techniques
  - Very efficient computation
- Majority of the image does not contain relevant information
  - No need for feature extraction on the whole image
  - Does not provide constant time results

PAN Image

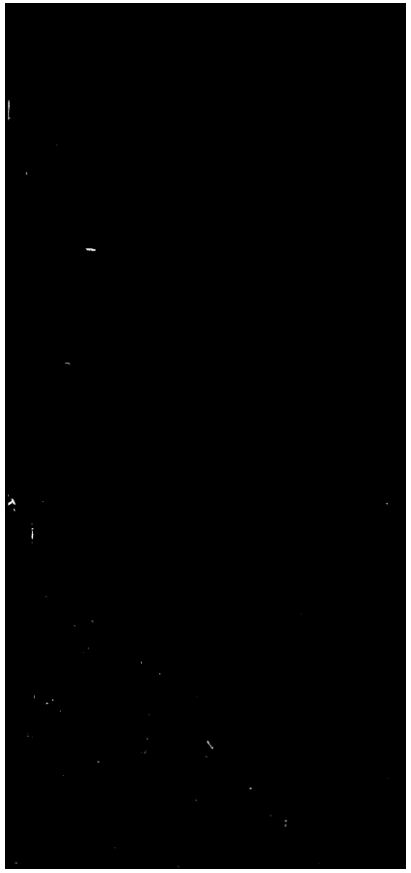
Candidate regions



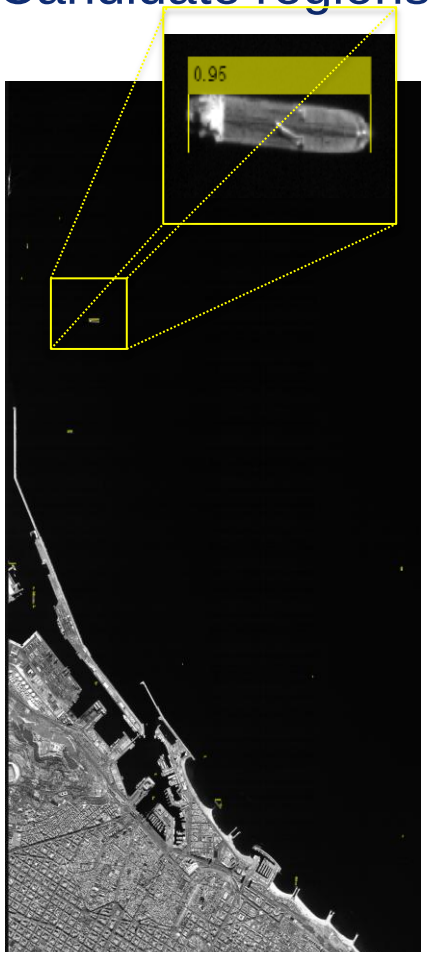
Ship Detection
Onboard Image Processing

Image Processing – **Ship Detection**

- Resize each candidate to a fixed size
- Ship inference based on **visual descriptors** and **machine-learning** classifiers



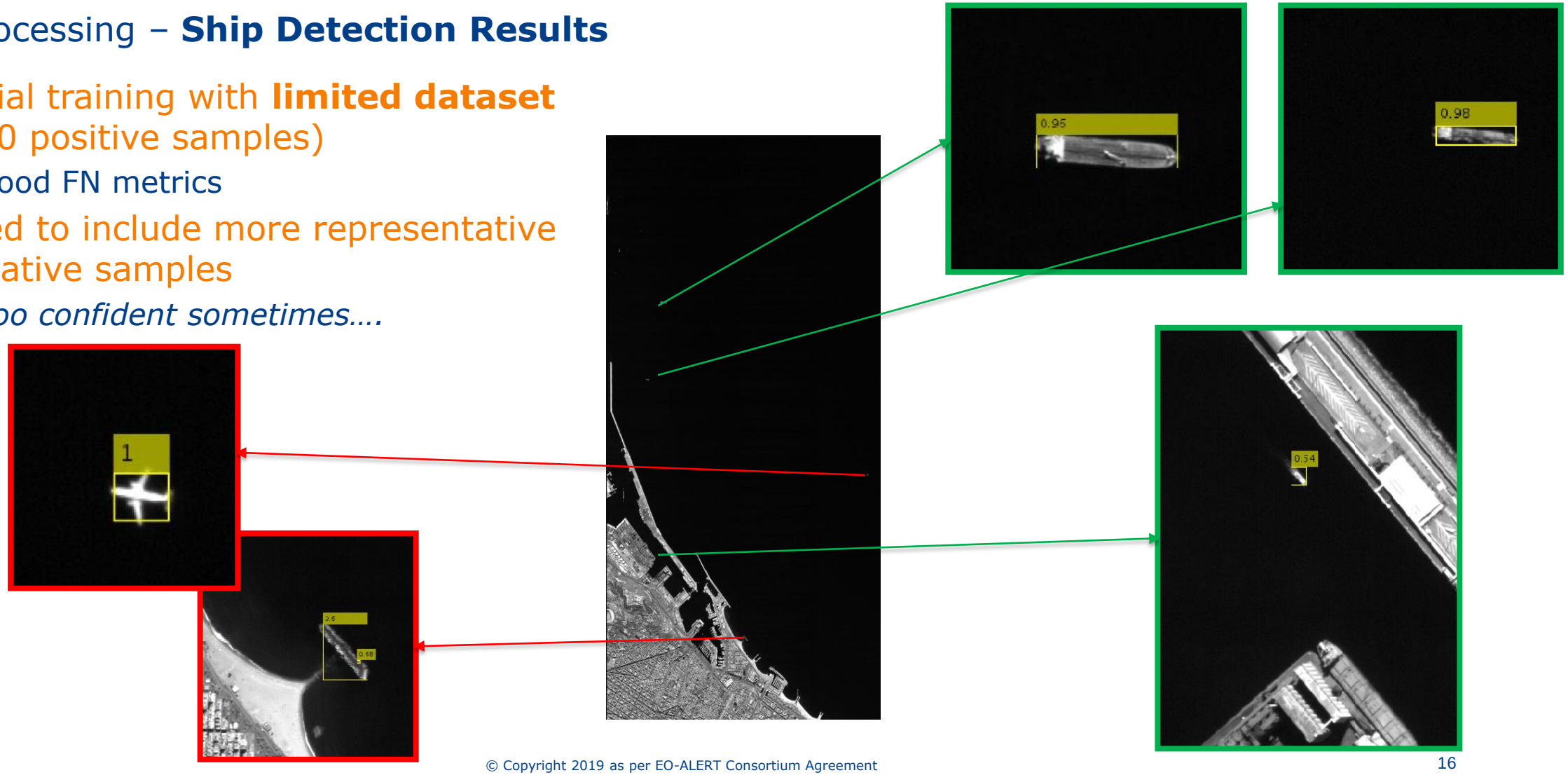
Candidate regions



Ship Detection
Onboard Image Processing: Ship Detection Results

Image Processing – **Ship Detection Results**

- Initial training with **limited dataset** (500 positive samples)
  - Good FN metrics
- Need to include more representative negative samples
  - *Too confident sometimes….*



Extreme Weather Onboard Image Processing

Current On-board approach

- Three steps:
  - Identification of candidate cells
  - **Computer-Vision** based cell **tracking**
  - **Machine-Learning** convective/non-convective **discrimination**

- Seviri images as input

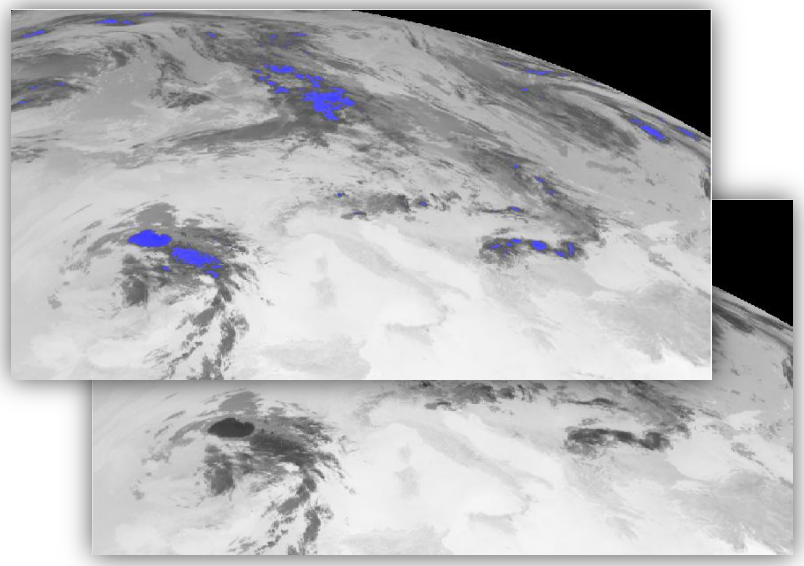
- OPERA weather radar composites as **ground-truth**
  - Training & Validation

Extreme Weather Onboard Image Processing

PRELIMINARY ALGORITHM

1. Identify candidate cells

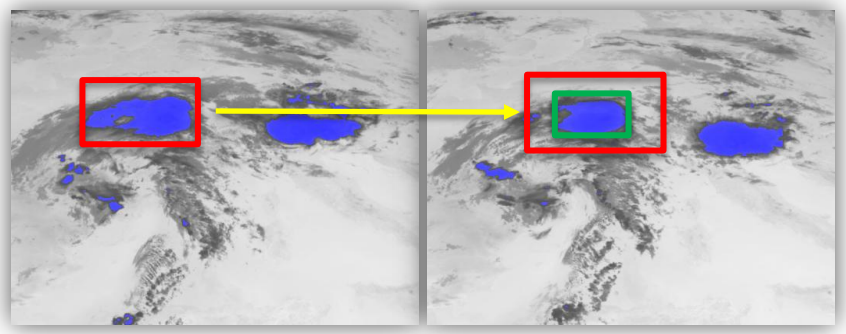
Based on cold top-cloud temperatures retrieved from the infrared 10.8μm



PRELIMINARY ALGORITHM

2. Track & Measure

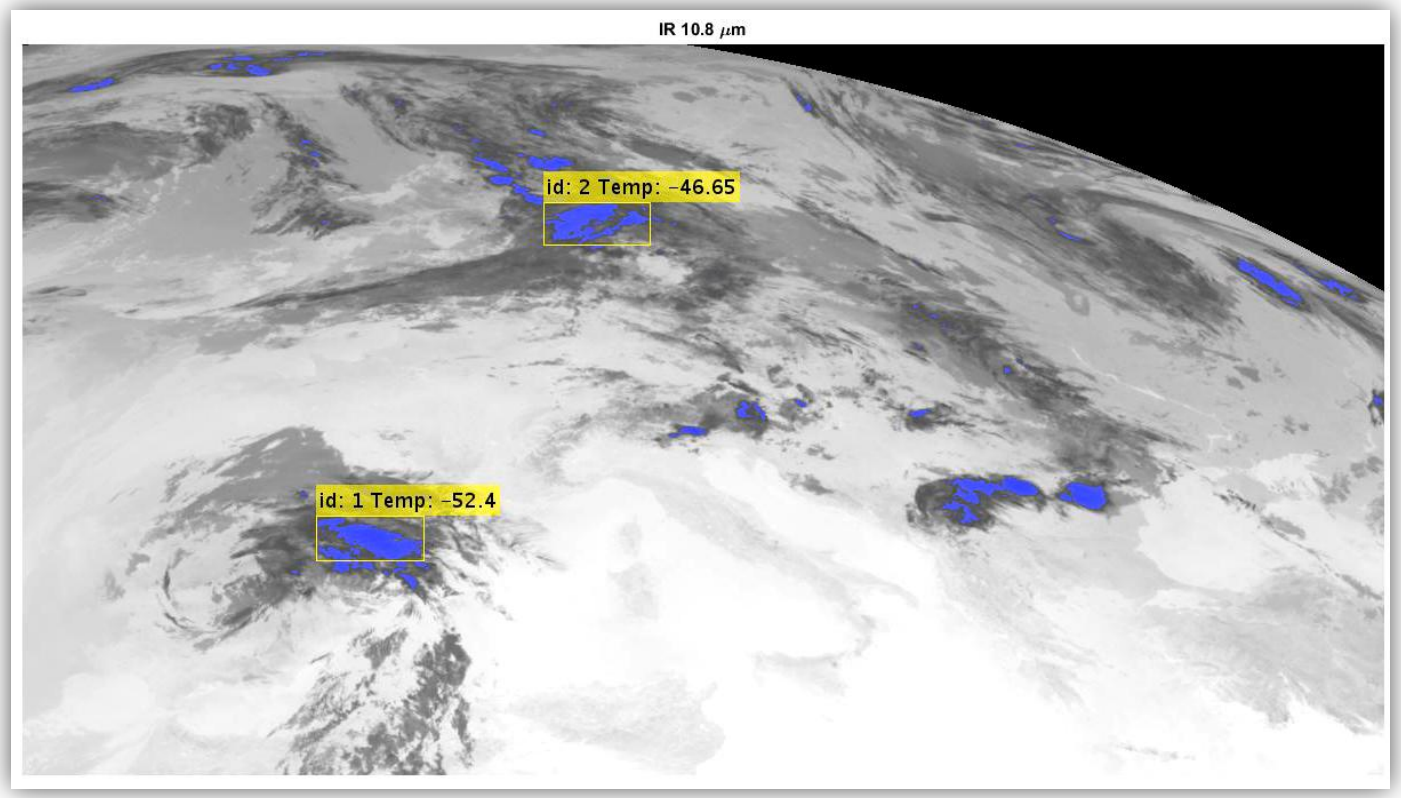
Based on Computer Vision trackers: shape and texture descriptors



Extreme Weather Onboard Image Processing

PRELIMINARY ALGORITHM

3. Classify based on temporal feature evolution



Current Status

- Latency requirement is considered feasible based on preliminary design
  - Latency in **Optical ~3 minutes** for 100km^2 (for DEIMOS-2 satellite)
  - Further paralelisation can improve these times (HW vrs latency trade)

- Key open points
  - Capability to provide bounded latencies independent of number of EO products (alerts)
  - Data flow for larger observation areas to be assessed
  - Confirmation of global vs local communications latencies
  - Overall system deltas: mass, power, cost, reliability
  - Pending HW-SW implementation

Way forward

- 2019
  - Detailed design: SW-HW implementation
  - Individual technologies verification
    - Ready for exploitation
  - Workshop 1 – End User outreach (commercial & insitutional) (Madrid)
- 2020
  - Full data chain ATB testing
  - EO-ALERT experiment data testing
  - Workshop 2 – Satellite developers and End Users (Madrid)

Planned Exploitation

- Actively searching for an IOD opportunity
- Pursuing commercial uptake
  - Individual techologies
  - Full data chain solution
- Anchor customer
- Planning evolutions of EO-ALERT solution

Summary

- EO-ALERT is an EC H2020 project of European partners, furthering European excellence in EO and satellite technologies
- EO-ALERT aims at addressing **very low latency** End User needs for EO image products, exploiting on-board processing capabilities
- It covers the whole acquisition chain, including data handling, processing and transmission to ground, **targeting latencies below 5 minutes**
- Current results show feasible to move VHR processing fully on-board
  - Confirmed at preliminary design for DEIMOS-2 and TerraSAR-X
- It will demonstrate the architecture and HW-SW solutions to TRL6, employing a representative avionics test bench (ATB) and EO experiment
- Technologies and solution ready for exploitation starting end of 2019

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