



EO-ALERT: A NOVEL FLIGHT SEGMENT ARCHITECTURE FOR EO SATELLITES PROVIDING VERY LOW LATENCY DATA PRODUCTS

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Deutsches Zentrum
für Luft- und Raumfahrt
German Aerospace Center



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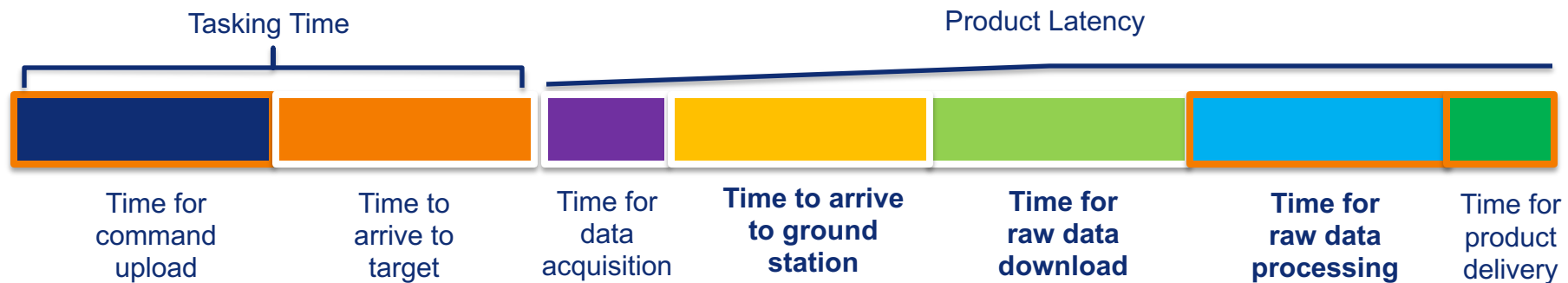


Importance of Latency in Satellite based Remote Sensing

Data latency and in particular **Product latency** are important in many EO scenarios, where **System Responsiveness** is a driver

Remote sensing data serves the needs of decision makers providing time-sensitive low latency or near real-time (NRT) satellite data for time critical services (e.g. disasters, emergency response)

Data latency (Product Latency) in satellite EO refers to the time between the data acquisition and its delivery to the End user





Remote Sensing Scenarios Requiring Very Low Latency



In many EO scenarios, the EO product is only useful if available in a very short time period. Scenarios needing very low latency products include:

- Disaster management and Emergency response (e.g. Floods, Fires, Earthquakes, Oil slicks, ..)
- Forecasting (e.g. extreme weather nowcasting, climate nowcasting, ...)
- Monitoring and Security (e.g. maritime smuggling, illegal fishing, illegal immigration, sea ice, ...)

There is a social need for EO products provided in almost real time (enhanced-NRT)

- Latencies below 5 minutes, approaching 1 minute desired

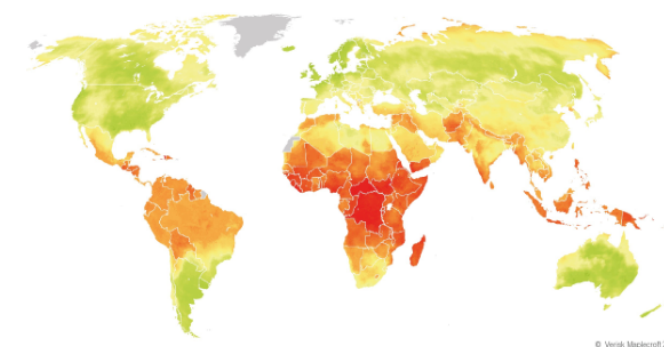
Motivated by UN SDGs, UN-SPIDER, WMO, etc e.g. recent findings of Global Commission on Adaptation:

- Invest in "Strengthening early warning systems"

Early warning systems for meteorology & climate are needed

- Accessibility to such systems is key

Climate Change Vulnerability Index 2017



The five worst performing countries					The five best performing countries				
Rank	Country	Region	Score	Category	Rank	Country	Region	Score	Category
1	Central African Republic	Africa	0.01	Extreme	191	Denmark	Europe	10.00	Low
2	DR Congo	Africa	0.20	Extreme	190	United Kingdom	Europe	9.96	Low
3	Haiti	Caribbean	0.24	Extreme	189	Uruguay	S.America	9.95	Low
4	Liberia	Africa	0.25	Extreme	188	Iceland	Europe	9.85	Low
5	South Sudan	Africa	0.41	Extreme	187	Ireland	Europe	9.83	Low





Existing Low Latency Civil EO Products



European:

Tendency is towards product latency of 15 to 30 minutes

Copernicus Emergency Management Service (EMS)

- Offers weather, fire, floods and general mapping services
- Latencies in the range of ~**1 hour** to several hours

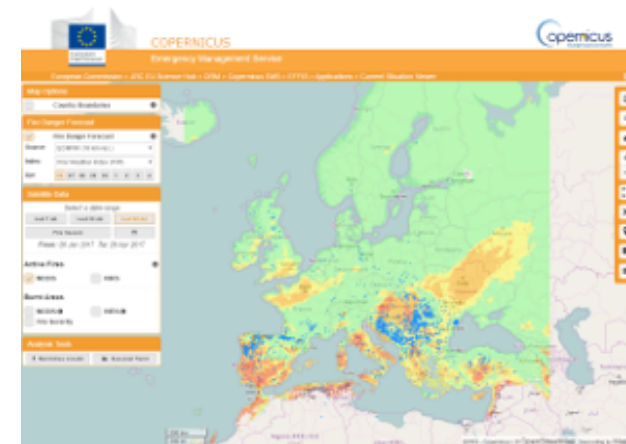
Copernicus Maritime Surveillance (CMS) Service / EMSA

- General sea activities monitoring
- Latencies in the range of ~**30 minutes** for the VDS

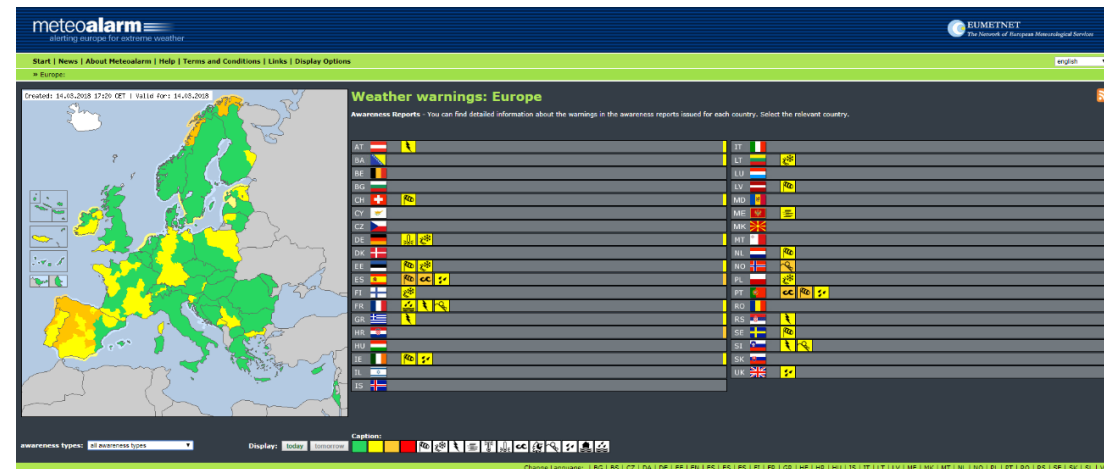
EUMETSAT

- General meteorological and climate products
- Latencies in the range of ~**30 minutes** for fastest products (e.g. RDT)

Similar services are available e.g. in the US with the LANCE system and service



View of the European Forest Fire Information System (EFFIS)



View of the European Meteoalarm service



EO-ALERT H2020 Project: Solution for Very Low Latency Products



Goal: to address the need for increased data chain throughput

- Develop a new approach for the provision of **very low latency Earth Observation (EO) data products**, exploiting the flight segment processing capabilities

Latency goal of < 1 minute

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

- Move key EO data processing elements from the ground segment to the satellite
- Applicable generally to scenarios that require NRT information: surveillance, monitoring, disaster management, emergency response
- Prove this for two real **VHR** Optical and Synthetic-Aperture Radar (SAR) instruments
 - TerraSAR-X (SAR) VHR satellite
 - DEIMOS-2 (OPT) VHR satellite
- Test in two scenarios: ship detection and extreme weather detection



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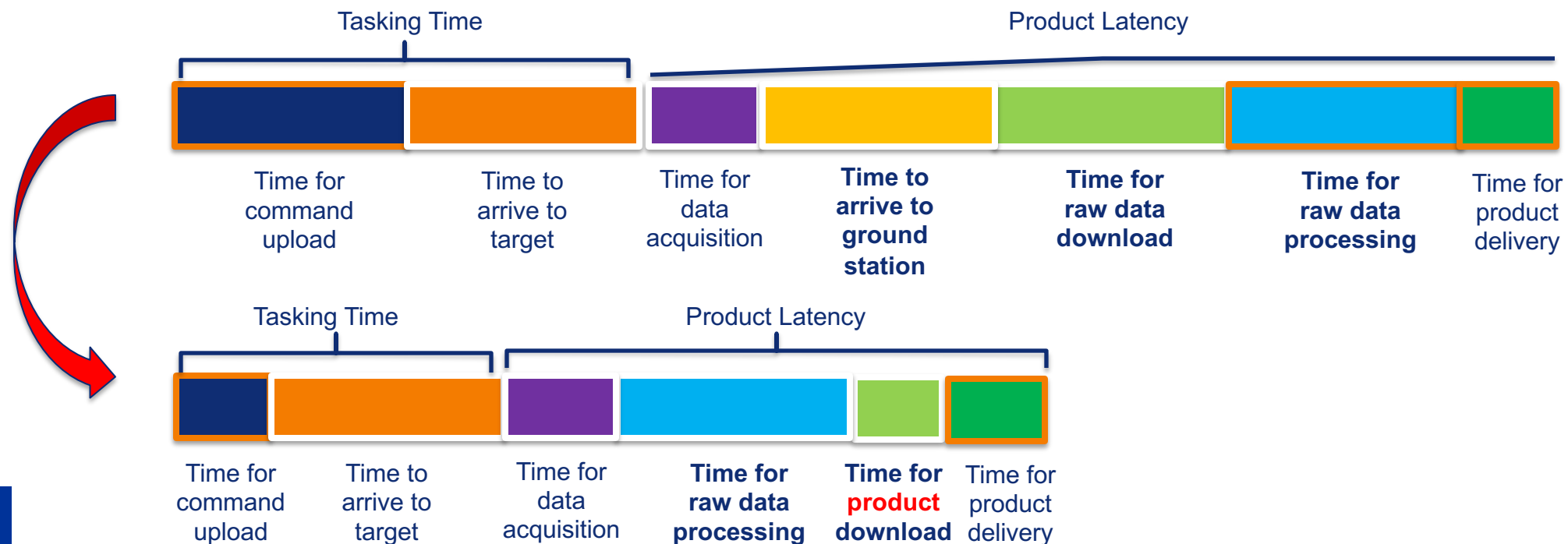




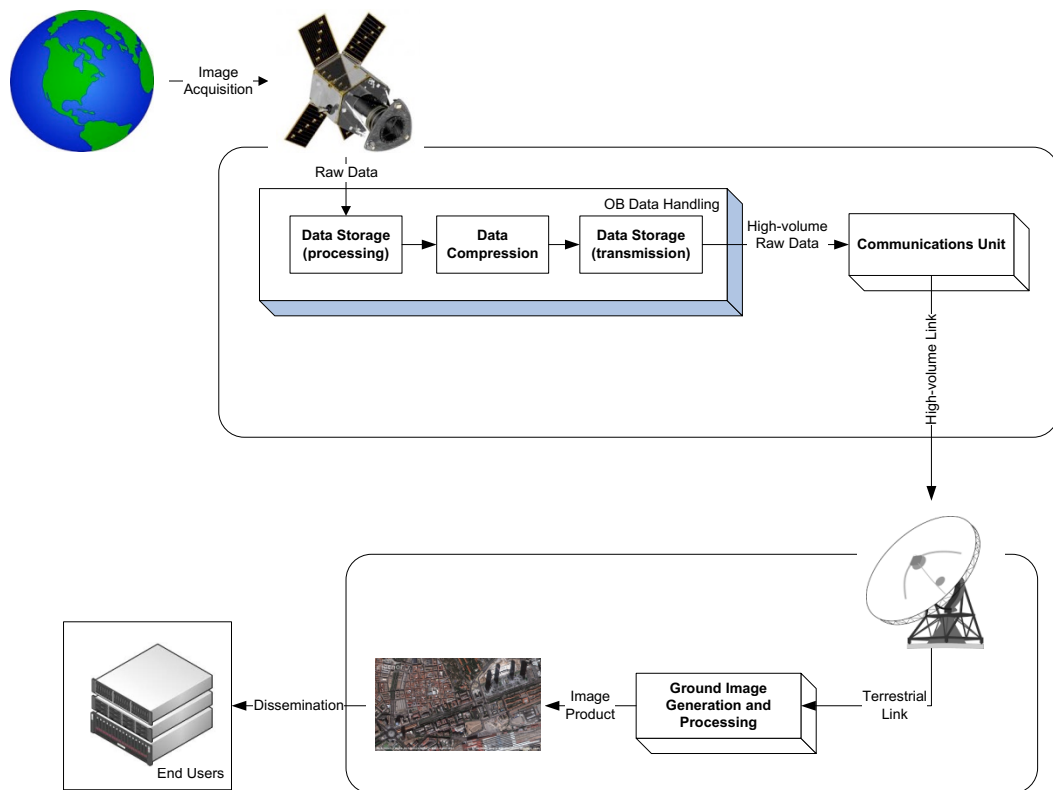
EO-ALERT Architecture for Very Low Latency Products

Propose On-board processing + LEO SATCOM network. Latency and responsiveness is greatly improved by:

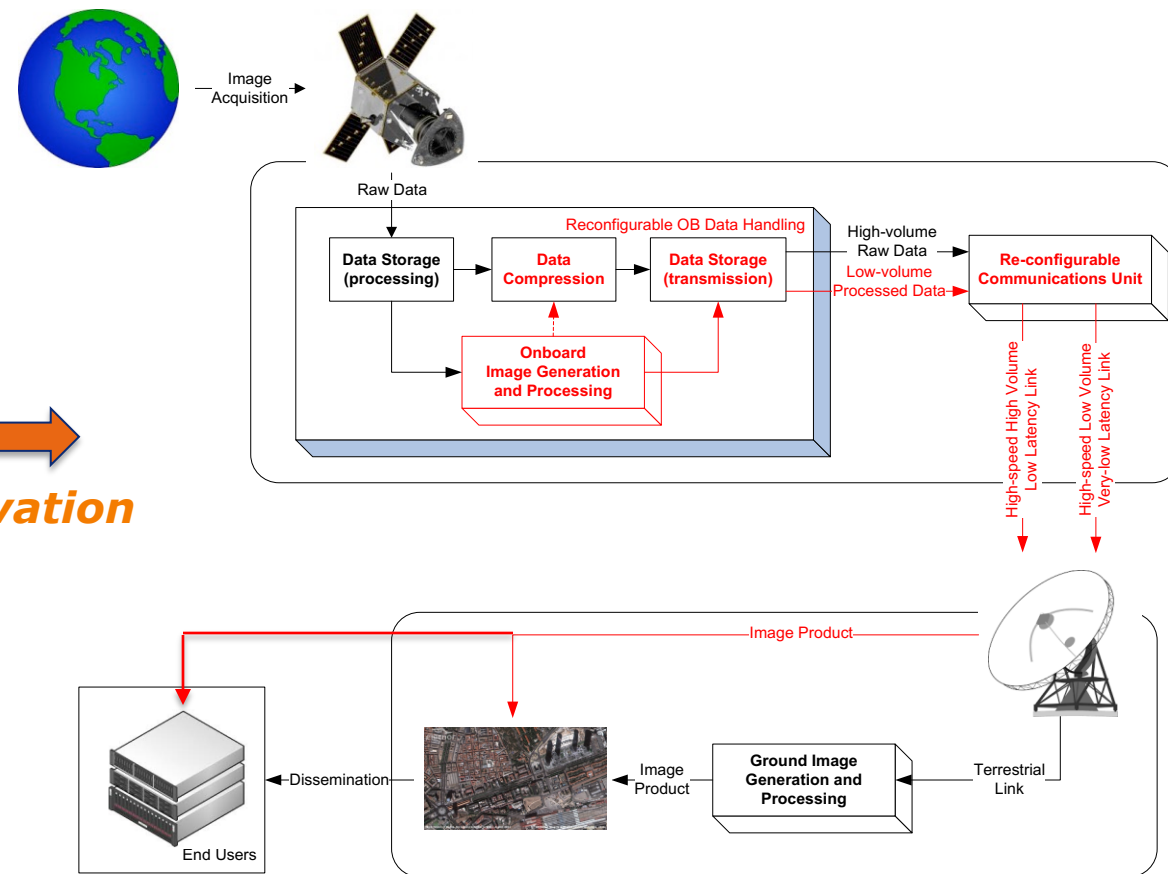
- Lower "Time for command upload" and removing "Time to arrive to the ground station" as global link
- Almost remove "Time for data download" given much lower data volume (normally <1% of raw data)
- Maintain low "Time for data processing" using **advanced On-board avionics**



Classical EO Data Chain



“New” EO Data Chain



Innovation

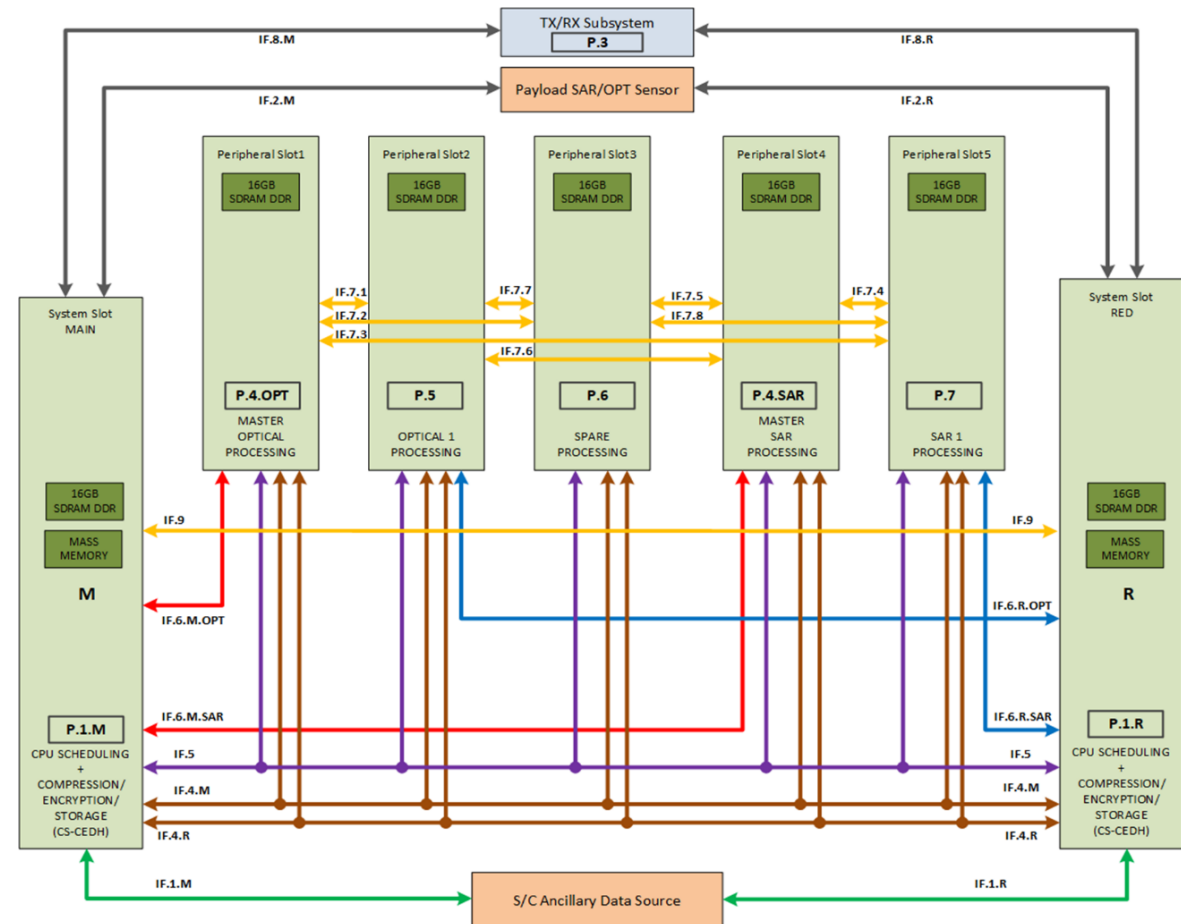


Physical Architecture (PDPU)

- High efficiency mixed COTS-radiation tolerant architecture



XILINX
ZYNQ
UltraSCALE+





EO-ALERT Project Results

Latency



Current Product Latencies

- EMSA VDS products (ship detection, classification, positioning)
- Tested on TerraSAR-X and DEIMOS-2 VHR satellite data
- Current results for SAR and Optical meet 5 minute requirement
- Below 1 minute with multiple boards for the optical payload

SAR

- 1 board**
- ~ 2.7 minutes**

Optical

- 4 boards**
- ~ 0.7 minutes**

✓ **Goal of < 1 minute**

OPT

100 km² image
~1m resolution
Up to 300 targets

Raw data ~200 MB
Product data 3 MB

SAR

375 km² – 500 km² image
~4m resolution
Up to 300 targets

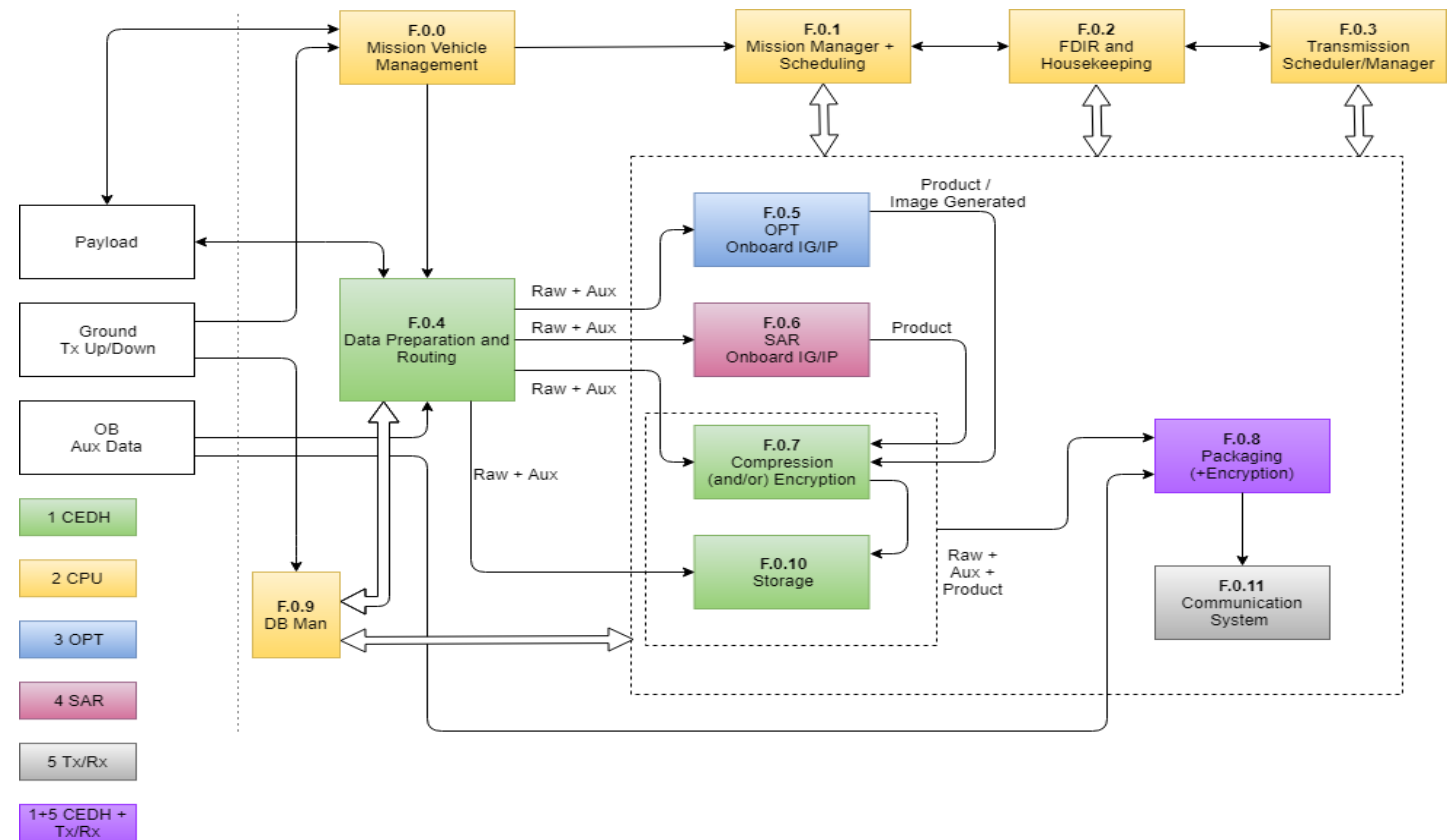
Raw data ~500 MB
Product data 3 MB

DMS-2 Optical Payload	
# boards	4
<i>Function</i>	<i>Latency (seconds)</i>
Processing	25
CEDH	4
IF	5
Scheduler	5
Comms	1
<i>Total</i>	~40

TSX SAR Payload	
# boards	1
<i>Function</i>	<i>Latency (seconds)</i>
Processing	133
CEDH	6
IF	10
Scheduler	10
Comms	1
<i>Total</i>	~160



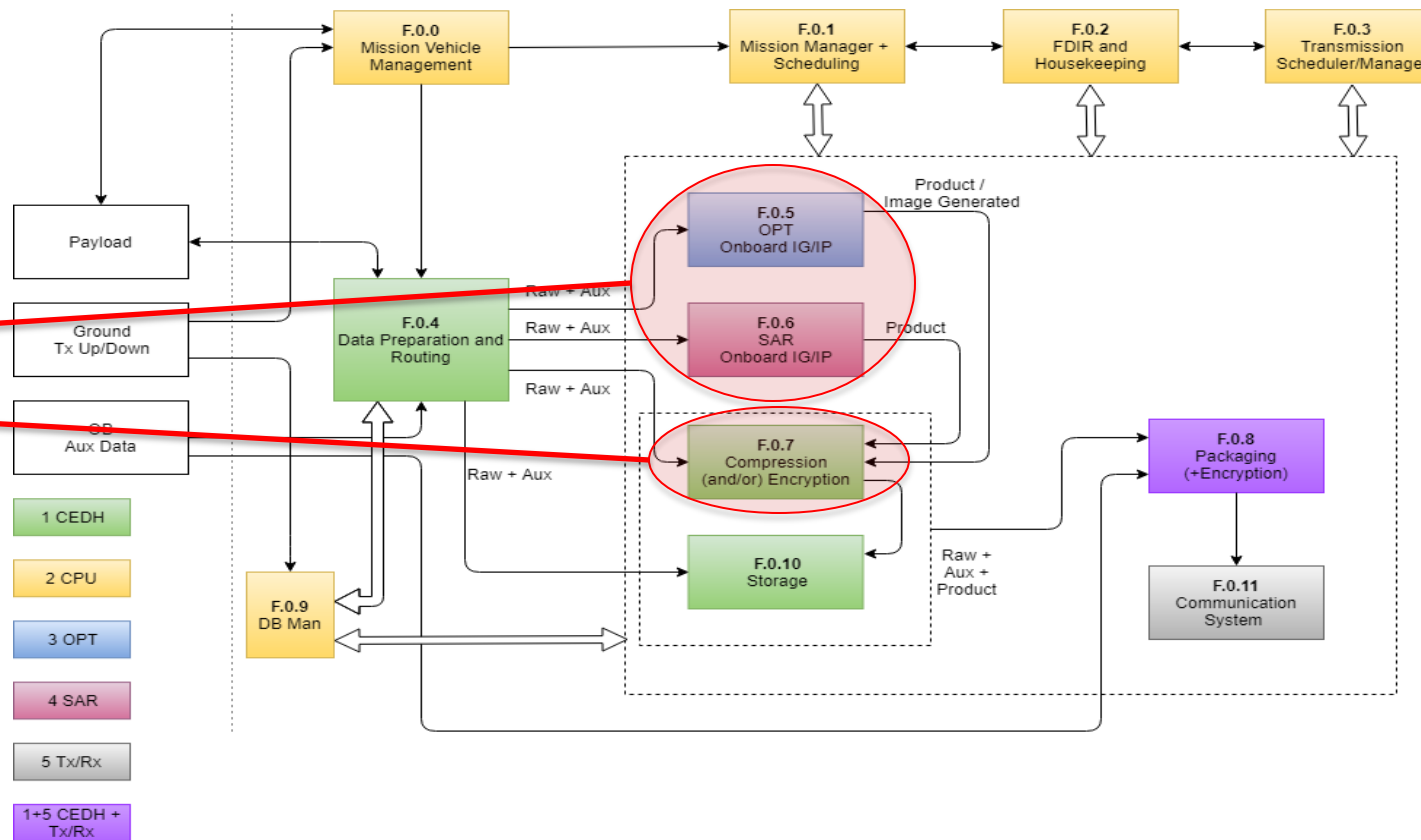
Functional Architecture



Functional Architecture

Where is the AI?

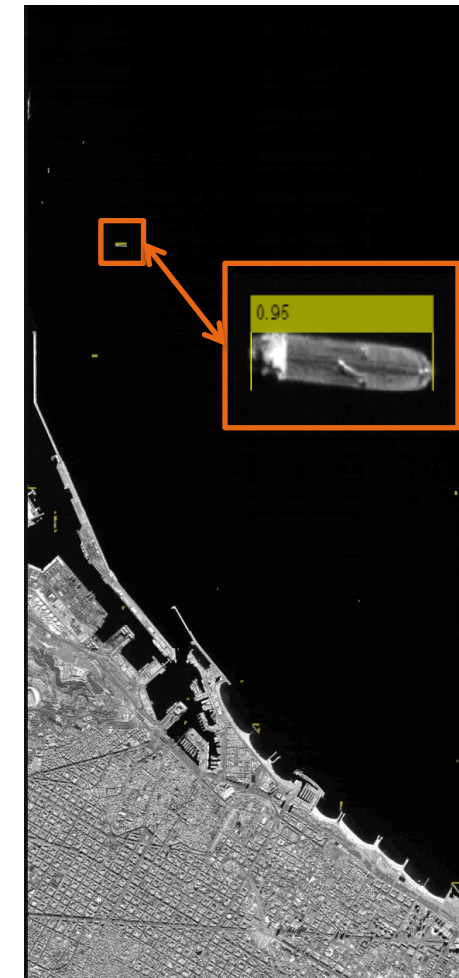
- Image Processing
- Compression and Encryption



EMSA VDS Like Product

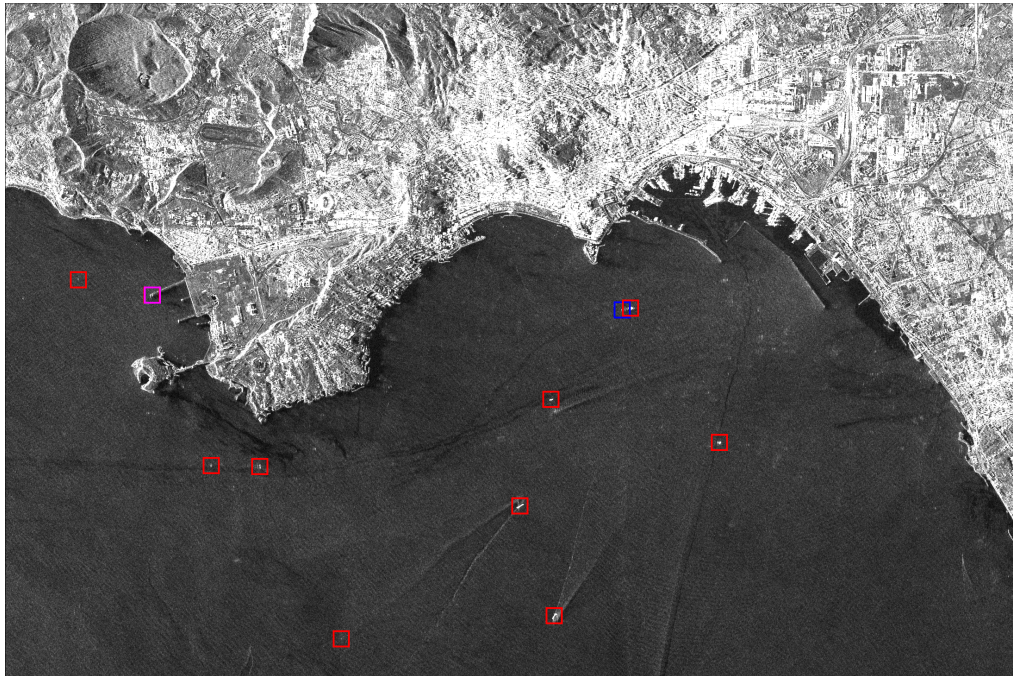
Product Name	Operational Details
Ship Detection	Position information: Latitude, longitude coordinates Time Stamp: Date/Time of acquisition Heading: Route direction Length and width: in meters Speed: Over Ground expressed in meters per second Confidence level: three different confidence levels for Ship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

DMS-2 Example Case



EMSA VDS Like Product

TSX Example Case (DLR)



DMS-2 Example Case

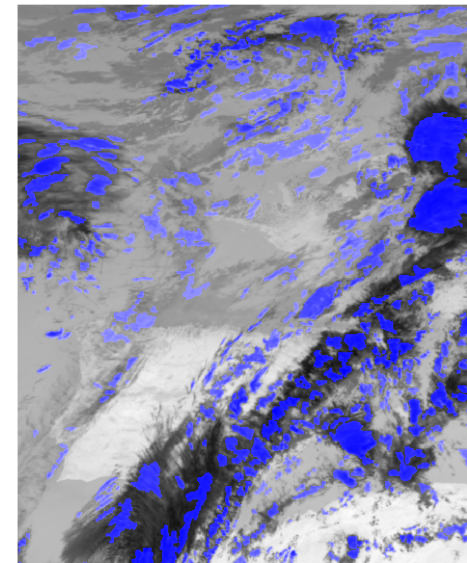


EUMETSAT Rapidly Developing Thunderstorm (RDT) Like Product

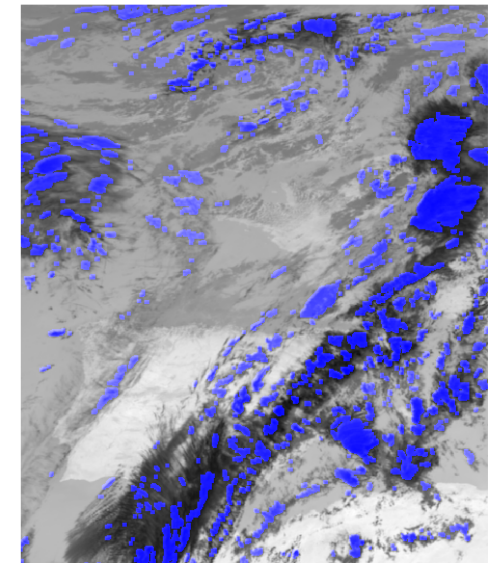
EUMETSAT SEVIRI Test for Storm Candidates Identification

Product Name	Operational Details
Storm Detection	Visual characteristics of the storm (shape, extension) Trajectory followed by the storm Expected speed and direction of the storm Information on cell merging and splitting Date/Time of storm detection in UTC Cloud top temperature Cooling/warming rate Severity index

Rapid Development Thunderstorms (RDT-PGE11 v3.0)
SAFNWC/MSG version 2013

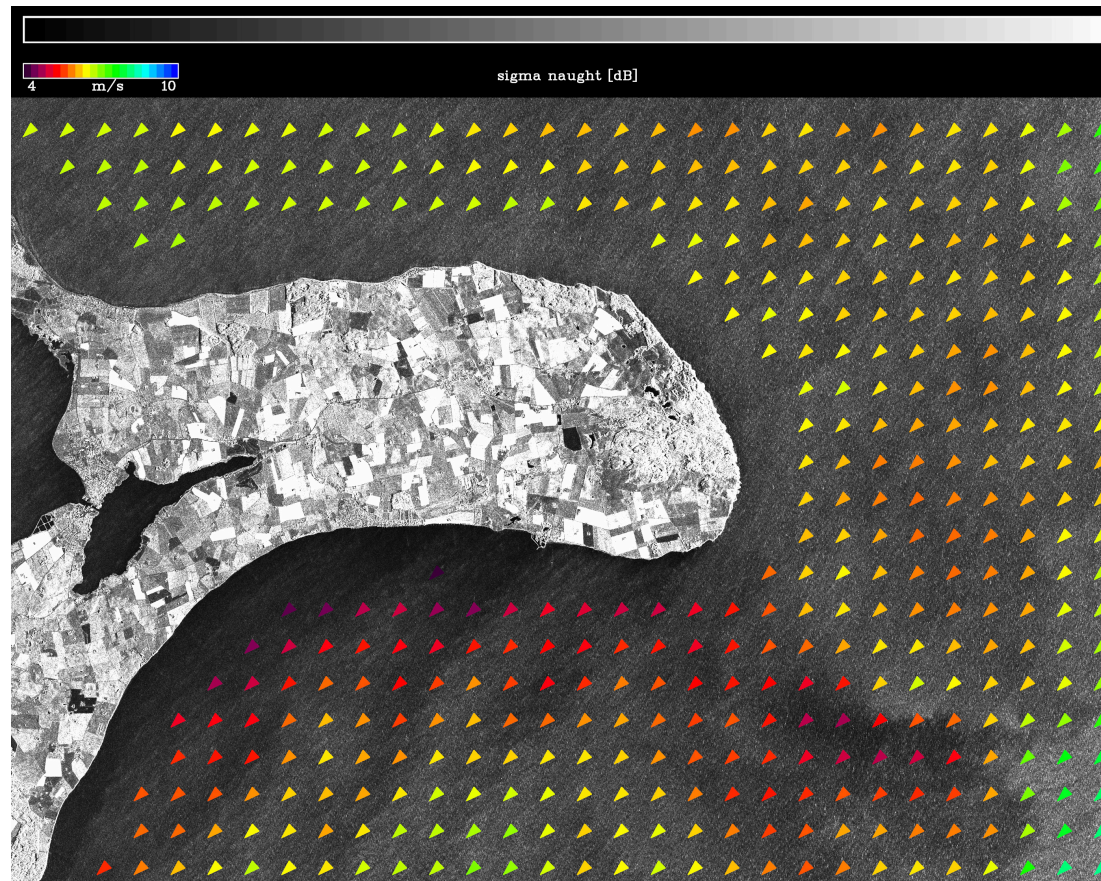


EO-ALERT



Wind Speed and Wave Height Product

TSX Example Case for Wind Estimation (DLR)

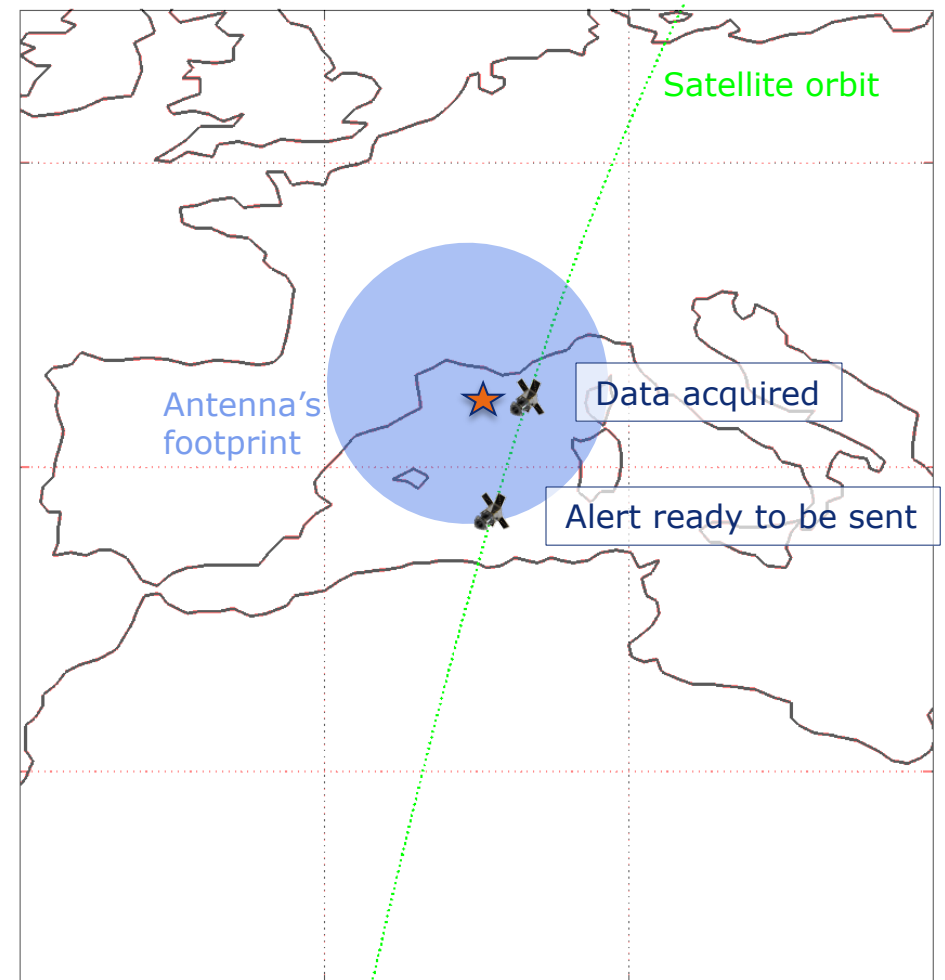




EO-ALERT as an Enabler for Direct EO Product Broadcasting

Optical Scenario: 1 min latency

- Alert detected close to French coast by optical payload
 - Satellite attitude: 10° across-track de-pointing
 - Image generation & processing time: **1 min**
 - S-band antenna along-track de-pointing
 - The alert can be sent to an area of about **700 km diameter** around the detected point
- Non-expert End-users can receive and use the products directly
 - Improves EO product accessibility
 - No internet connection required
 - Useful for non-space fairing nations



2019

- **Workshop 1** – November 2019, DEIMOS Space (Madrid)
 - Technical and End User outreach

2020

- Full data chain Avionics Test-Bench testing
- Archive data and EO-ALERT experiment data testing
- **Workshop 2** – Satellite developers and End Users (Madrid)

Current Exploitation

- **VHR optical on-board processing** part of DEIMOS' 3rd generation (0.5m) small satellite
 - Performed within **ESA Incubed framework**
- DEIMOS proposed to ESA to put the **on-board nowcasting** in a mission called **COPRIME** for the small satellite **ESA SCOUT mission**
- Looking to put these capabilities in future missions, such as EC satellites and nano/cube/minisat missions

EO-ALERT Experiment



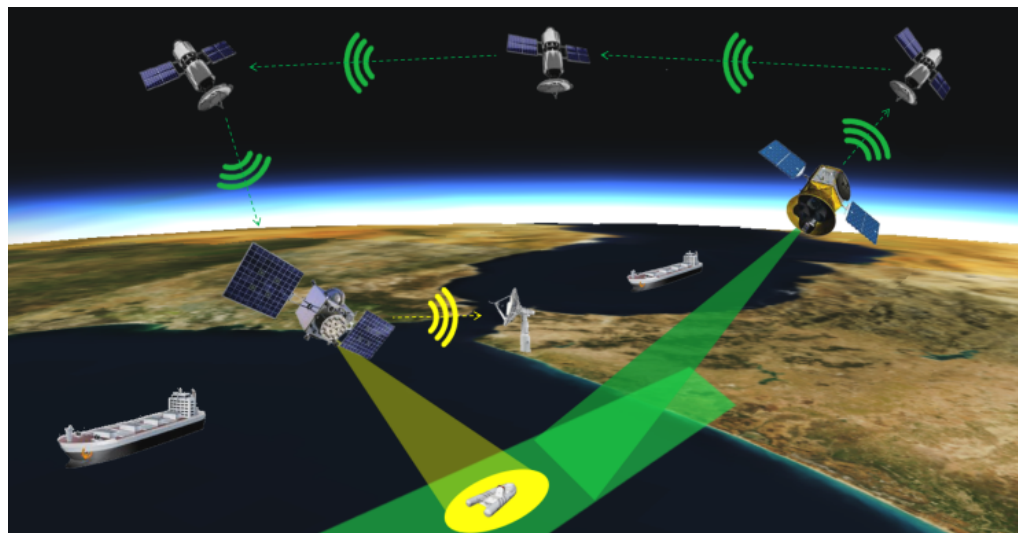
Envisaged EO Services from Autonomous Satellite Constellations

Enabler for future autonomous satellite constellations, with very high responsiveness

Enabler for scenarios where the 1st user is the flight segment

Provide worldwide responsive, very low latency EO products for civil services

Autonomous Satellites Constellations

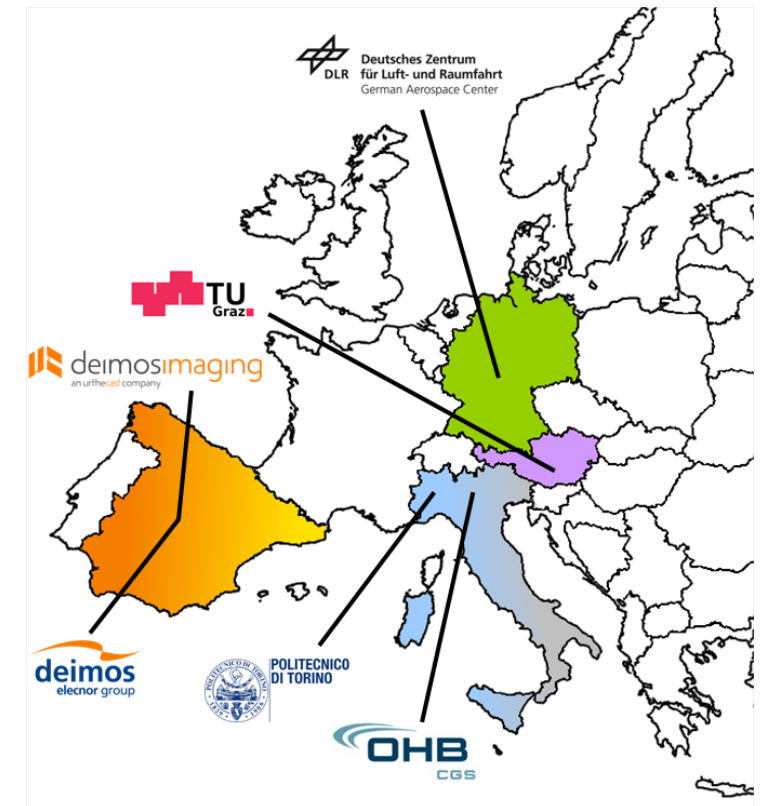


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Call: COMPET-3 2017 Call on "High speed data chain"

Title: Next Generation Satellite Processing Chain for Rapid Civil Alerts





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