NOVEL SATELLITE ARCHITECTURES FOR VERY LOW LATENCY EO DATA PRODUCTS THAT MEET SOCIETAL NEEDS

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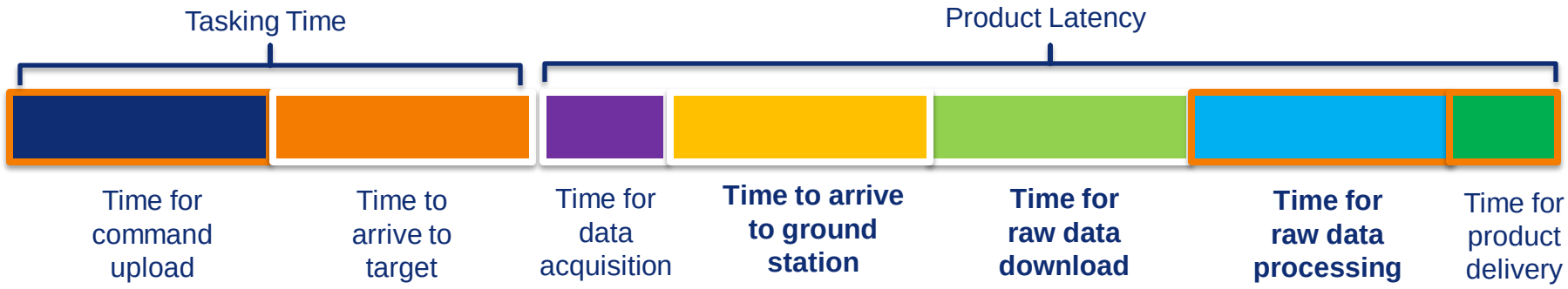
Importance of Latency in Satellite based Remote Sensing

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



Flashback to Personal Imaging

Until the 21st century, personal imaging took hours to days

Now instantaneous processing on your mobile phone device

What happened?? Camera film processing moved on-board the camera, which moved on-board the mobile phone

One could argue that the same is now happening with Satellite based remote sensing

Remote Sensing Scenarios Requiring Very Low Latency

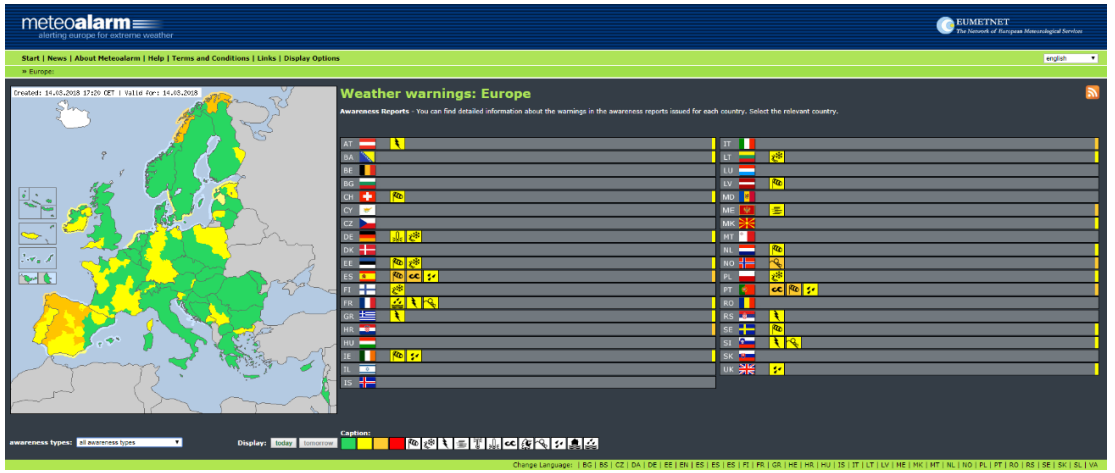
In many EO scenarios, the EO products is only useful if available in a very short time period. Scenarios needing very low latency products include:

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

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

- Latencies below 5 minutes, approaching 1 minute desired

View of the European Forest Fire Information System (EFFIS)



View of the European Meteoalarm service

Existing Very Low Latency Civil EO Products

European:

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)

US:

LANCE: NASA Near Real-Time Data and Imagery

- Offers general and mapping services for natural and man-made phenomena
- Latencies in the range of ~**30 minutes** to 4 hours

Mission Architectures for Very Low Latency Products

Existing classical architectures are limited in their ability to provide very high responsiveness and very low latency products

Three basic problems arise:

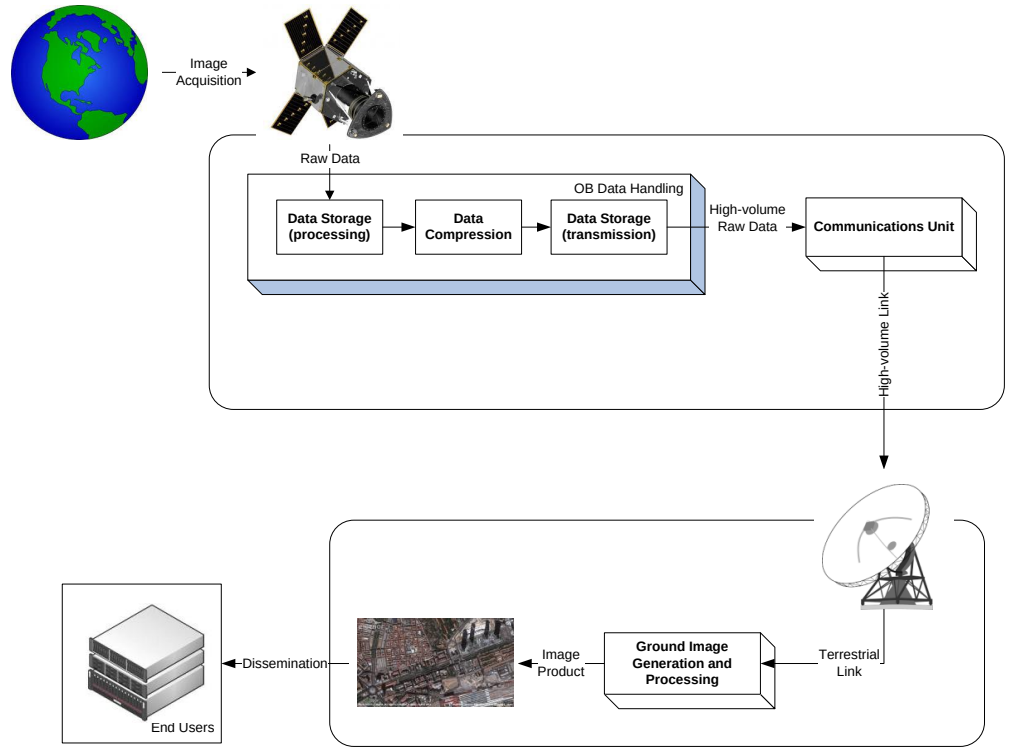
1. time for satellite tasking
2. time to arrive at the ground station for downlink
3. time for data download

Partially solve 1. via large constellations

Partially solve 2. via large network of ground stations

Partially solve 3. via faster direct-to-ground links (e.g. K-band, laser)

Solve 2. and 3. together using "new" architectures



Mission Architectures for Very Low Latency Products

"New" architectures offer solutions to the very low latency EO product challenge

Two architectures considered here are:

- European Data Relay System (EDRS) - *existing*
- On-board processing + LEO SATCOM network - *proposed*

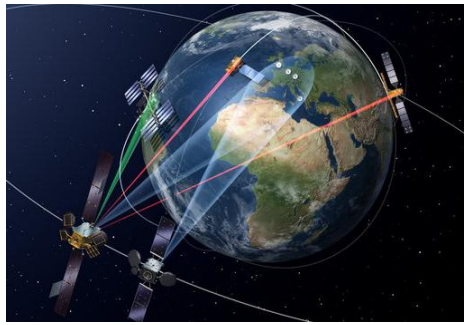
Represent two different approaches for very low Product latency

EDRS is an ESA developed operational service

- laser communication link from LEO to GEO and down to ground
- In **current use**, focus is on transferring the **large raw data** as quickly as possible
- Servicing the Copernicus missions with great success

On-board processing + LEO SATCOM network, which is that **proposed here**

- LEO SATCOM network for global communications
- Processing on-board satellite, leading to orders of magnitude reduction in data volume
- Focus is on transferring the **small product data** quickly, and directly to the End User
- *Enables on-board autonomy* (product can be used directly) & *direct broadcasting*



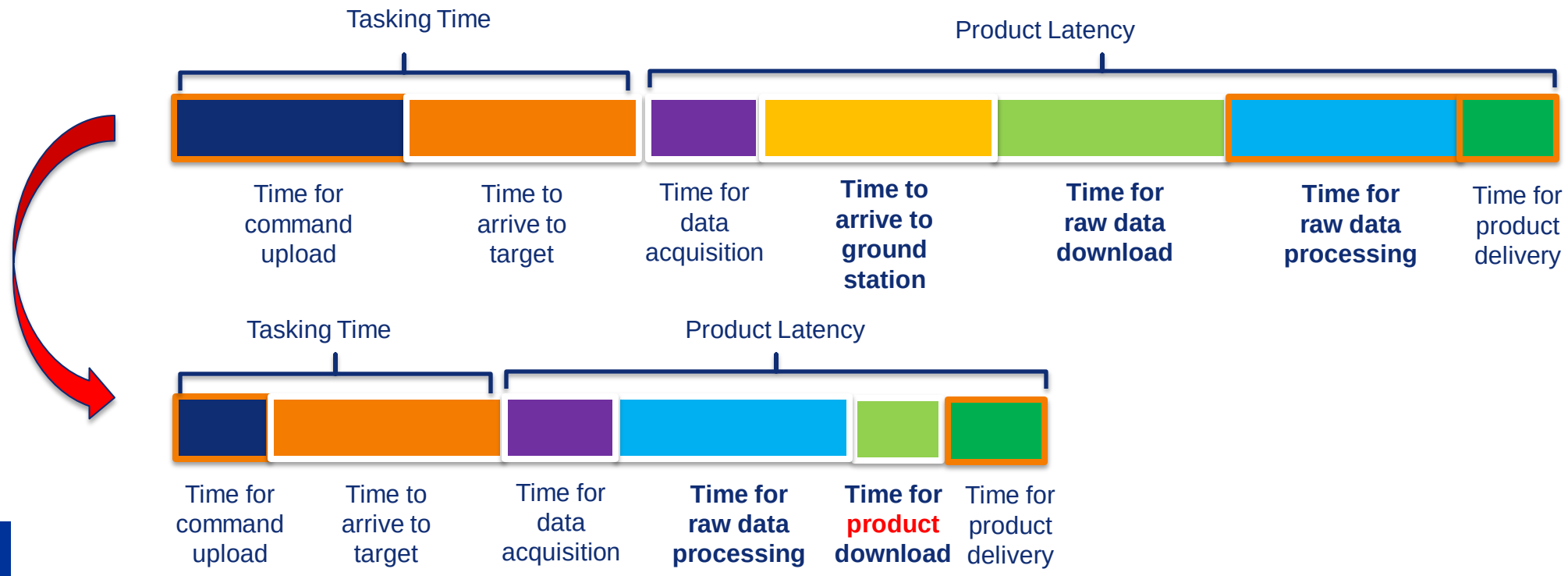
EDRS ©ESA

LeoSat constellation ©LEOSAT

Mission Architectures for Very Low Latency Products

Via On-board processing + LEO SATCOM network, latency and responsiveness is greatly improved by:

- 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**



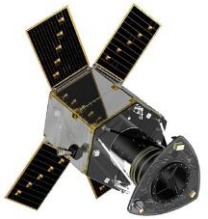
EO-ALERT H2020 Project

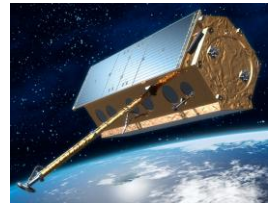
Goal: to address the need for increased data chain throughput

- Develop a new approach for the provision of very low latency Earth Observation (EO) data products, exploiting the flight segment processing capabilities
  - ✓ Goal latency: **< 1 minute**
  - ✓ Requirement latency: **< 5 minutes**

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

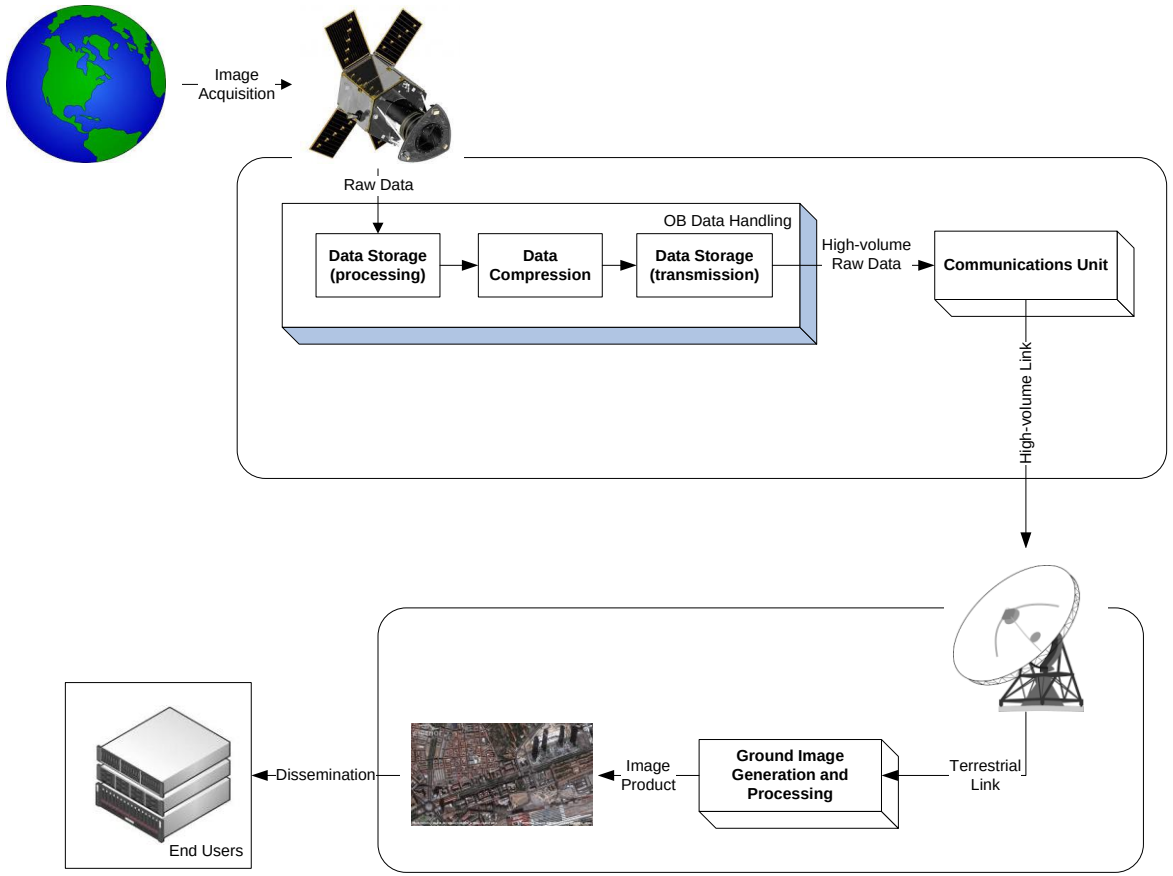
- Move key EO data processing elements from the ground segment to the satellite
- Applicable generally to scenarios that require NRT information: surveillance, monitoring, disaster management, emergency response
- Prove this for two real Optical and Synthetic-aperture radar (SAR) instruments
  - TerraSAR-X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



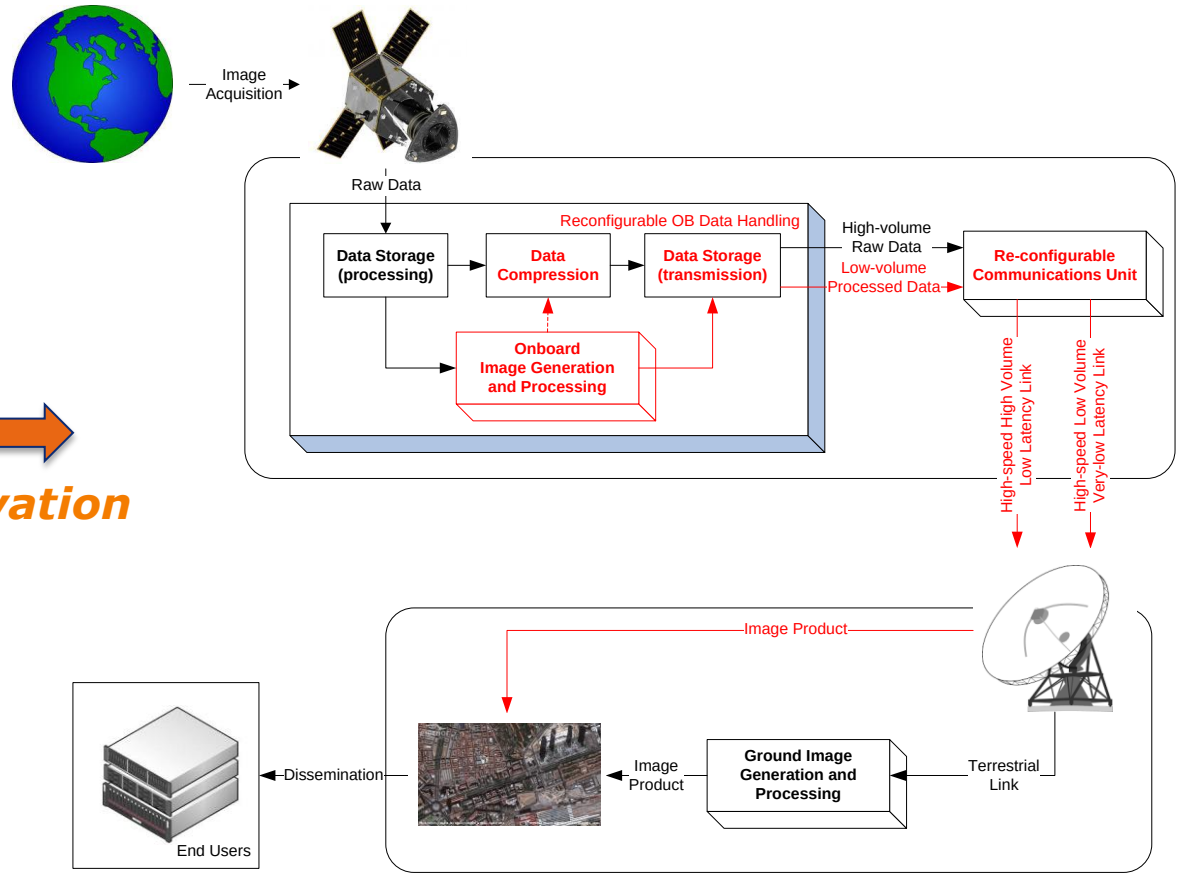


EO-ALERT Project Innovation

Classical EO Data Chain



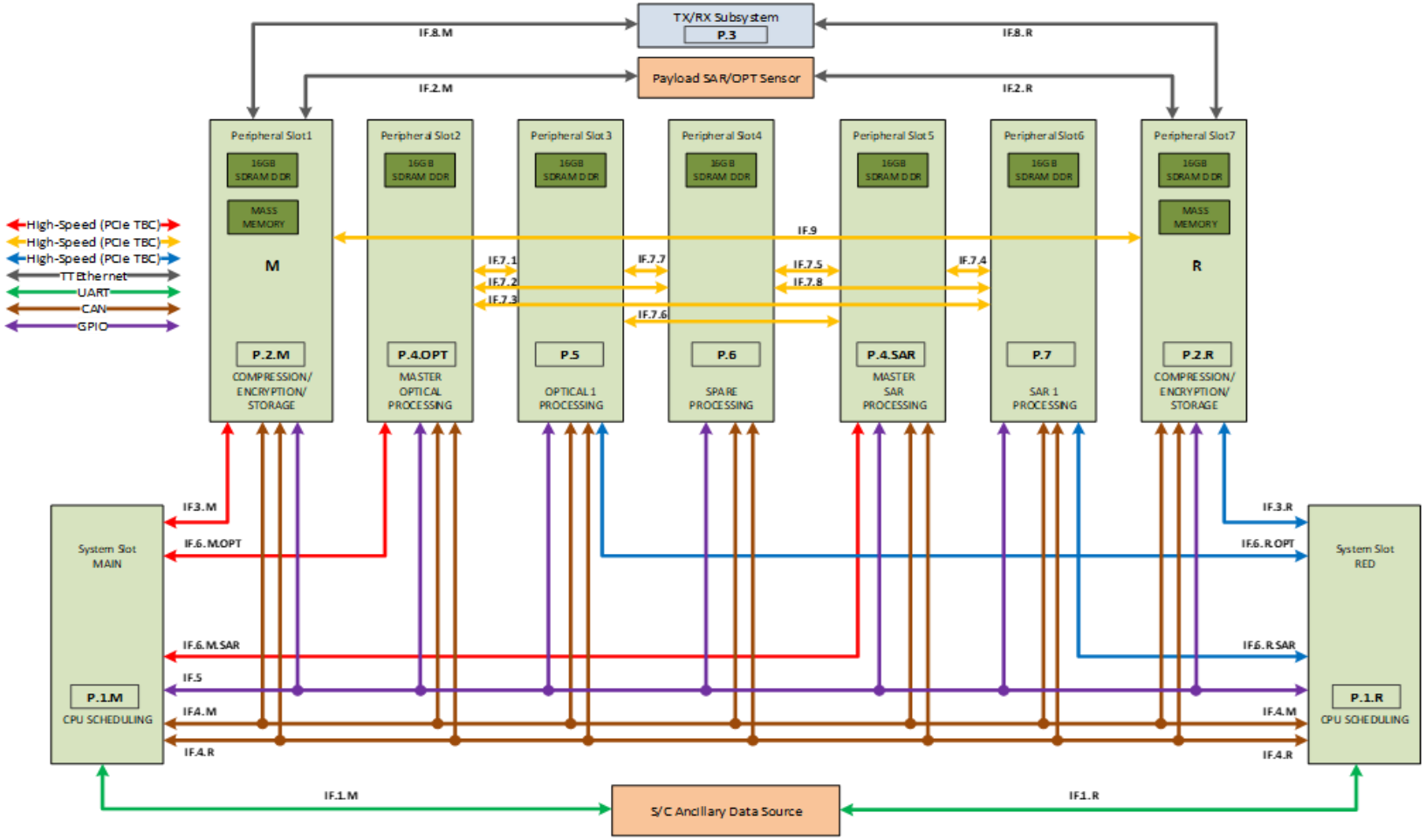
"New" EO Data Chain



Innovation

EO-ALERT Project Results

Physical Architecture (PDPU)



EO-ALERT Project Results

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

- **~2.7 minutes**

Optical

- **~0.7 minutes**

OPT
100 km^2 image
~ 1m resolution
Up to 300 targets

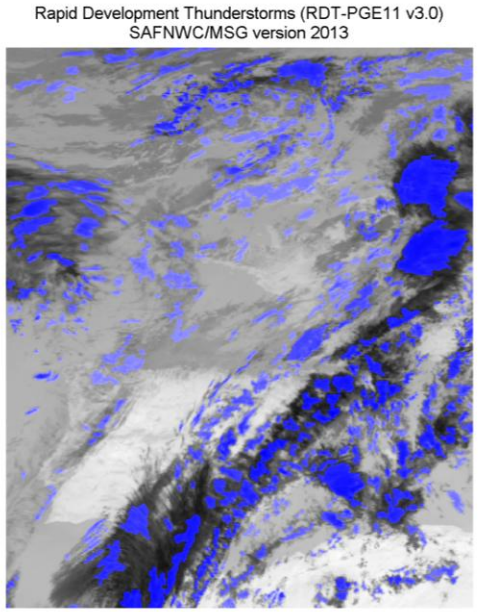
Raw data 200 MB
Product data 3 MB

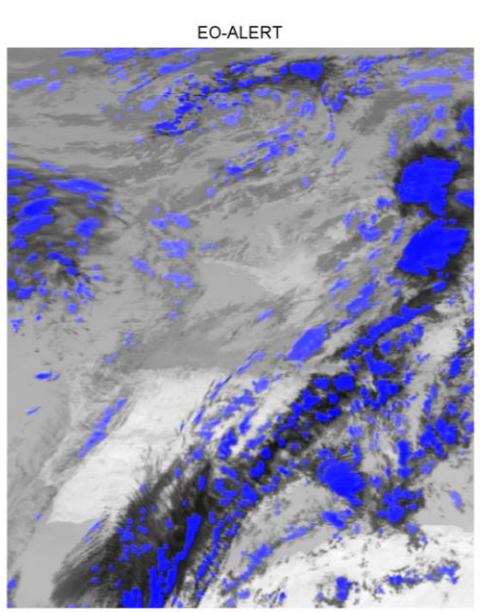
DMS-2 Optical Payload	
# boards	4
Function	*Latency (seconds)*
Processing	25
CEDH	4
IF	5
Scheduler	5
Comms	1
Total	~40

EO-ALERT Project Results

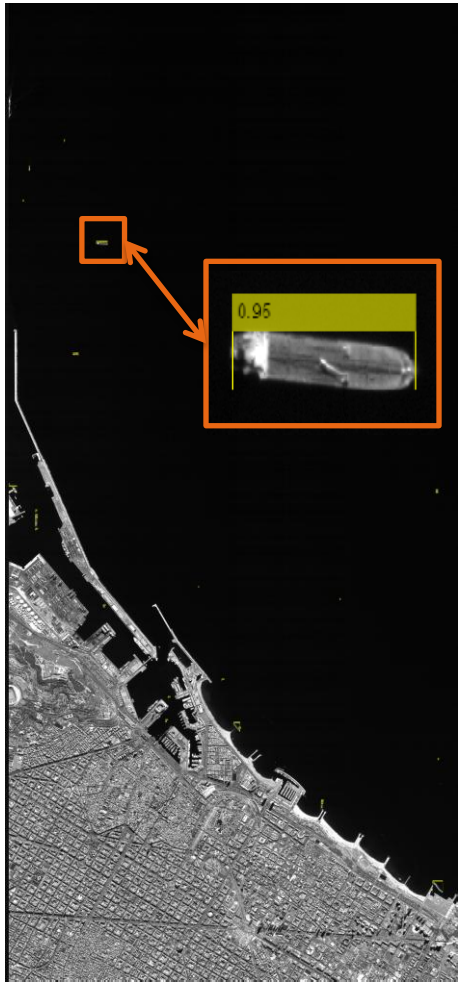
Example Products

EUMETSAT Rapidly Developing Thunderstorm Like Product





EMSA VDS Like Product



EO-ALERT Way forward

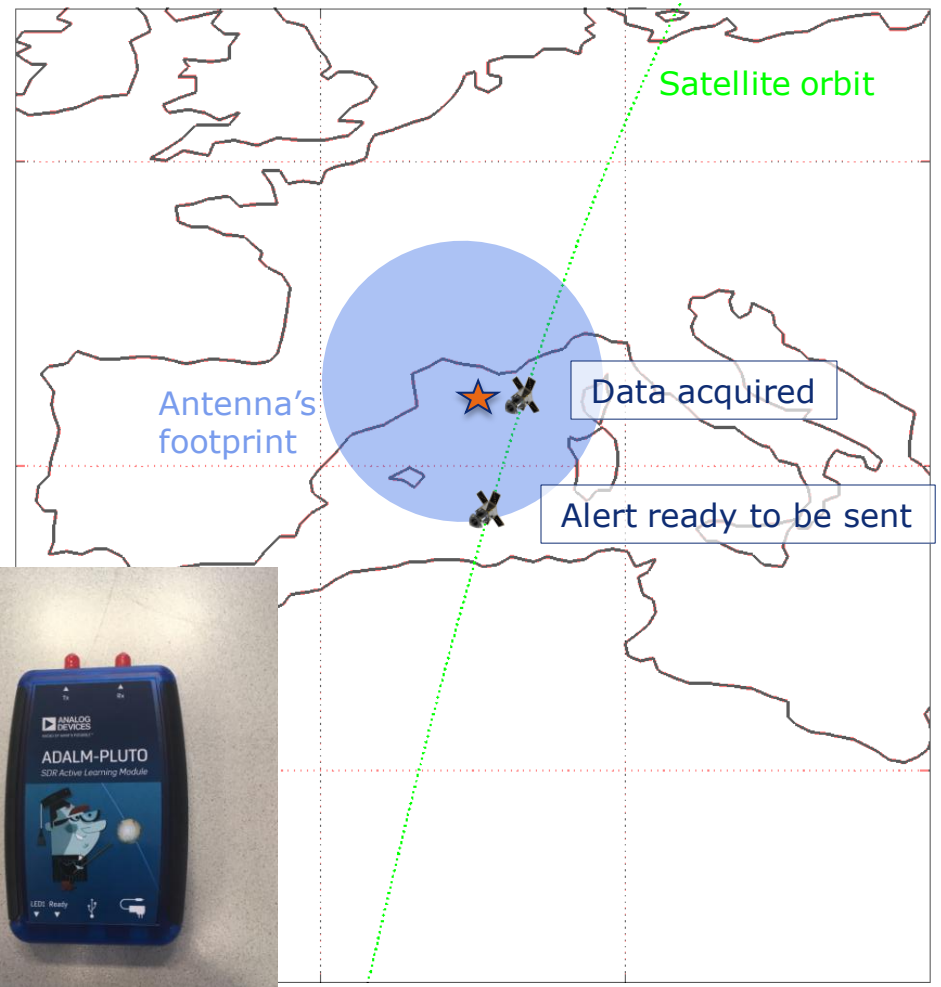
- 2019
  - **Workshop 1** – November 2019, DEIMOS Space (Madrid)
    - Technical and End User outreach
- 2020
  - Full data chain Avionics Test-Bench testing
  - Archive data and EO-ALERT experiment data testing
  - **Workshop 2** – Satellite developers and End Users (Madrid)
- Current Exploitation
  - **VHR optical on-board processing** part of DEIMOS' 3rd generation (0.5m) small satellite
  - Proposed to ESA to put the **on-board nowcasting** in a mission call **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

Enabler for Direct EO Product Broadcasting

Optical Scenario: 1 min processing time

- Alert detected close to French coast by optical payload
  - Satellite attitude: 10º across-track de-pointing
  - S-band antenna half-power beamwidth: 46º
  - Image generation & processing time: 1 min
  - S-band antenna along-track fixed de-pointing: 34º
  - The alert can be sent to an area of about 700 km diameter around the detected point
- Non-expert End-users can use the products directly
  - Possibly useful for non-space fairing nations
  - No internet connection required



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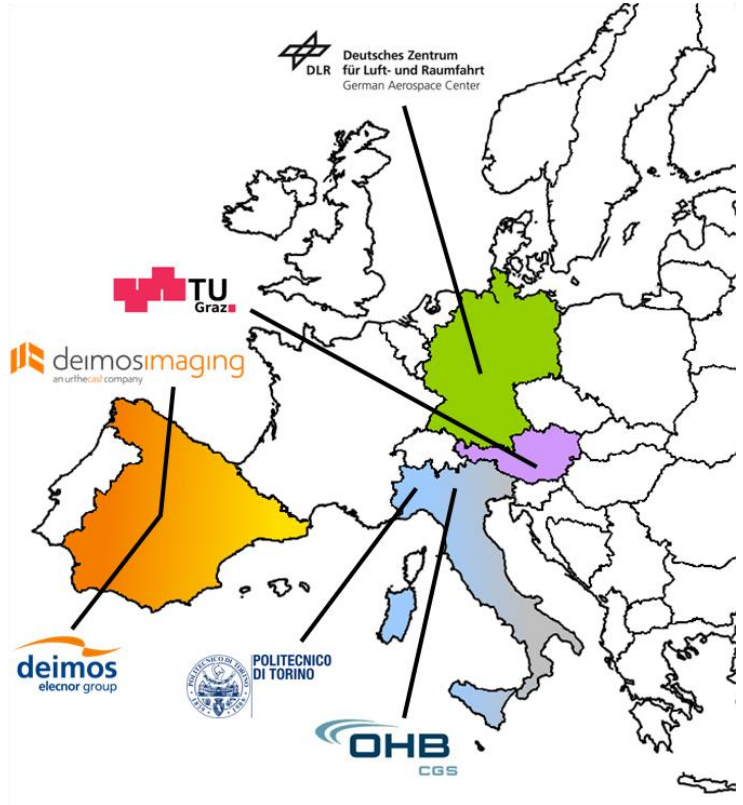
Call: COMPET-3 2017 Call on "High speed data chain"

Title: Next Generation Satellite Processing Chain for Rapid Civil Alerts



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