Intelligence and Autonomy in the Sat4EO+ Satellite

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Introduction

The responsiveness of an Earth observation (EO) service, in terms of the time from the initiation of satellite tasking after an End User request is accepted, until the availability of the Earth Observation product to the End User, is a key metric in many applications, such as security, disaster monitoring and nowcasting, and more generally in enhanced-NRT services.

Elecnor DEIMOS is currently developing its next proprietary Very-High Resolution (VHR) small satellite [1][2], Sat4EO+, to meet current and upcoming market needs for Earth Observation products derived from a sub-meter optical imaging capability. Sat4EO+ is an agile low-cost ~200kg VNIR optical satellite, providing ~50cm native VHR imaging. In Sat4EO+, responsiveness has been included as a key performance parameter, with a requirement that the Sat4EO+ service shall provide responsiveness down to 10 minutes, globally, for high-priority products.

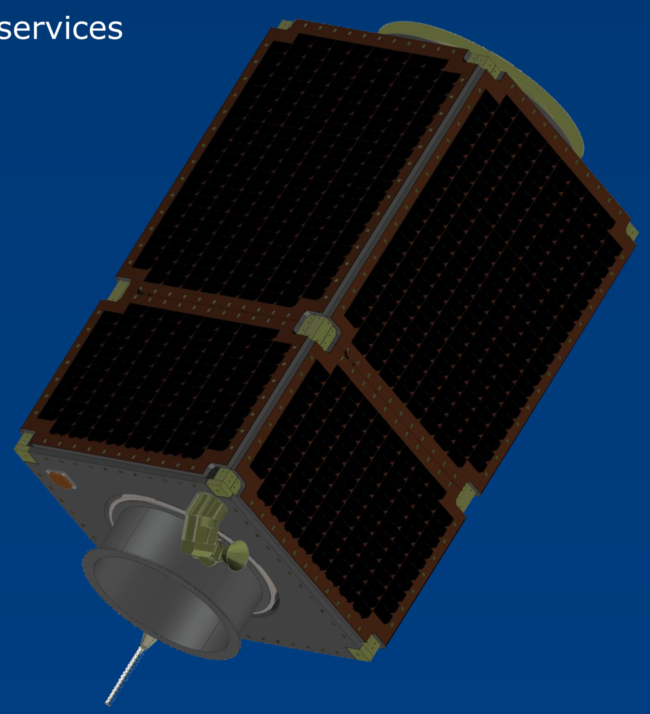
This poster describes the approach employed by DEIMOS to achieve this responsiveness requirement below 10 minutes globally in the Sat4EO+ satellite. The responsive service is based on several key capabilities for small satellites, which, when employed in combination, lead to an intelligent satellite, with increased autonomy, that provides for an innovative service to the End User. These capabilities are: rapid global tasking, exploiting a permanent communications link to the SAT4EO+ satellite through a global high-rate geo-relay link; re-configurable data handling on-board the satellite, to manage both high and standard priority products and their transfer to the End User; on-board processing, through DEIMOS' propriety **Insight4EO** HW/SW turnkey product embedding Artificial Intelligence (AI) and Machine Learning (ML) algorithms, allowing for the generation of high-priority Earth observation products on-board the satellite and their direct transfer to the End User globally with very low latency (real-time), exploiting the global communications link and the relative small size of such products; autonomous task management on-board the satellite, to manage autonomously high and standard priority tasks, and perform tasks such as data prioritisation, thus maximising the overall duty cycle of the satellite and the service performance and ROI.

Satellite Overview

SAT4EO+: an "intelligent" small satellite for responsive VHR optical services

Key performance parameters & innovative features

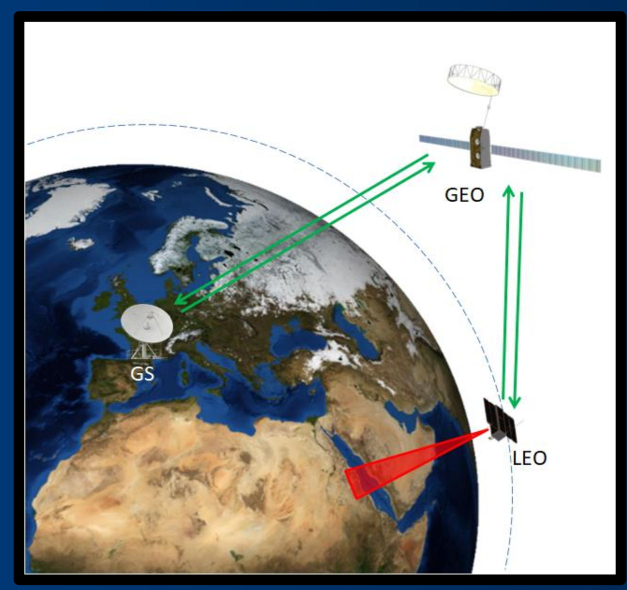
- ~200kg smallsat
- Optical VIS (RGB, PAN) and NIR payload
  - **VHR @0.5m native**
- Agile (stereo, rapid multi-pointing)
- Low cost
  - Hybrid COTS-RHAD architecture
  - **Insight4EO** used as Intelligence & Payload processing unit
- **Highly responsive (< 10 min) globally**
  - Global product latency <5 minutes (<1 min priority)
  - Global tasking < 5 minutes
  - Direct product delivery
- Intelligent
  - On-board re-planning
  - On-board payload processing
  - On-board data prioritisation



Responsive FS-GS Architecture

CONTINUOUS REAL-TIME MONITORING

- Existing classical EO architectures are limited. Three basic problems arise that limit responsiveness:
  - Time for satellite tasking (uplink)
  - Time to arrive at the ground station for up/downlink
  - Time for data download
- Constellations of "intelligent" autonomous small-sats with on-board processing and global comms links, offer a promising low-cost solution
  - Allows for continuous detection and monitoring of events in real-time
  - Can be deployed globally or regionally
- SAT4EO+ employs a **Global persistent comms link** & an **On-board processing & intelligence unit Insight4EO** for real-time tasking and direct product delivery, exploiting the heritage from [3]



On-Board Processing & Intelligence Architecture

SAT4EO+ employs a **complete on-board processing and intelligence architecture** to enable the responsiveness of the mission, for real-time rapid tasking and EO product delivery.

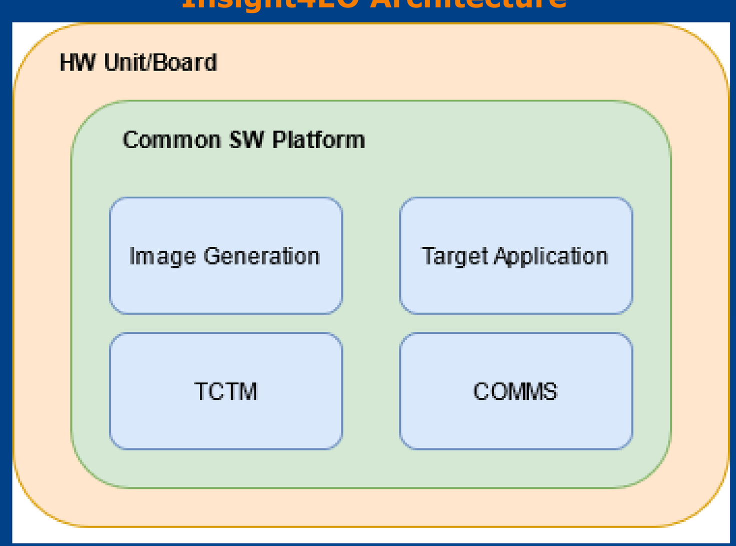
DEIMOS' proprietary on-board processing and intelligence HW/SW product **Insight4EO** is employed to perform the on-board processing tasks, embedding Artificial Intelligence (AI) and Machine Learning (ML) algorithms and applications for:

i) **on-board processing of the VHR optical payload** to L1B/C, generation of on-board cloud and land-sea masks, generation of higher level EO products for e.g. object detection/classification and data prioritisation

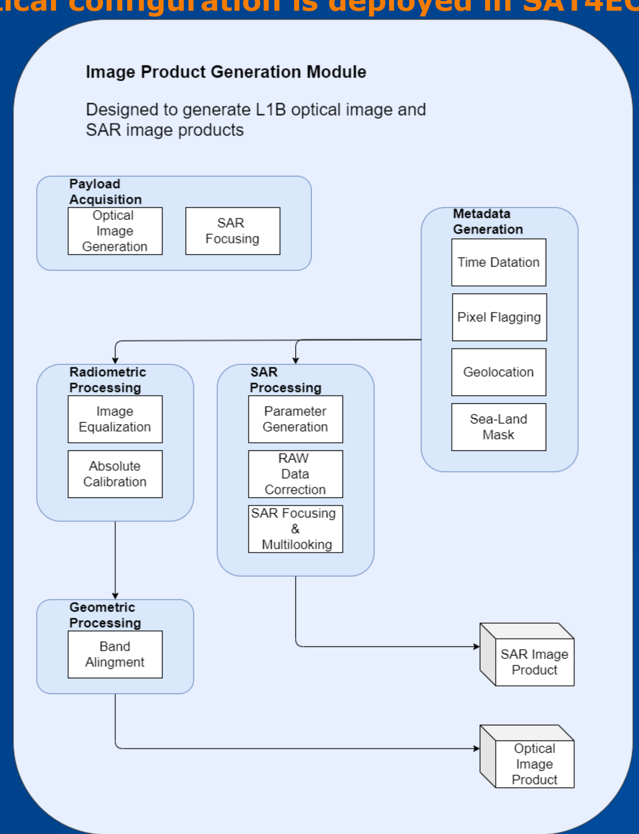
ii) **autonomous re-planning of the short-term tasking** of the satellite for payload acquisitions, based on the real-time reception of priority tasks and the evaluation of status and success of planned tasks

iii) **re-configurable data handling,** to prioritise the generation and transfer of priority products through the processing chain, expediting the deliver to the End User

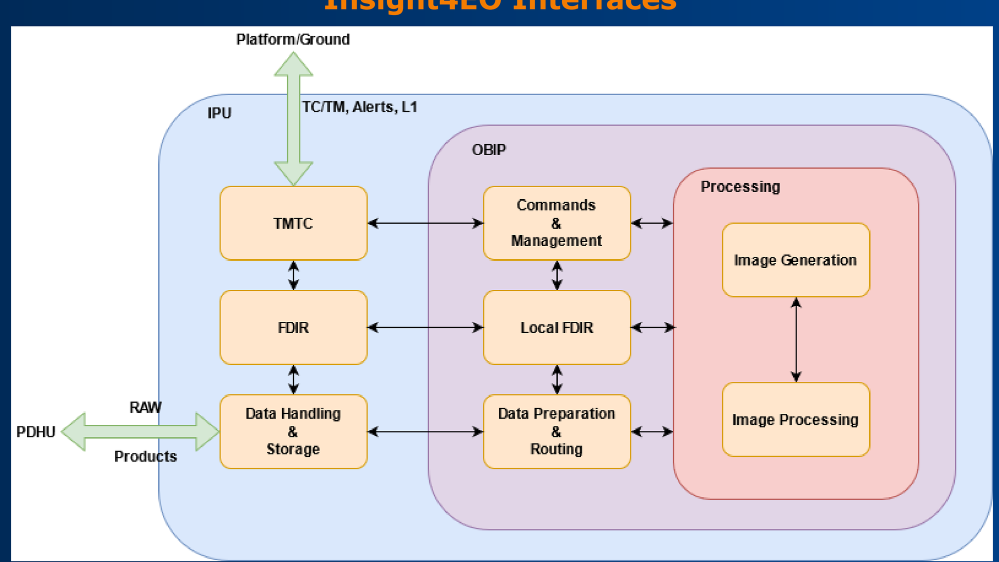
Insight4EO Architecture



Insight4EO L1B/C processing chain: only the optical configuration is deployed in SAT4EO+



Insight4EO Interfaces



Very-Low-Latency Products

To meet demanding customer needs for real-time EO product services, the on-board processing chain of SAT4EO+ includes APIs for a variety of mission products. Here the performances for **ship detection** are shown, for a service similar to the EMSA VDS product.

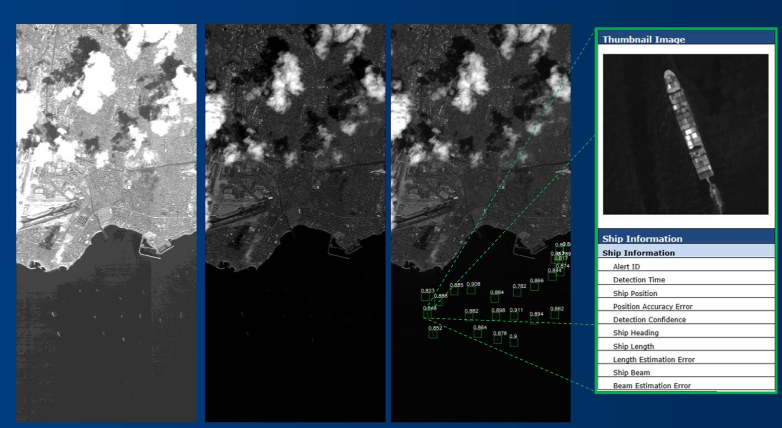
In this scenario, the on-board processing chain priorities the generation of the ship detection product on-board the spacecraft, its encryption, and transfers it directly to the end user using a GEO-relay service.

Here testing using DEIMOS-2 imagery is shown, from the raw data through to the L1B product, and the VDS-like product generation in the ship alert, comprised of the ship image thumbnail and the supporting metadata. Detection is performed using a trained ML/AI classifier.

On-board processing latency is below 1 minute

Global communications latency is below 30 seconds

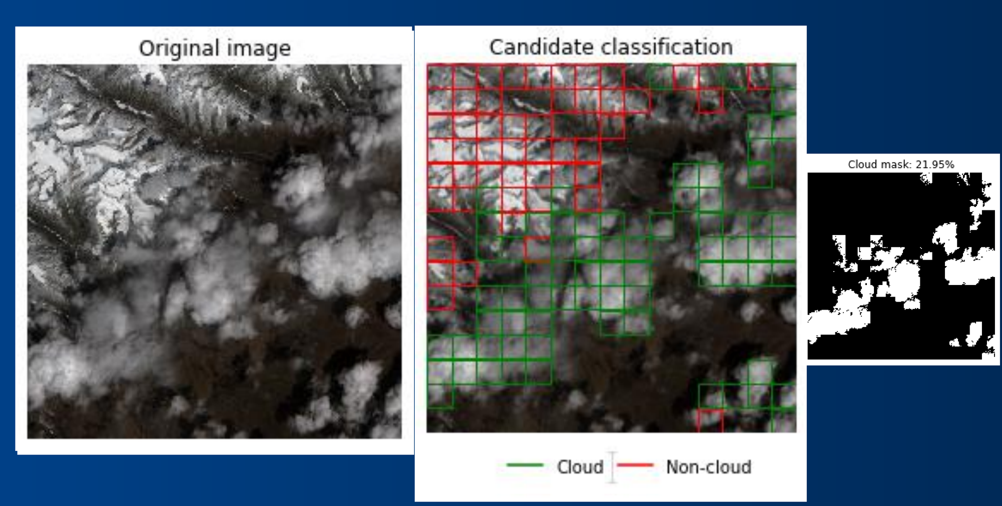
Total **product latency is below 1.5 minutes globally**



Data Prioritisation

To reduce data downlink volume, and **maximise the duty cycle and hence throughput of the mission (ROI),** all images are processed on-board to L1B including cloud mask, which is used to selectively download the data based on the % of cloud cover

Given the use of an optical payload with RGB-NIR channels, the distinction of cloud-ice-snow is not trivial as shown in this example. A **ML/AI trained classifier** is used to achieve the required performances and robustness



Summary

The SAT4EO+ satellite provides for a low-cost high-performance 0.5m native optical service for Earth observation. The satellite cost and design allows it to be employed in constellation for an innovative and responsive EO service provision. The satellite is currently in a pre-PDR status, with several critical elements under development at CDR status.

On-board processing and intelligence is a key capability of the SAT4EO+ satellite. It is provided by DEIMOS' proprietary Insight4EO HW/SW turnkey product, which when employed in combination with a global GEO-relay persistent communications unit and service, enables a responsive global EO service.

References

1 https://elecnor-deimos.com/sat4eoce/

2 "Overview of ESA's Earth Observation upcoming small satellites missions", AIAA/USU Conference on Small Satellites, 2020.

3 Kerr et al., (2019). EO-ALERT: A Novel Flight Segment Architecture for EO Satellites Providing Very Low Latency Data Products, Earth Observation Φ-week, September 2019, ESA-ESRIN. Frascati (Rome)

Acknowledgements

The SAT4EO+ satellite programme is supported by the Spanish CDTI through ESA GSTP funding and Spanish, UK and Romanian funding through the ESA Incubed framework. The support of the national delegations and ESA is greatly appreciated in both the SAT4EO System Engineering and Technology Prototype (GSTP) and SAT4EOCE contracts.

Small Satellite Conference
Virtual Event
7-12 August 2021

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