



Instantaneous Infrastructure Monitoring by Earth Observation: SAR-based railway obstacle detection

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INTRODUCTION

Motivation

- Critical human infrastructures like transport of goods/people or energy and water supply are the lifelines of our globalized society. Given the typical **large scale** and complex structure of such **infrastructural networks**, the task of keeping them functioning and efficient is only possible through **constant monitoring**.
- Currently, this demand is met by a variety of services, including sensor networks or on-demand/manual airborne/drone monitoring. These processes are **costly**, difficult to implement in remote areas and **poorly scalable**.

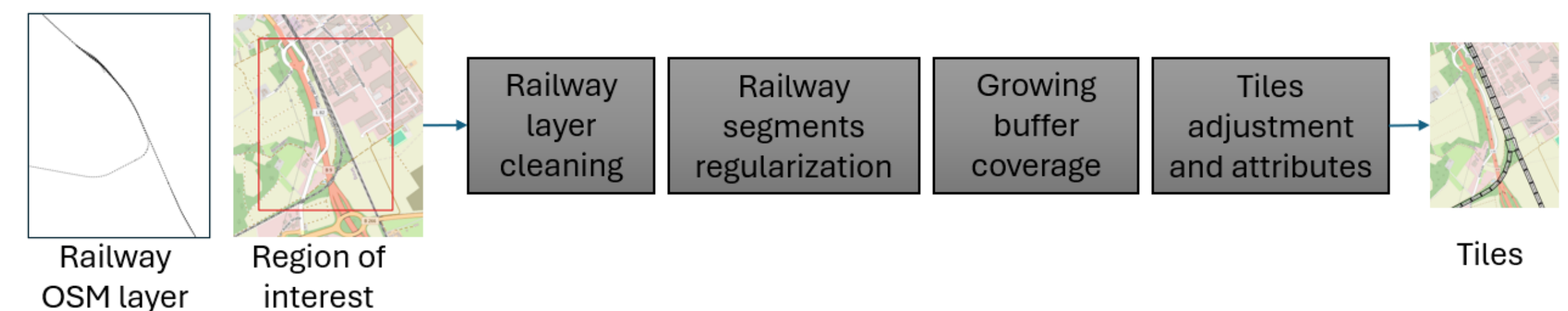
Objectives

- Design, implement and **demonstrate** key technological factors of a future **satellite-based EO system** capable of providing functions necessary for **instantaneous monitoring** of infrastructures in near real time.
- On-board both **SAR** (Ka-band) and **VIS** sensors and implementation of an end-to-end pipeline to support **image** acquisition over the targeted infrastructure, **multitemporal** analysis oriented to **obstacle detection** and geo-localization of potentially interrupted spots.
- Pilot case:** near real-time monitoring of **railroads** to secure a continuous service with only very short interruptions in the case of disasters.

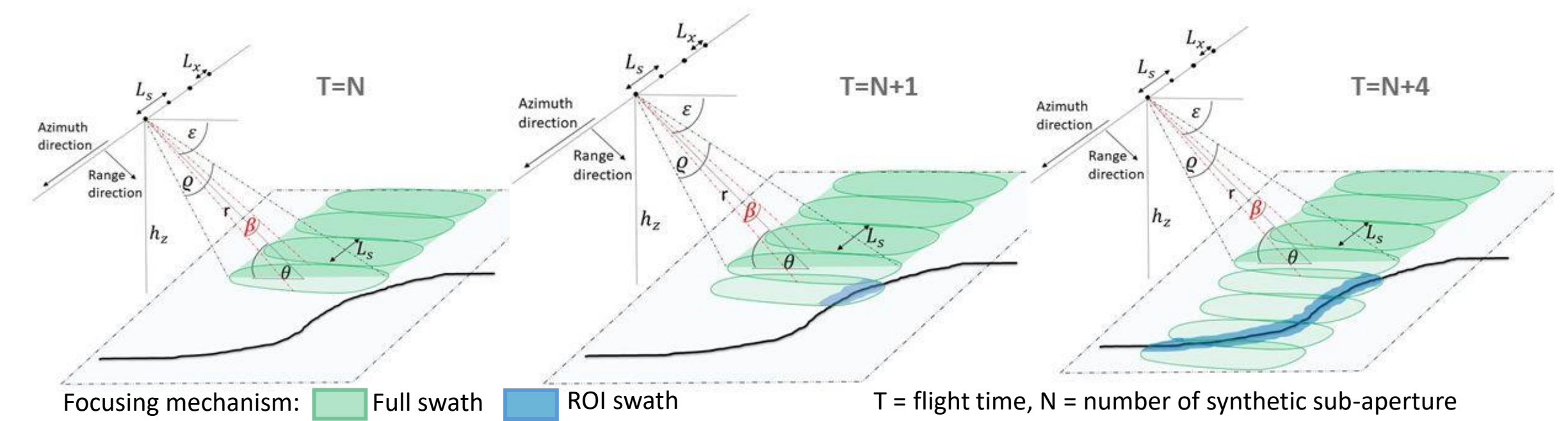


SAR OBSTACLE DETECTION

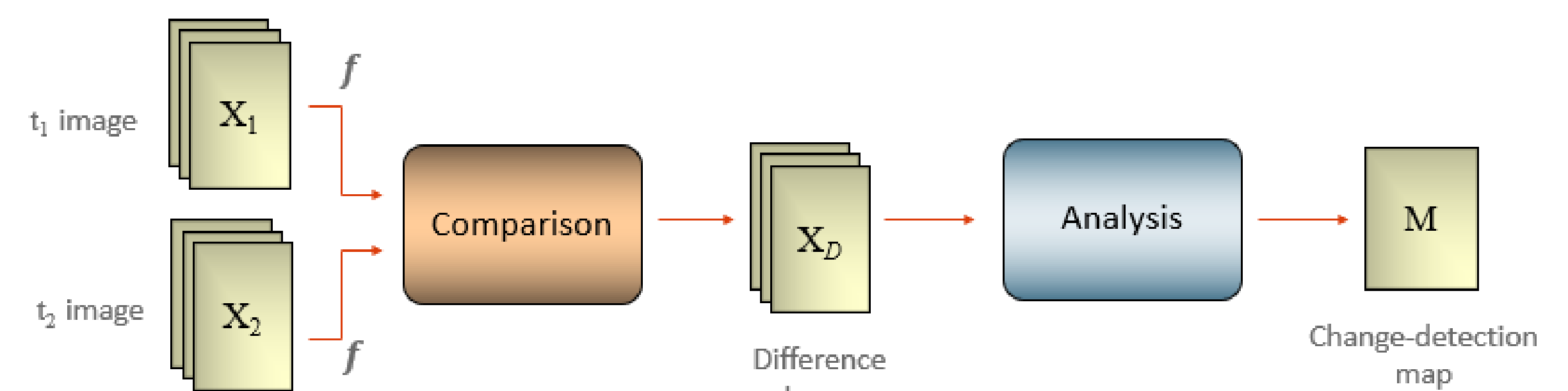
The IIMEO processing nodes to achieve SAR-based obstacle detection on railway tracks are essentially three:



Tiling algorithm: takes as input a railway geodata file and the geometry of the region of interest (ROI), within which the tiles must be generated, and returns a geometry collection of tiles (rectangle polygons) that cover the railway infrastructure.

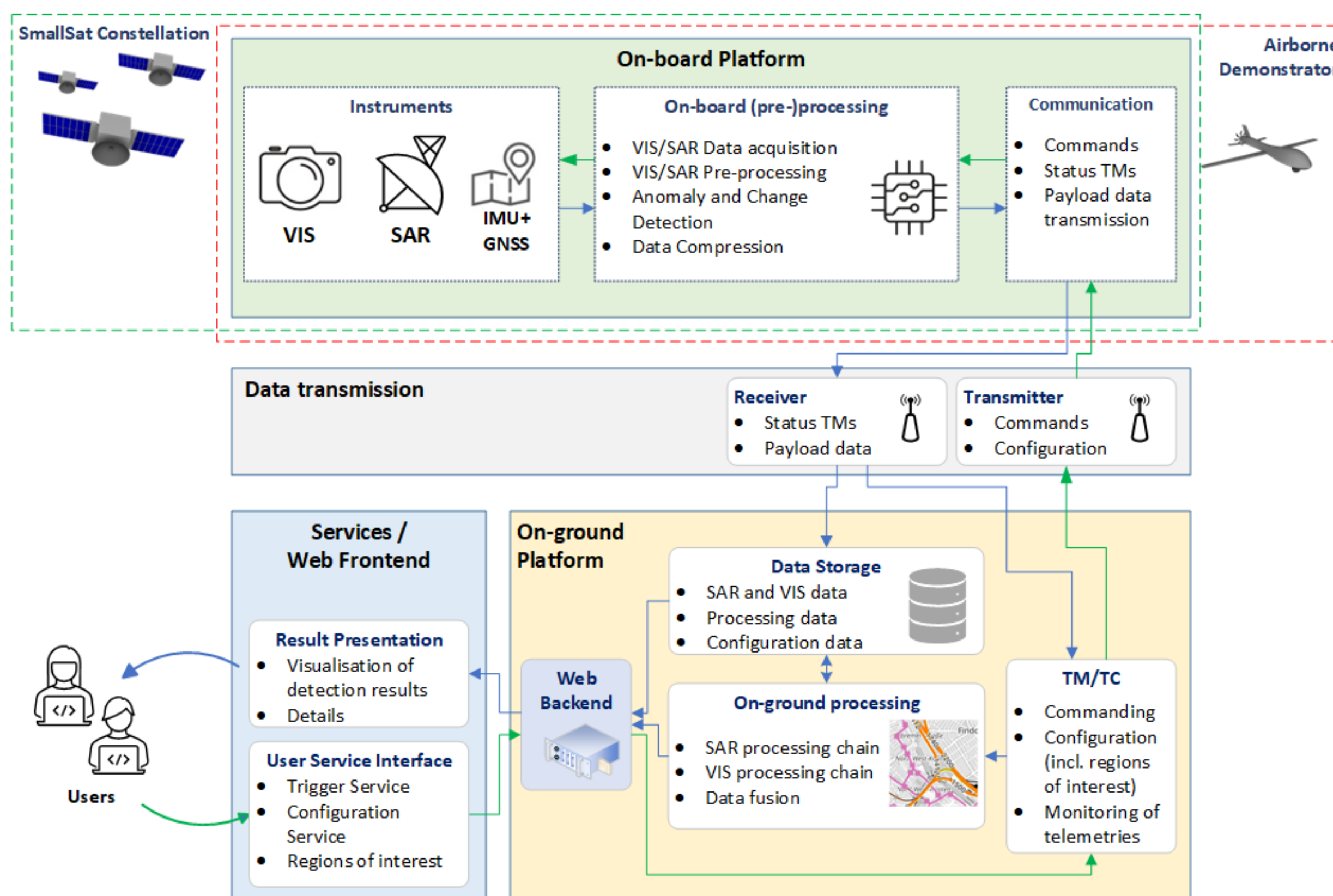


SAR focusing algorithm: SAR images are focused in hybrid-stripmap mode only over the tiles extension. Compared to a full-swath mode this implies a significant reduction of computational burden.



Change detection algorithm: Changes in SAR amplitude images are usually identified as significant variations in the backscattering values recorded at different times at the same spatial locations.

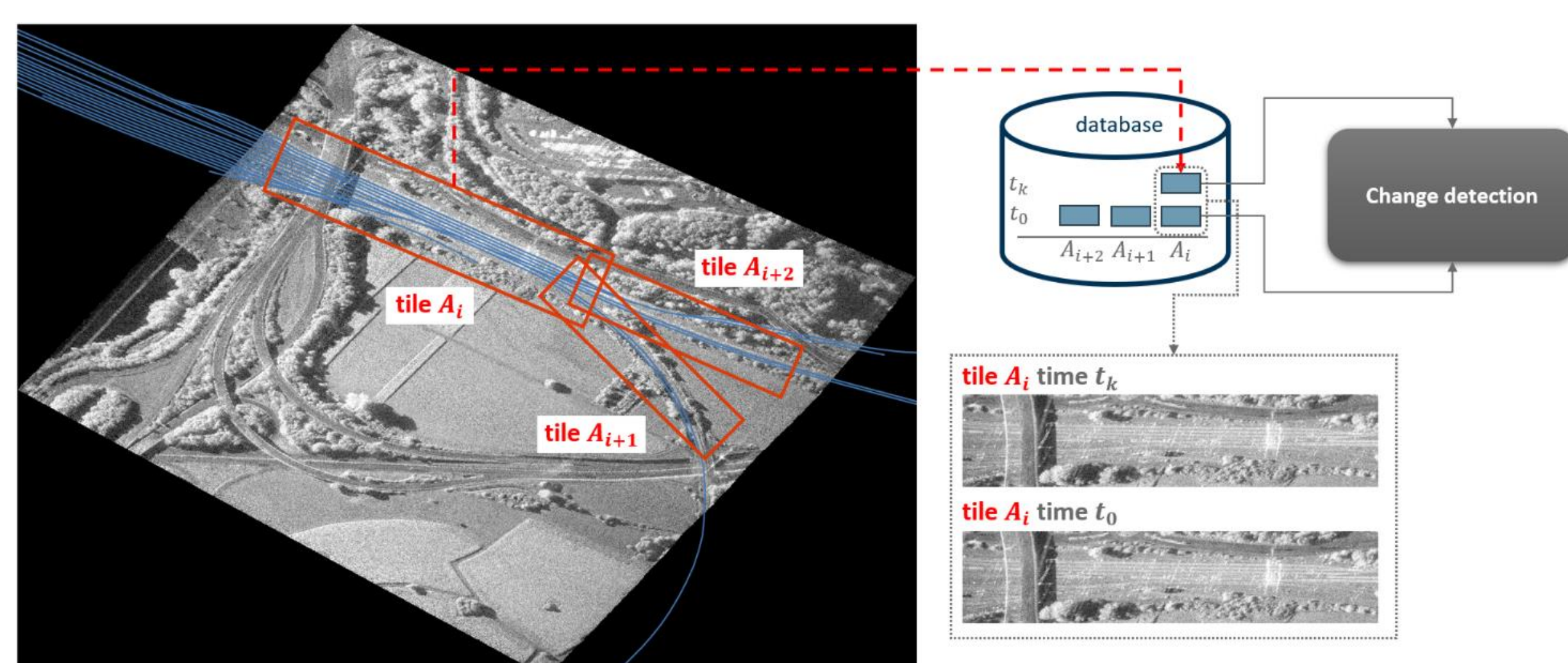
OVERALL SYSTEM AND TECHNOLOGY



The on-board platform represents the IIMEO payload units integrated on the **airborne demonstrator** (as well as on the satellites of the future IIMEO SmallSat constellation). It includes instruments, processors and communication hardware:

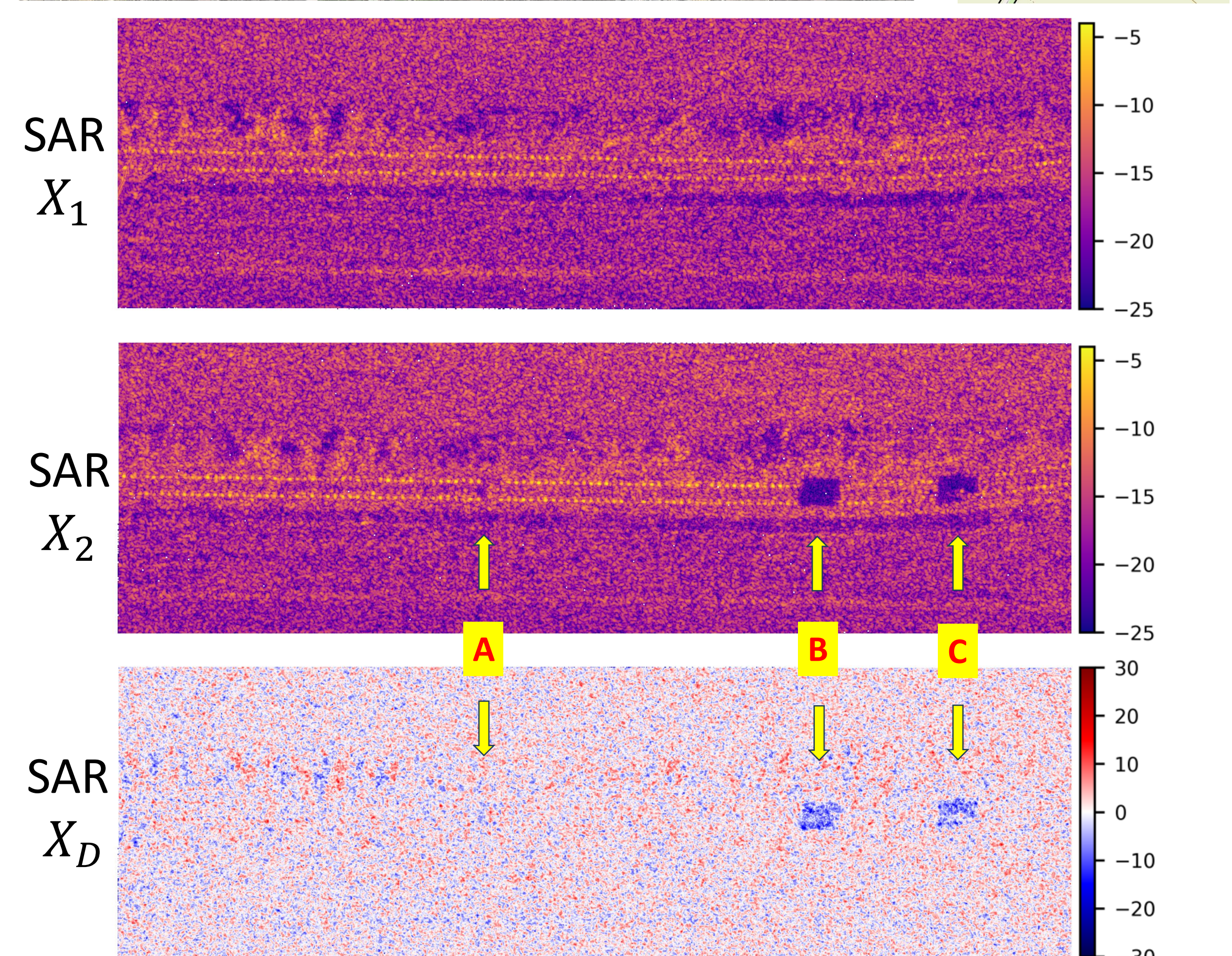
- MIRANDA Ka-band FMCW SAR sensor and processing hardware.
- Oblique and Nadir VIS cameras and processing hardware.
- On-board AI-based processing unit.

TILED DATA STRUCTURE



- The necessity of providing change information in near real-time has brought to a **design of the SAR** image acquisition system which is **target-oriented** and structured for the obstacle detection application.
- Images shall be acquired **only on the surrounding** area of the railway infrastructure following an a-priori spatially defined scheme fragmented into **tiles** to allow for confrontation with base information at every temporal instance during the service.

FLIGHT CAMPAIGN



- First flight campaigns in Germany aimed at **tuning** and **testing** the optimal **SAR parameters** like depression angle, ground spatial resolution, carrier frequency, flight altitude and power.
- In the first three **flight campaigns** the most successful acquisitions are obtained with 40° depression angle and 20cm ground resolution.
- In Ka-band, at ground spatial resolution 20-40cm, both sleepers and the rails are invisible. The only **railway component** that can be **detected** structurally and coherently from any looking angle (this is relevant, because the railways may appear to the sensor with various looking angles) and in different spatial configurations is the **rail fastening system** (see X_1 and X_2). Solid panels (obstacles B,C) are well detected, while tree trunks are difficult to detect (obstacle A).

ABSTRACT

The objective of the Horizon-Europe project "Instantaneous Infrastructure Monitoring by Earth Observation (IIMEO)" is to design, implement and demonstrate key technological factors of a future satellite-based EO system capable of providing functions necessary for instantaneous monitoring of infrastructures in near real time.

The system will implement a tiled acquisition of multitemporal Ka-band SAR images over a railway infrastructure and perform near real-time change-obstacle detection at every new acquisition within one hour after the satellite passes over the area. The tile-based obstacle change-detection multitemporal system is explained in detail.

CONSORTIUM



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