IRSC 2022

INTERNATIONAL RAILWAY SAFETY COUNCIL

SEVILLA, OCTOBER 16-21, 2022

MIRKO ERMINI

Innovative Research – Research&Development

Rete Ferroviaria Italiana

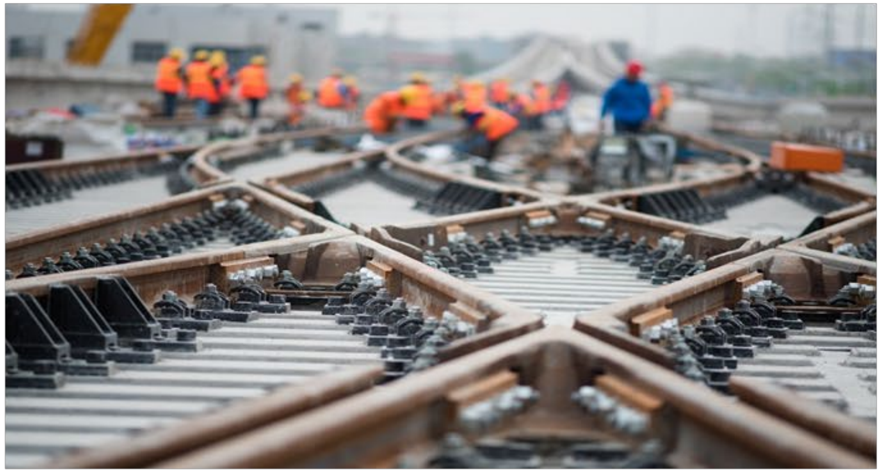
Satellite monitoring of the railway infrastructure

RFI's ongoing projects

Rete Ferroviaria Italiana

Company overview

Rete Ferroviaria Italiana (RFI): the national railway infrastructure manager



KPI AND SUSTAINABILITY

- **RAILWAY NETWORK**: ~ 16.779 km (34% in the South)
- **STATIONS**: ~ 2.200
- **WORKS OF ART**: ~ 8.000 bridge- overpass, ~ 1-700 tunnels
- **GOODS PLANTS**: ~ 207
- **LINES with TRAIN CONTROL SYSTEM**: 100%
- **ELECTRIFIED LINES**: ~ 72%
- **INVESTMENTS**: 4,5 mld
- **OPERATING REVENUES**: ~2,8 mld
- **NET INCOME**: ~0,3 mld
- **NET INVESTED CAPITAL**: ~36,2 mld
- **TRAINS.KM PRODUCED**: ~ 0,4 mld
- **EMPLOYEES**: ~ 26.000
- **ACTIVE SUPPLIERS**: ~ 8.000

OUR MEDIUM-LONG-TERM GOALS COMMON TO THE WHOLE FS GROUP ARE:

Energy and emissions	***Carbon Neutral*** *by 2050*
Sustainable Mobility	***Passengers****: **5% modal shift** from private car to public and soft shared mobility by 2030 (15% in 2050), compared to 2015*
	Goods*: 50% road transport and 50% train transport by 2050 (routes> 300 km)*
Safety	*Best in class in Europe. Vision:* ***zero Fatal Events*** *by 2050*

Rete Ferroviaria Italiana (RFI): the national railway infrastructure manager

Other stakeholder

No user

TRAVELERS

Non-user requests to choose the train: (survey 2018)

- Parking facilities at the station
- Bus timetable coordinated with trains
- Shuttle service to the station
- Reduction of delays risk
- Greater safety, decor and cleanliness

User

PEOPLE WITH REDUCED MOBILITY

- 14 SALE BLU
- 280 stations with PRM services
- 410.000 services provided up to 2021
- 98,5% fully satisfied

Expectations of PMR travelers (survey during 1° lockdown 2020):

- «rapprochement» relational and physical
- differentiation of the assistance service based on the type and severity of the disability
- more digital reservation/information tools for greater autonomy
- strengthening of operators' skills (i.e. LIS)

ASSOCIATIONS AND REPRESENTATIVE ORGANIZATIONS

- Socio-economic value for the territory

NATIONAL AND INTERNATIONAL SECTOR ASSOCIATIONS

Istitutional subjects

MIMS

- Investment planning

MEF

- Resource planning

ART

- Regulatory regime

ANSF

- Safety of people, plants and on work

Applicants

RAILWAY OPERATORS

- Railway network resilience
- Quality of service

REGIONS

- Investment planning

LOADERS

- Intermodality

FORWARDERS

- Intermodality

COMBINED TRANSPORT OPERATORS

- Intermodality

SUPPLIERS

- Supply chain sostenibile

EMPLOYEES

- Ethics and integrity
- Fair and inclusive workplace
- Safety of people, plants and on work

COMMUNITY AND TERRITORIAL INSTITUTIONS

- Protection of the territory
- Sustainable development of the network and territory

EUROPEAN COMMISSION INTERNATIONAL IG

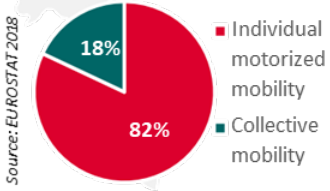
- International traffic with dedicated hubs

LISTENING TO THE NEEDS OF THE VARIOUS STAKEHOLDERS ALLOWS TO VIRTUOUSLY IMPROVE THE LINES OF ACTION FOR THE DEVELOPMENT OF THE INFRASTRUCTURE.

Rete Ferroviaria Italiana (RFI): the challenges

Transformation of mobility needs and **imbalance between public and private transport.**
Poor preference of people for railway services with expectations of greater **reachability and accessibility** on **stations** in the metropolitan and internal areas, serving all travelers starting with those **with disabilities** and reduced mobility (**PRM**).

Passengers mobility in Italy



Presence of a **gap in railway connectivity** in terms of integration between the various mobility systems and **inhomogeneity** in the performance levels of the lines and railway networks in the different areas of the country, with particular attention to the **safety**.

Progressive evolution of the **unique European railway area** and the regulatory context to promote **interoperability**, **competition** and **cooperation** between infrastructure menagers for the **modal shift** in the transport of people and goods and the **elimination of CO2 emissions**.

Increasing the role of **integrated sustainability and technological innovation** for the fair and durable competitiveness of the country and the development of a **new energy efficient and low environmental impact mobility system** as a lever to increase the **quality of life.**

Urbanization dynamics, growing impacts of **climate change and fragility of the territory**, with sudden and destructive events that require a continuous effort for the protection and resilience of the infrastructure and for the conservation of the territory.

New awareness, induced by the health emergency, **of the urgency of ecological transition** to contain the risk of irreversibility of the alteration of the global ecosystem and the increase in inequalites.

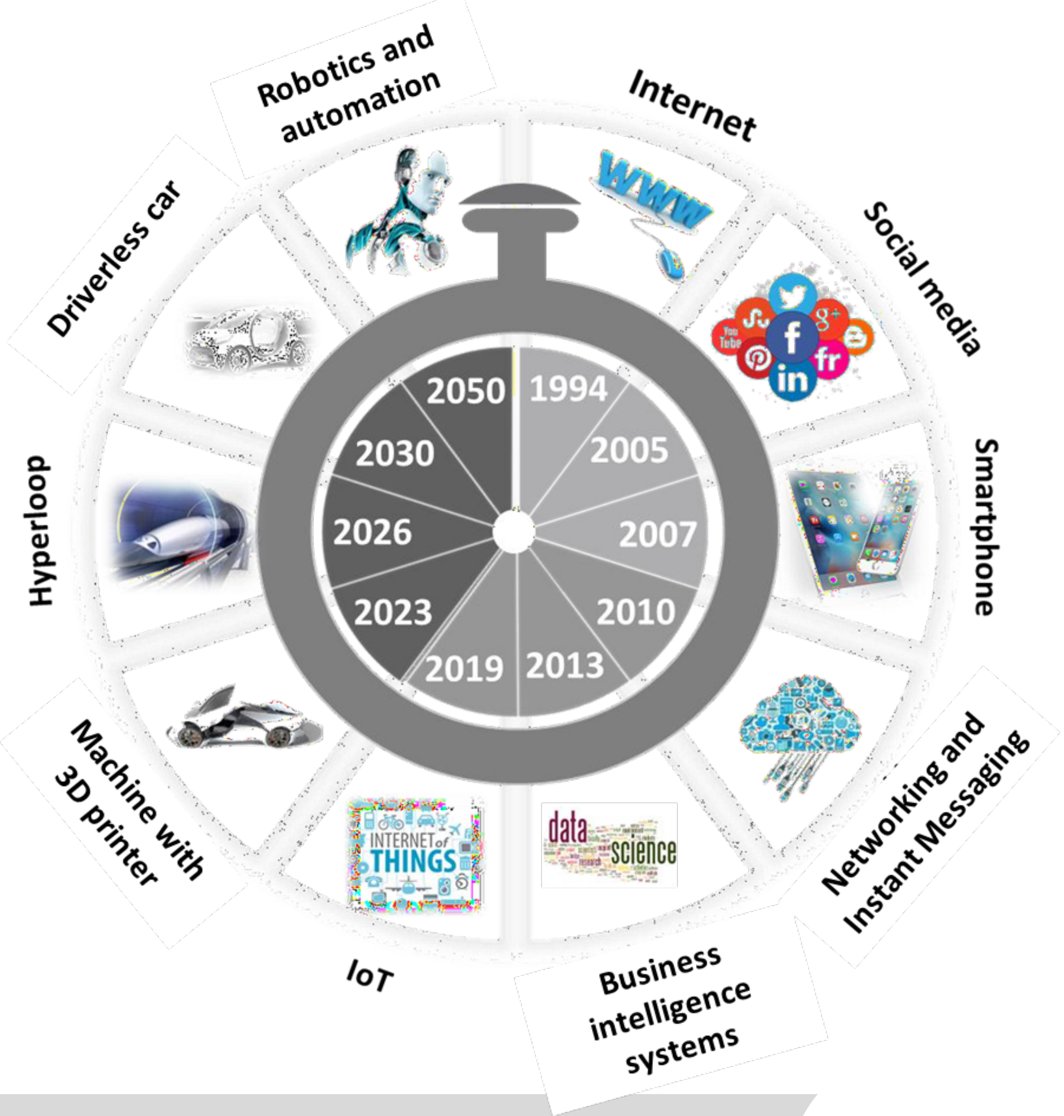
Rete Ferroviaria Italiana (RFI): the national railway infrastructure manager

*«In our **investment processes**, we look at **sustainability** issues that can **contribute to the company's long-term financial performance**»*

(Larry Fink - CEO BlackRock)

The new paradigm of financial competition is no longer based only on the **amount of available capital** but on the amount of **time available for development and adaptation to new technologies for environmental sustainability**.

Radical phenomena of technological innovation that will revolutionize lifestyles, production and work are already underway. Some macrotrends such as energy and sources of supply, digitization and automation, urbanization and new trade routes will become reality soon.



Infrastructure monitoring from satellite

Research project and goals

IRSC Spain

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EUROPEAN UNION AGENCY FOR RAILWAYS

AESF AGENCIA ESTATAL DE SEGURIDAD FERROVIARIA

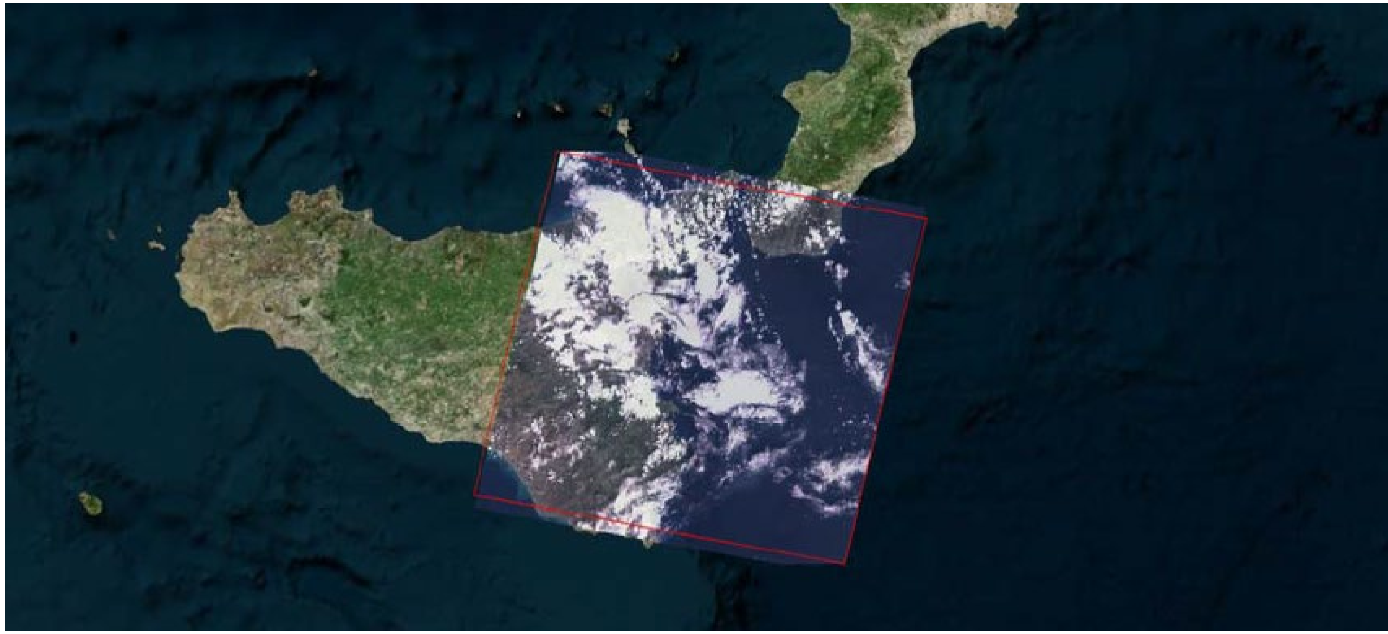
adif

RFI

Research project and goals

- To implement a satellite applications platform aiming to provide the final user with a **highly automated** system able to process and send **information extracted from long time series of satellite images** and to **support the decision-making chain** regarding the monitoring and management of the railway infrastructure.

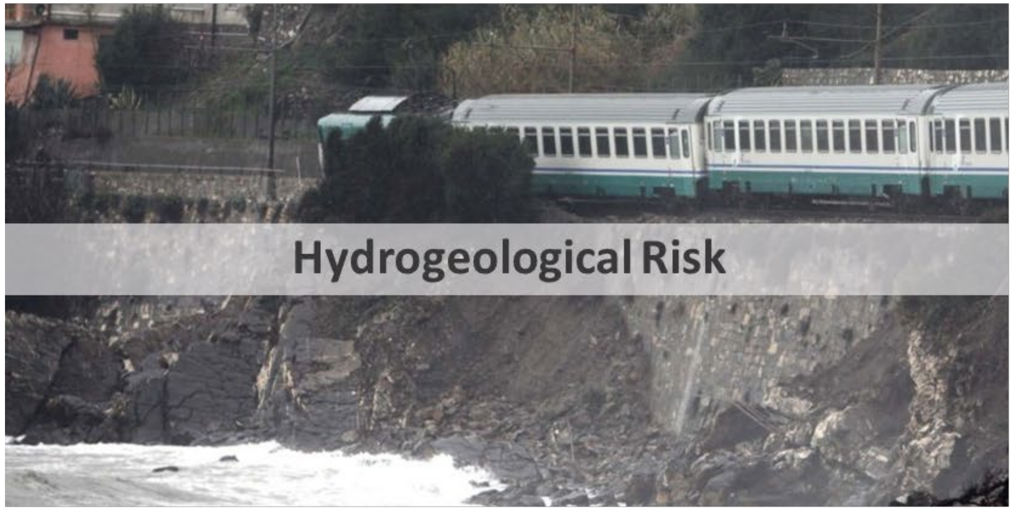
- The service can be activated on commercial data with higher spatial resolution (**up to 1 m**). This option would allow the monitoring of detailed areas close to specific infrastructures.



Research project and goals

- The satellite technologies currently on the market allow for **continuous and extensive monitoring of the territory** with such performance as to apply them even in the railway context.
- The development of applications capable to **integrate the satellite images with the latest objects identification techniques** based on AI (Artificial Intelligence) makes it possibile to use them also with a **predictive approach** towards any dangerous situations.
- The platform shall include:
  - **Monitoring,** of hydrogeological and anthropogenic hazards,
  - **identification** and, therefore, **prevention** of these, with the aim of ensuring efficiency and safety for traffic on its railway network.
- These hazards raise the need to develop satellite-based technologies capable to detect landslides, flooding, and other risky situations using **SAR** and **multispectral images** acquired from a satellite constellation.

Satellite inspection - Use cases

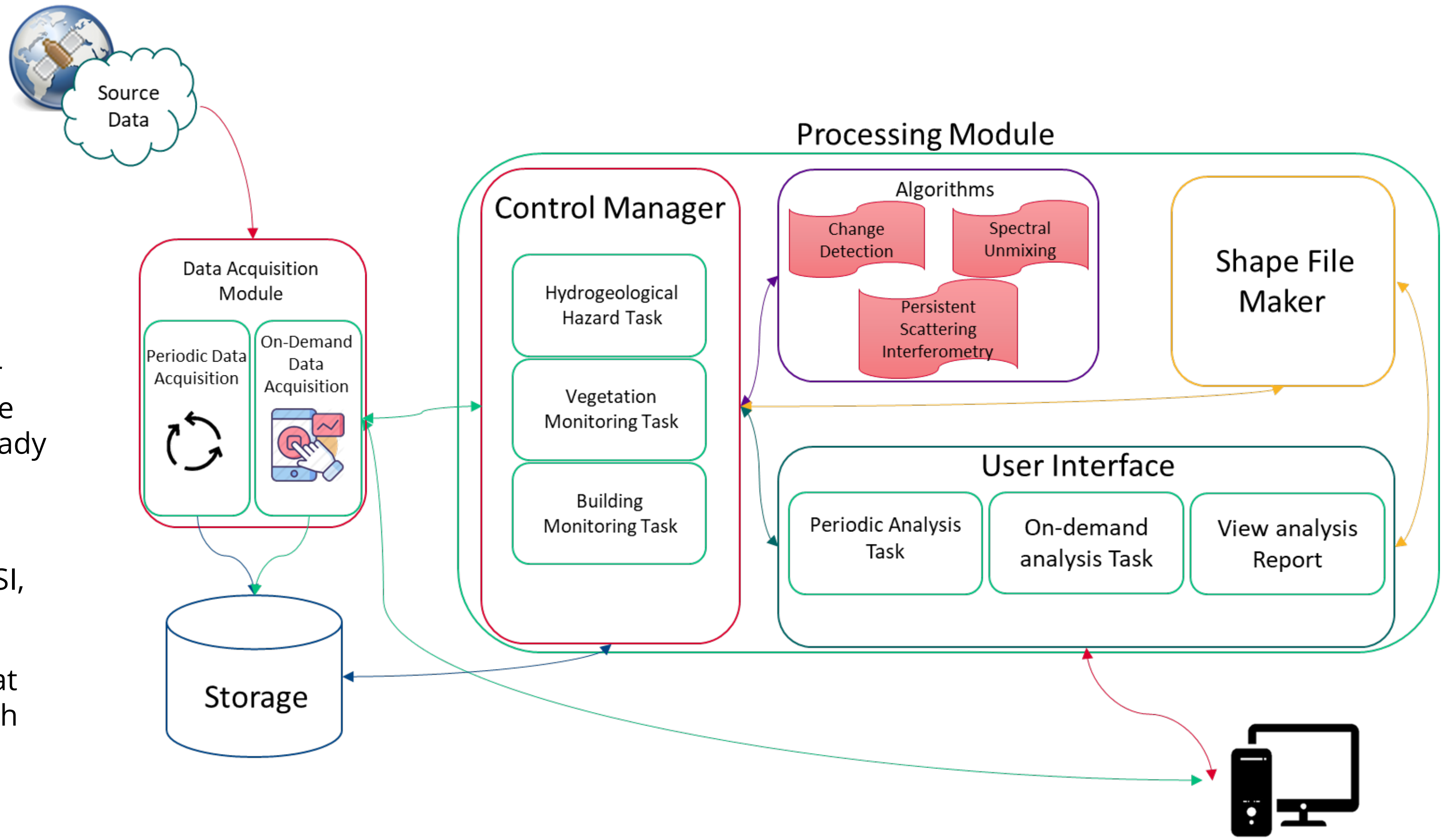


Proposed solution

System architecture and algorithms

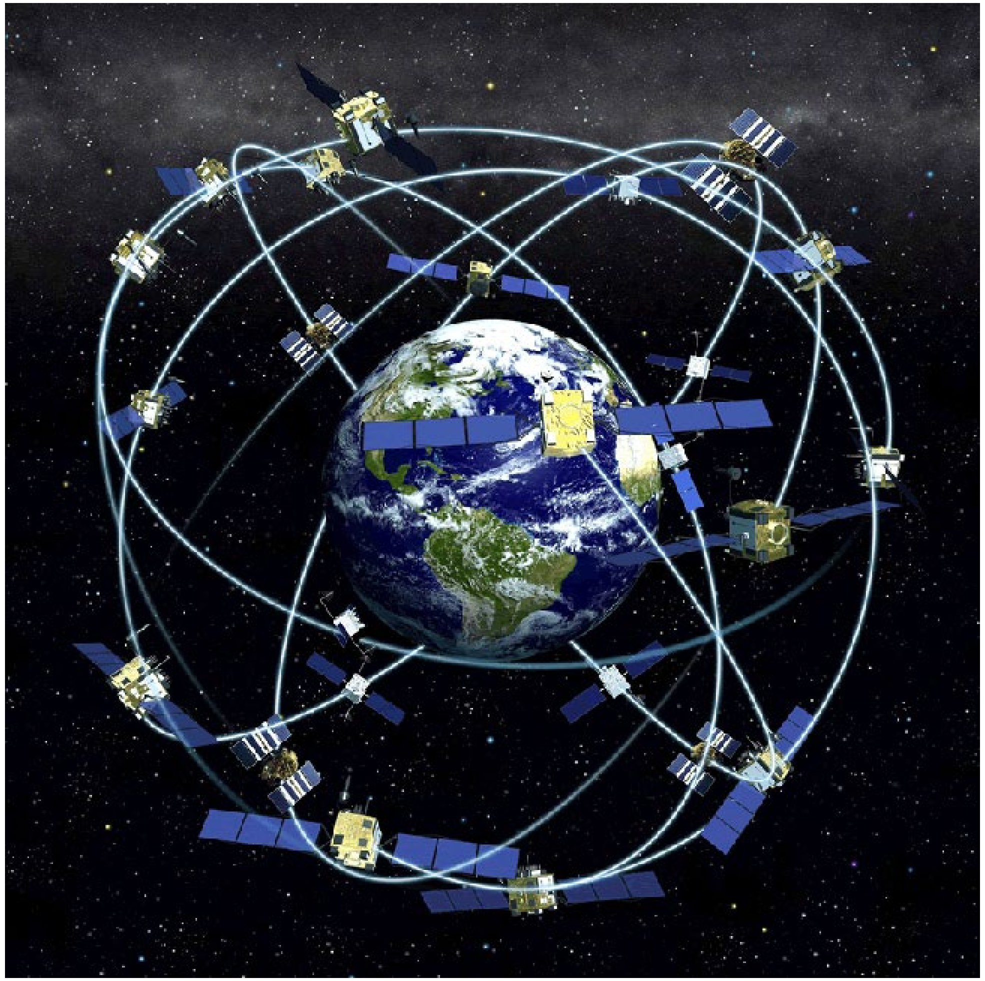
System architecture

- The functional blocks are:
  - **Data Acquisition Module**: provides access to databases containing satellite images of the various constellations and acquires the images useful for carrying out the required analyzes.
    This module shall have two methods of access:
    - **Periodic:** to acquire the images useful for the "On Time" Monitoring function;
    - **On-demand**: to acquire the images useful for the "On Demand" Control function, in case the user wants to select a specific image, not already included in the periodic acquisitions.
  - **Algorithms**: This is the module containing the implementation of artificial vision algorithms (e.g. PSI, Change Detection, Spectral Unmixing).
  - **Control Manager**: represents the software layer that coordinates the different modules of the system with each other to complete the required functionality.
  - **User Interface**: data analysis report, visualization services, raw data visualization, user-friendly interface.



Satellite constellations

- In particular, the space missions of our interest are:
    - The **Sentinel-1** mission (ESA) comprises a constellation of two polar-orbiting satellites, operating day and night performing C-band synthetic aperture radar (SAR) imaging, enabling them to acquire imagery regardless of the weather.
    - The Copernicus **Sentinel-2** mission comprises a constellation of two polar-orbiting satellites placed in the same sun-synchronous orbit, phased at 180° to each other. It aims at monitoring variability in land surface conditions, with high revisit time: 10 days at the equator with one satellite, and 5 days with 2 satellites under cloud-free conditions which results in 2-3 days at mid-latitudes.
    - **Landsat-8** is an American Earth Observation satellite. Providing moderate-resolution imagery, from 15 to 100 meters, of Earth's land surface and polar regions, Landsat 8 operates in the visible, near-infrared, short wave infrared, and thermal infrared spectrums.
    - **Plantescope** is a constellation of satellites that allows the acquisition of images with a much higher spatial resolution but a very reduced spatial coverage.



Algorithms

- Data acquired from different constellation of satellites is processed using techniques such as **Persistent Scatterer Interferometry**, **Change Detection** and **Spectral Unmixing**. The artifacts obtained at this stage are: vegetation indices, change detection maps and abundances maps.
- Results from the **neural networks** are post-processed until we obtain a **vegetation map**. In addition, if the user wants to perform more precise analyses, it is possible to use the images obtained from **PlanetScope**.

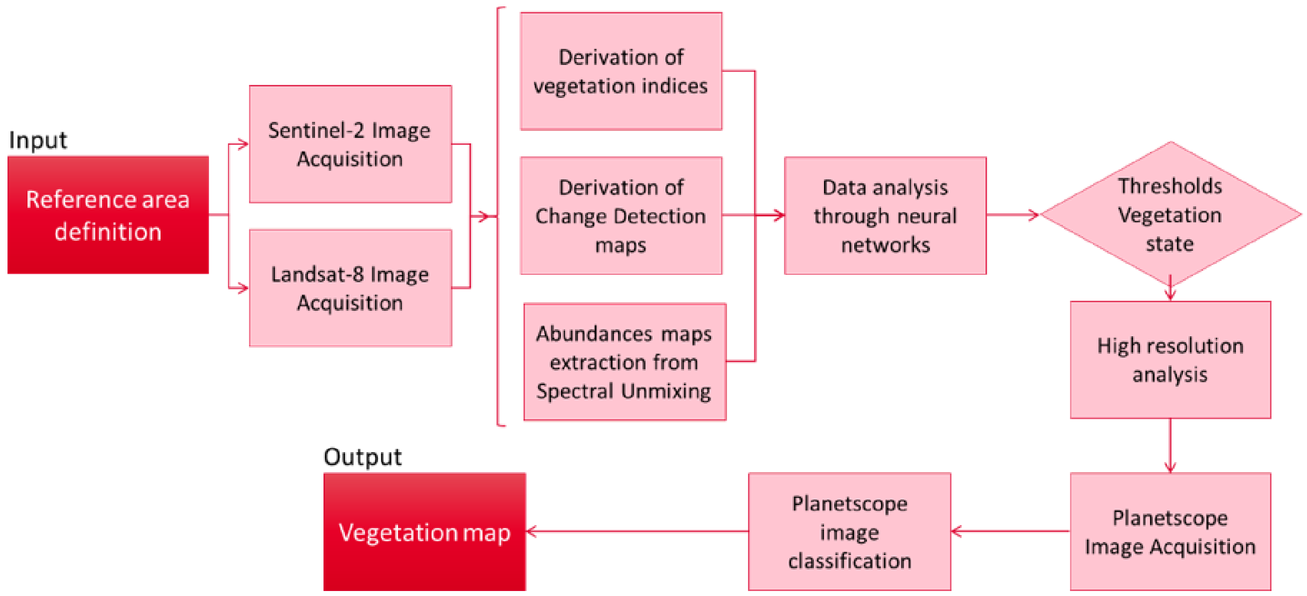
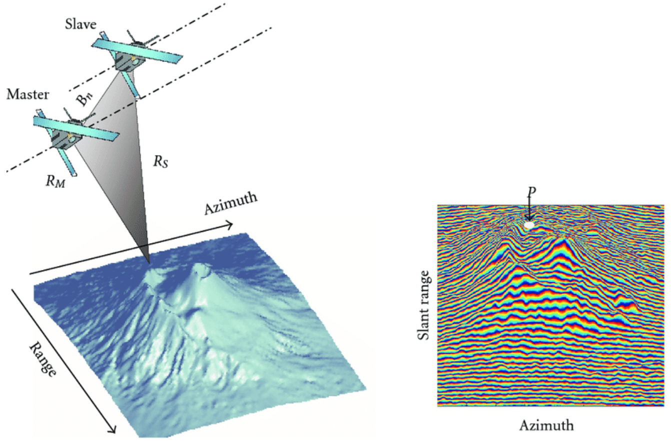
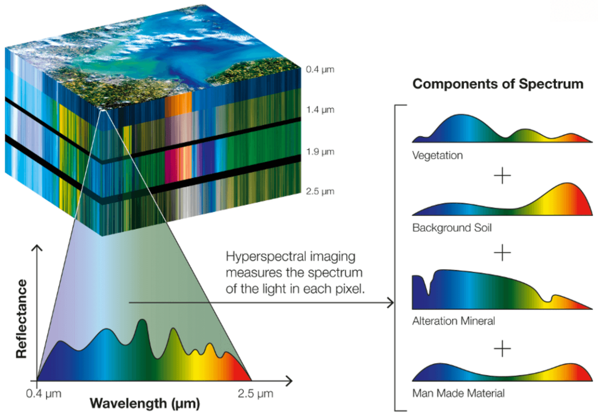


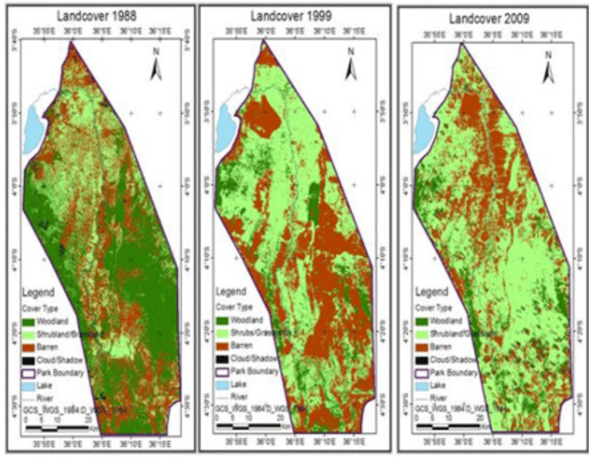
Figure 2 Algorithmic Approach for Vegetation Monitoring

Image Processing Techniques

- The techniques used for processing these images are:
  - **Persistent Scatterer Interferometry (PSI)** is a powerful remote sensing technique able to measure and monitor displacements of the Earth's surface over time. Specifically, PSI is a radar-based technique that belongs to the group of differential interferometric Synthetic Aperture Radar (SAR).
  - **Change Detection** can be defined as the process of identifying differences in the state of an object or phenomenon by observing it at different times. This process is usually applied to earth surface changes at two or more times. The primary source of data is geographic and is usually in digital format (e. g., satellite imagery), analog format (e. g., aerial photos), or vector format (e. g., feature maps).
  - **Spectral unmixing** is a technique used to identify, within a complex satellite image, the set of components present within the single pixel. The process decomposes the spectral signature of a mixed pixel into a set of *endmembers* and their corresponding *abundances*. Endmembers are spectra of the pure materials present in the image and abundances at each pixel represent the percentage of each endmember that is present in the pixel







Expected results

“On Time” Monitoring

- Surface movements for the detection of landslides;
- Monitoring of known landslides;

- Vegetation growth alongside railway line
- Measure distances from the nearest rail track
- Presence of new buildings within 30 meters from the nearest rail track

- Control of rail tracks placed in difficult-to-reach areas

Control and Monitoring “On Demand”

- Flooding areas maps
- Flood risk scenarios

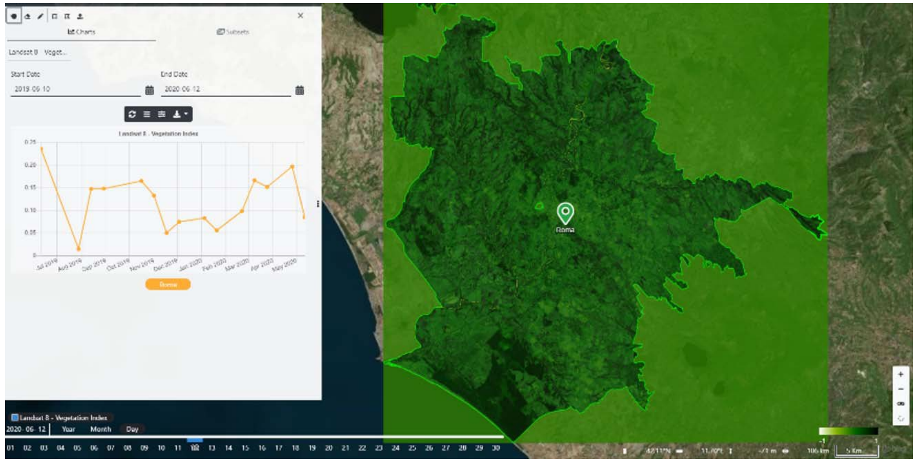
- Identification of vegetation type
- Tree height and encumbrance definition

- Monitoring of buildings already identified by other methods (art. 60 DPR 753/80)

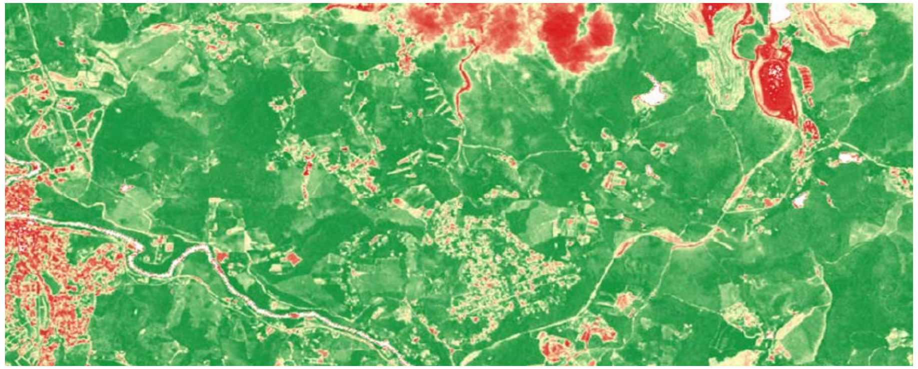
- Checks under critical conditions

Expected results

- **Vegetative cover monitoring** on a defined area of interest (for example regional/national territory). The service allows to create **vegetation coverage maps** from the Sentinel-2 platform on a weekly basis to evaluate the variation in the interest railway lines. Furthermore, it's possible to define variable **aggregation levels** (month, season, year).



- **Classification** of soil (Forest, Urban, Watersheds) and space/time monitoring of the classes (**floods, deforestation**). Land cover classification and monitoring of the **evolution of the classification** itself (Change Detection).
- **Monitoring of deformation and subsidence** of the soil in the selected areas of interest.
- Functions of **data aggregation** and **basic statistical extraction** such as, for example, temporal averages/cumulative values on a specific point/area, counting of particular events.

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