LEONARDO

Electronics

Helicopters

Aircraft

Cyber & Security

Space

Unmanned Systems

Aerostructures

Leonardo Electronics

La grande azienda come catalizzatore di opportunità sul territorio

Nuovi sensori elettro-ottici per minisatelliti e microsatelliti

Distretto Toscano dell'Aerospazio - Opportunità e Sinergie

Pisa, 15 Novembre 2022

Optical Payloads for Mini-Satellites

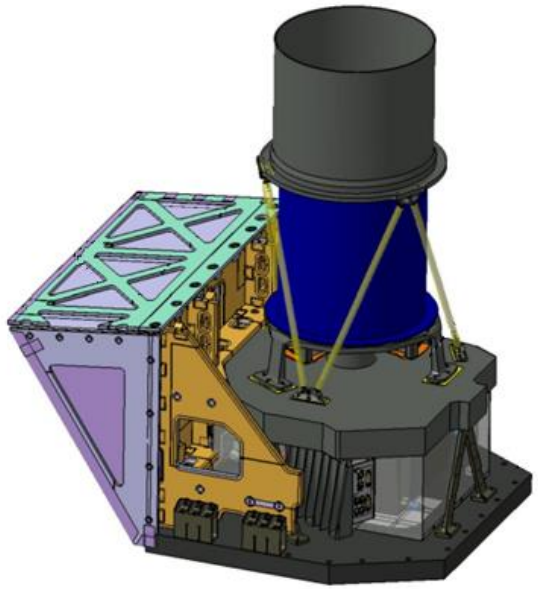
Sensori Ottici per Mini-Satelliti

Electro-Optical Earth Observation Systems for Remote Sensing applications

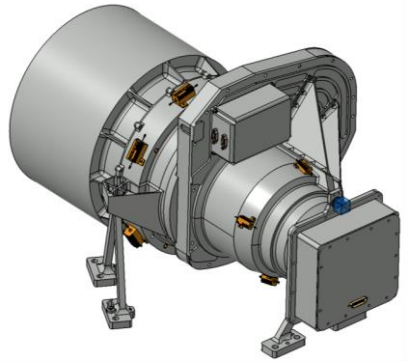
A suite of compact E-O Instruments is under development for employment in Mini-Satellite platforms.

Nowadays, the availability of quasi-real-time satellite imagery is key for strategic and persistent intelligence, tactical support and commercial operations.
Small Satellites, based on compact Optical Sensors, are affordable also for those Countries willing to implement a “National” solution dedicated to the surveillance of the territory, of the coasts, of the sea.

Compact Very High Resolution Camera



Compact Hyperspectral Camera



Thermal Infra-Red (TIR) Camera

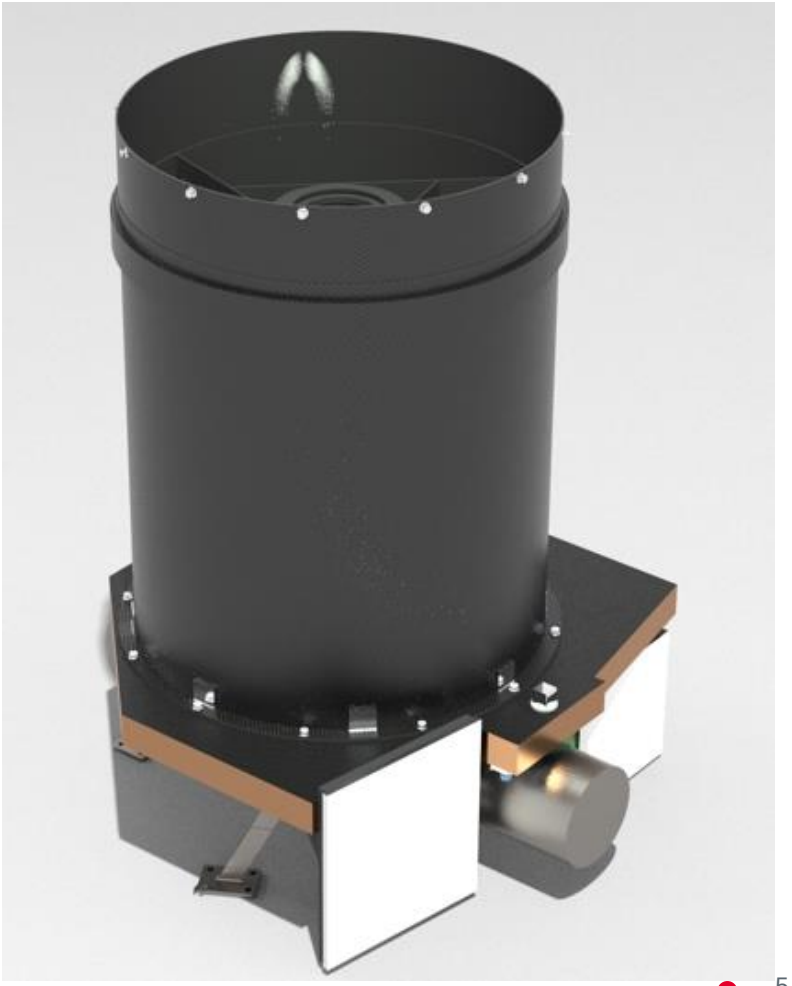
Very High Resolution payload (VHR)

Camera ad alta risoluzione

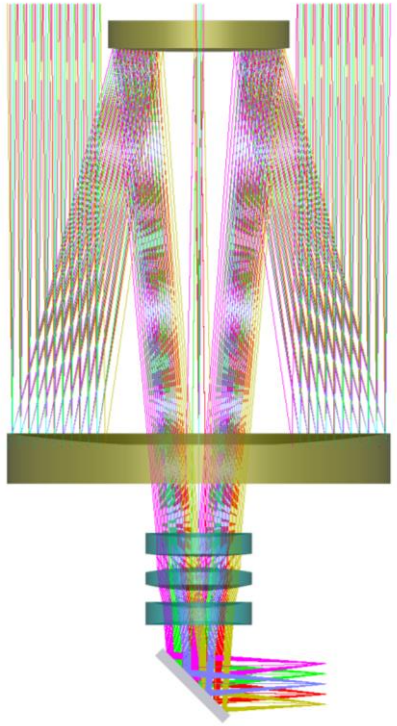
Very High Resolution Payload

- The VHR camera has started its development in Leonardo with internal funding.
- Specification has been defined by ASI (Italian Space Agency) and a first proto-flight model has been proposed to the Agency in the frame of Platino program for a delivery by end 2024.
- P/L design targets applications for mini-satellite constellations.
- VHR camera features high resolution and high fidelity (SNR & MTF) imaging thanks to a large format TDI detector.
- L0 to L2 ground processors are under development too.

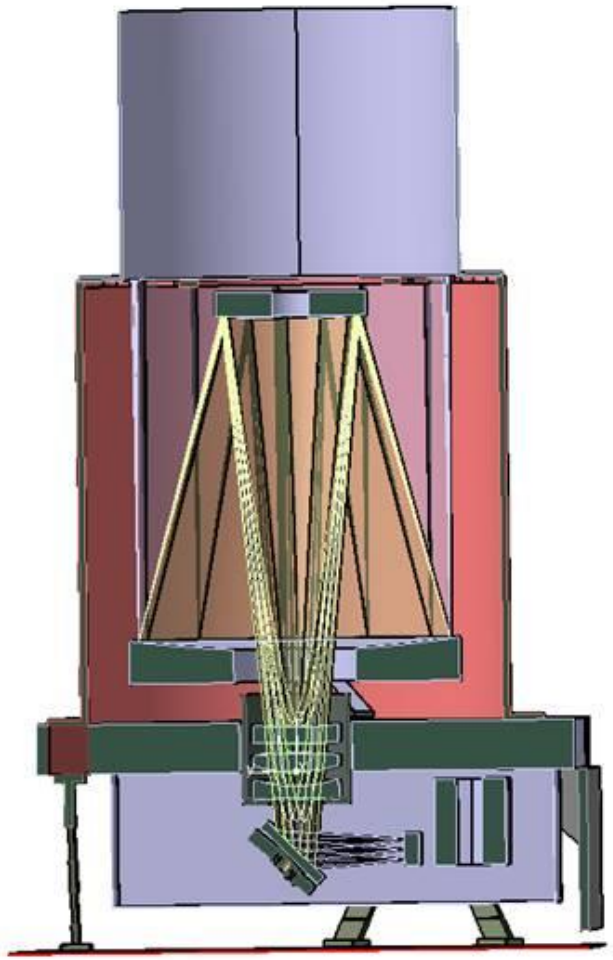
Parameter	VHR Performances
Reference Orbit	400Km
Native GSD @ Reference orbit	PAN = 0.5m MS = 2m
Swath	8Km
P/L MTF	PAN > 0.15 @ L1 MS > 0.15 @ L0
VNIR Spectral Bands (up to 6 VIS/NIR multi-spectral bands)	PAN =640nm Δλ=410nm B1 λc=475nm Δλ=70nm B2 λc=555nm Δλ=35nm B3 λc=660nm Δλ=35nm B4 λc=865nm Δλ=120nm
SNR (can be improved with slow down manoeuvre)	B1 > 155 B2 >160 B3 >162 B4 >110
Mass	< 90 kg *(including ICU and Harness)*
Volume	775mm X 670mm X 1163 mm
Power	135W
Reliability @3.5y	>0.95



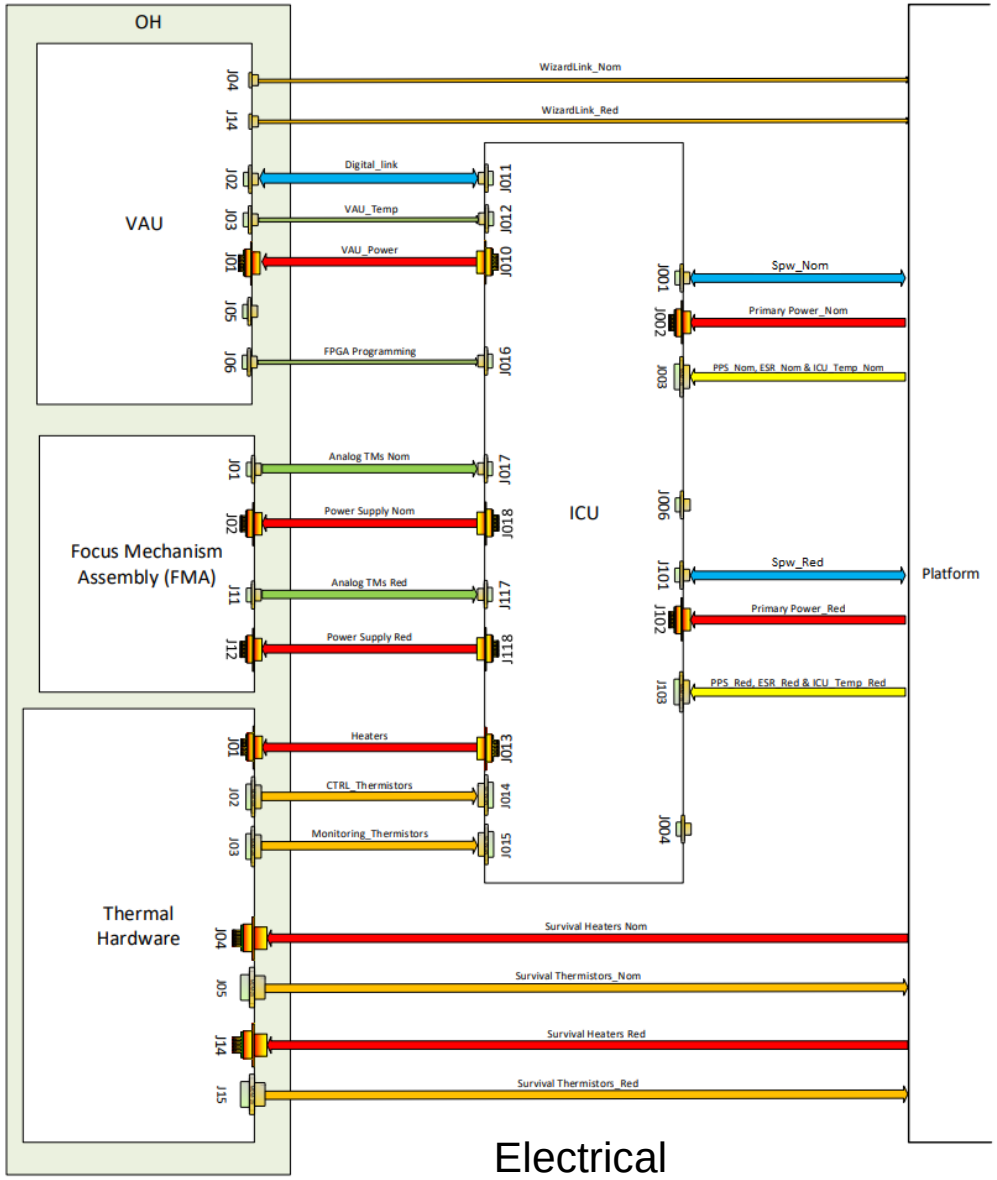
Very High Resolution Payload – Architectural Baseline



Optical



Mechanical



Electrical

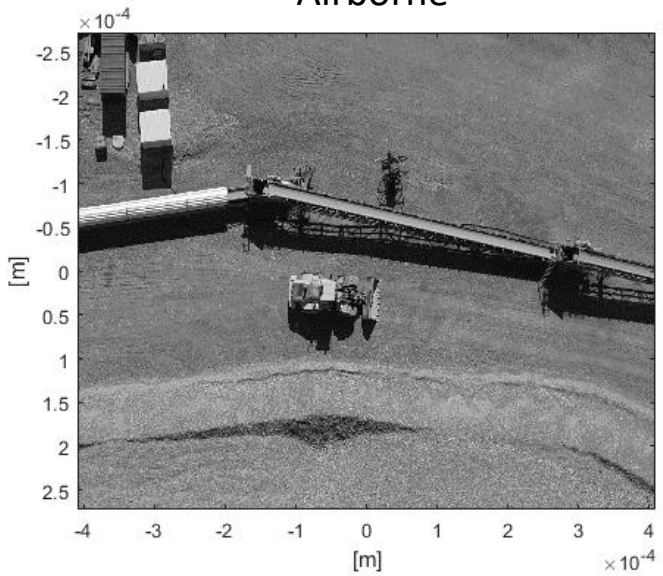
Very High Resolution Payload – Some Applications

- In Maritime applications: suitable warnings generation to identify illegal activities/routes, trafficking, oil spills.
- In Ground Surveillance applications: monitoring of infrastructures, vegetation, movements of enemy positions, which are instrumental to civil, environmental and tactical observations.

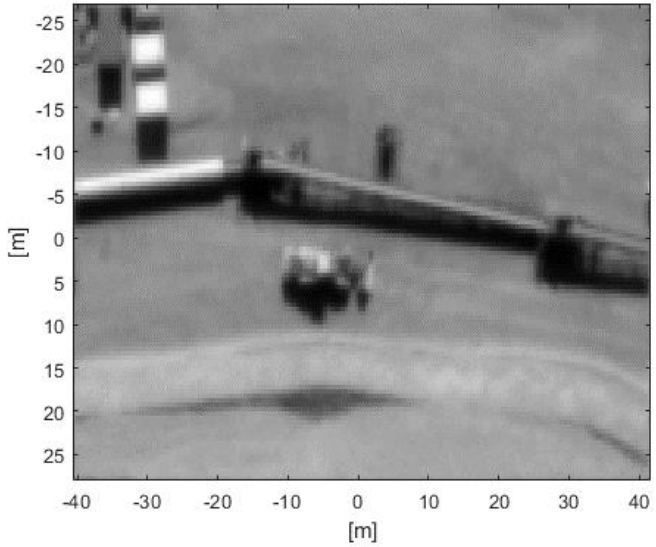
APPLICATION DOMAIN	THEMATIC AREA
Land Precision Planning	Detection and identification of small features (e.g. vehicles, roads, bushes).
	National mapping. map land use / land use changes, manage and protect natural resources, monitor urbanisation and plan infrastructure developments
Agriculture precision management	Land management and crop yields
	Identification and mapping of crop diseases
	Tree counting (palm trees, vineyards)
Defense and Security	imagery-delivered intelligence
	Tactical planning in urban/densely populated areas
Homeland Security	Mitigation and assistance in critical events
	Post-crisis assessment (earthquakes, volcanic eruptions)
Hydrology	Topography
	Drainage gradient on lands
Forestry	Forestry yields
	Counteracting illicit deforestation
Maritime and littoral surveillance	Vessel reconnaissance and contamination
	Harbour mapping
Asset Monitoring	Road, rail and oil pipelines planning and maintenance

Very High Resolution Payload – Examples of generated data

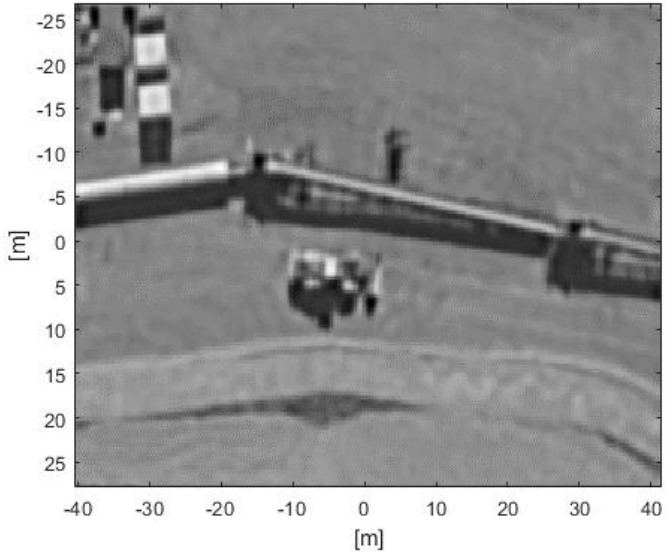
Airborne



Simulated L0 (GSD=0.5)



Restored L1 (GSD=0.25)

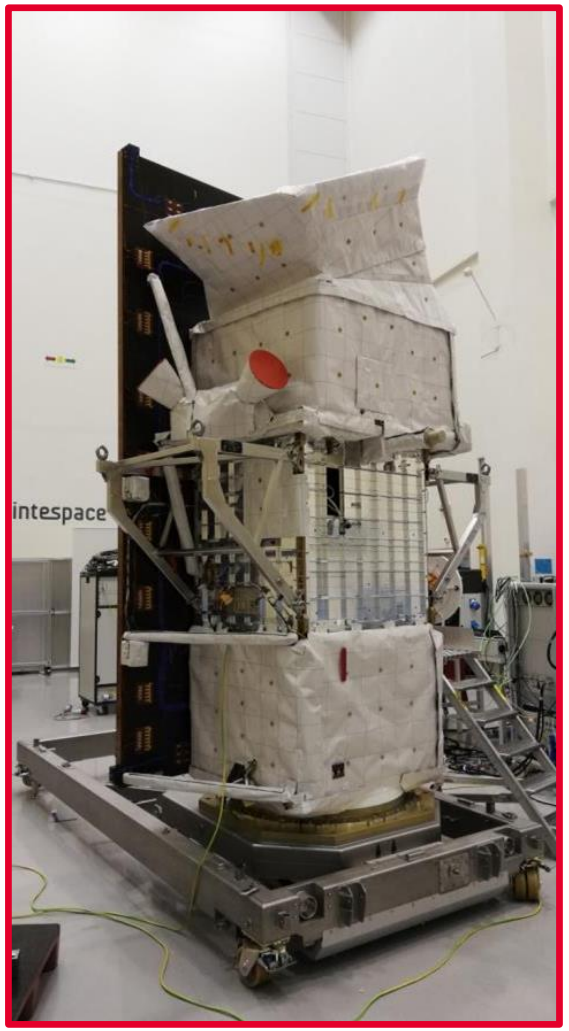


Hyperspectral payload (HYP)

Camera iperspettrale

Hyperspectral Observation

Each material features its own fingerprint that can be recognised through its response to different wavelengths



PRISMA Satellite

Leonardo HYP payload relies on a strong heritage:

PRISMA is the Italian (ASI) Hyperspectral instrument for Earth observation developed by LEONARDO. It is composed of a high spatial (30 m) & spectral resolution (10 nm average) VIS-SWIR spectrometer and a Panchromatic camera (5 m).

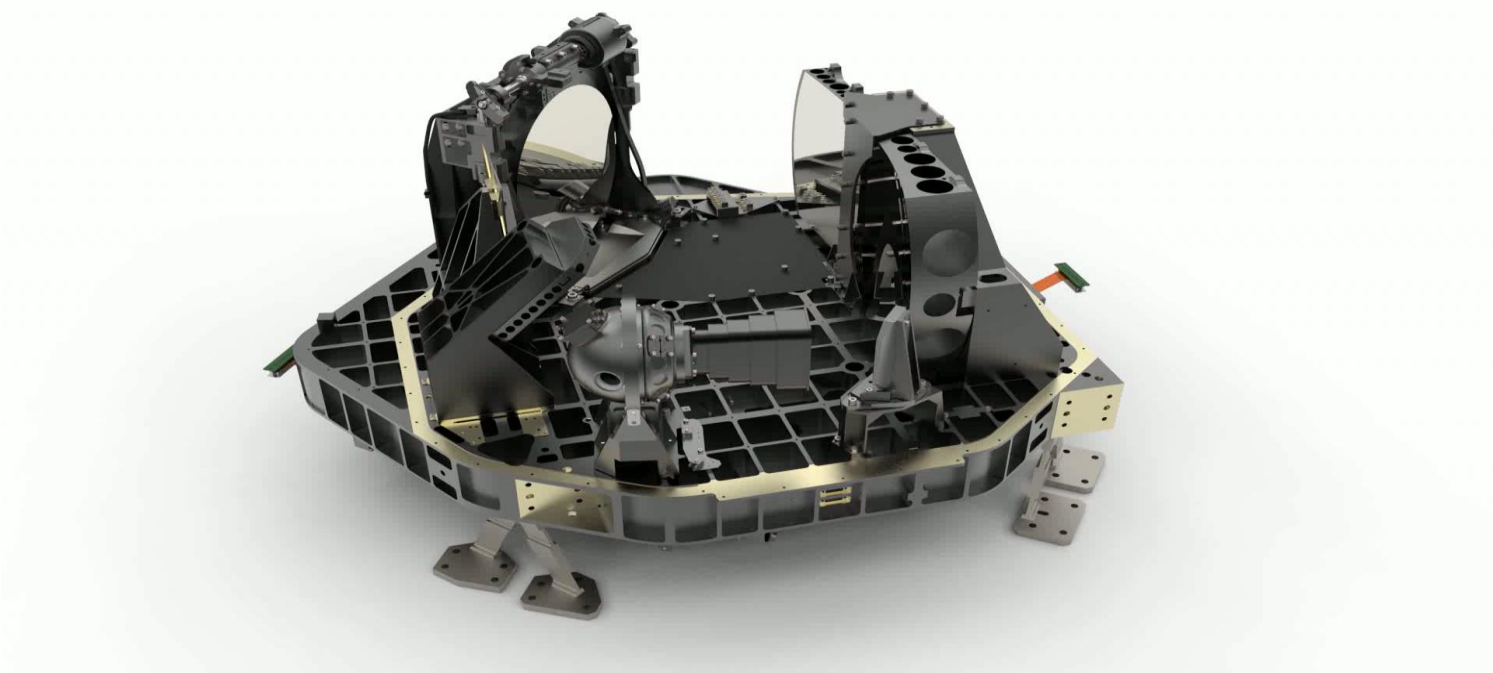
PRISMA is flying since March 2019 and its heritage and lessons learnt have been conveyed in the HYP Payload.

Mission Objectives:

- ✓ Environmental changes at a global level,
- ✓ Impact of human activities on ecosystems,
- ✓ Natural resources analysis for their management and environmental sustainability.

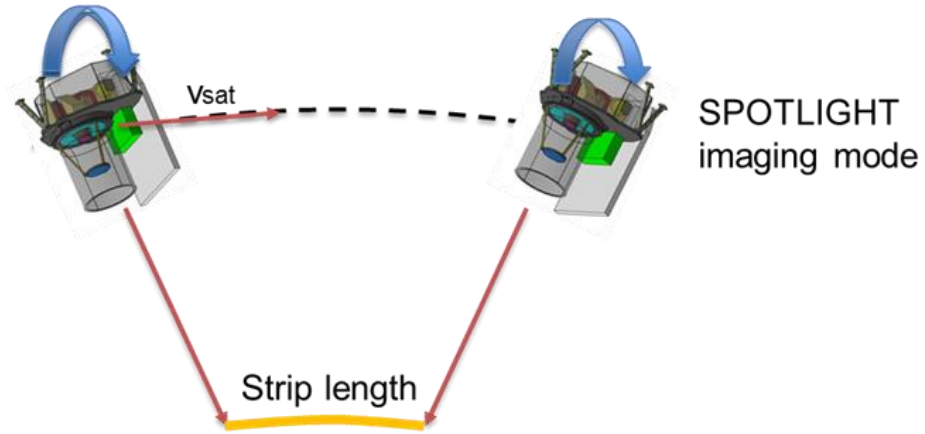
Main Features:

- ✓ 66 bands in VIS=400-1010 nm
- ✓ 174 bands in SWIR=920-2505 nm
- ✓ Co-registrated PAN camera (400-700 nm)



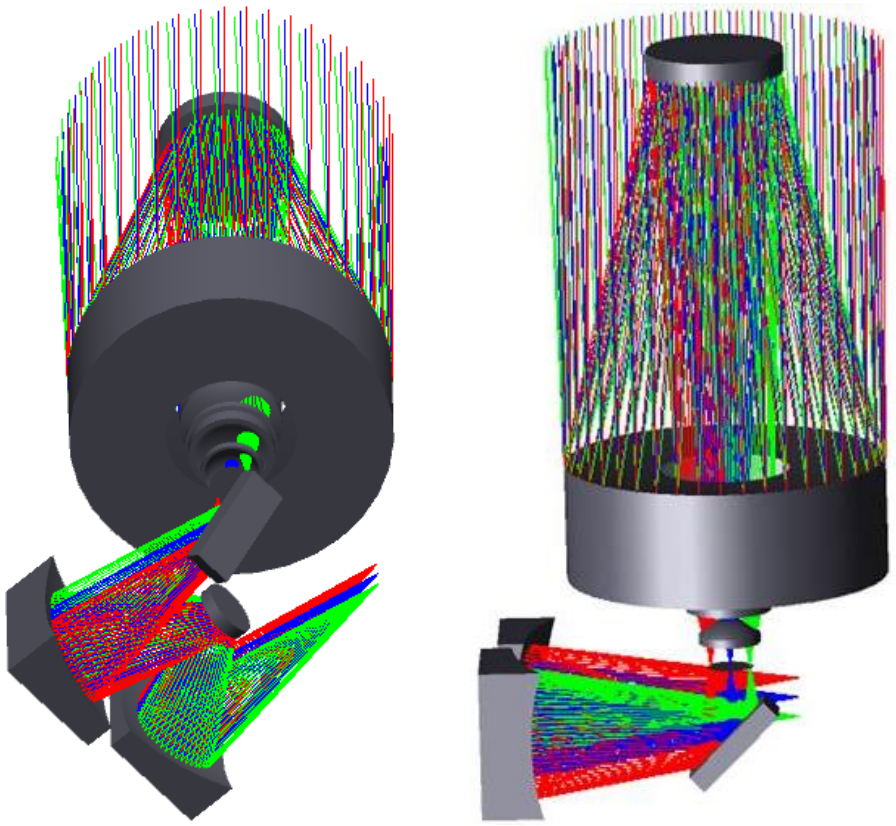
Hyperspectral Payload

- The HYP camera has started its development in Leonardo with internal funding.
- Specification has been defined by ASI (Italian Space Agency) and a first proto-flight model has been proposed to the Agency in the frame of Platino program for a delivery by end Q3 2024.
- P/L design targets applications based on mini-satellites constellations and takes advantage of Leonardo Heritage on PRISMA and CHIME project.
- HYP camera features high quality (SNR & MTF) imaging thanks to top class MCT cryogenic detector covering the full spectral range.



Parameter	HYP Performances
Reference Orbit	515Km
Native GSD @ Reference orbit	STRIPMAP = 30m SPOTLIGHT = 20 m PAN = 5m
Swath	20 Km
P/L MTF	HYP > 0.25 PAN > 0.10
Spectral Range Spectral Resolution Spectral Sampling	400nm - 2500nm $\Delta\lambda$ < 10nm SSI < 10nm
SNR With & without slow down manoeuvre	350 @ λ=450nm 400 @ λ=600nm 230 @ λ=1000nm 200 @ λ=1600nm 100 @ λ=2300nm
Radiometric Accuracy	< 5%
Mass	<100 kg *(including ICU and Harness)*
Volume	750mm X 991 mm X 1053 mm
Power	< 100W
Reliability @3.5y	> 0.95

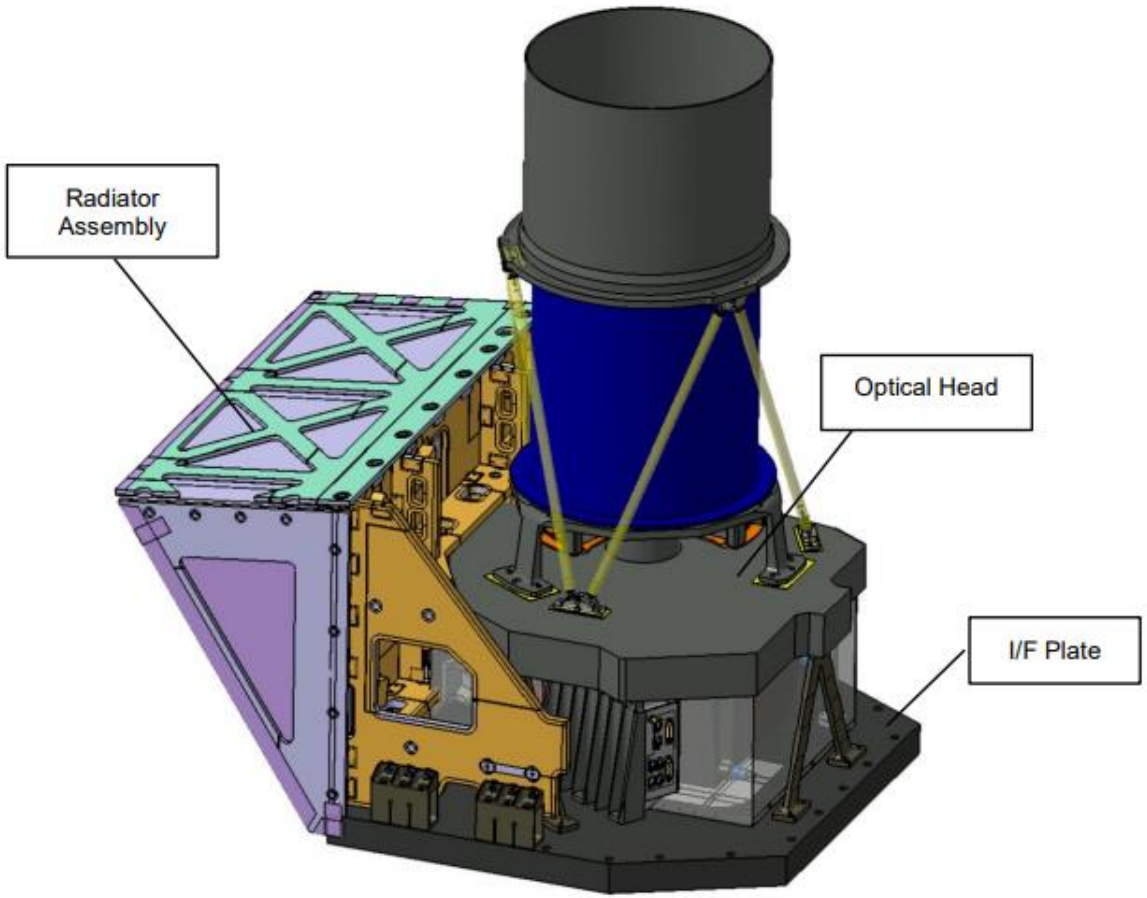
Hyperspectral Payload – Architectural Baseline



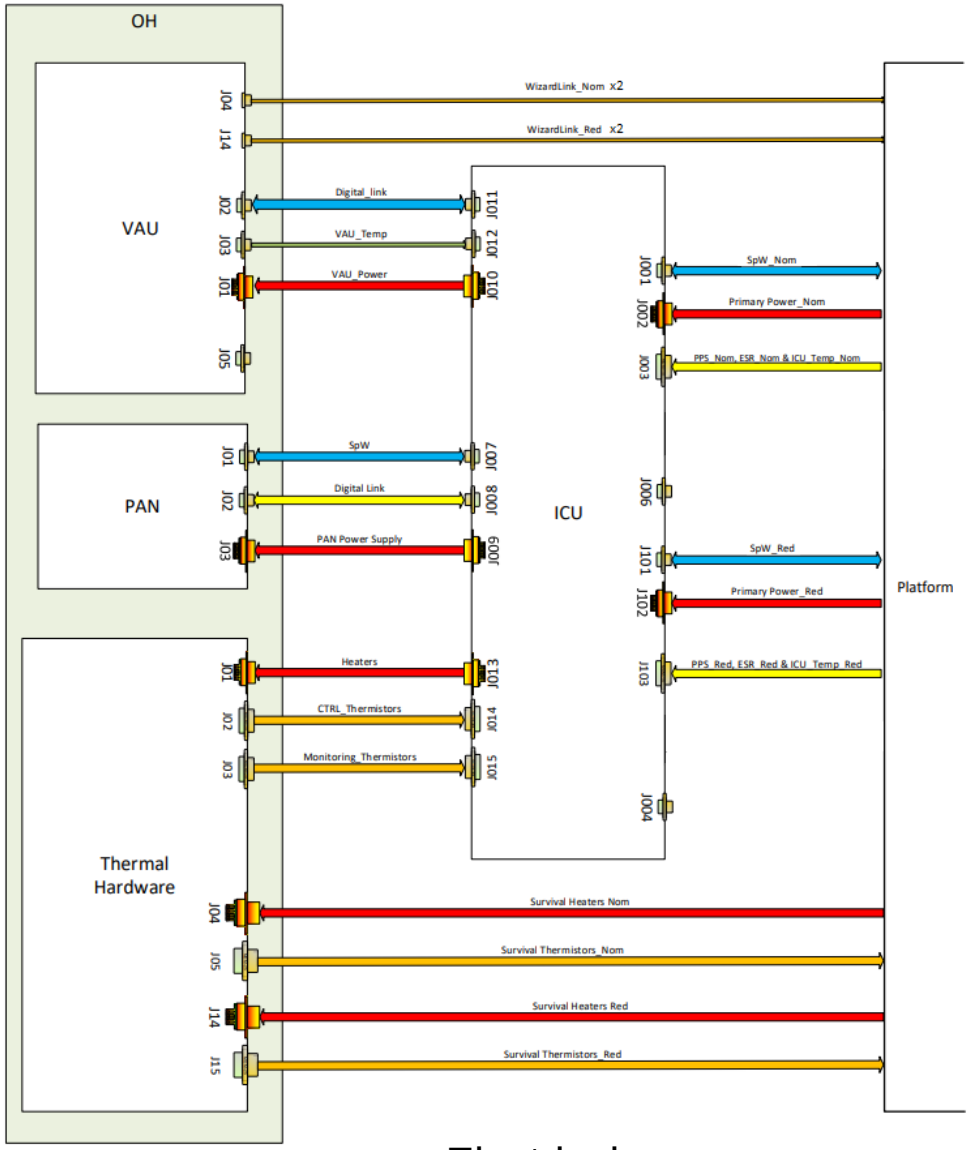
Optical

Configuration	Benefits
Detector (MCT)	High-performance MCT detector required to achieve SNR and MTF performances along the spectral range. One detector covers the full spectral range
Telescope: • Ritchey Chretién corrected • Primary mirror 300mm • f# = 3.2	Large pupil / compactness / simplicity / high TRL / available
Spectrometer: • Offner configuration • Dual blazed grating	Offner is a configuration well consolidated in Leonardo being developed for FLORIS. Design is optimised to use only spherical mirrors (reducing manufacturing and integration costs).
Passive cooling (radiator)	No moving parts. Based on consolidated technologies.

Hyperspectral Payload – Architectural Baseline



Mechanical



Electrical

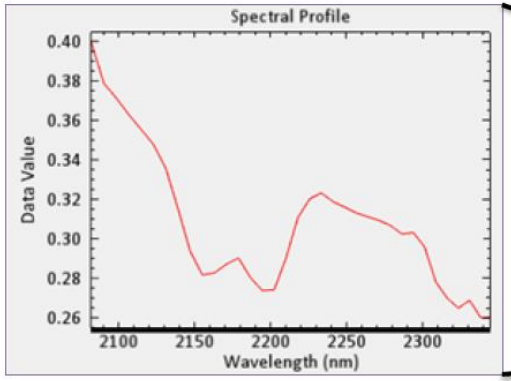
Hyperspectral Payload – Some Applications

APPLICATION DOMAIN	THEMATIC AREA
Agriculture & Food Security	Assessment of Biophysical and Biochemical Variables Related to The Crops and of Agronomic Interest
	Top Soil Properties
Ecosystem Structure & Composition (Biodiversity)	Land Cover and Use
	Land Degradation
	Vegetation Degradation
Inland & Coastal Water	Water Quality Monitoring and Assessment of Biophysical Parameters
	Bottom Substrate Characterization, Benthic Communities Mapping and Monitoring
	Shallow Water Bathymetry
	Characterization and Detection of Floating Materials
	Emerging Habitats And Wetlands
Geology & Minerals / Soils	Geophysical Parameter of Volcanic Activities
Urban Environment	Characterization and Mapping of Urban and Suburban Areas
Natural and Man-made Hazards	Forest Fire Front Identification And Damage Assessment
	Measurement of Air Pollution And Detection of Surface Phenomena from the Identification of Man Made and Natural Gas Emission
	Soil Pollution Related to Human Activities
	Water Pollution
Cultural Heritage	Archaeology Site Identification
Forestry, Vegetation Parameters and Processes	Vegetation Energy Dissipation Patways
Ice and Snow	Cryosphere Optical Properties

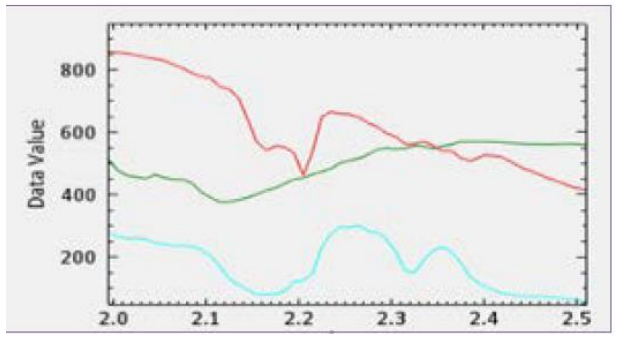
Examples of Hyperspectral data usage:

PRISMA mineral detection in Cuprite Hill (Nevada):

- Spectral profiles of pixels extracted in a “data cube” and compared to known materials spectra library

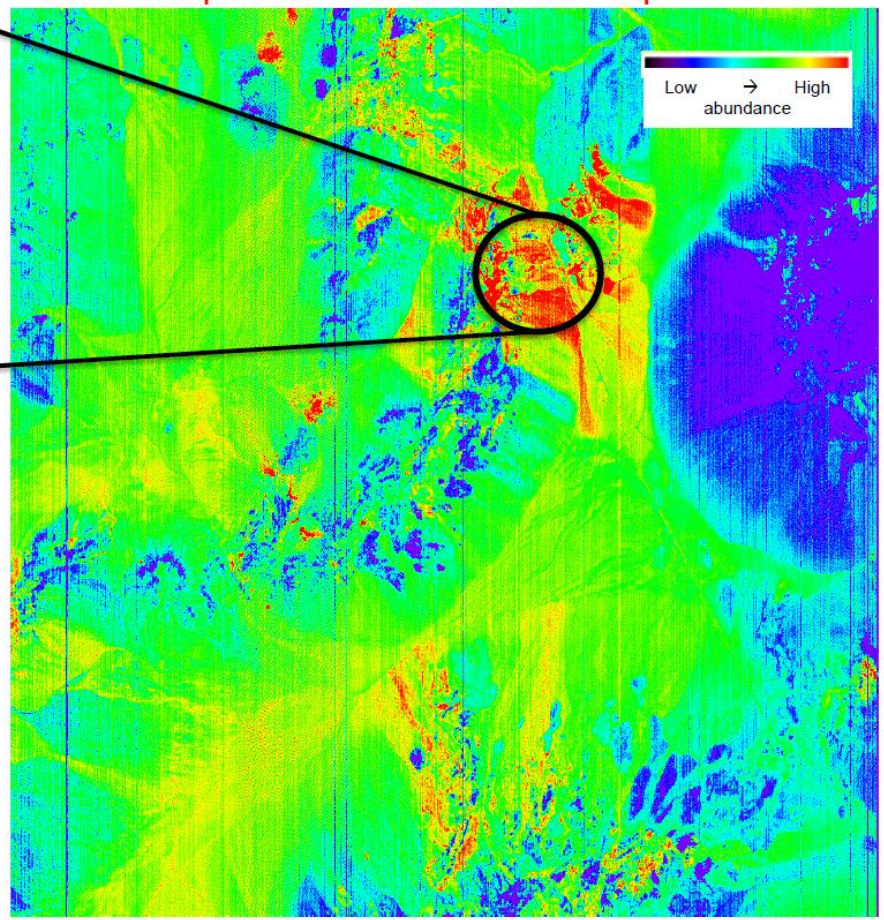


PRISMA Spectral profile in the SWIR region 2100-2400 nm



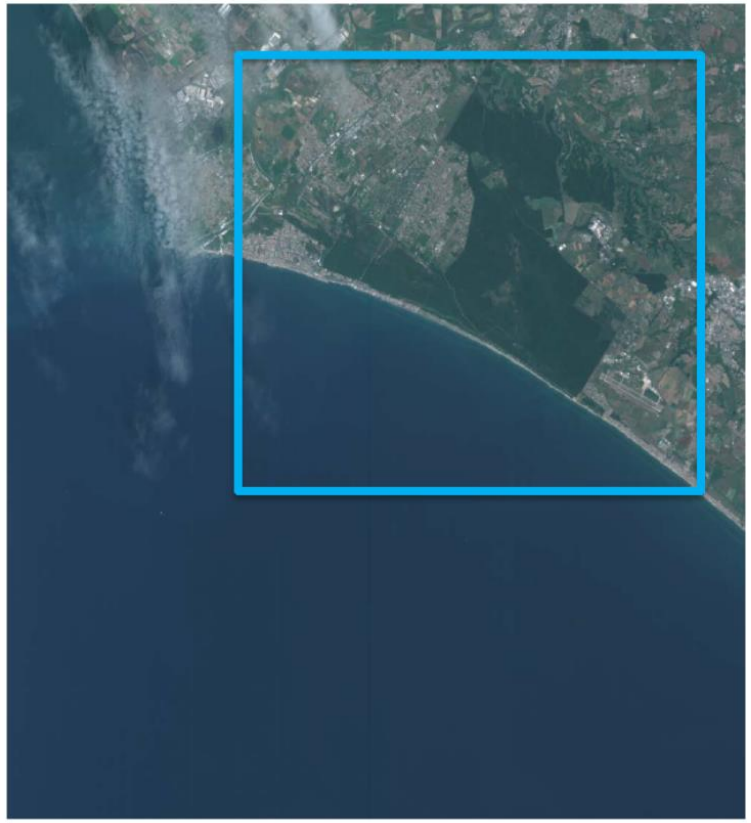
Spectral reflectance signature (in the range 2000-2500 nm) from USGS library: Kaolinite (red), Alunite (cyan), Buddingtonite (green)

Kaolinite qualitative abundance map

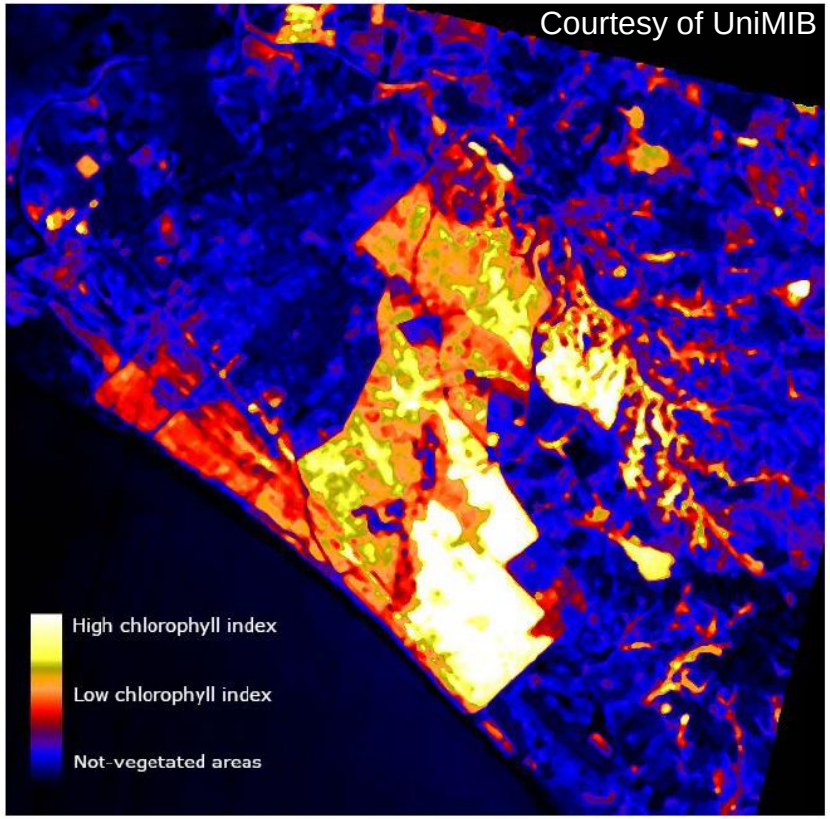


Examples of Hyperspectral data usage

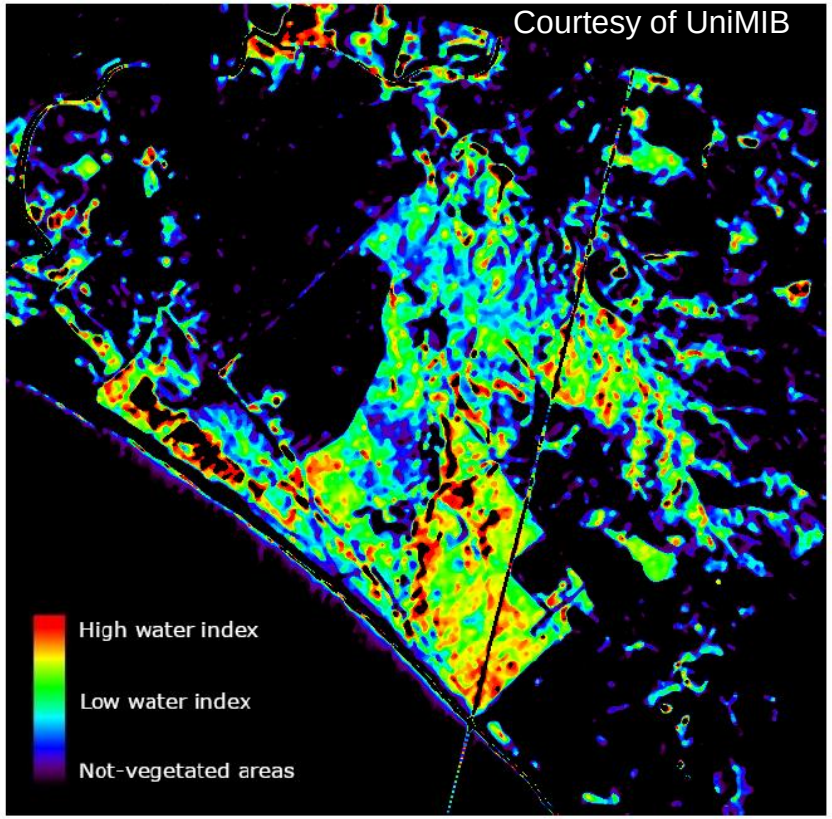
PRISMA offers a unique opportunity to detect vegetation stress and assess fire risk from space:



PAN Image: Italy, Castel Fusano



Clorophyll Level Map

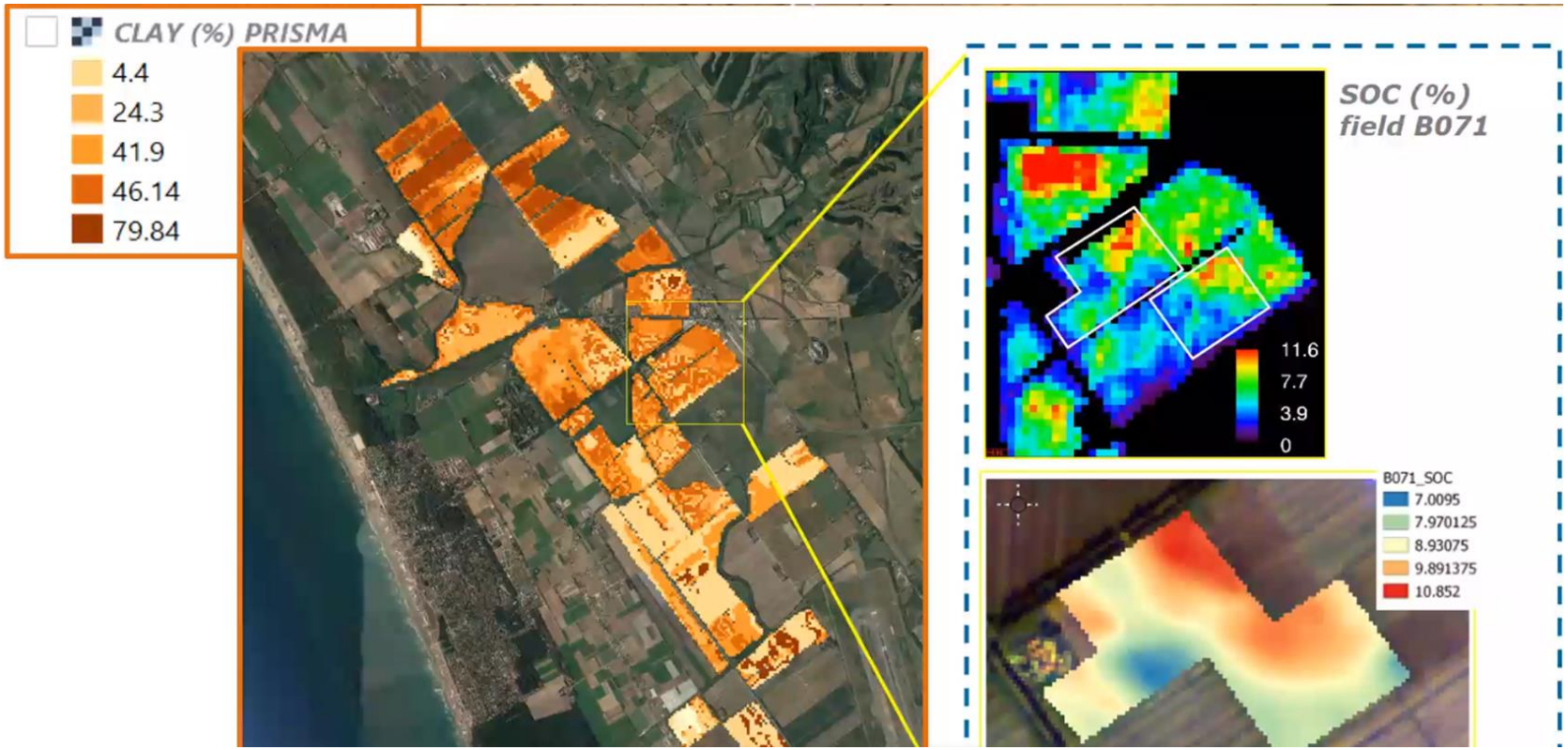


Irrigation Level Map

Examples of Hyperspectral data usage

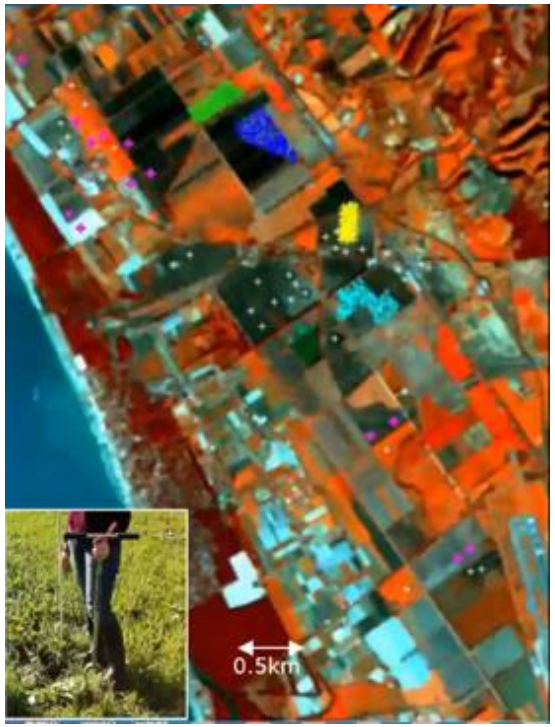
Surface soil layer characterization and retrieval of soil properties: clay, sand, silt (sediment), soil organic carbon (SOC) and soil carbonates.

- One experimental site used in 2020 is a technological farm (3500 ha) in Maccarese (IT). It belongs to Cutanic Luvisol on alluvial deposits



Precision farming
Courtesy of Abaco

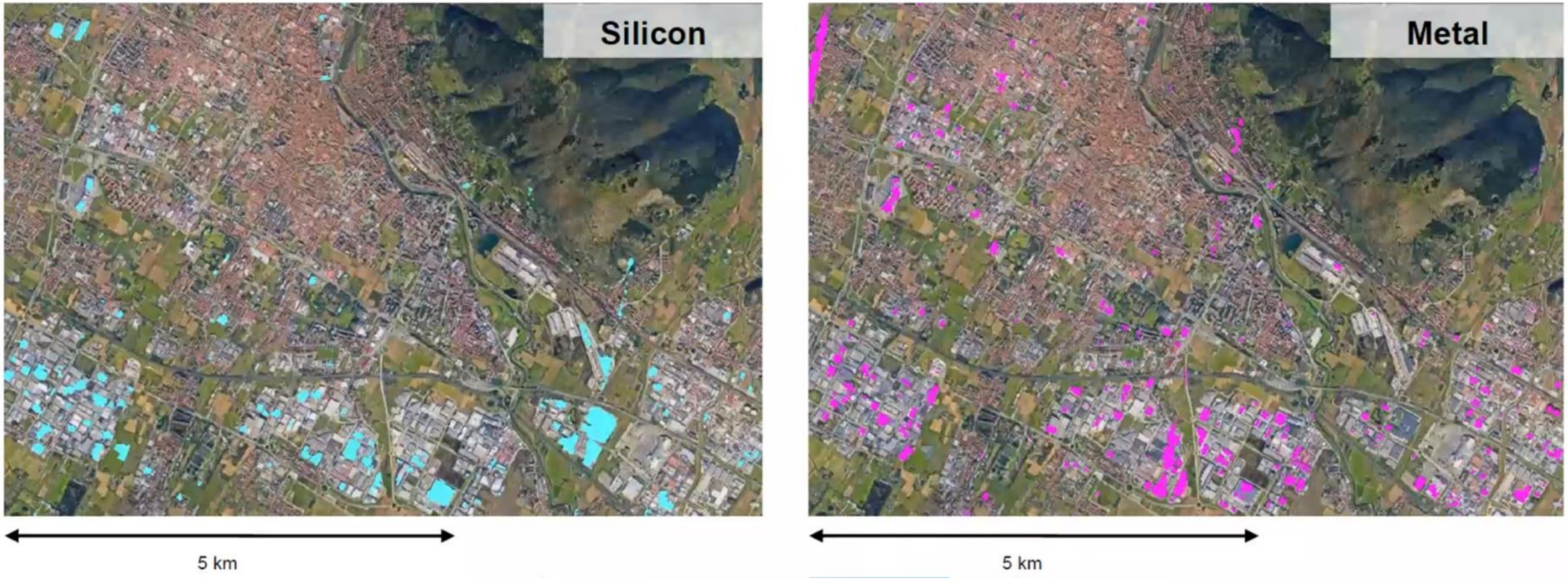
Soil Classification
Courtesy of CNR-IMAA



	Min	Max	Mean	Dev.St.
clay	4,37	79,84	38,47	21,33
silt	1,05	28,89	15,29	8,02
claysilt	6,96	96,49	53,76	26,56
sand	3,51	93,04	46,23	26,56
OC	0,18	2,10	0,97	0,40

Examples of Hyperspectral data usage

Detection of materials in urban areas:

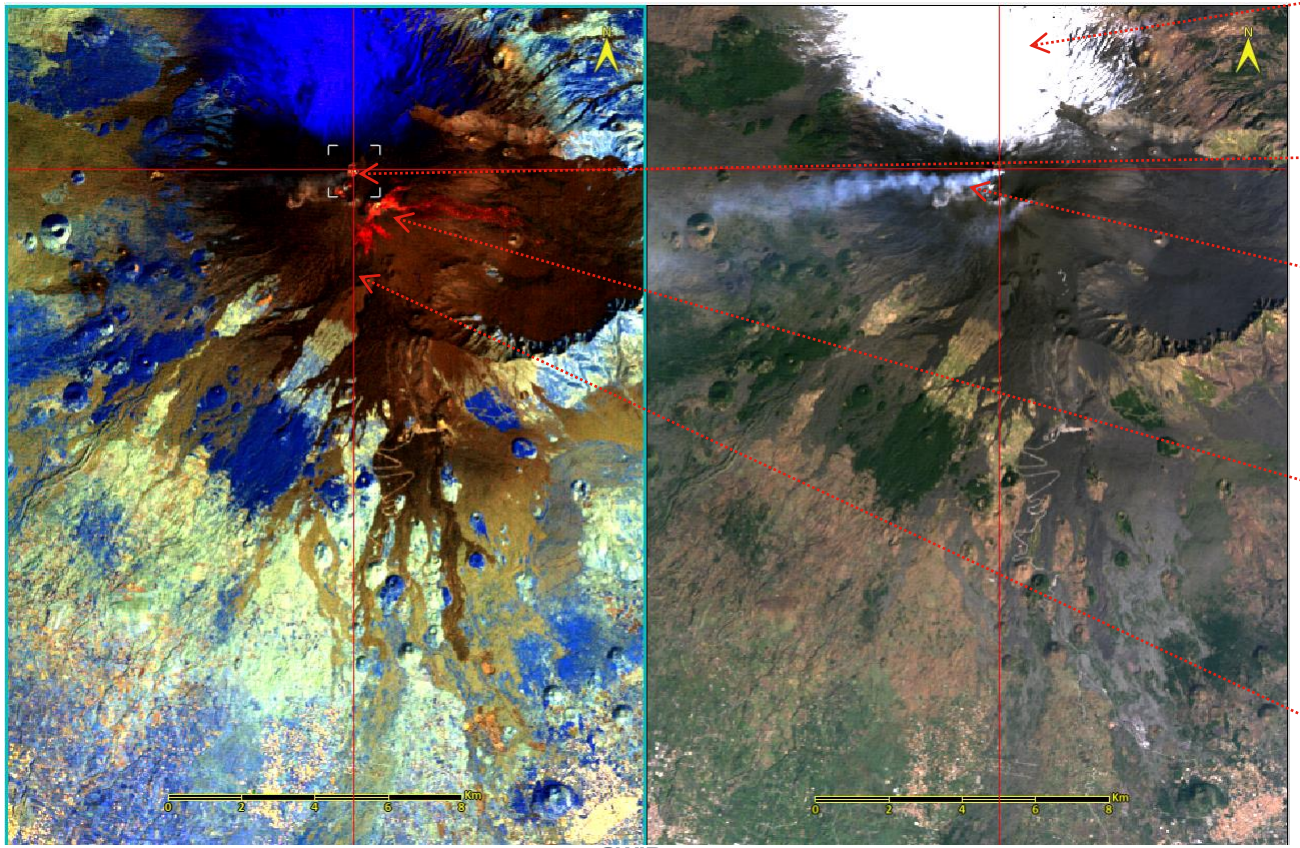


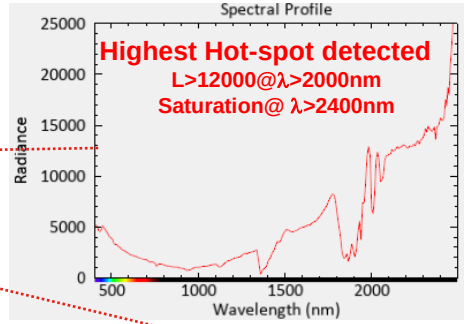
Urban mapping

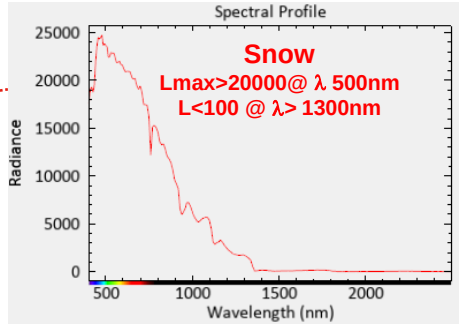
Courtesy of Regione Toscana

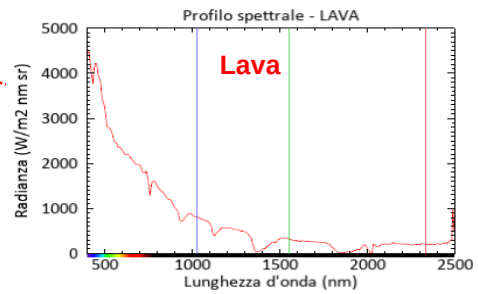
Examples of Hyperspectral data usage

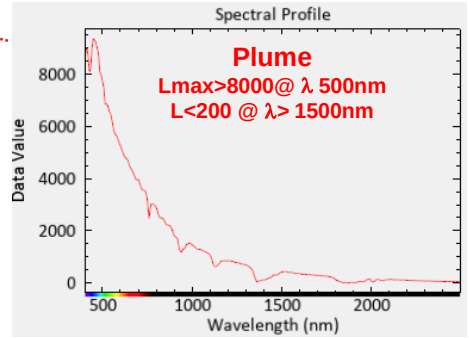
ETNA activity monitoring: spectral profiles for different targets spread over the Top of Atmosphere Radiance Image dynamic range:

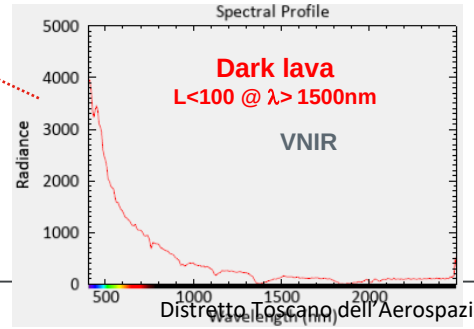










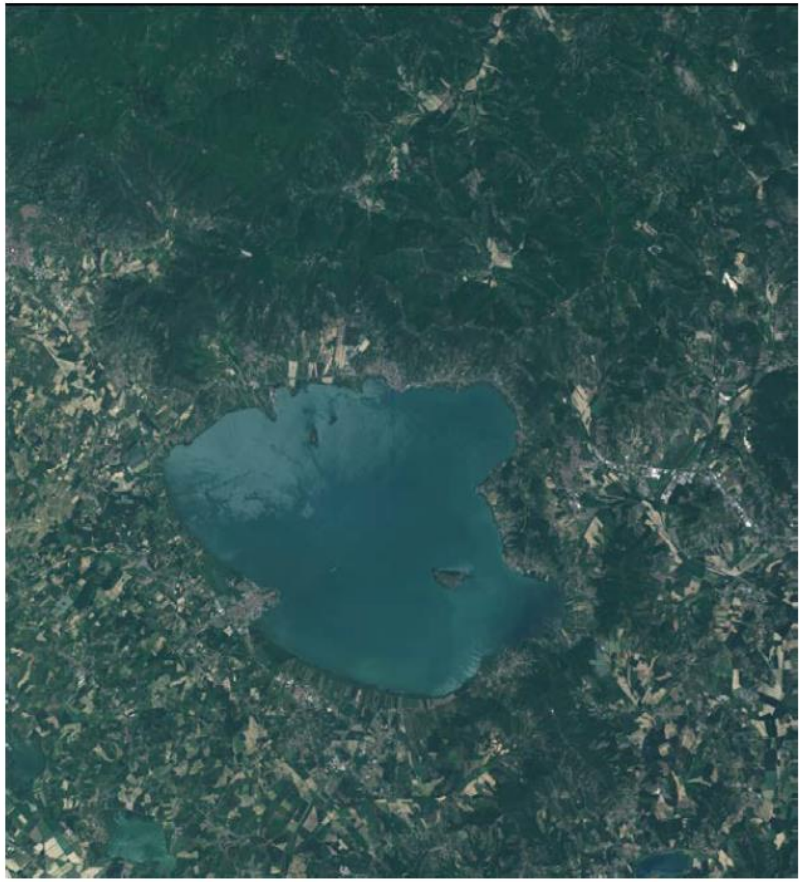


(source: Data / Information generated by Leonardo under an ASI License to use. Original PRISMA product - © ASI - 2021)

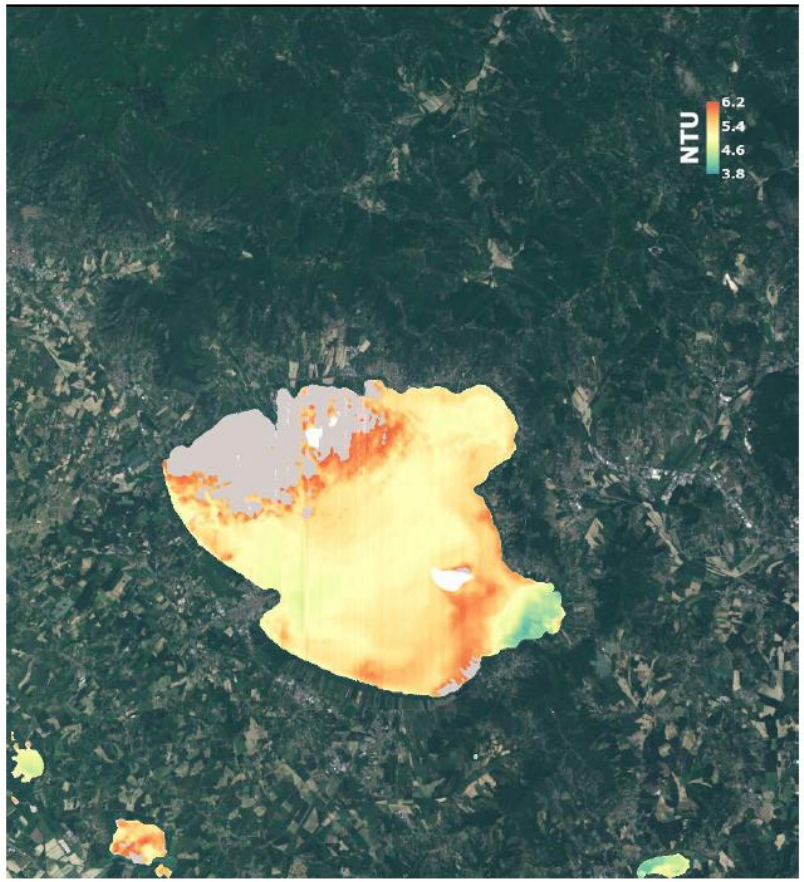
Examples of Hyperspectral data usage

Mapping of Water quality over Trasimeno Lake – Italy (lower NTU values means less turbidity):

VNIR RGB



Water turbidity map



Courtesy of CNR-IREA

Thermal InfraRed payload (TIR)

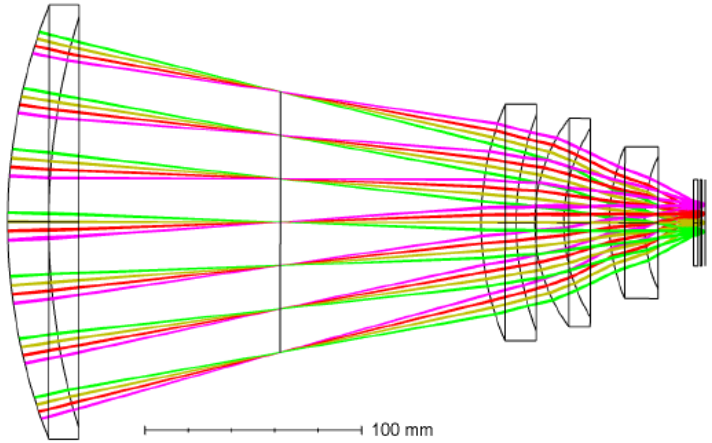
Termo-camera ad Infrarossi

TIR Payload

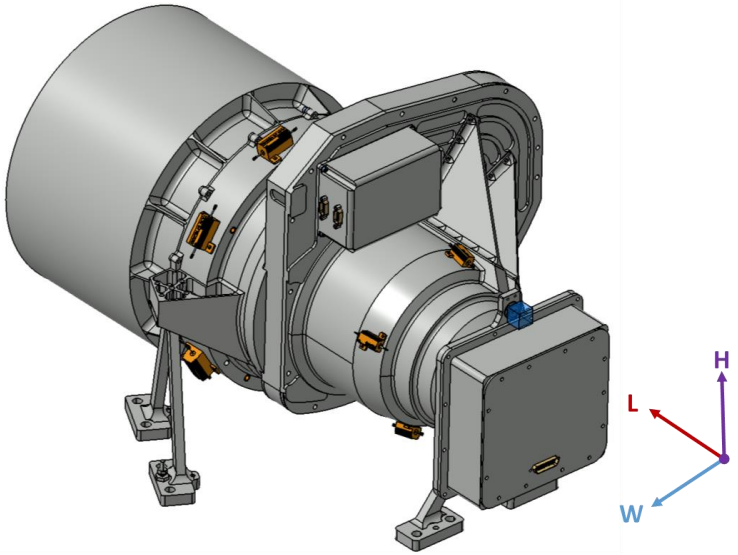
- The TIR Camera is under development in Leonardo in the frame of Platino program.
- The delivery of the proto-flight model is planned by Q1 2024.
- P/L design targets applications based on mini-satellites constellations and takes advantage of Leonardo heritage on thermal imagers for Space and Defence applications.
- TIR is an uncooled IR imager based on microbolometer detector covering the full spectral range.
- Typical applications:
  - Geology
  - Vulcanology
  - Combined imaging with VNIR Camera

Parameter	Specification
Reference Orbit	400 km
GSD	40m
Swath	40Km
Spectral bands (can be adjusted)	TIR1 8.6µm TIR2 9.1µm TIR3 10.3µm TIR4 11.5µm
MTF	0.2
NEdT	0.8K @250K (TIR1&2) 0.4K @250K (TIR3&4)
Absolute Accuracy	1.5K
Mass	OH: 16kg PE: 3kg PICU: 6kg Harness: 3kg
Volume	OH 540 x 390 x 320 mm PE 330 x 215 x 40 mm P-ICU 145 x 230 x 210 mm
Power Cons.	60 W (incl. TCS) in Idle 85 W (incl. TCS) in Imaging 75 W (incl. TCS) in Calibration

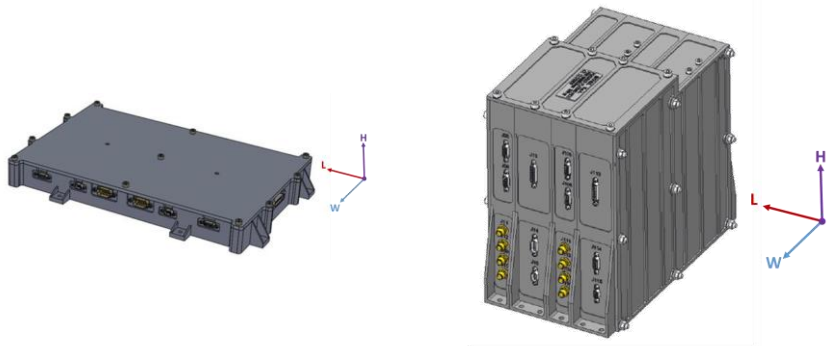
TIR Payload Imager – Architectural Baseline



Optical



Configuration of main subassembly	Rationale
Microbolometer detector	Best compromise between cost (COTS component), performances and needed resources needed (TEC-less technology). One detector covers the full spectral range (8-14µm).
Telescope: 4 lenses objective f#=1	Compactness / simplicity / high TRL / available / higher MTF
High Emissivity Shutter as Flight Calibration unit	OH thermal self-emission (offset) compensation and responsivity (gain) re-calibration



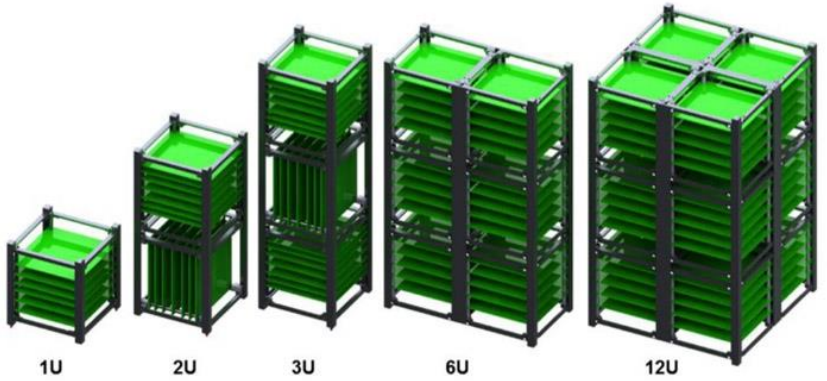
Mechanical

Payload Imagers for Cubesat’s

Camere Ottiche per Cubesat

CubeSats

- **Smaller size and weight:** these micro/nanosatellites follow the CubeSat standard which defines the outer dimensions within multiple cubic units of 10 x 10 x 10 cm
- Satellite subsystems are often available as “**Commercial Off The Shelf**” products
- Shorter development times
- Increased number of **launch opportunities**



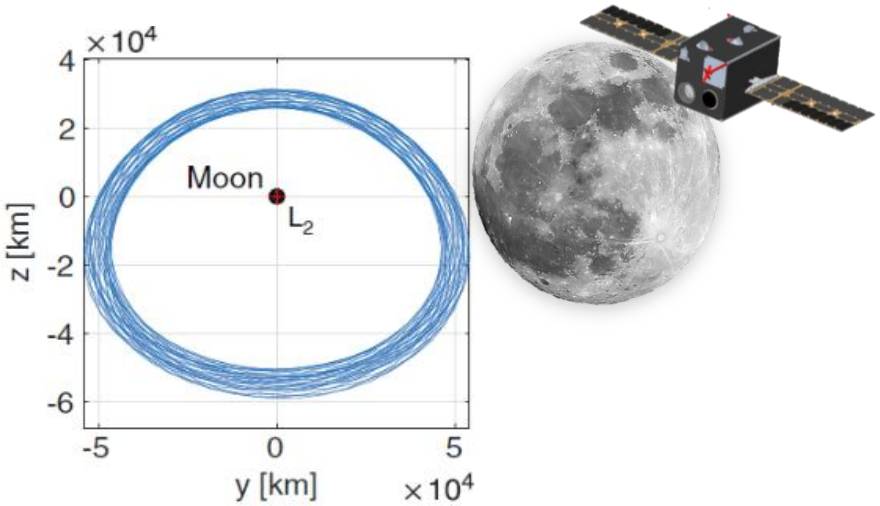
LEONARDO

POLITECNICO MILANO 1863

- **LUMIO**
- **E.Inspector**
- **Vulcain**

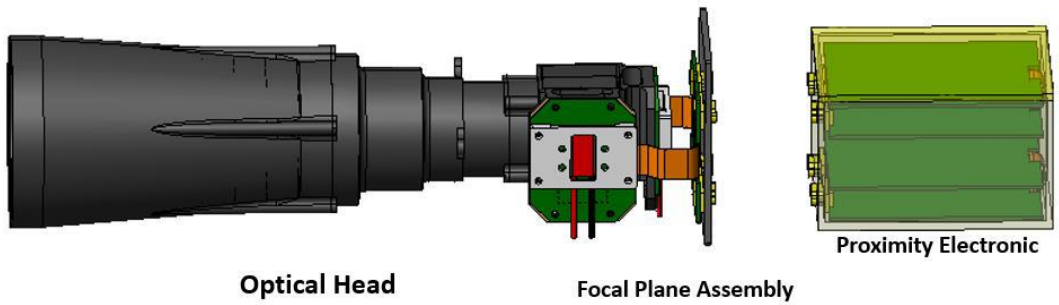
LUMIO Lunar Cubesat

- **LUMIO** is a 12U CubeSat mission to a halo orbit at Earth–Moon L2
- It that shall observe, quantify, and characterize meteoroid impacts on the lunar far side by detecting their impact flashes, complementing Earth-based observations to provide global information on the lunar meteoroid environment and contribute to **Lunar Situational Awareness.**



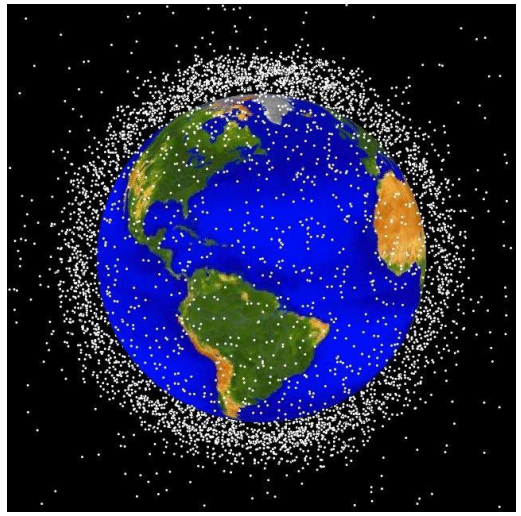
LUMIO-Cam

LUMIO-Cam is a compact imager that will observe, quantify and characterize meteoroid impacts on the lunar far side by detecting their **impact flashes.**



- **Visible: 450-800 nm**
- **Infrared: 850-950 nm**
- **Double Focal Plane Assembly configuration**
- **6 deg FOV**
- **15 fps**
- **On-board processing**

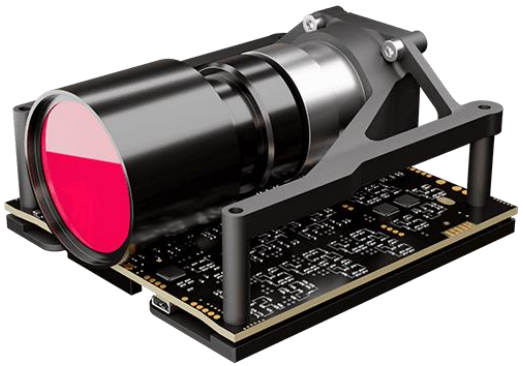
E.Inspector



- 12 U CubeSat mission for large **debris close inspection** to support successful removal.
- The proposed architecture can manage different object image size and illumination conditions, it is flexible for different target scenarios.

Payload

- **Visible Camera**
- **InfraRed Camera**



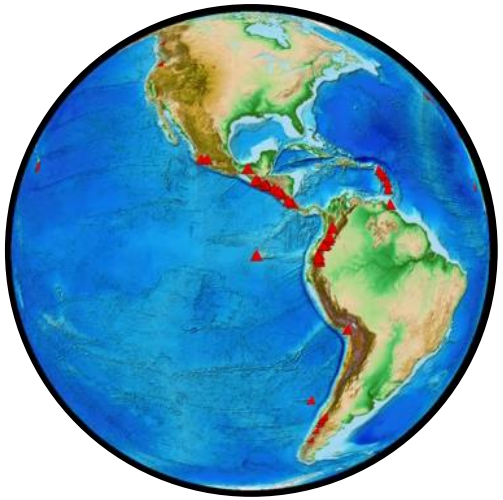
Characteristics	Value
Spectral Band	RGB
GSD @500 km	39 m
Swath @500 km	80 KM
Focal Length	70 mm
Pixel Pitch	5.5 μm

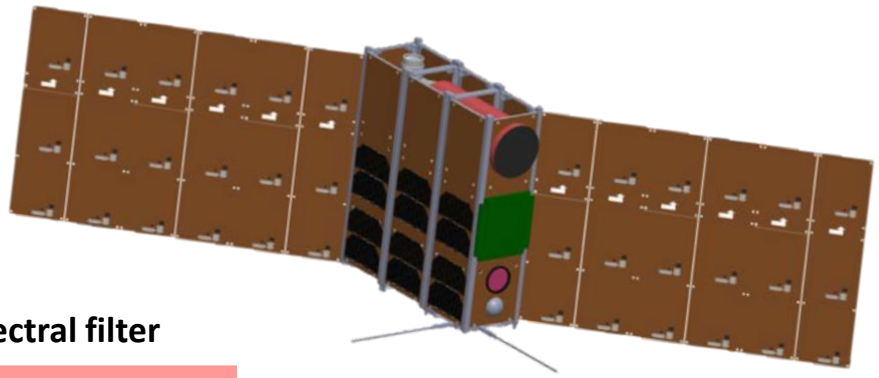
Characteristics	Value
Spectral Band	7.5 to 13.5 μm
Focal Length	100 mm
Pixel Pitch	17 μm
Number of pixels	640 x 512

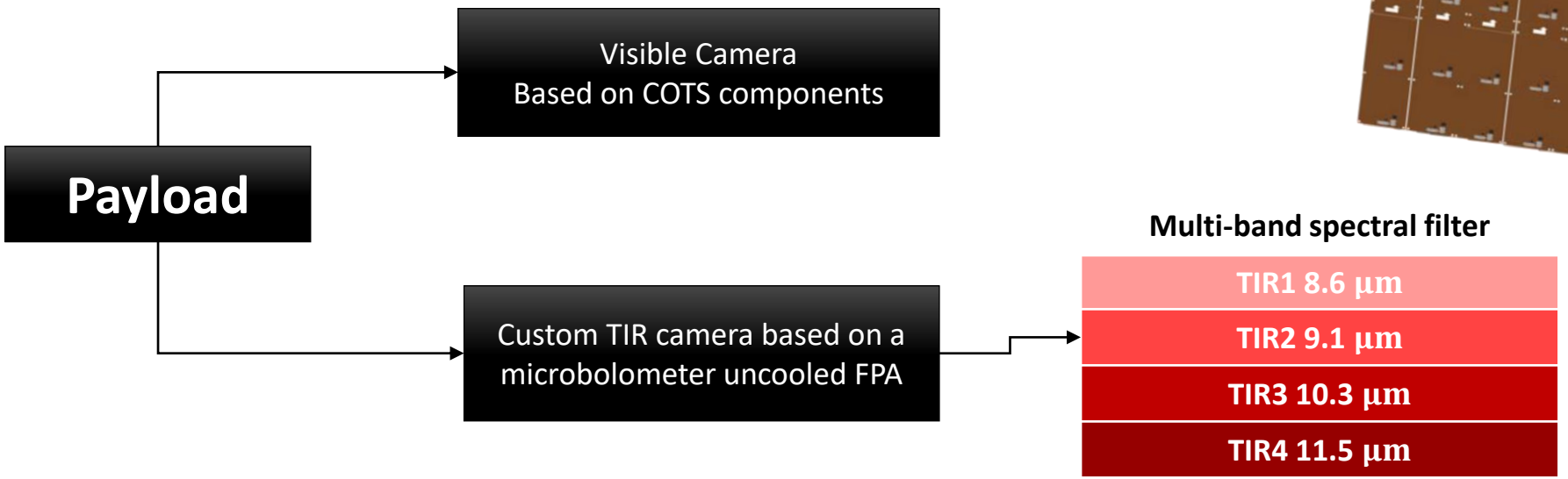
Vulcain

Vulcain is a 12 U CubeSat mission aiming at:

- Increasing IR observation of Volcanoes to detect surface **temperature changes related to volcano activity** in the Thermal InfraRed channels (300-400 K)
- Combining **VIS/TIR** data to enhance observation by adding morphological analysis
- **Stereographic** acquisition: target observed with two cameras separated by a certain baseline







THANK **YOU**
FOR YOUR ATTENTION

leonardo.com

For more information please contact:

Enrico Suetta
VP CTO & Capability
Optronics & Space Line of Business
Electronics Division

Email: enrico.suetta@leonardo.com
Tel: +39 335 7499480