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# Leonardo Spaceborne Infrared Payloads for Earth Observation: SLSTRs for Copernicus Sentinel 3 and PRISMA Hyperspectral Camera for PRISMA Satellite †

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**Abstract:** Leonardo has been involved in the realization of several infrared payloads for Earth Observation since 1990. Among the currently in orbit operative instruments we find the two SLSTRs and PRISMA. The SLSTRs are high accuracy radiometers of the Copernicus mission related to ESA Sentinel-3 space component to provide Sea Surface Temperature (SST) data continuity respect to previous (A)ATSRs for climatology in the next 20-years. The PRISMA Program is the first ASI (Agenzia Spaziale Italiana) optical hyperspectral mission for Earth observation. It is based on a high spectral resolution spectrometer operating in the VIS-SWIR channels optically integrated with a panchromatic camera.

**Keywords:** infrared payloads; ESA Sentinel 3 mission; ASI Prisma mission

## 1. Introduction

The SLSTRs are actually operative on the ESA Sentinel-3A and 3B satellites which have been launched respectively in 2016 and 2018 and operate in the same orbit with 140° phase delay. It is also foreseen to be embarked on the next Sentinel-3C and 3D which will be launched in the time frame 2023 to 2028. The PRISMA mission have been launched in March 2019. It is based on a mono-payload single satellite realized by an industrial consortium, where Leonardo has the full responsibility of the hyperspectral payload. In the following paragraphs both the SLSTR and the PRISMA payloads are described in terms of their main characteristics, performance and first images.

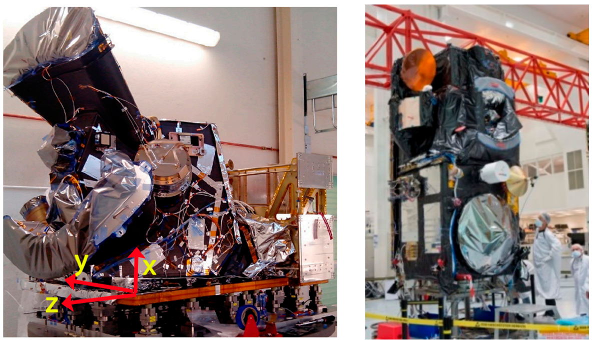
## 2. Sea and Land Surface Temperature Radiometers (SLSTRs) on the Copernicus Sentinel 3 European Space Agency (ESA) missions

### 2.1. Mission and Instrument Concept

The Sea and Land Surface Temperature Radiometers (SLSTRs) [1] are high accuracy radiometers of the Sentinel-3 space component of the European Copernicus program, devoted to establish a European capacity for Earth Observation. They provide operative climatological data continuity following on previous ESA environmental missions (ENVISAT, ERS2 and ERS1) that embarked respectively AATSR, ATSR-2 and ATSR. The S3 mission foresees a series of satellites, each having a 7.5-year design lifetime, over a 20-year period. Sentinel-3A and 3B have been launched in 2016 and 2018 while the 3C and 3D series are under development and will be launched in the timeframe 2023 to 2028, to be agreed with the EC, which will ensure overlap with the current satellites and continuity of the mission over the full 20 year lifetime. Two identical satellites are actually maintained in the same orbit with a phase delay of about 140°. Each SLSTR provides wide near nadir and oblique view swaths (1400 and 740 km) useful for global coverage of Sea and Land Surface

Temperature (SST/LST) with a daily or half a day revisit time (with two satellites) appropriate respectively for climate and meteorology (1 km spatial resolution at Sub Satellite Point SSP). Enhanced cloud screening and other products are implemented via the double spatial resolution (0.5 km at SSP) visible (S1 = 0.555 ± 0.010 µm, S2 = 0.659 ± 0.010 µm, S3 = 0.865 ± 0.010 µm) and Short Wave InfraRed (SWIR) (S4 = 1.375 ± 0.010 µm, S5=1.610±0.030 µm, S6=2.250±0.025 µm) channels. Moreover two additional fire channels in Medium wave InfraRed (MIR) (F1 = 3.74 ± 0.19 µm) and Thermal InfraRed (TIR) (F2 = 10.85 ± 0.45 µm) bands are included using dedicated elements within the detectors to monitor high temperature events such as forest fires. The contemporaneous observation of the same on ground pixel by means of two atmospheric path views in the three nominal infrared bands (S7 = 3.74 ± 0.19 µm, S8 = 10.85 ± 0.45 µm, S9 = 12.0 ± 0.50 µm) is of fundamental importance to achieve optimum correction of atmospheric aerosols (dual view) and water vapour (3 channels) for SST measurements with 0.3 K accuracy. Moreover the adopted conical scanning concept, as for the (A)ATSRs series, optimizes the radiometric calibration in the infrared bands, allowing constant optical area beam and incidence angles for all scan points (both scene and Black Bodies, BBs), low polarization effects and frequent BBs views (every 0.6 s corresponding to 2 successive complete rotations) with the same Earth observation geometry.

SLSTR comprises two physical units: first the SLstr Optical Scanning Unit (Figure 1), comprising the Opto-Mechanical Enclosure (OME) and the Detection Assembly (DA); second the Control & Processor Electronics unit which controls all subsystems and manages the data interface with the satellite. OME forms the main instrument structure holding two telescopes (for near-nadir and backward views), the Scan Electronic Unit, the calibration units for the visible and the infrared bands (Black Bodies BBs with associated Electronics Unit) and radiators, while DA comprises the Focal Plane Assembly containing the focalizing optics and detectors, the Front End Electronics and the Cryo-Cooler with its Electronics. Leonardo is the responsible for the instrument development within a consortium where Thales-F is the satellite prime and RAL-UK the responsible of the on ground calibration.



(**a**) (**b**)

**Figure 1.** SLSTR Front side (**a**) and disposition in Sentinel 3 satellite (TAS-F courtesy) (**b**) (the instrument reference frame is defined as –X = satellite speed direction, −Y = cold space view direction, +Z = nadir view direction).

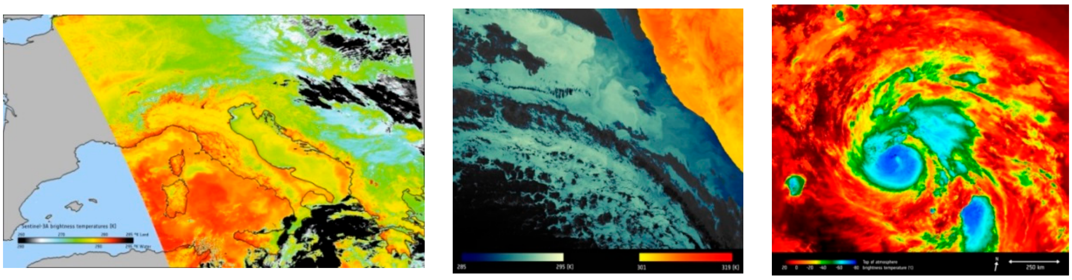
## *2.2. Radiometric Performance and Images*

The radiometric performance for the infrared channels have been evaluated on ground at RAL-UK by varying the temperature of a reference external well calibrated blackbody and comparing it with the instrument Brightness Temperature calibrated by using the two internal SLSTR Blackbodies. The measured on ground Absolute Radiometric Accuracy after calibration (that is the difference between the reference blackbody and the instrument brightness temperature) is less than 0.1 K in the temperature range 260-305 K for S7-S8-S9 channels, which are important for the SST measurements, and less than 3 K in the range 350-490K for F1-F2 channels, which are used for the forest fire detection.

The measured in flight NeDT (Noise Equivalent Differential Temperature) is of the order of 20 mK for S8-S9 and 50 mK for S7 channels for Near Nadir and Oblique views observation in agreement with the Instrument Requirements (Table 1). Many products can be derived from the SLSTR infrared images such as SST, LST, Fire Area and temperature, hurricanes temperatures, etc (some examples are reported in Figure 2).

**Table 1.** NeDT (Noise Equivalent Differential Temperature) in flight performance evaluated by looking at the two Blackbodies for model S3A and S3B (RAL courtesy) compared with mathematical model and instrument requirements. NeDT represents the input brightness temperature variation corresponding to instrument SNR equal 1 (at 1 sigma of standard deviation).

| | S3A | S3A | S3B | S3B | Mathematical Model BOL-EOL | | EOL Requirement goal-threshold |
|---|---|---|---|---|---|---|---|
| **Tscene** | 266 K | 304 K | 266 K | 304 K | 270 K (F1 = 350K, F2 = 330K) | 300 K | 270 K |
| **S7** | 50 mK | 17 mK | 43 mK | 16 mK | 51–56 mK | 22–24 mK | 50–80 mK |
| **S8** | 14 mK | 12 mK | 17 mK | 13 mK | 19–21 mK | 15–16 mK | 30–50 mK |
| **S9** | 22 mK | 18 mK | 19 mK | 15 mK | 20–24 mK | 17–19 mK | 30–50 mK |
| **F1** | 1.2 K | 0.275 K | 1.8 K | 0.470 K | 85–95 mK | 0.377–0.42 K | 1 K (350–500K) |
| **F2** | 28 mK | 34 mK | 31 mK | 30 mK | 30–33 mK | 35–38 mK | 0.5 K (330–400K) |



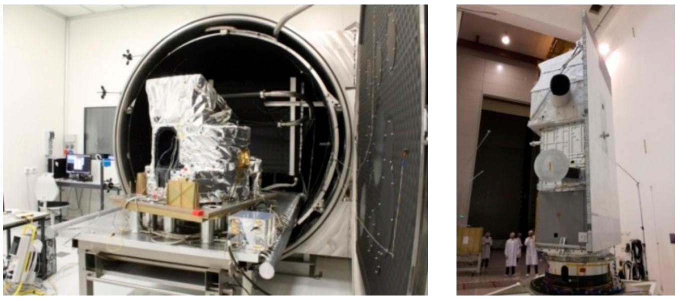
(**a**) (**b**) (**c**)

**Figure 2.** SLSTR thermal images: (**a**) Italy and Mediterranean sea, (**b**) Namibian SST and LST, (**c**) Ophelia Hurricane temperatures (from ESA web site).

## 3. PRISMA Hyperspectral payloads on the first Italian Space Agency (ASI) optical mission

### *3.1. Mission and Instrument Concept*

The PRISMA Payload is an electro-optical instrument for Hyperspectral Earth observation, composed of a high spectral resolution spectrometer optically integrated with a panchromatic camera. The Payload has been designed and manufactured by Leonardo (Figure 3), as part of a consortium including OHB-I and operating under the authority of the Agenzia Spaziale Italiana (ASI) [2]. The main objectives of PRISMA mission are the in orbit demonstration and qualification of a state-of-the-art hyperspectral imager, and the validation of end-to-end data processing, enabling the development of applications for environmental monitor and risk prevention. The PRISMA platform (Figure 3) which hosts the payload has been produced by OHB-I and has been launched in March 2019 by means of the European launcher VEGA. The satellite has been placed into a sun synchronous orbit at 620 km of altitude with a repeat cycle of 29 days. Observation covers the area between 70°S and 70°N. The instrument is based on the push-broom concept (no scanning mechanism on board, images in each spectral channel obtained by acquiring an across—track FOV moved in the along-track direction by means of satellite), and it provides hyperspectral images of the Earth with 30 m Ground Sample Distance (GSD), 30 Km swath width and spectral bands at interval less than 12 nm. The covered spectral range is the Visible and Near Infrared (VNIR) and the Short Wave Infrared (SWIR), with PAN images provided at higher spatial resolution (5 m), co-registered with the hyperspectral ones.



(**a**) (**b**)

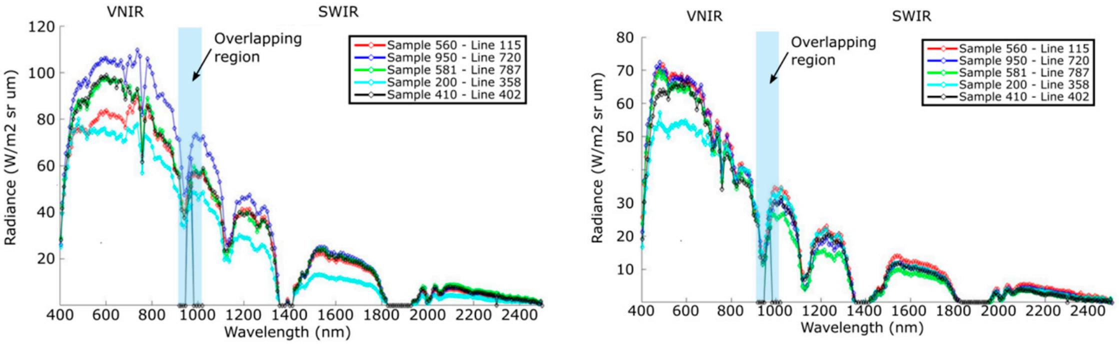
**Figure 3.** PRISMA instrument in the Leonardo cleaning room (**a**) and placed in the satellite (**b**) (ASI and OHB-I courtesy).

### *3.2. Performance and First Calibrated Data*

To achieve the high radiometric performance the instrument has been designed based on a prism spectrometer concept and the overall optical design has been addressed to exhibit the maximum optical transparency. The Signal-to-Noise Ratio (SNR) values listed in Table 2 refer to a typical scenario of 30% reflectance at a 30º Sun Zenith Angle (SZA) at Top Of Atmosphere (TOA) for a mid-latitude summer atmosphere. The first PRISMA radiances acquired in vegetated and not vegetated surfaces are reported in Figure 4.

**Table 2.** Principal PRISMA performance.

| | **VNIR Hyperspectral** | **SWIR Hyperspectral** | **PANchromatic** |
|---|---|---|---|
| **Swath** | 30 km | 30 km | 30 km |
| **Ground Sampling Distance** | 30 m | 30 m | 5 m |
| **Spectral Range** | 400–1010 nm | 920–2505 nm | 400–700 nm |
| **Number of bands** | 66 | 174 | 1 |
| **Spectral Width** | < 13 nm | < 14.5 nm | - |
| **SNR** | > 160 (> 450 at 650 nm) | > 100 (> 360 at 1550 nm) | > 240 |



(**a**) (**b**)

**Figure 4.** PRISMA Radiances (mW/m²/sr/nm) as a function of wavelength (nm) acquired on vegetated (a) and non vegetated surfaces (b). Each curve corresponds to a different pixel.

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**Conflicts of Interest:** The authors declare no conflict of interest.

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