SPACE SYSTEMS

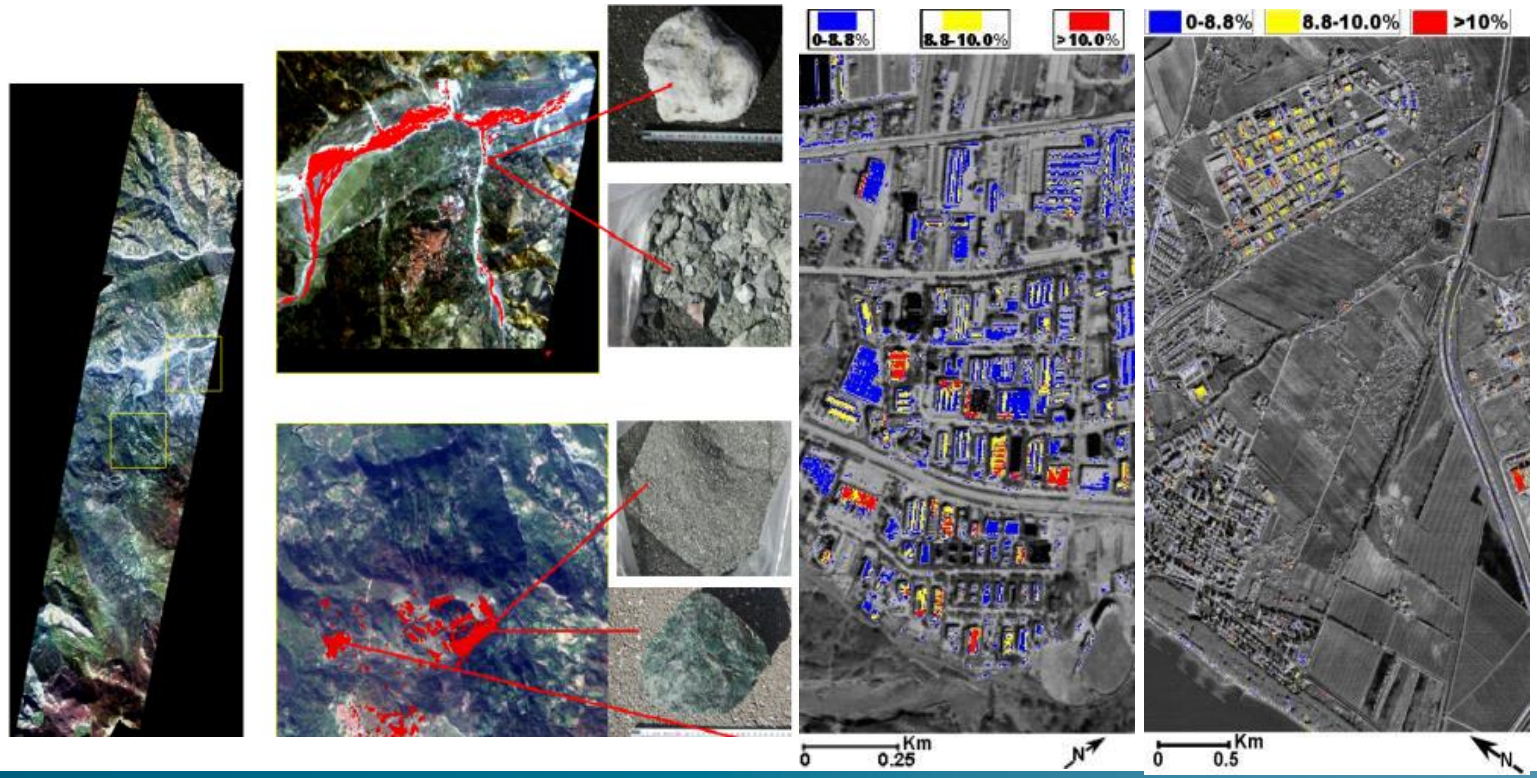
Performance and Functional Aspects of PRISMA payload for the PRISMA Space Mission

Data Exploitation della missione PRISMA, precursore delle missioni iperspettrali nazionali
Agenzia Spaziale Italiana (ASI)
Roma, 1-2 e 3 marzo 2017

PRISMA Hyperspectral Imager

PRISMA Payload is an electro-optical instrument composed by an Imaging Spectrometer (or Hyperspectral Imager), able to take images in a continuum of spectral bands ranging from 400 to 2500 nm, and a medium resolution Panchromatic Camera. Main applications are:

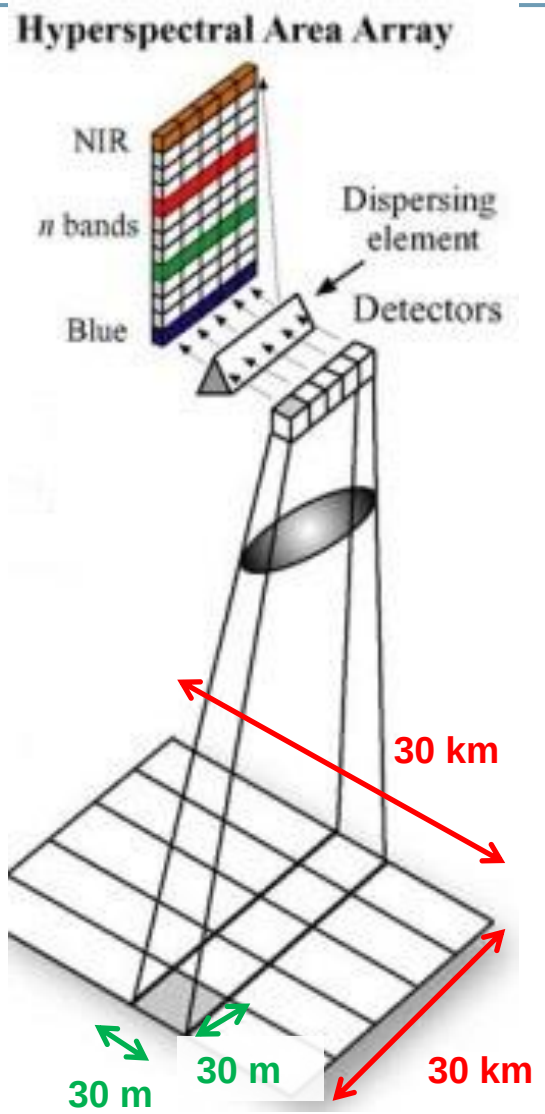
- Mapping of land cover and agricultural landscapes
- Pollution monitoring
- Quality of inland waters
- Coastal zones and sea
- Soil moisture
- Carbon cycle monitoring



Payload Introduction

- PRISMA instrument is and **hyperspectral payload** composed by an **high spectral resolution** spectrometer optically integrated with a **medium resolution panchromatic** camera
- Pushbroom acquistion concept
- Payload is designed to acquire all available bands in the spectral range 400-2500nm.
- Image acquisition area

  Longitude: in the range 180°W - 180°E
  Latitude: in the range 70°S - 70°N
- One earth pointing session per orbit
- Acquisition Frame= 30m x 30km (GSD x Swath) = 4,31msec
- Single Image (Minimum Image Length) = 30km x 30km = 1000x4,31msec = 4,31 sec
- Uninterrupted acquisition up to 1800km (258 sec)
- Selectable compression algorithm:
  - Lossless (baseline)
  - Near-lossless with quantization factor of 1-2-3
- Acquired Bands from Payload: 66 VNIR, 173 SWIR (each frame) (all spectral range)



Payload Main Characteristics

Swath / FOV /IFOV	30 km / 2.77° / 48 µrad
Ground Sampling Distance (GSD)	Hyperspectral: 30 m / PAN: 5 m
Spectral Range	VNIR: 400 – 1010 nm (66 spectral bands) SWIR: 920 – 2505 nm (173 spectral bands) PAN : 400 – 700 nm
Spectral Width (FWHM)	≤ 12 nm
Radiometric Quantization	12 bits
VNIR SNR	> 200:1
SWIR SNR	> 100:1
PAN SNR	> 240:1
Absolute Radiometric Accuracy	5%
MTF@ Nyquist freq.	VNIR/SWIR along track > 0.18 VNIR/SWIR across track > 0.34 PAN along track > 0.10 /PAN across track >0.20
Co-registration (Keystone, Smile)	≤ 0.1 pixel
Thermal Control System	Double stage passive radiator (1 for each channel) + stabilization heater
Mass	Optical Head: 175kg Thermal Shield: 25kg Main Electronics: 11kg
Power Consumption	Earth Observation /calibration: 90W Idle: 80W

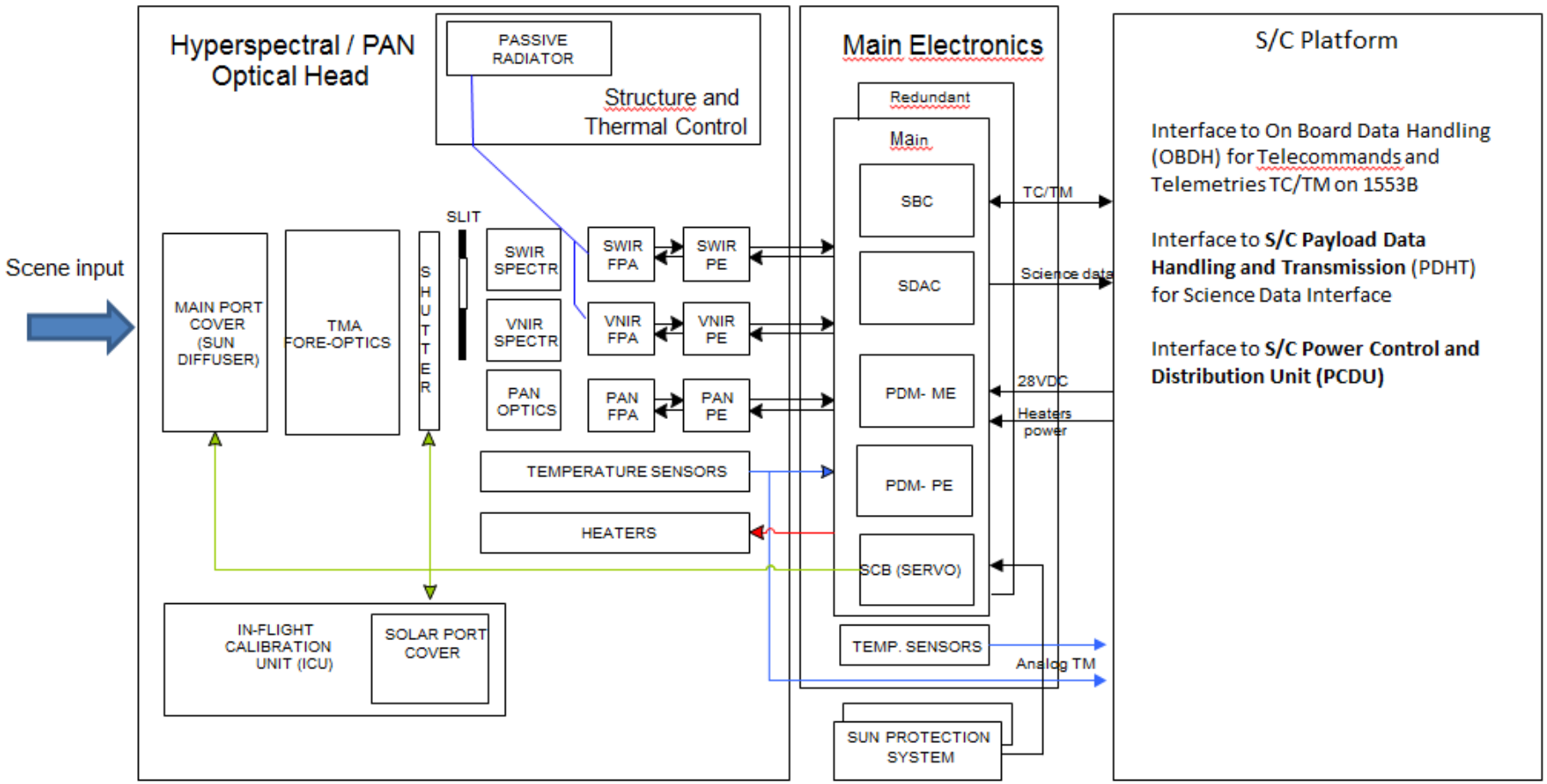
Payload Architecture

- The Hyperspectral/PAN Optical Head (OH) collects the radiation by a telescope, disperses the radiation by the two spectrometers, separates PAN channel using in-field separation technique, converts photons to electrons by means of state-of-the-art detectors and provides in-flight calibration capability. It has mechanical and thermal interfaces with the S/C.

- The Main Electronics (ME) box has the function to control the instrument and to handle, according to the agreed protocols, the bit stream representing the spectral images up to the interface with the S/C Electronics. It has mechanical, thermal and electrical interfaces with the S/C.

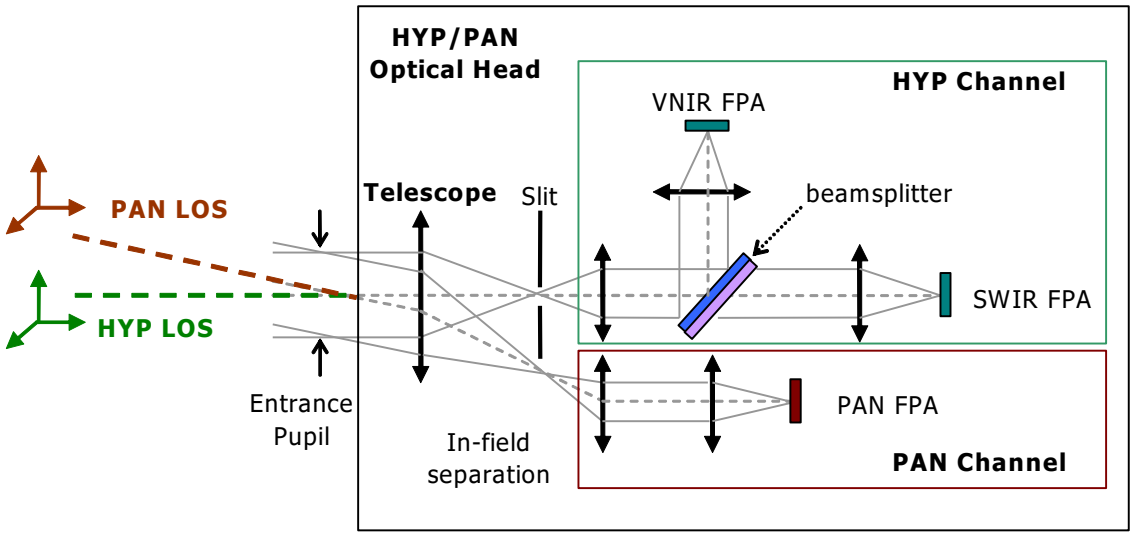
- The Sun Protection System (SPS) is an autonomous system, directly interconnected with PL ME and that is meant to activate a recovery action in case of failure of AOCS in order to prevent damages to the Payload Optical Head in case of direct exposition to the solar flux.

PRISMA p/l Block Diagram



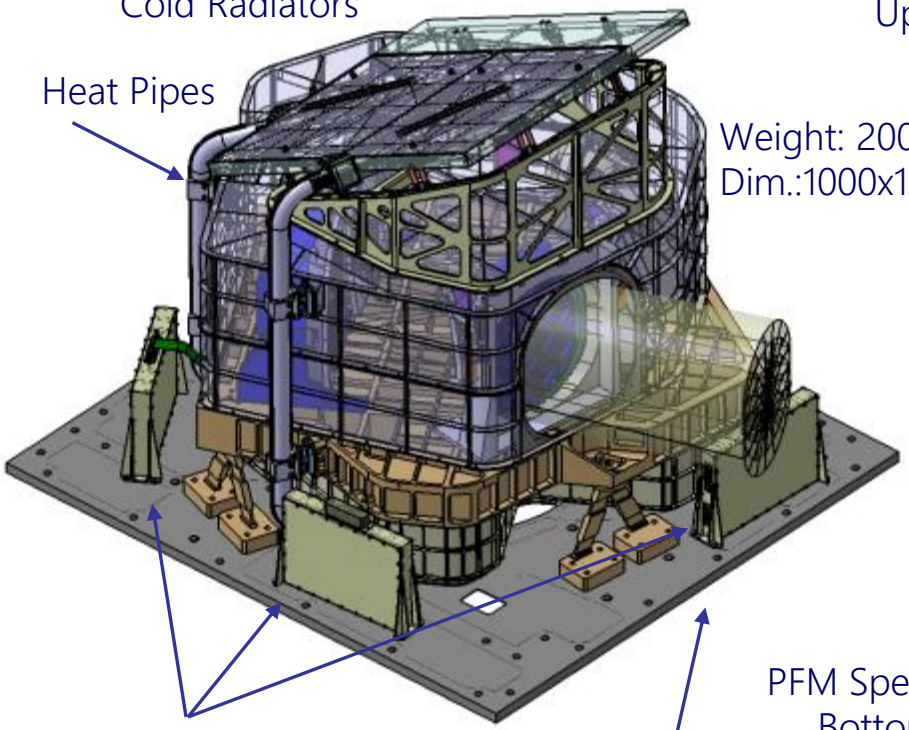
PRISMA light path

- Three mirror anastigmat (TMA) telescope: common to HYP and PAN channels
- In-field separation between HYP and PAN channel: 0.27° so that PAN has <1sec time delay wrt to HYP.
- Single slit for pushbroom HYP spectrometer.
- Beamsplitter for VNIR/SWIR channels separation.
- Prism based solution for spectral dispersion of VNIR-SWIR channels.
- Panchromatic channel.
- Internal Calibration Unit optical relay, with high reflectance integrating sphere and parabolic mirror to image sunlight and spectral lamps.



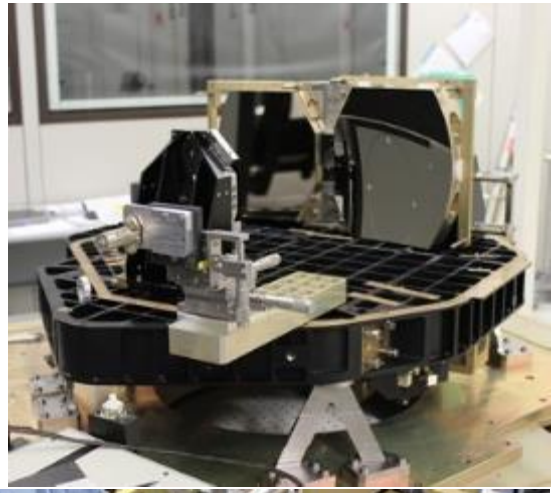
Payload Overview

Hyperspectral/PAN Optical Head (OH)



PFM TMA Side
Upper face of the bench

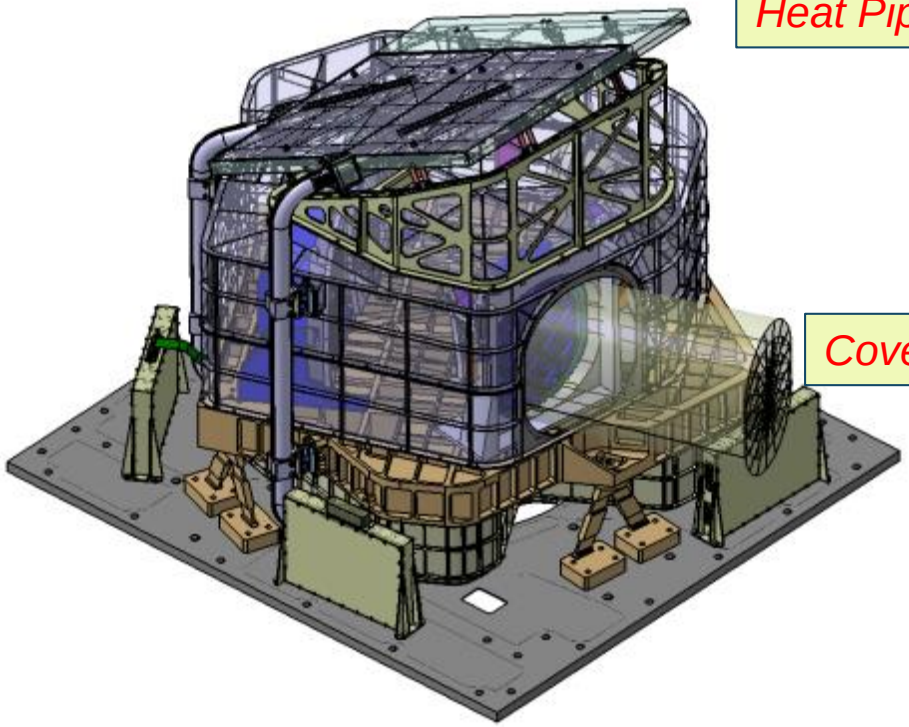
Weight: 200kg (incl.thermal shield)
Dim.:1000x1010x1650mm

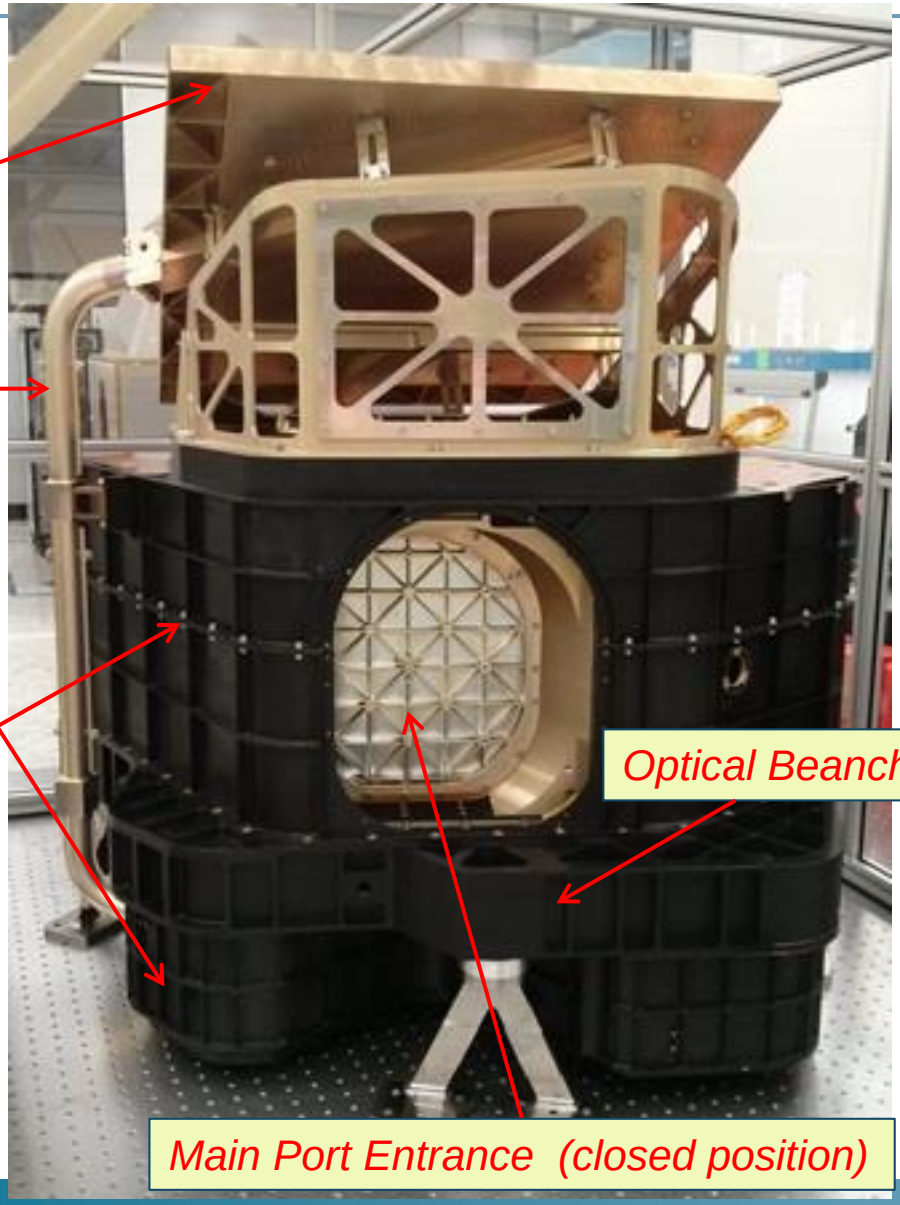


PFM Spectrometer/PAN Side
Bottom face of the bench

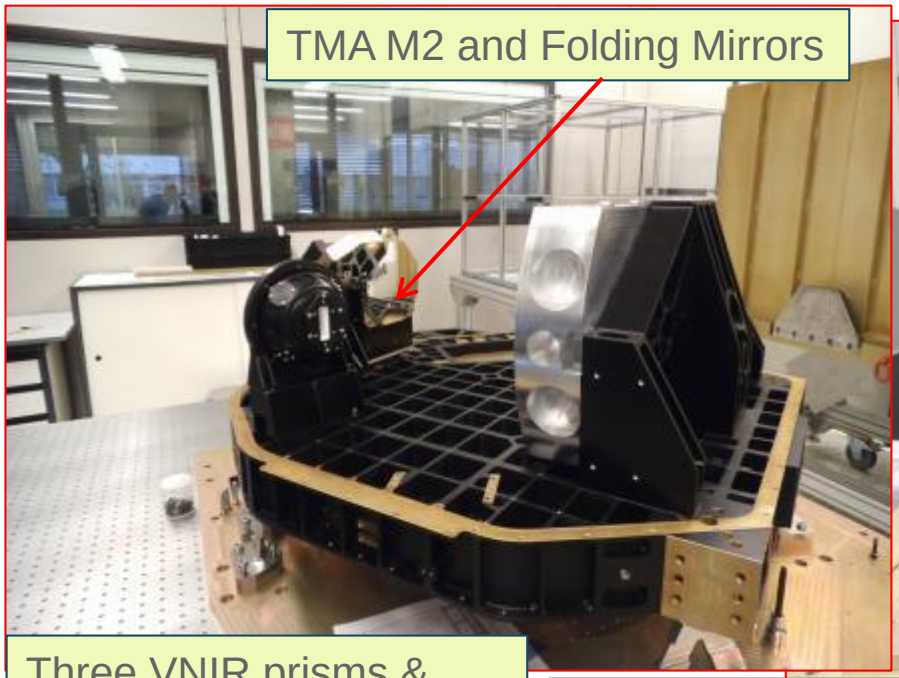
Payload Overview

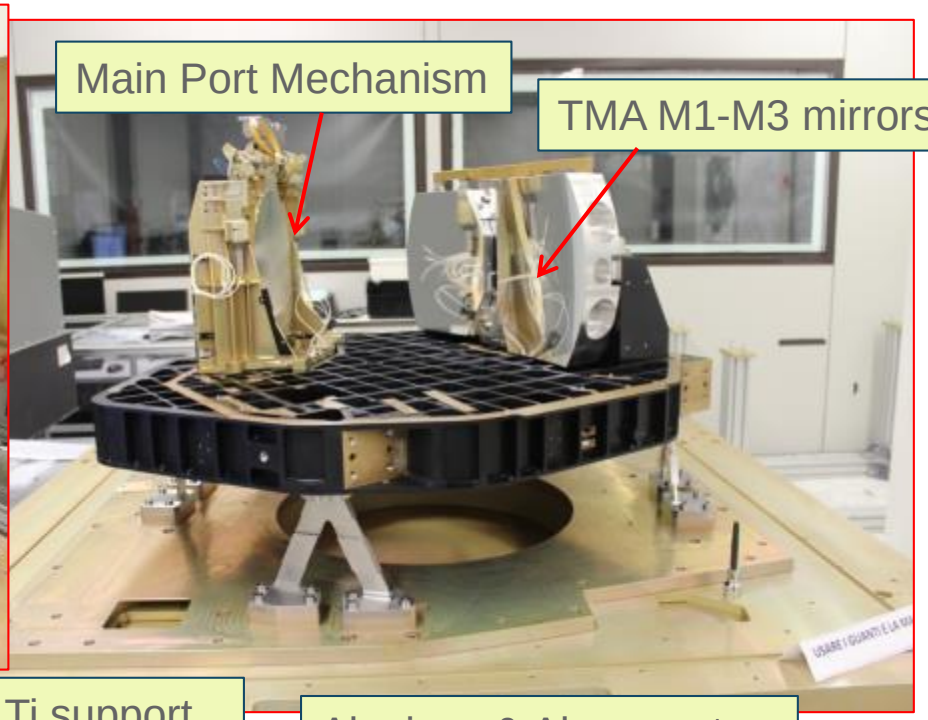
Hyperspectral/PAN Optical Head (OH): front view including covers, radiators, heat pipes.





Payload Overview





Three VNIR prisms & support

Dioptric optics & Ti support

Al mirror & Al support

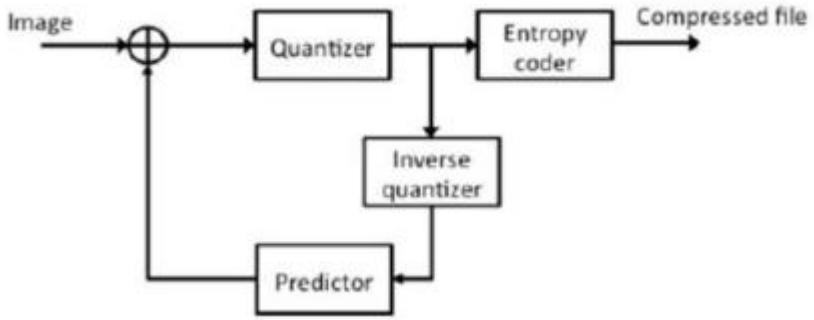
Payload Main Electronic

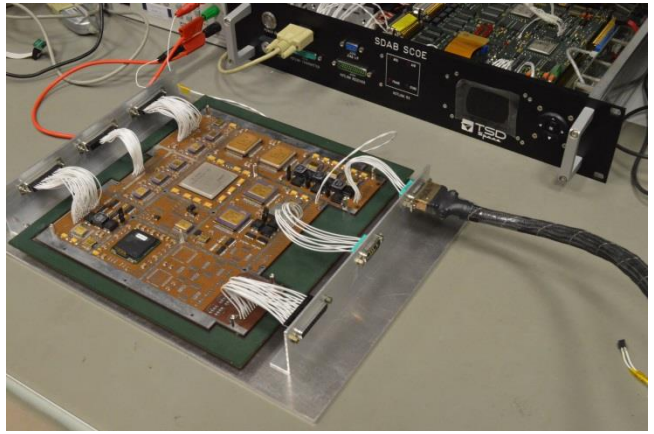
- SDAC (Scientific Data Acquisition & Compression) - scientific data I/O, compression, encoding, formatting and selection
- SBC (Single Board Computer) - CPU, TC/TM interfaces, Serial interfaces for instrument control
- SRV (Servo mechanisms board) – Electro-mechanics parts, heaters, housekeeping
- PDM-PE (Power Distribution Module for Proximity Electronics) - Feeding of SWIR, VNIR and PAN channel
- PDM-ME (Power Distribution Module for Main Electronics) – Main and redundant parts feeding
- MB (Main board) - ME boards interconnection

- Main Electronic is in cold redundancy configuration
- Main Electronic is interfaced on one side with Platform for Telecommand, Telemetry, Power and Scientific data.
- Main Electronic is interfaced on other side with Proximity electronic (one for each image acquisition channel), mechanisms (shutter, main port, solar port) and payload thermal control (on VNIR and SWIR detectors and optical bench)

Compression algorithm

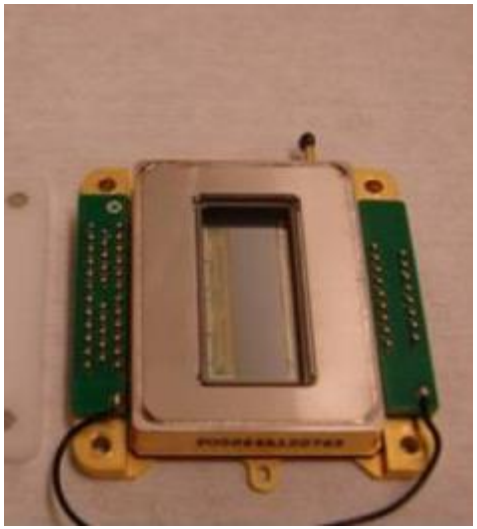
- A compression algorithm for scientific data is implemented to match the mission daily data volume requirements, taking into account the downlink capacity.
- The algorithm is an extension of the recently published CCSD123 recommendation intended for multispectral and hypespectral images.
- It includes a spatial/spectral predictor, a quantiser and a Golomb entropy coding stage.
- Lossless compression is the baseline, but a near-lossless mode for advanced compression is also available in case more enhanced performances are needed.
- Architectural drivers: low complexity, low resources needed, high throughput.
- Hardware implementation through the use of components specifically designed for process-intensive Space System. High grade of parallelism to maximise efficiency.
- Implemented on the SDAC board (inside PL Main Electronics)





Payload Detectors

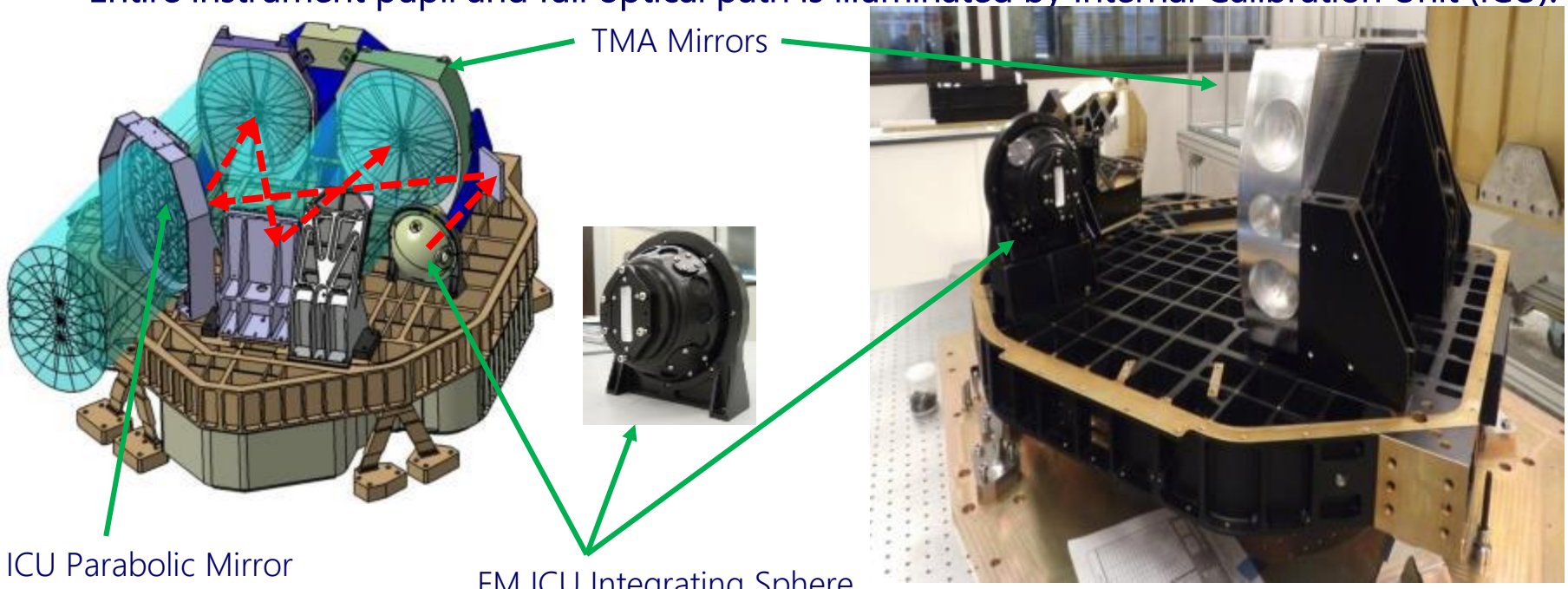
SWIR	*VNIR*	*PAN*
➢ MCT hybrid (λ_C ~ 2.5 µm) ➢ Spectral range: 1- 2.5 µm ➢ 1000 x 256 pixels ➢ 30 µm pitch ➢ 8 outputs ➢ QE > 85% ➢ 185K-195K	➢ MCT hybrid with substrate removed (λ_C ~ 2.5 µm) ➢ Spectral range: 0.4 – 2.5 µm ➢ 1000 x 256 pixels ➢ 30 µm pitch ➢ 8 outputs ➢ QE > 68% ➢ 185-195K	➢ CCD ➢ 12000 pixels (used 6000 pixels) ➢ 6.5 µm pitch ➢ 4 outputs ➢ Responsivity: >3.8 V/µJ/cm² ➢ At the optical bench temperature



Payload Internal Calibration Unit

The Internal Calibration Unit (ICU) goal is to maintain PRISMA calibration accuracies throughout the instrument operational lifetime, by quantifying calibration uncertainty and updating KDP set. The task of internal calibration sources (Lamps and Led) is to perform relative radiometric and spectral calibration.
The task of external natural source (Sun spectral radiance), observed through a dedicated solar port, is to perform absolute radiometric calibration.

Entire instrument pupil and full optical path is illuminated by Internal Calibration Unit (ICU).

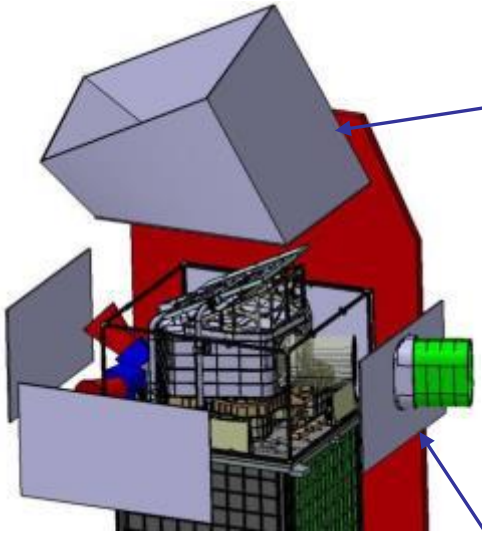


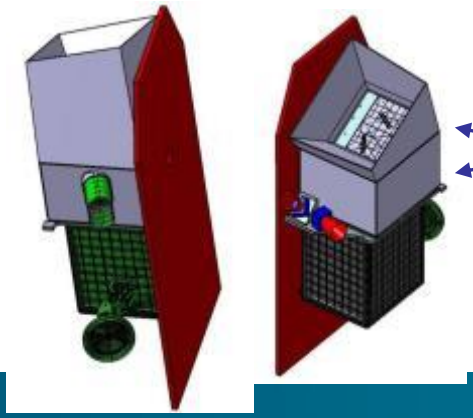
PAYLOAD BACKP SLIDES

Spacecraft Attitude

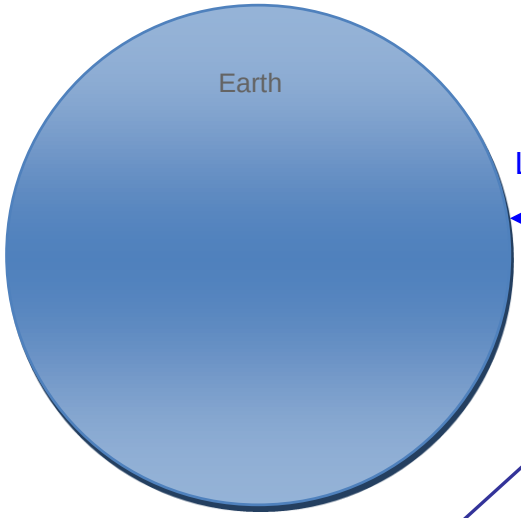
- Spacecraft is always in Sun Pointing attitude to recharge batteries. Payload performs calibration activities during this phase

- Spacecraft moves to Earth Pointing attitude to perform earth observation tasks: Payload works to acquire HYP and PAN images



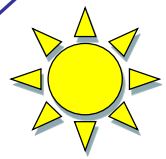


Thermal Shield



Line of Sight

Sun Entrance (for in-flight calibration purpose)



Radiator facing cold space for passive Thermal Control System of VNIR and SWIR detectors

Thermal shield:

- Protects all Payload sides from environment
- To radiatively decouple Payload from space and Spacecraft environment.
- design based on Al sandwich panels limit weight
- Covered externally with MLI

Payload Image Data

- Payload uninterrupted single acquisition = 1800 km along track (258 sec of continuous acquisition)
- Payload daily image acquisition capability: 200.000km2 daily
- Payload is very flexible infact it is possible to :
  - Select Spectral band to be acquired
  - Apply spatial grouping strategy (2 or 4 spatial sampling are summed: increase GSD)
  - Apply spectral binning strategy (2 adjacent bands are summed: increase in SNR)
  - Select compression algorithm:
    - Lossless (baseline)
    - Near-lossless with quantization factor of 1-2-3
- Acquired Bands from Payload: 66 VNIR, 173 SWIR (each frame) (all spectral range)
- Payload is designed to acquire all available bands in the spectral range 400-2500nm.

Payload Calibration: Summary

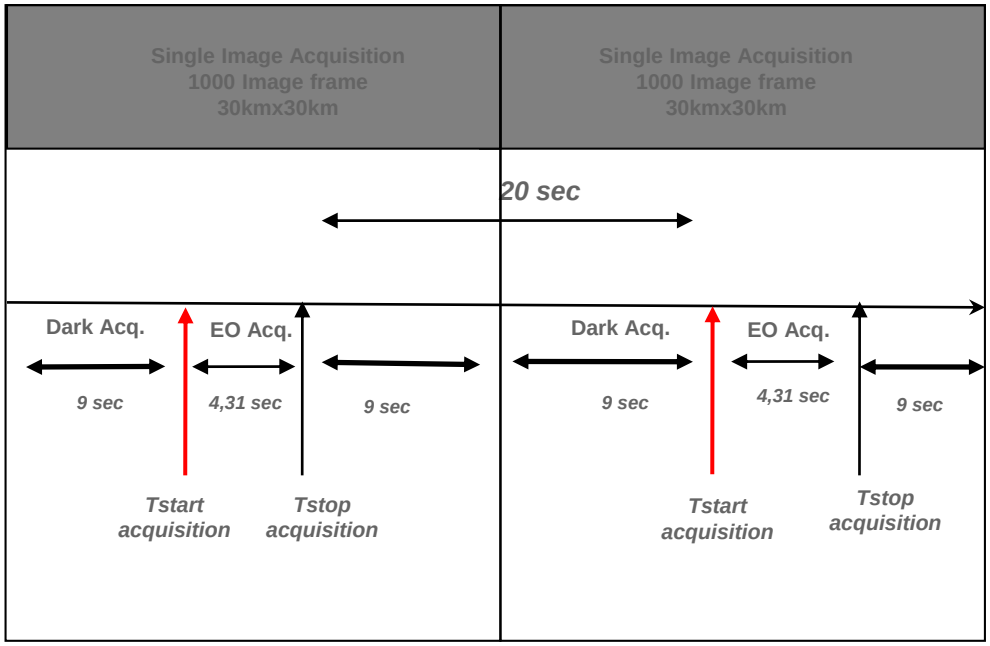
Type	PL Mode	Telecommand	Sequence ID	Prodotto	Note	S/C attitude	S/C Constraint	Off-Nadir [deg]	Settable Parameter	Frequenza	Durata
Dark-OBS	OBS	inclusa in EO acquisition		Dark_Calibration_file (DC)	Main port open, shutter close	Fine Pointing	No	-21/+21	SP_T_INT_OBSERVATION	inclusa in EO acquisition	9 sec
EO acquisition special	OBS	TC_Acquisition	Acq Purpose=1	Earth_Observation_CalVal_file (EOS)		Fine Pointing	No	No	SP_T_INT_OBSERVATION	1 mese	a richiesta
Dark-INT		TC_Dark_Acquisition		Dark_Calibration_file (DC)	Main port and shutter close	Sun pointing	No	-21/+21	SP_T_INT_DARK_CAL	a richiesta	8 sec
Internal not special	CAL	TC_Calibration	1	Internal_Calibration_file (IC)	BKG,DARK, LED, LAMP	Sun pointing	No	-21/+21	SP_T_INT_INTERN_CAL_1…4	7 giorni	4 min 30 sec
Internal special	CAL	TC_Calibration	2	Internal_Calibration_Special_file (S_IC)	BKG,DARK, LED, LAMP	Sun pointing	No	-21/+21	SP_T_INT_CAL_SPEC_1…20	1 mese	20 min
Sun	CAL	TC_Calibration	3	Sun_Calibration_file (SC)	SUN	Sun pointing	Sun normal to solar port con ±5 deg	No	SP_T_INT_SUN_CAL_1...20	1 mese	8 min 30 sec
Moon	CAL	TC_Calibration	4	Moon_Calibration_file (MC)	MOON	Moon pointing	sono necessari più orbite per coprire la superficie lunare	No	SP_T_INT_MOON_CAL	1 mese	40 sec
Flat Field SWIR	CAL	TC_Calibration	5 + EXT_FF_CAL_TYPE 0	Flat_Field_Special_file (FC)	FLAT FIELD SWIR	Flat Field pointing	Yaw 90° rotate	No	SP_T_INT_EXFF_CAL	3 mesi	35 sec
Flat Field VNIR	CAL	TC_Calibration	5 + EXT_FF_CAL_TYPE 1	Flat_Field_Special_file (FC)	FLAT FIELD VNIR	Flat Field pointing	Yaw 90° rotate	No	SP_T_INT_EXFF_CAL	3 mesi	35 sec
Flat Field PAN	CAL	TC_Calibration	5 + EXT_FF_CAL_TYPE 1	Flat_Field_Special_file (FC)	FLAT FIELD PAN	Flat Field pointing	Yaw 90° rotate	No	SP_T_INT_EXFF_CAL	3 mesi	35 sec
Autotest	CAL	TC_Calibration	6	Autotest_file (AU) da chiarire se aggiungerlo	solo check elettrico	All	No	-21/+21	SP_T_INT_AUTOTEST	a richiesta	3 sec

Timeline for Calibration here reported are detailed in PRS-MA-GAF-001 Payload_User_Manual

Earth Observation

This is the baseline configuration for Payload timeline but it can be modified according to mission/planning requirement:

- The number of dark frames to be performed before and after each acquisition is a parameter ;
- The dark acquisition can be disable in each single TC_Acquisition;



Sub-Acquisition	Main Door Cover	Sun Door Cover	Shutter	Lamp	Led
EO	Open	Closed	Open	Off	Off

Dark- OBS

Dark observation included in the EO acquisition timeline.

In the timeline a previous dark observation is included, a successive dark observation is optional.

It can be enable/disable by parameters included in the TC_Acquisition

Dark observation acquires 20 frames (baseline) but this number can be modified (it is PL Settable parameter)

It is performed by closing PL shutter.

S/C is already in Fine Pointing attitude due to planned EO acquisition.

Sub-Acquisition	Main Door Cover	Sun Door Cover	Shutter	Lamp	Led
DARK-OBS	Open	Closed	Closed	Off	Off

EO Acquisition Special

EO Acquisition special is a EO acquisition performed on special target.

It is marked as special because its acquired data are used for calibration purposes.

An Internal Calibration is needed before performing an EO Acquisition Special.

S/C is in Fine Pointing attitude because it is an EO acquisition.

Sub-Acquisition	Main Door Cover	Sun Door Cover	Shutter	Lamp	Led
SURF-OBS	Open	Closed	Open	Off	Off

Dark- INT

It is a standalone dark acquisition in AOI (OBS mode)

Dark observation acquires 20 frames (baseline) but this number can be modified (it is PL Settable parameter)

It is performed by closing PL shutter.

S/C is already in Fine Pointing attitude due to planned Observation mode.

Sub-Acquisition	Main Door Cover	Sun Door Cover	Shutter	Lamp	Led
DARK-INT	Closed	Closed	Closed	Off	Off

Internal NOT SPECIAL

It's a calibration performed in calibration mode by acquiring light from internal source (lamp and led mounted on the ICU)

It is a sequence of dark, background, lamp and led acquisitions.

Number of acquired frames is a PL Settable parameter.

Sub-Acquisition	Main Door Cover	Sun Door Cover	Shutter	Lamp	Led
DARK-INT	Closed	Closed	Closed	Off	Off

Sub-Acquisition	Main Door Cover	Sun Door Cover	Shutter	Lamp	Led
BKG	Closed	Closed	Open	Off	Off

Sub-Acquisition	Main Door Cover	Sun Door Cover	Shutter	Lamp	Led
LAMP	closed	Closed	Open	On	Off

Sub-Acquisition	Main Door Cover	Sun Door Cover	Shutter	Lamp	Led
LED	closed	Closed	Open	Off	On

Internal SPECIAL

It is a calibration performed in calibration mode by acquiring light from internal source (lamp and led mounted on the ICU)

It is a sequence of dark, background, lamp and led acquisition.

Number of acquired frames is a PL Settable parameter.

The difference between internal NOT SPECIAL and Internal SPECIAL is the number of acquisition/frame carried out and the integration time: these are settable paramenter => internal SPECIAL acquires more calibration data.

With the Internal Special it shall be possible to perform detectors linearity (vs integration time).

SUN

It's a calibration performed in calibration mode by acquiring light from Sun (passing through the ICU)

Number of acquired frames is a PL Settable parameter

S/C is in Sun pointing attitude with a latitude lower than -60 degrees

Sub-Acquisition	Main Door Cover	Sun Door Cover	Shutter	Lamp	Led
SUN OBS	Closed	Open	Open	Off	Off

MOON

It is a calibration performed in calibration mode by acquiring light from Moon (passing through the Main Port)

Number of acquired frames is a PL Settable parameter.

S/C is requested to point Moon with the Main Port.

The Moon does not cover the entire instrument Field of View (~1/5 only).

More orbits are needed to cover entire slit length (FOV) (optional acquisition)

Sub-Acquisition	Main Door Cover	Sun Door Cover	Shutter	Lamp	Led
MOON OBS	Open	Closed	Open	Off	Off

FLAT FIELD

It is a calibration performed in calibration mode by acquiring light from Flat Field target from Main Port.

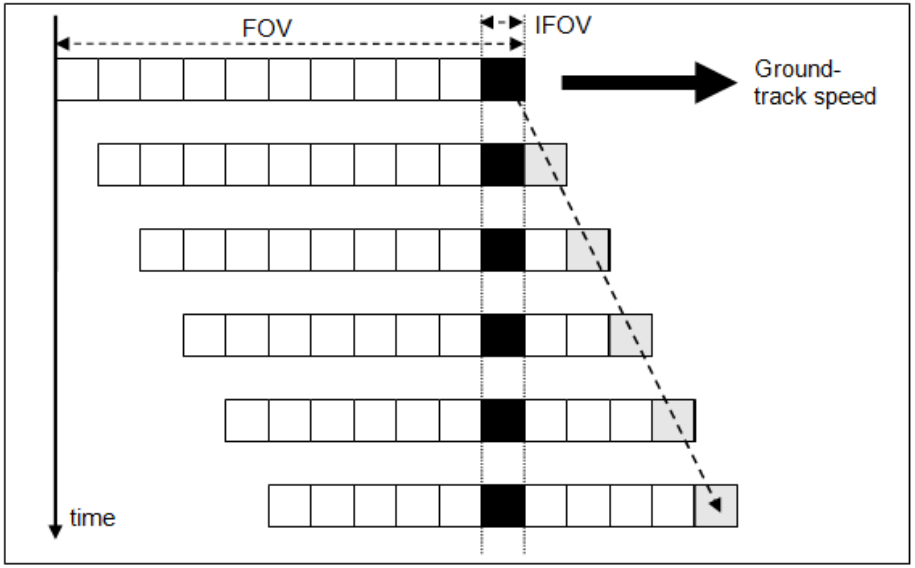
It is performed independently for VNIR, SWIR and PAN detector.

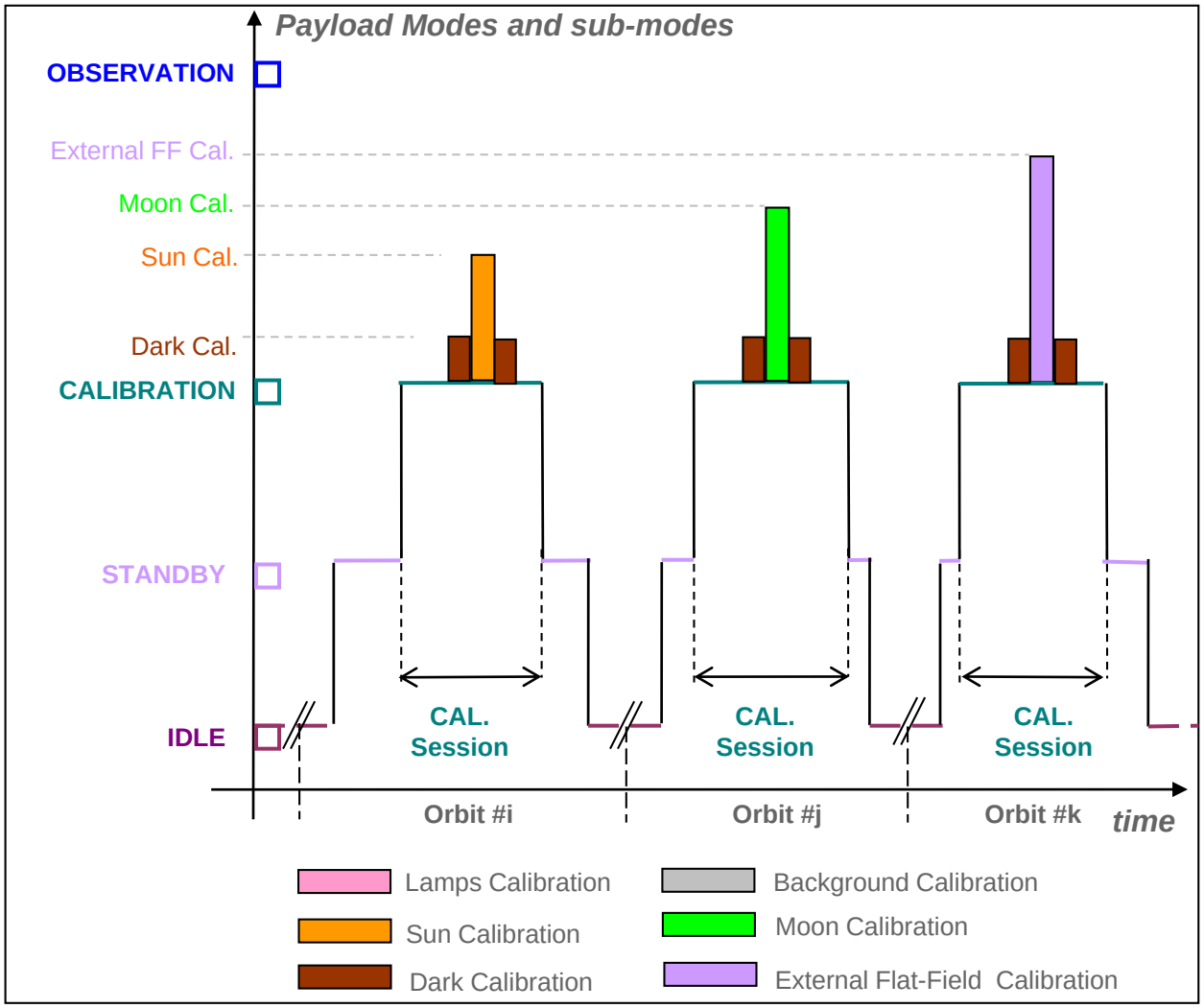
Number of acquired frames is a PL Settable parameter

S/C is requested to point Flat Field target by rotating S/C (yaw +90deg)

A target 2,9kmx2,9km area is needed, in order to take into account pointing error and alignment.

Sub-Acquisition	Main Door Cover	Sun Door Cover	Shutter	Lamp	Led
SURF-OBS-FF	Open	Closed	Open	Off	Off




Payload Modes and sub-modes
OBSERVATION
External FF Cal.
Moon Cal.
Sun Cal.
Dark Cal.
CALIBRATION
STANDBY
IDLE
CAL. Session
CAL. Session
CAL. Session
Orbit #i
Orbit #j
Orbit #k
time
Lamps Calibration
Sun Calibration
Dark Calibration
Background Calibration
Moon Calibration
External Flat-Field Calibration