“Forum Nazionale degli Utenti Copernicus”
14th July 2016

National developments for innovative remote sensing architectures

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Themes of the Presentation

- Space Technology Foundational Principles…
- …applied to the national Earth Observation Missions
- Approaching Hyperspectral
- Prisma
- Shalom

Space Technology Foundational Principles….

Meet the needs for new technologies to support future space missions and advance non-mission-focused technology supporting:

- Leadership consolidation and evolution in national flagship sectors.
- Scheme Changing maturing advanced space technologies and products that may lead to entirely new approaches for future space missions.
- Early-Stage Innovation focused on a wide range of low TRL efforts for advanced space system concept and initial technology development across academia and industry.

…applied to the national Earth Observation Missions

Strenghtening competencies: Italy is a world class player in two Remote Sensing key Technologies Radar and spectral/optical Imaging

- **Radar**
  - SAR X Band: fully developed, under operation
  - SAR L Band: key enabling technologies owned
  - SAR C Band: Under development advanced
  - SAR P Band: Under development Airborne
  - HF Bands (ie Ka, Ku, optical): under evaluation
  - Sounders: fully developed, under operation
- **Optical**
  - Radiometers: VIS SWIR MIR/TIR: fully developed, under operation
  - Hyperspectral SWIR/VNIR/PAN: under development
  - Avionic Hyperspectral SWIR/VNIR/PAN: fully developed, under operation
  - Spectrometers VIS-NIR-SWIR: fully developed, under operation
  - Spectrometers VIS-NIR-SWIR: under development
  - Stereo/HR camera under development
  - Camera (for NAV): fully developed, under operation
  - High Power Laser technology: under development

...applied to the national Earth Observation Missions

Scheme Changing:

- ✓ Multi-Band, Tunable and Steerable SAR sensors (e.g. L/C) – low frequencies P Band – Hi Frequencies Ka/Ku
- ✓ Multi sensors missions (Optical – Hyperspectral integrated sensors)
- ✓ Advanced architectural and system concepts and platforms for future missions

Early-Stage Innovation initiative

provides effort on low TRL technology concept in the following areas:

- ✓ Low TRL technologies enabling innovative missions
- ✓ EEE/Sensors/Detectors and optical/photonic devices;
- ✓ Photonics instruments

Hyperspectral innovative features

Need to cover a wide spectrum of applications and scientific questions

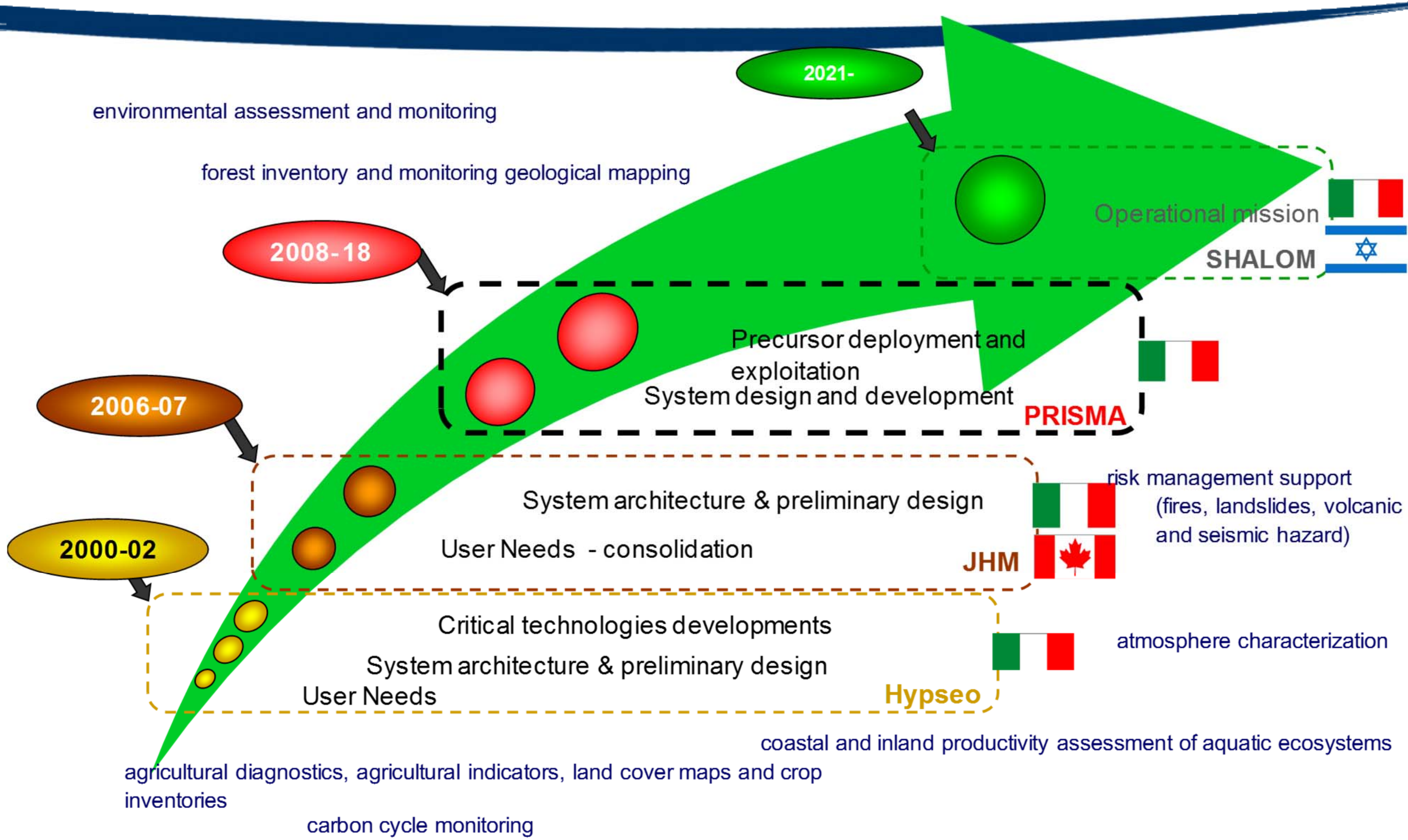
Several experiences based on space (i.e. Hyperion NASA) and avionic Hyperspectral instrumentation (e.g. AVIRIS NASA, MIVIS, SIM.GA) demonstrated the better capability to distinguish between features of a target.

ASI started National studies in the Hyperspectral field since the beginning of 2000’s in order to overcome the major limitation of broadband remote sensing products:

- ✓ Retrieval of critical information available in specific narrow bands
- ✓ contiguous covering of wider region of electro-magnetic spectrum that allow for target characterization
- ✓ no need for a pre-selection of spectral bands
- ✓ Flexibility of binning techniques that give the possibility to focus on specific bands

The narrow spectral channels that constitute hyperspectral sensors enable the detection of small spectral features that might otherwise be masked within the broader bands of multi spectral scanner systems

Hyperspectral national roadmap



Hyperspectral Data value is more perceived by consolidated actors in remote sensing being the technique at the higher level of the value chain for remote sensing products, (e.g. data fusion) through a combination with the product of different sensors (HR optical or SAR).

PRISMA Mission

Francesco Longo, Program Manager
Agenzia Spaziale Italiana (ASI)

Program: PRISMA
Event: -
Topic: PRISMA Mission
Date: Rome, 14 July 2016

Programme overview

PRISMA = PRecursore IperSpettrale della Missione Applicativa

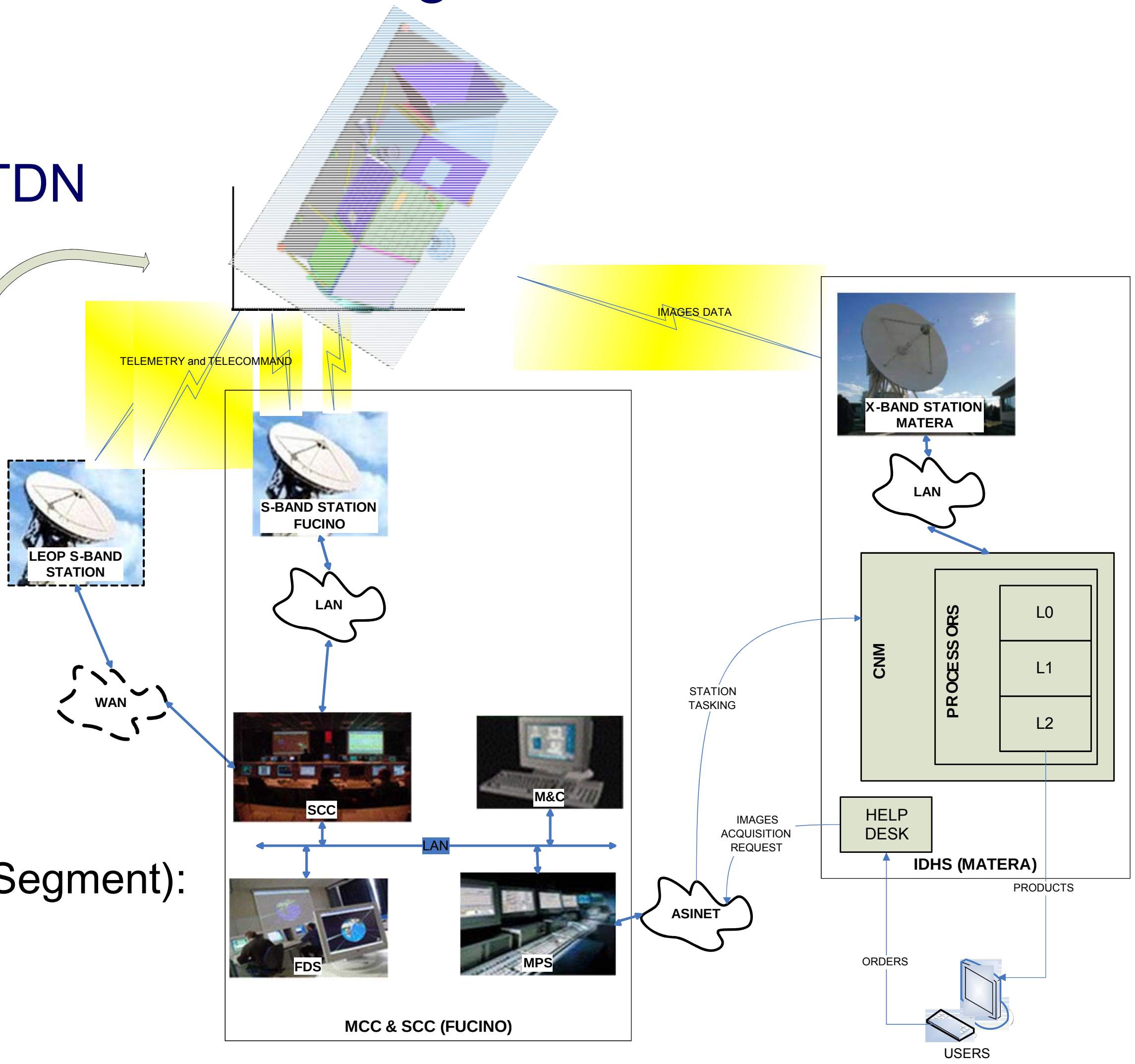
- **Mission Objectives:**
  - Pre-operational (improvements are on-going) and technology demonstrator
  - Focus on
    - Space qualification of PAN/HYP payload
    - Development and production of PAN/HYP products up to Level 2d

- **Program Highlights:**
  - National program
  - Fully funded by ASI
  - Mission includes System, interacting with Target and Users
  - System B2/C/D/E1 contract running
  - S-CDR

System Architecture at a glance

- **Orbit and lifetime:**
  - LEO SSO, 620km, 10.30 LTDN
  - 5 years lifetime

- **System elements:**
  - 1 Satellite
    - Platform
    - Pan/Hyp Payload
    - PDHT
  - Ground Segment
    - MCC/SCC: Fucino
    - IDHS (Image Data Handling Segment): Matera
  - Launch Segment
    - VEGA



Enhancements to the PRISMA system

Since the beginning of the PRISMA mission in 2007 there has been an evolution of the technology and of the applications in the field of Earth Observation and in particular in the sector of the image spectrometry.

On the applicative side, there was a significant increase of interest in the use of hyperspectral data and value-added products using the fusion of hyperspectral data with external data.

For the aforementioned reasons, ASI, in December 2014, re-directed the project to implement the following enhancements to the PRISMA system:

- Daily Imaging Capacity
- Daily Processing Capacity – All Hyperspectral/Panchromatic channels
- Primary Area of Interest
- Agility
- Payload protection
- Upgrade to the latest ECSS standard issues
- Schedule

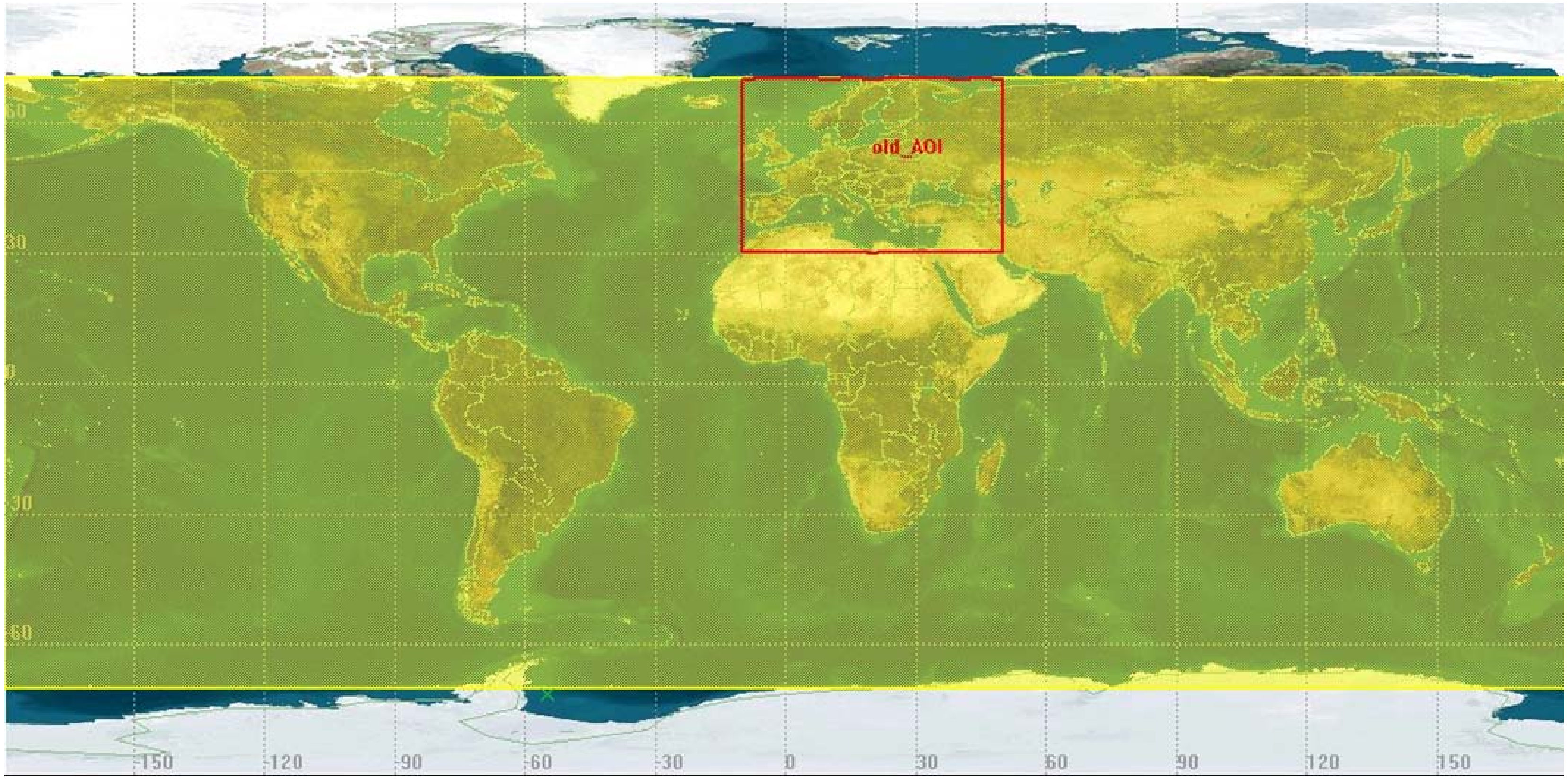
Mission highlights

- Coverage: Worldwide
  - Primary Area of interest (P-AoI)
    - Longitude: 180°W÷180°E
    - Latitude: 70°S÷70°N
- System Capacity:
  - Acquired data volume:
    - Daily >200.000 km^2
  - Daily products generation:
    - 200 HYP/PAN
- System Latencies (inside AoI):
  - Re-look time: < 7 days
  - Response time: < 14 days
    - Data Acquisition Latency: < 9,5 d
    - Data Processing Latency to level 2d < 4.5 days
- Mission modes:
  - Primary: User driven
  - Secondary: Data driven (background mission)

Primary - Area of Interest

- ❑ Longitude: 180°W÷180°E
- ❑ Latitude:70°S÷70°N

❑OLD P-AoI
- ❑ Long: 10°W÷50°E
- ❑ Lat: 30°N÷80°N



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Daily imaging & processing capacities (Hyp/Pan channels)

Capacity to acquire, download, process up to L0a (including quicklook) and archive all Hyperspectral and Panchromatic channels for a maximum of 200000 km^2 on a daily basis	❑OLD DESIGN ❑108000 km^2

- Imaging capacity:
  - 223 square images 30km x 30km instead of 120 (OLD DESIGN)

Capacity to daily process 200 hyperspectral scenes (30 km x 30 km) up to level 2d	❑OLD DESIGN ❑30 scenes

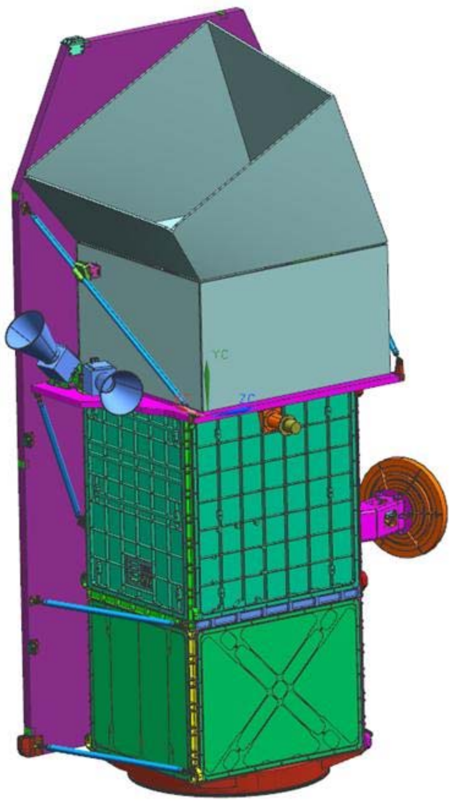
- Target access opportunities over the P-AoI:
  - duration/day: 240 minutes (28 min OLD DESIGN)
  - number of orbits/day: 15/15 (max 4/15 OLD DESIGN)

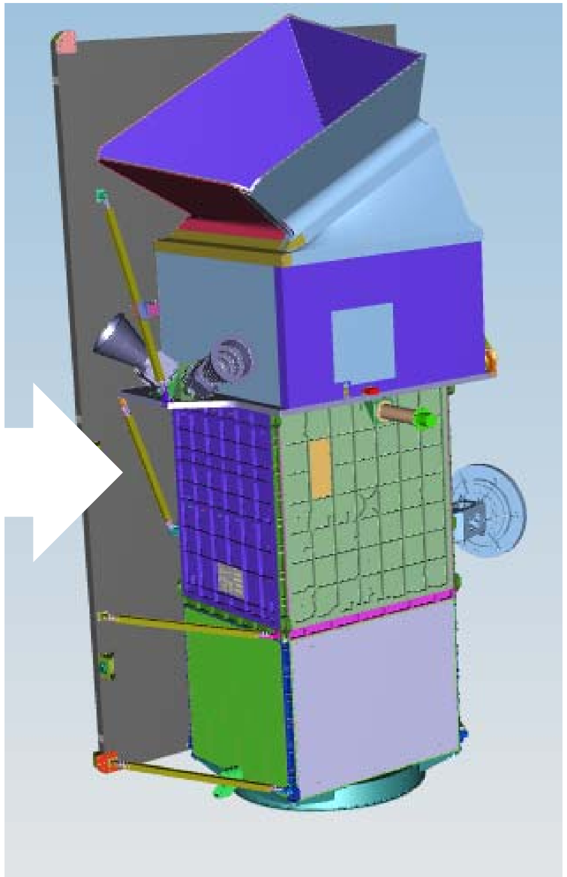
Agility

PRISMA satellite shall be able to manoeuver in order to capture two images at a maximum distance of 1000km in a single pass (from worst case left to right side looking and viceversa).

PRISMA S/C overview

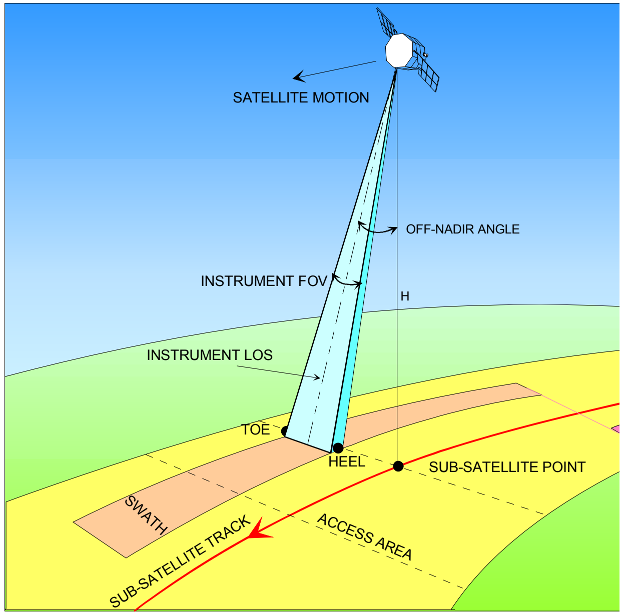
Prisma design evolved according to new requirements



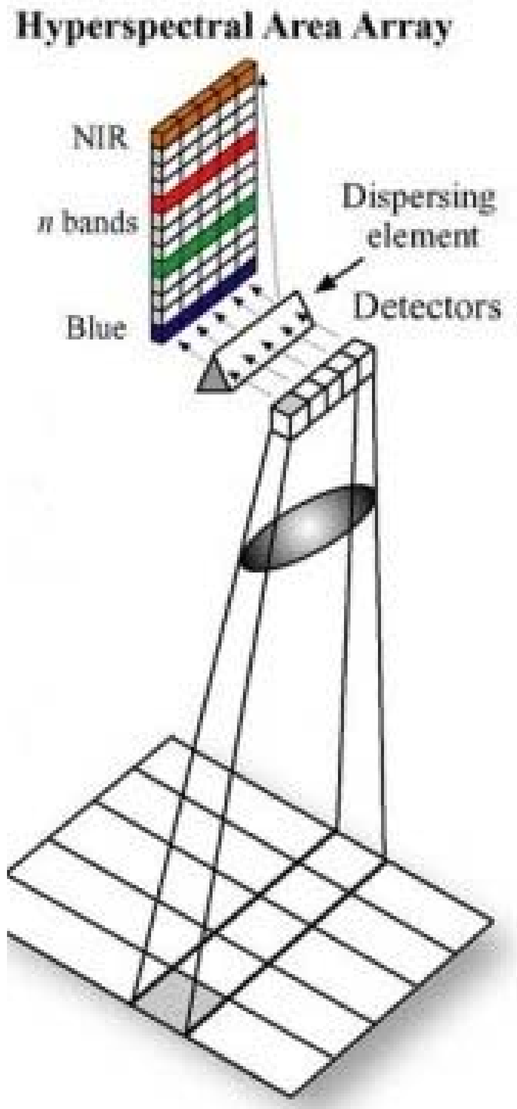


Parameter	Performance
Orbit	sun-synchronous
Altitude	620 km
LTDN	10:30
Lifetime	5 years
Mass P/L + P/F	≈ 830 Kg (including contingency and balance masses)
PL Imaging principle	push-broom

The Payload



The PRISMA Payload operates with a Pushbroom scanning concept that records reflected radiation from the Earth surface in the PAN range, in the visible/near infrared (VNIR) range and in the short wave infrared (SWIR) range with a band width of 10 nm.



The PAN sensor is characterized by a ground sampling distance of 5 m (nadir at sea level); the VNIR/ SWIR GSD is 30 m.

The Hyperspectral sensor utilizes prisms to obtain the dispersion of incoming radiation on a 2-D matrix detectors so to acquire several spectral bands of the same strip on ground.

P/L Spatial/Spectral characteristics

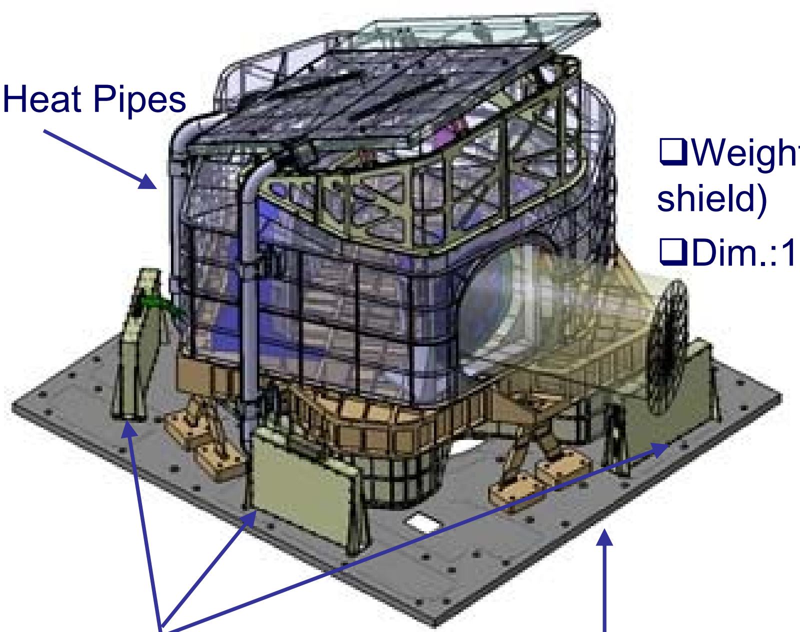
Swath / FOV	30 km / 2.77°
Ground Sampling Distance (GSD)	Hyperspectral: 30 m / PAN: 5 m
Spectral Range	VNIR: 400 – 1010 nm SWIR: 920 – 2505 nm PAN : 400 – 700 nm
Spectral Width (FWHM)	≤ 12 nm
Radiometric Quantization	12 bit
VNIR SNR	> 200:1
SWIR SNR	> 100:1
PAN SNR	> 240:1
MTF@ Nyquist freq.	VNIR/SWIR along track > 0.18 VNIR/SWIR across track > 0.34 PAN along track > 0.10 /PAN across track >0.20
Spectral Bands	66 VNIR 173 SWIR
Data processing	Lossless compression with compression factor 1.6 Near lossless compression
Thermal Control System	Double stage passive radiator (1 for each HYP channel) + stabilization heater
Mass (including 5% margin)	Optical Head: 175kg Thermal Shield: 25kg Main Electronics: 12kg
Power Consumption (including 10%margin)	Earth Observation /calibration: <105W Idle: <90W

Hyperspectral/PAN Optical Head

The OH has the functions to collect the radiation by a telescope, to disperse the radiation by two spectrometers, to convert photons to electrons by means of appropriate detectors, to amplify the electrical signal and to convert it into bits. It has mechanical and thermal interfaces with the S/C through the PL I/F Baseplate.

Cold Radiators

Heat Pipes



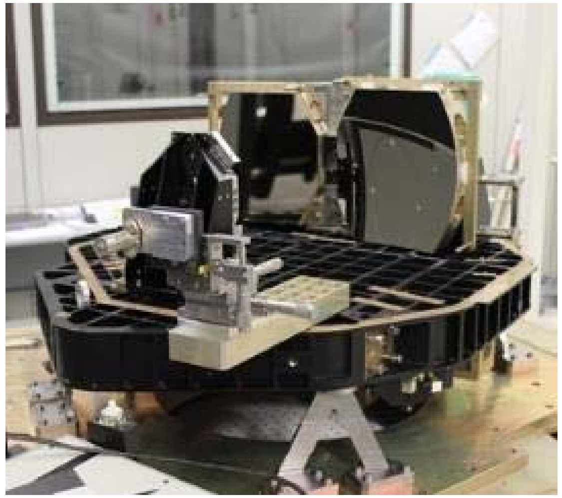
Proximity Electronics

PL Baseplate: I/F vs Satellite

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

PFM TMA Side

Upper face of the bench



PFM Spectrometer/PAN Side

Bottom face of the bench

Program: PRISMA
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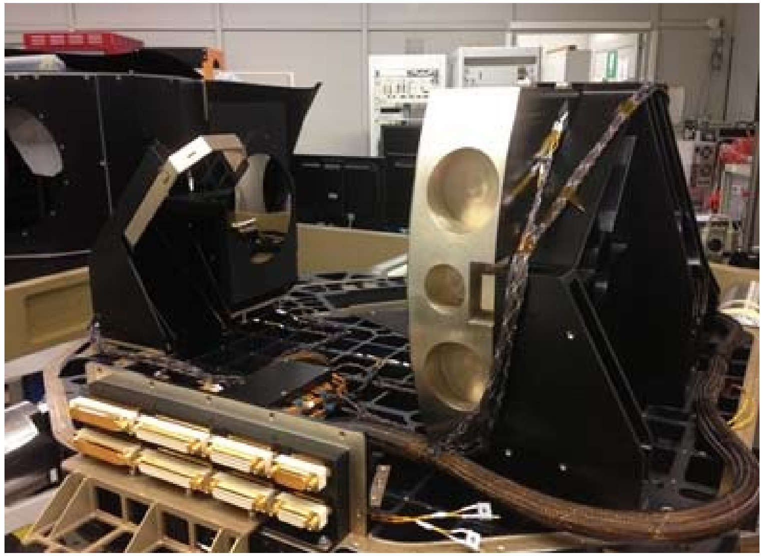
Hyperspectral/PAN Optical Head



PFM Optical Head (Open view, TMA side)

PFM Optical Head (Open view, TMA side)

PFM Optical Head (closed with cover)

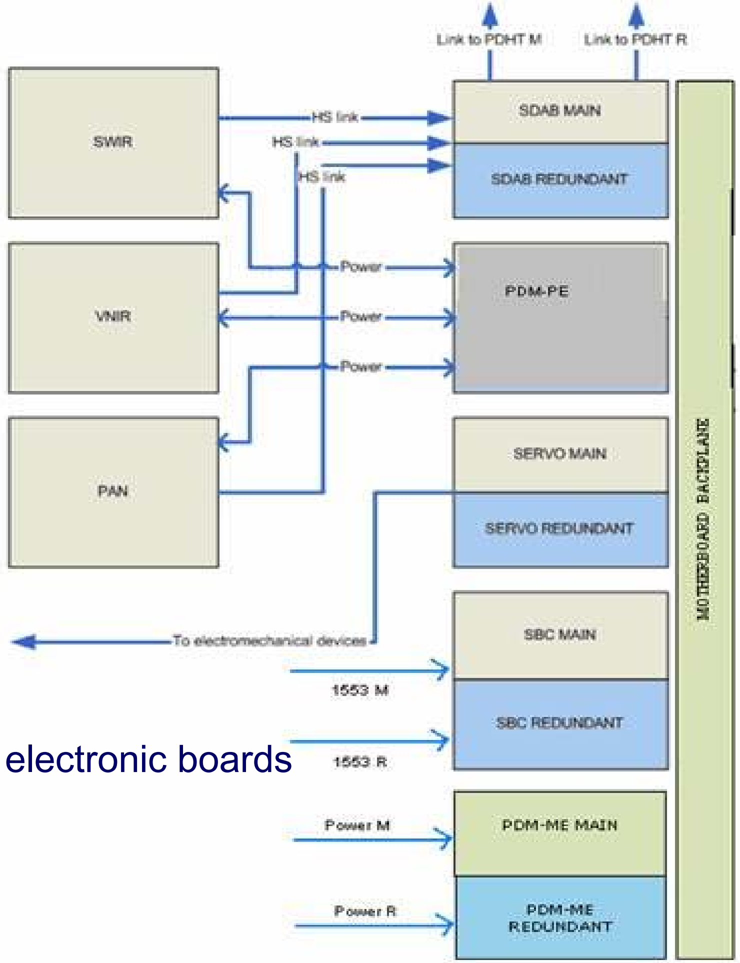
Main Electronics

The ME, based on a redundant sub-assembly architecture, is devoted to the control of 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 transmitter. It has electrical interface with Payload OH and with S/C.

ME EM PL Side

ME Total Weight 12kg

ME Dimensions: 254.2x298x240 mm



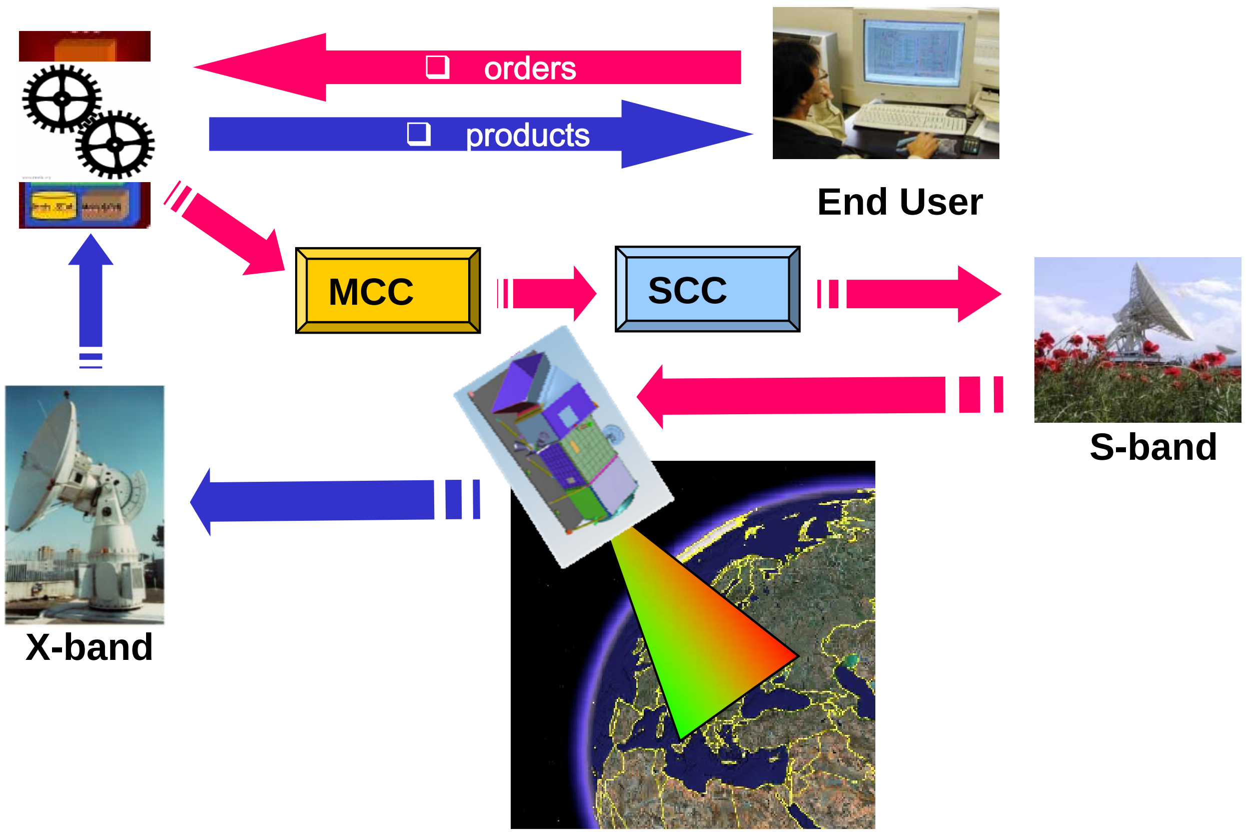
Five redundant electronic boards

PRISMA G/S

The PRISMA G/S is constituted by the following main elements:

- MCC - Mission Control Center
- SCC - Satellite Control Center
- IDHS - Image Data Handling Segment/Center including the following subsystems:
  - Centro Nazionale Multimissione (CNM)
  - L0 Processing
  - L1 Processing
  - L2 Processing
  - Hyper-spectral Image Simulator (HSIS)

User interaction with the system

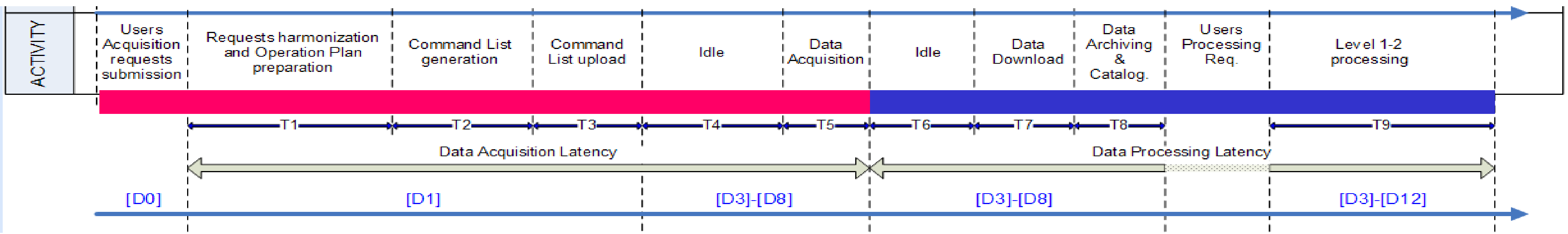


Data Acquisition Latency

- User request submission
- Request harmonization
- System programming
- Commands upload
- Time to site
- Image acquisition

Data Processing Latency

- Time to receiving station
- Data download
- Data archiving & cataloguing
- Data processing
- Product availability at UGS
- Product delivery



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Description and features of the IDHS Architecture

- Products processing is obtained cascading L0, L1, L2 processors:
  - chain is started by the downlinked Raw data
  - L0 processor decode raw data, strip the CCSDS frames and extract the image data
  - L1, L2 processors generate the corresponding products, also using Auxiliary / Calibration data (DEM, GCP, Calibration coefficients, Atmospheric correction models, etc)
- Quicklook images are generated from L0 data (by a specific processor) and stored in catalogue, along with the product metadata (generated during L0, L1, L2 processing)
- Archive does not store L1 and L2 data, which are always generated on the fly
- Further PRISMA specific components are placed outside IDHS:
  - Key Data Parameters processor, allowing calculation and update of calibration parameters to be used during L1, L2 product generation
  - Aux repository:
    - DEM and all other auxiliary data needed for L2 processing
    - GCP (Ground Control Point) repository, used during geocoding processing

PRISMA Processing Chain

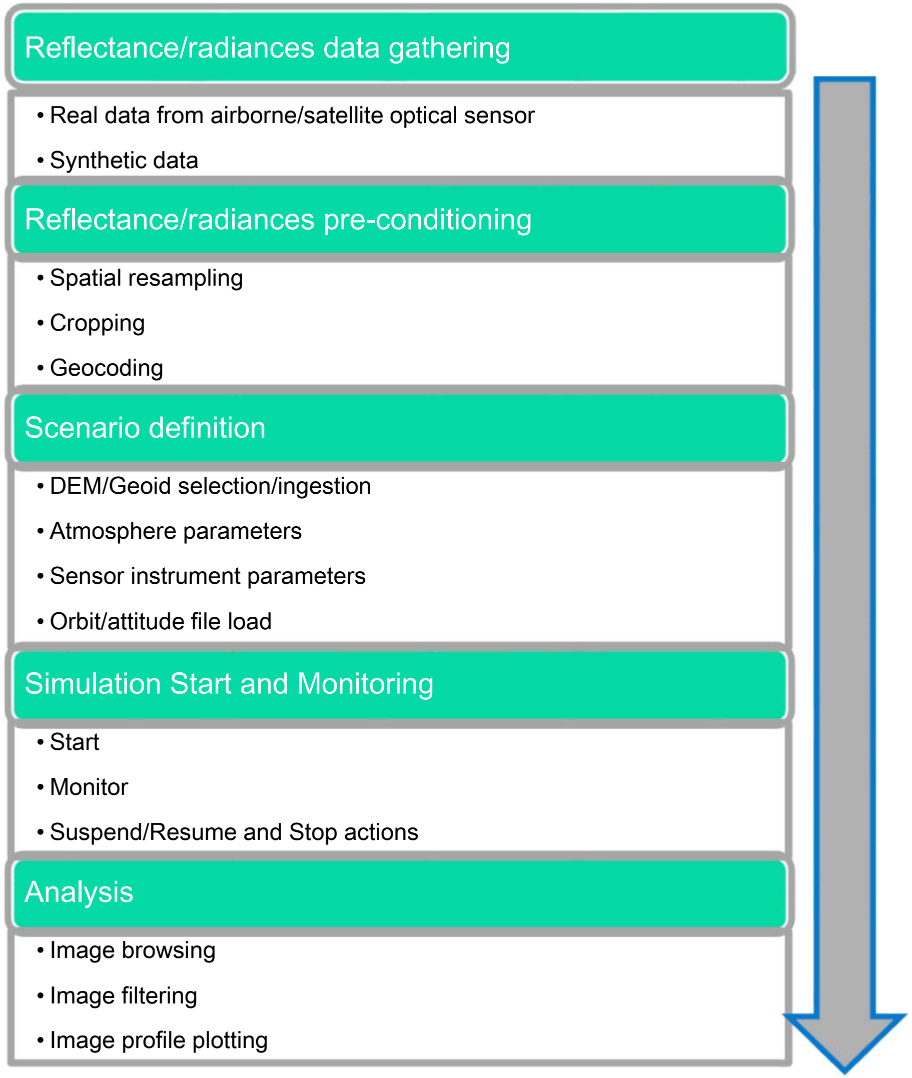
- **Level 0:**
  - Instrument data decoding and decompression
  - PAN, HYP layers and ancillary data rearrangement
  - Cloud cover percentage calculation (for image cataloguing)
  - Image preview (for image cataloguing)
- **Level 0 data archiving**
- **Level 1 (upon user request)**
  - Image rediometric, spectral and geometric calibration
  - Additional: user surface cover map
- **Level 2 (upon user request)**
  - Atmospheric corrections
  - Atmospheric load estimation (columnar water vapour and aerosol load, thin clouds optical thickness)
  - Image geo-referencing/geocoding

HSIS Functionalities

- Hyper-Spectral Image Simulator simulates the imaging of the PRISMA Hyperspectral and Panchromatic satellite sensors
- The most of the involved phenomena are taken into account:
  - Sun elevation and atmospheric effects.
  - The orbital and attitude movements of the satellite during push broom acquisition.
  - Earth surface properties as reflectivity and/ or TOA radiances, incidence angle, DEM.
  - Electro / Optical sensor characteristics taking into account geometric, spectral and radiometric behaviour.
  - L0 formatting in the CCSDS format

Operator Work-flow

- Operator must define the scenario:
  - ❑ Reflectance/radiances ingestion
  - ❑ processing parameters
  - ❑ Footprint definition
- Once the Scenario is defined, the simulation can be run, monitored and controlled.
- Finally, the produced intermediate and output products can be retrieved by the Operator to perform data analysis and post processing.



- For any further information, please contact:
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SHALOM Mission

Giancarlo Varacalli, Program Manager
Agenzia Spaziale Italiana (ASI)

Roma, 14th July 2016

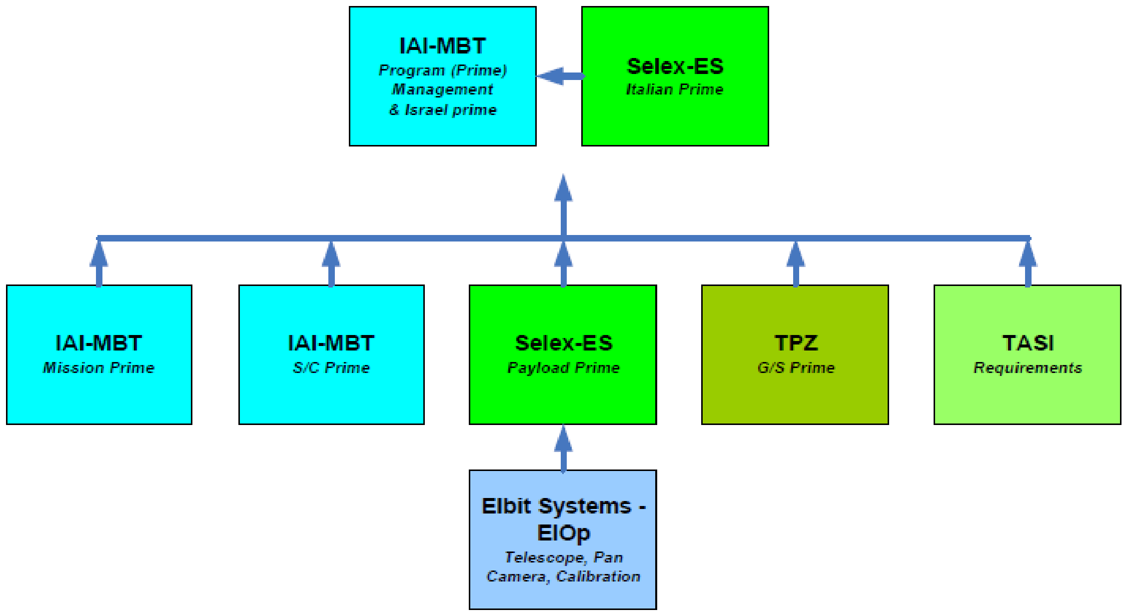
Italy-Israel Cooperation

- *Industrial, Scientific and Technological Cooperation Agreement*
  - Signed by Italian and Israeli Governments (2000)
- *Joint Declaration on Enhancing Space Cooperation for Peaceful Purposes*
  - Signed by ASI and ISA on the 30th March 2009
  - Areas of potential cooperations, among which “Earth Observation research and applications including SAR and Hyperspectral technologies”
- *Cooperation Agreement concerning Space Cooperation for Peaceful Purposes*
  - Signed by ASI and ISA on the 17th June 2009
  - Legal framework for the cooperation of both Agencies in the field of exploration and exploitation of space
- *Implementation Arrangement on Cooperation in a Joint Definition Phase of a Spaceborne Hyperspectral Applicative Land And Ocean Mission - “SHALOM”*
  - Signed by ASI and ISA on the 22/7/2010
- *Memorandum of Understanding on Cooperation in a Joint Hyperspectral Program - “SHALOM”*
  - Signed by ASI and ISA on the 13th October 2015

SHALOM Joint Definition Phase

- Italian Industrial Contract for the Joint Definition Phase (Phase A) assigned to a consortium (Selex-ES, Thales Alenia Space Italia and Telespazio), signed on the 16th February 2012.
- ISA assigned the Israeli activities to IAI/MBT and ELBIT Systems through 2 contracts.

- Kick-off Meeting held in Roma on the 18 April 2012.
- Final Review (FR) held on the 6th-7th November 2013 in Israel

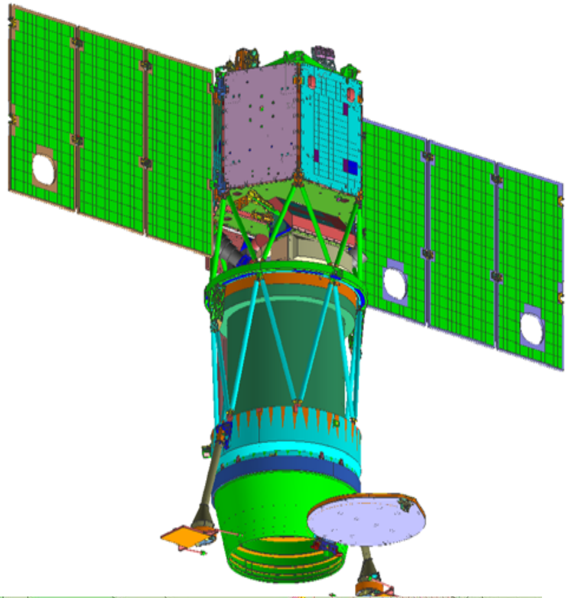


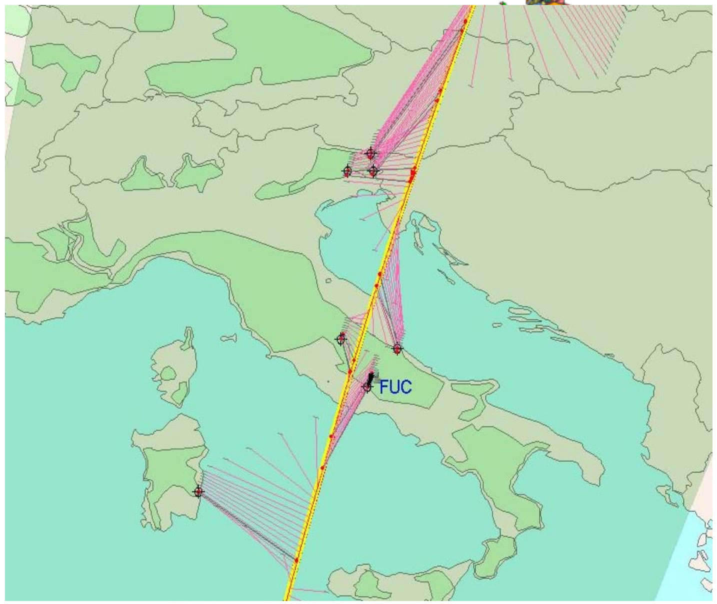
SHALOM: Mission definition

- Single satellite in SSO (640Km)
- Off-track acquisition capability: 30°
- Revisit Time: 4 days
- Daily acquisition capacity: 200.000 km2
- Coverage: worldwide
- Spectral range: 0.4-2.5 μm
- N. of acquired bands: 275
- Spectral resolution: 10nm
- Spatial resolution (VNIR-SWIR): 10m
- Spatial resolution (PAN): 2.5m
- SNR: 200-550 (from 0.4 and 1.75μm), >100 (from 1.95 e 2.35μm)
- MTF: 0.3 across track, 0.2 along track

SHALOM: the satellite

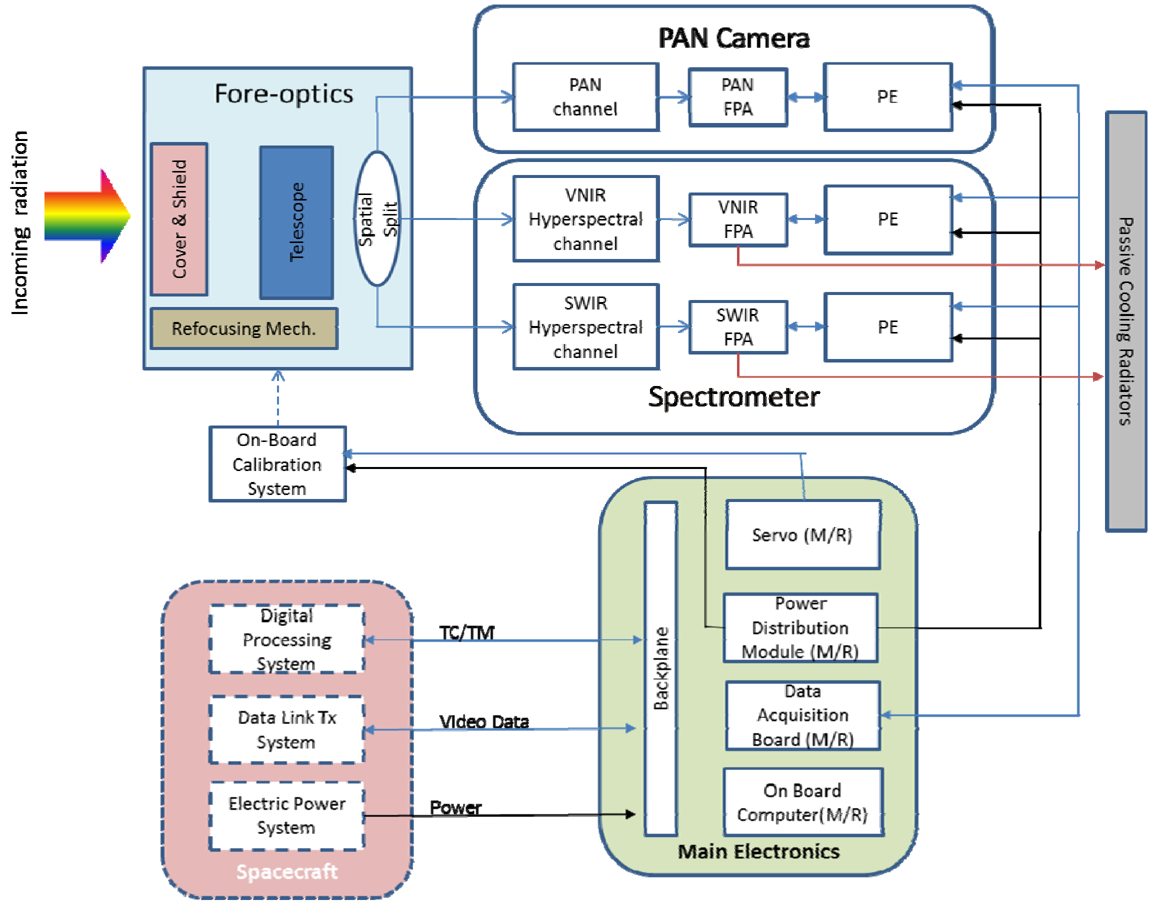
- Payload highly integrated with recurrent OPTSAT-3000 Platform
- S/C Mass: 404Kg
  - Payload Mass : 126Kg
- GMC (Ground Manoeuver Compensation) capability able to improve radiometric performance
- Compatibility with VEGA launcher (also in double launch configuration – VESPA)
- Lifetime: 5 years(reliability >0.6)
- Data Download: up to 933Mbps
- On-board compression: 1.6:1
- On-board memory: 1Tbit





SHALOM: the Payload

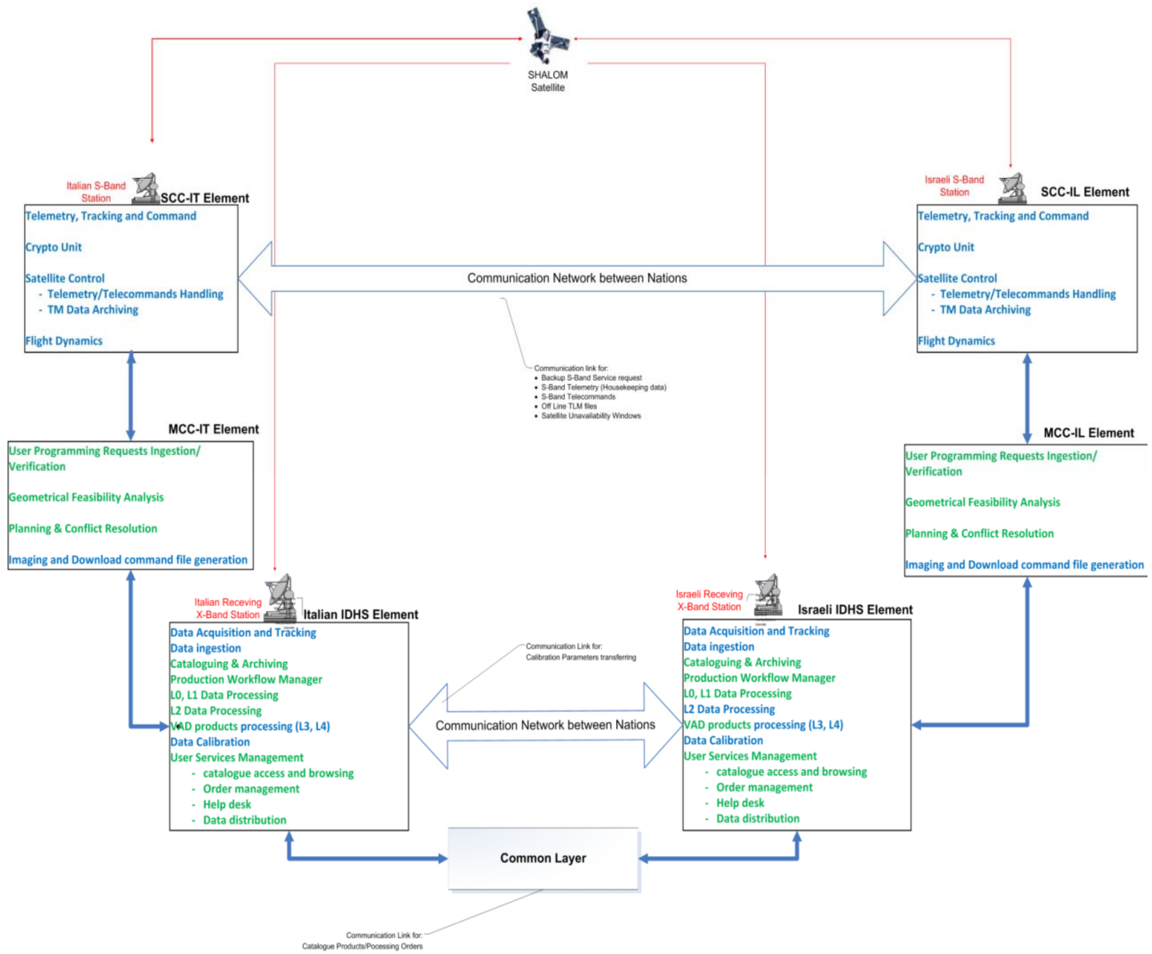
- PRISMA heritage exploitation
  - Detectors
  - Passive cooling
- Compact and lightweight design in order to comply with OPTSAT-3000 bus constraints
  - Use of gratings in place of prisms
  - Carbon fiber structure
  - Zerodur mirrors
  - R-C Telescope



SHALOM: Ground Segment

- BASELINE:
  - Duplication of Ground Segment in IT and IL (SCC-MCC-IDHS)
  - Dedicated control and tasking in pre-defined time windows
  - Fully balanced control of the spacecraft

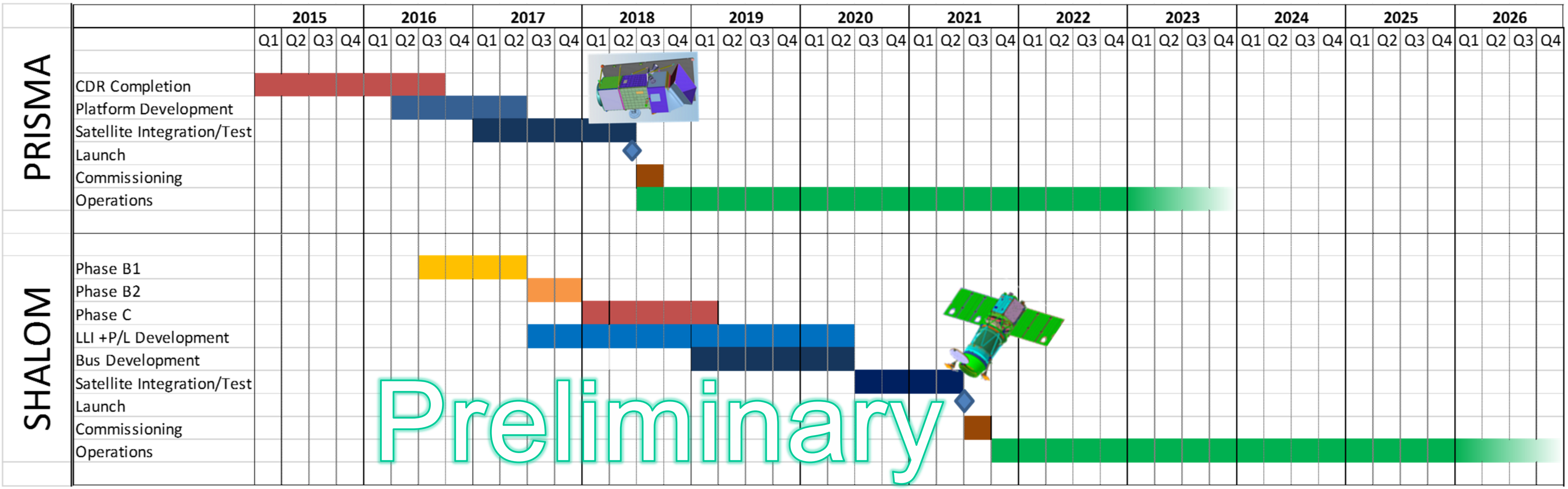
- OPTIONS
  - Satellite control (SCC) in Israel
  - Autonomous tasking
  - Re-use of HW/SW from other programs



SHALOM vs. PRISMA

	PRISMA	SHALOM
Spatial resolution(Hyp)	30m	10m
Daily acquisition capacity	200.000km2	200.000km2
Coverage	Global	Global
Daily image processing	200scenes 30x30km	2000 scenes10x10km
Revisit time	7days	4days
System flexibility	-	SNR/MTF/Capacity
Mission	Preoperative - scientific	Operative – commercial

SHALOM – PRISMA
Overall schedule



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