TRUTHS: Satellite & Payload Implementation

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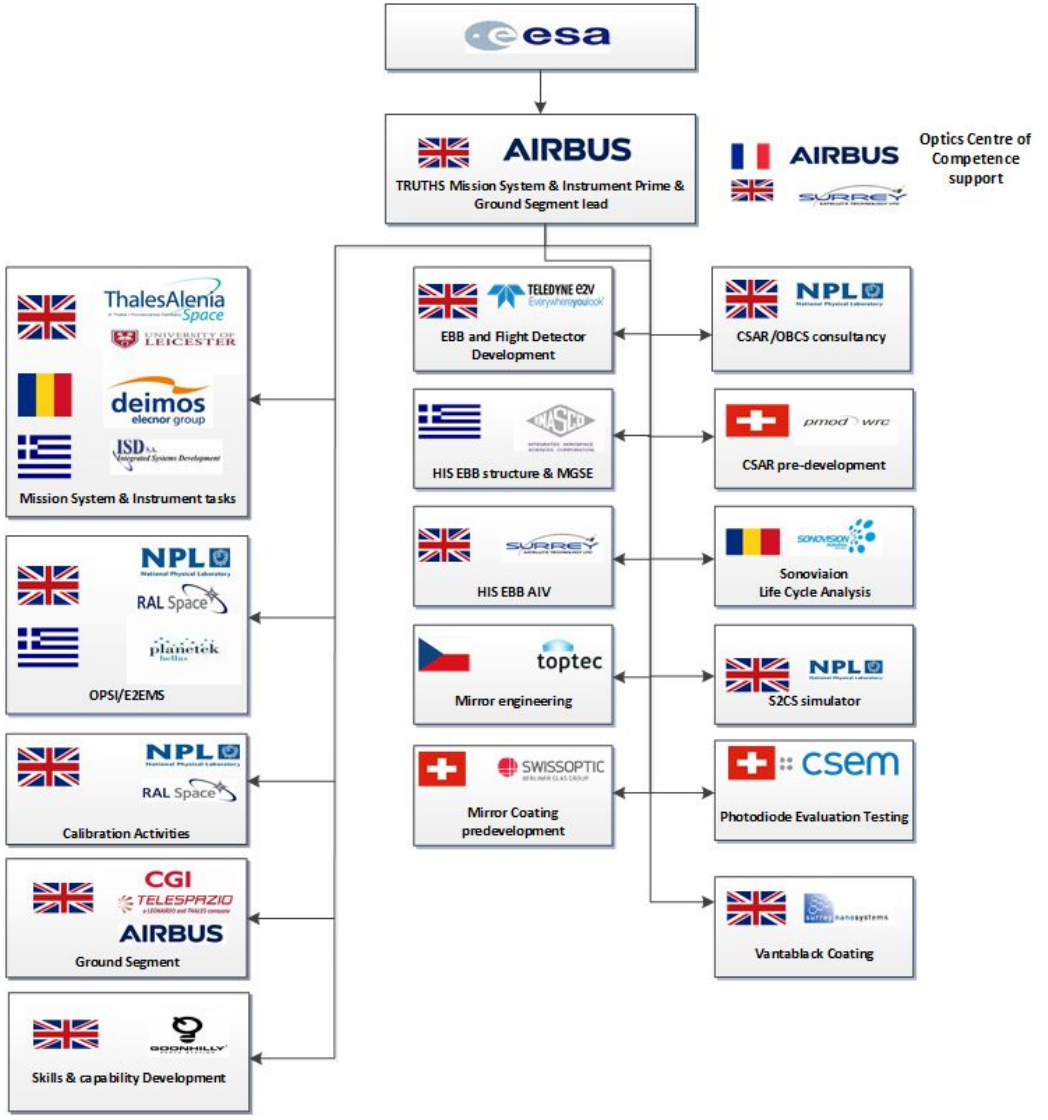
date

Phase A/B1 Study Setup

Company	Activity
Airbus Defence & Space Ltd	TRUTHS Mission Prime Payload Prime & Pre-developments
Thales Alenia Space UK	OBCS Detailed Design
CGI IT UK Ltd	PDGS
Science Technology Facilities Council (STFC-RAL)	Spatial & Geometric Calibration and OPSI Algorithm
NPL Management Ltd	Spectral & Radiometric Calibration and E2EMS Algorithm Definition Support
Goonhilly Earth Station Limited	Skills and Capability Development
Telespazio VEGA UK Ltd	Flight Operations Ground Segment (FOS)
University of Leicester	Scientific and Mission Support
Teledyne UK Ltd	Detector pre-development
NPL Management Ltd	Consultancy Support to Prime and Payload
NPL Management Ltd	S2SC calibration
SSTL	AIT Planning
Integrated System Development S.A (ISD)	On Board Compression
Planetek Hellas EPE	OPSI Software
INASCO	HIS EBB Structure and MGSE*
TOPTEC	Co-Engineering + Optics
Sonovision	Life Cycle Analysis
Deimos Space S.R.L	Re-entry Analysis
PMOD, World Radiation Centre	On-board voltage reference
PMOD, World Radiation Centre	CSAR detailed engineering - B1
CSEM SA	Photodiode evaluation testing
Airbus Defence & Space	WMS Mechanism De-risking
Surrey NanoSystems	Vantablack Testing
Airbus Defence & Space	OBCS Component Analysis
Swiss Optics AG	Mirror coating development



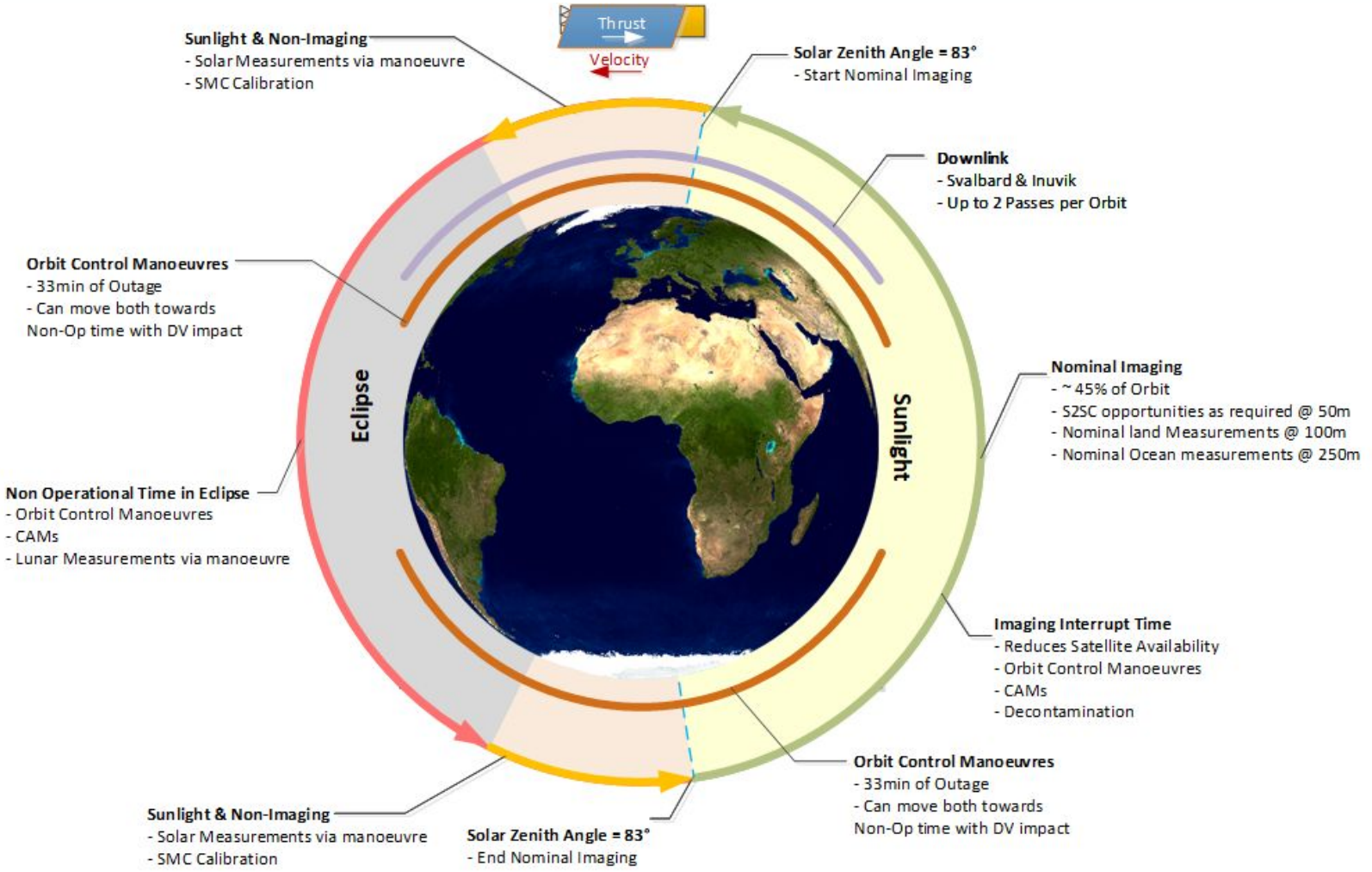
Mission Design & Operations - Spring/Autumn "Noon/Midnight" Configuration

Orbit:

- Earth Synchronous, polar, 61-day repeating orbit, at a height of ~620km.
- A RAAN=0 to maximise science and limit thermal complexity.

Operations:

- TRUTHS requires a complex operational scenario which varies with time of year due to the orbit plane drift w.r.t the Sun.
- Earth Measurements every orbit when SZA<83, including off-nadir observations of PICS & S2SC opportunities
- Solar & Lunar measurements once per day, using the windows between Earth imaging & non-operational times
- Solar Calibration, via SMC, once every two weeks for up to 55min.
- Non-operational time for other calibrations & activities not impacting the Earth imaging.



Mission Design & Operations - Summer "Dawn/Dusk" Configuration

Orbit:

- Earth Synchronous, polar, 61-day repeating orbit, at a height of ~620km.
- A RAAN=0 to maximise science and limit thermal complexity.

Operations:

- TRUTHS requires a complex operational scenario which varies with time of year due to the orbit plane drift w.r.t the Sun.
- Earth Measurements every orbit when SZA<83, including off-nadir observations of PICS & S2SC opportunities
- Solar & Lunar measurements once per day, using the windows between Earth imaging & non-operational times
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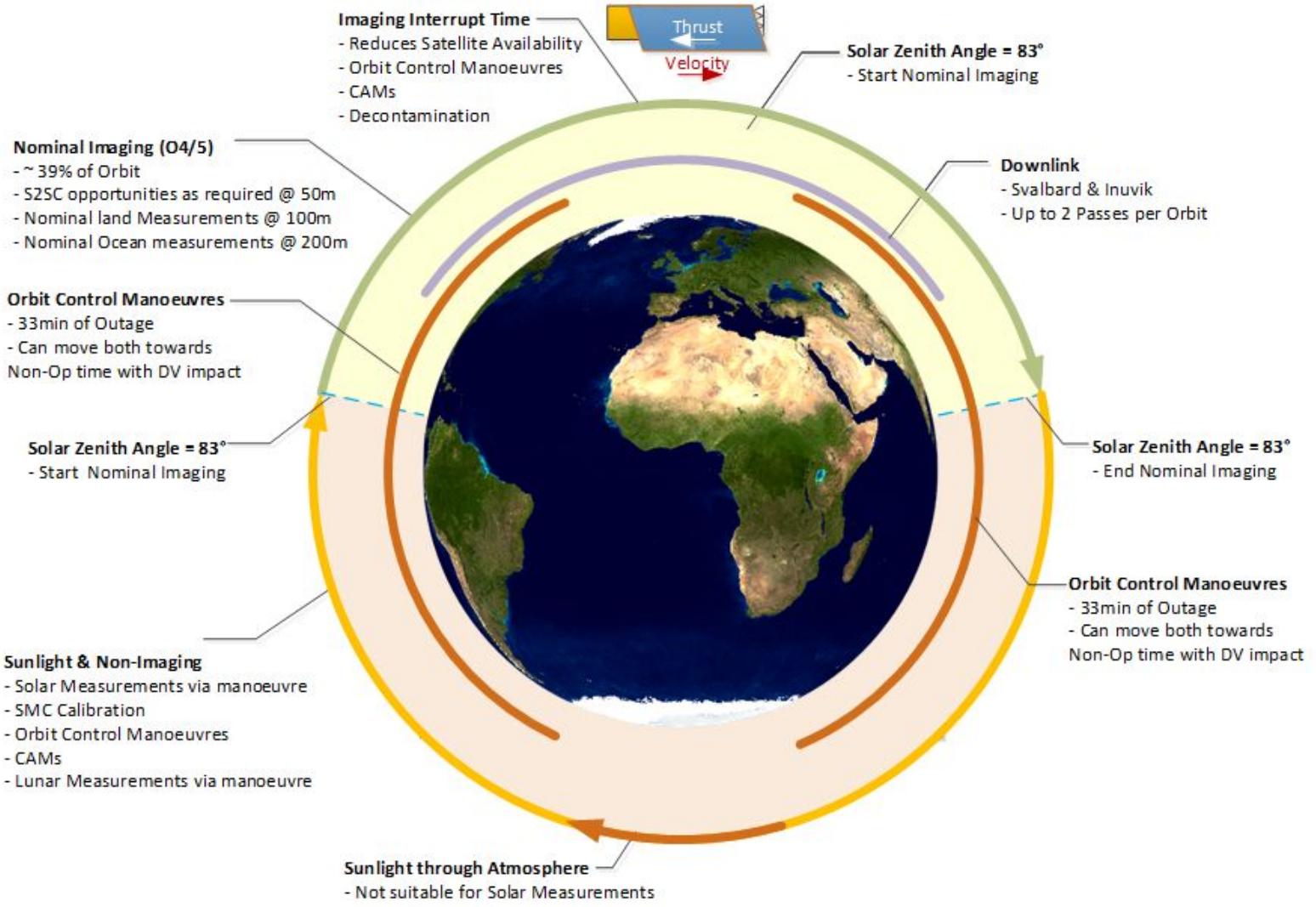


* Winter Operations are similar to Summer but with the hemispheres switched

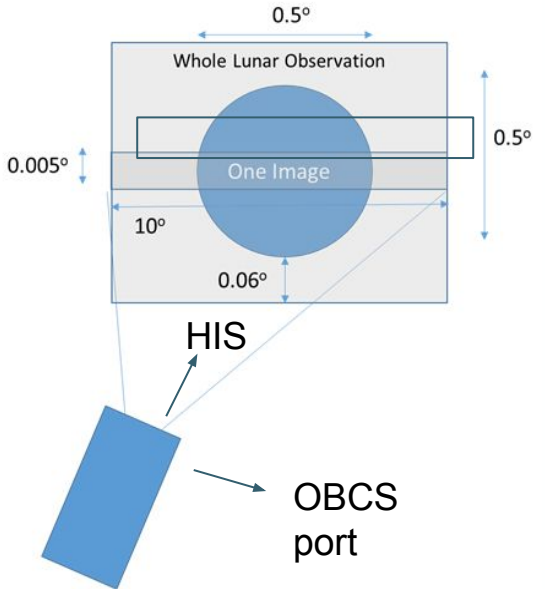
Solar and Lunar Observations

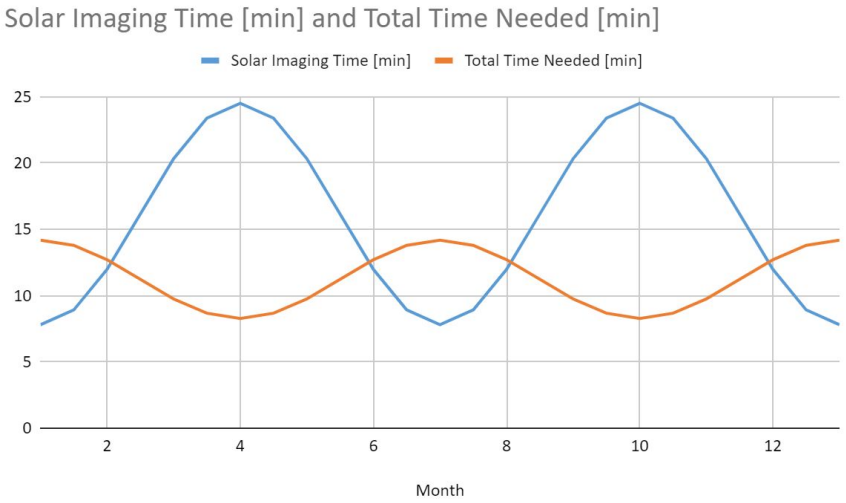
Moon is many times dimmer than the Sun so HIS port used to achieve required SNR

Hyperspectral Imaging Spectrometer (HIS)
- nominally Earth pointed
- pushbroom imager so very small field of view (~0.005 degrees) in along-track
- 2D detector provides spatial & spectral data

Irradiance = total radiance/solid angle

Lunar Spectral Irradiance:
- HIS Scans the Moon taking ~350 images
- Pixels are binned spatially to provide 1D data product: spectral only
- Manoeuvre over-scans the Moon to avoid strict pointing requirements on the spacecraft
- Accurate spacecraft scan speed removes double counting due to images overlapping
- Primarily imaging done in Satellite eclipse or non-operational zones, but to ensure complete Moon phases, impact on availability is expected





Solar Observations:
- Total Solar Irradiance (TSI) and Solar Spectral Irradiance (SSI) and SMC calibration.
- Solar Observations currently serial observations of TSI, via the CSAR and SSI, via a diffuser and using the HIS detector system
- Both are observed via FoV's perpendicular to the nominal Earth imaging port
- SMC calibration ports in the same direction and occurs once every two weeks.
- Imaging occurs in the Solar imaging windows between Earth imaging and non-operational (Eclipse) times.
- At specific times of year, the Earth imaging is temporarily interrupted to provide enough time for the Solar measurements.

Sensor-to-sensor Calibration: Direct & Indirect

Simultaneous Nadir Observations

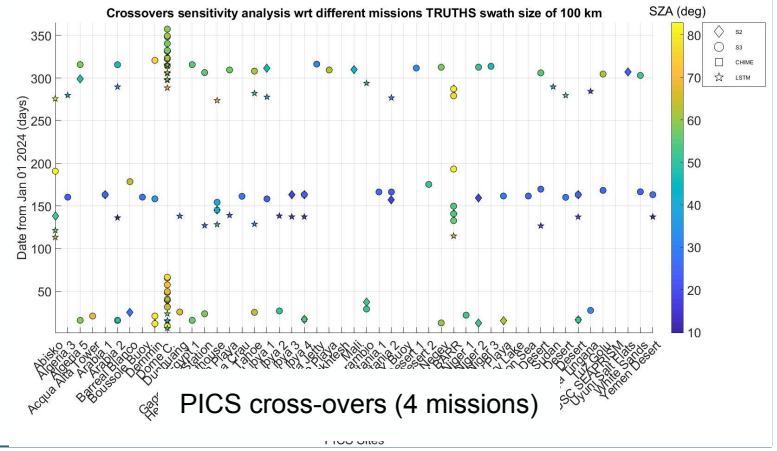
- Cross-overs analysed for a pre-agreed set of 9 target missions

Location	Max Temporal Mis-Match	Purpose
PICS	30 m	Stable Nature
Global	30 s	Full sensor dynamic range

- "Golden" cross-overs identified by considering a narrow swath for both
- For now TRUTHS is considered nadir pointing only, however it is likely that some off-pointing will be implemented to:
  - Obtain a cross-over that might otherwise not have occurred
  - Calibrate the outer swath of missions with a wider swath than TRUTHS

Mission	Number of "golden" Crossovers
S2	147
CHIME	140

"Golden" global cross-overs in 1 year period for 2 of the target missions analysed



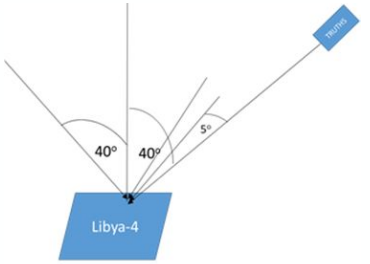
PICS cross-overs (4 missions)

Pseudo Invariant Calibration Sites (PICS) Characterisation

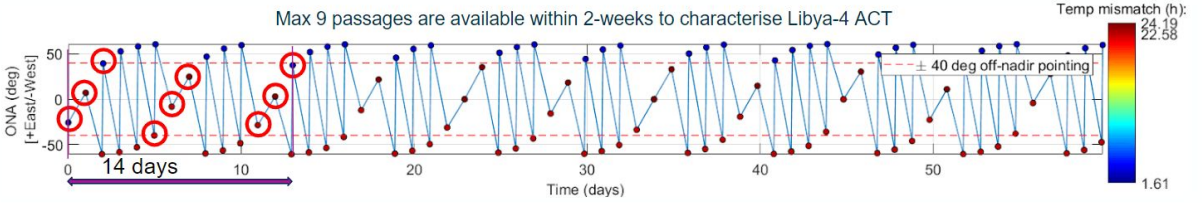
- TRUTHS SI traceability will validate BDRF models for these sites taking into account seasonal and long-term variation

Sites analysed within study:
- PICS list from US Geological Survey
- Buoys: MOBY & BOUSSOLE
- Aeronet-OC: Gageocho Station, USC SEAPRISM 2, Lucinda & Helsinki Lighthouse
- Acqua Alta Tower

- Site characterised 3 times within a year (seasonal) and one of these is replicated after 1 year (long-term)
- Single characterisation window limited to two weeks
- For each site the no. observations and the angle have analysed
- Nominal ground track only considered as "shifting" the ground track left or right to "see" the site more often uses too much fuel



Ideal characterisation



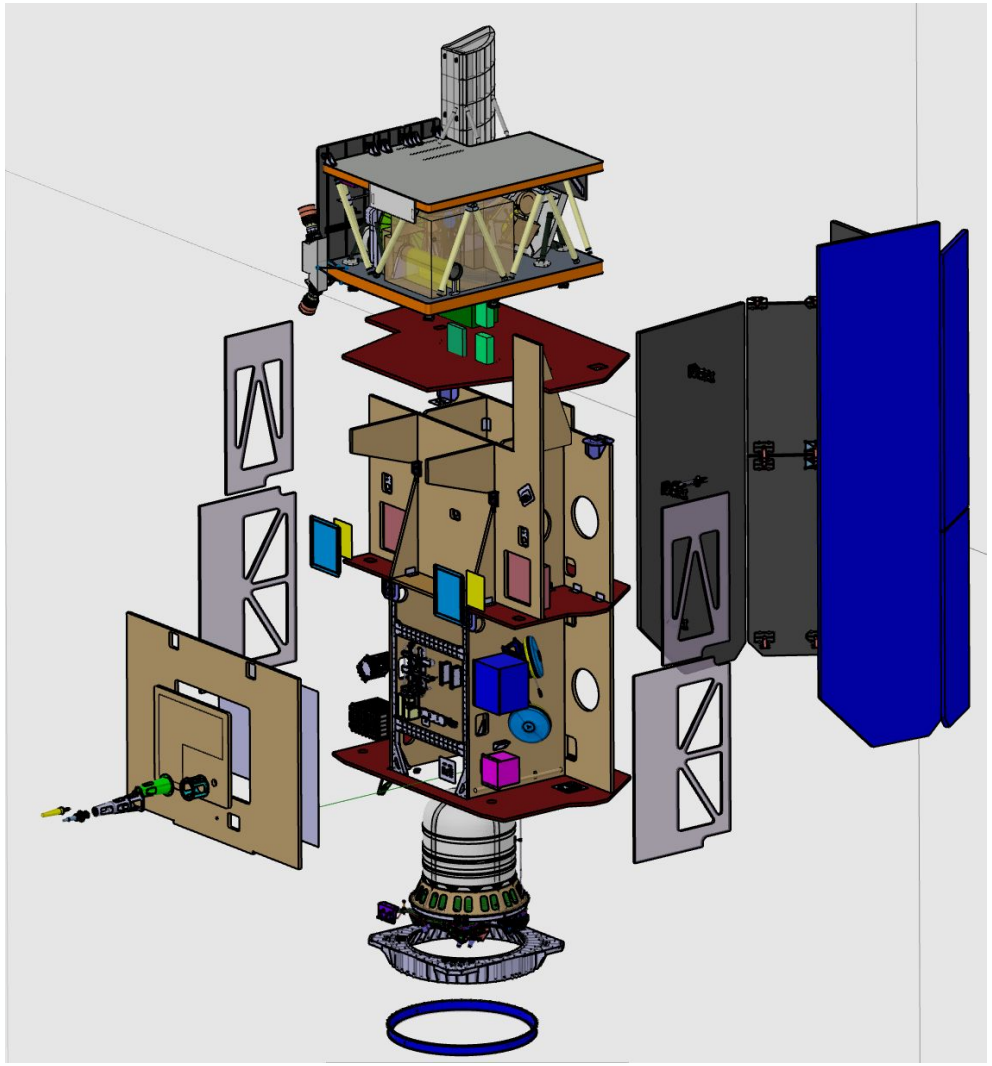
Satellite & Platform Design

Satellite Design

- Satellite is based on existing platform design, with strong heritage in the Cristal mission.
- The design is compliant with a single VEGA-C launch.
- Addresses key drivers of **high data throughput**, **precessing orbit, controlled re-entry** and **demanding payload mass/power requirements**

Adaptations of Existing Design

- Shortened Structure, extended arrays and leveraging complete Astrobus avionics set to deliver a TRUTHS specific mission.



Platform Capabilities

- System is complaint with a controlled re-entry scenario
- The X-band downlink subsystem is designed to deliver the scientific data to 2 ground stations per pass, with improvements being considered to allow a single station to be utilised.
- Removable battery, X-band downlink, Payload electronics bay panels and a modular propulsion system for Implementation Design for AIT considerations.
- 4 x Reaction wheels delviering agility required to image all targets with minimal impact on system - availability

Platform-Payload Interfaces

Payload units housed on platform on a dedicated panel (sub assembly):

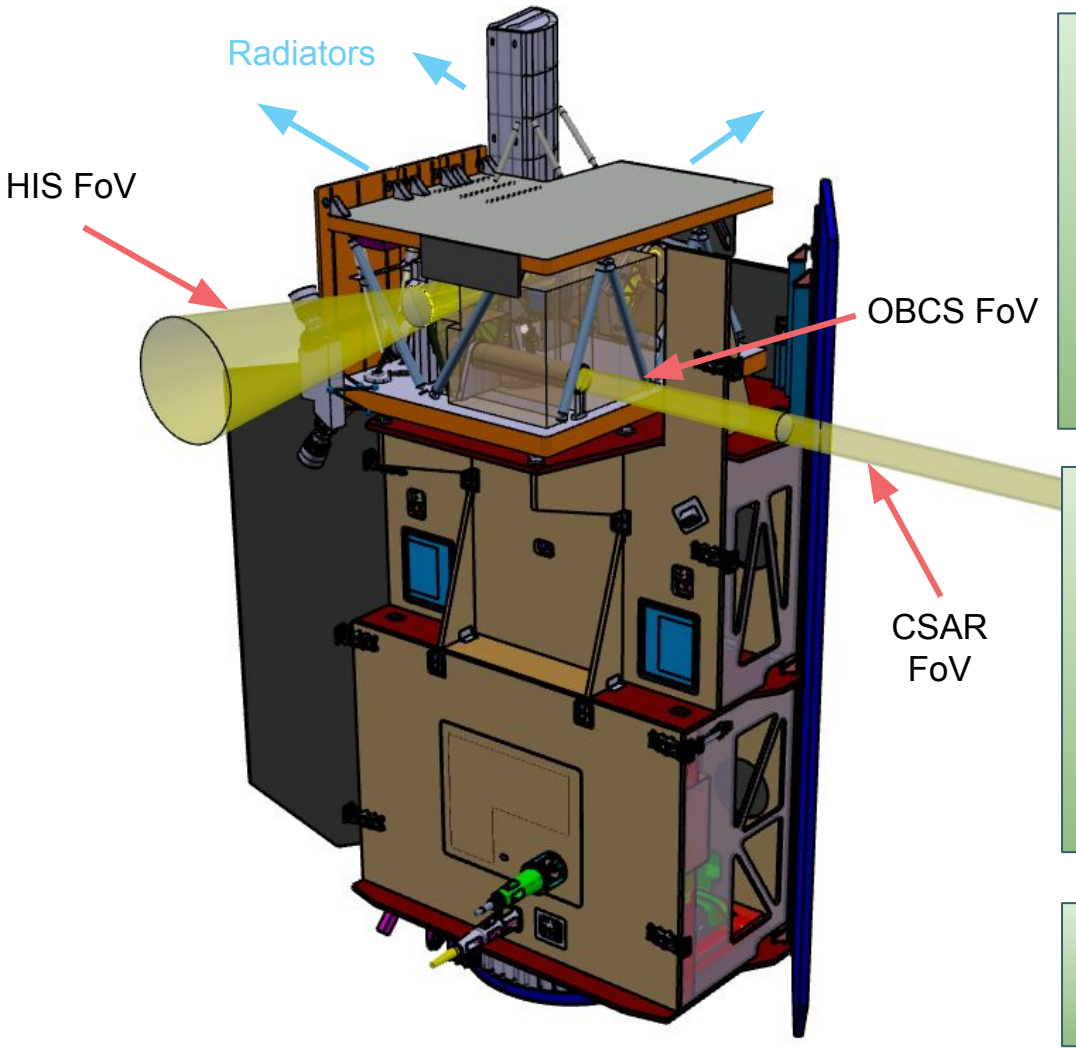
- Power Management & Control System (PMCS)
- Cryocooler Electronics
- Payload Processing Unit

Mechanical

- 6 bipods provide the mechanical interface to the platform.
- Instrument mass of ~400kg supported on the platform top floor.
- Microvibration sources during imaging; cryocoolers & reaction wheels, are controlled
- Extension of the Cristal structure to support overhanging payload.

Field of View

- Platform solar arrays are carefully sized to avoid infringement on CSAR, SMC and radiator fields of view
- Dedicated “exclusion zones” are specified driving how the satellite can perform slews



Electrical & Data

- Platform provides the power source and power lines to instrument, requiring ~450W on average.
- The Mass Memory & Formatting Unit has links to the PMCS for exchanging commands as well as receiving data over high-speed links (SpaceWire & WizardLinks)
- Housekeeping data on the instrument health is sent to the platform

Thermal

- 180 deg yaw slew performed every 6 months to keep a deep-space side to support instrument passive thermal control
- Bipods provide thermal de-coupling from the platform
- MLI protects instrument from thermal emissions from platform elements such as solar arrays

Platform Units on Instrument:

- Star Trackers to minimise pointing error due to thermo-elastic distortions

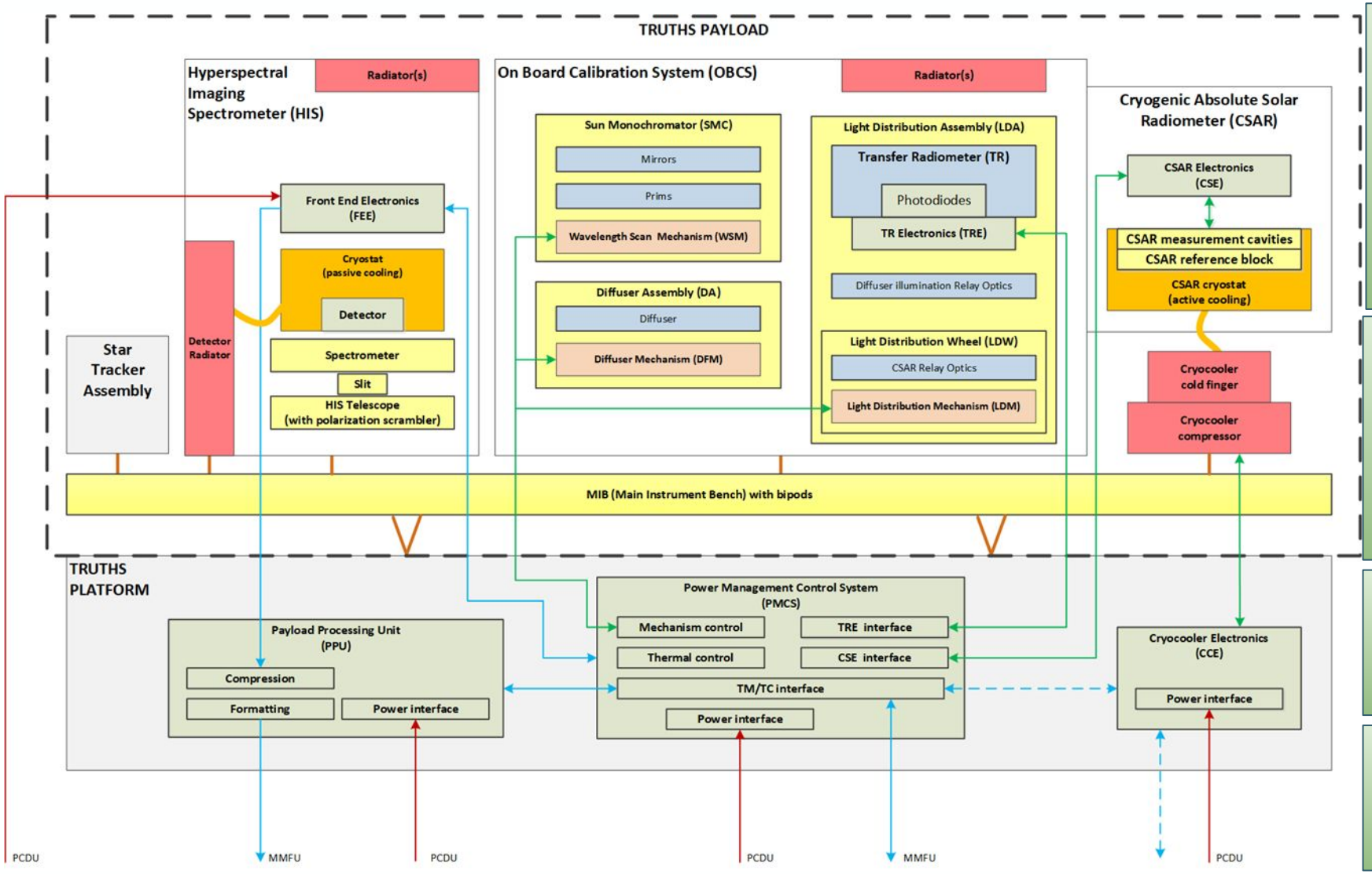
Payload Architecture

HIS:
4 Freeform Mirror Telescope & Offner Spectrometer images onto a passively cooled detector.

SMC:
Generates monochromatic light across TRUTHS spectrum, selected by the WSM.

PMCS:
Controls Sub-systems, mechanisms, interfaces to platform & implements thermal controls.

PPU:
On-Board Compression & Data Formatting.



CSAR:
Cryocooled cavities absorb 99.99% of incident solar radiation. Measurement using equivalence between optical and electrical power.

LDA:
Selects monochromatic or Solar light and distributes to selected detection chain: CSAR, TR or HIS.

TR:
Transfers calibrations between CSAR and HIS

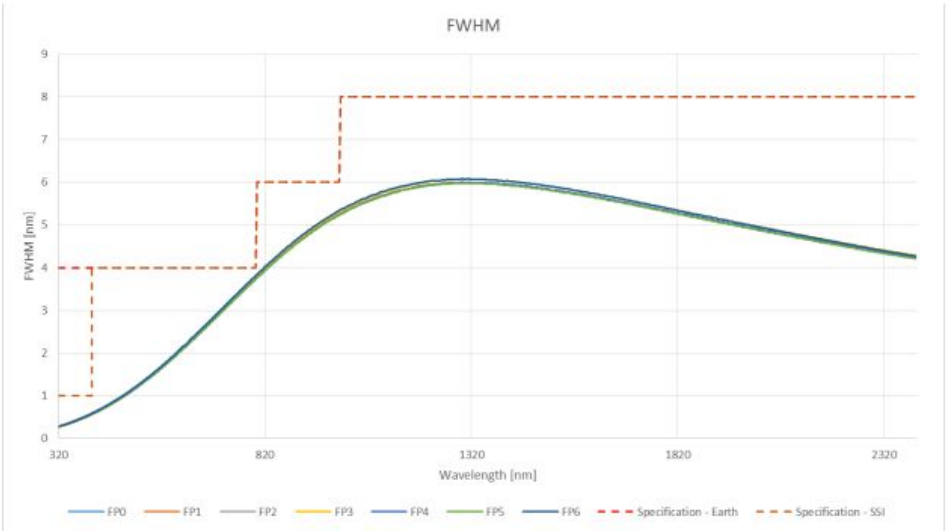
DA:
Simultaneous illuminates TR and HIS with diffuse light

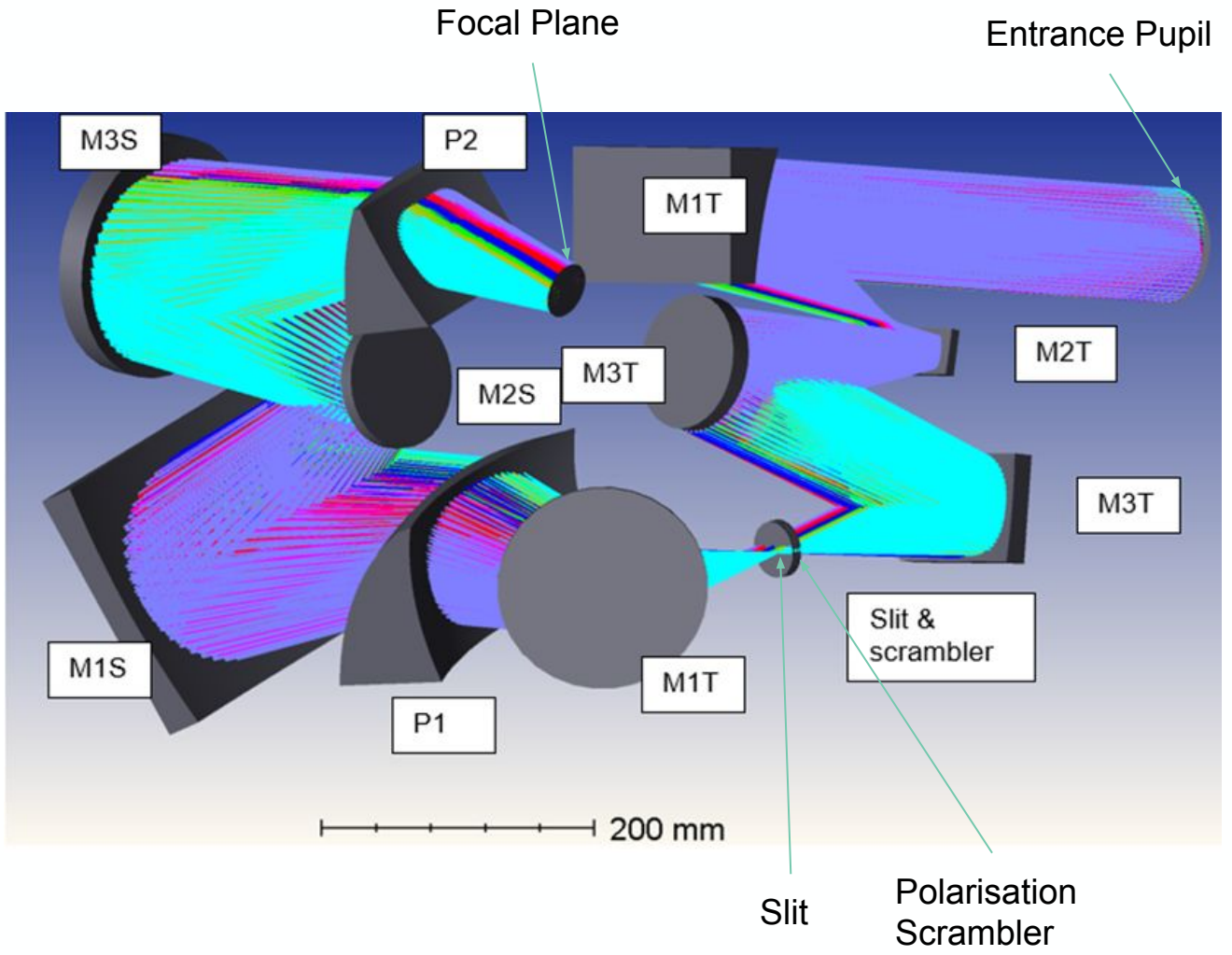
HIS Optical Layout & Performance

HIS Performance

- 100 km swath, 50m SSD, geolocation to < 25m
- ARA performance between 0.3-1% across spectral range
- SNR > 100 for 380-2400nm
- Spectral resolution
  - 1nm in UV
  - 4nm in VIS
  - 6-8nm in NIR/SWIR

Spectral Resolution





Payload Pre-developments

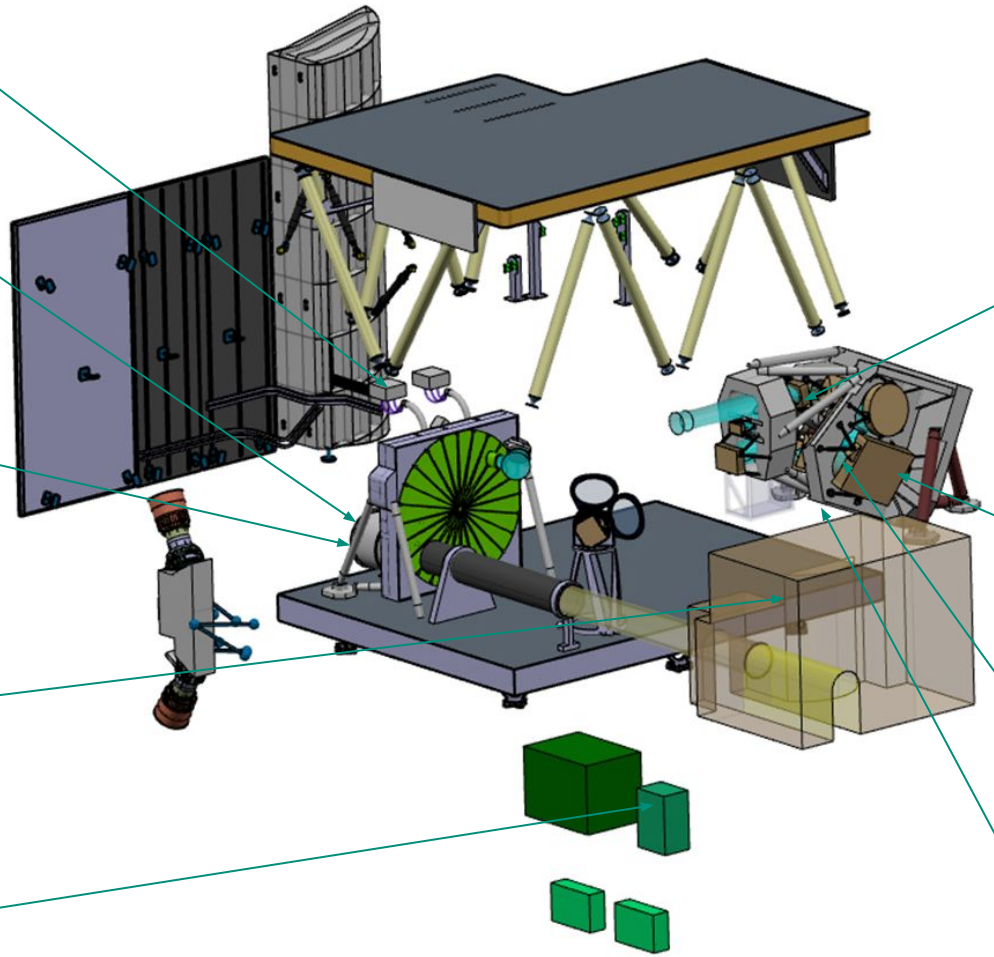
Transfer Radiometer Electronics: Photodiode Testing underway by CSEM (CH) and Airbus.

CSAR Electronics: Absolute Voltage Reference pre-development underway by PMOD, targeting uncertainty < 50 ppm over lifetime.

CSAR Cavity Coatings: Surrey Nanosystems (UK) engaged to verify performance and survivability of Vantablack S-VIS at CSAR operating temperature (60K).

Solar Monochromator: Wavelength Scanning Mechanism derisking activity underway to demonstrate low-speed performance by Airbus.

Payload Processing Unit: Compression Algorithms developed by ISD (GR)



On-board spectral calibration methodologies research studies studies conducted with NPL.

CHROMA-D Detector from Teledyne-e2v (UK)

- 2k x 1k Package Developed for TRUTHS
- Anti-Reflection Coating developed to offer performance over complete spectral range

High Reflectivity Coating developed by Swiss Optics (CH) to deliver performance over complete spectral range

De-risking of **Prisms & Polarisation Scrambler** through manufacture by TOPTEC (CZ) to be initiated in Phase B1 Extension

Preparatory activities towards a HIS EBB concluded with SSTL (UK) and INASCO HELLAS (GR)

Thank you ! Questions?