→ SENTINEL-2 FOR SCIENCE WORKSHOP

Sentinel-2 : one year from the 1st launch

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Sentinel-2 Project
ESA/ESTEC

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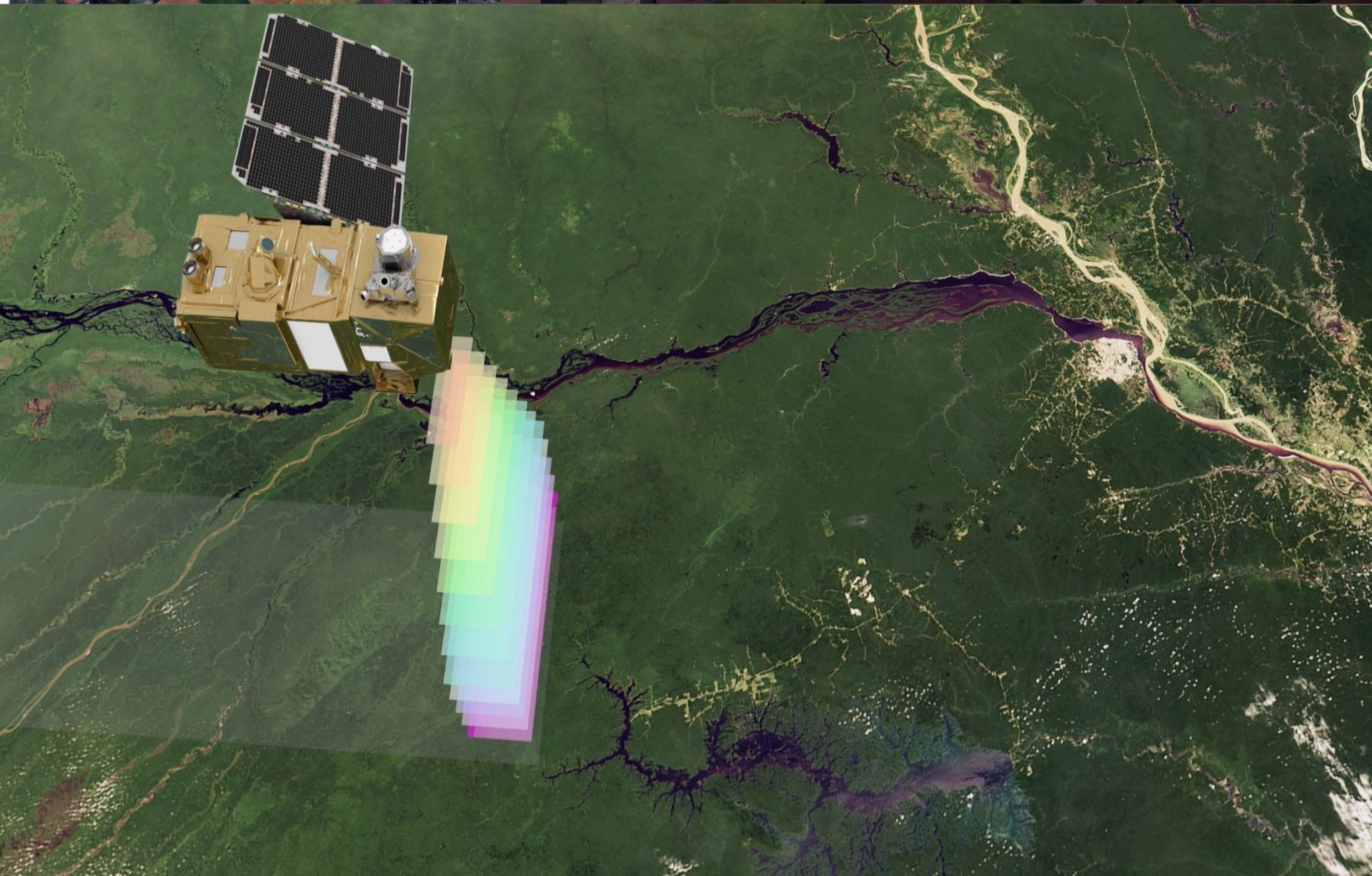
Context

Project status

Performance

The S2 mission context



Copernicus evolutions

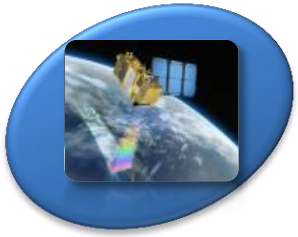
- The **Copernicus Programme was formally established** on the 3rd April 2014.Its formal Regulation is approved by the Presidents of the European Parliament & European Council: 3377MEuros cover the extended space component development (e.g. incl. C&D Sentinel-2 recurring models) & its system operations until 2020.
- Confirmation of the **free data access** policy for Sentinels.
- **Sentinel-1A successfully launched** on the 3rd of April 2014 by Soyuz from Kourou.

The Sentinels in orbit deployment has started

The Copernicus Sentinels

Sentinel-1 (A/B/C/D) – SAR imaging
All weather, day/night applications, interferometry

ESA GSC-1/2
EU FP7+GIO
EU MFF



Sentinel-2 (A/B/C/D) – Multi-spectral imaging
Land applications: urban, forest, agriculture,…
Continuity of Landsat, SPOT

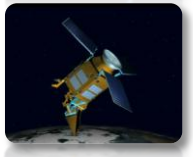
ESA GSC-1/2
EU FP7+GIO
EU MFF

Sentinel-3 (A/B/C/D) – Ocean and land monitoring
Wide-swath ocean color, vegetation, sea/land surface temperature, altimetry

ESA GSC-1/2
EU FP7+GIO
EU MFF

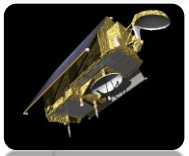
Sentinel-4 (A/B) – Geostationary atmospheric
Atmospheric composition monitoring, trans-boundary pollution

ESA GSC-2
EU FP7



Sentinel-5 precursor & Sentinel-5 (A/B/C) – Low-orbit atmospheric
Atmospheric composition monitoring

GSC-2 / FP7
GSC-3 / EU MFF



Sentinel-6 / Jason-CS (A/B) – Low inclination Altimetry
Sea-level, wave height and marine wind speed

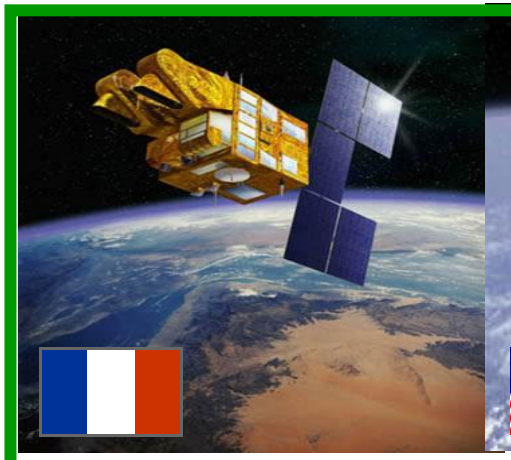
GSC-3 / EU MFF

Sentinel-2 services

Sentinel-2 addresses the Copernicus operational land, security and emergency services. These applications include:

- land cover, usage and change-detection-maps, spatial planning
- geophysical variable maps (leaf chlorophyll content, leaf water content, leaf area index, etc.)
- crop & forest monitoring, food security
- fast images for nature protection, surveillance of infrastructures and disaster relief, risk mapping

The European super Landsat



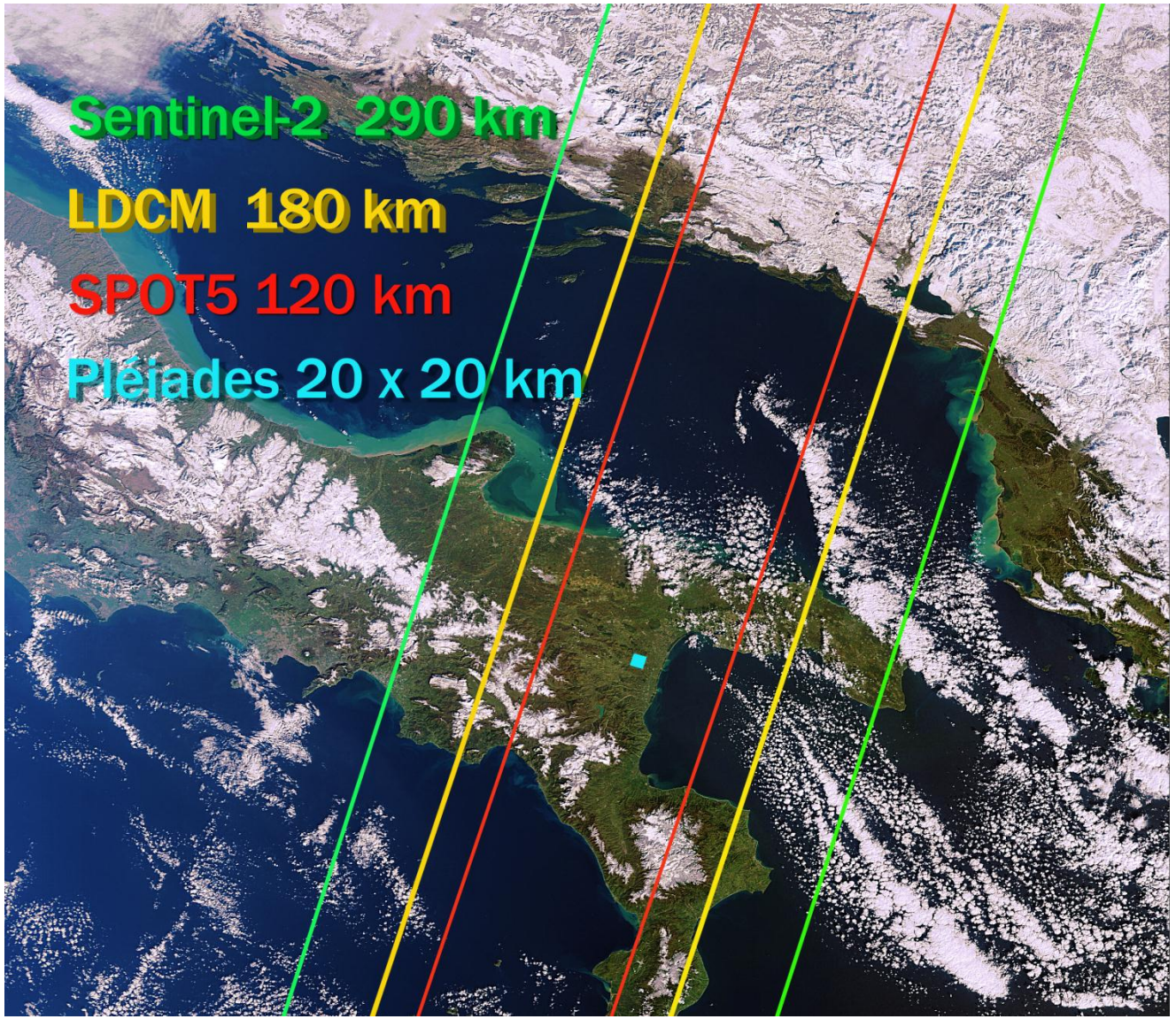
SPOT 5	Landsat 8	Sentinel-2

Coverage (d)	26	16	5 (2 satellites)
Swath (km)	60	185	290
Spectral bands	4+1	8+1	13
Resolution (m)	2.5	30,(15)	10,20,(60)

Sentinel-2 swath

Sentinel-2 (A+B): Full Earth Coverage *(at Equator)* in 5 days

Sentinels are complementary to High-Res commercial and national missions



The Sentinel-2 project status

Since the last S24science workshop

Some problems:

- Contamination of the SWIR FPA by droplets requiring long & tedious cleaning.
- 6 MSI large de-bonded inserts required customised re-enforcement by Titanium flanges.

Significant progress:

- **All MSI performance & qualification tests were successfully completed** in April 2014 by AirbusDS France. **The MSI PFM is on its way to AirbusDS Germany as we speak**.
- Platforms integration & test campaign: **all flight hardware integrated** for the environment test campaign. Qualification of flight software & **completion of most subsystem tests**.
- **Decision to launch S2A with VEGA:** PMAR closed, FMA ongoing (satellite-launcher compatibility tests in September 2014).
- The **S2 Ground System Validation & In Orbit Commissioning are being jointly defined** by the ESA Project and Ground System teams (with the support of CNES for Image Quality).

Sentinel-2A: 1 year to launch

MSI PFM integration

Satellite arrival at IABG(D)

OCP FM integration

QAR Board

Launch readiness (VEGA)

System IOCR

S2A

21 May 14

8 Aug. 14

30 Nov. 14

15 Mar. 15

30 Apr. 15

30 Jul. 15

MSI integration, Satellite final functional tests

Satellite environmental qualification tests

MSI integration

FAR Board

Launch readiness (ROCKOT)

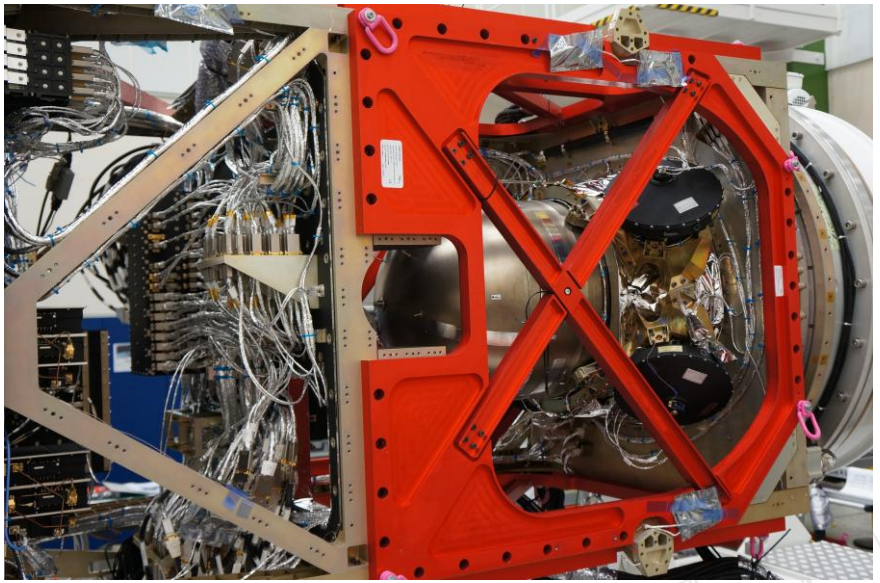
S2B

15 Jul. 15

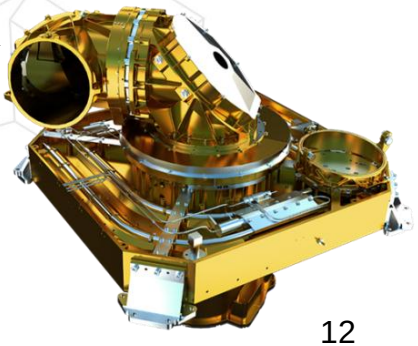
15 Mar. 16

30 Apr. 16

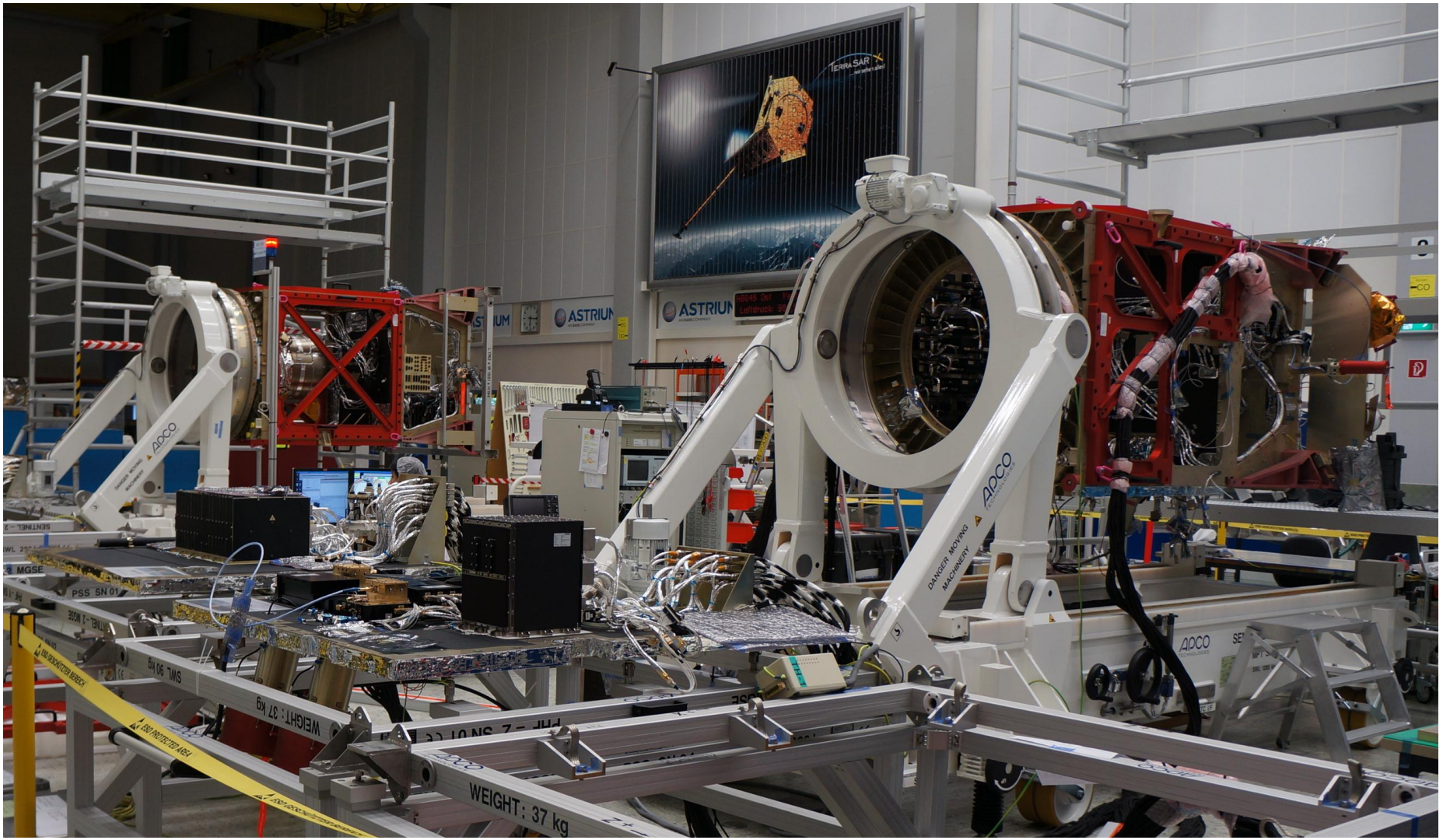
Sentinel-2 Satellite



- 1160 Kg, qualified for VEGA & ROCKOT, 3 axis stabilized, 12 years max. lifetime
- Data: 520Mb/sec at X band, 900 GBytes/day (optical communications with EDRS)
- Filter based pushbroom imager, 3 SiC mirrors, dichroic beam splitter
- Si CMOS VNIR detectors, HgCdTe SWIR detectors cooled to 195K
- Full FOV Sun calibration mechanism
- Radiometric resolution on 12 bits, radiometric accuracy 5%



Sentinel-2 development status



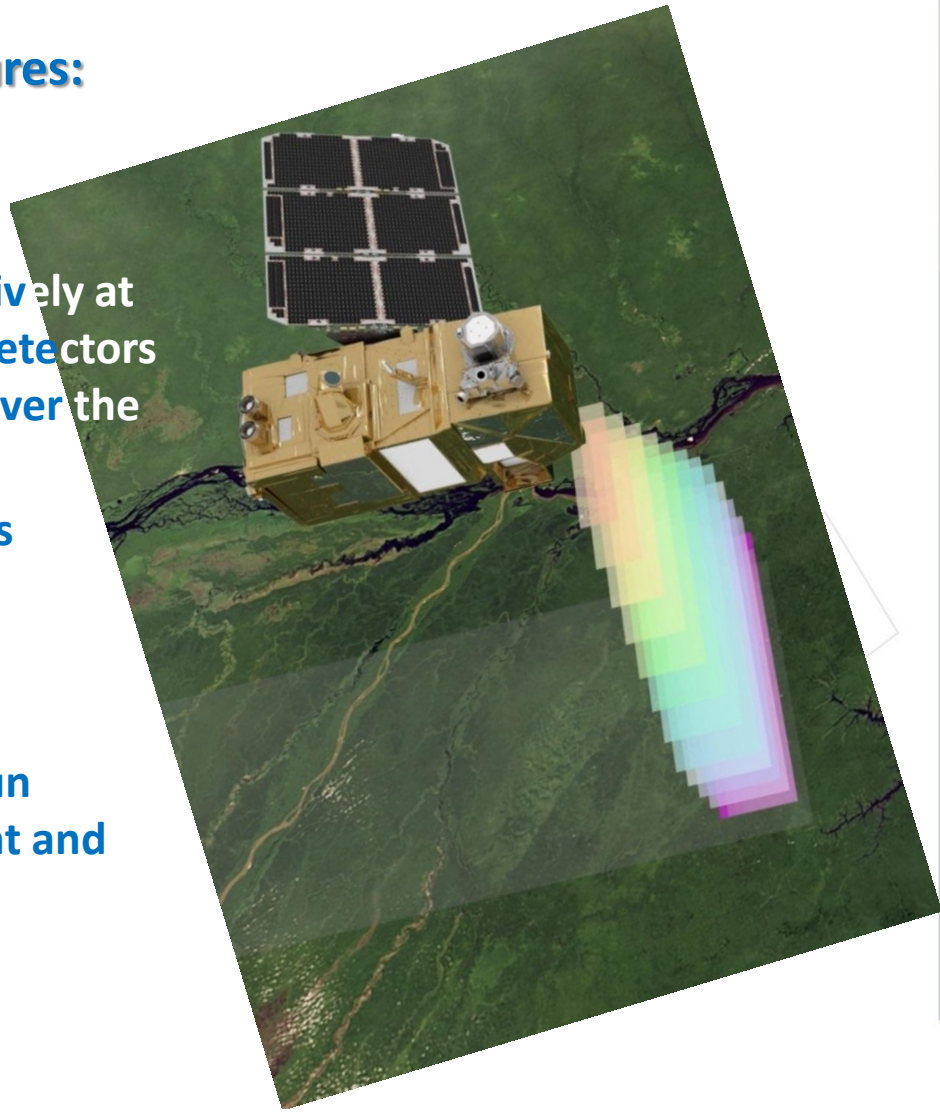
Sentinel-2A and -2B platforms at AirbusDS Germany

Sentinel-2 performance

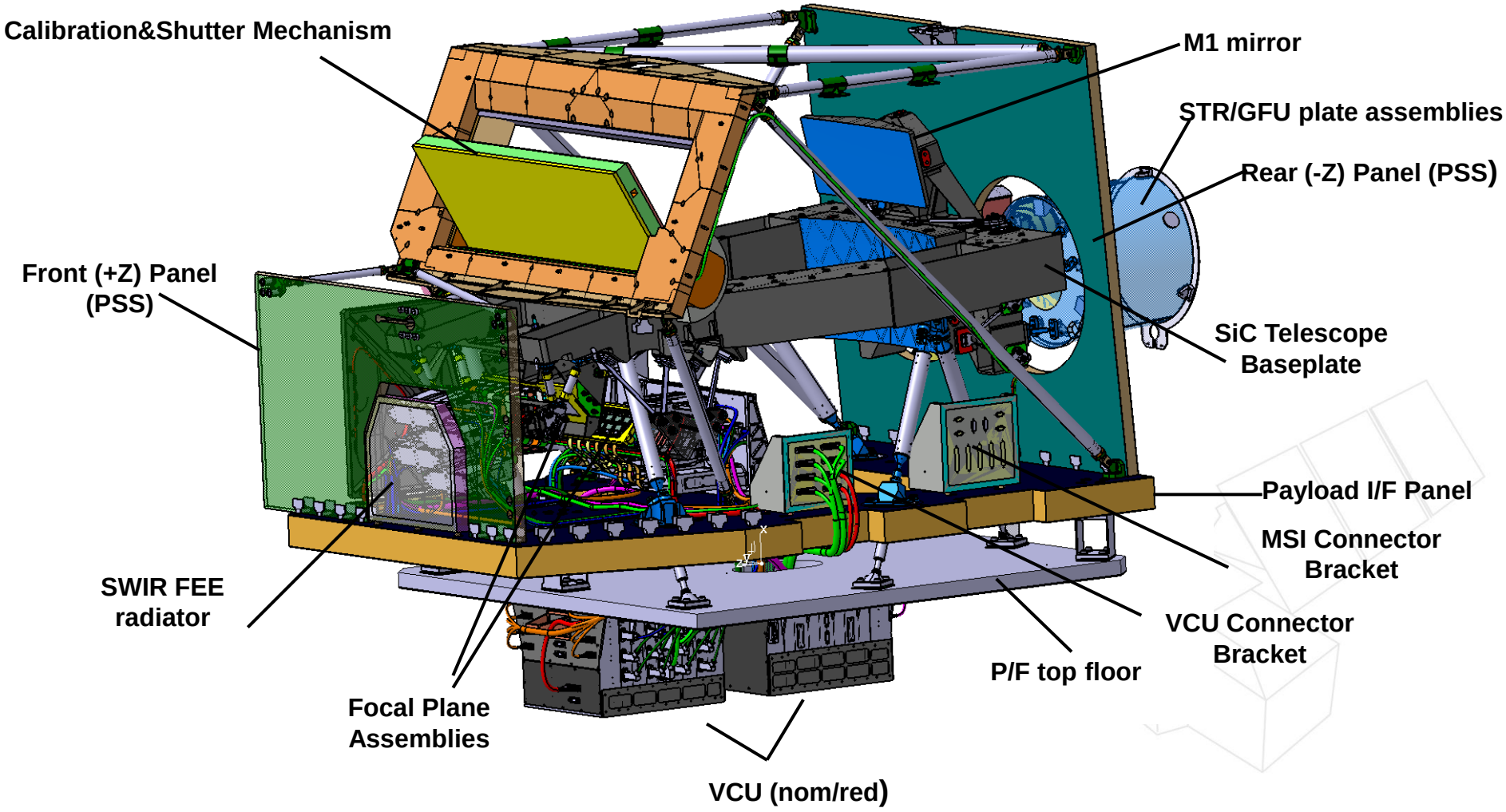
MSI main features

The MultiSpectral Instrument (MSI) features:

- Filter based push broom imager
- 13 Spectral Bands (10 VNIR, 3 SWIR)
- 2 Focal Planes (1 VNIR and 1 SWIR) respectively at 293 K and passively cooled at 195 K, with detectors deployed in a staggered configuration to cover the 290 km of FOV
- Integrated Video & Compression electronics (wavelet compression ratio ~ 2.4 to 3)
- Radiometric resolution 12 bits
- 5% Radiometric accuracy achieved with a combination of absolute calibration with sun diffuser, dark calibration over ocean at night and vicarious calibration
- Mass/Power/Volume: 290 kg, 250 W, 1m3



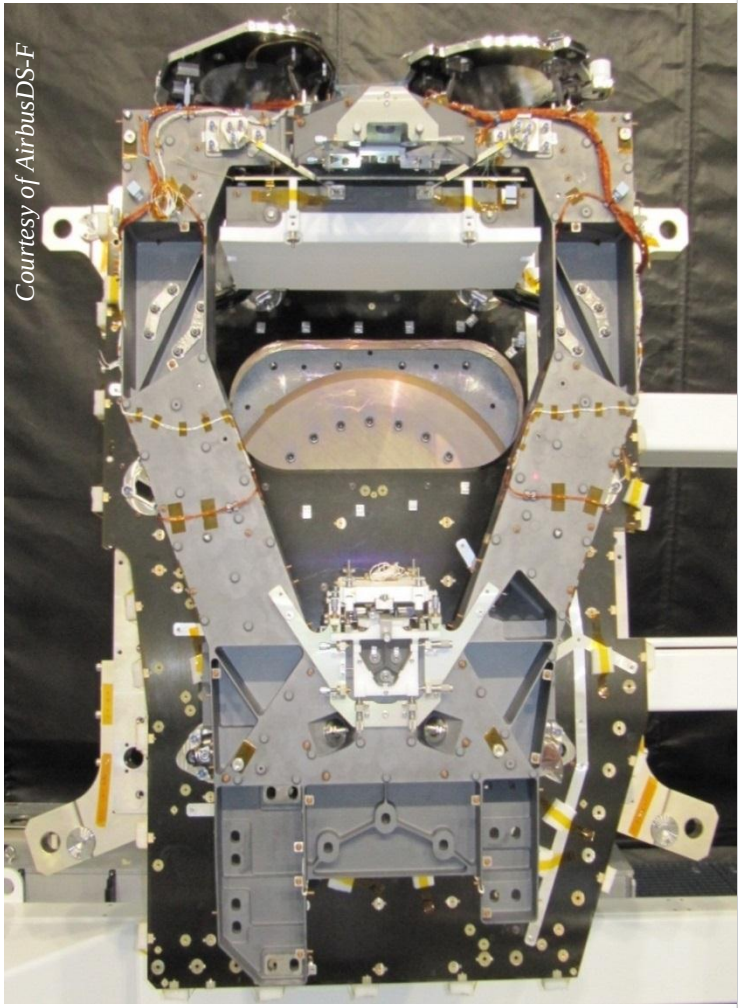
MSI internal view



MSI telescope

TMA Telescope with manufactured mirrors and baseplate in SiC, to minimize thermo-elastic deformations

- Large tertiary mirror, about 550x280 mm2
- Field of view: 21° resulting swath width 290 km
- Highly stable structure: Line of sight <5 µrad



Proto-Flight Model Telescope (AirbusDS-F, BOOSTEC (F), AMOS (B))

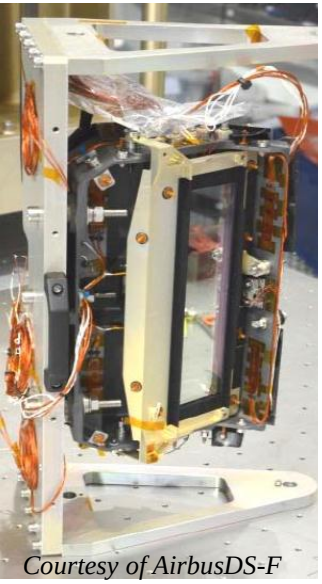
Beam Splitter Assembly composed of dichroic and compensator plates for in-field separation of VNIR bands by reflection and SWIR bands by transmission

Dichroic/compensator sizes: 288 x 96 mm2

Transmission > 90% in SWIR

Reflection > 98% in VNIR

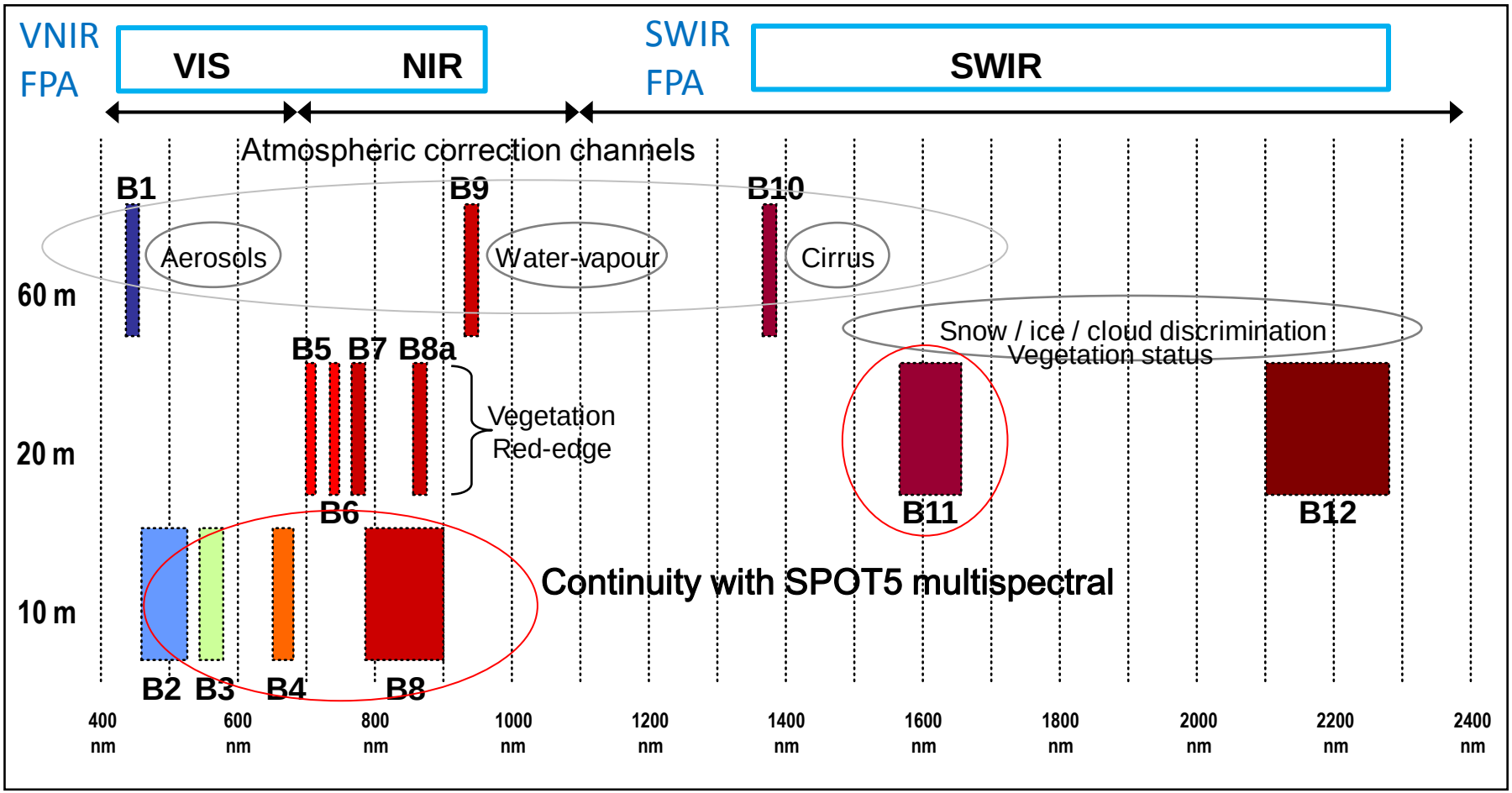
Polarization <1% in VNIR, and 2% in SWIR



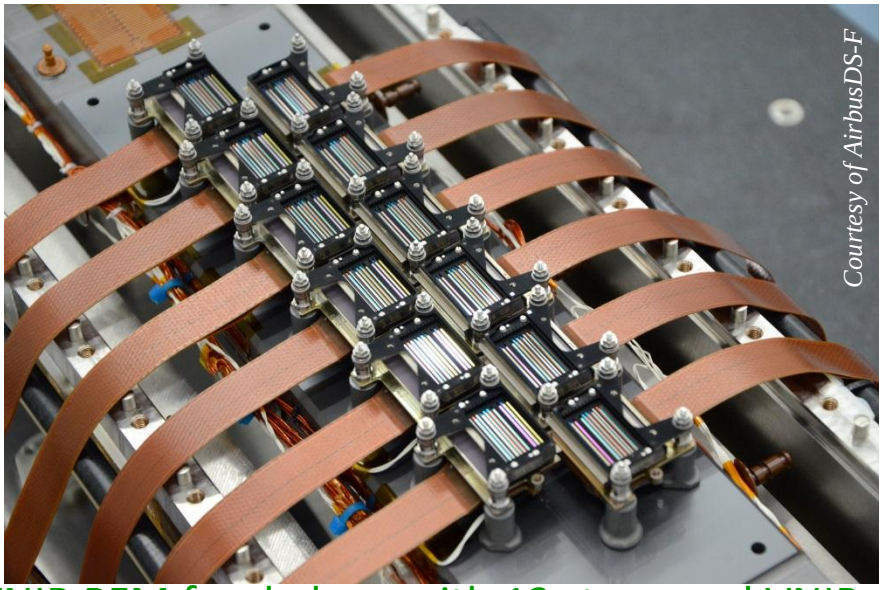
Courtesy of AirbusDS-F

Beam Splitter Assembly (AirbusDS-F)

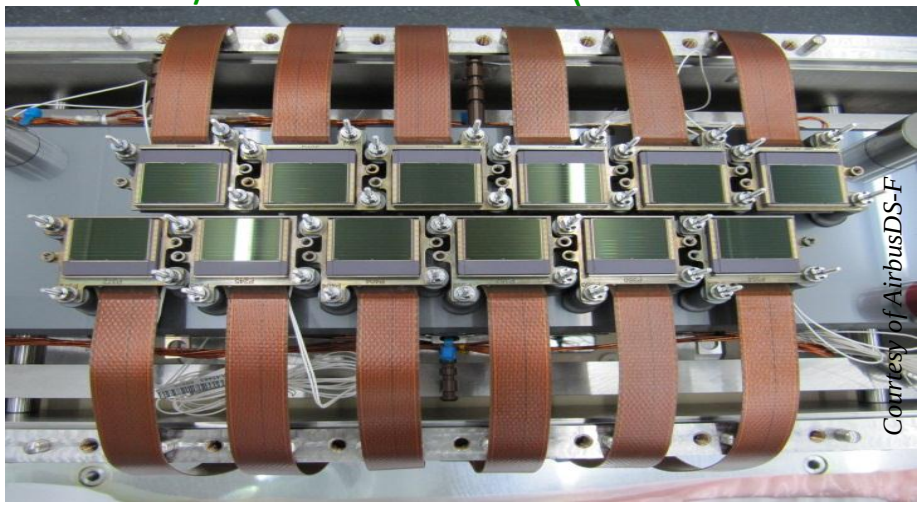
MSI spectral bands



VNIR Focal Plane



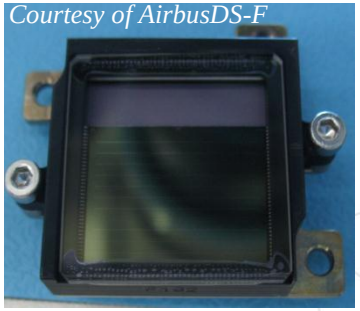
VNIR PFM focal plane with 12 staggered VNIR detectors / filters assemblies (AirbusDS-F & E2V)

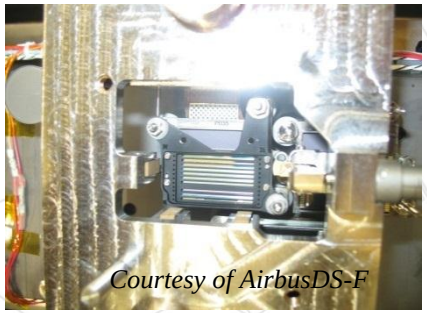


VNIR Focal Plane featuring:

- 12 CMOS multi-linear detectors, 7.5 and 15 µm pitch to cover 10m, 20m and 60m SSD

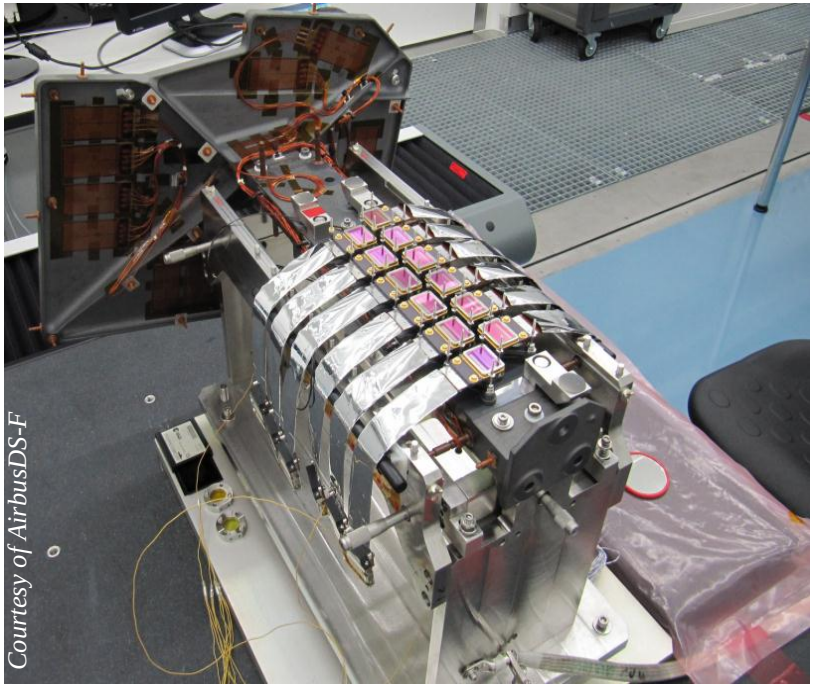
- 10 detection lines of 15500 / 31000 pixels (2 lines with 1 TDI stage), Low read-out noise working at 293K



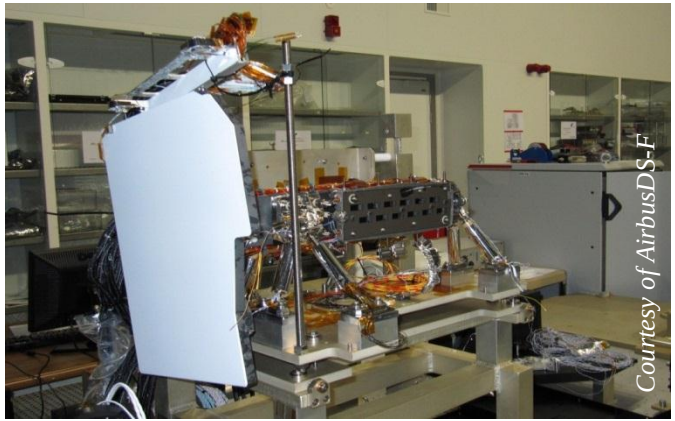


- Filter assemblies assembled by JOP (D) incorporate 10 filter stripes, 5 manufactured by OBJ (D) and 5 by Barr (US)
- Assembly design optimized to reduce stray-light (black-coated detector and filter assembly)

SWIR Focal Plane

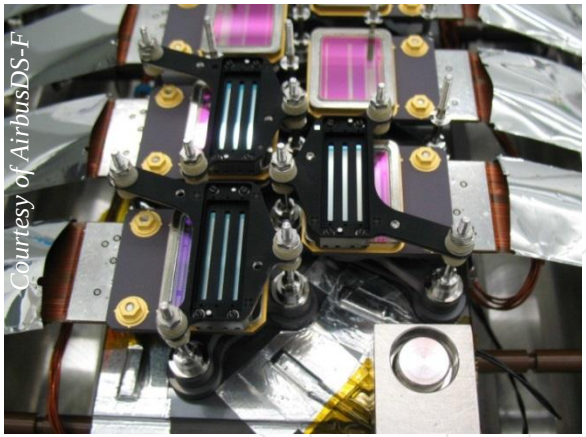


SWIR PFM focal plane with the 12 staggered detectors (AirbusDS-F & SOFRADIR)



SWIR Focal Plane featuring:

- 12 CMOS HgCdTe detectors , 15 µm pitch to cover 20m and 60m SSD
- FPA passively cooled at 195 K+/-200mK
- 3 detection lines of 15500 pixels (2 lines with 1 TDI stage and redundant pixels lines for optimised selection along the mission lifetime

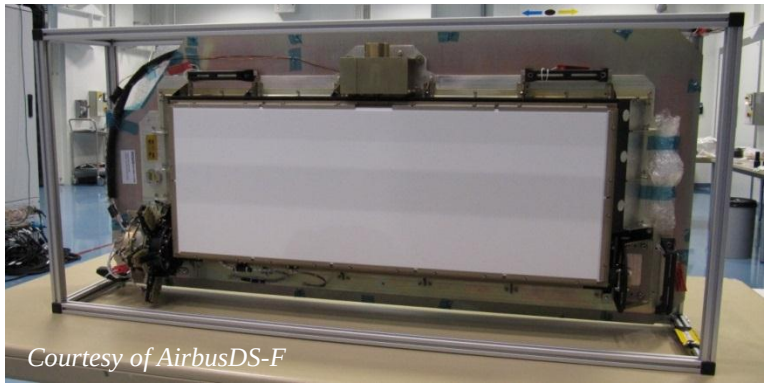


- Filter assembly incorporates 3 filter stripes, manufactured by OBJ (D)
- Assembly design optimized to reduce stray-light

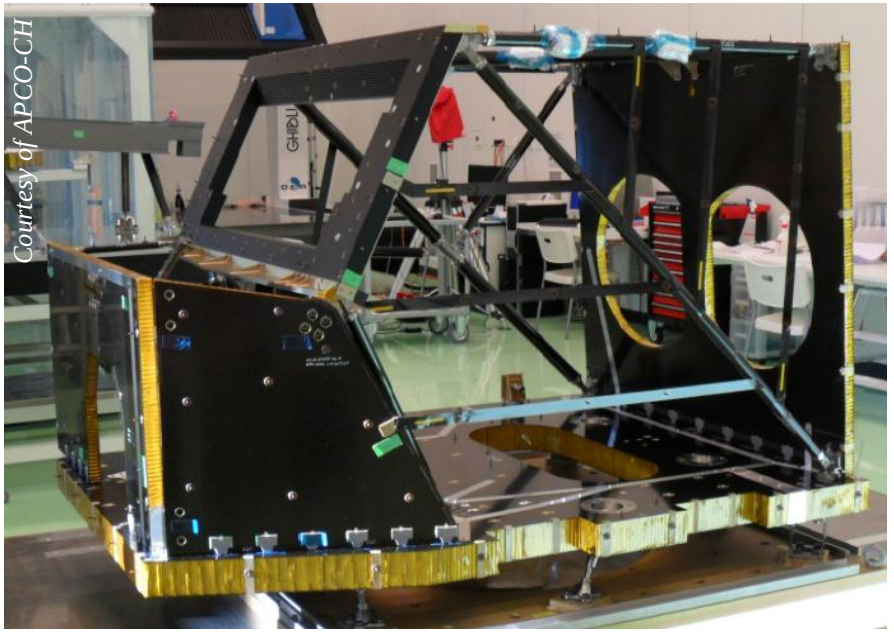
Calibration and Shutter Mechanism

Calibration and Shutter Mechanism (CSM) implemented to:

- Prevent the instrument from direct viewing the sun in orbit and from contamination during launch
- Calibration over the full field/full pupil on-board using a PTFE diffuser (> 700 x 250 mm2) ensuring calibration of each pixel into the FoV
- The CSM is integrated on the secondary structure of the MSI



CSM PFM, Sener (E) prior to its integration on the MSI PFM secondary structure



MSI primary and secondary structure (APCO-CH)

MSI Electronics and Data Handling

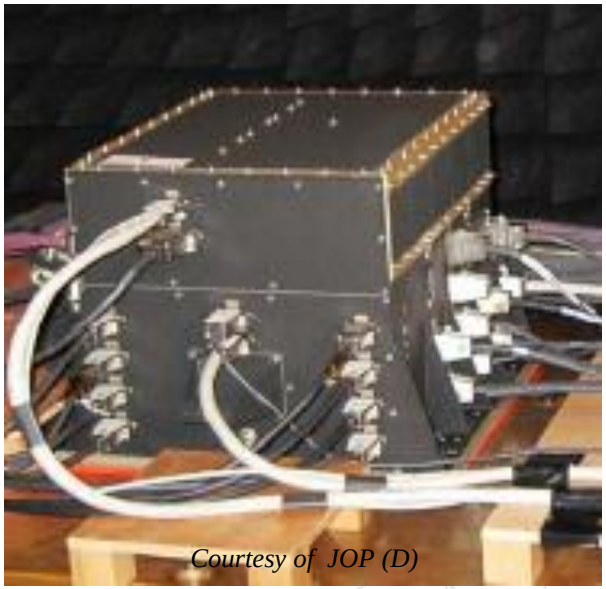
Modular and programmable electronics composed of 8 Frond End Electronic Modules (4 VNIR + 4 SWIR) and 2 Video and Compression Units (in cold redundancy), and performs:

- Selection of SWIR pixels
- Pre-amplification/conditioning of video signals
- Analog-to-Digit conversion on 12 bits
- Pixels Gain and offset equalization
- Wavelet compression (based on state-of-the-art ASICs from Pleiades)
- Data stream Formatting

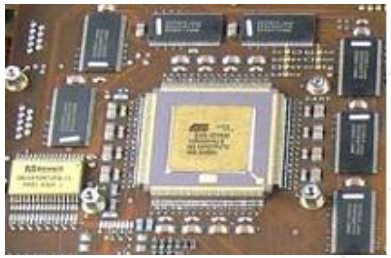
Data rate:

- Raw data rate 1.4 Gbits/s
- After compression 490 Mbits/s with compression ration between 2.4 and 3 tuned for each spectral band

Compression ratios, integration times and SWIR pixels selection are reprogrammable in flight



VCU PFM (JOP-D)

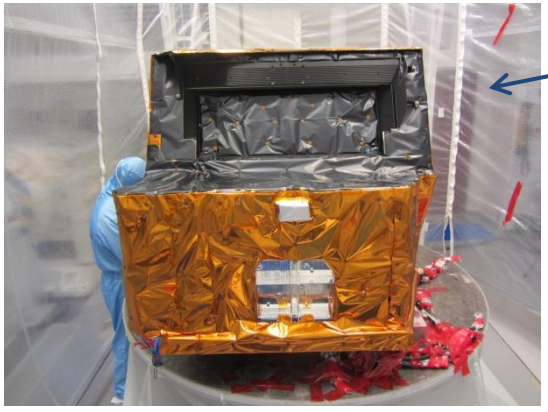


Compression ASIC (AirbusDS-F)

V-FEEM mounted on bracket (CRISA-E)

MSI Performance verification

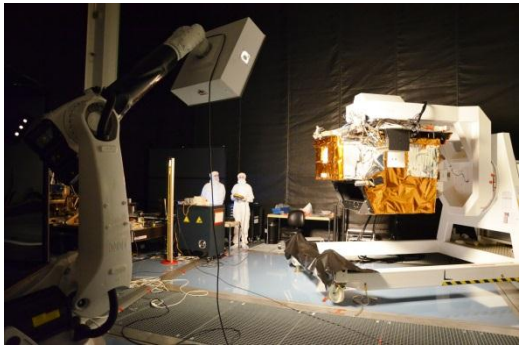
- The MSI Proto-Flight Model has **successfully undergone electromagnetic compatibility tests, vibration tests, thermal cycling tests**, completed by initial and final functional and performance tests (in ambient and under vacuum)



MSI PFM during vibration test (AirbusDS-F & Intespace-F)

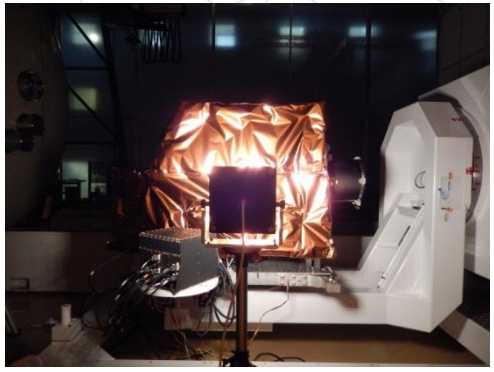
MSI PFM during thermal test (AirbusDS-F & CSL-B)

- Performance was verified at ambient for the VNIR FPA and under vacuum at operational temperature for the SWIR FPA, including a full end-to-end characterization of **geometrical, optical and radiometric performance** of the instrument, including a comprehensive characterisation of the straylight
- Overall **very good performance of the MSI is confirmed**



MSI PFM straylight test (AirbusDS-F)

MSI PFM light tightness test (AirbusDS-F)



MSI VNIR SNR performance

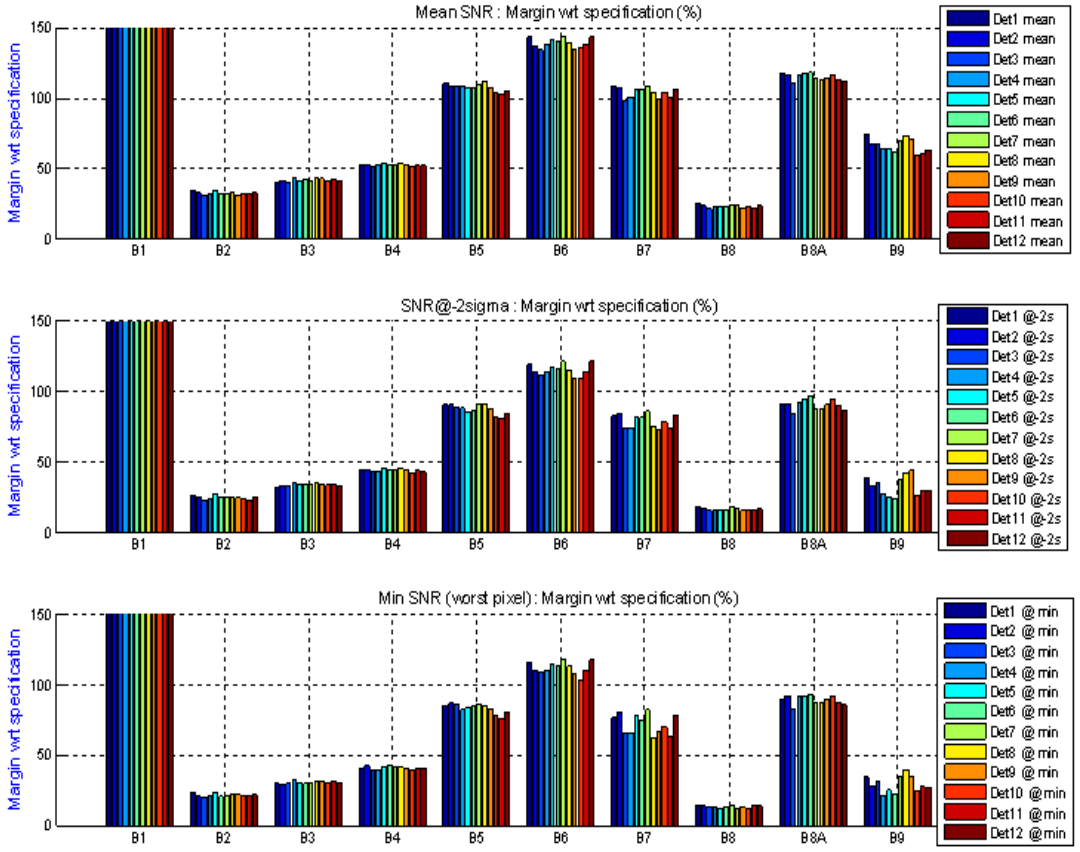
MSI mean SNR budget based on VNIR PFM FPA measurements

→ Exceeds the requirement with margin >20% over the full FPA

→More than 100% margin for the Red Edge bands

Band	Lmin	Lref	Lmax	SNR
	$W.m^{-2}.sr^{-1}.mm^{-1}$	**$W.m^{-2}.sr^{-1}.mm^{-1}$**	$W.m^{-2}.sr^{-1}.mm^{-1}$	**@ Lref**
B1	16	**129**	588	**129**
B2	11.5	**128**	615.5	**154**
B3	6.5	**128**	559	**168**
B4	3.5	**108**	484	**142**
B5	2.5	**74.5**	449.5	**117**
B6	2	**68**	413	**89**
B7	1.5	**67**	387	**105**
B8	1	**103**	308	**174**
B8a	1	**52.5**	308	**72**
B9	0.5	**9**	233	**114**

SNR requirements for VNIR bands



SNR measurements for VNIR bands at MSI level

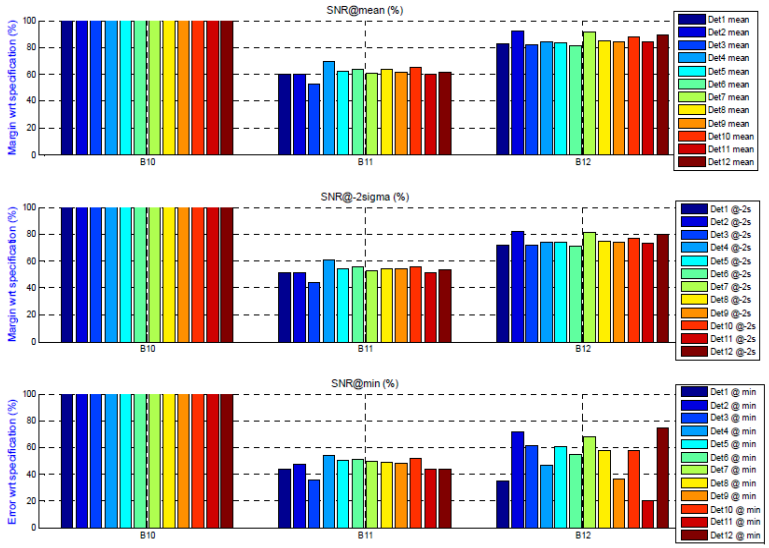
MSI SWIR SNR performance

MSI mean SNR budget based on SWIR PFM PFA measurements

→ Exceeds the requirement with margin > 50% over the full FPA @ LRef

→ Exceeds the requirement with margin > 20% over the full FPA @ Lhigh

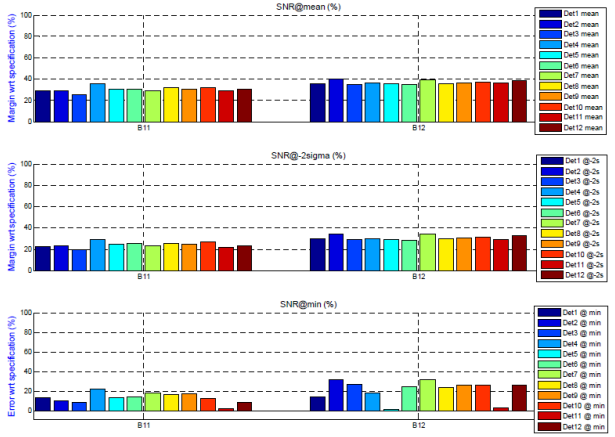
→ Consistent performance between test at SWIR FPA and MSI level



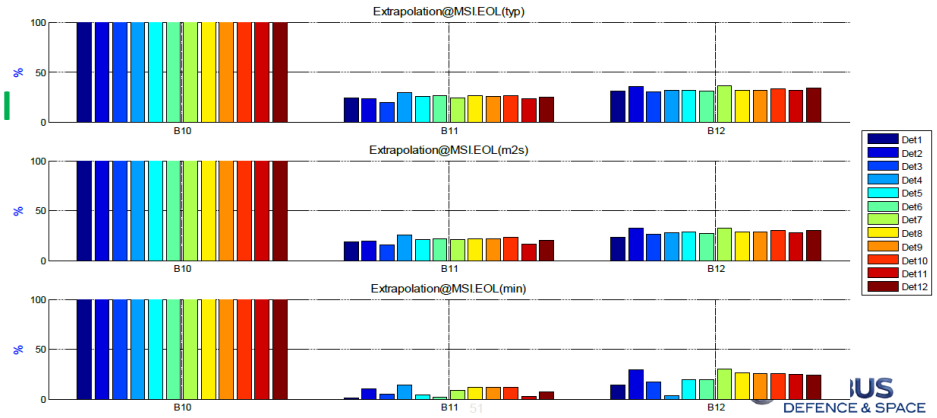
SNR measurements (Lref) for SWIR bands at FPA level

Band	Lref	Lhigh	SNR @ Lref	SNR @ Lhigh
	$W.m^{-2}.sr^{-1}.mm^{-1}$	$W.m^{-2}.sr^{-1}.mm^{-1}$		
B10	6	n/a	50	n/a
B11	4	32	100	504
B12	1.7	11	100	475

SNR requirements for SWIR bands



SNR measurements (Lhigh) for SWIR bands at FPA level



SNR measurements (Lhigh) for SWIR bands at MSI level

MSI performance (cont'd)

Modulation Transfer Function:

→ MTF requirement (0.15) met with significant margin > 50% for VNIR bands
→ MTF met for SWIR bands (marginally for 4 detectors on band B11)
→ Consistent between test at SWIR FPA and MSI level

Absolute Radiometric Accuracy:

→ 5% requirement met with margin at 300 m distance from cloud edge for bands B2 to B8a
→ 5% requirement met at 800 m distance from cloud edge for band B1
→ Performance for band B9 and SWIR bands under consolidation following complementary characterisation of the diffuser bidirectional reflectance (it is expected to meet 5% requirement at 1 km distance from cloud edge)

Geo-location:

→ 20 m requirement without Ground Control Points met with margin

In-orbit commissioning MSI Cal/Val

- During the in-orbit commissioning Phase E1, the **MSI Cal/Val will start as soon as the satellite has reached a stable configuration** (typically a few days after launch).
- Phase E1 Cal/Val objectives are to **assess the radiometric and geometric image quality** of the MSI data products and to **fine tune the on-board and on-ground image processing parameters** to achieve the best performance levels and to compare them to S2 mission requirements.
- MSI Cal/Val activities will include the **execution of all calibration modes** of the MSI and the on-ground processing of a significant number of products **up to Level-1 and in some cases up to Level-2**, using a set of facilities deployed in Europe, in cooperation between ESA and CNES for Image Quality.
- At the **In-Orbit Commissioning Review** planned at Launch+3 months, the MSI Cal/Val results will be presented and assessed with a view to conclude on the **handover from phase E1 (S2 project manager at ESA/ESTEC) to phase E2 (Mission Manager at ESA/ESRIN)**.

Sentinel-2: Conclusions

S2A Launch readiness end April 2015, S2B in April 2016

A unique combination between 10/20/60m resolution & 290 km swath

A very high 5 days geometric revisit at equator

Systematic acquisition of all land surfaces, islands and coastal waters

Thirteen VNIR and SWIR spectral bands

Accurate geo-location (<20 m without Ground Control Points) and multi-temporal pixel co-registration (0.3 Spatial Sampling Distance)

Very good image quality (SNR, MTF, radiometric accuracy)

On-board calibration using a full field of view Sun diffuser

***GLOBAL & FREQUENT* imaging**

high potential for downstream products and geophysical applications