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SENTINEL-2A: MULTI-SPECTRAL INSTRUMENT FIRST IN-ORBIT PERFORMANCE

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INTRODUCTION

Copernicus is a European Union (EU) led initiative designed to establish a European capacity for the provision and use of operational monitoring information for environment and security applications. Within the Copernicus program, ESA is responsible for the development of the Space Component and Ground Segment..

The Sentinel-2 mission provides continuity to services relying on multi-spectral high spatial resolution optical observations over global terrestrial surfaces. It will capitalize on the technology and the vast experience acquired in Europe and the United States to sustain the operational supply of data for services such as Risk Management (floods and forest fires, subsidence and land slides), European Land Use/Land Cover State and Changes, Forest Monitoring, Food Security/Early Warning Systems, Water Management and Soil Protection, Urban Mapping, Natural Hazards, and Terrestrial Mapping for Humanitarian Aid and Development. The design of the Sentinel-2 mission aims at an operational multi-spectral Earth-observation system that complements the American Landsat and French SPOT (Satellite Pour l'Observation de la Terre) families and improves data availability for users (Fig.1).

The Sentinel-2A satellite has been launched in June 2015 and has completed is in-orbit commissioning phase in October 2015. From now on, Sentinel-2A is entered into a ramp-up phase during which acquisition and processing capacity will gradually increase to reach full earth coverage before end of 2016. A second satellite, Sentinel-2B, currently in the final integration phase is foreseen to be launched by the end of 2016. The twin configuration will allow complying to the 5 days revisit. The procurement of the next satellites models (Sentinel-2C and -2D) have been initiated beginning of December 2015, allowing the mission continuity up to the end of the next decade.

With less than 9 months of in-orbit operations, Sentinel-2A has already produced an unprecedented amount of data (above 640TerraByte from December 2015 until April 2016) acquired over land surfaces, combining a high spatial resolution (i.e. Landsat-type and SPOT-type), over a wide field of view for multi-spectral observations covering the visible, near infrared and short wave infra-red part of the electromagnetic spectrum.

Number in serie	5*	7 + 1*	4*
Launch	1986 to 2002	1972 to 2013	2015 (S2A) 2016 (S2B)
Measurement principle	Pushbroom	Pushbroom	Pushbroom
Earth coverage (days)	26	16	5
Swath (km)	2 x 60	185	290
Multispectral bands	4 + 1 (panchromatic)	8 + 1 (panchromatic)	13 (9 VNIR and 3 SWIR)
Spatial Resolution (m)	10, 20 (2.5)	30, (15)	10, 20, 60
Evolution	* SPOT-6 launched in Sept. 2012, same bands and swath than SPOT-5, 1.5m resolution and S/C agility	* LandSat-9 is under devlopment	* Sentinel-2C and -2D development have been initiated in Dec.2015

Fig.1. Key characteristics of Landsat, SPOT and Sentinel-2

1. MISSION OVERVIEW

Frequent revisits of five days at the equator require two identical Sentinel-2 satellites operating simultaneously, with a 180° phasing over the orbit. The orbit is Sun-synchronous at 786 km altitude (14+3/10 revolutions per day) with a 10:30 a.m. local time at descending node. The local time was selected as the best compromise between minimizing cloud cover and ensuring suitable sun illumination. It is close to the Landsat local overpass time and matches SPOT's, allowing the combination of Sentinel-2 data with historical images to build long-term time series. The Sentinel-2 satellites acquire observations over land and coastal areas from -56° to 84° latitude including islands larger 100 km^2, EU islands, all other islands less than 20 km from the coastline, the whole Mediterranean Sea, all inland water bodies and closed seas. To reach radiometric performance requirement, the chosen calibration approach combines acquisition from on-board diffuser covering the full field of view and vicarious sites periodically acquired...

2. SENTINEL-2 PAYLOAD OVERVIEW

A.The Payload concept

The Sentinel-2 satellite is based on a rather compact design (Fig. 3) that ensures compatibility with small launchers type (e.g.VEGA, Rockot). The weight of the satellite is about 1.2 ton. The satellite lifetime is specified as 7.25 years with consumable sized for 12 years operations, including provision for de-orbiting maneuvers at end-of-life. The satellite is three-axis stabilized with an Attitude and Orbit Control System (AOCS) based on an advanced multi-head star tracker, a laser gyroscope and a dual-frequency Global Navigation Satellite System

(GNSS) receiver, allowing a very good geo-location accuracy of the mission data.

The MultiSpectral Instrument (MSI, Fig. 4) is based on a pushbroom concept. It features a Three Mirror Anastigmat (TMA) telescope with a pupil diameter of about 150 mm. The telescope structure and the mirrors are made of silicon carbide, iso-statically mounted on the platform to minimize thermo-elastic distortions.

The 13 spectral bands span from the visible (VIS) and the near infra-red (NIR) to the short wave infra-red (SWIR) at different spatial resolutions from 10 to 60 m. They are separated into two focal planes assemblies (FPA) with an in-field separation: one covering 10 VNIR bands, the other one 3 SWIR bands. Each FPA is composed of 12 CMOS Si detectors and 12 CMOS MCT detectors, positioned in a staggered configuration to cover the 290km field of view. The signal of each detector is amplified, filtered and sampled by the proximity electronic units, then digitized and compressed by a video compression unit before being stored in the mass memory unit.

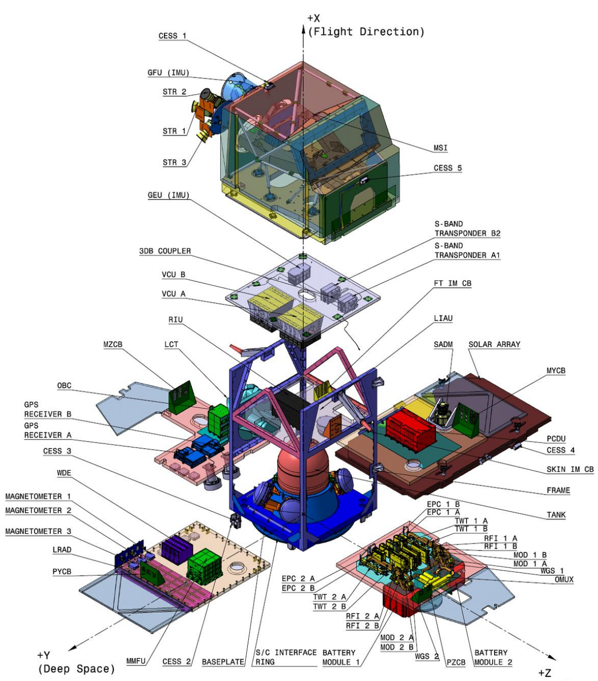

Fig.2. Sentinel-2 satellite architecture (Airbus-DS Germany)

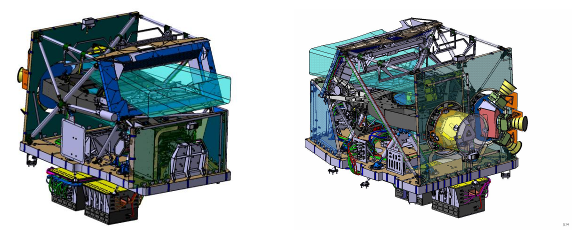

Fig.3. The Multi Spectral Instrument view (Airbus-DS France)

B. The Multi-Spectral Instrument Performance

The first months of the in-orbit operations, have been the opportunity to successfully complete the commissioning of satellite and to get first trends in routine phase of the instrument Beginning of Life performance. Radiometric and geometric performance have been evaluated, showing a very good compliance to the key mission requirements (see table-1).

On radiometric side, the Signal-to-Noise ratio for the RGB bands (10m bands) is close to 40% with the smallest margin >20% for B8. For the IR bands, the noise is kept low allowing to have margin on Signal-to-Noise ratio above 50%. Radiometric accuracy evaluated by comparison of in-situ or vicarious site allow to consider an accuracy better or equal to 5%

for the VNIR bands. The achieved Modulation Transfer Function (MTF) is above 0.15 for all 10m and 20m VNIR bands, in both along- and across-track directions. For SWIR bands, the MTF is well achieved in the along-track direction, with a marginal compliance in the across-track for one of the 2 bands.

On the geometric side, the geo-location accuracy is better than 12.5m at 2sigma, reaching already the requirement expected with Ground Control Point. The band-to-band co-registration is better than 0,3 pixel at 2sigma is met with a confortable margin and is expected to be further improved (<10m) by a refinement of the on-ground post-processing and usage of the new Global Reference Image.

Type	Subject	Performance estimation	Compliant
Radiometric performance	Signal-to-noise ratio (SNR) and minimum, reference and maximum radiance levels for each spectral band are presented in Table 3.11.1.	All bands compliant with > 20% margin	YES
Radiometric performance	The absolute radiometric accuracy shall be 3% (goal) / 5% (threshold).	B1 to B9: < 5%±2%	YES
Optical performance	The inter-channel spatial co-registration of any two spectral bands shall be better than 0.30 of the coarser achieved spatial sampling distance of these two bands	< 0.26 pixel at 3sigma	YES
Optical perfornance	The system modulation transfer function (MTF), at Nyquist frequency, shall be higher than 0.15 and lower than 0.30, in both across-track and along-track, for the spectral bands at 10 and 20 m SSD, and not higher than 0.45 for the spectral channels at 60 m SSD. MTF curves over the entire frequency range shall be calculated.	MTF > 0.15 for all bands except for B11(0.147 in ACT)	YES
Geometric performance	The geo-location uncertainty shall be better than 20 m at 2σ confidence level (without Ground Control Points).	< 12.36 m at 2s	YES

Table 1. Key mission performance of the Multi-Spectral Instrument

3. SUMMARY

Sentinel-2 has been designed to support Copernicus Land, Emergency and Security applications. The mission provides an enhanced continuity to the SPOT 4/5 multispectral missions and complements the Landsat series multispectral observations. The unique key features are the revisit time of five days, a wide swath width of 290 km, the 13 spectral bands providing high radiometric and geometric image quality and its global coverage - contributing to the fulfilment of Copernicus needs in terms of delivery of operational land services.

Following the successful completion of Sentinel-2A In-Orbit Commissioning review in October 2015, the satellite has entered in a phase allowing the presentation of the first in-orbit achieved performance. The presentation will provide (1) an up-to-date status of the Sentinel-2 satellites and payloads flight models development including C and D models, (2) a summary of the on-ground characterisation of the Sentinel-2B instrument and (3) the key performance of the proto-flight multi-spectral instrument of Sentinel-2A, verified during the first month of the in-orbit.