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SEOSAT/Ingenio: a high-resolution land imaging mission

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ABSTRACT

SEOSAT/Ingenio (**S**panish **E**arth **O**bservation **SAT**ellite) is a high-spatial-resolution optical mission procured by the European Space Agency on behalf of and funded through the Spanish program authority CDTI. The Seosat/Ingenio mission is part of the Spanish Earth Observation National Program for Satellites (PNOTS). The mission is devoted to provide land and coastal zone optical images (panchromatic and multispectral) for applications in cartography, land use and mapping, urban management, costal management, agriculture monitoring, precision agriculture, water management, environmental monitoring, risk management and security and is a potential contributor to the European Copernicus program.

The SEOSAT/Ingenio satellite will operate from a polar-heliosynchronous orbit at 670 km of altitude and has an imaging capability up to 2.5 Mkm^2 per day, with world-wide accessibility in less than 3 days and a design lifetime of 7 years. The satellite is based on an Astrobus-M platform architecture weighing about 800 kg and with 580 W installed power and is compatible with a launch with Vega.

The Primary Payload is a push-broom imager, observing simultaneously in a Panchromatic band with 2.5 m resolution and in 4 multispectral bands (B,G,R and NIR) with 10 m resolution, over a swath of 55 km. Bands are co-registered at 1/10 of the pixel and geo-located at subpixel level in post-processing. The Optical design relies on two Korsch on-axis 250 mm aperture telescopes with intermediate imaging plane, in-field spectral separation and staggered-detectors focal planes. The detection system is based on CCD’s (with TDI operation for the PAN) and has MS color filters with direct deposition of the pass bands and masks on a single substrate.

The Satellite flight model is undergoing final integration and testing after final characterization and calibration of the Primary Payload . The SEOSAT satellite is expected to be ready for launch by end 2019.

Keywords: Earth Observation, Land imaging, High-resolution, Visible, NIR, Korsch telescope

1. INTRODUCTION

SEOSAT/Ingenio (Spanish Earth Observation SATellite) is a high-spatial-resolution optical mission developed by a consortium led by Airbus Spain. It is together with PAZ (a synthetic aperture radar satellite) the optical sensor of the Spanish Earth Observation National Program for Satellites (PNOTS[1]). The Spanish Government through CDTI (Centro para el Desarrollo Tecnológico Industrial) entrusted ESA with the technical and project management authority of the SEOSAT/Ingenio development.

SEOSAT/Ingenio is devoted to providing high-resolution multi-spectral land optical images in first instance to different Spanish civil, institutional and governmental users, and potentially to other European users in the frame of Copernicus (the European Union's Earth Observation Program) and GEOSS (the Global Earth Observation System of Systems). Priority shall also be given to users in Central and South America, as well as in North Africa. SEOSAT/Ingenio will provide information for applications in cartography, land use, urban management, agriculture and forestry mapping, water management, environmental monitoring, risk management and security.

The SEOSAT/Ingenio Mission is being developed by an industrial consortium involving a large number of Spanish companies together with several European firms. Airbus Defence and Space España is the Prime Contractor of the Space Segment and responsible of satellite manufacturing integration and testing, with SENER as responsible of the Primary Optical Instrument and INDRA is the Prime contractor of the Ground Segment.

The Mission is in a mature development stage (Phase D) and launch readiness is currently forecasted at the end of 2019. The satellite will be launched by a Vega launcher from the European launch base in Kourou, French Guyana.

2. THE SEOSAT/INGENIO MISSION AND KEY PERFORMANCE

The SEOSAT/Ingenio mission is based on a single satellite flying in a frozen polar-heliosynchronous orbit at 670 km of altitude with a repeat cycle of 14 + 32/49 revolutions/day. A Local Time of the descending node (LTDN) of 10:30 is selected to optimize the observations illumination conditions for the latitudes of interest, while minimizing the cloudiness probability in any season. The choice of the orbit is also driven by the requirements of full geometric coverage of the Spanish territory in less than 2 months and of global geometric accessibility times of 30 days with OZA (Observation Zenith Angle) less than 6.5º (nominal mode for programmed observation) and of 3 days with OZA less than 40º (extended mode for emergency acquisition). This extended capability is especially aimed to support emergency observations in the occurrence of natural disasters or events requiring fast access, to ensure a fast global accessibility worldwide.

The longitude phasing of the ground tracks of the satellite has been selected to optimize the geometric coverage and accessibility times over Spain, which is the primary region of interest. Areas of special interest besides the Spanish territory are Europe, the Ibero-american countries, the North African countries with Mediterranean coast and Atlantic coast located north of latitude 10ºN , with a maximum distance from the coast in land of 400 km. The system however, is capable to acquire up to 2.5 million km^2/day, giving 60% spare capacity for observation also outside the interest areas. In the figure 1 here below, a simulation shows a reference scenario for a complete one-day acquisition, at maximum capacity.

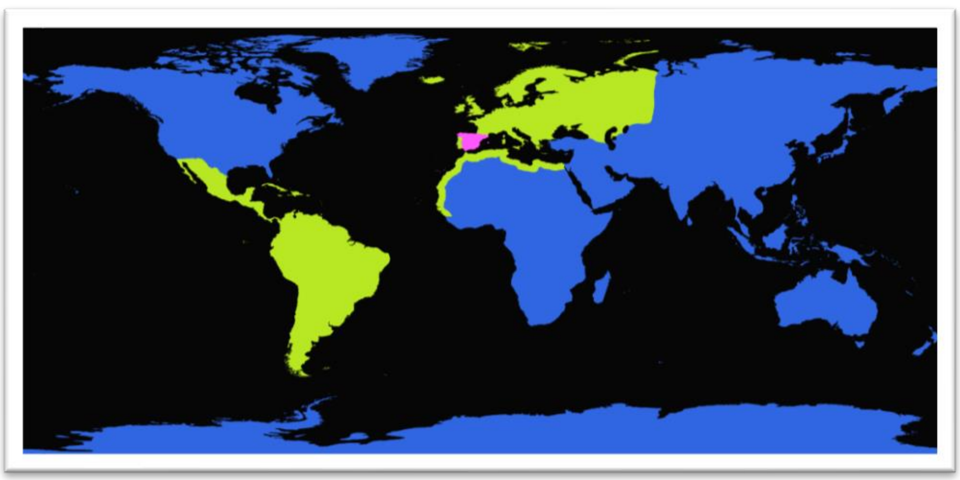

Fig.1: SEOSAT/Ingenio main areas of interest

The image acquisition is performed in push-broom mode simultaneously in one Panchromatic (PAN: 525÷670 nm) and four multispectral (MS: Blue, Green, Red and NIR) bands. With a swath of more than 55 km at all specified latitudes (between 83°N and 56°S) it has a resolution better than 2.5 m at Nadir in the panchromatic band and better than 10 m in the multi-spectral.

SEOSAT images will be geo-located at level 1-c (after deconvolution) , by means of ground control points (GCPs), with an error lower than one PAN pixel RMS (2.5 m) including errors from satellite AOCS, payload geometrical modelling and the accuracy of the applied Digital elevation Model (DEM) and of the GCP location itself. In the same process all bands are co-registered at 0.1 pixel.

At level 1-b, the radiometric calibrated product, the absolute geo-location accuracy is better than 50 m 2σ with margin (predicted value 43.2 m), including all contributors from satellite attitude control, line-of-sight jitter, thermo-elastic distortion and geometrical modelling and calibration residual errors.

The absolute pointing accuracy of the satellite is 44 m across-track and better than 250 m along-track, at 2σ confidence level.

The required image quality at level 1b is such to achieve a SW/SSD (ratio between the Spatial Width of the sample and the Spatial Sampling Distance) of at least 1.1 both for PAN and MS images. Following latest flight performance predictions based on measured instrument MTF (see section 3), the image quality is met by PAN products after restoration and by MS products in average (across/along-track) but without any use of deconvolution.

3. INSTRUMENT AND KEY PERFORMANCE

The optical payload of the SEOSAT/Ingenio satellite (see artist impression in Fig.2) is composed of two identical cameras, each one covering half of the specified field of view (total 5°). Each camera has Panchromatic (PAN) and Multispectral (MS) imaging capabilities and 2.5 m resolution in PAN and 10 m in MS. The two cameras are aligned to ensure a small overlap between their FoVs (measured 422 pixels) to implement the specified swath of 55 km and to ensure pixel overlap for image stitching during processing The equivalent numerical aperture is 14.06.

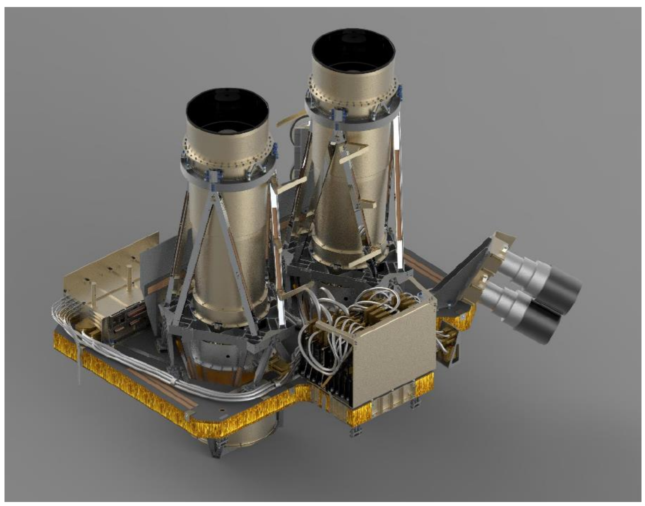

Fig.2: CAD view of the SEOSAT/Ingenio instrument

Each Camera (CAD view in Fig. 3) is composed by a Telescope, with its optical elements and baffles, a Focal Plane, which includes the filters, detectors and proximity electronics, all mechanically assembled and thermally controlled, as well as the necessary electronics for digitizing and transmitting the image data to the Spacecraft Payload Data Handling Unit. The satellite star-trackers optical heads (2 x 2) are installed also on the HSSP for maximum restitution accuracy of the instrument Line-of-sight and minimization of thermo-elastic errors.

The SEOSAT telescopes are of the Korsch type with three powered mirrors plus one flat folding mirror used to extract the focal plane and compact the whole structure. The primary and tertiary mirrors are concave ellipsoids while the secondary mirror is a convex hyperboloid. It works on-axis in pupil and field. The design has been chosen to cope with the large focal planes and to permit a relatively ease of manufacturing, aligning and straylight baffling, though it is not image-telecentric and typically suffer from certain degree of pincushion distortion. The optical aperture is 250 mm after baffling at the primary mirror and the realized focal length is 3573.4 mm. The four mirrors are all made of lightweighted Zerodur, being isostically mounted on Titanium supports and assembled by a set of Invar struts. Each telescope is also equipped with a refocusing device based on a thermal expansion aluminum ring attached to the secondary mirrors, to enable in-orbit refocusing of the instrument. This device has a total thermal range of ± 10 ºC, with an accuracy of ±0.1 ºC (equivalent to ± 0.18 μm in axial distance M1-M2).

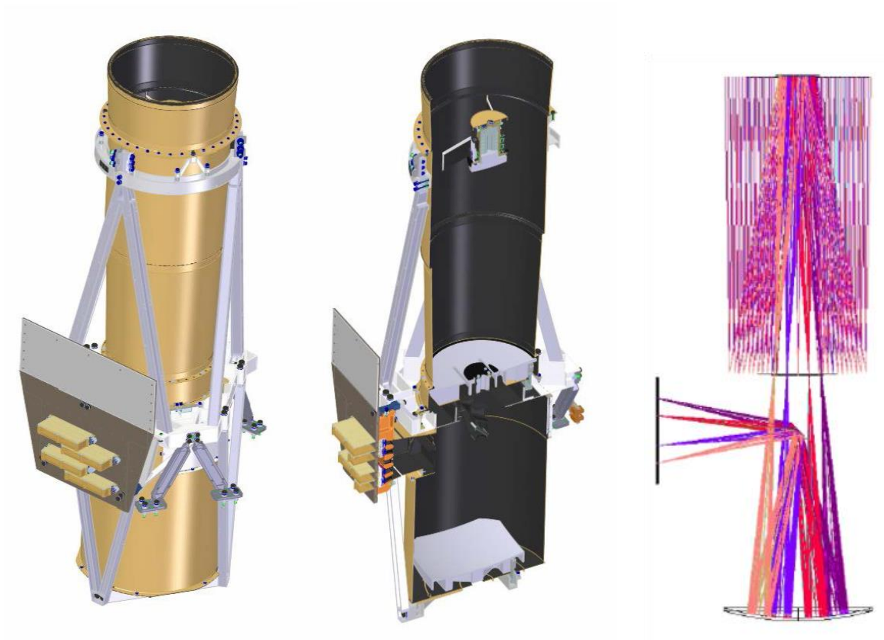

Fig.3: CAD representations and optical layout of the SEOSAT/Ingenio camera/telescope

The two identical focal planes are SiC plate where two PAN and two MS Detector assemblies are aligned with high precision (see fig. 4). PAN and MS detector assemblies overlap for about 50 pixels to ensure acquisition continuity throughout the full camera FoV. Each detector assembly is a stack of a CCD and a filter joined by a thin metallic frame bonded and bolted to each other with high accuracy.

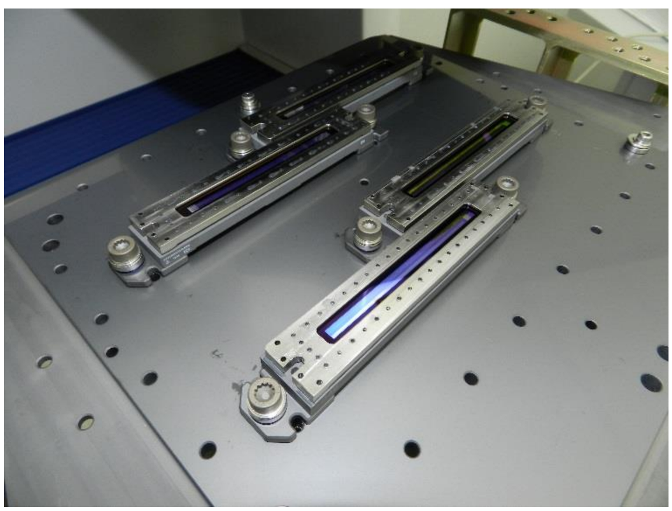

Fig.4: photo of a SEOSAT/Ingenio focal plane.

The PAN detectors are 20 by 6000 linear CCD's with 5 TDI sets implemented (7 to 20) and each pixel is 13 x 13 µm. The MS detectors are linear CCD's of 4 by 1500 pixels with a pixel size 4 times large (52 µm) and each line images the scene in a different MS band. Both CCD detectors have been manufactured by E2V and are derived from similar CCD's used for the Pleiades program. The filters are thin-film coatings directly deposited on fused Silica substrate and have been manufactured by Jena Optronik.

Each detector is connected to a Proximity Electronic unit. A Video Unit collects, multiplex and digitizes the samples from the CCD's and connects to the satellite PDHU via a G-link. A Video Supply Unit and Instrument Control Unit complete the payload electronica and are all installed on the High-Stability Support Structure (HSSP) panel which supports all elements of the instrument. The HSSP itself is a sandwiched honeycomb with CFRP sheets designed for high stability and low thermo-elastic distortion; either telescope is fixed with soft isostatic mounts to the HSSP, which on its turn is fixed to the satellite by 3 isostatic mounts complemented by rods to strengthen the structure against axial loads, while allowing lateral deformation. The first eigenfrequency of the instrument measured during vibration tests exceeds 65Hz.

The static MTF measured on-ground for each camera is around 0.15 for PAN (averaged ALT/ACT) and around 0.4 in MS bands. The diffuse straylight level measured are well within specification, whereas a slight ghost (1÷2%) has been observed at the edge of the FOV in each camera: its characterization is subject of another paper presented at ICSO 2018 by C.Miravet (SENER), co-author of the present contribution.

The SNR measured during on-ground radiometric campaign on the instrument PFM is exceeding the specifications in all bands with margin, even for the worst-case pixel. The SNR at L_{ref} and L_{min} in the center of the FoV are shown in the table here below:

Band/camera	**PAN** L_{min}/L_{ref}	**MS-Blue** L_{min}/L_{ref}	**MS-Green** L_{min}/L_{ref}	**MS-Red** L_{min}/L_{ref}	**MS-NIR** L_{min}/L_{ref}
Camera 1	75 / 153	167 / 242	135 / 261	104 / 258	61 / 410
Camera 2	73 / 152	159 / 234	131 / 255	109 / 266	63 / 416

Table 1. measured SNR at L_{min}/L_{ref} in the center of the FoV for both cameras of the instrument

The instrument weighs 152 kg and has a maximum power consumption of 240 W in acquisition mode.

The proto-flight model of the SEOSAT/Ingenio instrument has completed its qualification campaign (vibrations and thermal-vacuum / thermal-balance tests) and post-environmental characterization and it has been shipped to AIRBUS Spain in early September 2018 for integration into the satellite. The integration and optical AIT has taken place at Thales France facility of Cannes with participation of SENER, Thales France and Spain teams and the environmental tests have been carried out at INTA facilities in Spain. In the fig.5 here below the integrated PFM model of the instrument is shown in its integration fixture.

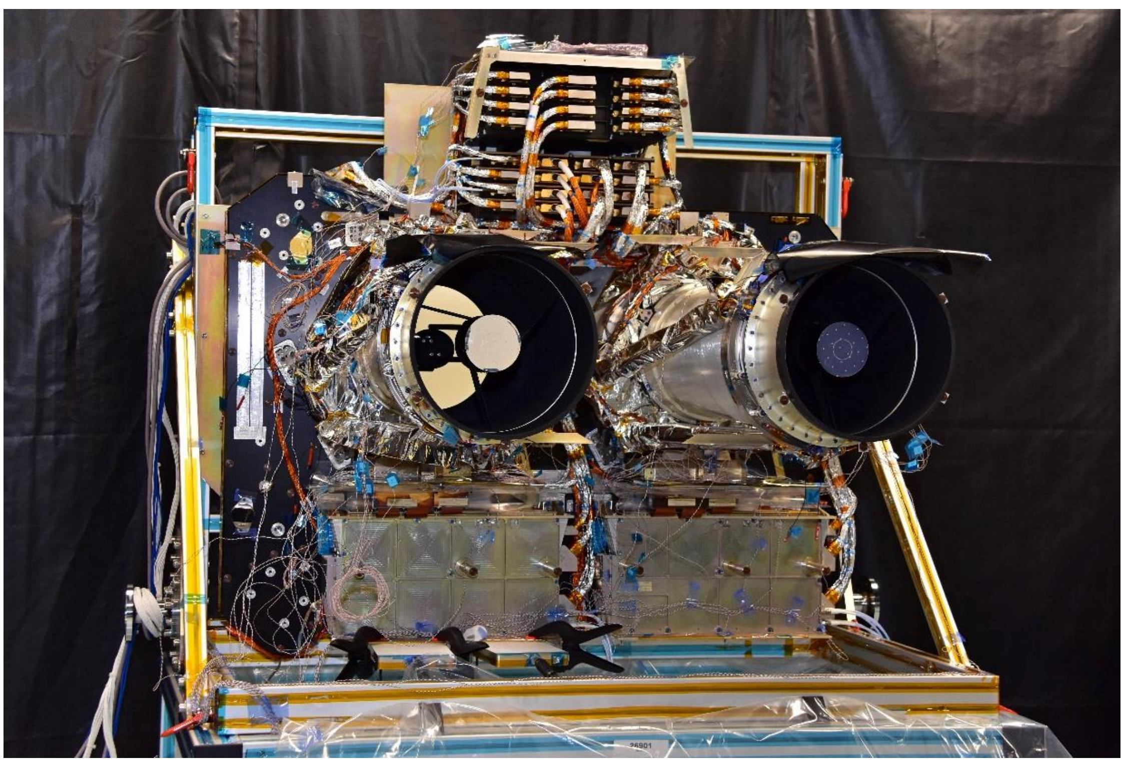

Fig.5: Photo of the SEOSAT/Ingenio instrument PFM during its test at Thales Alenia Space facilities in Cannes

4. SEOSAT SATELLITE AND OPERATIONS

The satellite is based on an Astrobus-M standard platform developed by AIRBUS for medium-size Earth Observation missions and integrated at AIRBUS Spain facilities (former CASA Espacio).

The satellite is composed of the platform and the payload, which consists in the main optical instrument described in section 3 and an opportunity experiment, Sensosol, developed by SolarMems technologies S.L. and the University of Seville (Spain) and funded by the Spanish Ministry of Science.

Sensosol is a miniaturized sun-sensor based on MEMS (Micro Electro-Mechanical Systems) technology, with 5 sensing unit in quadrant layout plus a central, etched on a Silicon substrate. The small solar sensor is capable of detecting the sun position in a FoV of ±60° with an angular resolution of the sun-position of 0.5°; when operated in narrow-FoV mode (± 30°) it reaches a resolution of 0.15°. Sensosol instrument has been delivered in 2015 and is already integrated in the satellite.

The platform has a box-shaped design with a hexagonal base and 6 aluminum faces sandwich panels, with 3 single-panel deployable solar array, for a total solar panel area of about 5.40 m^2. The panels of the platform can be opened as petals to ease AIV operations (see Fig.6).

Fig.6: Photo of the SEOSAT/Ingenio satellite during integration at AIRBUS facilities in Madrid

The Attitude and orbit control is based on a high performance 3-axes stabilised gyro-less architecture. The fine pointing is achieved by means of dual Star-trackers mounted on the instrument bench.

The On-board computer relies on a LEON-3 processor and communicates with the remote units via a 1553 bus. The Payload data handling includes a 280 Mbps X-band data transmission, and a mass memory device of 0.5Tbit, allowing 33.17 Mpixel/s for the PAN output rate and 8.22 Mpixel/s for the MS output rate, for each individual optical camera. The Payload data handling Unit has a G-link high-speed connection to the instrument Video Unit provides compression capability, based on a quasi-lossless algorithm derived from Pleiades development, with 5 selectable compression rates between 2 and 6 bpp (bits per pixel).

The satellite dry mass is about 720 kg and the average power is 580 W. It is designed for 7 years lifetime in orbit and has design and fuel provisions for de-orbiting in 25 years.

The SEOSAT/Ingenio satellite is currently in its final AIT campaign, undergoing environmental test in early 2019.

An artist's impression of SEOSAT/Ingenio satellite is shown here below in Fig. 7

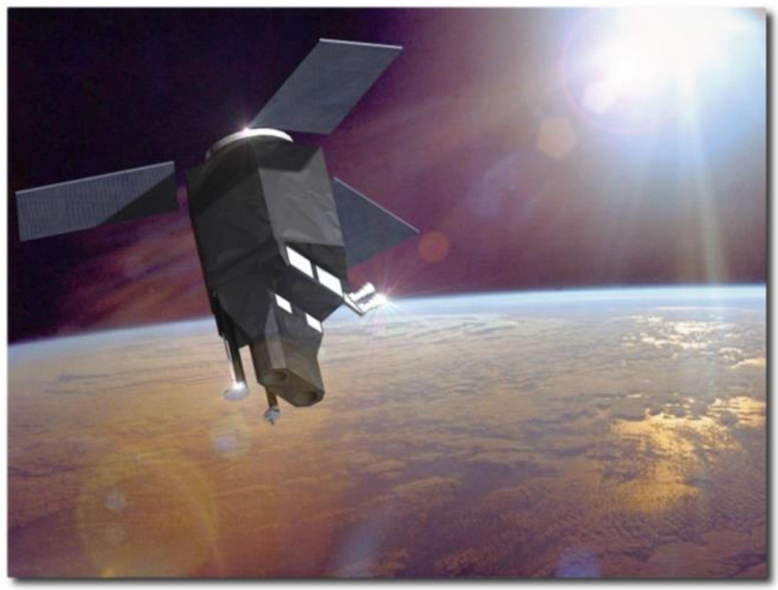

Fig.7: Artist's impression of the SEOSAT/Ingenio satellite

The industrial team comprises a consortium of Spanish and other European industries led by the Prime AIRBUS Spain (former Casa Espacio), including as main partners SENER (Primary Payload Contractor), Thales Alenia Space España (Payload Electronics and Communication Systems), Thales Alenia Space France (Instrument Alignment and AIT) CRISA (On-board platform electronics) and Airbus Space & Defence France (Avionics and Software).

The System will be operated from the ground station of Torrejon de Ardoz (Spain), which will be the primary Control Centre of the mission and using Maspalomas (Canary Islands) as backup station. Support of high-latitude stations such as Svalbard is foreseen to complete the accessibility and increase the data throughput when necessary.

The Ground Segment will generate and distribute to users panchromatic and multispectral products radiometrically calibrated (L1B) and ortho-rectified (L1C) in GML+Jpeg2000 format. Additionally, perfect sensor products (L1B2) will also be distributed together with the corresponding RPC (Rational Polynomial Coefficients) for fast projection. Catalogue consultation, archive search and retrieval service will be set up and made accessible through a User Service. Higher level products will be left to the user community and to the possibility of creation of a shared toolbox.

INDRA is the Prime contractor of the Ground Segment, with main industrial partners GMV and Deimos and the operations are going to be carried out by Hisdesat and INTA, which also hosts the Control centre of Torrejon.

5. CONCLUSIONS AND ACKNOWLEDGEMNTS

This paper gives a forcedly synthetic overview of a complex mission and a huge effort posed by the Industrial consortium, ESA and CDTI. Last but not least acknowledges the support and guidance of the Mission Advisory Group during the specification and execution phase of the project. The authors gratefully acknowledge the work and the effort of all the colleagues not mentioned in this paper for the unique contribution they have been providing through the years of development of SEOSAT/Ingenio.

REFERENCES

[1] Borges, A., Cerezo, F., Fernández, M., Lomba, M., López, M., Moreno, J., Neira, A., Quintana, C., Torres, J., Trigo, R., Ureña, J., Vega, E., Vez, E., "Spanish Earth Observation Satellite System". Proceedings of the ESA Living Planet Symposium, Bergen, Norway. (ESA SP-686, December 2010) Ed. by H. Lacoste-Francis, ESA communication.