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SEOSAT/INGENIO: a Spanish high-spatial-resolution optical mission

A. Marini

F. J. Reina Barragan

G. Crippa

B. Harnisch

et al.

SEOSAT/INGENIO -
A SPANISH HIGH-SPATIAL-RESOLUTION OPTICAL MISSION

A.Marini[1], F.J. Reina Barragan[1], G.Crippa[1], B.Harnisch[1], I. Fuente[1], M.Lopez[2], I. Cabeza[3] D.Zorita[4]

[1]ESA/ESTEC, the Netherlands. [2]CDTI, Spain,[3]Airbus Space & Defence, Spain,[4]SENER, Spain,

I.   INTRODUCTION

SEOSAT/Ingenio (Spanish Earth Observation SATellite) is a high-spatial-resolution optical mission developed, together with PAZ (a synthetic aperture radar satellite), under the Spanish Earth Observation National Program for Satellites (PNOTS) [1].

The mission is devoted to provide land optical images (panchromatic and multispectral) to different Spanish civil, institutional and governmental users, and potentially to other International and European users in the framework of Copernicus, previously known as GMES (Global Monitoring for Environment and Security) and GEOSS (Global Earth Observation System of Systems).

The overall mission objective is to provide information for applications in cartography, land use and mapping, urban management, costal management, agriculture monitoring, precision agriculture, water management, environmental monitoring, risk management and security.

The program is funded by CDTI (Spanish Centre for Development of Industry Technology), who remains responsible for the programmatic aspects of the mission. The European Space Agency (ESA) is entrusted with the technical and contractual management of the industrial activities. The SEOSAT Mission is being developed by an industrial consortium involving a large number of Spanish companies together with several European firms. Airbus Defence and Space is the Prime Contractor of the Space Segment, with SENER as responsible of the Primary Optical Instrument and INDRA is the Prime contractor of the Ground Segment.

The launch readiness for the SEOSAT/Ingenio mission is foreseen at the end of 2016

II.   MISSION CONCEPT AND KEY PERFORMANCE REQUIREMENTS:

The SEOSAT/Ingenio satellite will fly on a polar-heliosynchronous orbit at 670 km of altitude, with Local Time of Descending Node (LTDN) 10:30 and a revolution period of 14+32/49 rev/day. The mission is thus defined to provide world-wide accessibility in less than 3 days, with imaging capability up to 2.5 Mkm^2 per day, with special emphasis on the acquisition of images on the Spanish territory (including "carpet-mapping" for cartography applications) and other areas of interest like Europe, north of Africa and Ibero-America.

Fig. 1. SEOSAT/Ingenio orbit repeat cycle (ground-tracks for three-days coverage)

The SEOSAT mission will provide images of 55x55 km in the Panchromatic and Multispectral (Blue, Green, Red and near-Infrared bands) spectral domains at a spatial resolution (GSD – Ground Sampling distance) better than 2.5 m and 10 m, respectively. SEOSAT images will be geo-located, by means of ground control points (GCPs), with an error lower than one pixel RMS, and co-registered with an accuracy better than 0.1 pixel 2σ. 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. The instrument providing the imaging function of SEOSAT Ingenio is the Primary Payload, described in more detail in section IV.

The system is designed to provide nominal imaging within ± 6.5° OZA (Observation Zenith Angle), but allowing image acquisition up to ±40° off-nadir. This capability is especially aimed to support emergency observations in the occurrence of natural disasters or events requiring fast access, within the 3-days global accessibility worldwide.

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 ensure the data throughput.

The Ground Segment will generate and distribute to users panchromatic and multispectral products processed at level 1c and 1b-2, typically consisting of geo-located image in JPEG2000+GML format. RPC (Rational Polynomial Coefficients) are appended to the header of the level 1b2 products. 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.

III.   THE SEOSAT/INGENIO SATELLITE

The SEOSAT/Ingenio satellite is composed of a platform, a primary payload and hosts also 3 Complementary Scientific Payload (CSP), selected by the Spanish Ministry of Science by means of an Announcement of Opportunity.

The platform is an innovative development of Airbus Space & Defence (former EADS Astrium) based on the AstroSat 250 product, conceived for medium-size Earth Observation missions. The Service module has a box-shaped design with a hexagonal base and 6 aluminium 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.2**). The power distribution system relies also on a 150 Ah Li-Ion battery and an unregulated bus of 34 V DC, delivering a max. power of 580 W.

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 primary Payload bench for maximum restitution accuracy of the instrument Line-of-sight and minimisation of thermo-elastic errors. A sun sensor and magnetometers complete the suite of attitude sensors. Four reaction wheels and magneto-torquers are used as actuators for the acquisition and maintenance of the satellite modes, together with the propulsion system, which is based on a plug-in concept, packaged on a single and compact module with chemical mono-propellant hydrazine and a 80 litres fuel tank.

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 1Tbit, 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 high speed connection to the Payload data handling Unit is implemented with a G-link bus and there the data stream can be compressed, based on a quasi-lossless algorithm derived from Pleiades development, with 5 selectable compression rates between 2 and 6 bpp (bits per pixel).

The SEOSAT/Ingenio satellite is being integrated at Airbus Space & Defence Madrid (former EADS CASA Espacio) who is also the prime contractor of the Space Segment development. The industrial team comprises a consortium of Spanish and other European industries, including as main partners SENER (Primary Payload Contractor), Thales Alenia Space España (Payload Electronics and Communication Systems), CRISA (On-board platform electronics) and Airbus Space & Defence France (Avionics and Software).

The total mass of the satellite is 830 kg and the lifetime in orbit is 7 years, with consumables supporting 10 years operations.

The CSP (Complementary Scientific Payload) consists of three small/medium size instruments
− SENSOSOL, a miniaturised solar sensor based on MEMS technology, provided by the University of Seville
− TTT, an in-orbit dosimeter and radiation spectrometer hosting different sensors, provided by INTA (Instituto Nacional de Tecnica Aerospacial, Torreejon de Ardoz, Spain).
− UVAS, an ultraviolet and visible atmospheric sounder, provided by the Spanish Centre for Scientific investigations (CSIC − Consejo Superior de Investigaciones Cientificas)

The ground segment is being developed by an industrial consortium under the lead of INDRA, including other Spanish industries (Deimos, GMV, ISDEFE..)


Fig. 2. SEOSAT/Ingenio Flight Platform under integration (Courtesy of Airbus Space & Defence)

IV.   THE SEOSAT/INGENIO PRIMARY PAYLOAD

The primary payload is a push-broom imager composed by two identical cameras of 260 mm aperture and 3.65 meters of focal length, providing a total FoV (Field-of-view) of ~4.8 degrees. The total swath at Nadir of 55 km is achieved by tiling the individual FoV of the two telescopes side-by-side. The system requirements are translated into an optical MTF of the PAN channel > 0.115 and of the MS channels > 0.3. The required SNR at instrument delivery for the reference radiance (~80 W/m^2sr) is 110 for the PAN, 125 for the Blue (MS) channel and 200 for the other Multispectral lines (Green, Red, NIR). The challenge of the SEOSAT instrument is therefore to provide good image quality with excellent radiometry over a quite large field-of-view.

The optical system of each camera has been designed as on-axis Korsch telescope imaging the scene on a focal plane with staggered detector assemblies, where the swath of each camera is achieved by juxtaposition of two detector elements (two PAN and two MS). A certain degree of overlap is implemented through the design of the telescope isostatic mounts, by allowing nominally 700 pixels to overlap, in order to ensure seamless swath irrespective of the (predicted) wandering of the line-of sights of either telescope due to thermo-elastic distortions through the orbit cycle (an possible post-launch settling offset). Each camera has dedicated proximity and video electronics whereas a Video Supply Unit and an Instrument control unit are common to both camera's. In **fig. 3** a schematic of the primary payload is shown.
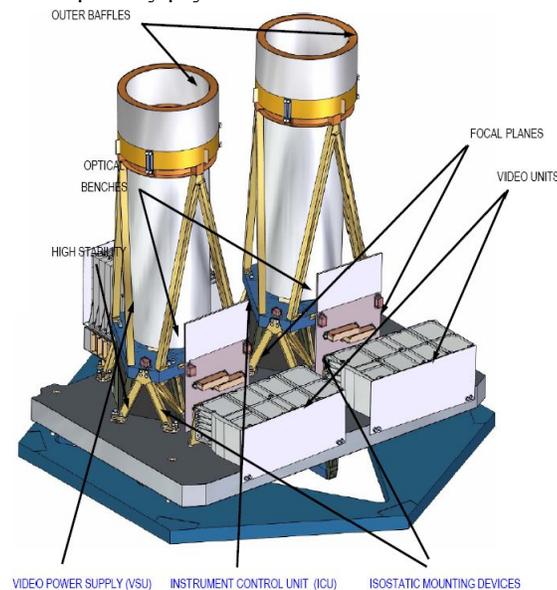
Fig. 3. SEOSAT/Ingenio Primary Payload configuration (Courtesy of SENER)

The Korsch telescope (see **fig. 4**) is non-telecentric and it is configured with the three aspherical mirrors aligned along the optical axis and a flat 45° folding mirror deviating the beam on the focal plane, which is installed with a bracket on one side of the telescope. The system forms a secondary image at the primary mirror where four slits are implemented to spatially transmit the fields mimicking the focal plane detector layout. The Korsch system has the advantage of being free of chromatic aberrations in an extended operative spectral range (visible-NIR) and capable of accommodating a quite large field-of-view.. The chosen configuration offers the advantage of a somewhat easier alignment than other telescope with anastigmatic mirrors (e.g. classical TMA's). Each telescope has a F# of 14,5 , being the clear aperture at the primary mirror 260 mm The four mirrors are all made of lightweighted Zerodur equipped with Titanium/Invar isostatic mounts, directly bonded to the mirrors. The mirrors are isostically mounted on Ti supports and assembled by a set of Invar struts. A thermal refocusing device allows to set the optimum focal distance once in flight, to possibly recover settlings and gravity relaxation effects.
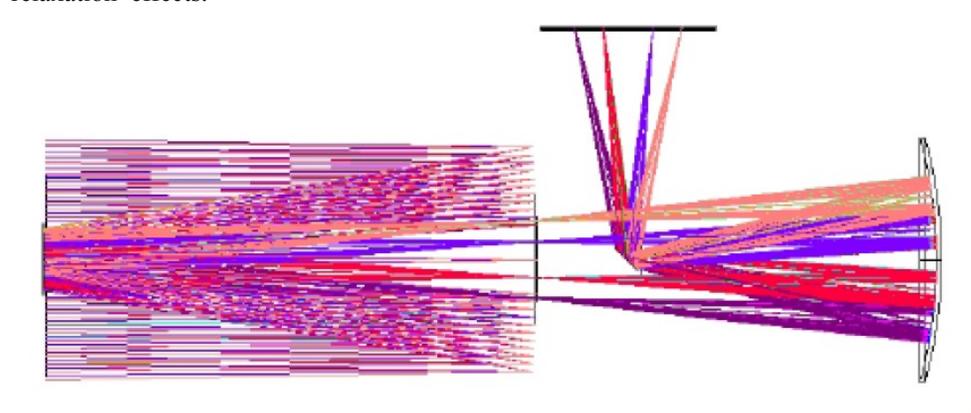
**Fig. 4.** SEOSAT/Ingenio Korsch telescope optical layout (Courtesy of SENER/INTA)

The focal planes (one for each camera) are SiC plates where two PAN and two MS Detector assemblies are aligned with high precision (see **fig. 5**). PAN and MS detector assemblies overlap for about 200 PAN pixels to ensure acquisition continuity throughout the full camera FoV. Each detector assembly is composed by a CCD and a filter joined by a thin metallic frame bonded and bolted to each other with high accuracy.

Fig. 5. SEOSAT/Ingenio integrated focal plane (Courtesy of SENER)

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 are manufactured by E2V and have been derived from similar CCD's used for the Pleiades program.

The filters are thin-film coatings directly deposited on fused Silica substrate (with a process developed by Jena Optronik, the manufacturer of the filters) and cover the following bands (see **fig. 6**)
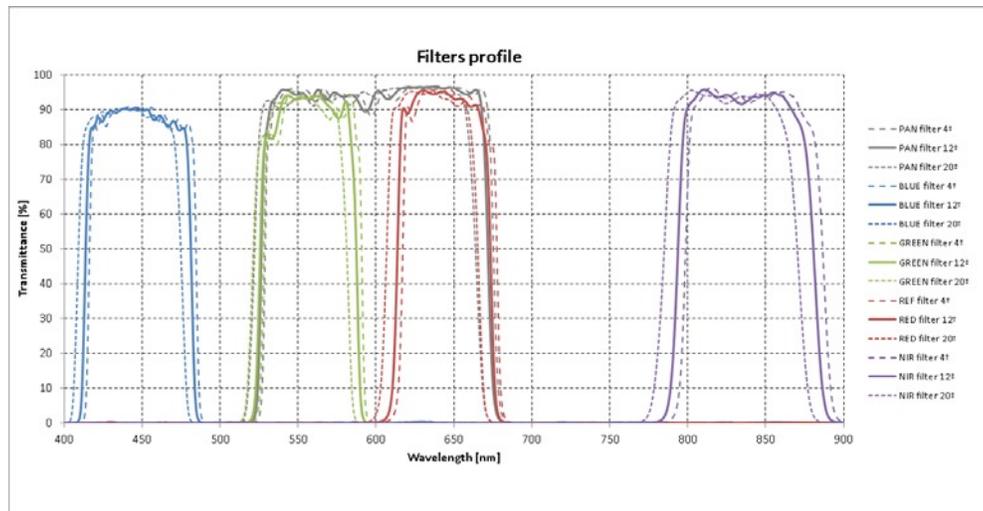
Fig. 6: Transmittance of the SEOSAT/Ingenio filters including spectral shifts at the edge of the FOV

The bands have been chosen with the PAN enveloping the G and R, and the visible bands optimised to match the common RGB rendering of the images, as provided also by other imaging satellites. The NIR has been chosen to include an absorption peak of the oxygen ion, but it is wide enough to avoid that different FOV position give different radiometric response. As a matter of fact the large FoV implies an angle of incidence up to 19° at the edge of the FOV cross-track, which produces a spectral shift in the bands of a few nm. This has been taken into account when designing the filters and the spectral shift has been analytically evaluated.

The primary payload has a predicted mass of 148 kg with a maximum power consumption of 240 W.

The Primary Payload Flight model is being manufactured and an Engineering Qualification model, based on a single operational camera and a dummy one, has been subject to functional and environmental testing. The integration, characterisation and the environmental testing of the primary Payload EQM have been carried at INTA facilities (Torrejon de Ardoz, Spain).

Fig. 7: The SEOSAT/Ingenio Primary payload EQM under integration in ISO-6 (courtesy of INTA)

V.   ACKNOWLEDGEMENTS

This paper summarises a few aspects of the large amount of work carried out at CDTI, at ESA and at the industrial teams. The co-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.

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