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SEEING: the SAFRAN EO payload for microsats

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ABSTRACT

Safran is presenting its concept of optical payload for microsatellites combining high performances and extremely low SWAP factor. It is offering a high resolution of 1.5-m over 10x6,6 km² area from the 500 km durable orbit. The concept is based on an advanced innovative diffraction limited optical system packaged in a unique very compact volume lower than 10U = 200x200x250 mm making it the ideal solution for 15-100 kg microsatellites. A maximum number of pixels are delivered to the end-user space imagery community thanks to 35 mm Full Frame sensors offering, as of today, 6600x4400 pixels. Panchro imagery and multispectral up to 8 bands 450 to 1000 nm can be offered thanks to 2D structured filters..

Keywords: microsatellite, camera, earth observation

1. INTRODUCTION

Remote sensing from space is becoming more and more affordable thanks to the development of more and more compact and efficient platforms, thus reducing the launch costs. Missions are now also conceived in term of constellations offering shorter revisit time. However, beside the plenty new players in the domain of platform, we observe that the offer in term of EO payload is not following a similar trend of high performance combined to very low SWAP factor.

Thanks to its expertise and long heritage in high performance space optics and optronic system development for defence application Safran is adressing this point and proud to offer to the space community the lowest SWAP factor EO payload for 18–27 U cubesats or 15-100 kg class of microsatellites. Such compact payload is expected to become a standard thanks to its modular design and multiplicity of potential applications.

2. SAFRAN CORE CAPABILITIES AND HERITAGE

2.1 Safran Reosc

Safran Reosc is European leader precision space optics and is serving this industry with telescopes, mirror assemblies, lens assemblies, precision filters and optical ground support equipment. In fact, Safran Reosc pioneered several key technologies for space optics like:

Zerodur mirror substrate lightweighting by machining in the 70’s,

Computer Controlled Robotic aspheric Polishing in the 80’s,

the use of Three Mirror Anastigmats with ISRO’s IRS 1-C optical system launched in 1995,

Silicon Carbide optics precision polishing with FORMOSAT-2 optics delivered to Airbus in 2000.

Extreme asphere with 90° deviation large diffraction limited OAP in 2014.

Precision freeform precision optics for MicroCarb in 2017.

Today Safran Reosc is delivering many small and large space optics and optical ground test equipment made from SiC or glass ceramic material, as well as precision lens assemblies, telescopes and specialty filters and coatings. While Safran Reosc has built its reputation on larger and larger space and astronomy optics we hold key capabilities in ‘small’ but high performance lens assemblies and catadioptric optics. These skills are now adapted to microsatellites optical payloads.

Figure 1. Safran Reosc space optics

2.2 Safran Electronics & Defense

Safran Electronics & Defense is European Leader in optronics for defense, i.e. combining precision optics with advanced Vis and IR sensors, specialized electronics, critical image processing software and integrating these equipment within orientation and stabilization gimbals to constitute systems offering ultimate pointing and tracking capabilities on-board any vehicle.

Safran Electronics & Defense also operate in Valence a unique electronics design, development and production of advanced electronics and already serve the space community with various power supply, video processing, memory module, etc. on-board satellites.

Figure 2. Safran optronics

In addition, Safran delivers unique Hemispherical Resonant Gyroscope (HRG) units that are critical contributors to the launch success on-board launch vehicles.

3. EXISTING OFFER AND CONSIDERATIONS ABOUT EO ONBOARD MICROSATS

3.1 Planet and the Dove constellations

Planet is the pioneer in earth observation from space with 3U cubesats, sent in constellation of 28 satellites in order to offer short revisit time. These satellites were initially fitted with amateur telescope optics of 90 mm aperture and 1400 mm focal length. They offer offer 3.70-m GSD from relatively short lived 475 km orbit. Rapidly Planet realized that hitech opto-mechanics is required to enable stable in-orbit performances corresponding to the design goals and iterated several times on the subject with improved optics design and opto-mechanical technology.

3.2 Media Lario Streego

Media Lario is offering its Streego payload based on a 200 mm aperture TMA telescope. This instrument is based on metal mirrors mounted within a metal structure with a much larger volume of 600x550x330 mm3 (plus a 200 mm long front entrance baffle). It is designed to deliver 2.75-m GSD imagery over 11.3x8.5 km² from 600 km orbit.

3.3 Satlantis

The Spanish entity Satlantis is developing a serie of iSIM sensors based on twin Cassegrain-type telescopes. The full field of view is apparently delivered by the combination of the images delivered by the two telescopes. The instrument volume is again relatively large with 590 x 490 x 318 mm3.

There are also several other actors like Hera Systems, Astrodigital, Malin Space, etc. developing their optical payloads, still based on conventional Cassegrain type optics with relatively large volume .

3.4 Airbus Astroterra

On the high end side of establised EO players, Airbus has developed the Astroterra constellation’s New Astrosat Optical Modular Instruments (NAOMI) offering 1.5 to 2.5-m GSD from long life 700 km orbit. These instruments are based on a Silicon Carbide Korsch type telescope with 200 mm aperture offering up to 30 km trace length in push-broom mode.

Let’s recall that Safran Reosc is proud to have been selected by Airbus for the supply of the Astroterra constellation optics. First two models SPOT-6 and SPOT-7 have been launched in 2011 and deliver excellent imagery.

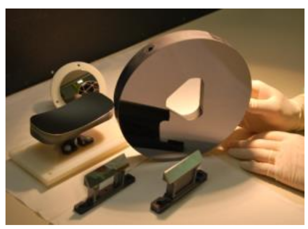

Figure 3. Astroterra optics kit delivered by Safran Reosc to Airbus

3.5 Harris

Harris in the US is offering its family of ‘Space View’ instruments of 23, 35 or 42-cm aperture targeting sub-meter resolution thanks to these large apertures. These larger instruments are built on a more conventional Cassegrain + field corrector or Korsch configuration. Due to their size and level of performances, we consider that they are more dedicated to the higher end of the market with minisatellites rather than microsatellites.

3.6 The importance of the orbit and piggyback effect

The resolution and field of view are directly linked to the altitude of the orbit where the satellite is set. The lower the orbit the higher the resolution. But also the smaller the FoV and as a direct consequence, the longer the revisit time. Lower orbit therefore impose to build larger and more complex constellation of many satellites in order to offer global imagery service to the community.

In addition, the lower the orbit, the shorter the lifetime. Down to 400 km orbit altitude the lifetime becomes less than 2 years. Therefore, in order to offer the imagery service over long period (typically 5 to 10 years) it is necessary to send to space a total of up to 5 constellations, thus multiplying the total cost for the end-user by nearly the same factor.

The difficulties for nanosats and microsats to find a cost-effective launch opportunity is today well known. Therefore these missions are lanched as piggyback payloads of larger satellite. The drawback resulting from this situation is that there is quite no choice possible for the orbit and the satellite is placed at the main instrument’s orbit. Most of the large satellites are placed on orbit of 600 km and above (or at ISS level). So they come to the low ISS orbit with very short lifetime or have to go at much higer orbits of 600 or 700 km where GSD is increased nd FoV reduced. The lesson we retain from this situation is that new payloads shall be designed for at least 500 or 600 km orbit in order to be able to offer their service for 5-10 years and not be penalized by piggyback effect. This results in a direct cost-saving factor by more than 5 for the investor in the EO imagery service.

3.7 The application

Our strategy is to develop and offer of space optics and EO payload designed to be able to address the maximum of potential applications. These can be classified along the two main parameters of spatial resolution (GSD) and spectral resolution as shown on the figure at right.

We have identified the green area of main applications of imagery from microsatellites with two limits in term of GSD with respectively 10-m and 1-m ground resolution.

In term of spectral resolution, panchro imagery and 4 to 8 spectral bands appears to us as capable to answer to the maximum potential needs of the community.

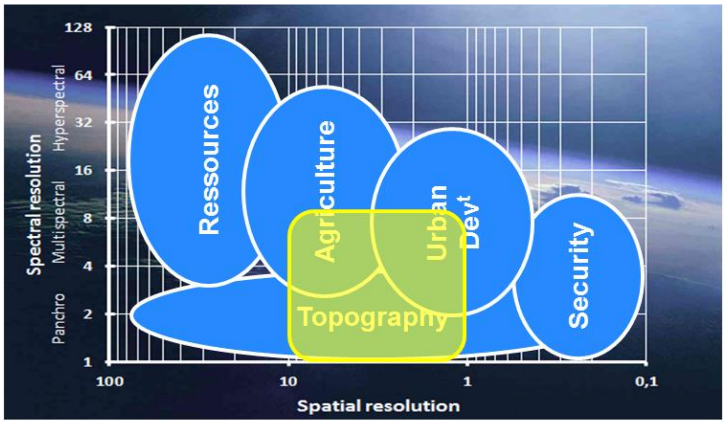

Figure 4. Spatial vs Spectral resolution

4. THE SEEING 1.5-M EO PAYLOAD

The concept of our **S**mall sat**E**llite instrument for **E**arth imag**ING** with 1.5-m resolution (SEEING 1.5-m) is presented on the figure below. This system is designed to take snapshots of a 10 x 7 km² area, with 1.5-m resolution in panchro mode or with several spectral bands.

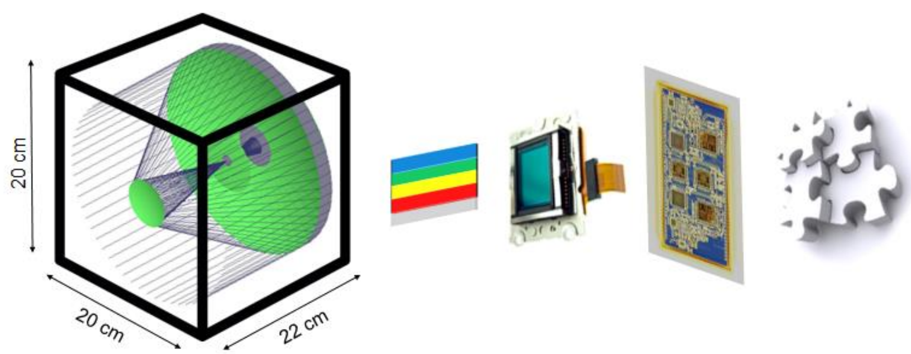

Figure 5. Concept of SEEING 1.5-m

4.1 The optics:

The detaile design of the optics is kept confidential at this time du to patent aplication in progress. It is a 190 mm aperture, 1800 mm focal length system delivering diffraction limited image quality over at least 24x36 mm image format corresponding to 1.14° x 0,76°. The optics is a pure mirror telescope system, thus covering broadband spectral domain and fitted within a nearly cubic very small volume thus enabling unique compactness and low weight for a space camera in this range of high level performances. The design MTF is better than 35% at 91 lp/mm corresponding to 5.5 µm pixel size and 1.5-m GSD from 500 km orbit. The distortion is very low, below 0,05%.

The optical design includes efficient baffling thanks to a field stop around an intermediate image. Such pure mirror design is therefore offering many decisive advantages:

- Wide spectral domain and total absence of chromatic aberration
- No glass sensitive to temperature and space radiations
- Simple broadband and durable reflective coatings
- Inherent efficient baffling and stray-light reduction
- Adaptation to high performance mono-material opto-mechanical concept

4.2 The filter

A 2D structured filter is placed in front of the detector. The required number of spectral bands is distributed through the Along Track dimension of the FoV. Each spectral band is therefore captured over a 24mm/N area, with N equal the number of spectral bands, plus 1 for the Panchro mode. Acquiring and combining images taken at the appropriate rate along the orbit of the satellite will therefore allow the reconstruction of the imagery with the desired N spectral bands. The N parameter can be tuned for each specific mission from 1 to 8 without entering into too low SNR configuration.

The filter technology is based on multi-dielectric design offering rectangular transmission curve, with double total throughput compared to the classical Fabry-Perot filter design. This is definitively contributing to the highest possible SNR for the instrument.

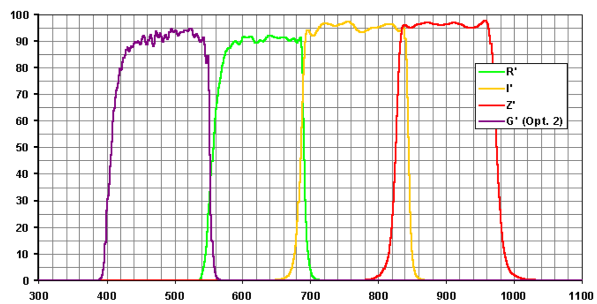

Figure 6: Example of 4 band MS filter made by Safran Reosc

We are considering the following spectral bands as the typical configuration for the system. These can of-course be tuned per specific request from the end-user of the mission to which it would be dedicated:

Panchro	400-1000 nm
MS 4 bands	400-500 / 500-600 / 600-700 / 800-1000 nm
MS 8 bands	400–450 / 450–500 / 500-550 / 550-600/ 600–650 / 650–700 / 700-800 / 800-900 nm

4.3 The 2D sensor:

A strategic choice has been made for our SEEING EO paylod in selecting the generous 2D sensor format of Full Frame 35 mm SLR camera, i.e. 24x36 mm². This will allow using sensors from several vendors and to benefit from evolution of the sensor technologies driven by the strong technology push provided by the photographic market without redesigning our optomechanics.

The choice between CCD sensors and CMOS technologies with 5.5 µm pixel size remains open at this date. While the space heritage and performance level of CMOS sensors are rapidly increasing for the benefit of the community, we conduct discussions with several sensor vendors. The end-user remains welcome to participate to the choice of the sensor if he finds some interest in such customization of the payload. At this date, at least one sensor is available on the market and do offer attractive performances.

We have conducted detailed evaluation of the SNR offered by the instrument with MODTRAN software. On typical vegetation or urban ground scene, we evaluate the SNR to 120 in Panchro, 80 in 4 band MS and about 60 in 8 band MS.

4.4 The electronics

Some electronics has to be adapted to the selected detector. This activity is in fact one of the core skills of Safran Electronics & Defense. There are also some reputed specialists like 3DPlus serving the market with innovative approaches and proven technologies for developing compact, powerful and space compatible electronics. Modular electronic concept is being developed to drive the 2D sensor and acquire the data.

4.5 Onboard data processing

Safran Electronics & Defense holds and extensive heritage and catalog of 'battle proven' image processing modules. These can be implemented for specific on-board image pre-processing and data volume reduction before transmission to the ground. Safran offers full flexibility to rapidly develop this section of the payload per the targeted mission of the instrument. Typical image processing functions are:

Removal of cloudy or water regions from the image to reduce its volume

Contrast enhancement and de-noising

Application of super-resolution algorithm allowing to target 1-m GSD and less for the payload

Detection of specific targets like ships on the sea, or specified infra-structures

Etc …

4.6 The structure and SWAP factor

The telescope is to be entirely made from ceramic material for high robustness, high thermal stability and low weight at the same time. Such mono-material design is offering many decisive advantages: inherent athermal performances and rapid thermal gradient reduction.

Thanks to its extremely small volume of 10 liter only the mass of the optics itself is kept below 5 Kg. Including the sensor and its electronics, the thermal protections and interface mounting flexures biods, the total mass of the instrument is evaluated to 6 kg only.

Our today preliminary evaluation of the electrical power needed to operate the sensor, its electronics, the various heaters, etc. is established at around 30 W.

5. CONCLUSION

Safran is developping its SEEING EO payload offering exceptional low SWAP factor with 10 times smaller volume and 3 times lower weight than other instrument offering similar performances. The payload is delivering high performance imagery with 1.5-m GSD from 500 km durable orbit. Super resolution processing shall allow to reach sub-meter GSD. We ar also convinced that such exceptional payload may find other applications in the domain of science, debris detection, pseudo-satellite or even UAV and defence.

The design effort presented above relative to advanced EO payload for microsatellite is undertaken on internal SAFRAN funding. Efforts will continue with a demonstrator optical system to be produced in 2019. Efforts on sensor and electronics detailed design and development are conducted in parallel.