# PLEIADES-HR IMAGE QUALITY COMMISSIONING FORESEEN METHODS

*Laurent LEBEGUE, Daniel GRESLOU, Françoise DELUSSY, Sébastien FOUREST, Christophe LATRY, Philippe KUBIK, Jean-Marc DELVIT*

CNES
18, avenue Edouard Belin 31401 TOULOUSE CEDEX 4
Phone: 33.(0)5.61.27.35.72 Fax: 33.(0)5.61.27.31.67
E-mail: laurent.lebegue@cnes.fr

## 1. INTRODUCTION ON PLEIADES-HR

PLEIADES is the highest resolution civilian earth observing system ever developed in Europe. This imagery program is conducted by the French National Space Agency, CNES. It is the French part of the French-Italian ORFEO program which also comprises COSMO-SkyMed, an Italian high-resolution radar system. It will operate in 2010-2011 two agile satellites designed to provide optical images to civilian and defense users. Images will be simultaneously acquired in Panchromatic (PA) and multi-spectral (XS) mode, which allows, in nadir acquisition condition, to deliver 20 km wide, false or natural colored scenes with a 70 cm ground sampling distance after PA+XS fusion. Coverage will be almost world-wide with a revisit interval of 24 h for 2 satellites.
The Image Quality requirements were defined from users studies from the different spatial imaging applications, taking into account the trade-off between on-board technological complexity and ground processing capacity. The PLEIADES-HR satellites will benefit from technology improvements in various fields which will allow achieving, at an affordable price, performances once reserved to ambitious military spacecrafts.
The major constraints of weight and agility led to the development of a highly compact satellite (about 1 ton weight), to minimize the moments of inertia. The instrument is partly embedded in a hexagonal shaped bus containing all equipment. The attitude control system uses 4 fiber-optic gyroscopes and 3 star trackers to provide restitution accuracy compatible with the system location specification of 12m for 90% of the products. These attitude sensors are mechanically fixed on the telescope support to minimize the thermo-elastic distortions.
Agility is a characteristic which allows the satellite to acquire off-nadir targets rapidly in a large flight envelope, in order to sequence numerous images. This agility is imposed by several requirements stated by the users. For instance, a 100x100 km2 zone can be acquired by the satellite from the same orbit thanks to a lateral multi-band coverage. As for stereoscopic capacities, 3 images from the same zone can be acquired in a single pass with B/H lying between 0.1 and 0.5. For multi-targets, the time between the end of an imaging segment and the start of the

next segment, including stabilization of the line-of-sight is specified less than 10 seconds for an excursion of 10° and less than 26 seconds for an excursion of 60° from nadir viewing. Guidance is mainly performed using roll and/or pitch steering (without slow motion), but fine yaw steering has to be used to respect the principle of acquisition set by the TDI device in the focal plane.

## 2. IMAGE QUALITY COMMISSIONING

The assessment of the image quality and the calibration operation will be performed by CNES Image Quality team during the commissioning phase that will follow the satellite launch. These activities cover many topics gathered in two families : radiometric and geometric image quality. Radiometric activities concern the absolute calibration, the normalization coefficients computation, the refocusing operations, the MTF assessment, the estimation of signal to noise ratio and also the tuning of the ground processing parameters in order to fit the images to the users needs.

Geometric activities deal with the geometric model calibration, the assessment of localization accuracy, focal plane cartography, multi-spectral and multi-temporal overlapping, static and dynamic stability, planimetric and altimetric accuracy.

These operations require specific control of the payload and dedicated guidance of the satellite platform. The new capabilities offered by PLEIADES-HR agility allow to imagine new methods of image calibration and performances assessment [1].

Starting from an overview of the satellite and instrument characteristics, this paper present all the operations that will be conducted during the commissioning phase and focus on some of the methods based on a dedicated guidance.

The first unusual guidance concern the computation of normalization coefficients. Because of inter-detector sensitivity differences, the image of a uniform landscape is striped vertically. Detector normalization aims at correcting these relative sensitivities and delivering uniform images of uniform areas. Because high resolution optical satellites like PLEIADES-HR have to face a lack of signal, which may move the useful signal range towards the non-linear part of the detector response, normalization may have to be run with a non-linear model. This non-linear parameters identification requires observation of several uniform landscapes and may be actually very difficult to run, because of the uniformity constraint. In order to reduce the in-flight operations, the so-called AMETHIST method [2] has been developed. An efficient way to bypass the quest of uniformity is to use the satellite agility in order to align the ground projection of the scan-line on the ground velocity. This weird viewing principle allows all the detectors to view the same landscape. Thus, non-linear normalization coefficients can be computed by a histogram matching method.

The second original guidance can be used for several image quality purposes. The principle is to steer the satellite so that the projection of the scan-line on the ground remains constant along the image. The dedicated guidance is mainly based on pitch steering to reach the appropriate slow motion. Therefore, each elementary detector view the same point on the ground along the column-wise direction with a slight change in the viewing direction. The image can be used to compute the temporal evolution of each elementary detector response and in the end, to assess the contribution of the instrumental noise in the radiometric signal to noise ratio budget. The activity concerning the measure of the line of sight dynamic stability will also take advantage of these images. Each line of the image can be correlated to the mean line or to a reference image to assess high frequency attitude stability.

The cartography of the focal plane uses a dedicated reference site, called super-site, which is very accurately geo-referenced thanks to ground control points and fine DEM and covered by many high-resolution aerial images. When the satellite overpass the site, an image is acquired and then compared to the reference site projected in the focal plane geometry. This approach induces a cost-effective update of the aerial imagery. A new method, called geometric auto-calibration [4], will be applied to achieve this cartography without any reference site. The idea is to acquire a same site twice on the same orbit thanks to Pleiades-HR agility. The correlation of the two images re-sampled in the same geometry allows a separation between the focal plane geometry and the attitude instability.

Other guidance will be operated to image celestial bodies. These acquisitions can be scheduled during the night orbit without interfering with the commercial programming and with the absolute certainty of avoiding the clouds.

The first object concerns the Moon. The Earth satellite is a very stationary photometric benchmark that will be used to compute the temporal evolution of the absolute calibration coefficients.

Then the stars will also become object of interest [3]. The Point Spread Function (PSF) is the image of a punctual source of light as seen by the instrument. As stars can be considered to be such a source, the image of the stars can lead to the determination of the PSF. Because of noise and aliasing, it is necessary to process several images to obtain the real MTF of the instrument. A new method, based on frequency analysis, allows to obtain excellent results, regardless of stars magnitude, and without any external knowledge relative to the instrument. This method is extremely time saving during the commissioning phase, with regard to alternative methods based on ground observation.

The search for the best focus is a very time consuming activity during commissioning. Several scenes must be imaged at different focus levels in order to determine the best position of the focusing mechanism. By introducing this position as an unknown variable in the previous MTF determination equations, the proposed method allow to perform this operation with a very small number of star images, taken at three different focus.

The expected attitude disturbances for Pleiades-HR are characterized by very low amplitude (less than 0.25 PA pixel) and numerous frequencies in the range [40-1000] Hz. These instabilities have to be assessed during commissioning. The idea of our method is to use the stars as references. By definition, a star is stationary in an inertial frame. If the satellite sensor remains pointed at the star, it will create a bright column in the image whose straightness depends on the line-wise behavior of the potential micro-vibrations.

The implementation of these methods need a good investigation of stars characteristics : spectrum, magnitude, accessibility, etc… Thus, depending on the measurement we want to perform, a strict selection must be done to ensure a good signal without saturating the detectors.

All of these methods are in development and should be operational for the commissioning phase by the end of 2010.

## 3. REFERENCES


[1] L.Lebègue & al, “Using Exotic Guidance for PLEIADES-HR Image Quality Calibration,” ISPRS Beijing 2008.

[2] Ph.Kubik & al, “AMETHIST :A MEthod for Equalization Thanks to HISTograms”, SPIE Maspalomas 2004.

[3] S. Fourest & al, “Star-Based Calibration Techniques for PLEIADES-HR Satellites”, CALCON Logan 2009.

[4] JM. Delvit & al, “Geometric improvement for Earth observation applications”, IGARSS Honolulu 2010.