

FIRST ASSESSMENTS OF PLEIADES SYSTEM POTENTIAL FOR IGN-FRANCE IMAGE ACQUISITION REQUIREMENTS.

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ABSTRACT:

The Pleiades-HR system, of which the first platform of the constellation shall be ready for launch by early 2009, is the next generation of high resolution optical sensor satellites developed by CNES, the French space agency. With its ability to provide photogrammetrists with instantaneous colour image stereo-pairs of 20km swath and 70cm resolution acquired with B/H ratios ranging from 0.15 to 2, the very agile and precisely pointing Pleiades platforms should open in many countries a new era for the updating of high scale maps, by probably avoiding heavy aerial survey campaigns in many cases.

In the framework of a cooperation agreement between CNES and IGN-France, designed to prepare an operational use of these images, several experimentations and simulations are being carried out, in order to verify the ability of the system to fulfil the technical and operational requirements of the map-making processes, in comparison with those presently based on digital aerial photography. Among others, present studies particularly focus on :

- the geometric and radiometric quality assessment of the planned system products (sensor level, orthoimages and mosaics).
- the capacity assessment of the Pleiades-HR constellation to meet the IGN-F cartographic mission needs in terms of image volume for the coverage of the national territory, whether in monoscopic or stereoscopic mode.

After an overview of the main characteristics of the Pleiades-HR system, the paper aims at presenting the first results of these studies, which will be of great importance, together with the economic side, in the decision process of IGN-France to transfer, or not, part of the supplying of fresh images from the aerial source to the satellite source.

1. INTRODUCTION

One of the missions of IGN-France, the French Mapping Agency, is to ensure an orthophotographic coverage of the whole national territory, according to a recurring rate of less than 5 years. In order to optimize public funding and to better answer growing demands for up-to-date geographic data, IGN-F is actually assessing the technical potential and the economic conditions for a dedicated use of submetric resolution satellite data, such as Pleiades imagery.

In this respect, a comprehensive partnership with CNES, the French Space Agency, has been recently agreed to prepare the arrival of Pleiades images into IGN-F acquisition and production lines by 2009.

In this article, after an overview of the Pleiades system products, we present results of a study, assessing the acquisition capability of the satellites to cover the French territory under various geographical and temporal constraints including cloud cover, viewing angle conditions and renewal hypothesis.

2. THE PLEIADES SYSTEM : A QUICK OVERVIEW

2.1 A system well suited for mapping purposes

The Pleiades system, designed by CNES, is developed by the French space industry with a contribution of several European countries. The first satellite shall be ready for launch by early 2009, a second one following one year later. Placed on the same sun-synchronous orbit at 694 km, these 2 satellites will acquire image strips of 20 km swath width, combining acquisitions in panchromatic band at 70 cm resolution (when nadir pointing) and in 3 visible (blue, red, green) and IR bands at 280 cm resolution, further merged into colour products.

The very high agility of the satellite platform as a whole (see figure 1) make possible various acquisition plans, such as a monoscopic cover up to 100x100 km² or a stereoscopic instantaneous cover up to 60x60 km².

Over the french metropolitan territory, this agility make it possible, within a single pass of the satellite, to cover one or two administrative units (départements) of 5000 to 10000 km² each, or to cover several big cities in three-fold stereoscopic mode.

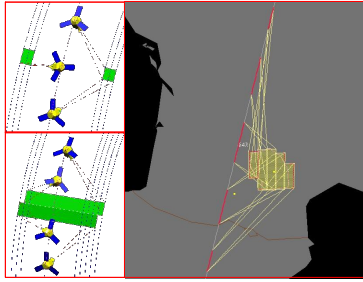


Figure 1 : Examples of Pleiades agility capabilities

Concerning the ground location accuracy of the images, the specification has been set to 12 m for 90% of the images without Ground Control Points (GCP).

2.2 Product levels delivered by the system

The ground segment is being sized to produce daily up to 200 products, whether it be single images 20x20km or big mosaics. All products provided by the system to the users will be processed automatically, whether from panchromatic band or by merging original bands into the desired colour composition (natural colour or false colours). Panchromatic and colour merged products will be delivered at 50cm ground sampling distance. The 3 product levels are the following :

- a “sensor” level , resulting from the correction of on-board systematic distortions and attitude variations of the platform ; this product is specially dedicated to photogrammetric use ;
- a “orthoimage” level, resulting from the correction of terrain distortions with a standard DEM and geocoding of a single image strip into a geographic reference system ;
- a “orthomosaic” level, resulting from a seamless assembling of individual strips and geocoding as mentioned hereabove.

Concerning the orthomosaic, the product specifications only concern a one-pass set of image strips, acquired under angle parameters to be defined when programming the satellite :

- An off-the-shelves DEM (Reference3D® or improved SRTM) shall correct image distortions due to the topographic surface elevations ;
- relative geometric distortions should be less than 1 pixel along the connecting line ;
- local and global radiometric discrepancies should be minimized, keeping in mind that viewing conditions may produce non rectifiable effects on building facades, if any located in the overlaps between image strips..

To achieve the best possible radiometric and geometric quality, the main methods designed by CNES are the following [deLussy, Gigord, Airault, ISPRS 2006] :

- refining by space triangulation the initial “sensor models”: therefore, an iterative matching process, helped by the local DSM data, shall select reliable homologous points inside the overlapping zones of each image pair ;
- refining local altimetric accuracy of the external DTM in overlaps ;
- determining radiometric look-up-tables grids in order to harmonize the radiometric rendering ;
- computing seam lines between the adjacent orthorectified strips

It should be noticed that several software or algorithms selected by CNES come out of aerial photo production lines operated and maintained by IGN-F on its own.

3. IGN-F EXPECTATIONS CONCERNING PLEIADES

The civilian mission assigned by CNES to Spot Image company, the pre-qualified image provider, is two-fold : meet the public sector requirements in France and Europe, under special rates covering merely operating charges, and the private sector needs in general, on a commercial rate basis.

At present and on a long-term contract basis with IGN-F, the French state widely grant-aid both the aerial digital acquisition and the 50 cm sampled colour orthophoto layer production (**BD Ortho®**), thus considering the systematic image coverage of the national territory at 50 cm resolution as a patrimonial and general service of interest. Therefore, the charged rate per km² for a data usage licence is actually much lower than the marketing rates of the present sub-metric satellite image standards.

In this context, the IGN-F choice to be or not one of the customers of Pleiades images by 2009 deadline widely depends both on the image price and on a continuous and secure supplying capacity from Spot Image, the pre-selected company in charge of image distribution. These questions are now being discussed in a joint team from CNES, Spot Image and IGN-F. Let’s now focus on some technical assets of Pleiades for IGN-F future missions.

3.1 Assessment of Pleiades potential for the IGN-F missions

While achieving by 2007 its national mission to equip the French territory with an exhaustive and homogenous digital cartographic reference (Réfèrentiel à Grande Echelle = **RGE®**) with its 1 m location accuracy in XYZ , IGN-F is presently reconfiguring part of its working teams and data collecting processes towards the updating of the various layers of the **RGE®** :

- renewal of the orthophotographic layer (**BD Ortho®**) every 5 years at least ;
- continuous updating of the topographic database (**BD Topo®**), with constraints to display all infrastructure and building features aged of more than a year.

In parallel, IGN-F is already thinking about how to answer emerging or insufficiently met needs from 2007 on, under economic constraints, such as a growing demand for always better renewed image covers or urban 3D models.

At present, the Pleiades high revisit potential is seen as a complementary source of the IGN-F aerial photo task force ; indeed, the satellite data could make it shorter in time the renewal of rapidly evolving areas (suburbs) or the surveillance of environmentally sensitive areas (coastal, flood plains,...).

In this respect, Pleiades acquisitions might contribute to :

- the achievement of a renewal of the BD Ortho® layer on a 3 year basis, with constraints related to the season (summer is preferable) and the trimming (administrative units)
- the “image monitoring” of specific areas (coasts, suburbs, flood plains) for early warning purposes
- the checking process of BD Topo® releases, as a comprehensive and external data source.

3.2 Some technical and operational issues

In relation with above, the first issue concerns the Pleiades acquisition capacity that can be devoted to IGN annual cover needs over the national territory (see first results in the next section), in conjunction with other recurring needs such as crop monitoring or land use updating, which actually do not fall into IGN-F missions. However, since steady renewing of covers may contribute to several applications, mutualization opportunities may be found somehow.

An other issue is linked to the intrinsic image quality, in terms of information radiometric content : what can be seen in colour images at 70 cm to 1 m resolution (30° off nadir) when the original colour information is acquired at four times lower resolution ? In this respect, the first simulations provided by CNES (50 cm re-sampled pan-sharpened XS images) show a quite compliance with the image quality of digital orthophoto presently acquired around 70 cm for the derived BD Ortho® product, even though IGN-F intends to inquire among a panel of present users of the BD Ortho® in order to confirm this point.

The intrinsic geometric coherence of images is also an acute issue. CNES has put an internal dispersion specification of maximum 1 pixel for a 80 km long strip. This figure is actually compliant with BD Topo® and BD Ortho® geometric specifications.

The absolute location accuracy (without control points), presently specified at 12m at 90%, could be improved after the commissioning phase and in the course of satellite life, according to first assessments.

The actual planned performance shall highly simplify the space triangulation process in terms of computing time, since less numerous GCP will be necessary.

Finally, the potential of two-fold and three-fold stereoscopic acquisitions is also to be investigated. First results with aerial simulations over Toulouse can be found in [Maillet 2006].

4. ASSESSMENT OF THE ACQUISITION CAPABILITY OF PLEIADES OVER FRANCE : FIRST RESULTS

4.1 The CNES simulation tool for Pleiades image programming

CNES develops and maintain an image programming simulation tool. Programming demands can be put on specific geographic sites over a defined period of time. These demands, either monoscopic or stereoscopic, are analyzed according to orbit availability, swath, platform tilting capability. After a classification into individual mesh, a programming plan is elaborated according to meteorological forecast, surface to be covered, angular constraints and acquisition priority. Several plans can be merged, for instance put by a customer in mapping, a customer in agriculture, etc. Downloading constraints are also taken into account in the programming loop.

For our study, we got full support from CNES for the implementation of this simulator.

4.2 Elaboration of scenarii for the RGE image providing

We only present here two scenarii over France, both taking into account IGN needs and also estimated annual demands for

other applications than topographic mapping. These other provisional demands were elaborated by Spot Image for Pleiades thematic needs and kindly provided for our study, which actually include mainly agricultural monitoring (multitemporal spots to be observed in spring-summer), coastal follow-up and response to natural hazard.

The first scenario aims at assessing the percentage of metropolitan territory covered within one year with 2 satellites according to specifications close to the ones of the present BD Ortho® acquisitions, but without the constraint to cover administrative units (“departements”) at once, for which the satellite orbit configuration is not as well appropriate as airborne dedicated flight plans can be. The territory, of approximately 540000 km², is divided into 216 mesh of 60x60 km, to be covered without clouds and according to 3 geometric conditions (see results in figures 2.a, 2.b, 2.c) :

2a. angles less than 30°

2b. angles less than 15°

2c. one pass 60x60km acquisition and angles less than 15°

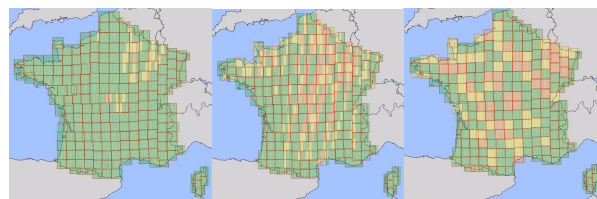


Figure 2.a
IGN=95% fulfillment
SpotImage=35%

Figure 2.b
IGN=68%
SpotImage=37%

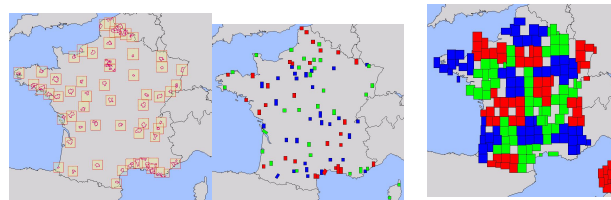
Figure 2.c
IGN=62%
SpotImage=41%

A second scenario covering a 3 years period has been set up, based on an hypothesis for IGN-F image comprehensive needs over the national territory by the years 2010 (see maps 3.a, 3.b, 3.c):

3a. The 60 cities of more than 100,000 inhabitants should be covered every year in monoscopic mode, as a one-pass shot 60x60km² area ;

3b. The 90 towns or urban districts of more than 50,000 inhabitants should be covered once every 3 years in stereoscopic mode, in order to help them update their own cartographic database ;

3c. The rest of the metropolitan territory should be covered within 3 years (30 towns per year)



Map 3.a : Cities >100,000 inhab.
Map 3b : Towns >50,000 inhab.
Map 3c : Rest of the territory

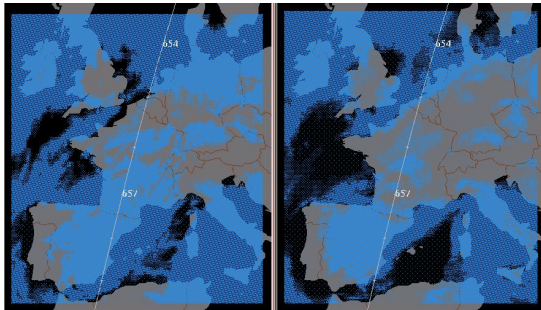
4.3 Results

In the first scenario, we only had at our disposal meteorological data elaborated on a statistical basis, i.e. data compiled from 10 years observations at a low resolution grid (1°). Let's call it climatic data.

In the second scenario, we got the opportunity to retrieve recently acquired and archived data by Météo-France for the year 2004, consisting of real nebulosity data observed with a

7x11 km² grid resolution, of which we could select forecast cloud cover maps 27 hours and 3 hours before the satellite pass around 10 a.m. local time (see an example of 2 cloud cover forecast maps over Western Europe in maps 4.a and 4.b). These two sets of data have been respectively used for the programming plan and the validation plan of the simulation process.

Due to time constraints, we only could play the second scenario with both meteorological data types (climatic and observed).

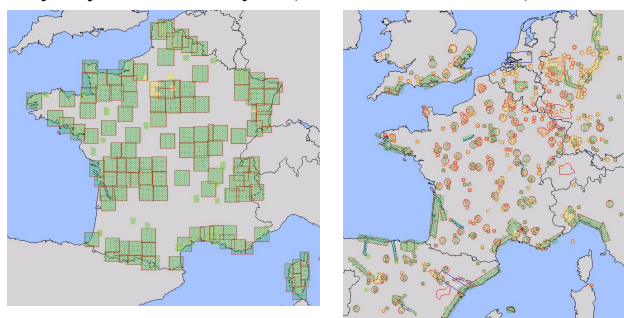


Map 4.a & 4.b : Forecast cloud cover data 27h and 3h before pass

In the first scenario (see results in maps 2.a, 2.b, 2.c), we can state that within one year, 95% of the French territory can be covered with 2 satellites and a 30° maximum angle, whereas approximately 2/3 of the territory with a 15° maximum angle, whether it be according to 20x60 km strips or 60x60 km single pass mosaics.

An other point is that the Spot Image demands are filled up to approximately 40%, whatever the IGN-F angular hypothesis.

In the second scenario (see results in maps 5.a and 5.b), the planned programme for the first year of IGN demands (from January to December) is achieved at 98% when putting climatic data as input, at 100% when putting real observed cloud cover. And this planned programme is even finished on early July of the current year (from Jan 1st to Dec 31st).



Map 5.a :
first year IGN demands (100% filled up)

Map 5.b :
first year Spot Image demands (83 % filled up)

4.4 Conclusions and perspectives

These results should be taken as a little optimistic, since the simulator tends to favour large covers (IGN-F demands) rather than the cover of smaller sites (agricultural monitoring). Furthermore, a one-shot success with 0% cloud cover is not realistic, a certain percentage of new acquisitions being necessary to fill up the hidden parts of the landscape.

Anyhow, Pleiades seems to be a good candidate for the fulfilment of part of the foreseen acquisition requirements of IGN-F at mid-term.

Further work should be done in cooperation with Spot Image, in particular to tune up cover scenarii according to specific seasons, in particular to test the stereoscopic potential assessment over large areas and to extend the investigation towards overseas territories.

Another objective of these studies is to evaluate the amount of IGN-F own demand within the national comprehensive demand, in order to propose a protocol for the sharing of the satellite resource over the country.