PLEIADES-HR IMAGE SYSTEM PRODUCTS AND QUALITY
PLEIADES-HR IMAGE SYSTEM PRODUCTS AND GEOMETRIC ACCURACY

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ABSTRACT:

Pleiades is a high-resolution optical Earth observation system developed by CNES, for civilian and militarian users. It is the French part of the French-Italian ORFEO program which also comprises COSMO-SkyMed, an Italian high-resolution radar system. The launch of the first Pleiades satellite is scheduled in 2008, the second, one year later. Their 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 and trying to match the actual needs. The Pleiades satellites are in realisation phase. The precise definition of the image ground processing is running. This paper presents the main technical characteristics of the satellite (agility, stability, localisation accuracy…) and its optical instrument. It gives an overview of the different system products: level 1 image, "Perfect Sensor" image, orthoimage and orthomosaic. We then focus on the "Perfect Sensor" image: a basic product specially designed for the photogrammetric community and delivered with two geometric models: the physical model and a rational function model. We finally highlight the high geometric accuracy of the rational function model in the case of the "Perfect Sensor" image".

1. INTRODUCTION

France decided to have a metric high resolution optical observation system developed by CNES (the French Space Agency) designed to follow on from the SPOT product line set up in 1986 with SPOT1 and continuing in 2002 with the launch of SPOT5. This system must constitute the optical component of the joint French-Italian Orfeo system in which Italy supplies the radar observation system. Some other countries have part in the optical component: Austria, Belgium, Spain and Sweden.

The mission of the Pleiades system is to meet an ambitious dual civilian/military order book in terms of number of images, supplying 20 km wide Earth images of a resolution equal to 0.70 m in panchromatic band and 2.80 m in colour for nadir viewing conditions. Coverage must be almost world-wide with a revisit interval of 24 h for 2 satellites. The Pleiades 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 Pleiades satellites will be compact (about 1 ton weight) and agile, meaning that the whole spacecraft body is tilted to achieve off-nadir viewing. 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:

- Lateral multiband coverage: a 100x100 km^2 zone can be acquired by the satellite from the same orbit.
- Stereoscopic capacity in a single pass: 3 images from the same zone must be acquired in a single pass with B/H lying between 0.1 and 0.5.

Aside from technology breakthrough, a key factor in achieving this goal is a proper dimensioning of the instrument. Taking into account image processing techniques from the beginning has allowed to define an instrument much smaller than would have been required if it had to obtain by itself the system performances.

The choice of the different parameters specific to the mission (specific spectral bands, field of view, resolution, B/H ratio) and the dimensioning of the parameters specific to image quality performances (MTF, signal-to-noise ratio) and some product characteristics were defined by means of consultation campaigns among future system users: this leaded to an optimized system design.

This article speaks about geometrical image quality, highlighted on Perfect Sensor Product. It describes first the main satellite and system characteristics useful for geometry, secondly instruments characteristics and finally system products. Only the system « Perfect Sensor » product processing, models and quality are detailed.

<u>Glossary</u>
DTM : digital ground model without human buildings and vegetation on the ground
DEM : digital elevation model
MTF: modulation transfer function
RFM : rational function model
RFC : rational function coefficients

2. GEOMETRICAL SIGHT OF PHR CHARACTERISTICS

2.1 PLATFORM

The orbit will be sun-synchronous, quasi-circular and phased. The mean altitude of the orbit is 694.9 km with a cycle of 26 days. This is the phased orbit performing 14 + 15/26 revolutions a day. This allows a revisit in 24h with 2 satellites. The nominal local time for passing through the descending node (excluding the equation of time) is 10h15.

The major constraints of weight and agility led to the development of a highly compact satellite, to minimize the moments of inertia. The instrument is partly embedded in a hexagonal shaped bus containing all equipment.
These high agility performances allow the acquisition of a large number of images per day, and give the ability to increase the swath by acquiring up to 6 strips in the same pass (fig. 1) and the capacity to perform twofold or even threefold stereoscopy in the same pass.
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.

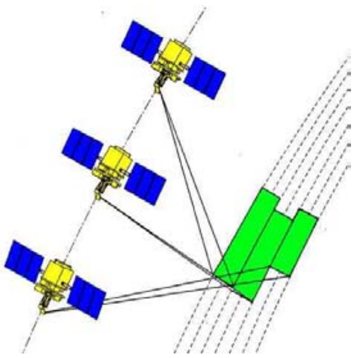

Figure 1: Agility capability and mosaic

The target access and the strip orientation asked by the user (generally North-South) is performed using roll and/or pitch steering. On top of that, fine steering (mainly yaw steering, without slow motion) has to be used, due to the use of a TDI device in the focal plane.
The range of satellite performance is limited to imagery acquisitions performed within a 30° off-nadir steering cone although the maximum steering angle is 47°.

Attitude control is performed by means of a cluster of 4 control moment gyroscopes which sequence the images far more quickly than with reaction wheels.
Users require a high level of system location accuracy preferably without ground control points. This location performance needs an extremely accurate determination of the imaging geometric model
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.
Orbit determination and time tagging are calculated onboard with metric accuracy by the Doris navigator, taking into account the attitude of the satellite.

Some geometric specifications aim at guaranteeing an efficient mission programming, they concern the ability of the system to optimally point a target on ground:

- Centring and along-track positioning: the current budget of the biases after in-flight commissioning is better than 150m for centring and 200m along the track with 24h orbit prediction.
- Stereo pair overlapping: the current budget limits the values of non-overlapping image parts to 0.5 % of the swath width for the probable instances (90% of images) and 0.8 % for the maximum with 24h orbit prediction.

2.2 The instrument

On the basis of the main image quality specifications, the instrument was designed in compliance with the weight and dimensional constraints compatible with a satellite weighing less than 1 metric ton. Its design is chiefly determined by the specifications for radiometric image quality in the panchromatic band which supplies the images with the sharpest resolution [5].

To start with, detection in the panchromatic band is performed using a CCD array working in Time Delay Integration mode (TDI) with 13µm square detectors. The TDI array has 6000 square detectors. The choice of TDI allows images to be performed without slow motion with a SNR that meets the specifications. The focal length of the instrument is f=12.90 m. The telescope is a Korsch type with a central obstruction of 30 %. The diameter, determined by the MTF specification and the optics realization budgets, is set at 65 cm.

The multispectral channels are detected by a four-colour CCD with 52 µm square detectors. The blue, green, red and near infrared filters are positioned in front of each of the 4 retinas of this CCD. The four-colour linear array has 4 lines of 1500 elementary detectors.

To acquire images over a field of view of 20 km, each line of sight is composed by aligning5 CCD components; this generates images of 30000 columns in the PA channel and 7500 columns in the XS bands. The XS and PA viewing planes are approximately 1.5 mrad apart, i.e. 2 cm in the focal plane of the telescope. Of the 5 CCD components of each retina, 2 operate by reflection and 3 by transmission around a beam-splitting mirror device which allows all the points in the field to be acquired almost simultaneously. The viewing directions of the detectors undergo the distortion of the instrument, which is approximately 2% at the edge of the field of view.

To decrease this distortion effect on MTF due to the radiometric sliding, the TDI arrays are not perfectly aligned: they are slightly tilted with respect to the central array (cf. fig. 2).

The onboard image system performs quantization over 12 bits, which is more than adequate considering the constant noise, and which serves to acquire all the useful scenes without requiring an adjustable imaging gain.

After quantization, the images are normalized on-board to correct detector response disparities. They are then compressed by a JPEG 2000 type multi-resolution algorithm which delivers between 1.7 and 3.3 bits per pixel. By consulting users, acceptable standard rates have been identified: 2 to 2.5 bits/pixel in PA, 2.5 to 3 bits/pixel in XS.

3. SYSTEM PRODUCTS

The system delivers 5 products in different levels:

- Colour Products (4-bands)
- PA product (B&W)
- Bundle (B&W and multispectral)
- PA-sharpened Products (4-bands)
- PA and PA-sharpened Products (5-bands)

The product format is under definition.
The Perfect Sensor Products are over-sampled with 7/5 ratio in order to guarantee that the RAW Image quality is preserved after resampling by users. The Orthoimage Products are also delivered with a unique 0.50m GSD. This choice doesn't change the actual resolution of PHR images (0.70 for nadir viewing).

3.1 RAW Product

This product is mainly for in-flight system commissioning and calibration.
This product cannot be Pan sharpened.
It is the result of image processing:

- Without geometric modification. So it is composed of 5 images for each band. For a Bundle product we will have 25 images. The arrays of the different bands are not registered.
- With radiometric ground correction. The radiometric corrections applied to this product (and higher level products) are inter-array radiometric correction and, depending on user choice, restoration of the panchromatic band.

With the different images of the RAW Product the PHR system give metadata which allow post processing. The geometric metadata are

- One set of ancillary data: ephemeris, filtered and sampled every 30s, satellite attitude quaternions sampled at 32Hz, ITRF polar position, time conversion, transformation between orbital, instrumental and restituted reference frames.
- One set of synthetic metadata (geoposition, steering angles, …)
- 25 sets of viewing directions (one for each detector) and time tagging bias

The accuracy of the post processed image will strongly depend on the correct use of this complex metadata.

3.2 Perfect Sensor product

The Perfect Sensor Imagery is the image which would have been got by a perfect pushbroom sensor in the same imaging conditions, so it is a virtual raw product.
It is designed for customers having photogrammetric capabilities and who want to exploit the geometric characteristics of the image (DEM or 3D extraction) without having to take into account the complex geometry of the real sensor.
This imagery is thus geometrically corrected from on-board distortions, but not mapped into any cartographic projection.

3.2.1 Perfect Sensor Geometry

PHR RAW Products will be very complex and not user-friendly, due in particular to the complexity of the detector layout in the focal plane: for instance, the panchromatic focal plane is composed of five slightly tilted arrays(cf. figure 2).
The figure below describes the focal plane layout and the approximate position of the Perfect Sensor virtual push-broom.

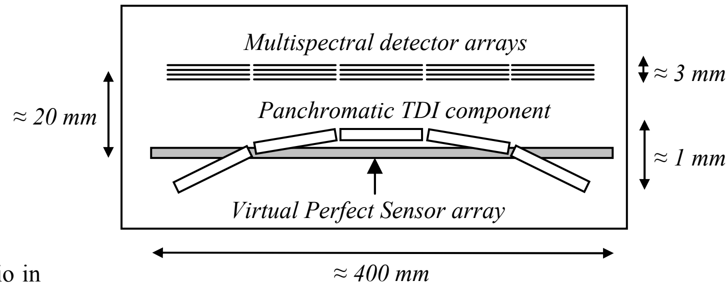

Figure 2: Focal plane layout and location of ideal array

In order to greatly simplify the use of sensor model, RAW Imagery and data are pre-processed into a standard format model which will be supported by most commercial imaging software applications.
The geometric reference frame for Perfect Sensor Imagery simulates the imaging geometry of a simple pushbroom linear array, located very close to the panchromatic TDI arrays. Besides, this ideal array is supposed to belong to a perfect instrument with no optical distortion and carried by a platform with no high attitude perturbations. This attitude jitter correction (made with a polynomial fitting) allows both for simple attitude modelling and more accurate representation of the imaging geometry by the rational functions sensor model described at §3.2.3.2.

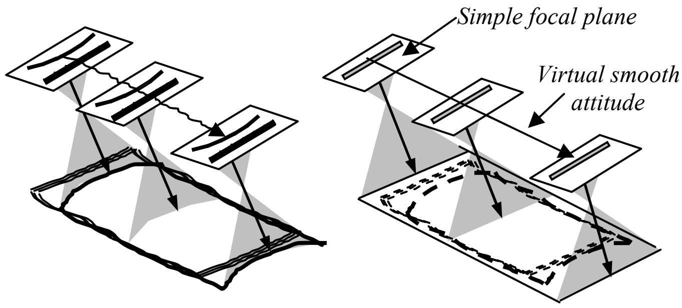

Figure 3: Perfect Sensor Geometry

The use of one single Perfect Model, common to all bands (panchromatic and multispectral) systematicly provides registered products: PA and multispectral Perfect Sensor Imagery are completely super imposable.
The Perfect Sensor Imagery resolution is related to the RAW imagery resolution which varies between 70 cm (at nadir) to 1m (30° off-nadir look angle) for panchromatic products, and 2.8 m (at nadir) to 4m (30° off-nadir look angle) for multispectral imagery

3.2.2 Processing

The production of this ideal linear array imagery is made from RAW Imagery and its rigorous sensor model.

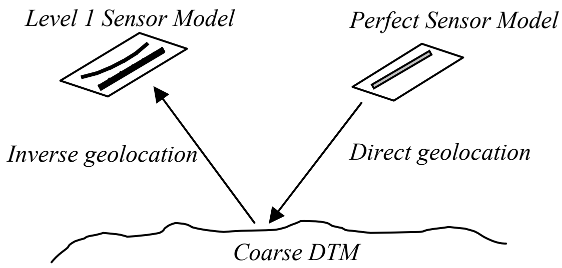

Figure 4: Resampling process

RAW Imagery is resampled into the Perfect Sensor geometry taking a coarse DTM into account. The direct geolocation is made with an accurate Perfect Sensor rigorous model.
Thus, Perfect Sensor Imagery and its Perfect Sensor Model are consistent.

The impacts of the above processing on the geometric accuracy of the resulting products have to be significantly small (errors less than centimetres). These errors are due to:

- Direct and inverse location function accuracy,
- The quality of the resampling process and
- The accuracy of the coarse DTM used (generally SRTM, and if not available, Globe.

To obtain optimized results:

- Location grid sampling is adequately chosen,
- Resampling process is made with a highly accurate method (using spline interpolators) which not shades off imagery, and
- the DTM is pre-processed in order to minimize the relief artefacts due to errors and/or blunders.
- And the geometric model differences (especially attitude and detector model) between Perfect sensor and RAW sensor are minimized to decrease the parallax and the altitude error effects.

So the Perfect Sensor Model is a compromise between its smoothness and its high similarity to RAW Sensor Model.

3.2.3 Quality of the Perfect Sensor Product:

The quality of a “Perfect Sensor” image is mainly the quality of the corresponding RAW Product, except for some budgets of distortion of the images, as sensor distortions are corrected.
The only remaining default is due to the little parallax between Perfect Sensor model and Real sensor (**less than 80µrad**) combined to a misknowledge of ground altitude. If needed (e.g. low quality of the reference DEM), this parallax could be minimized with a change of the viewing directions of the Perfect Sensor model from linear to parabolic (about 8 µrad max).

- Geolocation accuracy

The specification deals with the line of sight direction knowledge by using the geometrical model computed by the ground segment, after in-flight calibration. The current budget of the biases after in-flight commissioning is:
- 14 m probable (90% of the images) circular error
- 25 m maximum (99.7% of the images) circular error

It has to be noticed that the specification is on the reference ellipsoid, i.e. without taking into account the parallax errors (due to the quality of DTM used). This is comparable to the civilian GCP accuracy (15m 90%) and allows to avoid the use of GCP.

- Local Coherence

The local coherence specification deals with the regularity of the sampling of the pixels in both directions. The sampling regularity can be disturbed by static defaults (i.e. not temporally variable effects) as focal plane irregularities or dynamic defaults as medium and high frequency attitude perturbations. The current budget of distance irregularity between adjacent pixels is less than 0.1 pixels for 99.7 % pixels and 99.7% images.

- Multispectral registration

The nominal product of Pleiades-HR will be a colour image with panchromatic spatial resolution, obtained by fusion of the panchromatic band with the multispectral bands. The necessary condition to obtain a “good fusion” is to be able to register accurately the whole lot of bands. Pleiades instrument has no native multispectral registration, so the ground processing takes it into account. The registration budget for the Perfect Sensor product is1.5 pixels PA accuracy for 90% of the images and the user need for good fusion is 2 pixels PA.

- Length distortion

Length distortion performance is the accuracy of distance measures on images, using the geometric model. The ratio between the distance difference and the measured distance gives the length alteration. The budget is about 0.7 Pixel PA for d=1000pixel PA and less than 10^{-3} for d $\geq$ 1000 Pixel PA as probable value (90% of the images).

- Planimetry

This performance quantifies the remaining location errors after correction of the system physical geolocation model using perfect GCPs. This performance is the result of high frequency residual distortion in the images.
The Pleiades PHR current budget is less than 0.3 m probable (90% of images) and 0.5 m Max (99.7% of images).
The difference between Perfect Sensor images and real sensor images is less than 3.10^{-3} according to the SRTM 30m accuracy at 99.7%. For image above +-58° of latitude, GLOBE is used.
The project team will be free to modify the Perfect Sensor viewing directions to be closer to the real sensor in order to decrease the effect of SRTM artefacts and holes.

- Altimetry

Altimetric accuracy represents the stereoscopic restitution capacity of the system. It is based on the exploitation of stereoscopic pairs allowing altitude estimation (usually, B/H ratio > 0.6) with adjustment of the pair's geolocation using perfect GCPs. Pairs are then exploited into a DTM production process.
Altimetric accuracy results of combined location errors of each image of the stereoscopic pair. Thus, this performance is degraded by every non-linear error source for each image of the pair and is linked with planimetric accuracy.
The current budget is 0.7m maximum for 90% of images.

3.2.4 Perfect Sensor geometric Modelling

The geometric modelling refers to the relationship between raw pixels in the image (2D) and geographic coordinates (3D).
The Perfect Sensor product is delivered with a set of metadata files which provide parameters allowing to define two geometric sensor models: a rigorous sensor model and a rational function sensor model.
Users can reliably use either the rigorous sensor model, or the rational function sensor model supplied with Perfect Sensor products to process the imagery: results are very comparable.

3.2.4.1 Perfect Sensor Rigorous model

The rigorous sensor model of an image is used to reconstruct the physical imaging setting. This model is defined from a complete set of image acquisition metadata allowing advanced users to parameterize a rigorous sensor model. These parameters are:

- Alignment and focal plane layout information (ideal linear array, thus very simple)
- image timing (very simple too)
- Smooth attitude and ephemeris information spanning the imaging window

Combined with Earth and atmosphere models, these data define a rigorous model, relating geographic coordinates to image coordinates.
Such rigorous models are conventionally applied in photogrammetric processing because of the clear separation between various parameters representing different physical settings. They are also easy to use in bundle block adjustments. The format of this model will be supported by most commercial imaging software applications.

3.2.4.2 Perfect Sensor Rational functions model: RFM

The Rational Function model, RFM, is an approximation of the rigorous sensor model. It allows full three-dimensional sensor independent geolocation using a ratio of polynomials.
This model includes two kinds of functions:

- *An Upward RF which make an inverse geolocation*

$$c = \frac{P_1(X,Y,Z)}{P_2(X,Y,Z)}; \qquad l = \frac{P_3(X,Y,Z)}{P_4(X,Y,Z)}$$

- *A downward RF which make a direct geolocation*

$$X = \frac{P_5(c,l,Z)}{P_6(c,l,Z)}; \qquad Y = \frac{P_7(c,l,Z)}{P_8(c,l,Z)}$$

- (c,l) represent the images coordinates
- (X,Y,Z) the ground coordinates (WGS).

and $P_i(x,y,z)$ have the general form:

$$P_i(x,y,z) = a_0 + a_1x + a_2y + a_3z + a_4x^2 + a_5xy + a_6xz + \ldots + a_{18}yz^2 + a_{19}z^3$$

The maximum power of each term is typically limited to 3. In such case, each polynomial P_i is of 20-term cubic form.
These functions are easy to use and have the benefit of low computational complexity and wide support in existing software.
They allow a very simple relationship between raw pixels in an image (2D) and geographic coordinates (3D).
Besides, we will see that they also provide very high accuracy with respect to the rigorous model.
The RF model is generated by using the rigorous sensor model.

In detail, RFMs are performed as following (Tao and Hu, 2001):

- Determination of an evenly distributed image grid covering the full extent of the image
- Establishment of its corresponding 3D Object grid in Ground Space. The horizontal coordinates (X, Y) are calculated at a specified elevation Z, from a point (c,l) of the image grid, using the rigorous physical Perfect Sensor model. Thus, a 3-D object grid with 4 layers slicing the entire elevation range is generated .
- The unknown RFCs are then calculated by fitting RF model using the corresponding image and object grid points. This is made using an iterative least-squares process with a Tikhonov regularization.
- Finally, accuracy of RFM is checked with a high density check grid by calculating the difference between the coordinates of the original grid points and those calculated from the RFM. The measured accuracy of RFM model is given on metadata products.

The above method is made without knowledge of detailed terrain information: only information of total range elevation is needed. It is thus a solution that is terrain-independent.

3.2.4.3 Accuracy of the RFM for Perfect Sensor products

RFM determined by this way is able to achieve a very high accuracy with respect to the original physical sensor model. Accuracy assessment shows that RFMs yield a worst-case error below **0.02 pixel** compared with its rigorous sensor model under all possible acquisition conditions.
For very few images, in particular for very long East-West acquisitions (duration greater than 10s corresponding to a total length near to 70 km), accuracy of a single RFM applicable in the full extent image could reach **1** pixel. In order to reduce this value and increase RFM accuracy, product is delivered in these cases, with several RFM (4 maximum), each applicable in a reduced area and allowing a highly accurate modelling (0.02 pixel accuracy).
This fragmentation process is automatically applied, when necessary, in order to always provide users with RFM (one single global model or several partial models) with a guaranteed accuracy below 0.02 pixel.
Therefore, when the RFM is used for imagery exploitation, the achievable accuracy is virtually equivalent to the accuracy of the original physical sensor model: the 0.02 pixel (1.4 cm) difference between the two models is an order of magnitude smaller than the planimetric accuracy and is therefore a negligible error.
Besides, it should be noted that the accuracy of the RFM fully benefits from the pre-processing applied to generate the Perfect Sensor product by removing high frequency distortions, thus allowing rational functions to precisely represent this smooth geometric model.
This characteristic of the RFM is very attractive because users will able to make use of the images without knowing the physical sensor model: RFM can be used as a replacement sensor model for photogrammetric processing.

3.3 Orthoimage product

The reference product requested by many users is a submetric colour image that can be superimposed on a map, with the projection chosen by them. We call such a product an ortho-image as each of its points is, in fact, projected vertically onto the Earth's surface. It's not a true ortho-image as buildings and vegetation will not be rectified by the geometric corrections, which will be visible in case of oblique viewing. This choice of ortho-rectification was defined by means of consultation campaigns among future system users with simulated images.

The orthoimage is a true or false colour product with a 0.70m resolution in nadir steering: the images acquired in the different spectral bands must therefore be superimposed geometrically with a quality compatible with user needs.

This product must be very precisely located to be able to enter a geographic information system (GIS) using miscellaneous georeferenced data (images from different sensors, vector data) with little registration error. So the location of this product will be checked on an accurate DTM (Reference3D® TM, if available) with automatic GCPs, by an automatic process of multi-resolution image matching.

Reference3D® database has been designed to take advantage of high accuracy of SPOT5 stereoscopic images. It consists in three information layers: Digital Terrain Model (30 m resolution, uniform grid of terrain elevation values of the area of interest), Orthoimage (5 m resolution, orthorectified images from the D.T.M. with a high location accuracy) and Quality Masks ; with a specification of circular planimetric accuracy better than 16 m for 90 % of the points and elevation accuracy better than 10 m for 90% of the points [1].

If there isn't Reference3D® information overlapping the product, we shall use the best DTM SRTM or GLOBE. Furthermore users can also give their own DTM for this orthorectification.

The geometric accuracy of the orthoimage product depends strongly of the DTM quality and of the steering angles. So the product will contain the quality masks of the DTM used.

3.4 Orthomosaic product

The orthomosaic product aims at providing end-users with an image of larger size, as being the result of a seamless patchwork of individual strips. This is made possible thanks to the high agility and the precise pointing capability of the platform, which can tilt rapidly off-nadir to acquire several successive adjacent strips within a unique pass of the satellite over the targeted area. The output coverage may reach up to 10000 km² and even more, according to the length of the neighbouring strips and the tolerated B/H ratio between them (figure 6).
The automatic production process faces geometric, radiometric and topological* issues. The know-how of the French mapping survey (IGN-F), being the producer of the BD Ortho® †, is precious in this respect. For the time being, the defined product specifications only concern a one-pass set of images, acquired under restricted angle conditions still to be confirmed:

- An off-the-shelf DTM (but no DEM) should correct image distortions due to the topographic surface
- Relative geometric distortions should be less than 1 pixel along the connecting lines
- Local and global radiometric discrepancies should be minimized, keeping in mind that lightening conditions may produce non correctable effects on building façades

The future production line will consist in the main following steps:

a) Refining by space triangulation the a priori location of individual strips :
An iterative matching process, helped by the local DTM data, will first select reliable homologous points inside the overlapping zones of each image pair.
The initial Perfect Sensor models will then be refined together by bundle block adjustment.

b) Refining the altimetric accuracy of the external DTM (option) :
A specific dense matching process will produce a DEM in the image overlaps. This raw data shall be first filtered, so as to remove elevations and keep reliable ground altitudes, according to a criterion still to be benchmarked. The resulting grid shall then be smoothed and merged with the external DTM.

c) Defining suitable radiometric look-up-table grids :
Once geometric conditions have been adjusted and validated (planimetric and altimetric residuals), overlapping zones may be orthorectified and their histograms analyzed in order to harmonize the radiometric rendering. An overall histogram matching process will be benchmarked under various landscape conditions.

d) Computing seamlines between the adjacent orthorectified strips :
An automatic algorithm, commonly operated by IGN, will be integrated: based on dynamic programming and local cost criterion minimization, the result is most of the time satisfactory.

Finally, quality checking operations are mandatory, particularly along the seamlines. Due to the tremendous amount of pixels involved and, as a consequence, the required time to be spent on display screen, a performance criterion shall be defined and benchmarked, in order to guide the operator's work.
Once the quality is agreed, global resampling of all images will be activated.

4. CONCLUSION

The range of PHR products is especially promising according to the satellite high agility, its accurate geolocation, the ground resolution, the care brought to process the products with high accuracy and the different types of products, well suited to user needs.
The high radiometric and geometric performances needed on a satellite weighing less than 1 metric ton led to a complex design of the instrument, hence to a high complexity of the RAW sensor model. Therefore, the PHR Perfect Sensor model was designed to compensate for this complexity and ensure these high performances.
The PHR Perfect Sensor will be a very good photogrammetric basic product, both user-friendly and accurate, with its simple rigorous model and RFM. In the case of this Perfect Sensor product, the RFM will meet centimetre accuracy (wrt the rigorous sensor model), thus allowing stringent photogrammetric use.
On the other side, the automatic orthomosaic product will be very interesting for end users. It is another PHR ambitious innovation.

5. AKNOWLEDGEMENTS

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* In case of non simultaneous acquisitions

† Aerial image coverage of France, trimmed into administrative « départements »