



Pléiades Imagery User Guide

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ACKNOWLEDGMENTS



CENTRE NATIONAL D'ÉTUDES SPATIALES

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After more than 30 years of close cooperation (initiated by the creation of the Spot Image entity in 1982), we are as proud as excited to open a new page within our experience of satellite operator and global data provider, pursuing our teaming with them.

ORGANIZATION OF THE PLÉIADES IMAGERY USER GUIDE

The Pléiades Imagery User Guide provides essential information to the users about all Pléiades products and services.

The document is divided into four main parts, followed by technical appendices.

Chapter 1 details the Pléiades satellite system and its performances.

Chapter 2 explains the different Pléiades products.

Chapter 3 details product ordering.

Chapter 4 presents product delivery.

For the experienced users, several **Technical Appendices** complete the document by covering the following points:

- A. DIMAP V2 format
- B. Image quality performance
- C. Geometric modeling
- D. Spectral modeling



This document is meant to be as useful as possible. If you feel that information is missing or unclear, or for any feedback you may have on the content and format, please send an email to: customertechnicalsupport@spotimage.fr.

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1. PLÉIADES CONSTELLATION

With four new satellites - Pléiades 1A & 1B and SPOT 6 & 7 – launched or set to launch over the next two years, Astrium GEO-Information Services is gearing up to bring its customers the very best that space technology has to offer.

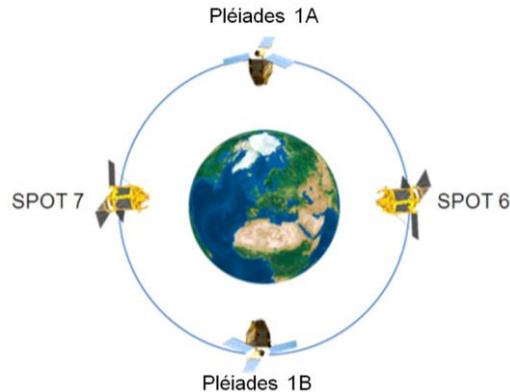


FIGURE 1: PLÉIADES 1A/1B & SPOT 6/7 CONSTELLATION

Ensuring continuity of Earth optical imaging service up to 2023, these satellites will operate as a true constellation, combining a twice-daily revisit capability with an ingenious range of resolutions.

The Pléiades twins are very high-resolution satellites delivering 50-cm Ortho products as a standard. SPOT 6 and 7 are designed to extend SPOT 5's success to the 1.5 m product family. Phased on the same orbit, the constellation will enjoy unprecedented reactivity, with same-day revisit capacity anywhere on the Earth. Multiple tasking plans per day result in an unrivalled optimization of data collection: unforeseen weather changes, as well as last-minute requests, can be taken into account for a first-class level of service.

The Pléiades 1A spacecraft was launched on December 16, 2011 on a Soyuz ST from Europe's spaceport in Kourou, French Guiana. It will be followed by Pléiades 1B in late 2012.



FIGURE 2: ARTIST VIEW OF THE PLÉIADES SATELLITE

Offering an ideal combination of coverage, resolution and speed, Pléiades products are especially useful for applications in defense, civil protection, hazard management, urban mapping, precision agriculture, and network and infrastructure management. Table 1 outlines the main Pléiades characteristics.

1 - Pléiades constellation

Number of Satellites	2 -- Pléiades 1A and Pléiades 1B
Launch	Pléiades 1A: 16 th December 2012; <i>Pléiades 1B: Q4 2012</i>
Altitude	694km
Type	Sun-synchronous, 10:30 AM descending node
Period	98.79 minutes
Inclination	98.2°
Cycle	26 days
Optical System	The telescope is a Korsch type combination with 65cm aperture diameter, focal length of 12.905m, f/20, TMA optics
Spectral Bands	Pan: 0.47-0.83 μm ; Blue = 0.43-0.55 μm , Green = 0.50-0.62 μm , Red = 0.59-0.71 μm , Near Infrared = 0.74-0.94 μm (NIR)
Detectors	Panchromatic array assembly: 5 x 6000 (30,000 cross-track) pixels Multispectral array assembly: 5 x 1500 (7500 in cross-track) pixels Each pixel having a size of 13 μm in Panchromatic
Ground Sampling Distance (nadir)	Panchromatic: 0.7m; Multispectral: 2.8m
Product Resolution	Panchromatic: 0.5m; Multispectral: 2.0m
Swath Width	20km at nadir
Dynamic Range at Acquisition	12 bits per pixel
NIIRS Class	6
Viewing Angle	Standard: +/- 30°; Maximum: +/- 47°
Revisit Frequency, using Both Pléiades 1A & 1B	<ul style="list-style-type: none"> with +/- 30° viewing angle, 1.3 days and better above 40° latitude, 1.7 days at equator; with +/- 45° viewing angle, daily revisit of any point on the globe
Pointing Agility	Roll of 60° within 25 seconds; Pitch of 60° within 25 seconds; 200km in 11 seconds including stabilization time
Acquisition Capability	450 segments/day (up to 600) – relying on the two main receiving stations, Toulouse (France) and Kiruna
Location Accuracy at Nadir	Performance (Oct. 2012): 8.5m CE90 with refined attitude data
Onboard Storage	600 GB (Solid State Mass Memory)
Instrument TM Link Rate	The output rate is nominally of 465 MB/sec, on three individual channels of 155 MB/sec each
Mission Lifetime	Minimum of 5 years with an estimated life of more than 10 years ¹

TABLE 1: MAIN CHARACTERISTICS OF THE PLÉIADES SYSTEM

1. SPOT 4 was launched in 1998 with a design life of 7 years, and SPOT 5 in 2002 with a design life of 5 years. Both are still in operation.

1.1 Flexibility, Agility and Availability

“The right information at the right time”

Pléiades is composed of two twin satellites operating as a true constellation on the same orbit and phased 180° from each other. Added to their oblique viewing capability (up to 45° angle) and exceptional agility, this orbit phasing allows the satellites to revisit any point on the globe daily - ideal for anticipating risks, managing crises effectively or speed up large areas coverage.

The phased orbit of the constellation’s satellites offers:

- 1-day revisit above 40° latitude within a +/- 30° angle corridor
- 2-day revisit between equator and 40° latitude
- 1-day revisit with two satellites and an increased angle (45°)

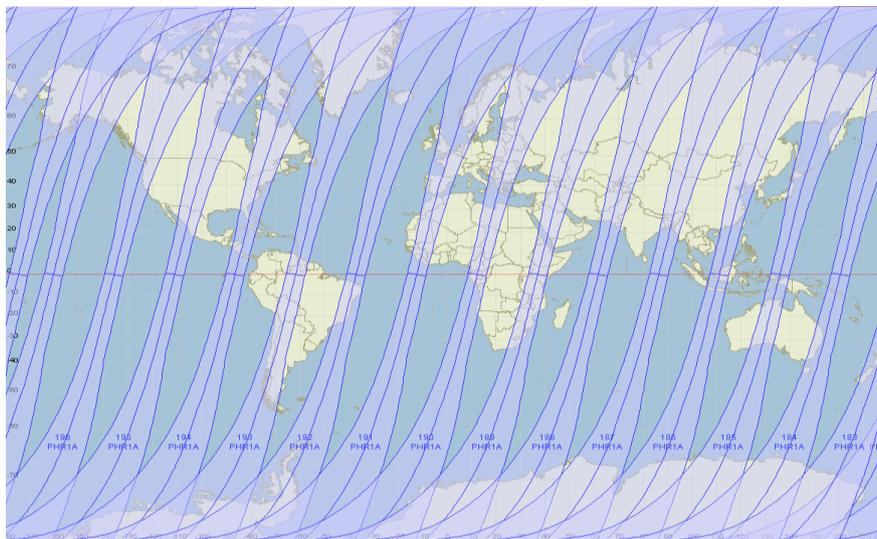


FIGURE 3: PLÉIADES 1A CORRIDOR OF VISIBILITY ON A GIVEN DAY (+/- 30°)

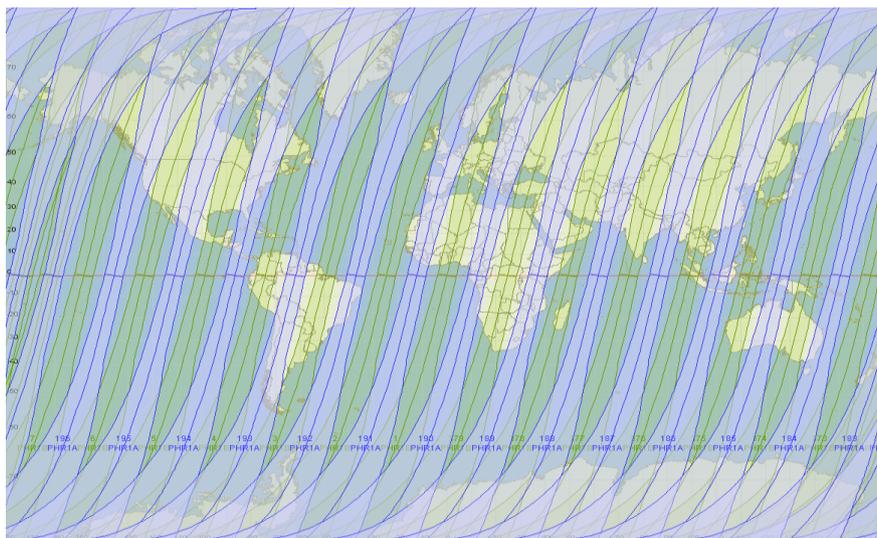


FIGURE 4: PLÉIADES 1A & 1B COMBINED CORRIDOR OF VISIBILITY FOR THE SAME DAY (+/- 30°)

1 - Pléiades constellation

The daily revisit capacity is backed by a reactive operational loop: work plans are updated every 8 hours (Figure 5). Three Pléiades uplink stations have been chosen according to the three tasking periods to meet worldwide customers' timeline requirements as efficiently as possible.

They will be located in:

- The Kerguelen Islands for morning passes, the best time to upload tasking commands for Europe, Africa and the Middle East
- In Sweden for midday orbits and coverage of North and South America
- In Toulouse for evening passes over Asia and Oceania

These multiple work plans per day enable easy handling of last-minute tasking requests as well as integration of the latest weather information, for an improved data collection success rate.



FIGURE 5: TASKING PLANS

The Pléiades satellites provide exactly the same coherent and high quality products. Tasking plans are natively optimized between the two satellites to fully leverage the synergies between the twins. For the user, this results in:

- More image collection opportunities
- Unprecedented capacity for disaster response, regular monitoring, or change detection
- Improved map update capacity (coverage)

Equipped with Control Moment Gyros (CMGs²), the Pléiades satellites benefit from exceptional performance in terms of agility (Roll pitch: 5° in 6.5 sec., 10° in 10 sec., 60° in 25 sec.). Time to slew over 200 kilometers is reduced to 11 seconds including stabilization time (satellites not equipped with CMGs do the same thing in approximately 20 seconds). That kind of performance results in a reduced average acquisition window for the users, allowing more images to be collected during the same pass: collection opportunities are more numerous, conflicts between contiguous requests are minimized, and the acquisition on the same pass of several targets at the same latitude becomes possible.

2. See "Abbreviations, Acronyms and Terms".

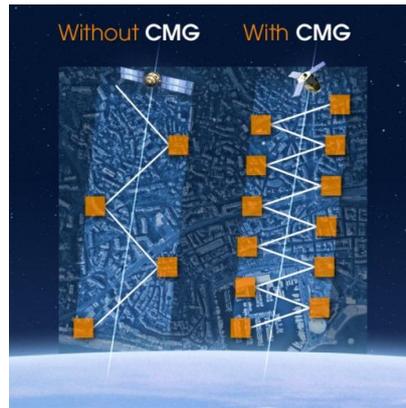


FIGURE 6: BENEFITS OF CMGs

1.2 Acquisition Capacity

Pléiades has an impressive acquisition capacity.

- The maximum theoretical acquisition capacity reaches 1 million square kilometers per day and per satellite (2 million for both).
- The useful acquisition capacity fully leverages the constellation's capacity. It takes into account the cloud cover optimization and the time needed to slew from one tasking request to another. It reaches 450, and in the best cases, up to 600 segments per day and per satellite.

1.2.1 Swath and Coverage

Pléiades coverage capacity is also due in part to its swath (20 km), the largest in this class of resolution, providing a larger native image footprint (from 30% to 73% better coverage compared to its peers in a single image).

This results in maximized information on a target and its surroundings, optimized production with diminished need for cutlines and mosaicking work over large areas, as well as easier data handling, with fewer folders and products to manipulate for a given large AOI.

1.2.2 Single Pass Collection Scenarios – Overview

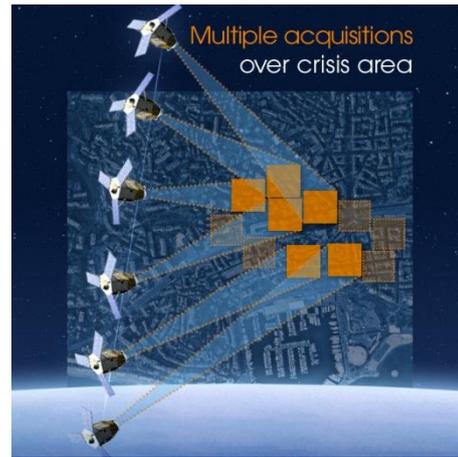
Image acquisition is tailored closely to match any user's needs, whatever the scenario:

- Target Collection: image multiple targets (① and ②): typically 20 targets within a 1,000 x 1,000 km area, in a corridor of +/-30 degrees, or 10 images over a crisis theater of 100 x 200 km
- Strip Mapping: large mosaics in a single pass (③): up to 100 x 150 km in the same pass
- Stereo and Tristereero Acquisition (④): for accurate 3D applications
- Corridor Acquisition (⑤): to follow linear features such as coastlines, borders, pipelines, rivers, roads, etc.
- Persistent Surveillance Mode (⑥): up to 25 images acquired over the same area to calculate the speed and direction of a moving target

1 - Pléiades constellation



① Multiple collections during the same pass, typically 20 targets within a country of 1,000 x 1,000 km



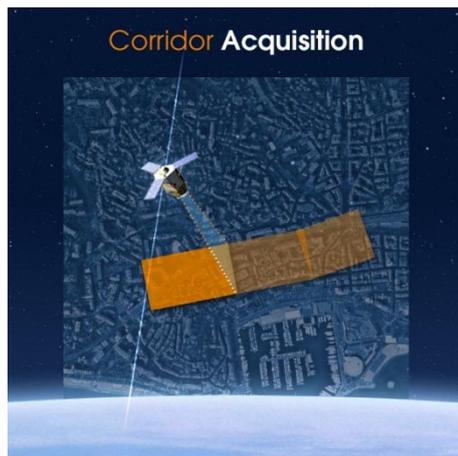
② CMGs allow maximizing numbers of acquisitions over a given area, typically 10 images over an area of 100 x 200 km



③ Strip Mapping over large areas, typically up to 5 contiguous strips of 150 km each



④ Stereo and Tristereo acquisitions for 3D applications



⑤ Corridor Acquisition over linear targets (borders, roads, railways, pipelines...)



⑥ Persistent Surveillance Mode, for moving targets and/or improved photointerpretation

FIGURE 7: SINGLE PASS COLLECTION SCENARIOS

1.2.3 Mosaics Acquired in a Single Pass

With its great agility, the system offers the possibility to artificially increase the instantaneous field of view. A mosaic image is built from several contiguous data strips acquired in the same orbit. Table 2 summarizes this capability vs. the authorized viewing angle. The Pléiades ground segment can then automatically compute the mosaicking and rectification.

Swath Cover	Maximum Length
Viewing Angle +/- 20°	
60km (3 strips)	185km
80km (4 strips)	110km
100km (5 strips)	70km
Viewing Angle +/- 30°	
60km (3 strips)	300km
80km (4 strips)	205km
100km (5 strips)	150km
120km (6 strips)	110km

TABLE 2: STRIP MAPPING COVERAGE

Moreover, it is possible to stitch together mosaics from data strips acquired during different orbits. In this case, the processing is done on a manual basis.

1.2.4 Stereoscopic Cover Capabilities

A great feature of Pléiades is to offer a high resolution stereoscopic cover capability. The stereoscopic cover is achieved within the same pass of the area, which enables a homogeneous product to be created quickly. As shown in Table 3, the system offers the possibility to achieve a “classical” stereoscopic imaging, composed of two images for which the angular difference (B/H) can be adjusted, but also stereoscopic imaging with an additional quasi vertical image (tristereoscopy), thus allowing the user to have an image and its stereoscopic environment.

Stereo		Tristereoscopy	
B/H	Length	B/H	Length
0.15	20km	0.3	20km
0.2	60km	0.4	60km
0.3	120km	0.5	90km
0.4	175km	0.6	120km
0.5	225km	0.7	145km
0.6	280km	0.8	175km

TABLE 3: PLÉIADES STEREO / TRISTEREO B/H

1 - Pléiades constellation

Tristereoscopic images can be used to create more accurate 3D models than can be done with basic Stereo, as the near nadir acquisition minimizes the risk of missing hidden items. This is ideal for dense urban and mountainous areas - Figure 8. Please refer to 3.2.2 (step 5) for more information about B/H.

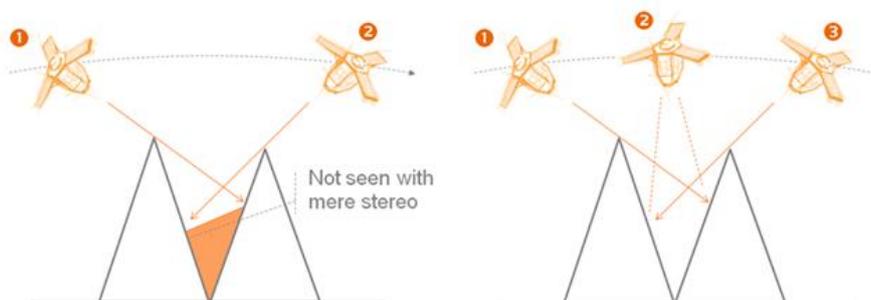


FIGURE 8: STEREOSCOPIC COVER CAPABILITIES OVER MOUNTAINOUS AREAS

1.2.5 Persistent Surveillance Mode

The Pléiades system offers the capability of persistent surveillance. This mode offers up to:

- 17 images of 20 x 20 km
- 25 images of 7 x 20 km

It is meant to:

- Assess trajectories, speed, and direction of moving targets
- Detect, characterize and identify small moving elements that would be undetectable elsewhere with a single shot at a similar resolution (e.g. people)

1.3 Pléiades Image Quality and Interpretability

1.3.1 GSD and Product Resolution

The first parameter that guarantees Pléiades' excellent image quality is the 50-cm post-processing resampling algorithm. This process, developed and implemented by the French Space Agency, CNES, is carried out through the following steps:

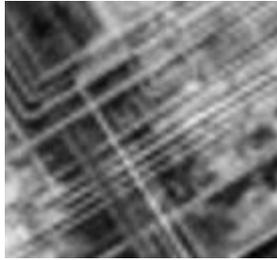
- Deconvolution, to enhance image sharpness
- De-noising
- Zooming factor on on-board resolution ($\sqrt{2}$ on primary level products)

The benefits gained by this processing are:

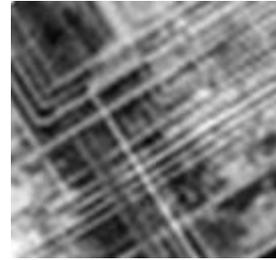
- Anti-aliasing
- Exhaustive preservation of the acquired information

- Robustness of the product, especially in the case of post processing, such as image rotation, reprojection, etc.

The figure below represents a Pléiades image without resampling, compared to the same image with 50 cm resampling.



1. Pléiades non resampled
Product (70 cm)



2. Pléiades resampled
product (50 cm)

FIGURE 9: VISUAL RENDERING OF PLÉIADES RESAMPLING

The benefits of the 50 cm zooming are significant and have been confirmed through experimental testing, notably by Defense photo-interpreters:

- The second image reflects better quality in terms of information content
- Further downstream processing applied by users on 50 cm images do not affect the image quality (robustness) and are not impacted by the type of interpolation used

Please refer to Appendix B for the detailed technical information about this process.

1.3.2 NIIRS Classes and Detection Capacity

The National Imagery Interpretability Rating Scale (NIIRS) is a scale used for rating the quality of imagery acquired from various types of imaging systems. The NIIRS defines different levels of image quality/interpretability based on the types of tasks an analyst can perform with images of a given NIIRS rating. The NIIRS consists of 10 levels, from 0 (worst quality) to 9 (best quality).

Please refer to the Federation of American Scientists website, for further detail about the NIIRS classification, <http://www.fas.org/irp/imint/niirs.htm>.

Pléiades, as well as GeoEye-1, WorldView-1, WorldView-2 and QuickBird, belongs to class 6 (0.40 - 0.75 m Ground Resolution Distance), which means that an analyst can perform equivalent tasks with all these sensors, as the same objects can be detected, recognized and identified. The sharpness and acuity of GeoEye-1 images, being the sensor featuring the closest GSD to the lower threshold, makes photointerpretation a little easier. However, Pléiades' resolution, as well as GeoEye-1, WorldView-1 & -2, and QuickBird resolutions, allows information to be visualized that cannot be retrieved from Ikonos, which belongs to a lower class.

Astrium has led a detailed study, including a side-by-side imagery comparison, to confirm these assessments over various sites:

1 - Pléiades constellation

Toulon, Panchromatic data

- *Pléiades 1A, Product id= DS_PHR1A_201202191041343_FR1_PX_E005N43_1105_00548, Acquisition date 2012-02-19*
- *GeoEye-1, Product id= 2009090910361081603031600149, Acquisition date 2009-09-09*
- *WorldView-2, Product id= 1030055000DF8B700, Acquisition date 2011-05-04*
- *Ikonos-2, Product id= 2010121010342140000011619315, Acquisition date 2010-12-10*

Melbourne, Bundle (Panchromatic + Multispectral)

- *Pléiades 1A, Product id= DS_PHR1A_201202250025536_FR1_PX_E144S38_1205_01120, Acquisition date 2012-02-25*
- *GeoEye-1, Product id= 2011062600280341603031608958, Acquisition date 2011-06-26*

Madrid, Pan-sharpened data

- *Pléiades 1A, Product id= DS_PHR1A_201201201112583_SE1_PX_W004N40_0512_01956, Acquisition date 2012-01-20*
- *Quickbird-2, Product id= 1010010004AAA800, Acquisition date 2005-11-23*
- *Ikonos-2, Product id= 2010111111182240000011627951, Acquisition date 2010-11-11*

The comparison has been done opening all images with ENVI and ERDAS software, without carrying any manual dynamic stretching. All adaptations are those proposed in automatic mode.

Unfortunately, the licensing of DigitalGlobe and GeoEye images does not allow Astrium to distribute this study. However, we are happy to provide free Pléiades samples to enable users to carry out their own comparison, just email to contact@astrium-geo.com.

1.3.3 Bit Depth at Acquisition

Pléiades' pixel depth at acquisition is 12 bits. For each spectral band, it means that each pixel can take one value out of 4096. Other Very High Resolution sensors have a pixel depth at acquisition of 11 bits, meaning that each pixel can take one value out of 2048, thus displaying less capacity when distinguishing subtle nuances, especially in the beginning or the end of the spectrum:

- It is more likely with Pléiades to detect objects in the darkness of the shadow of a building or a mountain, as more nuances can be taken by each pixel
- Similarly, it will be easier to detect pale-colored elements in very light / bright environments (sand, ice, nearly-white ground), according to the same principle, as more saturation problems are avoided

See

Figure 10. The 12-bit pixel depth of Pléiades makes the images easier to work with, as playing with extreme values does not degrade the rest of the image.

This characteristic also widens the range of "good images". Even during winter, humid weather, or with cloud shadows, Pléiades images are more likely to provide meaningful information.



© ISIS - Professional photointerpretation report with an 11-bit image



Pléiades image over the same area, dated March, 28th 2012: vessel is seen inside the reactor building © CNES – Distribution Astrium Services / Spot Image

FIGURE 10: VISUAL RENDERING OF 11-BIT VS. 12-BIT IMAGES

1.3.4 SNR, MTF and Other Parameters

SNR and MTF are key parameters for image quality. The MTF (Modulation Transfer Function) allows measuring the sharpness of the image. The SNR (Signal to Noise Ratio) is the ratio between the information present in the image and its noise. To measure how “good” an image is (i.e. sharp (=MTF) with little noise (=SNR)), the CNES has defined a “merit value” - a performance measured multiplying SNR and MTF.

SNR ratios, as measured during the in-flight commissioning phase, exceed the ground specifications: around 150 for each channel, and even 190 for B3 (NIR). The same goes for MTF for both line-wise and column-wise: on-board in-flight MTF was assessed as 0.15, without post-processing, for Panchromatic (specification was 0.08, and around 0.30 for Multispectral channels (specification was 0.20). The images do not need significant deconvolution in order to reach the final system MTF.

Therefore, the so-called “merit value” defined by the CNES from the above parameters to synthesize the overall optical quality of Pléiades was evaluated up to 24, against a before-launch specification of around 8 – three times greater than specified.

Moreover, the assessment of on-board geometry quality shows the care which has been taken during the design and manufacturing of the satellite. The geometric image quality of Pléiades allows, for instance, excellent DEM extraction.

All these parameters, and many more others, will be monitored by Astrium and CNES all along the life of Pléiades, and their evolution will be unveiled to the public.

All in all, these rather abstract values and facts merely show that Pléiades imagery is providing an excellent level of sharpness and legibility for every user, from automatic correlation for DEM extraction or change detection, to visual interpretation, classification, or communication to the general public.

Please refer to APPENDIX B: for more information about Pléiades Image Quality performance.

1.4 A Cooperation Program



CENTRE NATIONAL D'ÉTUDES SPATIALES

The decision to develop the Pléiades program is the result of an in-depth study about the evolution of user needs. A cooperation program was initiated between France and Italy, taking advantage of all the CNES Earth observation skills, to develop ORFEO, a dual Earth observation system with very high resolution capacity, in which Pléiades (France) is the optical component and Cosmo-SkyMed (Italy) is the radar component. In agreement with the governmental directives and respecting the constraints of the Franco-Italian agreement, co-operations have also been set up with Austria, Belgium, Spain and Sweden.

The French Space Agency, CNES, took over the responsibility of project manager for the Pléiades program. Astrium was appointed prime contractor for the satellite manufacturing, interacting with Thales Alenia Space, who designed the optical instrument. In an agreement signed in 2008, the CNES appointed Astrium GEO-Information Services (formerly known as Spot Image) as the civilian operator and the exclusive worldwide distributor of Pléiades data.



2. PRODUCTS, SERVICES AND OPTIONS

Pléiades delivers ready-to-use products, which can be easily integrated in GIS and/or transformed into thematic information while combined with other satellite, airborne or ground information.

Pléiades satellites always acquire images simultaneously in both modes:

- Panchromatic: 1 band (black and white)
- Multispectral: 4 bands (color)

Panchromatic and Multispectral image products are co-registered (completely superimposable).

The Pléiades twins offer a wide range of products and services, featuring different options to match as close as possible any customer's requirement.

2.1 Archive vs. New Image

Since December 2011, Pléiades has collected a vast amount of imagery on a daily basis. Once acquired and displayed in our catalog, these images constitute the Pléiades archive, and are ready for immediate order. Users can search the archive via www.geostore.com.

FIGURE 11: GEOSTORE - PLÉIADES ACCESS

2 - Products, Services and Options

A customer may also request that a new image be acquired.

- Automatic Tasking** - available for small areas of interest (max. 20 km east-west by 40 km north-south), with standard acquisition parameters of up to 15% cloud cover and a 30° viewing angle. This service, accessible via www.geostore.com, provides an estimated collection time based on the requested geographic zone: approximately 60 days in easy areas with low competition/good weather and 120 days in difficult areas with high competition/poor weather. Smaller collection timeframes (30 days) are available over easy areas. Through the Automatic Tasking, ordering a new image is as simple and quick as ordering archive image.
- Tailored Tasking** - ideal for broader, more complex areas of interest, often with specific parameters (reduced cloud cover, limited viewing angle, Stereo, Tristere, multiple acquisition over the same place, etc.), or for customers who prefer to work with a dedicated in-house expert. These customers will benefit from the experience, advice, and follow up of a satellite tasking specialist, fully engaged to ensure the success of their project. The Tailored Tasking Service is available through our Customer Care department and all levels of service are available: Standard, Priority, and Emergency.
- Instant Tasking** - for expert customers requiring imagery in an emergency. When a crisis occurs, or when information is required immediately, the customer goes to www.geostore.com, enters their Area of Interest (limited to a 20 x 20 km zone) and chooses the next satellites passes (Pléiades when resolution is required, SPOT 6 or 7 when coverage is needed). The customer's request is transmitted directly to the satellite with a maximum priority level. The image is acquired, produced and delivered as quickly as possible, with no commitment on cloud coverage. This is a fully-automated, 24/7 service utilizing the highest reactivity of the four-satellite (Pléiades 1A & 1B, SPOT 6 & 7) Astrium GEO-Information Services constellation.

Below is an overview of these three tasking options, Automatic, Tailored and Instant (Table 4).

	Standard Service	Priority Service	Emergency Service	Access Mode	Options
Automatic Tasking	Collection in 60 or 120 days	Collection in 30 days	N/A	Web Access (GeoStore)	Standard values only (monoscopic, single acquisition, 15% cloud cover, 30° angle)
Tailored Tasking	Collection in routine mode	Shorter collection in case of competition	Collection as soon as possible. Either as 'one shot' (no c.c. commitment), or in a minimum timeframe (cloud cover commitment)	Customer Service (PDF orderform)	All options available. Subject to a feasibility study
Instant Tasking	N/A	N/A	Collection on a given day (no cloud cover commitment)	Web Access (GeoStore)	Choice between Pléiades 1A & 1B and SPOT 6 & 7. Possibility to increase the angle up to 45° to improve revisit rate.

TABLE 4: TASKING OPTIONS

Cloud Cover Warranty:

Optimizing Pléiades satellite tasking in accordance with weather forecasts three times a day ensures that all resources are used as efficiently as possible. We propose image tasking with cloud cover less than 15%, 10% or 5% over the Area Of Interest (AOI) of the order. Depending on the area of interest, we can guarantee



small cloud-free zones, typically 2 x 2 km. Cloud cover does not include cloud shadow and semi-transparency haze.

2.2 Spectral Band Combinations

Combining the Panchromatic and Multispectral bands, images can be visualized as either black and white (50-cm product resolution), natural color, false color (2-m product resolution) or as a merged product (Pan-sharpened color image) with the resolution of the Panchromatic image.

2.2.1 Panchromatic

The Pléiades Panchromatic product includes only one black and white band. It covers wavelengths between 0.47 and 0.83 μm of the visible spectrum. The product pixel size is 0.5 m (Ortho).



FIGURE 12: EXAMPLE OF A PANCHROMATIC IMAGE

2.2.2 Multispectral

The Multispectral product includes four Multispectral (color) bands: Blue, Red, Green and Near Infrared. The product pixel size is 2 m (Ortho).



FIGURE 13: EXAMPLE OF A MULTISPECTRAL IMAGE

2.2.3 Bundle

The Panchromatic (0.5 m) and Multispectral (2 m) products, simultaneously acquired, are packaged together separately (not merged) for a single delivery (1 file for Multispectral + 1 file for Panchromatic).



FIGURE 14: EXAMPLE OF A BUNDLE PRODUCT

2.2.4 Pan-sharpened

Pan-sharpened products combine the visual information of the Multispectral data with the spatial information of the Panchromatic data, resulting in a higher resolution 0.5-m color product. Image fusion is a concept of combining multiple images into composite products, through which more information than that of individual input images can be generated.

As an example of image fusion, Pan-sharpening describes a process of transforming a set of “coarse” (high) spatial resolution Multispectral (color) images to fine (very high) spatial resolution color images, by fusing a co-georegistered fine spatial resolution Panchromatic image. Typically, three or four low-resolution visible bands – Blue, Green and Red or Green, Red and Near Infrared – are used as the main inputs in the process to produce a very high-resolution Natural Color or False Color image.

The Pléiades fusion processing used is:

$$MS_{merged}(i,j) = MS_{zoomed}(i,j) \cdot \frac{PAN(i,j)}{PAN_{soft}(i,j)}$$

Where: MS_{zoomed} = Multispectral image at the same spatial resolution as the Panchromatic image

PAN_{soft} = Panchromatic image at the same spatial resolution as the Multispectral image

i, j = Panchromatic (0.5m) image coordinates

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Figure 15 illustrates Pan-sharpening process.



Multispectral « zoom » image (with zoom 4)



Panchromatic image



Panchromatic « soft » image



Pan-sharpened image

FIGURE 15: ILLUSTRATION OF THE PAN-SHARPENING PROCESS

The upper left image is a natural color image with a spatial resolution of 0.5 m (resampled 400%), and the upper right image is a Panchromatic image with a spatial resolution of 0.5 m. By combining these images, a very high-resolution color Pan-sharpened image is produced. In the merged image, spectral signatures of the input color image and spatial features of the input Panchromatic image (the best attributes of both input images), are almost completely retained.

Pan-sharpened products are offered as 3- and 4-band products. The 3-band color products are available in Natural Color (Blue, Green and Red) or False Color (Green, Red and Near Infrared).

The Natural and False Color images are derived from Multispectral combinations, with bands that have been acquired simultaneously.

- To produce a Natural Color image, the Red band (B2) is put in the red component of the monitor, the Green band (B1) is put in the green component of the monitor, and the Blue band (B0) is put in blue component of the monitor. Figure 16 is an example of a Natural Color image.
- For a False Color image, any of the bands can be put in any RGB channel. The chosen band combination can be changed to highlight the desired features. Figure 17 is an example of the standard False Color composite produced by putting the Green band (B1) in the blue component of the monitor, the Red band (B2) into the green component of the monitor and the Near Infrared band (B3) in the red component of the monitor.

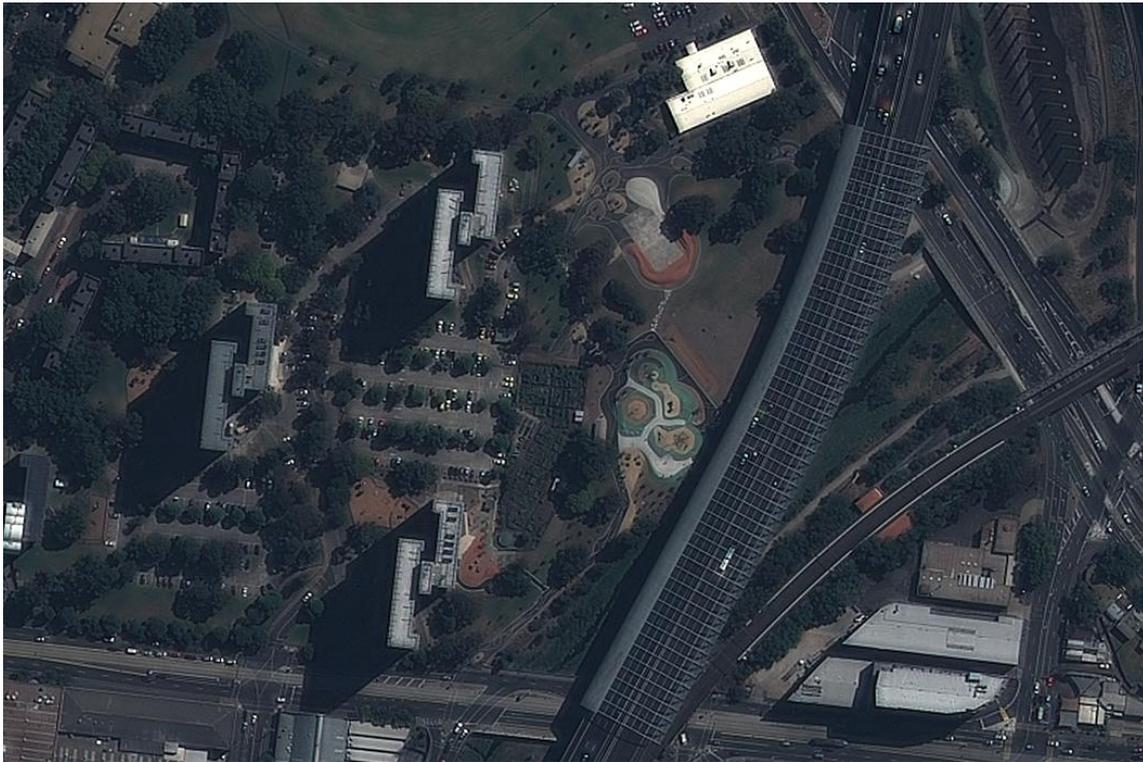


FIGURE 16: EXAMPLE OF A PAN-SHARPENED 3-BAND NATURAL COLOR IMAGE



FIGURE 17: EXAMPLE OF A PAN-SHARPENED 3-BAND FALSE COLOR IMAGE

2.3 Processing Level

Pléiades core imagery products are available in two different processing levels: Primary and Ortho.

All Pléiades products are corrected for radiometric and sensor distortions, using internal calibration parameters, ephemeris and attitude measurements.

Standard products offer the Panchromatic channel (product resolution: 0.5 m) or the Multispectral channels (4 bands, product resolution: 2 m) already registered and possibly merged.

2.3.1 Primary product

The Primary product is the processing level closest to the natural image acquired by the sensor. This product restores perfect collection conditions: the sensor is placed in rectilinear geometry, and the image is clear of all radiometric distortion. The Primary product is optimal for clients familiar with satellite imagery processing techniques wishing to apply their own production methods (orthorectification or 3D modeling for example). To this end, RPCs and the sensor model are provided with the product to ensure full autonomy and simplicity for users.

The Primary product is:

- In sensor geometry, synthesized on a perfect single and linear push-broom array,
- With an equalized radiometry on the native dynamic range of the sensor, 12 bits (4096 values).

The product is extracted from one strip acquisition. The support for this extraction is a polygonal region of interest in WGS84 coordinates.

The main geometric processing includes:

- The combination of all sub-swaths across in the field of view (20 km nadir condition): synthesis in a virtual focal plane represented by a single linear array for all spectral bands
- Correction of instrumental and optical distortions: viewing angles adjusted to the single linear array model
- Co-registration of all spectral bands: Multispectral and Panchromatic
- Attitudes and ephemeris data are refined at ground on the mean estimation:
 - Adjustment of the time stamp sampling (along scan line)
 - Attitudes filtering over time of acquisition or a posteriori extended over several orbits (aka Refined Attitude Data)
- Consistent alignment of the physical model ancillary data and RPC analytic model data

The main radiometric processing includes:

- Inter-detector equalization: correction of differences in sensitivity between the detectors (on board correction)
- Aberrant detectors correction (if any)
- Panchromatic band restored and denoised

- Pixel sampling at Shannon optimizing image quality for downstream value-added processing: Spline kernel resampling into the Primary geometry, zoomed to the factor $7 / 5$ (equivalent resolution of 0.5/2m in nadir condition)

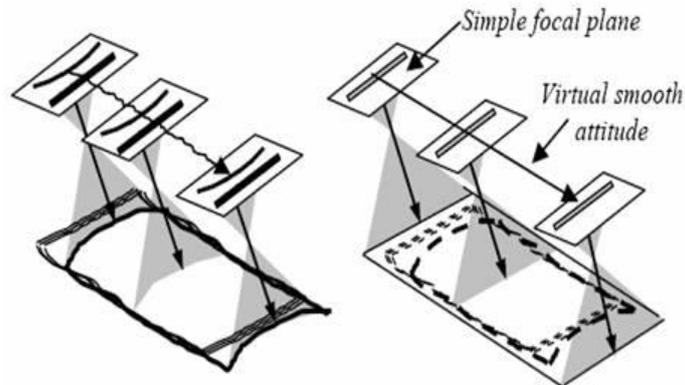


FIGURE 18: PERFECT SENSOR GEOMETRY

The final format includes:

- Masking of pixels (blackfill) outside the region of interest polygon
- Physical tiling: images beyond a certain size are split into several files (see A.4.3 for more details).

The user selects:

- The spectral band combination: Panchromatic, Pan-sharpened 3-Band Natural Color, Pan-sharpened 3-Band False Color, Pan-sharpened 4-Band, Multispectral 4-Band, Bundle
- The bit-depth: 12-bit native (4096 values) or reduced to 8 bits (adjusted linearly to 256 values) for screen display without adaptation
- The raster file format: JPEG 2000, with Optimized or Regular compression, or TIFF

Please refer to 3.2.2 for assistance in selecting the appropriate options (Step 6).

2.3.2 Standard Ortho

The Ortho product is a georeferenced image in Earth geometry, corrected from acquisition and terrain off-nadir effects. The Ortho is produced as a standard, with fully automatic processing.

The Standard Ortho product is an image that has been corrected (viewing angle and ground effects) so that it may be superimposed on a map. On top of radiometric and geometric adjustments, a geometric process using a relief model (known as orthorectification) eliminates the perspective effect on the ground (not on buildings), restoring the geometry of a vertical shot. The Ortho Product is optimal for simple and direct use of the image. It can be used and ingested directly into a Geographic Information System. This processing level facilitates the management of several layers of products, from the same sensor or others, while reducing localization gaps that can be caused by different viewing angles or relief between the various layers. The standard 3D model used for ground corrections is the worldwide Reference3D dataset, which is part of Astrium's Elevation30 suite.

The product is extracted from one to several contiguous strip acquisitions: single ortho or mosaic. Support for this extraction is a polygonal region of interest in WGS84 coordinates.

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The Ortho product inherits geometric corrections from the Primary product, with additional adjustments:

- Planimetric reset: On request, if ground reference data is available, the location is reset on Ground Control Points (Reference3D Ortho layer)
- Altimetric reset: correction of the panoramic effects induced by the off-nadir incidence angles over the relief thanks to a Digital Elevation Model (DEM). By default, the Reference3D DEM layer is used where available, otherwise SRTM is used.
- Mosaics of contiguous pass acquisitions (if acquired during the same pass)
- Map projection or geographic projection

The Ortho product inherits radiometric corrections from the Primary product, with additional adjustments:

- If mosaicking, color balancing of acquisitions (seamless)
- Pixel sampling at Shannon Sampling (Spline kernel) at a fixed resolution of 2 m for Multispectral products and 0.5 m for Panchromatic and Pan-sharpened products

The final format includes:

- Masking of pixels (black fill) outside the region of interest polygon and raster trim to the region of interest bounding box
- Physical tiling: images beyond a certain size are split into several files (see A.4.3)

The user selects:

- The possibility to reset the location on Ground Control Points if available
- The spectral band combination: Panchromatic, Pan-sharpened 3-Band Natural Color, Pan-sharpened 3-Band False Color, Pan-sharpened 4-Band, Multispectral 4-Band, Bundle (please refer to 2.2)
- The bit-depth: 12-bit native (4096 values) or reduced to 8 bits (adjusted linearly to 256 values) for screen display without adaptation
- The raster file format: JPEG 2000, with Optimized or Regular compression, or GeoTIFF

Please refer to part 3.2.2 for assistance in selecting the appropriate option (step 6).

Main Characteristic	Information
Geographic Projections	WGS84 - latitude/longitude sampling according to ARC or DTED2 zoning standards (Please refer to A.5.1 for more details)
Mapping Projection	Most of the projections registered by EPSG, in meters (Please refer to A.5.2 for more details)
GCP	Reference3D Ortho layer
DEM	Reference3D DEM layer (DTED2), SRTM (DTED1), GLOBE (DTED0)

TABLE 5: GEOMETRIC DETAILS OF THE ORTHO PRODUCT

2.3.3 Tailored Ortho

Aside from the Standard Ortho product, when different specifications are needed, Astrium GEO-Information Services can also provide on-demand, custom orthorectification, with a more precise 3D model provided by the client or acquired for the purpose. The Tailored Ortho product can also be requested to create a mosaic of images acquired at different dates. Ingestion of Ground Control Points can also improve the overall



precision of the product. Each Tailored Ortho product is subject to a feasibility study and specific delivery timeframes.

2.4 Products and Image Format

Pléiades products will be delivered in DIMAP V2, just like SPOT 6 and 7. The DIMAP V2 format is an improved version of SPOT's DIMAP V1 format:

- The image can be output in different raster formats: either GeoTIFF or JPEG 2000 (DIMAP V1 allowed only GeoTIFF)
- Rational Polynomial Coefficients (RPCs) are provided to easier orthorectification and geometric processing
- A KMZ is included for rapid, easy and user-friendly display of the main metadata in a Google Earth environment
- Product file naming has been improved (one product, one name, one ID) to better display the product information (sensor, date, processing level, spectral band combination). This also allows several products to be opened on the same computer (vs. DIMAP V1, where you have to close/exit an opened product before opening a second one)
- Quality and cloud cover masks are included

Within the products, the imagery file may come in two different formats, GeoTIFF or JPEG 2000. Although JPEG 2000 is used less today than GeoTIFF, this format saves on file space. JPEG 2000 files can be up to 5 times smaller than GeoTIFF files, making data warehouse management, handling, post-processing and streaming much easier. Depending on your need, you may choose between two compression rates:

- JPEG 2000 Optimized is meant for people looking for fast download and easy data sharing. It has a compression of 3.5 bits/pixel. It uses lossy compression: the compression rate is optimized to avoid any spatial effect but is not reversible. A spectral effect of 1/1000 is tolerated.
- JPEG 2000 Regular is perfect for users willing to do some high precision post-processing. It has a compression of around 8 bits/pixel. It uses lossless compression: the JPEG 2000 compression is completely reversible and does not include any effects in terms of information content.

Both JPEG 2000 compressions ensure no impact in terms of image quality. However, they have a direct impact on the file size: the Regular compression file size is twice as large as the Optimized compression file size.

The (Geo)TIFF format is free of any compression (the standard TIFF specification provides a simple JPEG compression scheme, which is unable to preserve the information content correctly). The file size is huge compared to JPEG 2000 because the GeoTIFF format stores integer values, encoded on the power of two: either 8 or 16 bits. Pléiades acquires images with a 12-bit depth, so GeoTIFF 16-bit products are storing 4 bits for no use.

Upon request, when a GeoTIFF product has been ordered, we will deliver the JPEG 2000 version free of charge for personal format assessment.

JPEG 2000	GeoTIFF
<p>Pixel encoding 12 bits</p> <ul style="list-style-type: none"> Optimized compression Regular compression 	<p>Pixel encoding 16 bits (12 bit-depth dynamic range)</p> <ul style="list-style-type: none"> Without compression
<p>Pixel encoding 8 bits</p> <ul style="list-style-type: none"> Optimized compression Regular compression 	<p>Pixel encoding 8 bits</p> <ul style="list-style-type: none"> Without compression

TABLE 6: IMAGE FORMAT OPTIONS

Please refer to 3.2.2 for assistance in selecting the appropriate option (step 6).

For more than a year before Pléiades 1A launch, Astrium has been working with the main image processing software providers to ease the ingestion of Pléiades data into their systems. The detailed status, per software and version, is available upon request at customertechnicalsupport@spotimage.fr.

2.5 Licensing

Astrium GEO-Information Services offers flexible licensing options to meet any kind of need.

- The Standard End-User License Agreement (EULA)** permits the end-user to share the Pléiades product with affiliated end-users identified in the data request form, in the frame of a joint project. The standard price of the Pléiades product may include up to 5 affiliated end-users. For 6 or more end-users, the “Multi” option shall be selected and entails a price uplift. Under this license, the end-user can:

 - Use the Pléiades product for their own internal needs
 - Create value added products containing imagery data (“VAP”) and use them for their own internal needs
 - Create derivative works (“DW”) which do not contain imagery data from the initial Pléiades product and are irreversible and decoupled from the source imagery data of the Pléiades product. DW may be freely used and distributed
 - Share the Pléiades product with their consultant and contractor for use on behalf of the end-user and/or affiliated end-users
 - Print or post online an extract of the Pléiades product (1024*1024 pixels) for promotion activities
- The Academic License** is focused on research and educational purposes. It permits the use of the Product by one educational entity for academic research or training. An extract of the Pléiades product may be reproduced on certain training tools and publications related to the results of a research.
- The Technical Evaluation License** permits the end-user to use the Pléiades product for technical evaluation only. The end-user shall not transfer the Pléiades product to any third party but may make the product available to a consultant or contractor for use on behalf of the end-user. The end-user shall inform Astrium GEO-Information Services of the results of the performed evaluation.
- Other Needs** For specific commercial needs, we may propose tailored license conditions (such as governmental license, web license, etc.) on a case by case basis. In such a case, please contact us.

3. PRODUCT ORDERING

3.1 Access to Pléiades Data

Pléiades data can be ordered either directly through the web portal www.geostore.com or contacting our Customer Care Service:

- By phone: +33 5 62 19 40 40
- By email: contact@astrium-geo.com
- By fax: +33 5 62 19 40 51

Depending on your location, you will be served directly by Astrium or put in contact with a local partner. See the list of partners on www.astrium-geo.com/en/34-commercial-network.

The order form is available on our website or can be provided by our Customer Care Service, upon request.

3.2 How to Order?

3.2.1 GeoStore

For the combined arrival of Pléiades 1A & 1B and SPOT 6 & 7, Astrium GEO-Information Services has released a new web portal to offer customers and partners an advanced 24/7 access service for satellite data. This unique e-business portal, called GeoStore, allows users to order and manage their geospatial content online.

This portal is backed by DataDoors. Developed by the U.S.-based company i-Cubed, DataDoors is a leading geospatial e-business platform perfectly suited for browsing and ordering satellite imagery, offering a seamless solution from data searching through to product delivery and order management.

The overall platform features multiple e-business functionalities to address the needs of a wide variety of users: distributors, value-added resellers, end-users, partners on their way to Pléiades Direct Access Services (Direct Receiving Station), etc. Easy, intuitive and autonomous, user- and map-centric, GeoStore is meant to become the backbone of the relation between the user and Astrium.

Above all, GeoStore is a powerful web catalog, powered by ESRI technology. Alerts can be set up over specific areas so users are notified as soon as new data is available. By default, GeoStore opens on the user's main AOI. Users with little Earth observation knowledge can search the catalog, without any specific technical criteria. Remote sensing experts can perform advanced searches with seasonal criteria, snow cover, cloud cover, angle, resolution, product type, etc., and even download an Arcgis plug-in to perform an archive search directly from their GIS.

Users with Premier accounts are granted access to the full Pléiades offer. They can order archived Pléiades images online, and also request new images through the different tasking services (Automatic Tasking,

3 - Product Ordering

Tailored Tasking, and Instant Tasking, see 2.1). The possibility to follow online the status of a specific tasking request will also be made available soon, including users having the ability to validate collections themselves (based on the quicklook).

In addition to Pléiades, users also have also access to the full SPOT series archive, from 1986 to present, and will soon have access to FORMOSAT-2, Deimos-1, TerraSAR-X and TanDEM-X archive data. SPOTMaps are also available through GeoStore. SPOTMaps, created from orthorectified 2.5-m natural color SPOT 5 images, provide nationwide or regional seamless coverage over currently more than 100 countries. The coverage of available 3D products such as Reference3D can also be consulted.

The e-business functionalities allow users to:

- Share information and selections in their baskets with other users (e.g. the end-user, in the case of a distributor account). The project sharing functionality enables users to share AOIs, search criteria, annotations over selected images (text, drawings) as well as search results
- Visualize all completed orders
- Sort and/or filter completed orders by date, end-user, country, order ID, or order status and export to an Excel file
- Visualize on a map the AOI of the ordered items, the quicklooks of the selected products (currently SPOT and Pléiades) and the footprints of the selected products

Other useful tools include:

- User rights management: For a given organization's account, different rights can be granted each individual user, from just being able to view the selections up to the ability to order online
- Automatic email notifications can be set up and sent to the internal manager of the organization's account, for all orders and deliveries done by any of the organization's users
- The possibility to set a threshold per user, for which the internal manager of the organization's account has to approve the order. For example, if user A is ordering more than €1,000, approval is needed, if customer B is ordering more than €2,000, approval is needed.
- Easy setup for prepaid accounts.



FIGURE 19: GEOSTORE – HOME PAGE

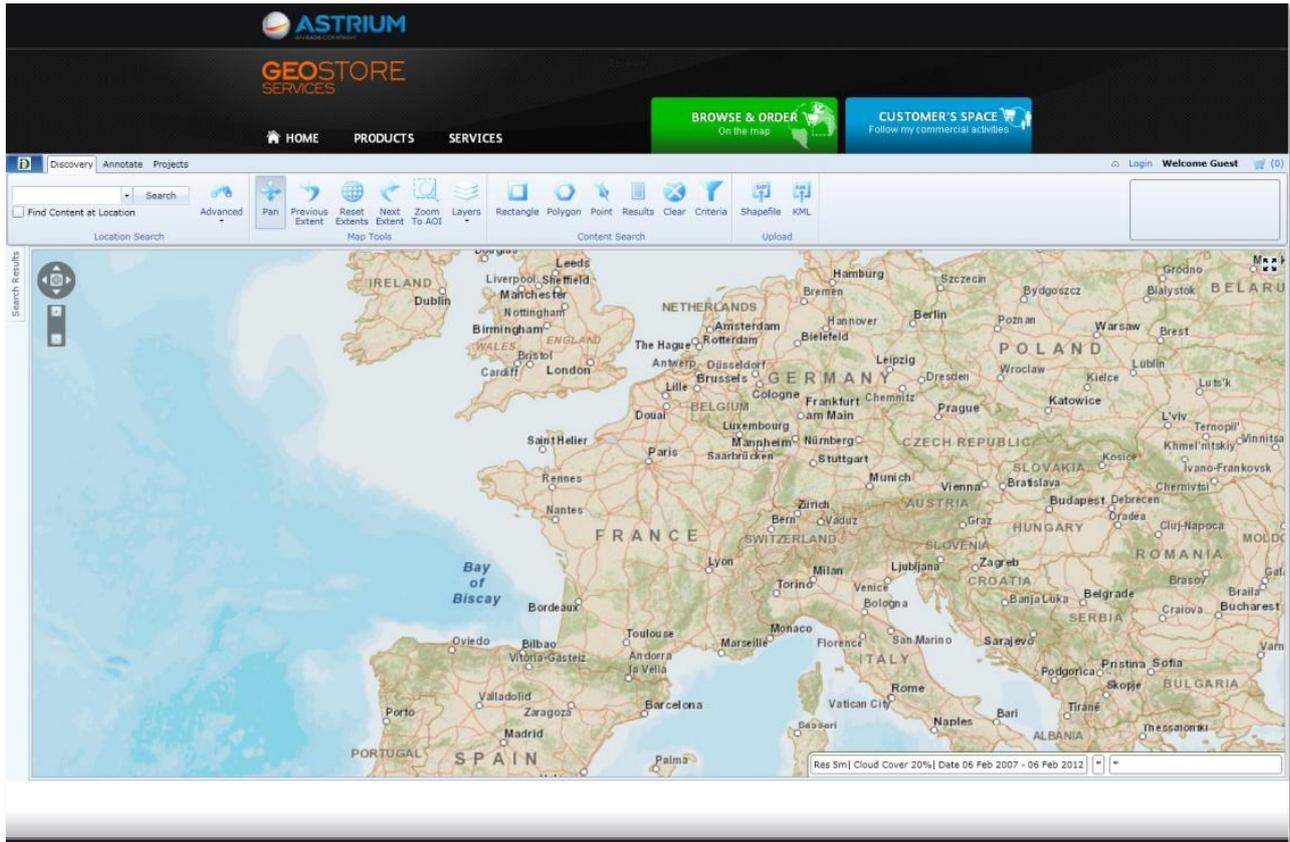


FIGURE 20: GEOSTORE CATALOG

3.2.2 Ordering Through Customer Service

Depending on your preference, you may place an order either through GeoStore or by filling out and sending a PDF order form to our Customer Care Service or our local partner. In the first case, please go to www.geostore.com and follow the online help instructions to select your product and order it online. In the second case, here is the document and some help in filling out the requested parameters.

Date request:

Project name:

Pléiades Data Request Form

Contact Information

Billing address

Company Name:	<input type="text"/>
Contact Name:	<input type="text"/>
Address, Country:	<input type="text"/>
Telephone Number:	<input type="text"/>
Email:	<input type="text"/>

Delivery address (if different from above)

Company Name:	<input type="text"/>
Contact Name:	<input type="text"/>
Address, Country:	<input type="text"/>
Telephone Number:	<input type="text"/>

Delivery

Media:	<input type="text" value="Select"/>
Email Address(es):	<input type="text"/>
Delivery Turnaround:	<input type="text" value="Select"/>

End User Information

End User market

Activity:	<input type="text" value="Select"/>
If "Other" please specify:	<input type="text"/>

Licensing

Licence type:	<input type="text" value="Select"/>
If more than one End User, please specify other Affiliated End Users:	Please include the company, name, address, country, email and telephone for all Affiliated End Users below
If "Other" please describe:	<input type="text"/>

Application

Choose an item:	<input type="text" value="Select"/>
If "Other" please specify:	<input type="text"/>

Area of Interest

Country and place name:	<input type="text"/>		
ESRI Shapefile / KML / KMZ <small>(UTM or Lat / Long, WGS84)</small>	If yes, please send it with this form.		
or Circle: <small>(Lat / Long, Decimal Degrees, WGS84)</small>	Centre point (Lat / Long)	Radius (km)	
or Rectangle: <small>(Lat / Long, Decimal Degrees, WGS84)</small>	Upper Left (Lat / Long)	Lower Right (Lat / Long)	



Product Type

Archive

Please specify:	Segment ID (if known)
-----------------	-----------------------

New acquisition

Temporal mode:	Select		
If "Single Acquisition":	Start: dd/mm/yy	End: dd/mm/yy	
If "Multi-period Acquisitions":	Period 1:	Period 2:	Period 3:
	Start: dd/mm/yy	Start: dd/mm/yy	Start: dd/mm/yy
	End: dd/mm/yy	End: dd/mm/yy	End: dd/mm/yy
If "Regular Acquisitions":	Start: dd/mm/yy	# of acquisitions:	
	End: dd/mm/yy	Min interval between two images:	
Acquisition mode:	Select		
If "Mono":	Select	If "Other", please specify:	
If "Stereo" or "Tristereo":	Min B/H:	Max B/H:	
Service:	Select		
Cloud Cover:	Select		
Snow Cover:	Select		

Product Options

Spectral Bands Combination:	Select	
Bit Depth:	Select	
If "8-bits", Dynamic Adjustment:	Select	
If "Custom":	Please specify Band Trim Offset values (min and max)	
Image Format:	Select	
Product Level:	Select	
Ortho Projection:	Geographic (Lat/Long):	WGS84
	Map Projection (E,N):	Select
	If other, please specify CRS ID or customised parameters:	

Customer's Comments

Please send your completed form to your Customer Relations Manager



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Step 1 – Contact Information:

Specify customer information, billing address, and shipping address (if different from billing address).

Step 2 – Delivery Method:

- a. *Delivery Media:* select from FTP, DVD, Hard Drive or Flash Drive (please refer to the pricelist). Hard Drives are limited to 500 GB, Flash Drives to 16 GB and DVDs to 4.7 GB.
- b. *Delivery Turnaround:* Standard delivery turnaround is 48 hours. Rush delivery is 12 hours, during working days and working hours. For archive products, T0 is the order confirmation sent by GeoStore (if the product has been ordered online) or by our Customer Service (telephone / email ordering). For new collections, T0 is the inventory time.

This rush delivery option is available:

- For the Primary and Standard Ortho processing levels (not for Tailored Orthos)
- In GeoTIFF or in JPEG 2000
- Only with FTP delivery
- For archive products with an uplift (please refer to the Pléiades Pricelist)
- For new acquisitions (free of charge), either Automatic Tasking 30 days or Tailored Tasking with Priority Service. For the Tailored Tasking with Emergency Service, or the Instant Tasking Service, the rush delivery option is automatically activated.

	Standard Service	Priority Service	Emergency Service
Automatic Tasking	Rush delivery not available	Rush delivery available without uplift	N/A
Tailored Tasking			Rush delivery automatically activated, without uplift
Instant Tasking	N/A	N/A	

Because these products shall be delivered within a short timeframe, no image quality control will be performed. For the same reason and if the rush mode is requested for a new acquisition, Refined Attitude Data will not be integrated.

Both standard and rush delivery times are applicable for archive data stored in one of our two main receiving stations, Toulouse or Kiruna. Delivery Turnaround for archive data stored in one of our partner’s Direct Receiving Stations might take more time.

Step 3 – End-User Information:

- a. *End-User Market:* Specify the activity of the end-user.
- b. *Licensing:* Please indicate the type of license which fits your needs (refer to Paragraph 2.5 for the licensing option summary): EULA (up to 5 affiliated end-users), Multi (more than 6 users),

Academic, Technical Evaluation and other. If multiple users will use the same product, please list them and provide their contact details in the Pléiades Data Request form.

c. *Application*: Please select the application for which the data will be used.

Step 4 – Area of Interest:

Indicate the country and the name of your area of interest.

You can define your Area of Interest using coordinates or a Shapefile, KML, or KMZ.

- ESRI Shapefiles as well as KML / KMZ files shall be provided in Universal Transverse Mercator Geographic Projection, using Latitude and Longitude, decimal or sexagesimal degrees, based on the WGS84 ellipsoid. Polygons must have a minimum of three points and a maximum of 999 points. The polygon must be one ring and cannot intersect itself. The minimum distance between two contiguous points shall be at least 500 m.
- Coordinates can be provided in two different ways: either as a circle, giving latitude and longitude information of the center in decimal or sexagesimal degrees, based on the WGS84 ellipsoid and a radius size, in kilometer, or by specifying the latitudes and longitudes of the upper left and the bottom right corners of a rectangle, still in decimal or sexagesimal degrees and based on the WGS84 ellipsoid.
- In all cases (Shapefile, KML, KMZ, coordinates), the AOI shall be a minimum 25 sq.km wide for archive orders and 100 sq.km wide for new acquisition orders, with a minimum width of 5 km in any direction for new acquisitions, and 500 m for archive.

Step 5 – Product Type:

In the Product Type section, please specify if you need archive data or a new acquisition.

- If you want *archive data*, you must fill in the first part. If you have found the data you need in our GeoStore catalog, please indicate the source segment ID(s). We also have a specific department in charge of managing archive searches on your behalf. This team can deal with standard or complex requests, including multi-sensor. If you prefer that Astrium makes the search for you, indicate 'don't know' in the appropriate field of the data request form.
- If you want a *new acquisition*, please fill in the second part of the 'Product Type' section.
 - a. *Temporal Mode*: If you need a new acquisition, please specify first if you need a Single Acquisition, Multi-period Acquisitions or Regular Acquisitions.
 - For a **Single Acquisition**, you may indicate your preferred collection period, with a start and end dates. For instance, if you indicate 01/01/12 – 31/03/12, it means that you want the image to be acquired during the first three months of 2012.
 - For **Multi-period Acquisitions**, you may indicate start and end dates as many times as needed. For instance, if you indicate 01/01/12 – 31/03/12, 01/05/12 – 15/05/12, 07/06/12 – 14/06/12, it means you want three images, the first one to be acquired within the first three months of 2012, the second to be acquired in the first 15 days of May 2012 and the third within a 7-day window in June.
 - For **Regular Acquisitions**, you may indicate an overall period of monitoring (the start and end dates of your monitoring) and the frequency. For instance, if you put 01/01/12 – 31/12/12 – monthly it means that you want an image to be acquired every month in 2012.
 - b. *Acquisition Mode*: If you need a new image, you may also specify if you need a Mono, a Stereo or a Tristereos acquisition. A Monoscopic image means a single image is

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delivered over your AOI. Stereoscopic (resp. Tristereoscopic) acquisition means that the satellite acquires two (resp. three) images over the area of interest within the same orbital pass. Each of the two (resp. three) images are shot with a different viewing angle within the same orbit, enabling the creation of 3D models over the area of interest. In case of Tristereoscopic acquisition, the second image is acquired nearly vertically. The near-nadir acquisition minimizes the risk of missing hidden items (ideal for dense urban and mountainous areas).

- If you select **Mono**, you may indicate the maximum viewing angle you want. The standard viewing angle is 30° (a maximum of 20° is recommended for Ortho products). Please refer to the Abbreviations, Acronyms and Terms section for the definition of the viewing angle. Note: the smaller the maximum viewing angle is, the longer the required collection window. The amount of additional time required depends on the latitude of your area of interest and your tasking choice. Please contact Customer Care Service for more information about how the viewing angle will affect your specific order.
- If you select **Stereo** or **Tristereoscopic**, you may express your requirements in terms of B/H. Please refer to the Abbreviations, Acronyms and Terms section for the definition of the B/H ratio.



The optimum B/H ratio to process 3D models by automatic correlation is in the range of 0.25 and above, depending on the relief. Generally, for Stereo, you may request a B/H of 0.25 to 0.40, if the 3D processing is automated, and even more if the processing is manual. You can request an increased B/H ratio for rather flat areas, with little relief or small buildings. In a mountainous or high building area, a large B/H ratio (>0.4) increases the rate of hidden items or areas (in between two high mountains or around buildings) and decreases the global automatic matching accuracy. This risk can be mitigated by using the Tristereoscopic mode. For Tristereoscopic, a B/H around 0.25 can be recommended for each pair (eg 12° / 0° / 15 °).

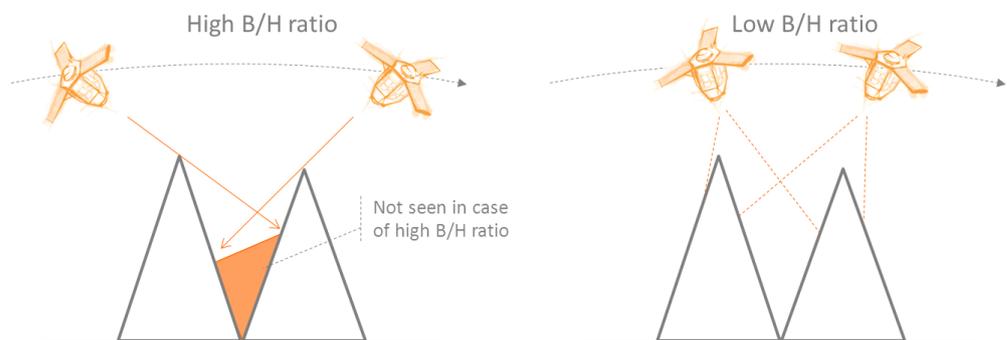


FIGURE 21: B/H RATIO AND HIDDEN ITEMS

- c. **Service:** If you need a new image, you may also select a level of service -- Standard, Priority or Emergency.
- **Standard Service** allows you to request specific image acquisitions if you cannot find what you need in the catalogue. It is particularly suited for applications that do not require images to be acquired within specific time windows or at extreme viewing angles.
 - **Priority Service** guarantees a high-priority image acquisition after an analysis of available satellite capacity and previous commitments. It ensures that your

acquisition request is considered high-priority, in case there is a high level of competition within your area. It is also suited to applications that are subject to time constraints or which require specific acquisition conditions. There is an additional cost associated with this option.

- **Emergency Service** guarantees that the image will be acquired as soon as possible after receiving a request. Users may select either:
 - An acquisition on a given day (one-shot concept), without a cloud cover commitment. A feasibility study will unveil the next satellite passes and attached viewing angle over the AOI. Angles above 30° up to 45° can be requested by the user as it allows for an increased revisit rate. Once accepted, the request is entered into the tasking plan with the maximum level of priority. The acquisition is performed with no consideration for cloud cover.
 - An acquisition, as soon as possible, of an image with a specified cloud cover. In this case, even if a very high level of priority is attached to the request, it may happen that an image is not attempted if the weather forecast is bad.

In both cases, the image is processed and delivered as fast as possible. This option is subject to an extra fee. Please refer to the Pléiades price list.

- d. **Cloud Cover:** The standard value is 15%. If you need a lower cloud cover commitment, please select another cloud cover threshold or describe your need in the “Customer comments” section at the bottom of the second page. This space can also be used for requesting a small cloud-free zone (max 2 km x 2 km) that will be submitted for a feasibility study with the rest of your parameters.
- e. **Snow:** Select the appropriate option to fit your need. Other specifications (haze, sand wind) can be specified in the blank space left for “Customer comments”.

Step 6 – Product Options:

- a. Specify the **spectral band combination** you wish (see part 2.2 for complete details)
 - **Panchromatic (50 cm):** black and white
 - **Pan-sharpened 3-Band Natural Color (50 cm):** merging the Panchromatic with the Blue, Green and Red bands
 - **Pan-sharpened 3-Band False Color (50 cm):** merging the Panchromatic with the Green, Red and Near Infrared bands
 - **Pan-sharpened 4-Band (50 cm):** merging the Panchromatic with the full set of color Blue, Green, Red and Near Infrared bands
 - **Multispectral 4-Band (2 m):** full set of color Blue, Green, Red and Near Infrared bands
 - **Bundle (Panchromatic, 50 cm + Multispectral 4-Band Color, 2 m):** one Panchromatic image + the Multispectral (Blue, Green, Red and Near Infrared) bands delivered separately (not merged)
- b. Specify the **pixel depth** you want. Pixel depth determines the maximum number of colors that can be displayed at one time. The dynamic range of the Pléiades sensor is 12 bits at acquisition. The Pléiades products are available at either:
 - JPEG 2000: **8 bits** or **12 bits** depth per pixel
 - GeoTIFF: **8 bits** or **16 bits** (only the 12-bit depth is used) per pixel

If you are interested in easy-to-use images for visual interpretation, you should select 8-bit images. In an 8-bit image, each pixel is represented by 256 shades of gray per band. If you are interested in the full dynamic range, you should select the 12-bit option; each pixel is represented by 4096 shades of gray, which provides more information to discern subtle feature differences. Some older software

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versions cannot manage 12 bits. Contact your software provider or our Technical Support for more details (customertechnicalsupport@spotimage.fr).

When you select 8-bit image, a **linear adjustment** is necessary to range the original 4096 shade scale into a 256 shade scale. As the 8-bit image is intended for users who do not have the software tools to custom stretch imagery on native 12-bit imagery, the 8-bit linear adjustment should be done with a linear stretch adjustment, possibly with a luminosity enhancement. We recommend to select *Auto*, to let the system enhancing the image luminosity. If *None* is selected, no luminosity enhancement is applied, preserving any addition of saturation. The level of shade may decrease with 8-bit images, this product could be not recommended for users intending to perform scientific analysis or spectral classification as the pixel values of the original data cannot be accurately recovered from the 8-bit dynamically adjusted product. The 12-bit image maintains absolute radiometric accuracy and full dynamic range. No linear adjustment will be performed prior to delivery.



FIGURE 22: EXAMPLE OF 8-BIT PRODUCT WITHOUT (LEFT) AND WITH (RIGHT) LINEAR ADJUSTMENT

- c. Please select an *image file format*. The Pléiades product format is DIMAP V2. Inside that product, you may select the image format:
- JPEG 2000, Optimized compression (3.5 bits/pixel), perfect for fast download and easy data sharing
 - JPEG 2000, Regular compression (8 bits/pixel), recommended for users willing to do some high precision post-processing
 - GeoTIFF (uncompressed)

Please refer to part 2.4 for a complete overview of the Pléiades format. Full technical details can be found in A.4.

- d. You may also select the *level of processing* you want: Primary, Ortho or Tailored Ortho. Please refer to chapter 2.3 for the differences between each level. If you select Ortho or Tailored Ortho, a maximum viewing angle of 20° is recommended. If you select Tailored Ortho, please indicate your specifications in terms of location accuracy. Before a Tailored Ortho order is accepted, Astrium GEO-Information Services must verify that we can obtain the required DEMs and GCPs to make your product or use and ingest the DEM and GCPs you provide to compute your orthorectified product. In the first case, Astrium GEO-Information Services will work to acquire the appropriate support data for your order, as determined by the specifications of the product. Alternatively, we can accept customer provided DEMs and GCPs upon request. DEMs and GCPs must conform to format requirements that are available through our Customer Care Service.

- e. Lastly, you may indicate the *projection* you want for your product. Please refer to chapter A.5 for available geographic and cartographic projections.

If you have any questions about any of the order parameters, please contact our Customer Care Service.

Step 7 – Feasibility Study

Once you have completed the Pléiades data request form, we will verify the physical feasibility of your request, especially if you requested a new acquisition. We essentially check if Pléiades can physically maneuver to image your area of interest within your specified collection window. Astrium's Tasking Department will also check the competitive feasibility of your request, determining if we can fulfill your order, considering that other tasking orders may be in competition with your area of interest and collection window. If a conflict exists, we will come back to you with proposed solutions to enhance your probability of success (raise the priority level, extend/change preferred collection window, change angle, adjust cloud cover requirement, etc.).

Step 8 – Order Confirmation

For archive imagery orders (with the exception of the Tailored Ortho), Customer Care Service will contact you within one business day after receipt of your order to confirm that your order has been activated, to quote a final price and to provide an estimated shipping date.

For new acquisitions, Tailored Ortho orders, or large archive orders, Customer Care Service will need approximately three business days to determine feasibility. Upon the completion of physical, competitive, and production feasibility, you will be contacted with a final price and an estimated ship date. Table 7 presents the minimum amount of time needed to administrate tasking requests.

Tasking Service	Small AOI (≤ 3 x 20km x 20km)	Large AOI (≤ 3 x 20km x 20km)
Standard	24h (working day) before tasking starts	Case by case
Priority	24h (working day) before tasking starts	Case by case
Emergency	24h (working day) before tasking starts	Case by case

TABLE 7: TIMEFRAMES FOR TASKING REQUESTS

3.3 Order Cancellation, Order Modification, Terms and Conditions

Please refer to our General Supply Conditions of Satellite Imagery Products: <http://www.astrium-geo.com/supply-conditions>

4. PRODUCT DELIVERY

4.1 Order Completion and Delivery

Once an order is confirmed, users can begin requesting information about the progress of their requests either by logging on to the order management page of GeoStore (www.geostore.com), or through our Customer Care Service.

On the GeoStore, users can track all completed orders, sort and/or filter them by country, date, amount, end-user, order ID and order status. This list may be exported to an Excel file to ensure easy compatibility with the Information System of your organization.

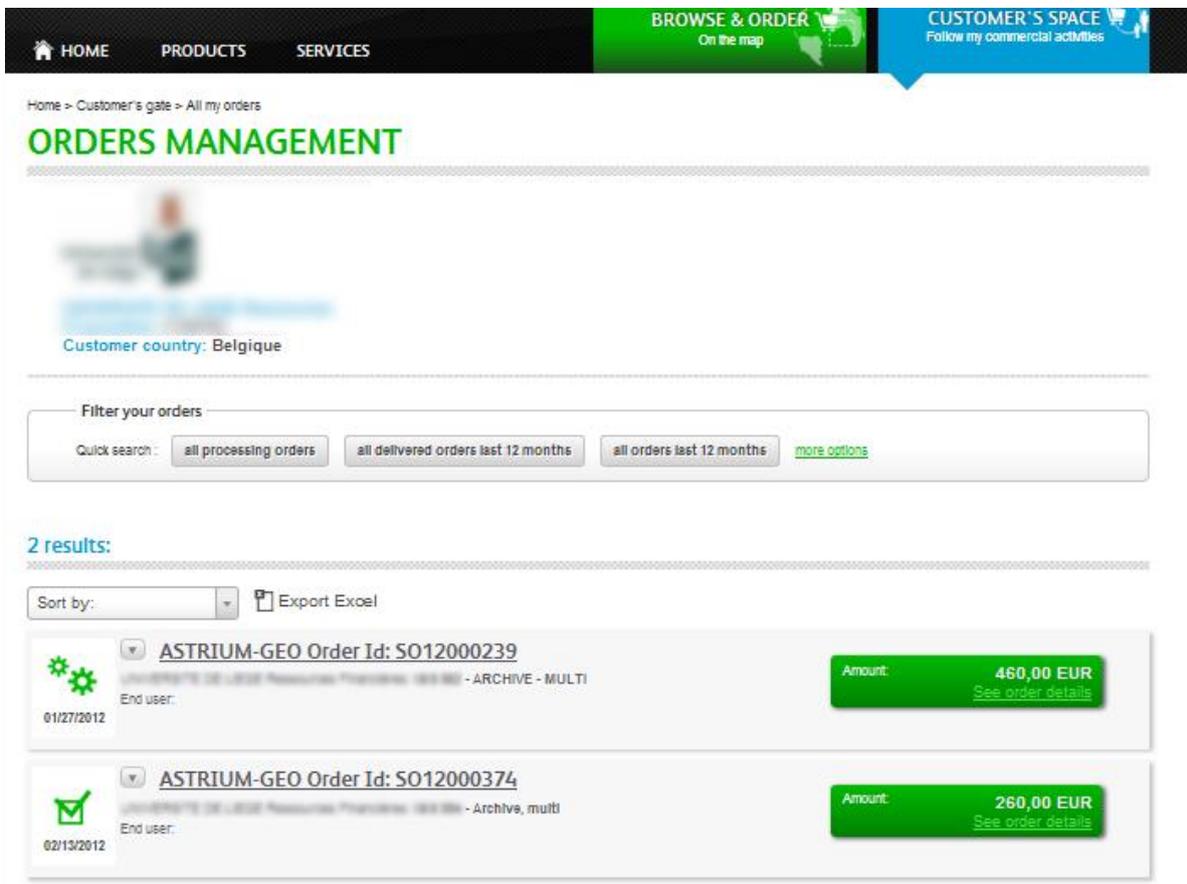


FIGURE 23: GEOSTORE ORDER MANAGEMENT PAGE – LIST VIEW

You may also view the AOI, quicklooks and footprints of each order on the map. Soon, users will also be able to track and follow tasking requests online, including seeing all completed attempts and personally validating attempts based on quicklooks.

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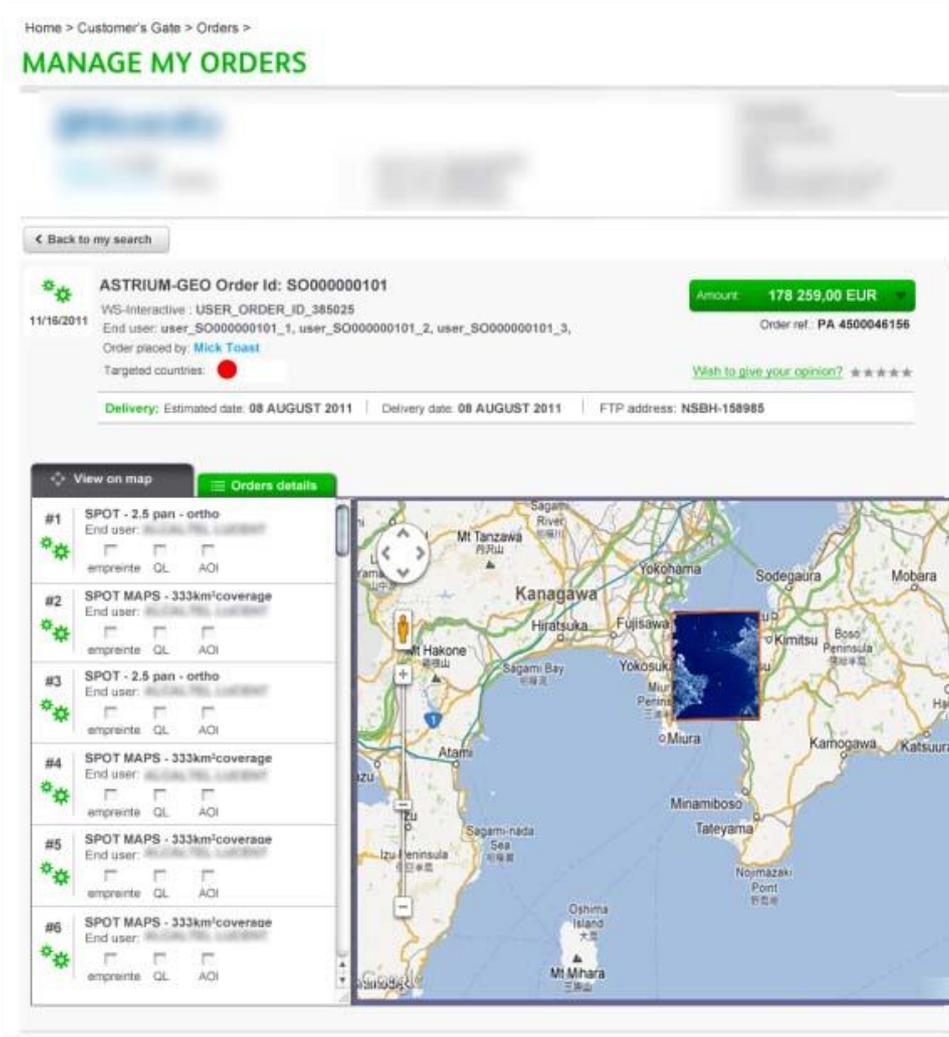


FIGURE 24: GEOSTORE ORDER MANAGEMENT PAGE – MAP VIEW

After Astrium has successfully collected all of the appropriate data, we will process and deliver orders. The table below describes the estimated processing timelines based on the combination of the product and order parameters chosen.

Description	Standard	Rush
Primary, Standard Ortho, any spectral band combination – source segment data available in Toulouse or Kiruna	48 hours	12 hours during working days, JPEG 2000 or GeoTIFF, FTP delivery only
Primary, Standard Ortho, any spectral band combination – source segment data available in a Partner's Direct Receiving Station	72 hours (indicative)	N.A.
Tailored Ortho	Ad hoc estimate provided with the quotation	N.A.

TABLE 8: DELIVERY TIME

Processing timelines for all Tailored Ortho products do not begin until all imagery is collected and all the necessary support data (DEMs and GCPs) are received. The timeframe to obtain DEMs and GCPs depends on the geographic location of the area of interest. Large orders may require additional processing time.

Depending on the delivery method selected, the order will either be posted to an FTP site or shipped. Please contact our Customer Care Service at any time during the order process for further information or to check on the status of your order.

4.2 Deliverable

There are various delivery methods to choose from: FTP, DVD, Hard Drive, or Flash Drive.

Product Size

The product size depends on the area size, spectral mode, resolution, format, and image compression. The table below illustrates an example for a 50-cm, Pan-sharpened 4-band, 400 sq.km product.

JPEG 2000	GeoTIFF
<p>Bit-Depth 12 bits</p> <ul style="list-style-type: none"> Optimized: 2.6 GB Regular: 6 GB (max) 	<p>Bit-Depth 12 bits <i>(storage 16 bits)</i></p> <ul style="list-style-type: none"> 12 GB
<p>Bit-Depth 8 bits</p> <ul style="list-style-type: none"> Optimized: 2.6 GB Regular: 6 GB (max) 	<p>Bit-Depth 8 bits</p> <ul style="list-style-type: none"> 6 GB

TABLE 9: EXAMPLES OF FILE SIZE

For 12-bit products, a JPEG 2000 file is two times smaller with a Regular compression, and around five times smaller with an Optimized compression, than the same product delivered as a GeoTIFF.

▶ *JPEG 2000 12-bits vs. GeoTIFF 12-bits: the image features the same dynamic and the same quality, but the file size is much smaller.*

Theoretically, for JPEG 2000, file sizes are the same for 8 and 12 bits in Optimized and Regular compression. This is related to the fact that the JPEG 2000 compression process determines a targeted bit-rate (3.5 bits/pixel for Optimized compression, 8 bits/pixel for Regular), which can be directly linked to a target file size, whether the dynamic range is 8 or 12 bits.

▶ *JPEG 2000 12-bits vs. JPEG 2000 8-bits: the image features a larger dynamic, but the file size is almost the same.*

Image Files

The product contains one image file (regardless of tiling) for each spectral mode, containing one or several bands:

Band Combination products	Image files (*)	Number of band
Panchromatic (Black and White, 50cm)	1	1
Pan-sharpened 3-Band (Natural Color, 50cm)	1	3
Pan-sharpened 3-Band (False Color, 50cm)	1	3
Pan-sharpened 4-Band (Color, 50cm)	1	4
Multispectral 4-Band (Color, 2m)	1	4
Bundle (Panchromatic, 50cm + 4-Band Color, 2m)	1 + 1	1 + 4

(*) Regardless of tiling

TABLE 10: NUMBER OF IMAGE FILES AND OF BANDS PER PRODUCT TYPE

Image Tiling

Products exceeding a certain size limit are broken up into smaller pieces called “tiles” constituting the whole product. Each tile can be opened separately.



FIGURE 25: PRODUCT TILING

If a product is not tiled, the file name is: ‘product_R1C1.JP2’

If a product is tiled, there are as many image files as tiles, named ‘Product_RiCi.JP2’.

```

IMG_PHR1A_PMS_201202250025599_OR_T_IPU_20120523_2858-001_R2C2.JP2
IMG_PHR1A_PMS_201202250025599_OR_T_IPU_20120523_2858-001_R2C1.JP2
IMG_PHR1A_PMS_201202250025599_OR_T_IPU_20120523_2858-001_R1C2.JP2
IMG_PHR1A_PMS_201202250025599_OR_T_IPU_20120523_2858-001_R1C1.JP2
    
```

A georeferencing worldfile J2W (or TFW for GEOTIFF products) is associated to each image tile.

IMG_PHR1A_PMS_201202250025599_ORT_IPU_20120523_2858-001_R2C2.J2W
 IMG_PHR1A_PMS_201202250025599_ORT_IPU_20120523_2858-001_R2C1.J2W
 IMG_PHR1A_PMS_201202250025599_ORT_IPU_20120523_2858-001_R1C2.J2W
 IMG_PHR1A_PMS_201202250025599_ORT_IPU_20120523_2858-001_R1C1.J2W

All other metadata (RPC XML and DIM XML) are not tiled and are applicable to the whole product.

Tile size limit is approximately:

- 2 GB for GeoTIFF products
- Max. 4 GB for JPEG 2000 products

Since the product size depends on the image format, the same product will be cut into more tiles in GeoTIFF than in JPEG 2000. For example, for one Pan-sharpened, 4-band, 400 sq.km product, a JPEG 2000 12-bit (Optimized) product will be 2.6 GB: no tiling is needed. A GeoTIFF 12-bit product will be approximately 12 GB, with 6 image tiles.

4.2.1 Overview of the Product

Pléiades products are delivered in DIMAP V2 format.

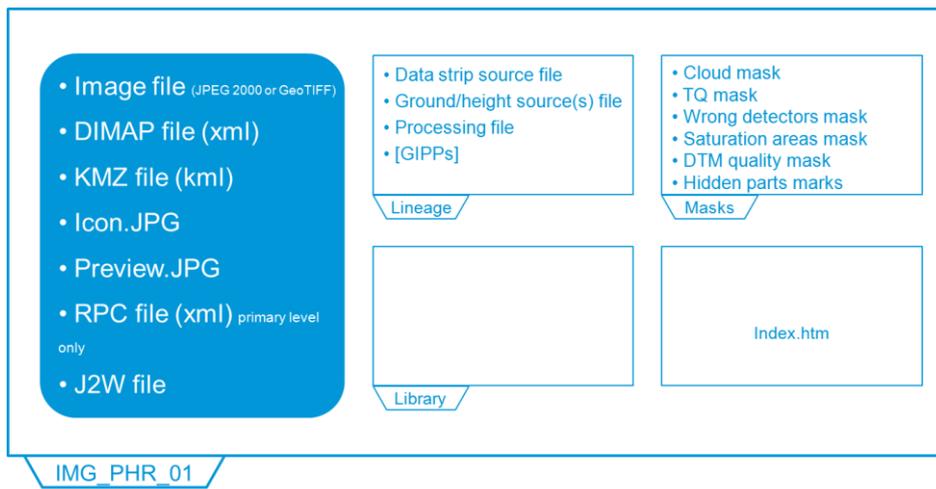


FIGURE 26: DIMAP V2 STRUCTURE

4.2.2 Example

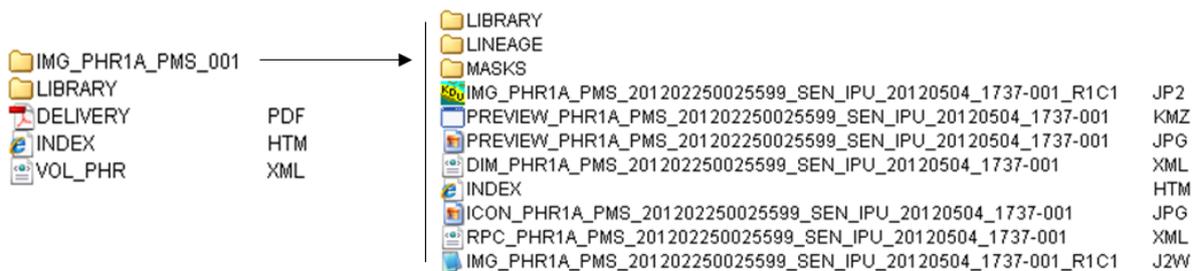


FIGURE 27: EXAMPLE OF DIMAP V2 STRUCTURE

4 - Product Delivery

Primary and Ortho products consist of:

- The delivery PDF file
- The image file, including The 'PREVIEW' quicklook files, either in KMZ or JPEG
- The index file named 'INDEX.HTM', that allows an easy display of the main information about the product

Delivery File

In the delivery PDF file, you will find general technical information of the product such as: acquisition angles, band information, coordinate system, and histograms.

Image File / KMZ (PREVIEW_...KMZ)

This file gives a visual and easy-to-use overview of the products. You can open it from Google Earth and:

- Preview the footprints:

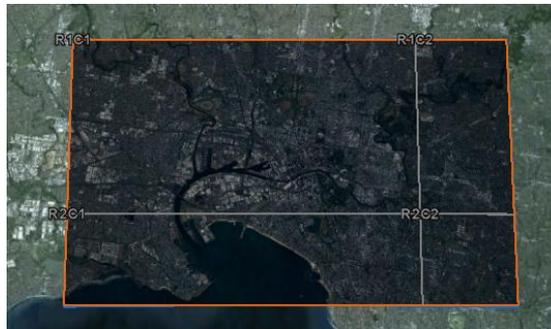


FIGURE 28: KMZ PREVIEW, FOOTPRINT

- Click on different objects to get more information:

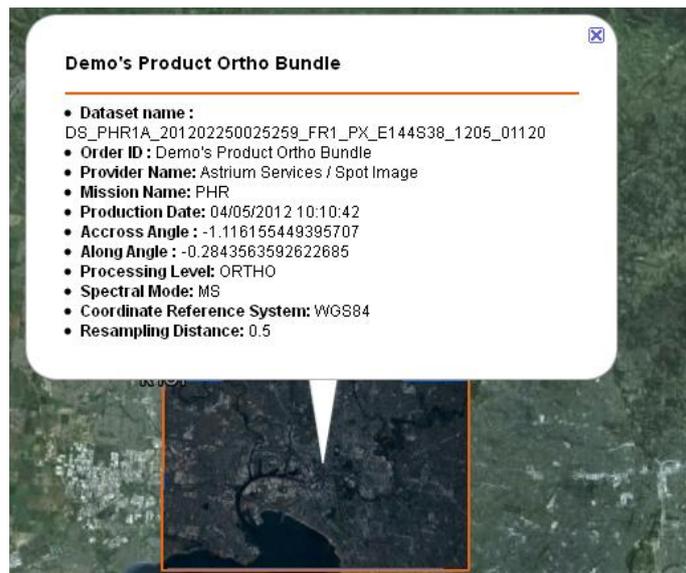


FIGURE 29: KMZ PREVIEW, BUBBLE

The file contains several information layers which can be displayed or hidden:



FIGURE 30: KMZ PREVIEW, LAYERS

Start animation: By double-clicking on this layer, you zoom on the product.

Sources: This layer displays the entire footprint and information (date, angles) of all source strips, necessary for the production of the product.

Sources Extracts: This layer provides the footprint of the source strips, intersecting with the area of interest.

Tiles: This layer shows the footprint and information (name, media) of each tile contained in the product.

Product: This layer gives the footprint, information (name, mode, angle ...), and preview of the whole product.

Image File / Main Metadata File (DIM_...XML)

The file contains all the product metadata needed for image processing.

Top level information can be found by opening it in a web browser like Internet Explorer or Mozilla Firefox: product description, quicklook, coordinate system ...

More information can be found by opening it with a text editor like WordPad: find all data related to the image acquisition, processing parameters, etc. Examples:

- Radiometric values: gain and offset to radiance count:

```
<GAIN>9.1</GAIN>
<BIAS>0</BIAS>
```

- Geometric values: Acquisition angles :

```
<AZIMUTH_ANGLE>179.9662330145161</AZIMUTH_ANGLE>
<VIEWING_ANGLE_ACROSS_TRACK unit="deg">0.8921924132232172</VIEWING_ANGLE_ACROSS_TRACK>
<VIEWING_ANGLE_ALONG_TRACK unit="deg">-0.08521426592279865</VIEWING_ANGLE_ALONG_TRACK>
<VIEWING_ANGLE unit="deg">0.8962513185196064</VIEWING_ANGLE>
<INCIDENCE_ANGLE_ALONG_TRACK>-0.2708528386076501</INCIDENCE_ANGLE_ALONG_TRACK>
<INCIDENCE_ANGLE_ACROSS_TRACK>-0.9928120136270051</INCIDENCE_ANGLE_ACROSS_TRACK>
<INCIDENCE_ANGLE>1.029080944248358</INCIDENCE_ANGLE>
```

RPC File (RPC_...XML)

This file allows users to do geometric processing (orthorectification, DEM extraction) easily with software that supports RPC models.

J2W or TFW File (IMG_...J2W)

This file (worldfile) allows software to georeference images (coarse for Primary products).

Please refer to part APPENDIX A: for a complete DIMAP V2 description.

4.3 How to Open Your Product

To open a Pléiades product and access the image coordinates and metadata, it is possible to use a GIS or image processing software. Most commercial off-the-shelf software is able to read, georeference and process (orthorectify, etc.) Pléiades products. The various software packages use different methods to georeference Pléiades products. Georeferencing is achieved by reading:

- a. The GMLJP2 header*, J2W worldfile**, or XML metadata file for products in JPEG 2000
- b. The GEOTIFF header*, TFW worldfile**, or XML metadata file for products in GeoTIFF

(*) Not applicable for Primary products. (**) Coarse for Primary products.

For more than a year before Pléiades 1A launch, Astrium has been working with the main image processing software providers to ease the ingestion of Pléiades data into their systems. The detailed status, per software and version, is available upon request at CustomerTechnicalSupport@spotimage.fr.

4.4 Technical Support and Claims

No matter whether you are looking for specific metadata, need to know how to use the RPC file, have questions about the format you need, think your image does not look right, cannot open the file, or anything else, we are here to help. For any question, advice or problem, please contact your Customer Care representative or the Technical Support Team: CustomerTechnicalSupport@spotimage.fr. They will give you information about products, format, processing, software, or provide you assistance with problem you could meet, using your product.

APPENDIX A: FILE FORMAT – DIMAP V2

The following physical format applies to Primary and Standard Ortho products. For Tailored Ortho products, the physical format is shared with other sensors and is based on the standard we describe thereafter.

A.1 File and Folder Naming

A.1.1 Naming Conventions

Names provide concise information about the product and its context. The naming is composed of:

- a prefix
- a suffix (possibly)
- a variable string composed of key information contained in the DIMAP V2 metadata file
- a file extension

A.1.1.1 Fixe Names

The prefixes are the following:

Prefix	Folder	File	Subject	Remark
VOL_		X	Index file of products contained in the delivery	
IMG_	X	X	Product directory, or image file(s), or associated georeferencing file(s)	
DIM_		X	DIMAP, main product metadata file	
RPC_		X	DIMAP, RPC metadata file	Primary Product only
PREVIEW_		X	Quicklook raster file, or associated KMZ file	
ICON_		X	Thumbnail raster file	
STRIP_		X	DIMAP, Data Strip Source metadata file	One per Data Strip Source
GROUND_		X	DIMAP, Ground Source metadata file	If Ground reset at Ortho level, one per source
HEIGHT_		X	DIMAP, Height Source metadata file	If Vertical reset at Ortho level, one per source
PROCESSING_		X	DIMAP, processing lineage file	
GIPP_		X	GIPP file	

APPENDIX A: File Format – DIMAP V2

Prefix	Folder	File	Subject	Remark
ROI_		X	Region of Interest vector mask	
CLD_		X	Cloud vector mask	
QTE_		X	Synthetic QT vector mask	
SNW_		X	Snow vector mask	
DET_		X	Out of order detectors vector mask	
VIS_		X	Out of order detectors vector mask	Ortho and Mosaic
SLT_		X	Straylight vector mask	
DTM_		X	DTM quality vector mask	

TABLE 11: NAMING - PREFIXES

The suffixes are:

Suffix	Folder	File	Subject	Remark
_DIM		X	Various DIMAP metadata files (different from the main product metadata file)	
_R/Cj		X	Image product file, possibly tiled	ij, Row (R) and Col (C) tile indexes
_MSK		X	Mask, raster or vector	Vector, GML format

TABLE 12: NAMING - SUFFIXES

The following files/directories have fixed naming:

Names	Folder	File	Subject	Remark
DELIVERY		X	Delivery note	
LICENSE		X	License file	
LINEAGE	X		Directory for source information	
MASKS	X		Directory for mask information	
LIBRARY	X		Directory for files activated by the XML Style Sheet	
LOGO		X	Logo file	

TABLE 13: NAMING - MAIN DIRECTORIES

The file extensions are:

Extension	File	Subject	Remark
.GML	X	GML vector files	Mask file
.HTM	X	HTML file	

Extension	File	Subject	Remark
.JPG	X	JPEG raster file	Thumbnail and quicklook files
.JP2	X	JPEG 2000 raster file(s)	image file(s)
.J2W	X	ESRI World file(s) for JPEG 2000	simple georeferencing file(s)
.KMZ		KML file (archived in zip format)	Preview file
.PDF	X	PDF file	Delivery file
.TIF	X	TIFF/GeoTIFF raster file(s)	image file(s)
.TFW	X	ESRI World file(s) for TIFF/GeoTIFF	simple georeferencing file(s)
.XML	X	DIMAP file encoding in XML or simple XML file	Metadata files
.XSL	X	XML Style Sheet file	

TABLE 14: NAMING - EXTENSIONS

A.1.1.2 Variable Key Information

The naming convention uses key information contained in the DIMAP product metadata file.

The product directory name is comprised of:

<DirImage_ID>

PHR<SAT_NUMBER>_<SPECTRAL_PROCESSING>_<NUM_PRODUCT>

Example: **PHR1A_PMS_001**

Where: <SAT_NUMBER> = {1A, 1B}, Pléiades 1A or Pléiades 1B, or one of them if both used in a mosaic
 <SPECTRAL_PROCESSING> = {P, MS, PMS, MS-N, MS-X, PMS-N, PMS-X}

SPECTRAL_PROCESSING	Spectral Mode
P	Panchromatic
MS	Multispectral 4 bands
PMS	Pan-sharpened 4 bands
PMS-N	Pan-sharpened 3 bands (B, G, R bands)
PMS-X	Pan-sharpened 3 bands (G, R, NIR bands, False color)

TABLE 15: NAMING – SPECTRAL PROCESSING

<NUM_PRODUCT> = Product index within the Volume. Format is three digits from 001 to 999

APPENDIX A: File Format – DIMAP V2

The product name for Primary and single Ortho files is comprised of:

<Product_ID>

PHR<SAT_NUMBER>_<SPECTRAL_PROCESSING>_<IMAGING_TIME>_<PROCESS_LEVEL>_<JOB_ID>

Example: **PHR1A_PMS_201006181052299_ORT_123456789**

Where: <SAT_NUMBER> = see previous section
 <SPECTRAL_PROCESSING> = see previous section
 <IMAGING_TIME> = UTC strip source acquisition start time. Format = "YYYYMMDD_HHMMSSS"
 <JOB_ID> = Internal production identifier. Format = variable string
 <PROCESS_LEVEL> = {SEN, ORT, MOS}

PROCESS_LEVEL	Product
SEN	Primary (abbreviation for SENSOR)
ORT	Ortho, single image
MOS	Ortho, mosaic image

TABLE 16: NAMING – PROCESSING LEVELS

Specifically, the product name of Ortho mosaic files are derived from the same principle:

<ProductMOS_ID>

PHR_<INTERNAL_REF>_<SPECTRAL_PROCESSING>_<PROCESS_LEVEL>_<JOB_ID>

Example: **PHR_Mymosaic_PMS_MOS_123456789**

Where: <INTERNAL_REF> = Internal identifier, generally shared with the customer. Format = variable string.

Name(s) of Pléiades Data Strip Source metadata file(s) is comprised of:

<DATA_STRIP_ID>

DS_PHR<nn>_<YYYYMMDDHHMMSSS>_<RRR>_<PP>_<XxxxYyy>_<KKLL>_<TTTTT>

Example: **DS_PHR1A_201006181052297_FR1_PX_E001N43_0612_06488**

Where: <nn> = satellite number {1A, 1B}
 <YYYYMMDDHHMMSSS> = UTC strip source acquisition start time
 <RRR> = initial archiving center acronym
 <PP> = acquisition spectral mode {PA, XS, PX [i.e. PA+XS]}
 <XxxxYyy> = closest square degree of the strip center with:
 X = {W,E}, West or East, xxx longitude degree (000 to 180)
 Y = {N,S}, North or South, yy latitude degree (00 to 90)
 <KKLL> = closest cell in the Pléiades Grid of the strip center with:
 KK = step number in longitude
 LL = step number in latitude
 <TTTTT> = Number of source frames PA (or XS if spectral mode is XS)

Name(s) of Height Source metadata file(s) for an Ortho produced with a standard DEM is comprised of:

<DEM_Source_ID>

- For Reference3D DTED2 DEM layer (one arc second):

<DEM_Source_ID> = R3D_DT2_<Tile_ID>

Example: R3D_DT2_N44E001

Where:

<Tile_ID> = one-square-degree tile South-West corner geographic coordinates in degrees {N|S}xx{E|W}yyy

- For SRTM1 DEM Source (nine arc seconds):

<DEM_Source_ID> = SRTM_DT1

Example: SRTM_DT1

- For Global DEM Source (thirty arc seconds):

<DEM_Source_ID> = GLOBE

Example: GLOBE

Name(s) of Ground Source metadata file(s), for an Ortho reset on standard ground source is comprised of:

<OR_Source_ID>

- For the Reference3D Ortho layer Source (one sixth of an arc second)

<OR_Source_ID> = R3D_OR_<Ref3D_Tile_ID>

Example: R3D_OR_N44E001

Where:

<OR_Source_ID> = one-square-degree tile South-West corner geographic coordinates in degrees {N|S}xx{E|W}yyy

A.1.2 Tree Structure

The delivery tree layout is a typical DIMAP product data structure, with three hierarchic levels of information:

- The root level index
- A product level (1 to n)
- Inside a product level, a set of sub-levels with additional information like striping masks

The layout is the same for all kinds of deliveries, physical delivery (DVD, Hard Drive or Flash Drive) or electronic delivery via FTP.

A.1.2.1 Primary or Single Ortho Image Products

The file naming convention is detailed in the previous section. The usual file structure is as follows:

Primary, Single Ortho Image	
VOL_<MISSION>.XML [1:1]	
INDEX.HTM [1:1]	
DELIVERY.PDF [1:1]	
 LIBRARY	
LOGO.JPG	
STYLE.XSL	
 IMG_<DirImage_ID>	
INDEX.HTM	
DIM_<Product_ID>.XML [1:1]	
RPC_<Product_ID>.XML [0:1]	<i>for Primary Product only</i>
PREVIEW_<Product_ID>.KMZ [1:1]	
PREVIEW_<Product_ID>.JPG [1:1]	
ICON_<Product_ID>.JPG [1:1]	
IMG_<Product_ID>_RiCj.JP2 [1:n]	<i>n if image is physically tiled</i>
IMG_<Product_ID>_RiCj.J2W [1:n]	<i>n if image is physically tiled</i>
 LINEAGE	
PROCESSING_<Product_ID>_DIM.XML [1:1]	
STRIP_<DATA_STRIP_ID>_DIM.XML [1:1]	
GROUND_R3D_OR_<Ref3D_Tile_ID>_DIM.XML [0:n]	<i>if Ortho Product if ground reset</i>
HEIGHT_R3D_DT2_<Ref3D_Tile_ID>_DIM.XML [0:n]	<i>or</i>
HEIGHT_SRTM_DT1_DIM.XML [0:n]	<i>or</i>
HEIGHT_GLOBE_DIM.XML [0:n]	<i>if Ortho Product vertical reset</i>
 MASKS	
CLD_<Product_ID>_MSK.GML [1:1]	
QTE_<Product_ID>_MSK.GML [1:1]	
SNW_<Product_ID>_MSK.GML [1:1]	
DET_<Product_ID>_MSK.GML [1:1]	
SLT_<Product_ID>_MSK.GML [1:1]	

ROI_<Product_ID>_MSK.GML [1:1]	
VIS_<Product_ID>_MSK.GML [0:1]	<i>for ortho and mosaic products only</i>
DTM_<Product_ID>_MSK.GML [0:1]	
 LIBRARY	
LOGO.JPG	
STYLE.XSL	

For products delivered in TIFF/GeoTIFF format instead of JPEG 2000 format, file extensions TIF and TFW replace file extensions JP2 and J2W.

A.1.2.2 Mosaic Ortho Image Products

The previous <Product_ID> is slightly modified in <ProductMOS_ID>, since the final Mosaic is a merge of several images, at different times and possibly dates. Each image is considered an independent source described by its own DATA_STRIP lineage metadata file.

The file naming convention is detailed in the previous section. The usual file structure is as follows:

Mosaic Ortho Image	
VOL_<MISSION>.XML [1:1]	
INDEX.HTM [1:1]	
DELIVERY.PDF [1:1]	
 LIBRARY	
LOGO.JPG	
STYLE.XSL	
 IMG_<DirImage_ID>	
INDEX.HTM	
DIM_<ProductMOS_ID>.XML [1:1]	
PREVIEW_<ProductMOS_ID>.KMZ [1:1]	
PREVIEW_<ProductMOS_ID>.JPG [1:1]	
ICON_<ProductMOS_ID>.JPG [1:1]	
IMG_<ProductMOS_ID>_RiCj.JP2 [1:n]	<i>n if image is physically tiled</i>
IMG_<ProductMOS_ID>_RiCj.J2W [1:n]	<i>n if image is physically tiled</i>
 LINEAGE	
PROCESSING_<ProductMOS_ID>_DIM.XML [1:1]	
STRIP_<DATA_STRIP_ID>_DIM.XML [1:n]	<i>n if multi pass mosaic</i>

APPENDIX A: File Format – DIMAP V2

GROUND_R3D_OR_<Ref3D_Tile_ID>_DIM.XML [0:n]	<i>if ground reset</i>
HEIGHT_R3D_DT2_<Ref3D_Tile_ID>_DIM.XML [0:n]	or
HEIGHT_SRTM_DT1_DIM.XML [0:n]	or
HEIGHT_GLOBE_DIM.XML [0:n]	<i>ground reset</i>
 MASKS	
CLD_<ProductMOS_ID>_MSK.GML [1:1]	
QTE_<ProductMOS_ID>_MSK.GML [1:1]	
SNW_<ProductMOS_ID>_MSK.GML [1:1]	
DET_<ProductMOS_ID>_MSK.GML [1:1]	
SLT_<ProductMOS_ID>_MSK.GML [1:1]	
ROI_<ProductMOS_ID>_MSK.GML [1:1]	
VIS_<ProductMOS_ID>_MSK.GML [1:1]	
DTM_<ProductMOS_ID>_MSK.GML [0:1]	
 LIBRARY	
LOGO.JPG	
STYLE.XSL	

For products delivered in TIFF/GeoTIFF format instead of JPEG 2000 format, file extensions TIF and TFW replace file extensions JP2 and J2W.

A.1.2.3 Product Delivered on Several Media

When the product image size exceeds the delivery medium capacity, the tree structure is duplicated on every medium. Each medium gets a subset of image raster tiles up to the media limit. The complete product can be gathered with the information provided into index, metadata and KMZ files.

The same rule applies to electronic delivery via FTP, considered here to have the same capacity as a DVD (4 GB).

A.2 Levels of Information and File Short Contents

File name	Standard Products		Others Products
	Primary	Ortho	
Root Level			
Index File	Y	Y	Y
Delivery File	Y	Y	
Product Level			
Product File	Y	Y	Y
RPC File	Y	N	
World File	Y	Y	
KMZ File	Y	Y	
Preview File	Y	Y	Y
Thumbnail File	Y	Y	Y
Lineage Sub-Level			
Data Strip Source File	Y	Y	
Ground Source File	N	If set	
Height Source File	N	Y	
Processing File	Y	Y	
Mask Sub-Level			
Mask File	Y	Y	

TABLE 17: OVERVIEW OF AVAILBLE INFORMATION VS. PROCESSING LEVELS

A.2.1 The Root Level Index

The root level index provides information on all products collected by the delivery order. This level is also called the volume level. The delivery may be stored on one or several media. The delivery contains one or several products. Each is a component of the full delivery.

A.2.1.1 Index Metadata File

VOL_<MISSION>.XML: file encoding = XML, metadata format = DIMAP V2

The Index metadata file, or Volume file, lists all components of the delivery order (i.e. all unitary products on the media): the access path to the metadata file and the associated tiled images. For delivery on several media, the index metadata file collects all volume entries (multi-volume) and the index flag indicates the medium allocation.

APPENDIX A: File Format – DIMAP V2

Using Web tools supporting XLST, the integrated XSL style sheet allows the main information and product navigation to be displayed. The display is activated with the file itself or through the INDEX.HTM file.

A.2.1.2 Delivery File

DELIVERY.PDF: format = PDF

The delivery PDF file is easier to print than the XML/HTML files. It gathers significant information from the index and product metadata files. The order and processing identifications are summarized in the headings. Like the index metadata file, the first page gives an overview of the media content.

The content provides, for each product, a selection of information, and possibly for standard products, the histograms of each spectral band.

A.2.1.3 License File

The product and its content are copyright protected. The user must refer to the conditions of agreement and licensing authorized by Astrium GEO-Information Services.

A.2.2 The Product Level

IMG_<DirImage_ID>

The product directory contains the product itself and the associated discovery files.

A.2.2.1 Product Metadata File

DIM_<Product_ID>.XML: file encoding = XML, metadata format = DIMAP V2

The product metadata file provides, in detail, the product information consistent with its final processing level. It also provides links to all files incorporated into the product: image, lineage files, and mask files.

The information is organized by groups of DIMAP metadata, with the following:

Metadata_Identification	Metadata format and language identification
Dataset_Identification	Brief text and a visual representation of the dataset. This information is mainly provided for dataset search and discovery purposes Rights and constraints to access and use
Dataset_Content	Localization of the dataset and geometric extent. User should use this information for cataloging purposes and not for accurate positioning Links to the main files encapsulated into the current dataset (component)
Product_Information	Responsible party of the product: contact, order, and delivery information
Coordinate_Reference_System	Coordinate Reference System (CRS) into which the data will be related. The DIMAP CRS scheme is based on the industrial standard

	<p>EPSG. It includes five single entities:</p> <ul style="list-style-type: none"> - Projected: map projection, horizontal plane usually Cartesian coordinates in linear unit - Geodetic: Earth mapping based on a geographic (angular unit) or geocentric shape of the Earth - Vertical: CRS used for gravity-related (geoid) height or depth data - Temporal: CRS used for recording time data - ECI: CRS used for recording Earth-Centered Inertial data <p>Projected and geodetic are the common ones for image mapping. Conventionally, Primary image are recorded with WGS84 geodetic CRS</p> <p>CRS are recorded to EPSG registry if known. The subsequent parameters are only given if no identifier is found in the registry (commonly known as a "user-defined" definition)</p>
Geoposition	<p>Easiest relationship between the dataset coordinates and the CRS coordinates:</p> <ul style="list-style-type: none"> - Georectified data (Ortho): insertion point and dimension - Raw image (Primary): link to RPC analytic model
Processing_Information	<p>Information on production facility, level of processing, processing settings: geometric, radiometric, sampling, MTF</p>
Raster_Data	<p>Raster file path(s) and tiling size organization, encoding and displaying</p>
Radiometric_Data	<p>Radiometric information, how to set the image count (pixel values) to radiometer measurement: dynamic range, radiometric adjustment performed on data, histogram, radiometric calibration values as spectral range, radiance, solar irradiance</p>
Geometric_Data	<p>Geometric information:</p> <ul style="list-style-type: none"> - Raw image (Primary): data for rigorous sensor model (acquisition time and date, ephemeris, attitudes, and geometric calibration of the instrument). This data is consistent with the inner image geometry and self-contained for the user processing (any data in other files is required, please refer to Technical Appendix) - Pre-computed useful geometric location data at fixed posting in the image: acquisition angles, solar incidence, ground sample distances
Quality_Assessment	<p>Quality information. Should be:</p> <ul style="list-style-type: none"> - Planimetric accuracy (Ortho Product) - Vertical accuracy (DEM product) - Link to various data giving quality information: lineage masks
Dataset_Sources	<p>Original data identification from which the current dataset was made and a link to the corresponding lineage metadata file(s)</p>

TABLE 18: METADATA ORGANIZATION

APPENDIX A: File Format – DIMAP V2

Using Web tools supporting XLST, the integrated XSL style sheet allows the main information and product navigation information to be displayed. The display is activated with the file itself or through the INDEX.HTM file.

A.2.2.2 RPC Metadata File

RPC_<Product_ID>.XML: file encoding = XML, metadata format = DIMAP V2 (NITF V2.1 naming)

The RPC file contains the coefficients and normalization parameters for the Rational Polynomial Coefficients (also called Rapid Positional Capability, Rational Function Model) geometric analytic model. This file is only given for images supporting a sensor geometry (Primary product).

The metadata names are those specified by the Controlled Extension (CE) of NITF V2.1 (direct model). The coefficients are arranged in the RPC00B order.

The RPC file provided the following functions:

- Direct analytic model (Image → Ground)
- Inverse analytic model (Ground → Image)

Each function is estimated for the whole image (Global). In some cases, several subset functions (partial) are added for a better accuracy.

RPC is a generalized analytic model independent of the sensor data handling by the most current software. Users needing the highest level of accuracy (estimation greater than 3rd degree polynomial, block adjustment...) **should prefer the rigorous sensor model.**

The specific metadata are in the following DIMAP groups:

Direct_Model	Rational function polynomial coefficients from image to ground
Inverse_Model	Rational function polynomial coefficients from ground to image
Global_RFM	Global Model defining the best fit model to the whole dataset, as delimited by the RFM Validity
Partial_RFM	Partial Model(s) defining the best fit model to a dataset subset, as delimited by the RFM Validity Domain.

TABLE 19: RPC METADATA FILE

A.2.2.3 World File

IMG_<Product_ID>_RiCj.J2W/TFW: file encoding = ASCII, metadata format = ESRI

ESRI World File is a popular way for geographic information systems to reference the image in the image Ground Coordinate Reference System (CRS). For details, users can refer to ESRI ArcGIS documentation. (See help.arcgis.com/en/arcgisdesktop/10.0/help/index.html#//009t00000028000000.htm or refer to the georeferencing section).

The J2W is the file extension of JPEG 2000 raster format. The TFW is the file extension of (Geo)TIFF raster format.

For Primary products the affine transformation parameters are given on WGS84 and can provide only a rough ground location. As the scale and rotation terms are not set to zero, the user should be aware that the data displayed may only be supported by software having the capability to perform on-the-fly or pre-computed resampling.

A.2.2.4 KMZ File

PREVIEW_<Product_ID>.KMZ: file encoding = ZIP, metadata format = KML V2.2

The KML fulfills the KML specification with the Google extension namespace. The Google extension is selected for advanced objects in KML. As specified by the OGC, these specific tags must be ignored by a KML parser based on the standard version V2.2.

The KML file is zipped with the associated PREVIEW image into a KMZ file for independent distribution such as e-mail or web server.

The KML file is composed of six layers of features displayed or selected by double-clicking on the viewer. The places panel may be helpful to arrange hierarchically or expand the features. These layers provide a preview of features positioning. The associated place marks are textual information brought into DIMAP and GML mask files. The different layers are the following:

Start Animation	A quick animation activated by double-clicking on the layer from the satellite to the dataset footprint (Viewer supporting Google extension)
Sources	The acquisition extent of source strip(s) and acquisition scan line positioning at the middle of the extract for the current product
Sources Extracts	The outline extract(s) performed by the data production system for the current product
Tiles	The footprint of each image tile with its media identifier
Product	The footprint of the whole product (order polygon) and its PREVIEW image
Logos Layer	

TABLE 20: KML METADATA FILE

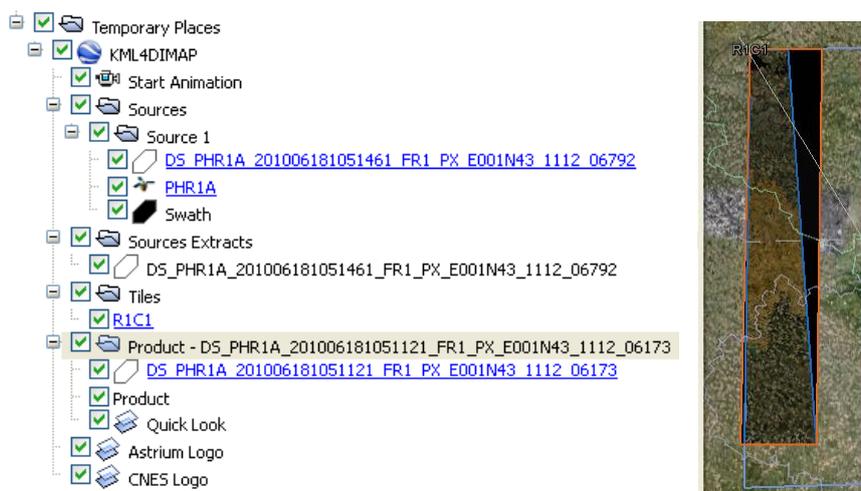


FIGURE 31: KMZ OVERVIEW

APPENDIX A: File Format – DIMAP V2

Note: KML figures are provided for preview or discovering purposes only. For exact positioning, please refer to the metadata information. The reason is KML features are not necessarily located at the true Ground Surface, but positioning with the following conventions:

- Sources - the source strip extent(s) at a mean elevation value over the complete strip area, using a rigorous model.
- Source extracts - the outline extract(s) at a mean elevation value over the complete extract area, using a simplified location model.
- Tiles - the footprint of each tile is positioned:
 - For Primary products, at a mean elevation value over the area of each individual tile. According to the relief, this elevation value may vary from tile to tile.
 - For Ortho products, at Ground surface, according to planimetric accuracy of the product.
- Product - the footprint of the product is positioned:
 - For Primary products, at the elevation values given at each vertex by the system DEM (possibly coarse).
 - For Ortho products, at Ground surface, according to planimetric accuracy of the product.

For products with a significant acquisition angle and/or on significant relief, some misalignments between KML features may occur, especially with Primary products. In Google Earth, we recommend to deactivate the "Show terrain" option to avoid incorrect mapping.

A.2.2.5 Preview Raster File

PREVIEW_<Product_ID>.JPG: file format = JPEG

The sub-sampled image (also called a quicklook), is compressed and dynamically stretched (by default 2%). Typically, the PREVIEW image is sub-sampled by a ratio of 32 towards the original image sampling (8 towards XS), i.e. approximately 22 m.

A.2.2.6 Thumbnail Raster File

ICON_<Product_ID>.JPG: file format = JPEG

This is the thumbnail of the image. The ICON image is sub-scaled from the PREVIEW image to fit a fixed size of 128 columns.

A.2.3 Sub-Levels With Additional Information

A.2.3.1 The Lineage Sub-Level

LINEAGE

The lineage directory deals with information about the processing history. It gathers files from the initial source data used to process the current product and also a processing metadata file.

A.2.3.1.1 Data Strip Source Metadata File

STRIP_<DATA_STRIP_ID>_DIM.XML: file encoding = XML, metadata format = DIMAP V2

The data strip file relates to the full imagery strip used to generate the product. It is generally a variable portion extracted from a strip, given by the order polygon. For mosaic products resulting from the mosaicking of several input strips, extracts of each original data strip file are provided.

The information contained in data strip files relates to their processing level before the extraction of the product. As this processing level (Archive, L1...) is prior to the final product processing level, the content must be used for information use only or some raw data assessment by expert.

The specific metadata are in the following DIMAP groups:

Strip_Identification	Brief identification of the strip, the mission and the instrument
Acquisition_Configuration	Configuration information and specific data about the spacecraft, its subsystems and instruments at strip acquisition
Telemetry_Acquisition	Downlink and receiving information
Raster_Data	Raster file extracted from the original imagery strip
Radiometric_Data	Erroneous data into the original data strip. Mosaic product only: radiometric data related to the input strip extract -- dynamic range, histogram, radiometric calibration values for spectral range, solar irradiance
Geometric_Data	Acquisition time and date of the full strip Mosaic product only: pre-computed, useful, geometric location data at a fixed posting related to the input strip extract -- acquisition angles, solar incidence, ground sample distances
Catalog	Coordinate of the strip as stored in the catalog system

TABLE 21: DATASTRIP SOURCE METADATA FILE

A.2.3.1.2 Ground Source Metadata File

GROUND_R3D_OR_<Ref3D_Tile_ID>_DIM: file encoding = XML, metadata format = DIMAP V2

The ground source file describes the quality of the planimetric source data used at orthorectification to reset the native location of the image, if requested when placing the imagery order. This file is not supplied for Primary products nor products with no reset applied (native location of the sensor data).

For Standard Ortho products, the location reset is performed on the Reference3D™ database orthorectified layer, organized by square degree. For each tile used for the processing, the file stores the tile identifier and its accuracy values. The specific metadata are in the following DIMAP groups:

Source_Information	Name of the source data
Source_Content	Source data identifier
Quality_Assessment	Accuracy measurements (specification values)

TABLE 22: GROUND SOURCE METADATA FILE

A.2.3.1.3 Height Source Metadata File

HEIGHT_{R3D_DT2_<Ref3D_Tile_ID>, SRTM_DT1, GLOBE}_DIM.XML: file encoding = XML, metadata format = DIMAP V2

The height source file describes the quality of the elevation source data used at orthorectification to reset the off-nadir effects of the image caused by the relief in the orthorectification process.

For Standard Ortho products, the location reset is performed on the Reference3D™ database DTED2 layer. If Reference3D is unavailable, SRTM DTED1 is used, and if SRTM is unavailable, the location reset is done on the global DTED0 DEM. For each tile used for the processing, the file stores the tile identifier and its accuracy values.

DIMAP groups: same as Ground Source metadata file.

A.2.3.1.4 Processing Metadata File

PROCESSING_<Product_ID>_DIM: file encoding = XML, metadata format = DIMAP V2

The processing file describes the processing steps and the ground image processing parameters (GIPP) files activated during the process from the archiving system to standard level production. Downstream steps might not be documented. The specific metadata are in the following DIMAP groups:

Processing_Step_List	Significant processes or events occurring during the dataset production
Processing_Parameter_List	Significant ground image processing parameters applied at dataset production

TABLE 23: PROCESSING METADATA FILE

A.2.3.2 The Mask Sub-level

MASKS

The mask directory contains the overlaying masks delivered with the product in vector or raster format.

A.2.3.2.1 Mask Files

{ROI, CLD, SNW, QTE, DET, SLT, VIS, DTM}_<Product_ID>_MSK.GML: file encoding = XML, metadata format = GML V3.1.1

GML vector masks are available for standard products. They are registered with the image product (same geometry and CRS) for overlaying purposes. They include:

- Masks related to an ordering parameter: cloud cover (CLD), snow indicator (SNW), technical quality rate (QTE).
- Masks built by the data process:

- Product footprint (ROI, Region Of Interest - one per strip extract for mosaics, i.e. the intersection between the global ROI and each strip)
- Image quality masks: out of order detectors (DET), saturation or straylight (SLT), hidden areas (VIS, visibility).

A.3 Metadata Contents and Organization

The metadata are encoded in DIMAP format using XML scheme. DIMAP is a public-domain format for describing geographic data, developed in partnership with space agencies like CNES, SSC and ESA. The format was introduced in May 2002 for SPOT products. The format has been improved in 2012 with DIMAP V2. DIMAP V2 is the standard used by Astrium GEO-Information Services for Pléiades 1A, Pléiades 1B, SPOT 6 and SPOT 7 products and other Ortho imagery.

For an overview of the main improvements brought by DIMAP V2 compared to DIMAP, please refer to part 2.4.

A.4 Image Format

Products are available in two raster formats:

- TIFF (including GeoTIFF)
- JPEG 2000

The file sizing is managed by image tiling. Both formats offer dynamic range (also called bit-depth or radiometric resolution) of 12 bits (4096 values) or 8 bits (256 values). The original 4096 scale into a 256 scale is performed with a linear adjustment. The original 4096-bit scale could be recovered with the DIMAP group `Dynamic_Adjustment` (MIN, MAX, BIAS, SLOPE).

A.4.1 JPEG 2000

The CODEC uses Part I of the JPEG 2000 standard, ISO/IEC 15444-1, plus some options of Part II. Using the Kakadu Library, settings should be expressed as (informative):

```
Sdims={4000,4000} -flush_period 2048 Stiles={2048,2048} Ssigned=no Sprecision=16 Cycc=yes
Creversible=yes Qstep=0.000015 Cblk={64,64} Clevels=5 Cuse_precincts=yes
Cprecincts={256,256},{256,256},{128,128},{128,128},{64,64} Corder=RPCL ORGgen_plt=yes -
no_weights -rate 9 Clayers=5.
```

Two compression schemes are available:

- JPEG 2000 Optimized is meant for people looking for fast download and easy data sharing. It has a compression of 3.5 bits/pixel. It uses the so-called lossy compression: the compression rate is optimized to avoid any spatial effect but is not reversible. A spectral effect of 1/1000 is tolerated.
- JPEG 2000 Regular is perfect for users willing to do some high precision post-processing. It has a compression of around 8 bits/pixel. It uses the so-called lossless compression: the JPEG 2000

APPENDIX A: File Format – DIMAP V2

compression is in this case completely reversible and does not include any effects in terms of information content.

- Both JPEG 2000 compressions ensure no impact in terms of image quality; however, they have a direct impact on the file size. The Regular compression file size is about twice as large as the Optimized compression file size.

A.4.2 TIFF

The file is coded according to the TIFF V1.0 specification. The 32-bit offset capability (4 GB) like BigTIFF is not used. The TIFF requires huge file sizes compared to JPEG 2000, as TIFF is not a compressed format and the 12-bit dynamic range is coded over 2 bytes (16 bits).

A.4.3 Image Tiling

Products exceeding a certain size limit are broken in several image pieces, called physical tiles. This limit is approximately:

- 2 GB file size for GeoTIFF products
- Max. 4 GB file size for JPEG 2000

In the future, this limit could change as software capabilities progress.

The physical tiling is based on an orthonormal regular grid (as a matrix): y-axis for each row (Ri) and x-axis for each column (Cj) of the grid.

The tile size is constant, meaning all tiles have the same size, with a possible exception of the tiles in the last rows and columns, as black fill pixels are not included to fill the constant size.

- The tiles of the first row begin at the upper and left borders of the bounding rectangle of the AOI
- The tiles of the last row and column are trimmed to the bottom and right borders of the bounding rectangle of the AOI
- Tiles are not overlapping

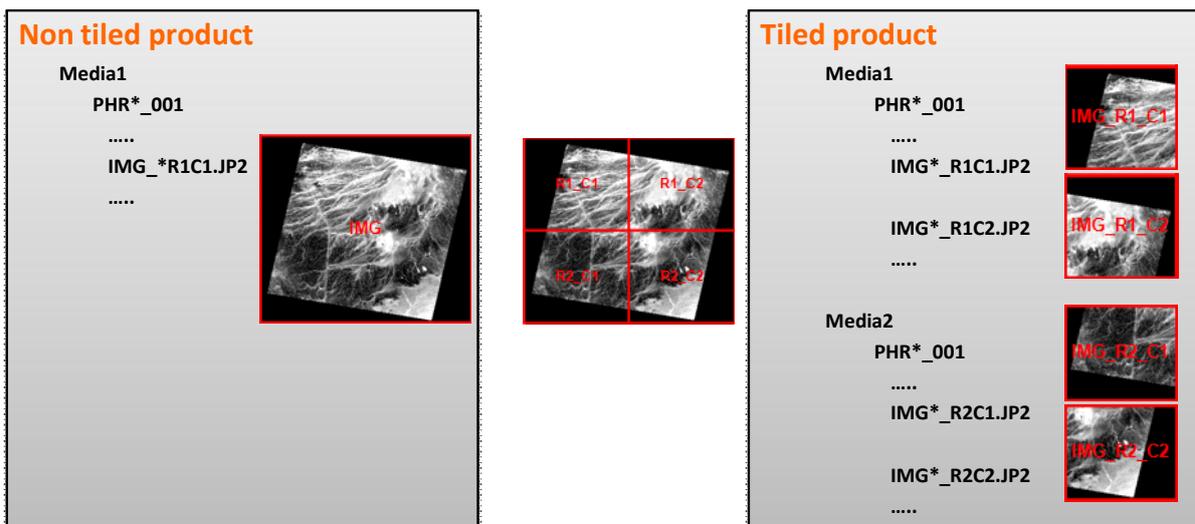


FIGURE 32: TILING

The product metadata file describes:

- The tiling characteristic for the full product (Raster_Data/Raster_Dimensions)
- The list of all tiled images composing the product (Raster_Data/Raster_Access)

The Index metadata file (multi-volume) describes the distribution of tile images within one or several media.

A.5 Available Geographic and Cartographic Projections

Astrium GEO-Information Services offers orthorectification in nearly any geodetic parameters and National Mapping System registered in the EPSG database.

A.5.1 Geographic Projections

A Geographic projection is a simple mapping projection based on a geodetic datum and ellipsoid model of the Earth to convert the coordinates to a planar system as angular coordinates.

Astrium's geographic projections are related to WGS84 geodetic datum/ellipsoid in decimal degree angular unit. The pixels are regularly posted in latitude/longitude according to the two following zoned systems:

- DTED2: 5 zones: [0° to 50°], [50° to 70°], [70° to 75°], [75° to 80°], [80° to 90°] North or South latitude
- ARC: 8 zones: [0° to 32°], [32° to 48°], [48° to 56°], [56° to 64°], [64° to 68°], [68° to 72°], [72° to 76°], [76° to 80°] North or South latitude

A.5.2 Mapping Projections

A mapping projection is based on a geodetic Coordinate Reference System (CRS) and uses a map projection model to convert the coordinates to a horizontal plane as Cartesian linear coordinates.

Astrium's mapping projections are related to National Mapping Agencies or International Authorities. The default parameter values are those registered in EPSG. The linear unit is the meter.

Some six hundred CRS mapping projections are offered for Standard Ortho Products. Others are available for Tailored Ortho Products. Please ask Customer Care Service for availability. The CRS should use one of the following map projection models.

Map Projections
Albers Equal Area
American Polyconic
Azimuthal Equivalent
Azimuthal Equidistant
Bonne
Cassini-Soldner

Map Projections
Hotine Oblique Mercator
Laborde Oblique Mercator
Lambert Conic Conformal (1SP)
Lambert Conic Conformal (2SP)
Mercator (1SP)
Mercator (2SP)
Oblique Mercator
Transverse Mercator
Transverse Mercator (South Oriented)
Mollweide
Oblique Stereographic
Polar Stereographic

TABLE 24: MAP PROJECTIONS

A.6 How to Georeference the Image

The product offers various ways to georeference the image. The following table gives the corresponding fields, if relevant:

DIMAP	TIFF/GeoTIFF	JPEG 2000/GMLJP2	World File
NCOLS	ImageWidth	gml:high ⁽¹⁾	n/a
NROWS	ImageLength	gml:high ⁽¹⁾	n/a
NBITS	BitsPerSample	In Jp2h :ihdr	n/a
NBANDS	SamplesPerPixel	In Jp2h :ihdr	n/a
XDIM / YDIM	ModelPixelScaleTag	gml:offsetVector ⁽²⁾	A / E
ULXMAP/ULYMAP	ModelPixelScaleTag	gml:pos	C / F
Projected_CRS or Geodetic_CRS	GTModelTypeGeoKey		n/a
PROJECTED_CRS_CODE	ProjectedCSTypeGeoKey	attribut SrsName	n/a
PROJECTED_CRS_NAME	PCSCitationGeokey		n/a
GeoDETTIC_CRS_CODE	GeographicTypeGeoKey	attribut SrsName	n/a

DIMAP	TIFF/GeoTIFF	JPEG 2000/GMLJP2	World File
GeoDETIC_CRS_NAME	GeoCitationGeokey		n/a
VERTICAL_CRS_NAME	VerticalCitationGeoKey		n/a
VERTICAL_CRS_CODE	n/a		n/a

(1) GML: counting from 0 (gml:high = NROWS-1 NCOLS-1); DIMAP & GeoTIFF: counting from 1 -- (2) GML: offset; DIMAP & GeoTIFF: dimension

TABLE 25: GEOREFERENCING

A.6.1 GMLJP2

The GMLJP2 header is stored in the XML box embedded in the JPEG 2000 file according to the OGC V1.0 Specification (OGC-05-047r3): JPEG 2000 Part I (XML BOX) and II (label BOX and association BOX).

- Primary products: the image is in raw geometry, header does not have any geocoding information and uses a simple Grid feature scheme.
- Ortho products: the header uses the RectifiedGrid feature type scheme (grids.xsd)
 - Upper left pixel as the location origin and a vector that specify the posting locations into the image. Axes are ordered in conformity with EPSG standard. For instance, WGS84 geographic projection (EPSG: 4326) axis 1=Geodetic latitude, axis 2=Geodetic longitude (y then x). Most software packages manage this automatically using a lon/lat order (x then y) by default.
 - Coordinate Reference System (CRS) encoding in conformance with the EPSG standard.

A.6.2 GeoTIFF Tags

The GeoTIFF tags are embedded in the TIFF file, according to the GeoTIFF V1.0 Specification:

- Primary products: the image is in raw geometry, no GeoTIFF information
- Ortho products:
 - Upper left pixel as the location origin and a dimension for sizing the pixel
 - Coordinate Reference System (CRS) encoding in conformance with the EPSG standard (if unknown "user-defined" encoding)

A.6.3 World File

Georeferencing with world file is accurate if the image is in map geometry (Ortho), but rough if the image is in sensor geometry (Primary). For accurate georeferencing, refer to the RPC metadata file or the geometric modeling section.

One World File is associated with each image tile. It describes the georeferencing through an affine transformation. The six parameters of the affine transformation are in the form:

$$x1 = Ax + By + C$$

$$y1 = Dx + Ey + F$$

Where: x1 = calculated x-coordinate of the pixel on the Ground CRS
 y1 = calculated y-coordinate of the pixel on the Ground CRS

APPENDIX A: File Format – DIMAP V2

- x = column number of a pixel in the image
- y = row number of a pixel in the image
- A = x-scale; dimension of a pixel in CRS units in x direction (XDIM)
- B, D = rotation terms
- C, F = translation terms; x, y CRS coordinates of the center of the upper left pixel (UL{X,Y}MAP)
- E = negative of y-scale; dimension of a pixel in CRS units in y direction (YDIM)

For the Ortho product, the CRS is the one formatted with the product. For the Primary product (sensor geometry) the CRS is WGS84.

The y-scale (E) is negative because the origins of an image and a Ground coordinate system are different. Row values in the image increase from the origin downward, while y-coordinate values in the map increase from the origin upward.

The rotation terms B and D are:

- Zero value if the image is in Map geometry: Ortho-image and Mosaic
- Other than zero, if the image is in sensor geometry. In that case, they are computed from the (lat, long) coordinates of the global image corners provided in the metadata

The translation terms C and F, for tiled images, are the location of the center of the upper left pixel for each tile:

- At Ground surface, according to planimetric accuracy, if the image is in map geometry: Ortho-image and Mosaic
- At a mean elevation value over the area of each individual tile, if the image is in sensor geometry. According to the relief, this elevation value may vary from tile to tile

The World File is an ASCII file containing six lines, giving the six parameters in the following order (one per line):

Parameter	Example
A	20.17541308822119
D	0.0000000000000000
B	0.0000000000000000
E	-20.17541308822119
C	424178.11472601280548
F	4313415.90726399607956

TABLE 26: WORLDFILE

APPENDIX B: IMAGE QUALITY AND RESAMPLING PROCESS

B.1 Design Specification vs. Performances

The following table gives Image Quality performances (measured in October 2012) significant for the user. They are compared with the original design specification of the Pléiades satellites.

The measurements are expressed as:

- Geometry - inside the cone of 30° around nadir
- Radiometry - at nearly 100 W/m²/sr/microns (L2)
- Resolution - no sampling factor. Bpp= 2.86 for Pan and 3.33 for MS

Abbreviations: MTF: Modulation Transfer Function; SNR: Signal to Noise Ratio; IQF: Image Quality Factor; bpp: bit per pixel.

MTF/SNR: Satellite = RAW data; Restored = after Ground denoising and deconvolution

Image Quality Item	Design Specification	Up-to-Date Performance	Remark
GEOMETRY (Global)			
Pointing Accuracy (satellite tasking)	Across track: 500m LE99.7 Along track: 1000m LE99.7	320m CE99.7	
Dynamic Effect (high frequency jittering)	0.8 pixel Pan LE99.7	0.1 pixel Pan LE99.7	
GEOMETRY (Rigorous Geometric Model accuracy without GCP: all products)			
Location Accuracy	12m CE90 24m CE99.7	8.5m CE90 @ Nadir 10.5m within 30°	With refined attitudes
Length Distortion	0.5ppm CE90	0.31ppm CE90	Between 2 points distant of 1000 pixels Panchromatic
MS Registration	0.25 pixel MS CE90	0.18 pixel MS CE99.7	
MS and Pan Co-registration	0.5 pixel MS CE90	0.22 pixel MS CE99.7	
Global RPC Discrepancy vs. Rigorous Model	-	0.3 pixel PAN CE90	
GEOMETRY (Rigorous Geometric Model accuracy reset on (perfect) GCP and DEM)			
Planimetric Accuracy (Panchromatic)	0.5m CE90	0.30m CE90	
Planimetric Accuracy (Multispectral)	0.5m CE90	0.43m CE90	

APPENDIX B: Image Quality and Resampling Process

Image Quality Item	Design Specification	Up-to-Date Performance	Remark
Vertical Accuracy B/H=0.6 (absolute error)	1m	0.46m LE66 0.86m LE99.7	
Vertical Accuracy B/H=0.25 (absolute error)	3m	0.7m LE66 1.4m LE99.7	
RADIOMETRY (Radiometric Model accuracy (DN conversion to Radiance) known accuracy performance with pre-launch measurement)			
Absolute Calibration	>20%	Panchromatic: 5% Blue/Green: 10% Red/NIR: 5%	
Relative Cross-band Calibration	>10%	5%	
Relative Multi-temporal Calibration	>10%	5%	
RESOLUTION			
Satellite MTF (X/Y axis): Panchromatic	Pan: 0.08/0.08	Pan: 0.15/0.155	
Satellite SNR: Panchromatic	Pan: 90	Pan: 159	
IQF (MTF x SNR): Panchromatic	Pan: 7	Pan: 23.8/24.6	
Restored MTF (target): Panchromatic	0.2	0.26	
Satellite MTF (X/Y axis): Multispectral	Blue: 0.2/0.2 Green: 0.2/0.2 Red: 0.2/0.2 NIR: 0.2/0.2	Blue: 0.33/0.28 Green: 0.33/0.27 Red: 0.33/0.25 NIR: 0.33/0.26	
Satellite SNR: Multispectral	Blue: 90 Green: 90 Red: 90 NIR: 90	Blue: 158 Green: 152 Red: 153 NIR: 190	
IQF (MTF x SNR): Multispectral	Blue: 18/18 Green: 18/18 Red: 18/18 NIR: 18/18	Blue: 52.1/44.2 Green: 50.2/41 Red: 50.5/38.2 NIR: 62.7/49.4	

TABLE 27: SPECIFICATIONS AND PERFORMANCES

B.2 Principle of Image Resampling

B.2.1 Introduction

CCD arrays working in Time Delay Integration (TDI) mode are used for Panchromatic detection. To acquire images over a field of view of 20 km, five arrays of 6000 pixels each are used, which give 30,000 columns.

The choice of TDI technology allows images to be obtained with a SNR that meets the system specifications.

Panchromatic images are acquired with a nadir resolution of 70 cm. Products prepared for users will be resampled to correct geometric distortions related to:

- The instrument and the platform motion (Primary)
- The terrain relief (Ortho)

The impact of the resampling on the image quality is carefully considered. The interpolation filter must guarantee that the information content of the raw image quality is preserved. Moreover, users often apply further processing on system products, and consequently resample the image. It is therefore important to generate system products (Primary or Ortho), robust with regard to further processing.

To satisfy the two above-mentioned criteria, the optimal solution chosen by CNES, and demonstrated through experimentation, consists of applying a zooming factor, leading to a sampling distance of 50 cm. This zooming enhancement is effective thanks to a specific restoration method, developed and validated by CNES.

B.2.2 Why 50 cm?

B.2.2.1 Accessible Spatial Frequencies

Pléiades raw images are sampled in a way (70 cm) which is consistent with the value of the instrument MTF, at Nyquist frequency. Consequently, they are free of aliasing artifacts. However, higher spatial frequencies than the Nyquist frequency (line or column) do exist within the image. Finer details correspond to contours and modulations at +/- 45° with respect to raw lines and columns, as shown in the following schema:

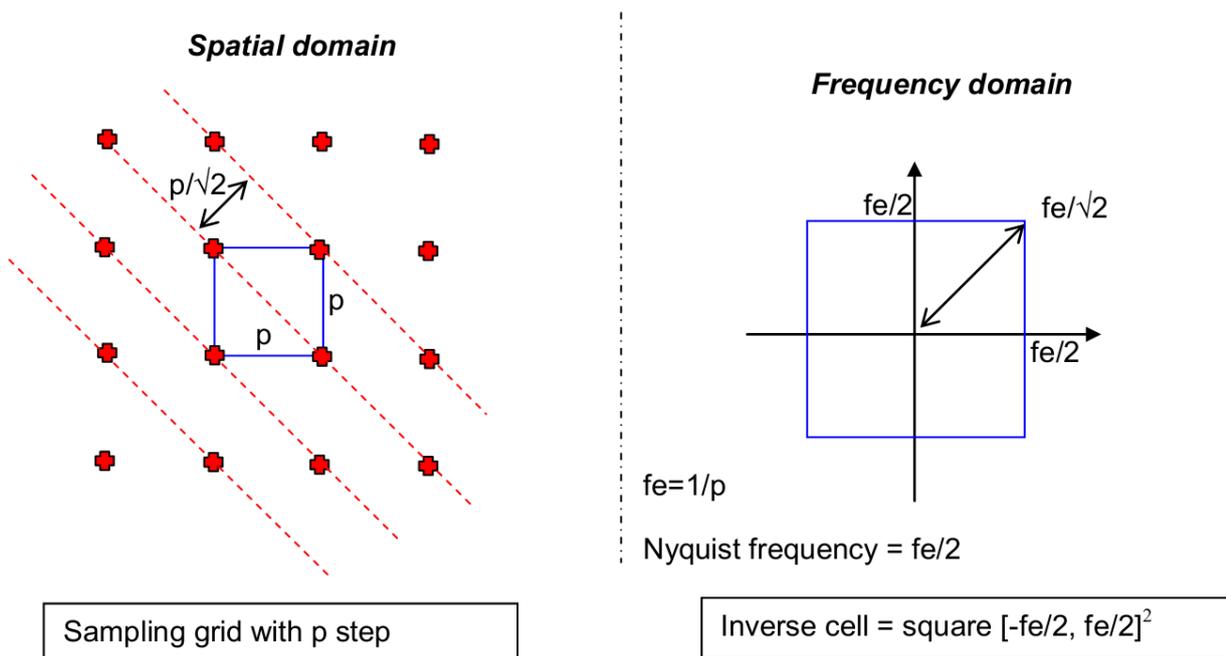


FIGURE 33: SPATIAL DOMAIN VS. FREQUENCY DOMAIN

APPENDIX B: Image Quality and Resampling Process

It is therefore possible to identify on Pléiades images details rotated by 45°, corresponding to $\frac{f_e}{\sqrt{2}}$ spatial frequency, i.e. 1m^{-1} for nadir viewing. This kind of object is quite common in industrial areas (networks, linear structures). More generally, "diagonal" patterns are rendered thinner than vertical or horizontal patterns.

The following image is extracted from a Panchromatic Pléiades image, including a radial pattern. It illustrates the resolution variation along different directions.

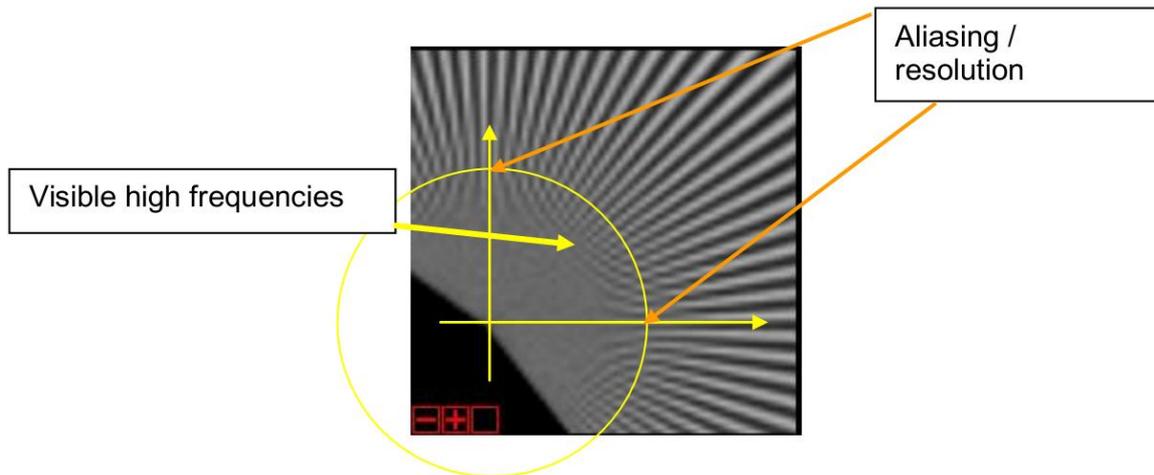


FIGURE 34: ISO-FREQUENCY LINE

The yellow circle describes an iso-frequency line: on line and column axis, the pattern disappears quickly inside the circle, and is still visible around the diagonal direction (45°).

B.2.2.2 Restoration of the Panchromatic Band

The restoration processing includes deconvolution and noise removal. The raw Panchromatic image must be deconvoluted to compensate for the contrast reduction (Instrument MTF). This process is followed by a noise removal step. The noise filtering technique is used to control the level of white noise (column noise) at processing output. This restoration processing is followed by the application of a zooming factor on the Panchromatic band at the end of this process.

B.2.3 Zooming Before Interpolation

To preserve the raw image contents, it must be possible to rotate the inverse cell within the extended frequency domain. The zooming factor to be applied to the raw image is therefore 1.414 (7/5), which gives a sampling distance of 50 cm for Panchromatic Pléiades images.

In these conditions, the raw image spectrum is always included within the final inverse cell, for any rotation applied on the image during further processing. The 45° worst case scenario is shown on the following figure:

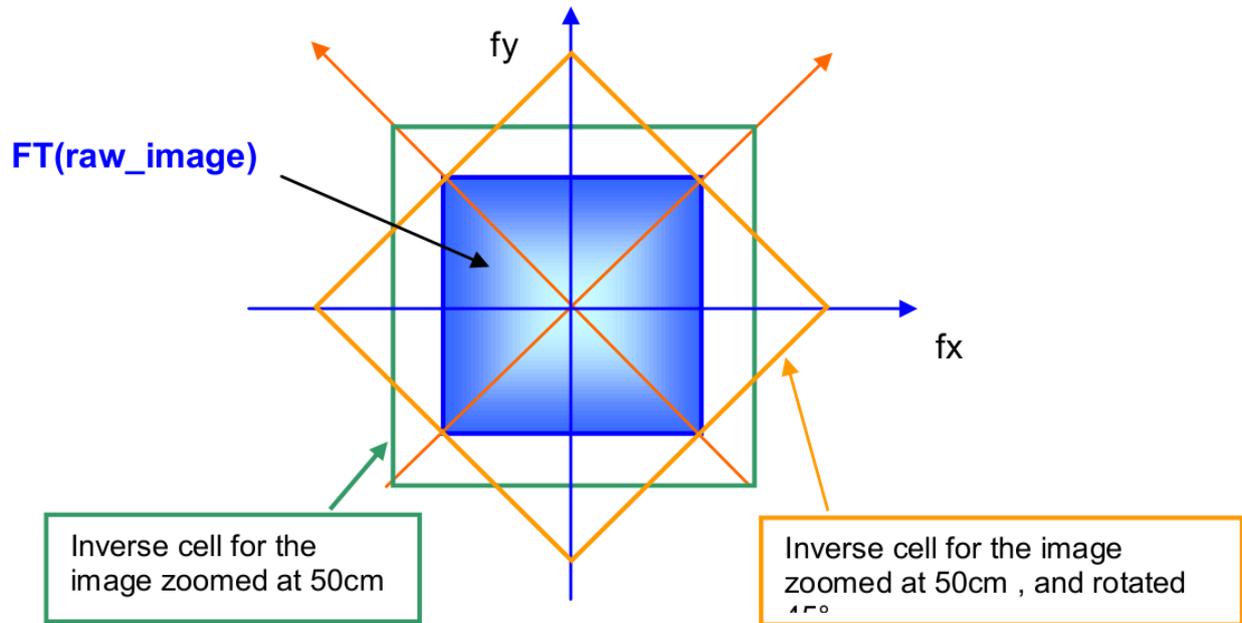
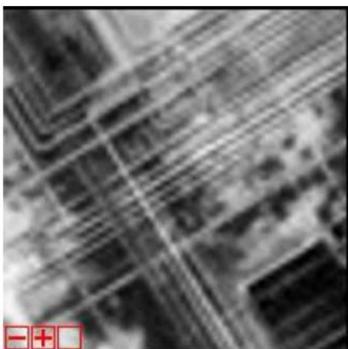


FIGURE 35: RAW IMAGE AND FINAL INVERSE CELL

Reminder: Zooming an image does not bring extra information. In the frequency domain, it means that in the inverse cell of the 50 cm image, only the $[-1/(2*0.7) \text{ m}^{-1}, 1/(2*0.7) \text{ m}^{-1}]^2$ frequency bandwidth contains information.



◀ Raw images, resampled at 70 cm

The improvement brought by zooming to 50 cm is clearly demonstrated on following extracts:

APPENDIX B: Image Quality and Resampling Process

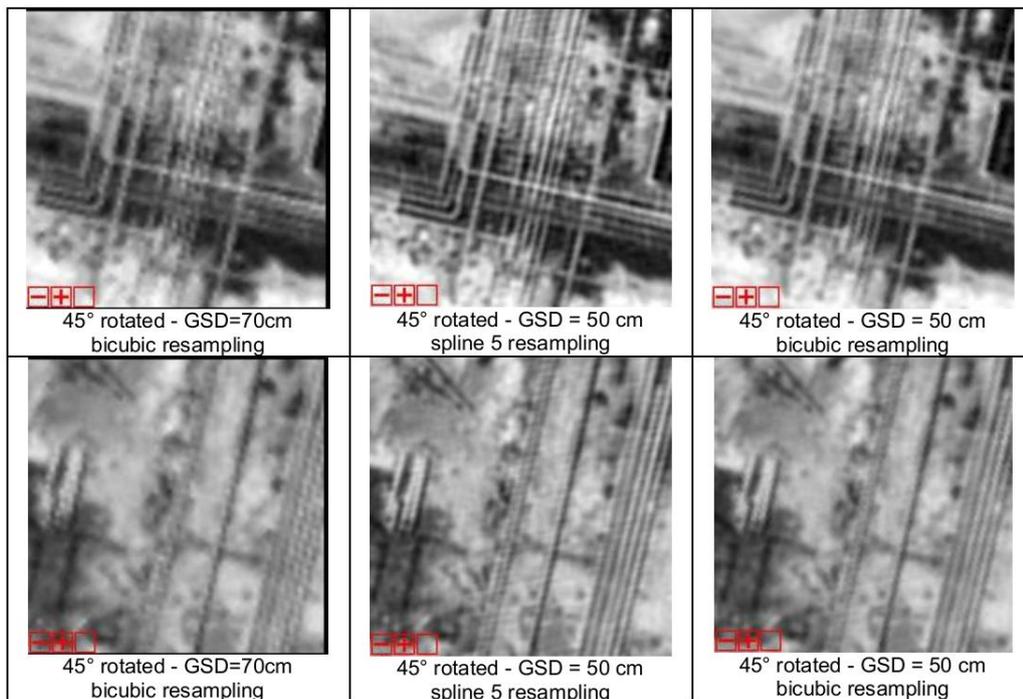


FIGURE 36: VISUAL ENHANCEMENTS ACHIEVED THANKS TO 50 CM RESAMPLING

The first column shows images, 45° rotated, sampled with a 70 cm GSD.

The 2 last columns show 50-cm resampled images and then 45° rotated, zoomed using a spline 5 filter (column 2). Column 3 shows the result of a bicubic filter.

The benefits of the 50 cm zooming are significant and have been confirmed through experiments, notably by Defense photo-interpreters:

- Images in the last two columns reflect a better image quality, in terms of information content
- Further downstream processing applied by users on 50 cm images maintains the image quality (robustness) and are not impacted by the type of interpolation used

APPENDIX C: GEOMETRIC MODELING

The aim of geometric modeling is to describe the relationship between image and ground coordinates for a given sensor.

C.1 Geometry

Pléiades raw products are very complex and not user-friendly, due in particular to the complexity of the detector layout in the focal plane. For instance, the Panchromatic raw focal plane is composed of five slightly angled arrays.

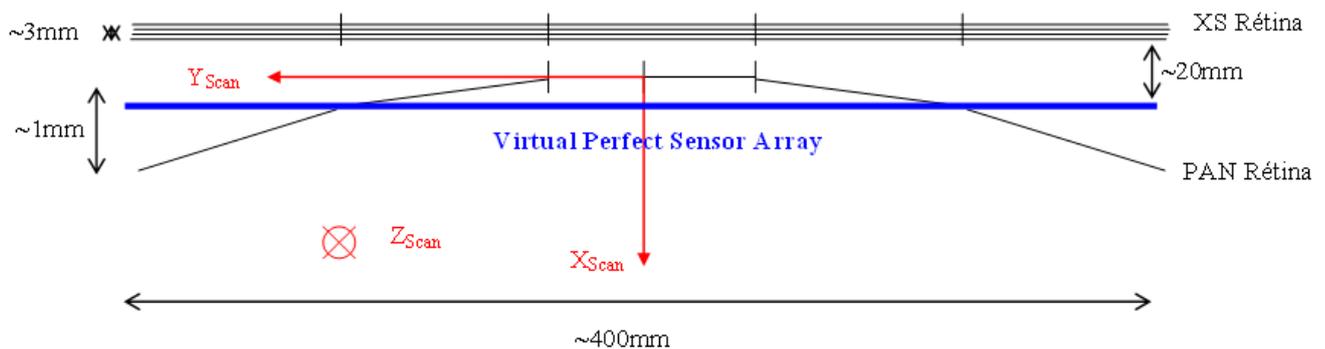


FIGURE 37: RAW FOCAL PLANE LAYOUT AND LOCATION OF PRIMARY VIRTUAL ARRAY

The Primary product has been designed to remove this complexity and offer end-users a simple product with state-of-the-art geometric and radiometric accuracy. Technically, the Primary processing is also called Sensor, Perfect Sensor or Virtual Sensor.

The geometric reference frame for Primary imagery simulates the imaging geometry of a single pushbroom linear array, located very close to the raw 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 altitude perturbations. This attitude variation correction (made with a polynomial fitting) allows for both simple attitude modeling and more accurate precision of the imaging geometry by the rational functions sensor model.

The Primary product GSD is related to the raw imagery resolution, which varies between 70 cm (at nadir) to ~1m (30° viewing angle) for Panchromatic products, and 2.8 m (at nadir) to ~4m (30° viewing angle) for Multispectral imagery (see Table 28). To ensure perfect radiometric accuracy and image restoration, the end product is zoomed with an optimized ratio of 5/7.

APPENDIX C: Geometric modeling

Global viewing angle from satellite $\alpha(^{\circ})$	PAN GSD (cm)	MS GSD (m)	SWATH (km) width	PAN GSD _c (cm)	MS GSD _c (m)	SWATH _c (km) width	GSD _c -GSD (cm)	GSD Error (%)
<i>Please refer to part C.4.1 for more details</i>	<i>Without taking into the rotundity of the Earth</i>			<i>Taking into the rotundity of the Earth</i>				
.	70	2.8	20.0	70	2.8	20.0	0.0	0%
5	70	2.8	20.0	70	2.8	20.0	0.1	0%
10	72	2.9	20.6	72	2.9	20.6	0.4	1%
15	75	3.0	21.4	76	3.0	21.7	0.9	1%
20	79	3.2	22.6	81	3.2	23.1	1.8	2%
25	85	3.4	24.3	88	3.5	25.1	3.3	4%
30	93	3.7	26.6	99	3.9	28.3	5.6	6%
35	104	4.2	29.7	114	4.5	32.6	9.6	8%
40	119	4.8	34.0	135	5.4	38.6	16.5	12%
45	140	5.6	40.0	169	6.8	48.3	29.5	17%
47	150	6.0	42.9	188	7.5	53.7	37.8	20%

TABLE 28: GSD VS. VIEWING ANGLE

Notes:

$GSD = h_{sat} \cdot \tan(\alpha + IFOV) - h_{sat} \cdot \tan(\alpha)$, without taking into account the rotundity of the Earth.

$$GSD_c = R_E \cdot \left[\frac{\left(1 + \frac{h_{sat}}{R_E}\right) \cdot \cos(\alpha)}{\sqrt{1 - \left(1 + \frac{h_{sat}}{R_E}\right)^2 \cdot \sin^2(\alpha)}} - 1 \right] \cdot IFOV, \text{ taking into account the rotundity of the Earth.}$$

With:

h_{sat} (km)	695
PAN IFOV (rad)	1.00E-06
MS IFOV (rad)	4.00E-06
Earth	
Semi-major axis (km)	6378.14
Semi-minor axis (km)	6356.75
R_E (km) (mean)	6367.45

C.2 Using the Physical Model for the Primary Products

Two reference frames are used in the physical model for Primary products: image focal plane frame and geocentric Earth frame.

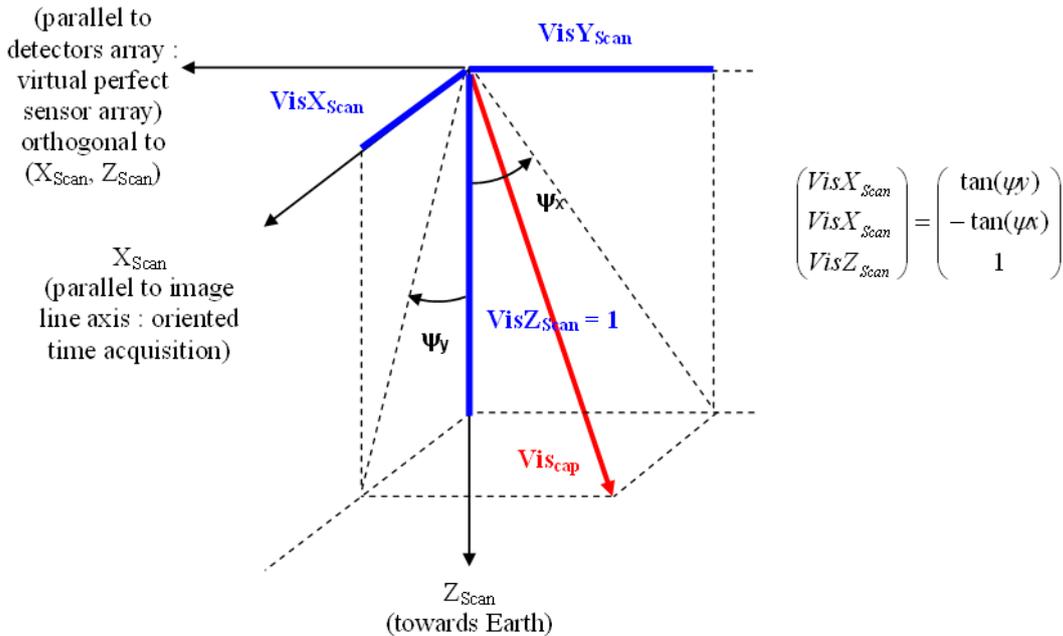


FIGURE 38: IMAGE FOCAL PLANE FRAME

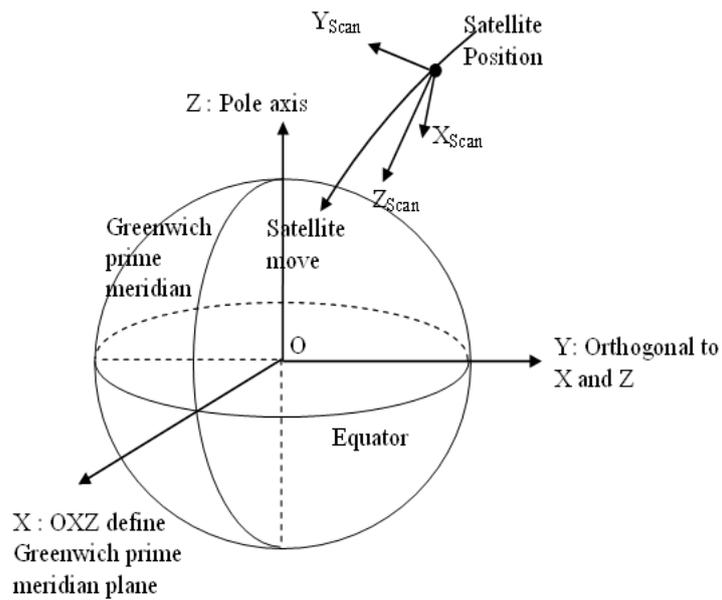


FIGURE 39: GEOCENTRIC EARTH FRAME (WGS84)

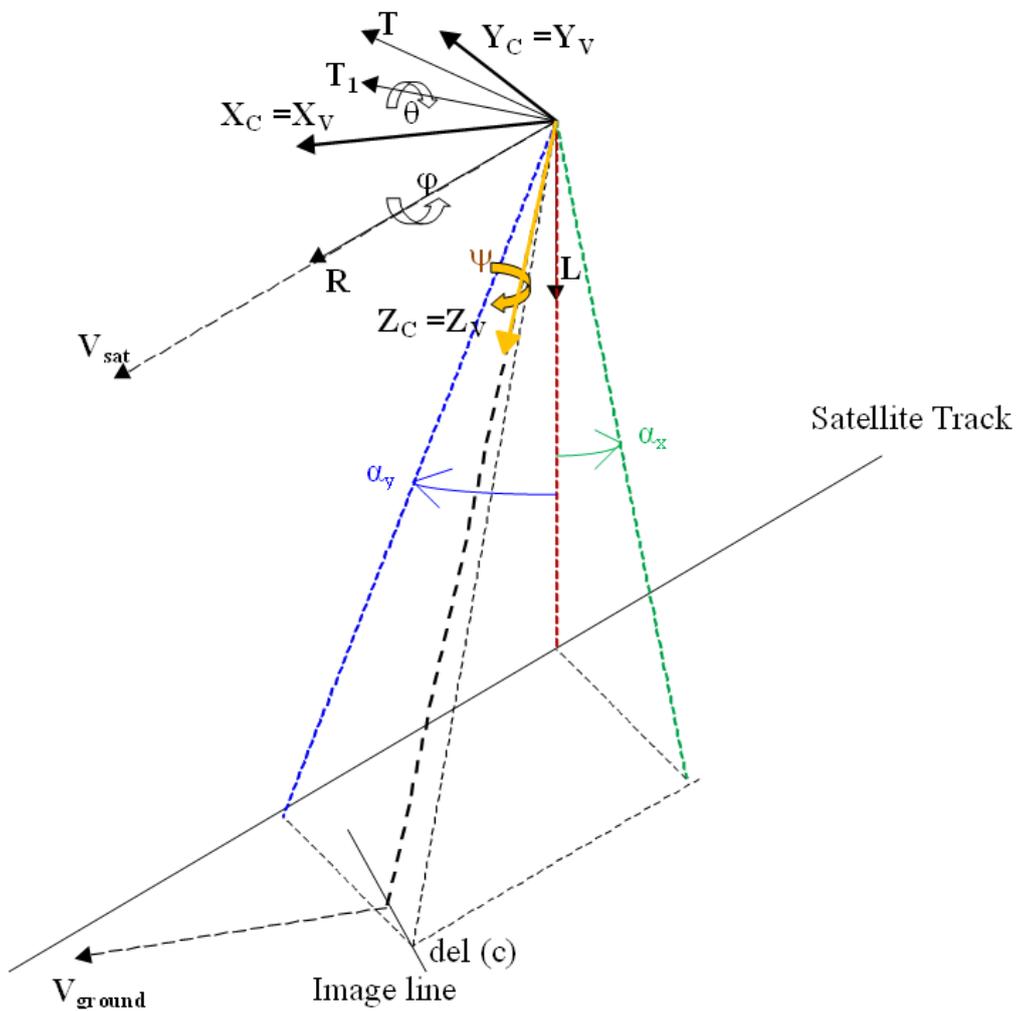


FIGURE 40: FRAMES SUMMARY

Notes:

- Image orientation and satellite track are different
- In case of Virtual Perfect Sensor Array, image focal plane frame (X_{Scan} , Y_{Scan} , Z_{Scan}) and frame to pilot (X_v , Y_v , Z_v) are identical
- A quaternion polynomial describes satellite attitude. At a given time, one can compute the quaternion and build directly the transformation matrix between image focal plane frame and geocentric earth frame (WGS84)
- All the data needed by the physical model is in the "DIM_*.XML" metadata file under the node <Refined_Model>
- All acquisitions times and dates are expressed in UTC
- All satellite locations are expressed in Cartesian coordinates (O, X, Y, Z) in the ECF frame WGS84
- In the dataset extent, ground coordinates are expressed in geographic coordinates (unit degrees)
- All of these coordinates are related to the WGS84 geodetic system

C.2.1 Direct Localization: Image to the Ground

Given image coordinates (col, lin) and altitude h, ground geographic coordinates (λ , φ) can be found by using physical model data. The ground coordinates may be calculated as followed:

Viewing time calculation for a given image line

$$t_{lin} = t_{ref} + period * (lin - lin_{ref})$$

Default value: $lin_{ref} = 1$

CALCULATION OF VIEWING ANGLE IN IMAGE FOCAL PLANE FRAME FOR A GIVEN COLUMN IMAGE (DETECTOR)

Apply the polynomial models:

$$TanPsiX = \sum_{i=0}^n CoeffPsiX_i * (col - col_{ref})^i$$

$$TanPsiY = \sum_{i=0}^n CoeffPsiY_i * (col - col_{ref})^i$$

Calculation of the viewing angle in the image focal plane frame:

$$\begin{pmatrix} VisX_{Scan} \\ VisY_{Scan} \\ VisZ_{Scan} \end{pmatrix} = \begin{pmatrix} TanPsiY \\ -TanPsiX \\ 1 \end{pmatrix}$$

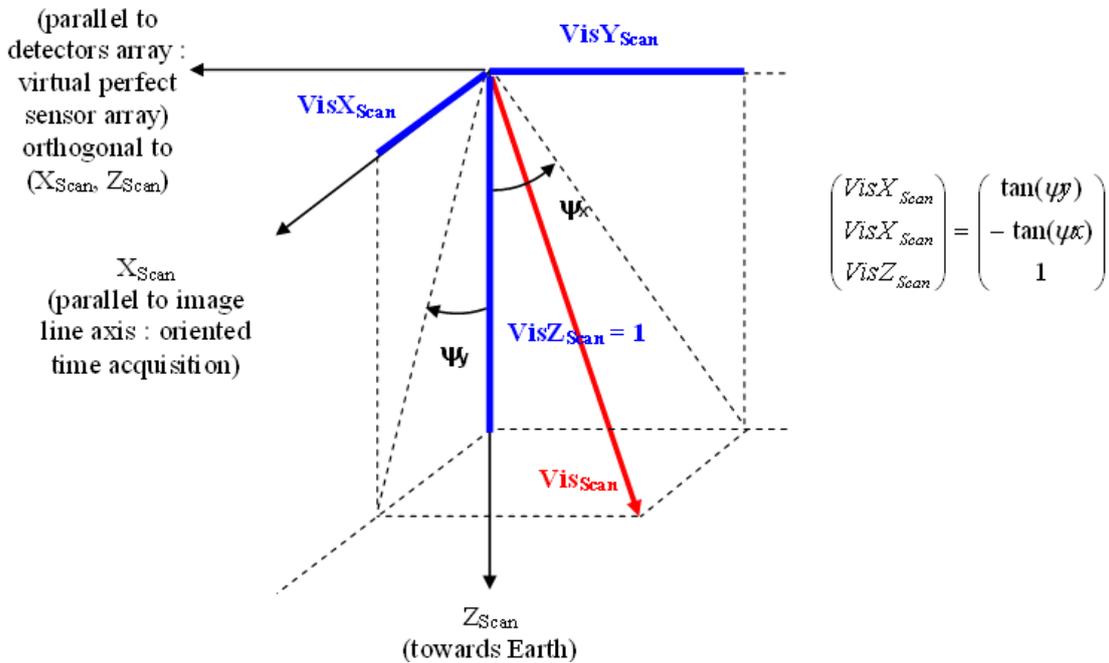


FIGURE 41: VIEWING ANGLE IN IMAGE FOCAL PLANE FRAME

APPENDIX C: Geometric modeling

SATELLITE LOCATION INTERPOLATION FOR A GIVEN TIME

It is recommended to center acquisition times and dates:

$$t_{mean} = \frac{\sum_{i=1}^m t_i}{m} \text{ and } trel_i = t_i - t_{mean}$$

Each satellite location component (PosX, PosY, PosZ), is calculated by Lagrange interpolation with n samples:

$$PosX(t) = \sum_{i=1}^n \frac{\prod_{j=1, j \neq i}^n (trel - trel_j)}{\prod_{j=1, j \neq i}^n (trel_i - trel_j)} * PosX(t_i)$$

Notes:

- n = 8 is recommended when time step between sample is 30 s.

The same formula is used to compute PosY(t) and PosZ(t).

In order to compute the viewing direction in the Earth geocentric frame, only the attitude quaternion is used (transformation between image focal plane frame and earth geocentric frame). Velocity data is not necessary for viewing direction orientation.

Velocity is used when the user would like to improve the model (computation of Orbital Local Frame Axis which needs satellite inertial velocity in WGS84 ECF frame).

SATELLITE ORIENTATION INTERPOLATION FOR A GIVEN TIME

Centered normalized time value calculation:

$$t_{CN} = \frac{(t - offset)}{scale}$$

With: "offset" = the UT time (in number of seconds from midnight) of the middle of image acquisition.

Apply polynomials for each quaternion component -- Q0, Q1, Q2, and Q3:

$$Q0 = \sum_{i=0}^n CoeffQ0_i * t_{CN}^i$$

Same formula is used for Q1, Q2, and Q3.

ATTITUDE QUATERNION NORMALIZATION AND TRANSFER MATRIX CALCULATION BETWEEN IMAGE FOCAL PLANE FRAME AND GEOCENTRIC EARTH FRAME

Quaternion normalization:

$$norme = \sqrt{Q0^2 + Q1^2 + Q2^2 + Q3^2}$$

$$\begin{pmatrix} w \\ x \\ y \\ z \end{pmatrix} = \begin{pmatrix} \frac{Q0}{norme} \\ \frac{Q1}{norme} \\ \frac{Q2}{norme} \\ \frac{Q3}{norme} \end{pmatrix}$$

Transformation matrix calculation between the image focal plane frame and the geocentric Earth frame:

$$Mat_{PF \rightarrow Ter} = \begin{pmatrix} w^2 + x^2 - y^2 - z^2 & 2.(x * y - w * z) & 2.(x * z + w * y) \\ 2.(x * y + w * z) & w^2 - x^2 + y^2 - z^2 & 2.(y * z - w * x) \\ 2.(x * z - w * y) & 2.(y * z + w * x) & w^2 - x^2 - y^2 + z^2 \end{pmatrix}$$

Calculation of the viewing angle in the geocentric Earth frame.

Apply the Transformation matrix on the viewing angle in the image focal plane frame:

$$\begin{pmatrix} VisX_{Ter} \\ VisY_{Ter} \\ VisZ_{Ter} \end{pmatrix} = Mat_{PF \rightarrow Ter} * \begin{pmatrix} VisX_{Scan} \\ VisY_{Scan} \\ VisZ_{Scan} \end{pmatrix}$$

GROUND POSITION COMPUTATION GIVEN SATELLITE LOCATION, VIEWING ANGLE (IN GEOCENTRIC EARTH FRAME) AND EARTH MODEL (ELLIPSOID)

Given

Satellite location at a given time:

$$\vec{Pos} = \begin{pmatrix} PosX(t) \\ PosY(t) \\ PosZ(t) \end{pmatrix}$$

Viewing angle in geocentric Earth frame:

APPENDIX C: Geometric modeling

$$\vec{Vis} = \begin{pmatrix} VisX_{Ter} \\ VisY_{Ter} \\ VisZ_{Ter} \end{pmatrix}$$

Earth model (ellipsoid) with 2 axes (a, b)

Find the point on the ground at height h above ellipsoid.

Note:

- Finding the intersection point between the viewing direction and an ellipsoid (a + h, b + h) is different than finding the point at height h (see Figure 42).

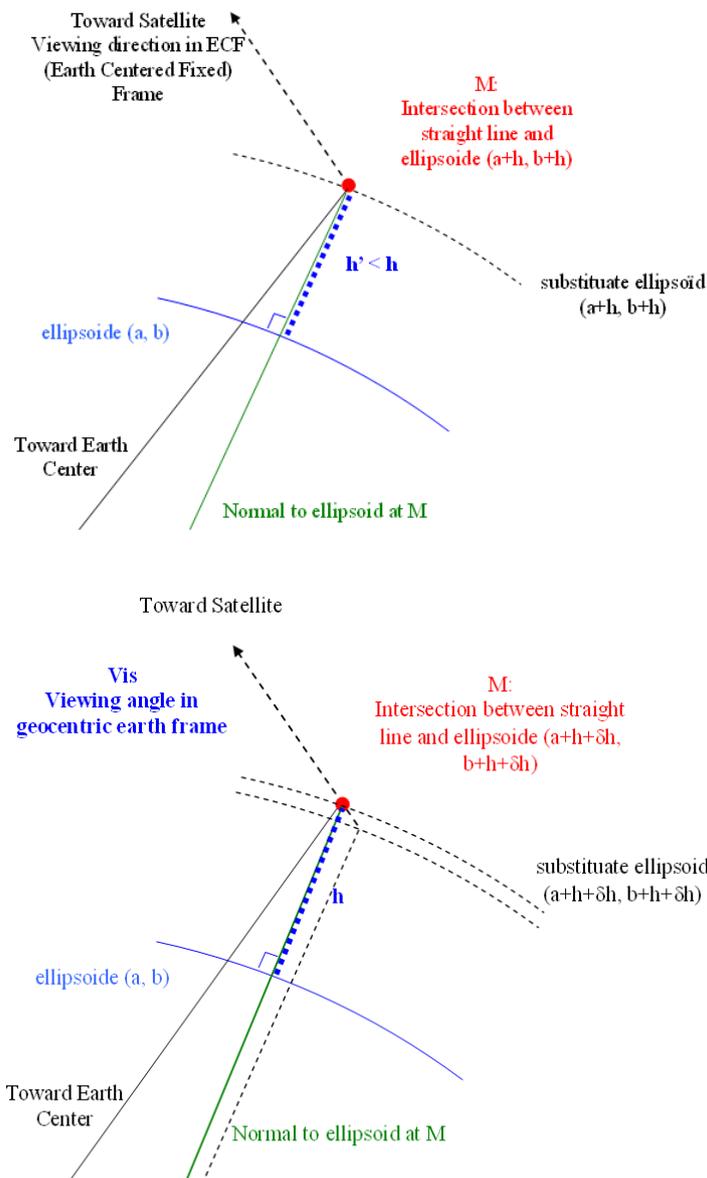


FIGURE 42: FIND THE POINT ON THE GROUND AT THE RIGHT ALTITUDE H

The method is iterative in order to find the substitute ellipsoid ($a + h + dh$, $b + h + dh$), which gives the point at height h above ellipsoid.

Let's start with $he = h$.

Do {

Compute point M (X, Y, Z) in ECF frame: Intersection between viewing direction and substitute ellipsoid ($a + he$, $b + he$).

(X, Y, Z) coordinates are the solution of the following equation system:

$$\begin{pmatrix} PosX(t) - X \\ PosY(t) - Y \\ PosZ(t) - Z \end{pmatrix} = \alpha * \begin{pmatrix} VisX_{Ter} \\ VisY_{Ter} \\ VisZ_{Ter} \end{pmatrix}, (1)$$

$$\frac{X^2 + Y^2}{(a + he)^2} + \frac{Z^2}{(b + he)^2} = 1, (2)$$

Equation (1) means that point M belongs to the viewing direction straight line: satellite location, viewing direction.

Equation (2) means that point M belongs to the substitute ellipsoid ($a + he$, $b + he$).

Finding the solution is equivalent to solve a quadratic equation (unknown α).

The solution is the smallest root.

Transform orthogonal coordinates (X, Y, Z) into geographic coordinates and height above ellipsoid (λ , φ , h').

See: http://geodesie.ign.fr/contenu/fichiers/documentation/algorithmes/notice/NTG_80.pdf

ALG0012 - Coordinate transformation: Cartesian coordinates → Geographic coordinates

Calculate the height difference: $\delta h = h - h'$

Continue with $he += \delta h$

} Until height difference δh will be less than the tolerance (parameter).

The preceding algorithm is available for the first approximate localization.

For an accurate localization, one should take into account the atmospheric refraction and light transmission delay.

The correction due to atmospheric refraction should be applied only if an atmospheric refraction correction model is given in the product.

The correction model is a refraction index table depending on altitude. The following table is given for information only.

APPENDIX C: Geometric modeling

Altitude (m)	Mean Atmospheric Refraction	Altitude (m)	Mean Atmospheric Refraction
-1000	1.000306	14000	1.000052
0	1.000278	18000	1.000028
1000	1.000252	23000	1.000012
3000	1.000206	30000	1.000004
5000	1.000167	40000	1.000001
7000	1.000134	50000	1.000000
9000	1.000106	100000	1.000000
11000	1.000083		

TABLE 29: ALTITUDE VS. ATMOSPHERIC REFRACTION

The correction due to atmospheric refraction should be applied on the ground in the viewing direction plane.

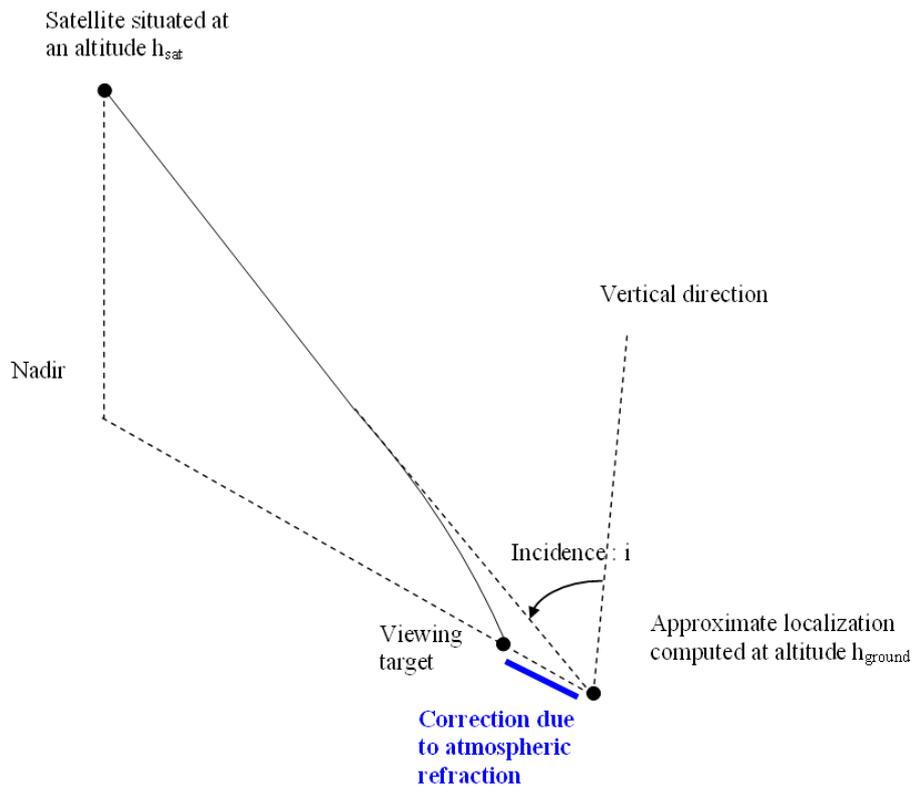


FIGURE 43: LOCALIZATION CORRECTION DUE TO ATMOSPHERIC REFRACTION

One transforms the refraction indexes into reduced refraction indexes: $n_{red}(h) = n(h) - 1$.

One performs a double integration: $I_{n_{red}}(h) = \int n_{red}(h)dh$ and $I_2 n_{red}(h) = \int \int n_{red}(h)dh$

One interpolates at altitude h_{sat} the following values: $n_{red}(h_{sat}), \int n_{red}(h_{sat}), \int \int n_{red}(h_{sat})$,

One interpolates at altitude h_{ground} the following values: $n_{\text{red}}(h_{\text{ground}})$, $\int n_{\text{red}}(h_{\text{ground}})$, $\iint n_{\text{red}}(h_{\text{ground}})$.

The refraction index at altitude h_{sat} : $n(h_{\text{sat}})$.

In order to compute the correction due to atmospheric refraction, one needs an atmospheric refraction correction model. This model is composed of refraction indices tabulated in altitude.

The correction due to atmospheric refraction is computed as follows:

$$\text{correction} = \alpha * \left(- \int n(h_{\text{vis}}) \right) + 2 * \beta * \left(- \iint n(h_{\text{vis}}) \right)$$

where: $\alpha = \tan(i) * (1 + \tan^2(i))$

$$\beta = \frac{\alpha * (2 + 3 * \tan^2(i))}{Rt}$$

The value of the atmospheric refraction correction depends on the incidence (null when viewing at nadir, approximately 2m when incidence equals 15 degrees).

C.2.2 Inverse Localization: Ground to Image

Given ground plane coordinates (λ, φ) and an altitude h , find the image coordinates (col, lin) by using the physical model.

First, it is necessary to calculate an inverse localization predictor at different altitudes. This may be calculated as follows:

Calculation of a direct localization grid at different altitudes.

$(\text{col}, \text{lin}) \rightarrow (\lambda, \varphi)_{h1} \quad (\lambda, \varphi)_{hi} \quad (\lambda, \varphi)_{hn}$

For each altitude, compute an inverse localization predictor by least-squares using grid samples $(\text{col}, \text{lin}, \lambda, \varphi)$:

$$\begin{aligned} \text{col}_{hi} &= f_{hi}(\lambda, \varphi) \\ \text{lin}_{hi} &= g_{hi}(\lambda, \varphi) \end{aligned}$$

Compute an approximation of the image position.

Apply the polynomial at different altitudes:

$$\text{col}_{h1} = f_{h1}(\lambda, \varphi) \quad \text{col}_{hi} = f_{hi}(\lambda, \varphi) \quad \text{col}_{hn} = f_{hn}(\lambda, \varphi)$$

$$\text{lin}_{h1} = g_{h1}(\lambda, \varphi) \quad \text{lin}_{hi} = g_{hi}(\lambda, \varphi) \quad \text{lin}_{hn} = g_{hn}(\lambda, \varphi)$$

Interpolate the approximate image position at the given altitude h :

$$\text{col_app}_h = \text{Interpolate}(\text{col}_{h1}, \dots, \text{col}_{hi}, \dots, \text{col}_{hn})$$

$$\text{lin_app}_h = \text{Interpolate}(\text{lin}_{h1}, \dots, \text{lin}_{hi}, \dots, \text{lin}_{hn})$$

Let's start the iterative process with the approximate image position:

$$\text{col}_{\text{cur}} = \text{col_app}_h$$

$$\text{lin}_{\text{cur}} = \text{lin_app}_h$$

Do {

Direct localization function is applied on the current image position at altitude h in order to obtain the current ground position:

$$\text{DirLoc}(\text{col}_{\text{cur}}, \text{lin}_{\text{cur}}, h) \rightarrow (\lambda_{\text{cur}}, \varphi_{\text{cur}})$$

Calculate the difference between the current ground coordinates and the target ground coordinates:

$$d\lambda = (\lambda - \lambda_{\text{cur}})$$

$$d\varphi = (\varphi - \varphi_{\text{cur}})$$

Calculate the image coordinates variation corresponding to the ground coordinates difference by using inverse partial derivatives:

$$\begin{pmatrix} d\text{col} \\ d\text{lin} \end{pmatrix} = \begin{pmatrix} \frac{\partial \lambda}{\partial \text{col}} & \frac{\partial \lambda}{\partial \text{lin}} \\ \frac{\partial \varphi}{\partial \text{col}} & \frac{\partial \varphi}{\partial \text{lin}} \end{pmatrix}^{-1} * \begin{pmatrix} d\lambda \\ d\varphi \end{pmatrix}$$

Apply the correction to the current image coordinates:

$$\text{col}_{\text{cur}} += d\text{col}$$

$$\text{lin}_{\text{cur}} += d\text{lin}$$

}

The process iterates until image coordinates converge (image coordinates difference (dcol, dlin) less than a tolerance parameter).

C.3 Using the Analytical Model or the Rational Polynomial Coefficient (RPC) Model

All the data relative to the rational polynomial coefficient model (RPC) are in the RPC file (RPC_*.xml).

The polynomial coefficients order follows the NITF 2.1 norm (RPC00B model).

The rational polynomial coefficient (RPC) model is an analytical model which gives a relationship between:

- Image coordinates + altitude and ground coordinates (direct model: image → ground)
- Ground coordinates + altitude and image coordinates (inverse model: ground → image)

Ground coordinates used by inverse model or calculated by direct model are (longitude, latitude) in WGS84 geodetic system, the “altitude” used is a height above ellipsoid.

As NITF has only documented inverse models, inverse model is the most popular method in COTS.

All coordinates must be center-normalized.

Center-normalized coordinates are calculated as followed:

$$\text{col}_{\text{CN}} = (\text{col} - \text{SAMP_OFF}) / \text{SAMP_SCALE}$$

$$\begin{aligned} \text{lin}_{CN} &= (\text{lin} - \text{LINE_OFF}) / \text{LINE_SCALE} \\ \text{lon}_{CN} &= (\text{lon} - \text{LONG_OFF}) / \text{LONG_SCALE} \\ \text{lat}_{CN} &= (\text{lat} - \text{LAT_OFF}) / \text{LAT_SCALE} \\ \text{alt}_{CN} &= (\text{h}_{\text{ground}} - \text{HEIGHT_OFF}) / \text{HEIGHT_SCALE} \end{aligned}$$

C.3.1 Direct Localization Algorithm

When using direct model (image → ground), users give image coordinates (col, lin) and an altitude (alt). The results of the application model are geographic coordinates (lon, lat).

Transform image coordinates into center-normalized image coordinates:

$$\begin{aligned} \text{col}_{CN} &= (\text{col} - \text{SAMP_OFF}) / \text{SAMP_SCALE} \\ \text{lin}_{CN} &= (\text{lin} - \text{LINE_OFF}) / \text{LINE_SCALE} \end{aligned}$$

Transform altitude coordinate into center-normalized altitude coordinate:

$$\text{alt}_{CN} = (\text{alt} - \text{HEIGHT_OFF}) / \text{HEIGHT_SCALE}$$

For direct model, the rational function polynomial equations are defined as:

$$\begin{aligned} \text{lon}_{CN} &= \frac{\sum_{i=1}^{20} \text{SAMP_NUM_COEFF}_i \cdot \rho_i(\text{col}_{CN}, \text{lin}_{CN}, \text{alt}_{CN})}{\sum_{i=1}^{20} \text{SAMP_DEN_COEFF}_i \cdot \rho_i(\text{col}_{CN}, \text{lin}_{CN}, \text{alt}_{CN})} \\ \text{lat}_{CN} &= \frac{\sum_{i=1}^{20} \text{LINE_NUM_COEFF}_i \cdot \rho_i(\text{col}_{CN}, \text{lin}_{CN}, \text{alt}_{CN})}{\sum_{i=1}^{20} \text{LINE_DEN_COEFF}_i \cdot \rho_i(\text{col}_{CN}, \text{lin}_{CN}, \text{alt}_{CN})} \end{aligned}$$

The rational function polynomial equation numerators and denominators are each 20-term cubic polynomial functions of the form:

$$\begin{aligned} \sum_{i=1}^{20} C_i \cdot \rho_i(\text{col}_{CN}, \text{lig}_{CN}, \text{alt}_{CN}) = & \\ & C_1 \dots\dots\dots + C_6 \cdot \text{lig}_{CN} \cdot \text{alt}_{CN} + C_{11} \cdot \text{col}_{CN} \cdot \text{lig}_{CN} \cdot \text{alt}_{CN} + C_{16} \cdot \text{col}_{CN}^3 \\ & + C_2 \cdot \text{lig}_{CN} \dots\dots\dots + C_7 \cdot \text{col}_{CN} \cdot \text{alt}_{CN} + C_{12} \cdot \text{lig}_{CN}^3 \dots\dots\dots + C_{17} \cdot \text{col}_{CN} \cdot \text{alt}_{CN}^2 \\ & + C_3 \cdot \text{col}_{CN} \dots\dots\dots + C_8 \cdot \text{lig}_{CN}^2 \dots\dots\dots + C_{13} \cdot \text{lig}_{CN} \cdot \text{col}_{CN}^2 \dots\dots\dots + C_{18} \cdot \text{lig}_{CN}^2 \cdot \text{alt}_{CN} \\ & + C_4 \cdot \text{alt}_{CN} \dots\dots\dots + C_9 \cdot \text{col}_{CN}^2 \dots\dots\dots + C_{14} \cdot \text{lig}_{CN} \cdot \text{alt}_{CN}^2 \dots\dots\dots + C_{19} \cdot \text{col}_{CN}^2 \cdot \text{alt}_{CN} \\ & + C_5 \cdot \text{lig}_{CN} \cdot \text{col}_{CN} \cdot \text{alt}_{CN} + C_{10} \cdot \text{alt}_{CN}^2 \dots\dots\dots + C_{15} \cdot \text{lig}_{CN}^2 \cdot \text{col}_{CN} \dots\dots\dots + C_{20} \cdot \text{alt}_{CN}^3 \end{aligned}$$

Where coefficients C1..C20 represent the following sets of coefficients:

SAMP_NUM_COEF_n, SAMP_DEN_COEF_n, LINE_NUM_COEF_n, LINE_DEN_COEF_n, which can be found under the node “Direct Model” in the RPC file.

Transform center-normalized ground coordinates into ground coordinates:

APPENDIX C: Geometric modeling

$$lon = lon_{CN} * LONG_SCALE + LONG_OFF$$

$$lat = lat_{CN} * LAT_SCALE + LAT_OFF$$

C.3.2 Inverse Localization Algorithm

When using the inverse model (ground → image), the user supplies geographic coordinates (lon, lat) and an altitude (alt). The results of the application model are image coordinates (col, lin).

Transform ground coordinates into center-normalized ground coordinates:

$$lon_{CN} = (lon - LONG_OFF) / LONG_SCALE$$

$$lat_{CN} = (lat - LAT_OFF) / LAT_SCALE$$

Transform altitude coordinate into center-normalized altitude coordinate:

$$alt_{CN} = (alt - HEIGHT_OFF) / HEIGHT_SCALE$$

For inverse model, the rational function polynomial equations are defined as:

$$col_{CN} = \frac{\sum_{i=1}^{20} SAMP_NUM_COEFF_i \cdot \rho_i(lat_{CN}, lon_{CN}, alt_{CN})}{\sum_{i=1}^{20} SAMP_DEN_COEFF_i \cdot \rho_i(lat_{CN}, lon_{CN}, alt_{CN})}$$

$$lin_{CN} = \frac{\sum_{i=1}^{20} LINE_NUM_COEFF_i \cdot \rho_i(lat_{CN}, lon_{CN}, alt_{CN})}{\sum_{i=1}^{20} LINE_DEN_COEFF_i \cdot \rho_i(lat_{CN}, lon_{CN}, alt_{CN})}$$

The rational function polynomial equation numerators and denominators are each 20-term cubic polynomial functions of the form:

$$\sum_{i=1}^{20} C_i \cdot \rho_i(lat_{CN}, lon_{CN}, alt_{CN}) =$$

$$C_1 \dots + C_6 \cdot lon_{CN} \cdot alt_{CN} + C_{11} \cdot lat_{CN} \cdot lon_{CN} \cdot alt_{CN} + C_{16} \cdot lat_{CN}^3$$

$$+ C_2 \cdot lon_{CN} \dots + C_7 \cdot lat_{CN} \cdot alt_{CN} + C_{12} \cdot lon_{CN}^3 \dots + C_{17} \cdot lat_{CN} \cdot alt_{CN}^2$$

$$+ C_3 \cdot lat_{CN} \dots + C_8 \cdot lon_{CN}^2 \dots + C_{13} \cdot lon_{CN} \cdot lat_{CN}^2 \dots + C_{18} \cdot lon_{CN}^2 \cdot alt_{CN}$$

$$+ C_4 \cdot alt_{CN} \dots + C_9 \cdot lat_{CN}^2 \dots + C_{14} \cdot lon_{CN} \cdot alt_{CN}^2 \dots + C_{19} \cdot lat_{CN}^2 \cdot alt_{CN}$$

$$+ C_5 \cdot lon_{CN} \cdot lat_{CN} \cdot alt_{CN} + C_{10} \cdot alt_{CN}^2 \dots + C_{15} \cdot lon_{CN}^2 \cdot lat_{CN} \dots + C_{20} \cdot alt_{CN}^3$$

Where coefficients C1...C20 represent the following sets of coefficients:

SAMP_NUM_COEF_n, SAMP_DEN_COEF_n, LINE_NUM_COEF_n, LINE_DEN_COEF_n, which can be found under the node "Inverse Model" in the RPC file.

Transform center-normalized image coordinates into image coordinates

$$col = col_{CN} * SAMP_SCALE + SAMP_OFF$$



$$\text{lin} = \text{lin}_{\text{CN}} * \text{LINE_SCALE} + \text{LINE_OFF}$$

C.3.3 Global or Partial RFM and Estimated Accuracy

The term “Global_RFM” means that the RPC model is available in the whole image. This global RFM model is always computed.

When the acquisition duration is more than a threshold (nominally 4 seconds), partial RFMs are automatically computed, each one addressing a subset of the image (its validity domain).

Partial_RFM has a better accuracy than Global_RFM, because domain validity is reduced. In the case of Global_RFM, the least squares method is applied on samples located in the whole image, thus the RMS error is more important.

Important

Partial RFM must be applied inside the validity domain, otherwise functions diverge and the result would be completely wrong. There is no continuity between partial RFM unlike global RFM.

An error corresponding to 3 * standard deviation is given for each model (99.7 % of evaluation samples).

C.4 Other Informative Geometric Data

The other geometric data associated to the image area are under the node:

<PHR_DIMAP_Document><Geometric_Data><Use_Area><Located_Geometric_Values>

These data are given for information only. These data are given at the beginning, the middle and the end of image acquisition.

C.4.1 Acquisition Angles

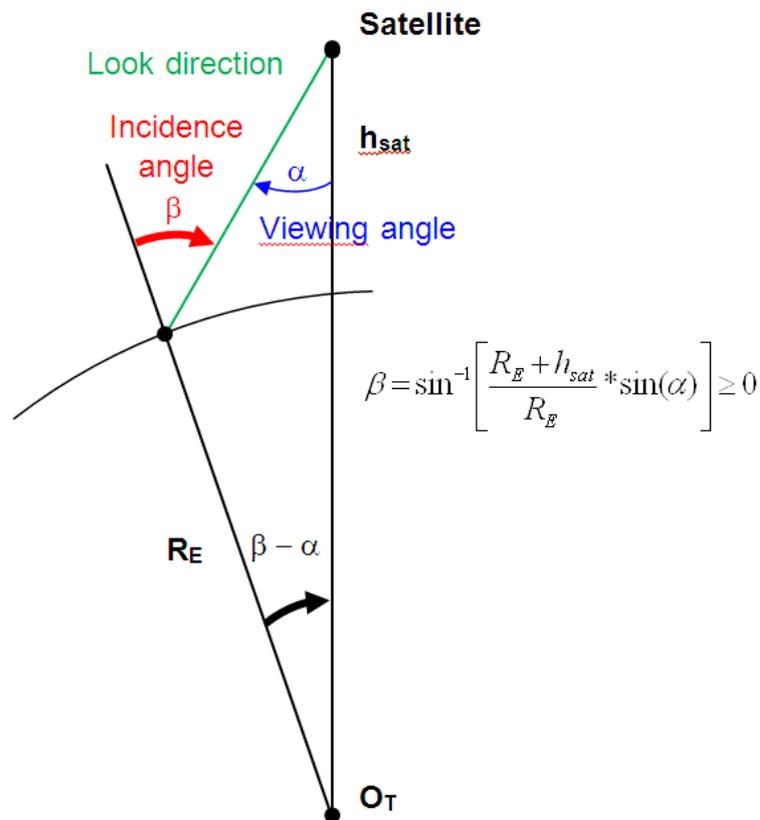


FIGURE 44: RELATION BETWEEN INCIDENCE ANGLE AND VIEWING ANGLE

Incidence angle β (or global incidence) is the angle between the ground normal and look direction from satellite. For Pléiades, the range for the incidence angle is [0, 33.6 degrees].

Azimuth angle Az is the angle between geographic north and the image line direction on the ground (also called Scan Axis). The range for the azimuth angle is [0, 360 degrees], clockwise positive. As shown on Figure 45.

Azimuth and incidence angle are calculated on the ground.

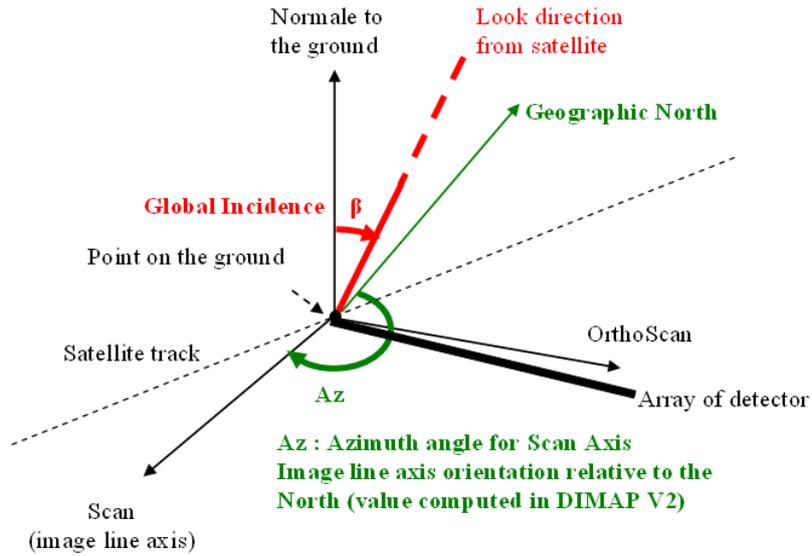


FIGURE 45: INCIDENCE ANGLE AND AZIMUTH OF SCAN

AZIMUTH_ANGLE = Azimuth angle of Scan

The user must not confuse this azimuth definition with other conventions, typically the angle between geographic North and satellite track on the ground as shown on Figure 46. If the azimuth of the satellite track is not provided, then Figure 46 is for information only.

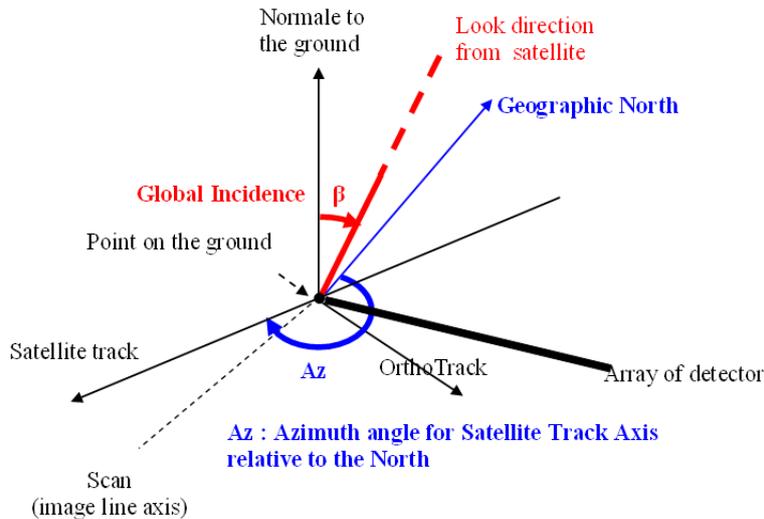


FIGURE 46: INCIDENCE ANGLE AND AZIMUTH OF SATELLITE TRACK

The look direction from the satellite on the ground may be projected on two planes: (normal to the ground, Scan Axis) and (normal to the ground, OrthoScan axis).

Thus, incidence may be measured in both planes:

- INCIDENCE_ANGLE_ALONG_TRACK: Incidence in the Scan axis direction (image line axis on the ground)
- INCIDENCE_ANGLE_ACROSS_TRACK: Incidence in the OrthoScan axis direction

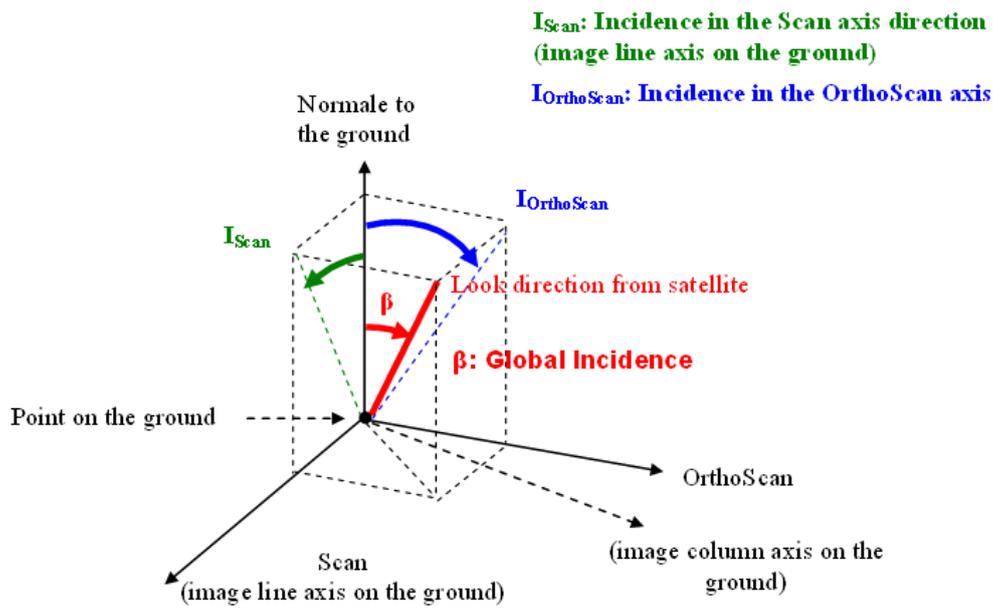


FIGURE 47: INCIDENCE ANGLE PROJECTED ON TWO PLANES

The viewing angle from the satellite α (also named VIEWING_ANGLE in DIMAP PHR format) is the angle between look direction from the satellite and nadir. For Pléiades the range for the viewing angle is generally [0, 30 degrees] – but can be opened to raise revisit frequency over a given target.

Look direction from the satellite may be projected onto two planes defined in the local orbital frame: (yaw axis, pitch axis) and (yaw axis, roll axis) - see Figure 48.

Thus, viewing may be measured in both planes:

- VIEWING_ANGLE_ACROSS_TRACK (α_X): viewing angle in the across-track axis direction (roll)
- VIEWING_ANGLE_ALONG_TRACK (α_Y): viewing angle in the along-track axis direction (pitch)

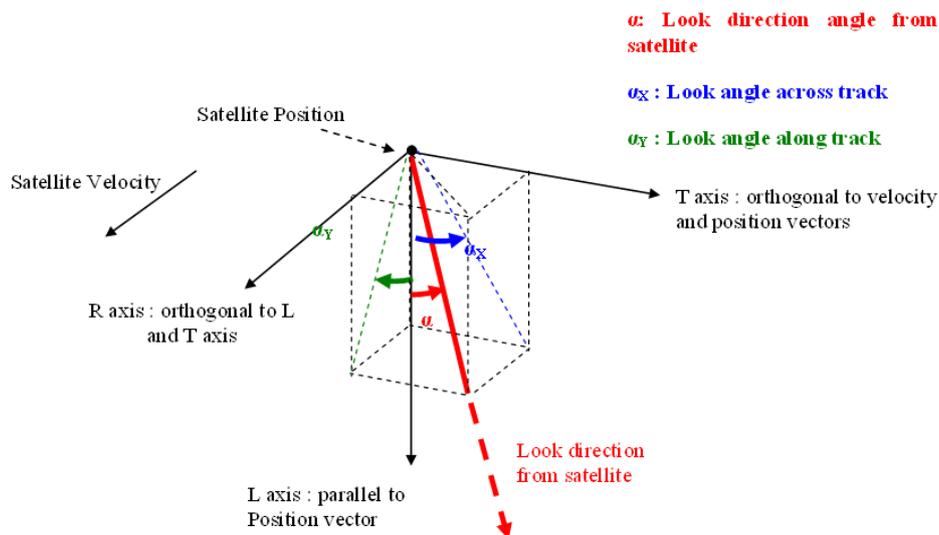


FIGURE 48: VIEWING ANGLE ALONG AND ACROSS TRACK

C.4.2 Solar Angles

The following angles (see Figure 49) are calculated in a local Earth frame (Normal to the ground, North, East):

- SUN_AZIMUTH
- SUN_ELEVATION

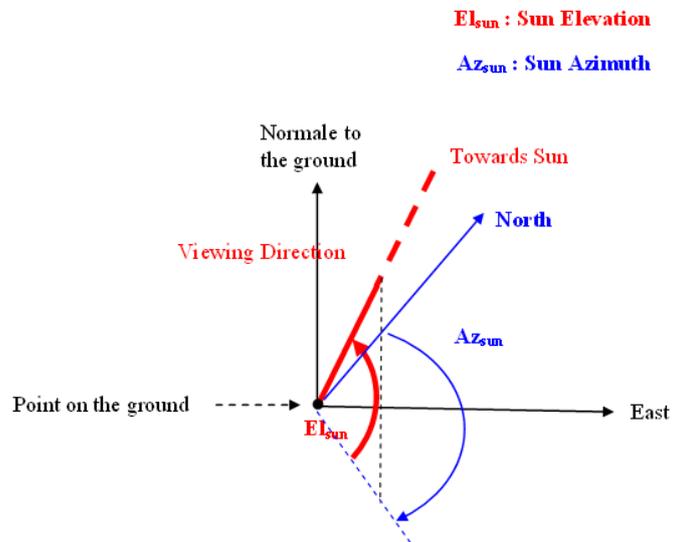


FIGURE 49: SOLAR INCIDENCES

C.4.3 Ground Sample Distance (GSD)

Ground Sample Distance (GSD) is the Ground distance in meters viewed on board by two consecutive pixels along both directions: image line direction and image column direction at acquisition.

GSD_ACROSS_TRACK: pixel size along image column direction

GSD_ALONG_TRACK: pixel size along image line direction

APPENDIX D: SPECTRAL MODELING

Bio-physical applications require conversion of raw digital count numbers (DN) to physical units. Current physical units include radiance (at-Ground or at-Top Of Atmosphere), reflectance, or albedo.

D.1 Pléiades Spectral Bands

Pléiades acquires images in five spectral ranges. Following spectral ranges are based on a rejection at 1%:

Spectral ranges	λ_{\min}	λ_{\max}
Panchromatic	0.47 μm	0.83 μm
B0 - Blue	0.43 μm	0.55 μm
B1 - Green	0.50 μm	0.62 μm
B2 - Red	0.59 μm	0.71 μm
B3 - Near Infrared	0.74 μm	0.94 μm

TABLE 30: PLÉIADES SPECTRAL BANDS

D.2 Converting Digital Count to TOA Radiance

For a respective band (b), the conversion of the Digital Count of a pixel $DC(p)$ to Top Of Atmosphere (TOA) radiance $L_b(p)$ (in $W \cdot sr^{-1} \cdot m^{-2} \cdot \mu m^{-1}$) is done by the absolute radiometric calibration coefficients GAIN and BIAS:

$$L_b(p) = \frac{DC(p)}{GAIN(b)} + BIAS(b)$$

Absolute radiometric calibration coefficients are updated periodically, typically 4 times per year, asset on the sensor native radiometric range of 12 bit-depth.

The values are recomputed for products ranged to 8 bit-depth with a linear adjustment, meaning a non-zero BIAS value.

These values have no sense when other radiometric adjustment like seamless (Mosaic) have been applied on the data.

D.3 TOA Spectral Reflectance

The Top Of Atmosphere (TOA) spectral reflectance is the ratio of the TOA radiance normalized by the incoming solar irradiance:

$$\rho_b(p) = \frac{\pi \cdot L_b(p)}{E_0(b) \cdot \cos(\theta_s)}$$

To take into account the spectral sensitivity of the sensors (see next paragraph), an equivalent spectral radiance will be computed:

$$L_{eq}(b) = \frac{\int L_b \cdot S_b(\lambda) \cdot d\lambda}{\int S_b(\lambda) \cdot d\lambda}$$

D.4 Spectral Sensitivity of the Pléiades Sensors

Any sensor is sensitive to all wavelengths of the electromagnetic spectrum. For each band, the sensor has a characteristic response curve as a function of wavelength.

The spectral normalized sensitivities of the Pléiades sensors are represented on the following figure:

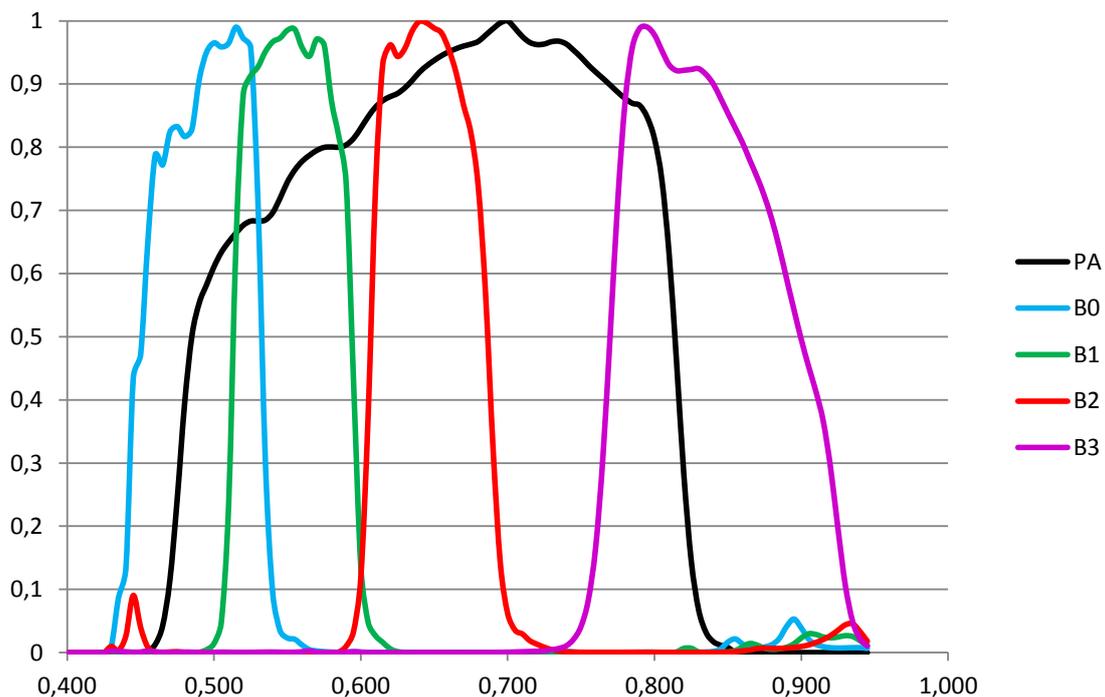


FIGURE 50: SPECTRAL NORMALIZED SENSITIVITIES OF THE PLÉIADES SENSORS

The min and max sensitivities given for spectral band range are asset with a rejection at 1/100.

For applications requiring very accurate radiometric profiles, these data values can be provided upon request by submitting an email to CustomerTechnicalSupport@spotimage.fr.

ABBREVIATIONS, ACRONYMS AND TERMS

Area Of Interest (AOI): The abbreviation for area of interest. An AOI outlines a particular region by panel, shape, preset values, or by a defined line and sample. An AOI is used for clipping an image area or for processing a subset of image data.

Attitude: The angular orientation of a spacecraft as determined by the relationship between its axes and a reference line or plane or a fixed system of axes. Usually, "Y" is used for the axis that defines the direction of flight, "X" for the "cross-track" axis perpendicular to the direction of flight, and "Z" for the vertical axis. Roll is the deviation from the vertical axis (the angle between the Z axis of the vehicle and the vertical axis, or angular rotation around the Y axis). Pitch is the angular rotation around the X axis. Yaw is rotation around the Z axis.

Azimuth: The arc of the horizon measured clockwise from the north point to the point referenced, expressed in degrees. Azimuth indicates direction, and not location.

B/H: The Base-over-Height ratio of a stereo pair. This parameter characterizes the stereoscopic capacity of a couple (see Figure 51, given that the 'Height' value is constant and equals the altitude of the satellite, the larger the base, the larger the angle). Thus the Base-over-Height ratio reflects the angular difference between the two images. It should be high for rather flat areas and low for urban or mountainous areas. See page 31 for more details about how to select the right B/H ratio.

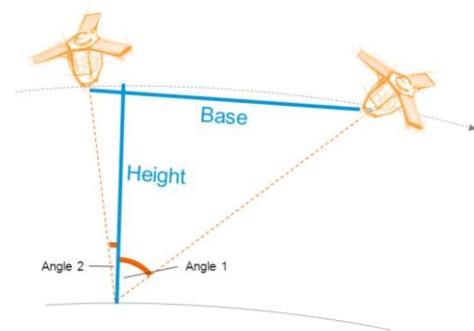


FIGURE 51: STEREOSCOPIC - B/H

CE90: Circular Error with a confidence level of 90% (positioning accuracy on both axes). It indicates that the actual location of an object is represented on the image within the standard accuracy for 90% of the points.

Map Scale	CE90	RMSE
1:2,400	2m	1m
1:4,800	4m	2m
1:12,000	10m	5m
1:24,000	12m	6m
1:50,000	25m	15m

TABLE 31: APPROXIMATE MAPSCALE EQUIVALENCIES BASED ON THE US NMAS³

See also *Geolocation accuracy, RMSE.*

CMGs – Control Moment Gyros: The CMG principle relies on the gyroscopic effect to rapidly and instantaneously generate an important output torque by using the spin axis' rotation of a momentum wheel thanks to a cardan gimbaled mechanism. The CMGs are used both for the maneuver guidance to ensure

3. US NMAS: United States National Map Accuracy Standard.

Abbreviations, Acronyms and Terms

transitions between image acquisitions and for the acquisition guidance in order to guarantee the image quality. See part 1.1 for benefits of CMGs.



FIGURE 52: A CONTROL MOMENT GYRO

Conflict: Two (or more) tasking requests are said to conflict when the satellite is not in a position to image the two (or more) areas during the same orbit. These two tasking requests are also said to be in competition. When there are different priority levels attached to each tasking request, the satellite will image the tasking request with the highest priority level first.

Coordinate Reference System (CRS): A coordinate system related to the Earth through one datum. This definition includes coordinate systems based on geodetic or Cartesian coordinates and coordinate systems based on map projections.

DEM – Digital Elevation Model (or DSM – Digital Surface Model): A digital 3D ground model, including the maximum altitude in every point: with human superstructures and canopy.

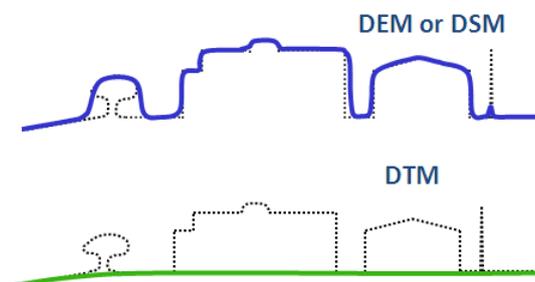


FIGURE 53: DEM VS. DTM

DRA – Dynamic Range Adjustment: An algorithm used to enhance the imagery histogram. It modifies the luminosity and contrast of the imagery. Through this enhancement, the initial radiometric properties of the imagery are lost, but the color balance is adjusted to get an aesthetically pleasing image on a screen. With DRA turned on, the pixel values of the original data cannot be recovered from the product. That is why this option is not recommended for users intending to perform scientific analysis, photointerpretation or spectral classification. DRA is different from linear adjustment (see below).

DRS – Direct Receiving Station: An antenna and a terminal enabling a given partner to receive Pléiades telemetry directly at their facility. More about the Pléiades DRS at <http://www.astrium-geo.com/en/54-pleiades-direct-access-services>.

DTM – Digital Terrain Model: A digital natural ground (bare Earth) model, meaning without human superstructures or canopy. See DEM.

DTED – Digital Terrain Elevation Data Level: A uniform gridded matrix of ground elevation. It is a standard used to classify DEMs upon their precision and posting. DTED standards encompass several levels of accuracy, from DTED level 0 to DTED level 3. Level 0 content is equivalent to the elevation information of a 1,000,000-scale map (more or less equivalent to GTOPO30, or GLOBE), DTED level 1 to a 250,000-scale map (SRTM public data), and DTED level 2 to a 1: 50,000 map.

	LEVEL 0	LEVEL 1	LEVEL 2	LEVEL 3
Posting	30 arc sec.	3 arc sec.	1 arc sec.	0.4 arc sec.
at Equator	± 900m	± 90m	± 30m	± 12m
at 45° latitude	± 630m	± 63m	± 21m	± 9m
<i>Posting values decrease towards the poles to cope with meridian convergence.</i>				
Absolute horizontal		50m CE90	23m CE90	10m CE90
Absolute vertical		30m CE90	18m CE90	10m CE90
Relative horizontal		--	--	3-10m CE90
Relative vertical		20m CE90	12 -15m CE90	1-3m CE90

TABLE 32: DTED CLASSES

ECF or ECEF: Earth Centered Earth Fixed coordinates. The Earth Centered Earth Fixed or conventional terrestrial coordinate system rotates with the Earth and has its origin at the center of the Earth. The X axis passes through the equator at the prime meridian. The Z axis passes through the North Pole but it does not exactly coincide with the instantaneous Earth rotational axis. The Y axis can be determined by the right-hand rule to be passing through the equator at 90° longitude.

For more information: metadata.dod.mil/mdr/ns/GSIP/crs/WGS84C_3D

FOR - Field Of Regard: The area covered by the detector of the system when pointing to all mechanically possible positions.

Geolocation Accuracy: Geolocation accuracy means positional accuracy using satellite ancillary data only. It is a measure of the possible difference between the locations of features in the data versus their actual location on the ground. It is usually expressed in units plus or minus some distance (e.g. + or – 50m) from the actual ground position in either the horizontal or vertical plane. To exclude local terrain effects the specification is asset globally on Ellipsoid. See also CE90, RMSE.

Geometric Modeling: The relationship between image and ground coordinates for a given sensor.

GeoTIFF - Geographic Tagged Image File Format: GeoTIFF is a public domain metadata standard which allows georeferencing information to be embedded within a TIFF file. The potential additional information includes map projection, coordinate systems, ellipsoids, datums, and everything else necessary to establish the exact spatial reference for the file.

GIS – Geographic Information System: A geographic information system is a system designed to capture, store, manipulate, analyze, edit, manage, and present all types of geographical data.

Ground Control Point (GCP): A geographic feature of a known location (e.g. corner of a building, rock reflector,...) that is recognizable on an image and can be used to determine geometric corrections to improve the geolocation accuracy of the image.

Abbreviations, Acronyms and Terms

Ground Sampling Distance (GSD): The Ground Sampling Distance is the distance at Ground view by two consecutive pixels (in meters) along both directions: image line direction and image column direction. See *IFOV and Figure 54*.

HR – High Resolution: Imagery with a resolution between 1 m and 10 m.

Incidence Angle: See *Viewing angle*.

Instantaneous Field Of View (IFOV): (1) In a scanning system, this refers to the solid angle subtended by the detector when the scanning motion is stopped. Instantaneous field of view is commonly expressed in milliradians or picoradians. (2) The ground area covered by this solid angle. See *GSD*.

JPEG 2000: An image compression standard and coding system. It is the default image format for Pléiades products. See *part 2.4 for more information about JPEG 2000 benefits*.

KML - Keyhole Markup Language: An XML notation for expressing geographic annotation and visualization within Internet-based, two-dimensional maps and three-dimensional Earth browsers. KML was developed for use with Google Earth, which was originally named Keyhole Earth Viewer. It was created by Keyhole, Inc, which was acquired by Google in 2004. KML is an international standard of the Open Geospatial Consortium.

LE90: A linear error with a confidence level of 90% (positioning/vertical accuracy on one axis). It indicates that the actual elevation of an object is represented within the stated accuracy for at least 90% of the elevation posts.

Linear Adjustment: An algorithm used to rescale bit-depth from 12 to 8 bits. It does not affect the properties of the image histogram (linear transformation) in order to preserve the initial radiometric quality of the imagery. It is activated each time a customer orders 8-bit products, either with automatic values or custom values.

Monoscopic: Which has been obtained by imaging a precise area from a single viewpoint on the orbit.

Mosaic: A mosaic is the end result of combining multiple smaller images into one larger, cohesive image. Geographically, a mosaic is a raster data set composed of multiple raster datasets merged together.

MTF - Modulation Transfer Function: a measure of the image sharpness (the spatial frequencies) of a camera and/or image.

Multispectral (MS): Generally denotes remote sensing in two or more spectral bands (and less than 20 bands), such as visible and infrared. Multispectral capacity enables a sensor to deliver color images.

Nadir: The point on the ground vertically beneath the sensor.

Near Infra-Red (NIR): The preferred term for the shorter wavelengths in the infrared region (the entire infrared region extends from about 0.7 μm , visible red, to about 3 μm).

Orthogonal: Having three right angles.

Orthorectified: Describes an image which has had the displacements due to tilt and relief removed. The resulting image can be virtually overlaid on a map.

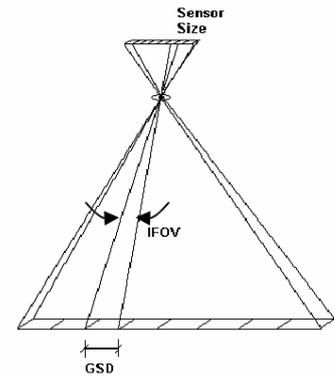


FIGURE 54: IFOV AND GSD

Pan-sharpening: The practice of using the highest resolution Panchromatic band in conjunction with the other lower resolution multispectral bands to increase the apparent spatial resolution of a multi-band (color) product.

Panchromatic (PAN): Detectors that are sensitive to visible colors of the spectrum. Pléiades has a Panchromatic band that extends into the near-IR and covers the spectral region between 0.47 - 0.83 μm .

Pitch: The rotation of a spacecraft about the horizontal axis normal to its longitudinal axis (in the along-track direction) so as to cause a nose-up or nose-down attitude. The pitch axis is referred to as the X axis. See *attitude*.

Planimetric Accuracy: The positional accuracy of the image projected on an Earth mapping system and reset with a DEM (vertical reset) and possibly with GCPs (horizontal reset). Unlike Geolocation Accuracy, the Planimetric Accuracy depends on the intrinsic accuracy of the external data (DEM and GCP). Planimetric Accuracy is dedicated for georeferenced products like ortho images.

Priority: A system of hierarchy for different tasking requests. In areas of high competition, priority service requests are served first, so customers will see a shorter collection window for priority service requests than for standard service requests.

Pushbroom: The pushbroom scanner, otherwise known as the linear array sensor, is a scanner without a mechanical scanning mirror, or moving parts. Instead, it has a linear array of sensors with one sensor for each area sampled on the ground. Charge-coupled devices (CCDs) are usually used for the sensors. This enables the pushbroom scanner to record one line of an image simultaneously, with this line being perpendicular to the flight direction. As with mechanical scanners, forward motion is achieved through the flight direction of the platform. See *Figure 55*.

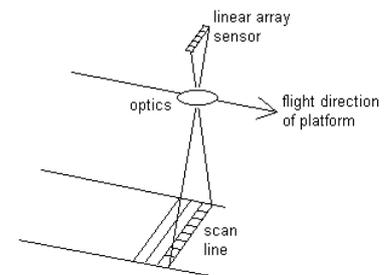


FIGURE 55: PUSHBROOM SENSOR

Quicklook: Sometimes called a browse image. A quicklook provides an overview of the product with a degraded resolution to make browsing an image catalog quicker and easier. It gives an immediate understanding of the image quality and cloud cover. Quicklooks of images are for instance the images that are used and displayed in the GeoStore catalog. Basically, the quicklook is a sub-sampled image. It is compressed and dynamically stretched (by default 2%). Typically, the quicklook image is sub-sampled by a ratio of 32 vs. the original Panchromatic image sampling (approximately 22m).

Radiance: A measure of radiant intensity per unit of a projected source area in a specified direction. The unit is the rate of transfer of energy (Watt, W) recorded by a sensor, per square meter on the ground, for one steradian (solid angle from a point on Earth's surface to the sensor), per unit wavelength being measured.

Reference3D®: A database that has been designed to take advantage of highly accurate SPOT 5 stereoscopic images. It consists of three information layers: SPOT DEM (30 m resolution, uniform grid of terrain elevation values of the area of interest), Orthoimage (5m resolution, orthorectified images from the DEM stereo pairs) and Quality Masks; with a specification of circular planimetric accuracy between 6 m and 10 m for 90% of the points, depending on the location, and an elevation accuracy better than 10 m for 90% of the points, depending on the steepness of the slopes. The average is 5 m. For more information: <http://www.astrium-geo.com/en/2788-reference3d-your-geographic-reference-system>

Refined Attitude Data: The *attitude data* is a main element for geolocation accuracy without GCP. It provide information about the attitude / orientation of the satellite and it is measured by the satellite' sensors for each acquired image. The *refined* attitude data is the average of attitude data gathered on various consecutive orbits. It allows minimizing individual attitude data errors (improve geolocation). It is calculated twice per day

Abbreviations, Acronyms and Terms

and automatically re-integrated in the processing chain. It is not available case of rush production of a recently acquired image (< 12h). It is neutral if on-board attitude data are already accurate. This automatic processing secures Pléiades' geolocation and is nominally integrated in Direct Receiving Stations ground processing chains.

Reflectance: The ratio of the reflected radiance divided by the incoming radiance. Note, that this ratio has a directional aspect. Reflectance provides a standardized measure, which is directly comparable between images. Reflectance is unitless and thus is measured on a scale from 0 to 1 (or 0-100%). Top-of-Atmosphere (TOA) reflectance does not attempt to account for atmospheric effects. Surface reflectance attempts to correct for the atmosphere while also converting to reflectance.

Resolution (Spatial Resolution): A measure of the smallest angular or linear separation between two objects that can be resolved by the sensor. There is a relationship between the size of the feature to be sensed and the spatial resolution of the optical system. It is simply the dimension in meters of the ground-projected instantaneous field of view (IFOV).

RFC: Rational Function Coefficients (from RPC).

RFM: Rational Function Model (with RPC).

RMSE – Root Mean Squared Error: Commonly used for quoting and validating geodetic image registration accuracy. A RMSE value is a single summary statistic that describes the square-root of the mean horizontal distance between all photo-identifiable GCPs and their respective twin counterparts acquired in an independent geodetic survey. *See also CE90.*

Roll: The rotation of a spacecraft about its longitudinal axis (in the along-track direction) so as to cause a side-up or side-down attitude. The roll axis is referred to as the Y axis. *See attitude.*

RPC – Rational Polynomial Coefficient: A mathematical model of the image geometry, in the form of a set of rational polynomial coefficients, that one can use to orthorectify the image. This procedure also requires a DEM (Digital Elevation Model). One can often improve the fit of the rational polynomial model to a particular image by re-georeferencing the image using accurate 3D ground control points. *See also Orthorectified.*

Sensor Model: A sensor model is a physical representation of a sensor in its state at the time of image collection. The algorithm accounts for refraction, position, orientation, velocity, and viewing directions along the sensor array through the camera. It calculates the transformation between 3-D ground space and image line and sample coordinate points, and vice versa. Every image has unique sensor model parameters that reflect the location and orientation of the sensor at the time the image was collected. The sensor model is native to the image's support measurement functions with ground surface.

Scan Line: The ground trace of a narrow strip that is recorded by the instantaneous field of view of a detector in a scanner system.

SHP – Shapefile: A popular geospatial vector data format for Geographic Information Systems software. It is developed and regulated by ESRI as a (mostly) open specification for data interoperability among ESRI and other software products.

Shapefiles spatially describe vector geometries: points, polylines, and polygons. These, for example, could represent water wells, rivers, and lakes, respectively. Each item may also have attributes that describe the items, such as the name or temperature.

SNR – Signal to Noise Ratio: SNR measures the radiometric accuracy of an image.

Spectral Band: An interval in the electromagnetic spectrum defined by two wavelengths, frequencies, or wave numbers (e.g. Pléiades' blue band covers an area between 0.43 and 0.55 μm).

Stereo(scopic): Which has been obtained by imaging from two viewpoints on the same orbit.

Sun-synchronous: An Earth satellite orbit in which the orbital plane remains at a fixed angle with respect to the Sun, precessing through 360° during the period of a year. The Pléiades satellites are in a near-polar orbit of this type and maintain an orbital altitude such that each pass over a given latitude on the Earth's surface occurs at the same mean Sun time every day.

Swath: The width of an image. Pléiades' swath is 20 km at nadir. The swath increases proportionally with the angle.

Time Delay Integration (TDI): A time delay integration charge-coupled device (CCD) is widely used for observation of high speed moving objects undetectable by classic CCD. This technique senses charge patterns and shifts them across the charge-coupled device (CCD) array in sync with the movement of the image, to integrate more light from the scene.

UTC: Universal Time Coordinated.

UTM – Universal Transverse Mercator: A projection system which divides the Earth into sixty zones, each a six-degree band of longitude, and uses a secant transverse Mercator projection in each zone.

VHR – Very High Resolution: Imagery with a resolution below 1m.

Viewing Angle: The angle from the instrument point of view. It represents the angle between the look direction from the satellite and nadir, combining the pitch and roll angles. It is different from the incidence angle.

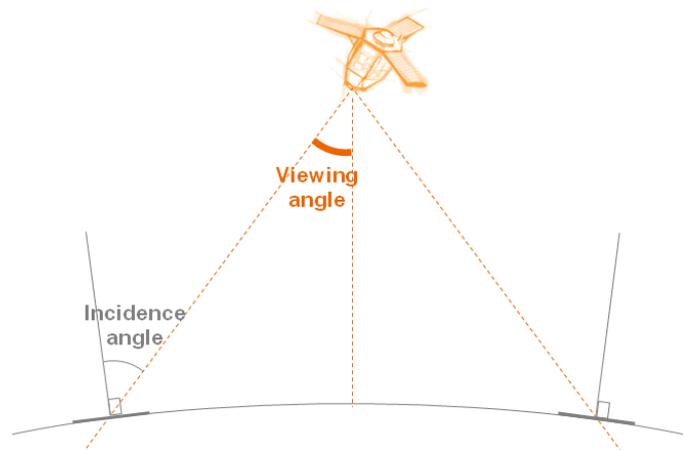


FIGURE 56: VIEWING ANGLE

Yaw: The rotation of a spacecraft about its vertical axis so as to cause the spacecraft's longitudinal axis to deviate left or right from the direction of flight. The yaw axis is referred to as the "Z" axis. See *attitude*.

Zenith: The point in the celestial sphere that is exactly overhead. The opposite of nadir.

TABLE OF SYMBOLS & VALUES LOCATION IN DIMAP V2

This section defines all the symbols (mathematical or specific to Pléiades) involved within at least one of the equations of this document.

Symbol	Description <Location of values in DIMAP V2 format>
Az	Azimuth angle of the image line axis between the geographic north and the scan line direction. Unit in degree (°). <Geometric_Data><Use_Area><Located_Geometric_Values><Acquisition_Angles><AZIMUTH_ANGLE>
B	Spectral band identifier. Examples P, B0, B1, B2, B3 = Resp. Panchromatic, Blue, Green, Red and Near Infrared bands. <Band_Measurement_List><Band_Radiance><BAND_ID><GAIN>
BIAS	A bias value. <Band_Measurement_List><Band_Radiance><BAND_ID><BIAS>
C	Light speed.
CoeffPsiX(i)	Polynomial model coefficients: $\text{TanPsiX} = f(\text{col} - \text{colref})$. <Geometric_Data><Refined_Model><Geometric_Calibration><Instrument_Calibration><Polynomial_Look_Angles><XLOS_(i)>
CoeffPsiY(i)	Polynomial model coefficients: $\text{TanPsiY} = g(\text{col} - \text{colref})$. <Geometric_Data><Refined_Model><Geometric_Calibration><Instrument_Calibration><Polynomial_Look_Angles><YLOS_(i)>
CoeffQ0_(i)	Polynomial coefficients: $Q0 = f(t_{CN})$. <Geometric_Data><Refined_Model><Attitudes><Q0>
CoeffQ1_(i)	Polynomial coefficients: $Q1 = g(t_{CN})$. <Geometric_Data><Refined_Model><Attitudes><Q1>
CoeffQ2_(i)	Polynomial coefficients: $Q2 = h(t_{CN})$. <Geometric_Data><Refined_Model><Attitudes><Q2>
CoeffQ3_(i)	Polynomial coefficients: $Q3 = k(t_{CN})$. <Geometric_Data><Refined_Model><Attitudes><Q3>
Col	Image column coordinate.
col_{ref}	Reference column for polynomial models. <Geometric_Data><Refined_Model><Geometric_Calibration><Instrument_Calibration><Swath_Range><FIRST_COL>
del(c)	Elementary detector.
E_o(β)	E _o (β) is the mean Top of Atmosphere (TOA) solar irradiance for the band (b) in W/m ² /micrometer. <Band_Measurement_List><Band_Solar_Irradiance><BAND_ID><VALUE>

ERR_BIAS_X	Error at 99.7% (corresponding to 3 * standard deviation) for the longitude (unit meter) between RPC model and physical model. <ERR_BIAS_X>
ERR_BIAS_Y	Error at 99.7% (corresponding to 3 * standard deviation) for the latitude (unit meter) between RPC model and physical model. <ERR_BIAS_Y>
ERR_BIAS_COL	Error at 99.7% (corresponding to 3 * standard deviation) for the column (sample) (unit pixel) between RPC model and physical model. <ERR_BIAS_COL>
ERR_BIAS_ROW	Error at 99.7% (corresponding to 3 * standard deviation) for the line (sample) (unit pixel) between RPC model and physical model. <ERR_BIAS_ROW>
FIRST_COL LAST_COL	Validity domain for column image coordinate (sample) available for Global RFM or partial RFM. <Rational_Function_Model><Global_RFM> or <Partial_RFM><RFM_Validity><Direct_Model_Validity_Domain><...>
FIRST_ROW LAST_ROW	Validity domain for line image coordinate (row) available for Global RFM or partial RFM. <Rational_Function_Model><Global_RFM> or <Partial_RFM><RFM_Validity><Direct_Model_Validity_Domain><...>
FIRST_LAT LAST_LAT	Validity domain for latitude coordinate available for Global RFM or partial RFM. <Rational_Function_Model><Global_RFM> or <Partial_RFM><RFM_Validity><Inverse_Model_Validity_Domain><...>
FIRST_LON LAST_LON	Validity domain for longitude coordinate available for Global RFM or partial RFM. <Rational_Function_Model><Global_RFM> or <Partial_RFM><RFM_Validity><Inverse_Model_Validity_Domain><...>
GAIN	A gain value. <Band_Measurement_List><Band_Radiance><BAND_ID><GAIN>
H	Altitude.
h_{ground}	Ground altitude.
h_{sat}	Altitude of satellite.
HEIGHT_OFF	Altitude offset used in RPC model. <Rational_Function_Model><Global_RFM><RFM_Validity><HEIGHT_OFF >
HEIGHT_SCALE	Altitude scale factor used in RPC model. <Rational_Function_Model><Global_RFM><RFM_Validity><HEIGHT_SCALE >
I	Viewing incidence.
Lin	Image line coordinate.
lin_{ref}	Reference line to line-timing model.
lat, long	Geographic coordinates.
LAT_OFF	Latitude offset used in RPC model. <Rational_Function_Model><Global_RFM><RFM_Validity><LAT_OFF>
LAT_SCALE	Latitude scale factor used in RPC model.

Table of symbols & values location in DIMAP V2

	<Rational_Function_Model><Global_RFM><RFM_Validity><LAT_SCALE>
LINE_DEN_COEFF_i	Polynomial coefficients used to calculate the denominator (Q) in order to obtain centre-normalized latitude (i from 1 until 20). Direct model: <Rational_Function_Model><Global_RFM><Direct_Model><LINE_DEN_COEFF_i> Inverse model: <Rational_Function_Model><Global_RFM><Inverse_Model><LINE_DEN_COEFF_i>
LINE_NUM_COEFF_i	Polynomial coefficients used to calculate the numerator (P) in order to obtain centre-normalized latitude (i from 1 until 20). Direct model: <Rational_Function_Model><Global_RFM><Direct_Model><LINE_NUM_COEFF_i> Inverse model: <Rational_Function_Model><Global_RFM><Inverse_Model><LINE_NUM_COEFF_i>
LINE_OFF	Line offset used in RPC model. <Rational_Function_Model><Global_RFM><RFM_Validity><LINE_OFF>
LINE_SCALE	Line scale factor used in RPC model. <Rational_Function_Model><Global_RFM><RFM_Validity><LINE_SCALE>
LONG_OFF	Longitude offset used in RPC model. <Rational_Function_Model><Global_RFM><RFM_Validity><LONG_OFF>
LONG_SCALE	Longitude scale factor used in RPC model. <Rational_Function_Model><Global_RFM><RFM_Validity><LONG_SCALE>
M	Number of time stamp samples found in the product.
n(h)	Tabulated atmospheric refraction correction model.
(O, X, Y, Z)	Terrestrial Cartesian Coordinate.
O	Earth gravity center.
X	OXZ define Greenwich prime meridian plane.
Y	Y orthogonal to X and Z.
Z	Pole axis.
O_s	Satellite gravity center.
(O_s, T, R, L)	Local Orbit Frame.
T	Pitch axis $\vec{T} = \frac{\vec{Vit} \wedge \vec{Pos}}{\ \vec{Vit} \wedge \vec{Pos}\ }$
R	Roll axis : $\vec{R} = \vec{T} \wedge \vec{L}$
L	Yaw axis (build with Satellite Position : $\vec{L} = -\frac{\vec{Pos}}{\ \vec{Pos}\ }$)

(O_G, X_v, Y_v, Z_v)	Steering frame (or viewing frame).
X_v	Parallel to scan line direction.
Y_v	Parallel to detector array.
Z_v	Towards Earth.
(O_G, X_c, Y_c, Z_c)	“Pointing” frame. (X _c , Y _c , Z _c) = (X _v , Y _v , Z _v) when attitude control is perfect.
Offset	Offset used in centered normalized time value calculation. <Geometric_Data><Refined_Model><Attitudes><Polynomial_Quaternions><OFFSET>
Period	Line period (in ms). <Geometric_Data><Refined_Model><Time><Time_Stamp><LINE_PERIOD>
PosX(t) PosY(t) PosZ(t)	Satellite location at the given time.
PosX(t_i) PosY(t_i) PosZ(t_i)	Satellite locations at different times t _i . <Geometric_Data><Refined_Model><Ephemeris><Point_List><Point(i)> <LOCATION_XYZ>
R_E	Mean Earth Radius (R _E ≈ 6367,45km).
S_b	The spectral sensor sensitivity of b band.
SAMP_OFF	Column (sample) offset used in RPC model. <Rational_Function_Model><Global_RFM><RFM_Validity><SAMP_OFF>
SAMP_SCALE	Column (sample) scale factor used in RPC model. <Rational_Function_Model><Global_RFM><RFM_Validity><SAMP_SCALE>
SAMP_DEN_COEFF F_i	Polynomial coefficients used to calculate the denominator (Q) in order to obtain centre-normalized longitude (i from 1 until 20). Direct model: <Rational_Function_Model><Global_RFM><Direct_Model><SAMP_DEN_COEFF_i > Inverse model: <Rational_Function_Model><Global_RFM><Inverse_Model><SAMP_DEN_COEFF_i >
SAMP_NUM_COEFF F_i	Polynomial coefficients used to calculate the numerator (P) in order to obtain centre-normalized longitude (i from 1 until 20). Direct model: <Rational_Function_Model><Global_RFM><Direct_Model><SAMP_NUM_COEFF_i > Inverse model: <Rational_Function_Model><Global_RFM><Inverse_Model><SAMP_NUM_COEFF_i >
Scale	Scale factor used in centered normalized time value calculation. <Geometric_Data><Refined_Model><Attitudes><Polynomial_Quaternions><SCALE>
T	Viewing time computed for a given line.

Table of symbols & values location in DIMAP V2

t_{CN}	Centered normalized time value.
t_i	Ephemeris point times. <Geometric_Data><Refined_Model><Ephemeris><Point_List><Point><TIME>
t_{mean}	Absolute mean time computed with ephemeris point times.
t_{rel_i}	Ephemeris point times relative to mean absolute time.
t_{ref}	Reference time corresponding to reference line (see lin_{ref}). <Geometric_Data><Refined_Model><Time><Time_Range><START>
V_{ground}	Image orientation on the ground.
V_{sat}	Satellite velocity.
Vis_{Scan}	Viewing angle in image focal plane frame.
$VisX_{Scan}$	X coordinate of Vis_{Scan}
$VisY_{Scan}$	Y coordinate of Vis_{Scan}
$VisZ_{Scan}$	Z coordinate of Vis_{Scan}
X_{Scan}	Parallel vector to image line axis.
Y_{Scan}	Parallel vector to detector array.
Z_{Scan}	Vector towards Earth.
A	Incidence angle (°). <Geometric_Data><Use_Area><Located_Geometric_Values><Acquisition_Angles> <VIEWING_ANGLE>
α_x	Viewing angle in the across-track axis direction (roll). <Geometric_Data><Use_Area><Located_Geometric_Values><Acquisition_Angles> <VIEWING_ANGLE_ACROSS_TRACK>
α_y	Viewing angle in the along-track axis direction (pitch). <Geometric_Data><Use_Area><Located_Geometric_Values><Acquisition_Angles> <VIEWING_ANGLE_ALONG_TRACK>
B	Incidence angle (°). <Geometric_Data><Use_Area><Located_Geometric_Values><Acquisition_Angles> <INCIDENCE_ANGLE>
θ_s	The sun zenith angle (zenith angle = 90° – sun elevation angle) (°). <Geometric_Data><Use_Area><Located_Geometric_Values><Solar_Incidences><SUN_ELEVATION>
θ	Pitch angle.
φ	Roll angle.
ψ	Yaw angle.
ψ_x	Viewing direction angle in the Y_{Scan} direction (parallel to detector array).
ψ_y	Viewing direction angle in the X_{Scan} direction (parallel to image line axis).
Ω	Earth rotation angular speed.

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