SPOT 6 & SPOT 7 Imagery User Guide

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ASTRIUM
AN EADS COMPANY

ORGANIZATION OF THE SPOT 6 & SPOT 7 IMAGERY USER GUIDE

The SPOT 6 & SPOT 7 Imagery User Guide provides essential information to the users about all SPOT 6 products and services.

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

Chapter 1 details the SPOT 6/7 constellation and its performance.

Chapter 2 explains the SPOT 6 / SPOT 7 products offer.

Chapter 3 details product ordering options.

Chapter 4 presents product delivery.

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

A. DIMAP V2 format

B. Image quality performance

C. Geometric modeling

D. Spectral modeling

FEEDBACK 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. THE ASTRIUM SERVICES OPTICAL CONSTELLATION

With four new satellites - Pléiades 1A & 1B and SPOT 6 & SPOT 7 – launched in a two-year timeframe, Astrium Services is gearing up to bring its customers the very best that space technology has to offer.

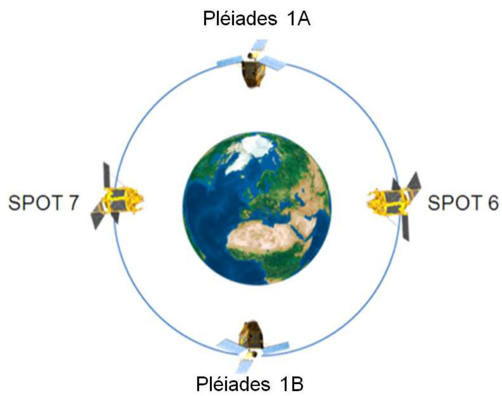


FIGURE 1: PLÉIADES 1A/1B & SPOT 6/7 CONSTELLATION

Ensuring continuity of Earth optical imaging service up to 2024, these satellites operate in 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 SPOT 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.

SPOT 6 and SPOT 7 satellite imagery offer an affordable source of information for analysing, monitoring, forecasting and managing resources and human activity on our planet. SPOT products are true decision-support tools for a large range of applications such as civil and military mapping, natural and man-made disaster management, natural resource exploration, land planning, crop and forestry monitoring, environmental protection and maritime surveillance.

Following tables outline the main characteristics of the SPOT 6/7 space and ground systems.

Number of satellites	2
Launch periods	SPOT 6: September 9th, 2012 SPOT 7: to be launched in the Dec. 2013-Jan. 2014 period
Design lifetime	10 years
Size	Body: ~ 1.55 x 1.75 x 2.7 m Solar array wingspan 5,4 m2
Launch mass	712 kg
Altitude	694 km
Onboard storage	1 Tbits end of life (Solid State Mass Memory)

TABLE 1: MAIN CHARACTERISTICS OF THE SPACE SYSTEM

SPOT 6 and SPOT 7 missions are designed to achieve efficiently both collection of large coverage and collection of individual targets that are possible thanks to the extreme agility of the satellite.

Orbit	Sun-synchronous; 10:00 AM local time at descending node
Period	98.79 minutes
Cycle	26 days
Viewing angle	Standard: +/- 30° in roll | Extended: +/- 45° in roll
Revisit	• 1 day with SPOT 6 and SPOT 7 operating simultaneously • Between 1 and 3 days with only one **satellite in operation**[1]
Pointing agility	Control Moment Gyroscopes allowing quick maneuvers in all directions for targeting several areas of interest on the same pass (30° in 14s, including stabilization time)
Acquisition capacity	Up to 6 million sq.km daily with SPOT 6 and SPOT 7 when operating simultaneously
Nominal imaging mode	60km-swath strips oriented along North-South axis; up to 600km length
Stereo capability	Single pass stereo and tri-stereo (Fore, nadir and aft mode)

TABLE 2: ORBITAL CHARACTERISTICS AND VIEWING CAPABILITY

[1] Depends on the latitude of the area of interest

Optical system	**One instrument made of 2 identical Korsch telescopes, each** with a 200 mm aperture**, delivering the expected swath.**
Detectors	PAN array assembly: 28,000 pixels MS array assembly: 4 x 7000 pixels
Spectral bands (specification)	Panchromatic: 0.450-0.745 µm Blue: 0.450-0.520 µm Green: 0.530-0.590 µm Red: 0.625-0.695 µm Near Infrared: 0.760-0.890 µm *The 5 bands are always acquired simultaneously.*
Swath	60km at nadir
Dynamic range at acquisition	12 bits per pixel
Location accuracy specification	• 35m CE 90 without GCP within a 30° viewing angle cone • 10m CE90 for Ortho products where Reference3D is available
Instrument telemetry link rate	X-band channel - 300 Mbits/s

TABLE 3: MAIN CHARACTERISTICS OF THE SPOT 6 AND SPOT 7 OPTICAL INSTRUMENTS

Main receiving stations	• Toulouse (France) • Kiruna (Sweden)
S-Band uplink stations	• Kiruna (Sweden) • Inuvik (Canada)
Programming centre	Astrium Service – Toulouse (France) Astrium Service – Chantilly VA (USA)
Production centre	Astrium Service – Toulouse (France)
Tasking plans refresh frequency	6 times/day/satellite
Update of weather forecast	4 times/day – fully automatic process
Satellite control centre	Astrium Satellite – Toulouse (France)

TABLE 4: MAIN CHARACTERISTICS OF THE SPOT 6/7 GROUND SEGMENT

1.1 Reactivity and Rapid Coverage Capacity

SPOT 6/7 constellation 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 up to daily revisit capacity:

Viewing angle	SPOT 6 or SPOT 7 only	SPOT 6 and SPOT 7
<5 degrees	26 days	13 days
<20 degrees	7 days	4 days
<30 degrees	5 days	2 days
<45 degrees	2 days	**1 day**

TABLE 5: REVISIT CAPACITY

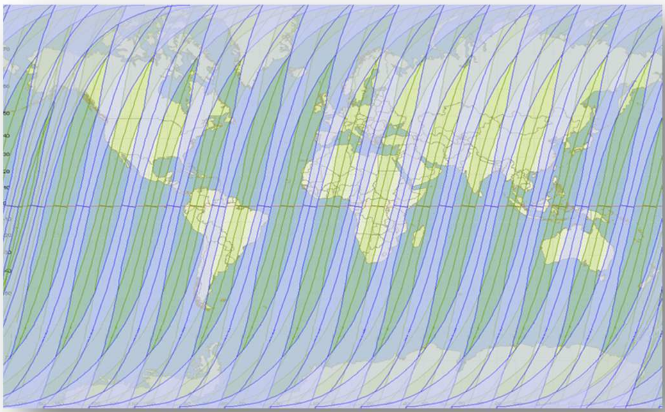


FIGURE 2: SPOT 6 (BLUE) AND SPOT 7 (GREEN) COMBINED CORRIDOR OF VISIBILITY ON A GIVEN DAY (+/- 30°)

The daily revisit capacity is backed by a reactive operational loop: mission plans are updated every 4 hours. Two polar uplink stations are used to optimize the upload of work plans.

They are located in:

- Kiruna (Sweden) – upload of two mission plans daily
- Inuvik (Canada) – upload of four mission plans daily

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

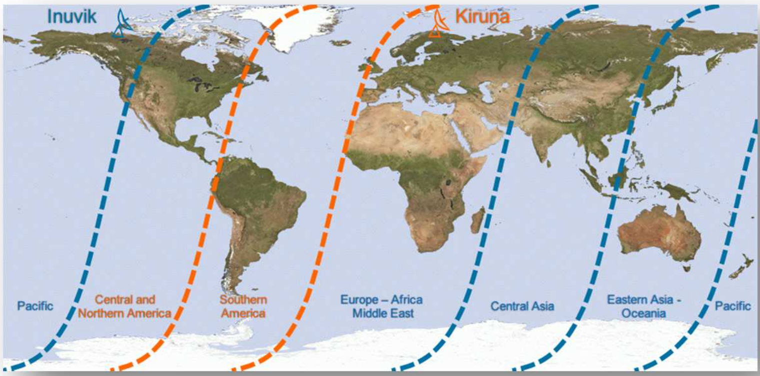


FIGURE 3: TASKING AREAS

SPOT 6 and SPOT 7 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 images collection opportunities
- Unprecedented capacity for disaster response, regular monitoring, or change detection
- Rapid coverage of areas of interest

1.2 Acquisition Capacity

SPOT 6/7 constellation has an impressive acquisition capacity of 6 million square kilometres per day. In addition the time needed to slew from one tasking request to another is reduced thanks to the agility of the systems and the successful acquisition rate is increased with the integration of frequent updates of weather forecasts.

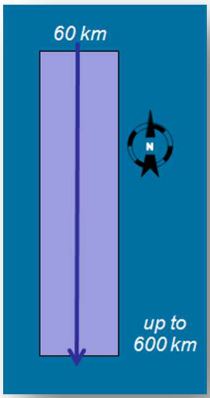
1.2.1 Swath and Coverage

The swath of 60 km, already available on previous SPOT missions, has been maintained on SPOT 6 and SPOT 7. SPOT 6 and SPOT 7 have been especially design to cover large areas in a shortest timeframe, therefore in nominal acquisition mode, the satellites acquired long strips, up to 600 km long

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.

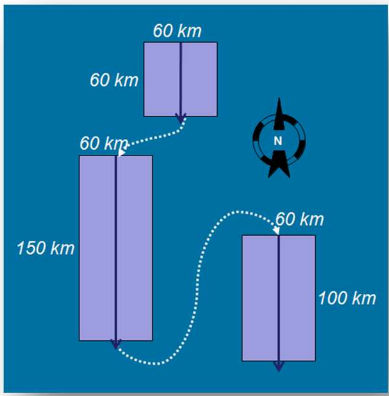
1.2.2 Single Pass Collection Scenarios – Overview

SPOT 6 and SPOT 7 mission takes benefits from the high agility of the satellite to offer efficient data collection capabilities making them particularly suitable to serve cartographic and monitoring applications.



a.

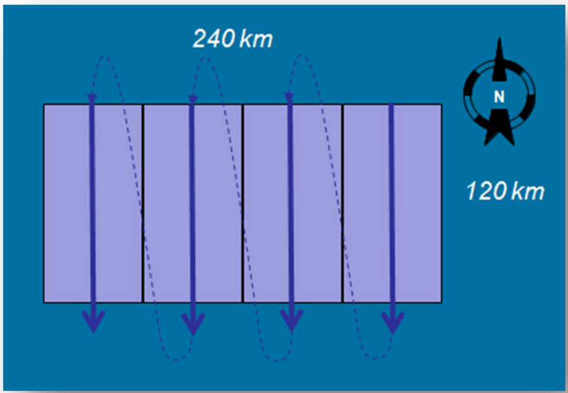
Standard data collection: Long strip



b.

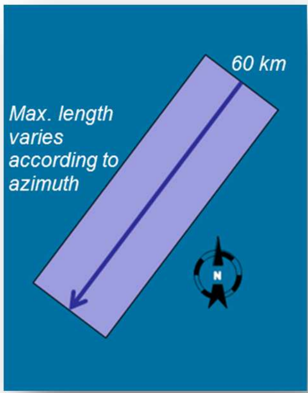
Standard data collection: Target

Standard data collection mode enables to acquire in one pass (a) North-South long strip of up to 600 km length. In addition, the high satellite agility allows (b) very quick moves from one scene to another along an orbit. This provides a high efficiency to complete, in the shortest time, global data coverage over a large area of interest, allow acquisition conflicts avoidance and makes possible the collection of number of distant targets in a given geographical area in a single pass.



c .

Single pass | Multi-strip collection



d.

Single pass | Corridor collection

SPOT 6 and SPOT 7 are able to acquire (c) contiguous image segments collected from a single pass along one orbit. This provides capability to cover areas of more than 240 km x 120 km or 180 km x 180 km in a single pass. Corridor acquisition (non North-South oriented) allows rapid covering of certain areas in an effective way (e.g. rivers, borders…)

FIGURE 4: SINGLE PASS COLLECTION SCENARIOS

1.2.3 Stereoscopic Cover Capabilities

SPOT 6 and SPOT 7 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 6, the systems allow the possibility to achieve a stereoscopic imaging composed of two images (fore and aft acquisitions) for which the angular difference (B/H) can be adjusted. An additional acquisition at nadir can be performed in addition (tristereoscopy).

Stereo		Tristereo	
B/H	**Length**	**B/H**	**Length**
0.15	35km	0.3	35km
0.2	60km	0.4	60km
0.3	120km	0.5	90km
0.4	180km	0.6	120km
0.5	240km	0.7	150km
0.6	300km	0.8	180km

TABLE 6: STEREO / TRISTEREO ACQUISITION CAPACITIES ACCORDING TO B/H

Tristereo 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. It is prescribed for dense urban and mountainous areas - Figure 5. Please refer to 3.2.2 (step 5) for more information about B/H.

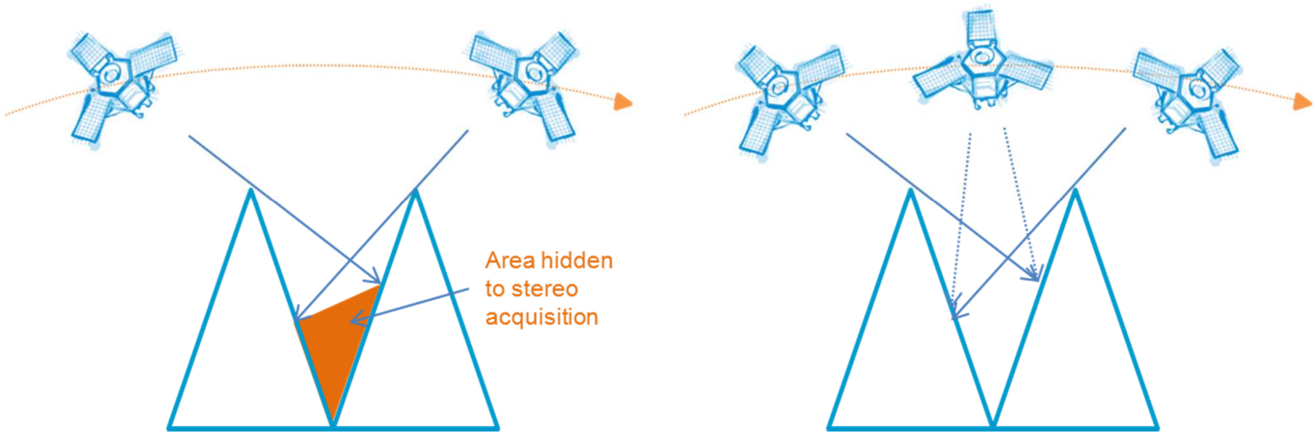


FIGURE 5: STEREOSCOPIC COVER CAPABILITIES OVER MOUNTAINOUS AREAS

2. PRODUCTS, SERVICES AND OPTIONS

SPOT 6 and SPOT 7 products can be easily integrated in GIS environment or used to derive thematic geo-information while combined with other satellite, airborne or ground information.

SPOT 6 and SPOT 7 instruments always acquire images simultaneously in both modes:

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

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

SPOT 6 and SPOT 7 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 May 1986, more than 100 billion square kilometres of Earth surface have been covered by SPOT successive missions and are ready for immediate order. *Archive* prices apply as soon as data is available in the **Astrium Services' archive catalogue** at www.astrium-geo.com/geostore.
SPOT 6 data started feed this archive since October 17th, 2012 with an average rhythm of 150 million new square kilometres every quarter.

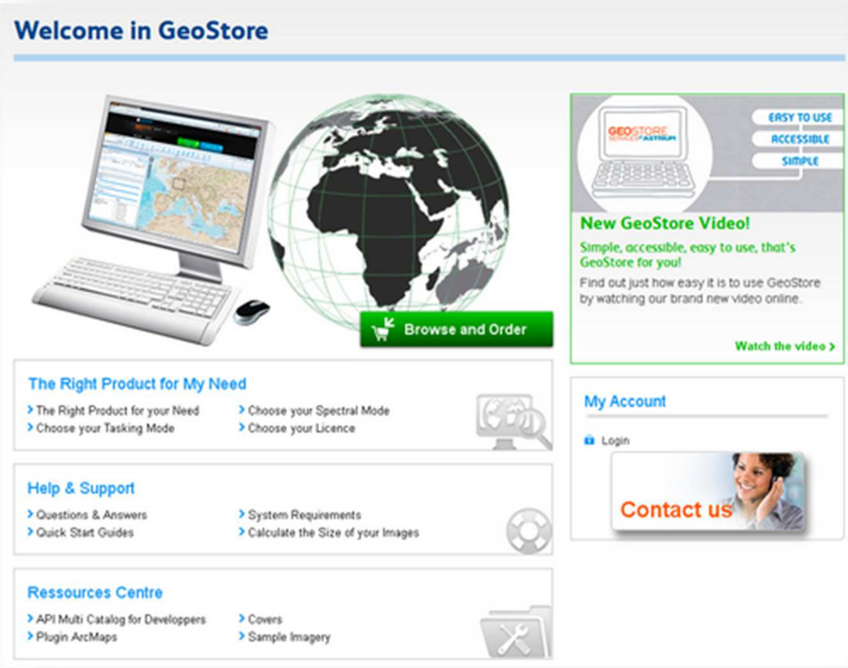


FIGURE 6: GEOSTORE - HOME PAGE

In case new acquisition is required, two services are proposed:

- **Tailored Tasking** - ideal for broad, complex areas of interest, Tailored Tasking offers the whole range of acquisition parameters (consideration of cloud cover, restrained viewing angle, regular acquisition, Stereo, Tristereo, etc.). Dedicated feasibility study is prepared with the full benefit of 27-year experience and know-how of the programing team. Customers benefit from the advices 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.
  Three levels of service are available: **Standard**, **Priority**, and **Emergency**.

- **Instant Tasking** - for customer requiring imagery to face an emergency situation. When a crisis occurs, or when information is required immediately, the customer goes to www.astrium-geo.com/geostore, enters its Area of Interest and chooses the next satellites passes. This service is integrates the resource from the whole Astrium Services' optical satellite constellation. Pléiades is prescribed when highest resolution is required over limited surface (maximum 20 km by 20 km), and SPOT 6 or SPOT 7 when bigger coverage is needed, up to a 50 km by 100 km-bounding box, oriented in any direction. The customer's request is directly integrated in the next mission plan with a maximum priority level. The image is acquired, downloaded, automatically produced and delivered, with no commitment on cloud coverage. This is fully-automated, 24/7 service provides the highest reactivity of the four-satellite constellation.

Below is an overview of these tasking services: (Table 7):

	Standard service	Priority service	Emergency services	
			Tailored	Instant Tasking
Access mode	Customer service (pdf order form)			www.astrium-geo.com/geostore
Minimum order size	1,000 sq.km > 20km in any direction			100 sq.km > 5km in any direction
Maximum order size	N/A			Within a 100kmx50km bounding box
Feasibility study	Yes	Yes	Yes, with priority	No
Duration of the tasking period	User defined	User defined	4 days after first attempt[2]	1 attempt in a 7-day period
Multi-period acquisitions	Yes	Yes	No	No
Regular acquisitions	Yes	Yes	No	No

[2] Customer to select an acquisition from the period to be produced and delivered.

	Standard service	Priority service	Emergency services	
			Tailored	Instant Tasking
Rush delivery	No	Optional	Optional	Yes
Access to extended angles	No	Optional	Optional	Optional
Access to corridor mode	No	Optional	Optional	Optional
Acquisition priority	No	Yes	Yes	Yes
Stereo/Tristereo acquisitions	Yes	Yes	No	No
Cloud cover	Standard: <10%, Optional: 0%	Standard: <10%	Standard: <10%	N/A

TABLE 7: TASKING SERVICES OPTIONS

Cloud Cover Warranty:

Optimizing SPOT 6 and SPOT 7 tasking in accordance with weather forecasts four times a day ensures that all resources are used as efficiently as possible. By default, we propose image tasking with cloud cover less than 10% over the Area Of Interest (AOI) of the order. In case weather conditions are difficult in the area to cover, feasibility study may advise users to set cloud cover percentage to higher value in order to get their area covered in shorter time. Cloud cover does not include cloud shadow and semi-transparency haze.

Cloud free option can be requested. Priority tasking fees is applied in that case.

2.2 Spectral Band Combinations

Combining the Panchromatic and Multispectral bands, images can be visualized as either black and white (1.5-m product resolution), natural colour, false colour (6-m product resolution) or as a merged product (Pan-sharpened colour image) with the resolution of the Panchromatic image.

2.2.1 Panchromatic

The Panchromatic product includes only one black and white band. It covers wavelengths between 0.450µm and 0.745 µm of the visible spectrum. The product pixel size is 1.5 m (Ortho).

FIGURE 7: EXAMPLE OF A PANCHROMATIC IMAGE

2.2.2 Multispectral

The Multispectral product includes four Multispectral (colour) bands. Specification values are:

- Blue: 0.455µm – 0.525µm
- Red: .530µm – 0.590µm
- Green: 0.625µm – 0.695µm
- Near Infrared: 0.760µm – 0.890µm.

The product pixel size is 6 m (Ortho).

FIGURE 8: EXAMPLE OF A MULTISPECTRAL IMAGE

2.2.3 Bundle

The Panchromatic (1.5 m) and Multispectral (6 m) products, simultaneously acquired, are packaged together separately (not merged) and co-registered for a single delivery (1 file for Multispectral + 1 file for Panchromatic).

Panchromatic image

Multispectral -4 bands- image

FIGURE 9: 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 1.5-m colour 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” spatial resolution Multispectral (colour) images to fine spatial resolution colour images, by fusing a co-registered fine spatial resolution Panchromatic image.

Panchromatic image

Multispectral image (zoom factor x4)

Pan-sharpened image

FIGURE 10: PAN-SHARPENED PROCESS

The upper left image is a natural colour image with a spatial resolution of 1.5 m (resampled 400%), and the upper right image is a Panchromatic image with a spatial resolution of 1.5 m. By combining these images, a very high-resolution colour Pan-sharpened image is produced. In the merged image, spectral signatures of the input colour 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-band and 4-band products. The 3-band colour products are available in Natural Colour (Blue, Green and Red) or False Colour (Green, Red and Near Infrared).

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

- To produce a Natural Colour image, the Red band is put in the red component of the monitor, the Green band is put in the green component of the monitor, and the Blue band is put in blue component of the monitor.
- For a False Colour image, any of the bands can be put in any RGB channel. The band combination can be changed to highlight the desired features.

2.3 Processing Level

SPOT 6 and SPOT 7 imagery products are available in two different processing levels: Primary and Ortho.

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

SPOT 6 and SPOT 7 imagery offer contains Panchromatic channel (product resolution: 1.5m), Multispectral channels (4 bands, product resolution: 6m) already registered when ordered in bundle and possibly merged in a Pan-sharpening product.

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, or a collection of acquisitions along the same path (case of stereo pairs or stereo triplets). 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 (60 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 on ground reference data if available
    - Attitudes filtering over time of acquisition
- 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
- Pixel sampling at Shannon optimizing image quality for downstream value-added processing: optimized bicubic kernel resampling into the Primary geometry, zoomed to the factor 7 / 5 (equivalent resolution of 1.5/6m in nadir condition)

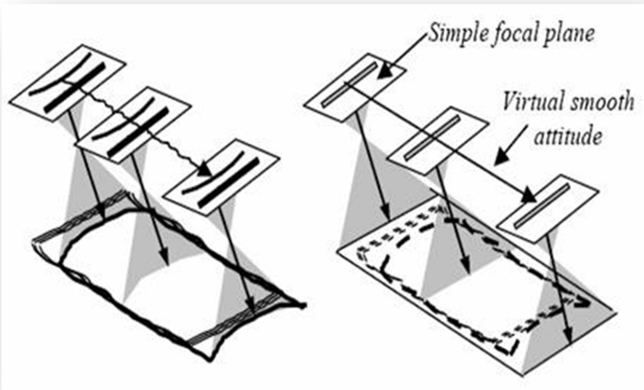


FIGURE 11: PERFECT SENSOR GEOMETRY

The final format includes:

- Masking of pixels outside the area of interest
- Physical tiling: images beyond a certain size are split into several files (see A.4.4 for more details).

The user selects:

- The spectral band combination: Panchromatic, Multispectral 4-Band or Bundle
- The bit-depth: 12-bit native (4096 values) or reduced to 8 bits (adjusted 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.

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.
- Map projection or geographic projection

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

- Pixel sampling at Shannon Sampling (optimized bicubic kernel) at a fixed resolution of 6 m for Multispectral products and 1.5 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.4.4) 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 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 (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 8: GEOMETRIC DETAILS OF THE ORTHO PRODUCT

2.3.3 Tailored Ortho

Aside from the Standard Ortho product, when different specifications are needed, Astrium 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

SPOT 6 and SPOT 7 products will be delivered in DIMAP V2, just like Pléiades ones. 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 could 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. SPOT 6 and SPOT 7 acquire 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
Pixel encoding 12 bits • Optimized compression • Regular compression	**Pixel encoding 16 bits** (12 bit-depth dynamic range) • Without compression
Pixel encoding 8 bits • Optimized compression • Regular compression	**Pixel encoding 8 bits** • Without compression

TABLE 9: IMAGE FORMAT OPTIONS

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

2.5 Licensing

Astrium 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 product with affiliated end-users identified in the data request form, in the frame of a joint project. The standard price of the product may include up to 5 affiliated end-users. For 6 or more end-users, the “Multi” option shall be selected and entails price uplift. Under this license, the end-user can:
  - Use the 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 product and are irreversible and decoupled from the source imagery data of the product. DW may be freely used and distributed
  - Share the 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 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 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 product for technical evaluation only. The end-user shall not transfer the 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 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 SPOT 6 and SPOT 7 Products

SPOT 6 and SPOT 7 products can be ordered either directly through the web portal www.astrium-geo.com/geostore 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 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 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 SPOT offer. They can order archived images online, and also request new SPOT 6 and SPOT 7 images through the different tasking services (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).

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 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
- Easy setup for prepaid accounts.

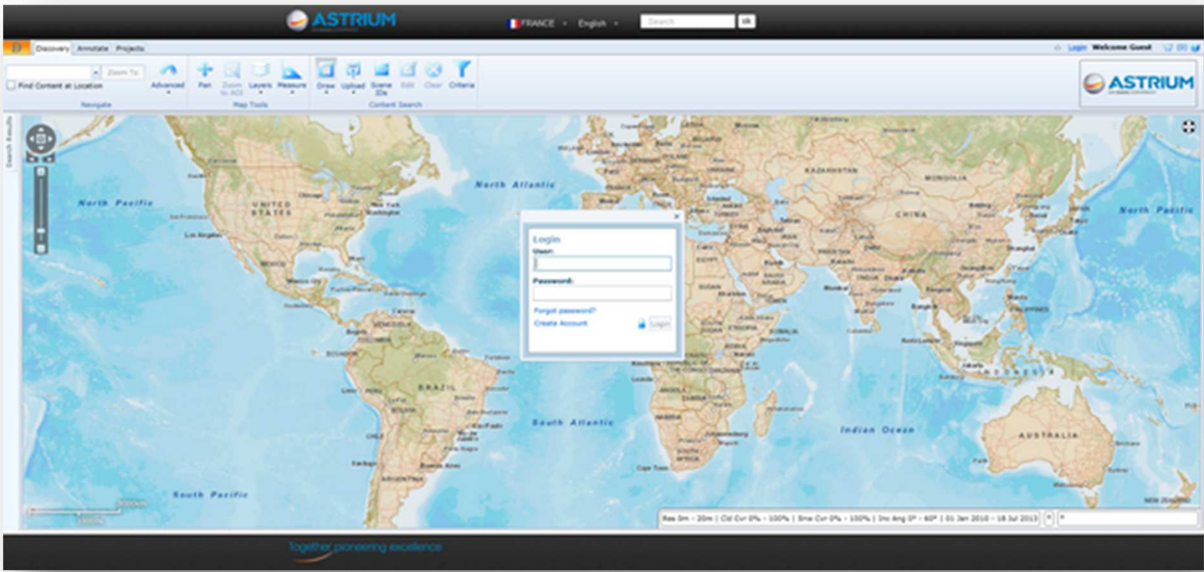


FIGURE 12: GEOSTORE – RESEARCH INTERFACE

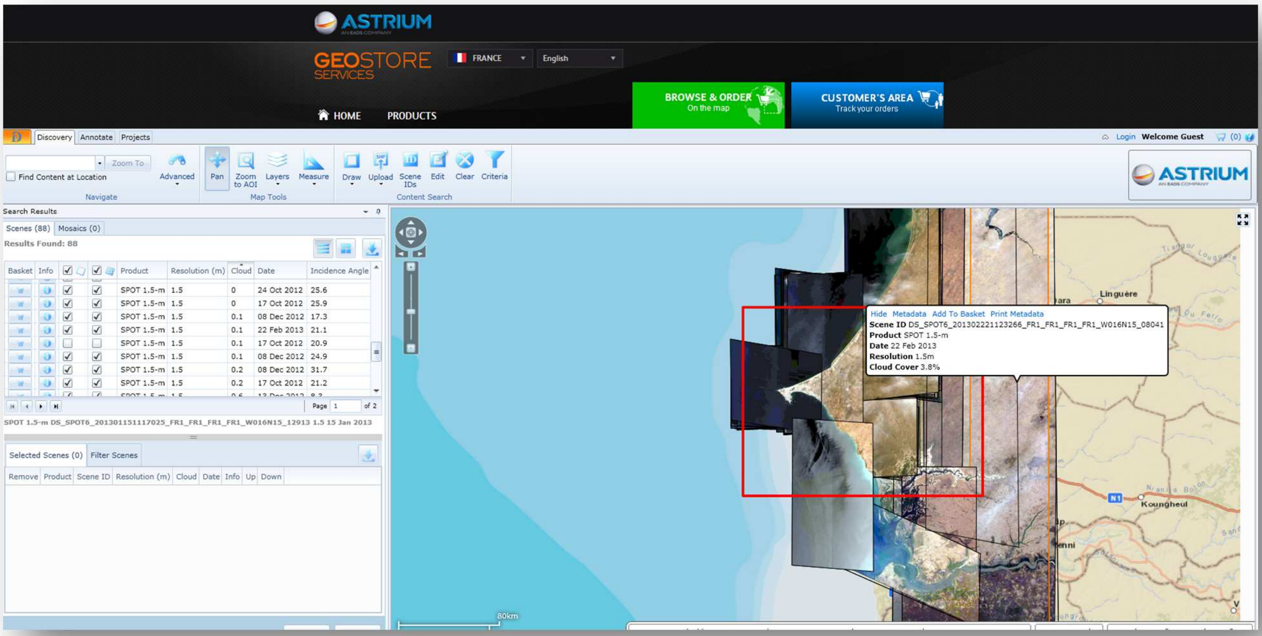


FIGURE 13: GEOSTORE - BROWSING ARCHIVE CATALOG

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.astrium-geo.com/geostore 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.

Contact Information

Billing address

Your order identification	
Customer ID (optional)	
Company Name:	
Contact Name:	
Address, Country:	
Telephone Number:	
Email:	
VAT Number	

Delivery address (if different from above)

Company Name:	
Contact Name:	
Address, Country:	
Telephone Number:	

Delivery

Media:	Select
Email Adress(es):	
Delivery Turnaround:	Select

End User Information

Final end user market

Choose an item:	Select
If "Other" please specify:	

Licensing

Choose an item for SPOT archive products:	Select
If more than one end user, please specify other affliated end users:	Please include the company, name, address, country, email and telephone for all affiliated end users below.
If "Other" please describe:	

Application

Choose an item:	Select
If "Other" please specify:	

Step 1 – Contact Information

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

Step 2 – Delivery

a. *Delivery Media:* choose Network for FTP delivery or Physical medium for DVD, Hard Drive or Flash Drive. Physical medium is selected by Astrium Services according to the size to the delivery:
   - DVD for delivery up to 4.7 GB
   - Flash Drive for delivery up to 16GB
   - Hard Drives for delivery above 16GB.

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 SPOT 6 Pricelist)
- For new acquisitions (free of charge) 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
Tailored Tasking	Rush delivery not available	Rush delivery available without uplift	N/A
Instant Tasking	N/A	N/A	Rush delivery automatically activated, without uplift

Because these products shall be delivered within a short timeframe, no image quality control will be performed.

Both standard and rush delivery times are applicable for archive data stored in Toulouse storage facility. Delivery Turnaround for archive data stored in one of our partner's Direct Receiving Stations may be slightly longer.

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 SPOT 6& SPOT 7 Data Request form.

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

Area of Interest

Country and place name:		
ESRI Shapefile (UTM or Lat / Long WGS84) Google Earth KML / KMZ (Lat / Long, WGS84)	name of the file:	
or Circle: (Lat / Long, Decimal Degrees, WSGS84)	Centre point (Lat / Long)	Radius (km)
or Rectangle: (Lat / Long, Decimal Degrees, WSGS84)	Upper Left (Lat / Long)	Lower Right (Lat / Long)

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.
- Coordinates can be provided in two different ways: either as a circle, giving latitude and longitude information of the centre in decimal or sexagesimal degrees, based on the WGS84 ellipsoid and a radius size, in kilometre, 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.
- The AOI shall be a minimum 250 sq.km wide for archive orders and 1000 sq.km wide for new acquisition orders, with a minimum width of 20 km in any direction for new acquisitions, and 5 km for archive.

Polygons must have a minimum of three points and a maximum of 999 points. The polygon must be one ring and should not intersect itself.

Archive

Please specify Segment ID (if known):	
Attached document in your email:	Select

New acquisition

Temporal mode:	Single Acquisition					
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:	Mono					
If "Mono":	Standard angle (30°	If "Other", please specify:				
If "Stereo" or "Tristereo":	Min B/H:		Max B/H:			
Service:	Standard					
Max Cloud Cover:	< 10%					
Cloud free	☐ cloud free acquisition	(priority tasking fees apply)				

Product Options

Spectral bands combination:	PMS: Pansharpening (4 bands)
Bit depth:	12 bits
Radiometric adaptation:	Stretching
Image Format:	JPEG2000 regular
Product Level:	Ortho
Ortho Projection:	Map Projection (E,N): UTM/WGS84
Scenes mosaicking	No
Comments	

Step 5 – Archive or New acquisition?

Archive

For ***archive data***, you must fill in the first part. If you have found the data you need in our GeoStore catalogue, 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 Customer Service makes the search for you, indicate 'don't know' in the appropriate field of the data request form.

New acquisition

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 01/01/13 – 31/03/13, it means that you want the image to be acquired during the first three months of 2013.
- For **Multi-period Acquisitions**, you may indicate start and end dates as many times as needed. For instance, if you indicate 01/01/13 – 31/03/13, 01/05/13 – 15/05/13, 07/06/13 – 14/06/13, it means you want three images, the first one to be acquired within the first three months of 2013, the second to be acquired in the first 15 days of May 2013 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 01/01/13 – 31/12/13 – monthly it means that you want an image to be acquired every month in 2013.

b. *Acquisition Mode:*

If you need a new image, you may also specify if you need a Mono, a Stereo or a Tristereo acquisition. A Monoscopic image means a single image is 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 is shot with a different viewing angle within the same orbit, enabling the creation of 3D models over the area of interest. In case of Tristereo 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 (Cf. *c. Incidence angle* below)
- If you select **Stereo** or **Tristereo**, 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 Tristereo mode. For Tristereo, a B/H around 0.25 can be recommended for each pair (eg 12° / 0° / 15 °).

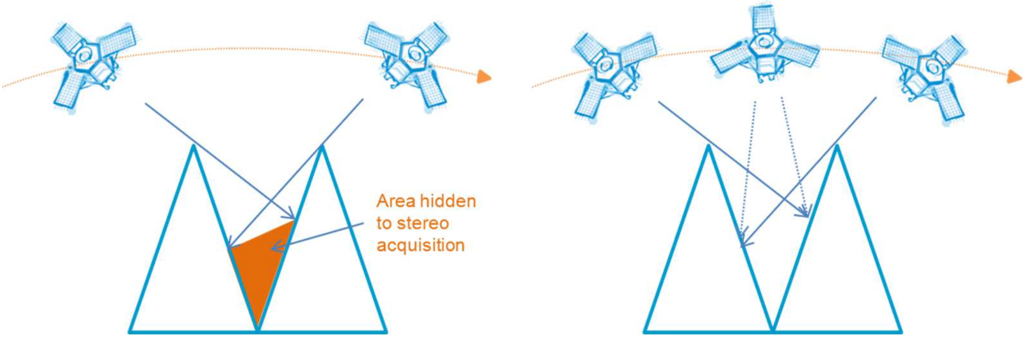


FIGURE 14: B/H RATIO AND HIDDEN ITEMS

c. Incidence angle:

Standard range for incidence angles is 0-30°.

SPOT 6 and SPOT 7 are able to acquire data up to 45°. Nevertheless the geometric quality is out of standard product specifications for incidence angles above 30°. It is however available when priority and emergency tasking are selected. The user who agrees with using extended angle is aware of the impact in term of geometric quality.

Please refer to the Abbreviations, Acronyms and Terms section for the definition of the viewing angle.

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. In case of Ortho production, when best geolocation accuracy is required, we advise to limit incidence angle to 20°, even 15° for rough terrain areas.

In case of Ortho production, when best geolocation accuracy is required, we advise to limit incidence angle to 20°, even 15° for rough terrain areas.

Please contact Customer Care Service for more information about how the viewing angle will affect your specific order.

d. *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 his option.
- **Emergency Service** guarantees that the image will be acquired as soon as possible after receiving a request with a specified cloud cover. When acquired the image is processed and delivered as fast as possible. This option is subject to an extra fee. Please refer to the SPOT 6 price list.

e. *Max. Cloud Cover:*

Default and minimum value for standard new acquisitions is <10%

In case weather conditions are difficult in the area to cover, users are able to set cloud cover percentage to higher value in order to get their area covered in shorter time.

Cloud free option can be requested. Priority tasking fees is systematically applied in that case.

Step 6 – Production options:

a. *Spectral band combination* you wish (see part 2.2 for complete details)

- **Panchromatic (1,5 m)**: black and white
- **Pan-sharpened 3-Band Natural Colour (1,5 m)**: merging the Panchromatic with the Blue, Green and Red bands
- **Pan-sharpened 3-Band False Colour (1,5 m)**: 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 colour Blue, Green, Red and Near Infrared bands
- **Multispectral 4-Band (6 m)**: full set of color Blue, Green, Red and Near Infrared bands
- **Bundle (Panchromatic, 1,5 m + Multispectral 4-Band Colour, 6 m)**: one Panchromatic image + the Multispectral (Blue, Green, Red and Near Infrared) bands delivered separately (not merged)

b. *Bit depth:* SPOT 6 and SPOT 7 dynamic range at acquisition is 12 bits. It means that each pixel can take one value out of 4096 for each spectral band. This characteristics helps for instance to detect objects in the darkness of the shadow of a building or a mountain, as more nuances can be taken by each pixel.

SPOT 6 and SPOT 7 products are proposed with either full dynamic range or reduced to 8 bits.

- 12 bits (JPEG 2000 format)/ 16 bits (GeoTIFF format): 12 bit-depth (4,096 levels) keeps the initial dynamic range of the source.
- 8 bits**:** Dynamic range is reduces from 4,096 to 256 levels through a linear adjustment algorithm.

If you are interested in easy-to-use images for visual interpretation, 8-bit images is to be chosen as there is no visual difference and files are much lighter.

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

c. *Radiometric adaptation*

A radiometric adaptation (linear adjustment) is systematically applied on products when ordered with an 8-bit dynamic range.

An additional option, called Optimized Visual Rendering (OVR) will be available before the end of 2013. This processing will includes adjustments in terms of Sharpness, Enlighting, Contrast and Atmospheric offset removal. It is mainly designed for users who do not have the tool to perform color stretches or who want a good looking basemap to be displayed in their GIS.

d. *Image format*.

SPOT 6 or SPOT 7 products are delivered in the DIMAP V2 format. Inside the 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 user willing to do some high precision post processing

- GeoTIFF (uncompressed)

Use of JPEG2000 format should be preferred for any users as the weight of products is much lower **with exactly the same image quality**.

In addition, performances of JPEG2000 for streaming access are much effective.

More about DIMAP V2 and JPEG 2000?

www.astrium-geo.com/en/3030-pleiades-and-spot-6-7-format-delivery

Please refer to part 2.4 for a complete overview of the DIMAP V2 format. Full technical details can be found in APPENDIX A:

e. *Product level*

Three options are provided for product processing level: Primary, Ortho or Tailored Ortho. Please refer to chapter 2.3 for more details on each level.

- Primary

Imagery data with radiometric correction and basic geometric processing aiming at rebuilding as best as possible an image which would have been acquired from a unique ideal Push-Broom sensor.

Primary level is preferred when users need to keep the parallax effects of the acquisition.

Primary is the only processing level authorized for Stereo/Tri-stereo acquisitions

By definition, orthorectification process modifies the shape of the original image, especially when acquired over contrasted areas. In that case, we highly recommend to apply a buffer around the area of interest when ordered, in order not to miss any part of it.

- Ortho

Imagery data orthorectified to match accurate map projection for cartography and mapping usages, and to allow image fusion with other geographical information of various types (vectors, raster maps and other satellite images)

As standard GEOElevation30 (Reference3D) or Reference3Dalpha are used where available (about 110 million of sq.km available) as ortho and DEM layer. The geolocation accuracy of the Ortho produced with these sources is then better than 10 metres CE90.

Technical information on Reference3D product: www.astrium-geo.com/en/198-elevation30

In case Reference3D doesn't cover the full AOI, SRTM is used.

In case neither SRTM nor Reference3D cover the full AOI, GTOPO30 is used.

It is possible to force the use of SRTM, in case the user needs to overlay the product with other datasets already ortho-rectified with SRTM reference. This option is not available for orders through Geostore.

A maximum viewing angle of 20° is recommended for both Ortho and Tailored Ortho levels.

- Tailored Ortho

User is able to provide its own reference for Ortho production –i.e. DEM and ortho layer/GCP.
When Tailored Ortho is selected, feasibility study is performed and quotation provided accordingly.
For Tailored Ortho, please indicate your specifications in terms of location accuracy.
Before a Tailored Ortho order is accepted, Astrium 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 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.

Tailored Ortho is not available for orders through Geostore.

f. *Ortho projection*

It is possible to select the projection system to be used for Ortho processing.

- Standard

Geographic coordinates and a list of projection systems are available as standard. Please refer to chapter A.5 for available geographic and cartographic projections.

UTM projection system is recommended versus geographic coordinates.

- User-defined

This option should be selected when the projection system you require for Ortho processing is not available. Projection parameters should be provided. This option is not available for orders through Geostore.

g. *Scene mosaicking*

A set of SPOT 6 and/or SPOT 7 products these cover an area of interest can be delivered separately or mosaicked to cover the whole areas, seamless.

When Mosaic option is selected, feasibility study is performed and a quotation is provided accordingly.

Production delay depends on the size of the AOI

This option is not available for Ortho level products

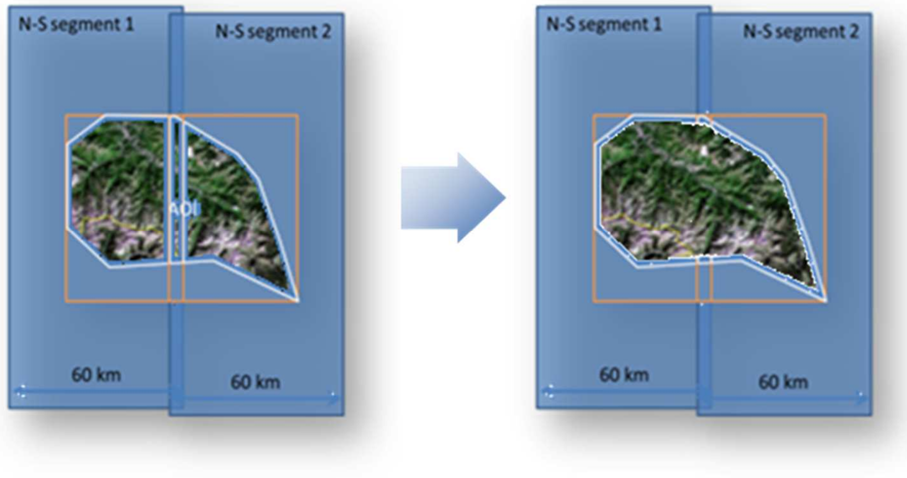


FIGURE 15: PRODUCTS MOSAICKING PROCESS

For any questions about any of the order parameters, please contact our Customer Care Service.

Step 7 – Feasibility Study

Once you have completed the data request form, we will verify the feasibility of the request, especially in the case of new acquisitions. We first check the feasibility to cover the area of interest within the specified collection window. Astrium's Tasking Department will also check the potential conflicts over the requested area of interest during the collection window. If a conflict exists, we will come back to you and propose 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 working day after reception 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 working 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 10 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 10: TIMEFRAMES FOR TASKING REQUESTS

3.3 Order Cancellation, Order Modification, Terms and Conditions

Please refer to our General Supply Conditions of Satellite Imagery Products: 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.astrium-geo.com/geostore), 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.

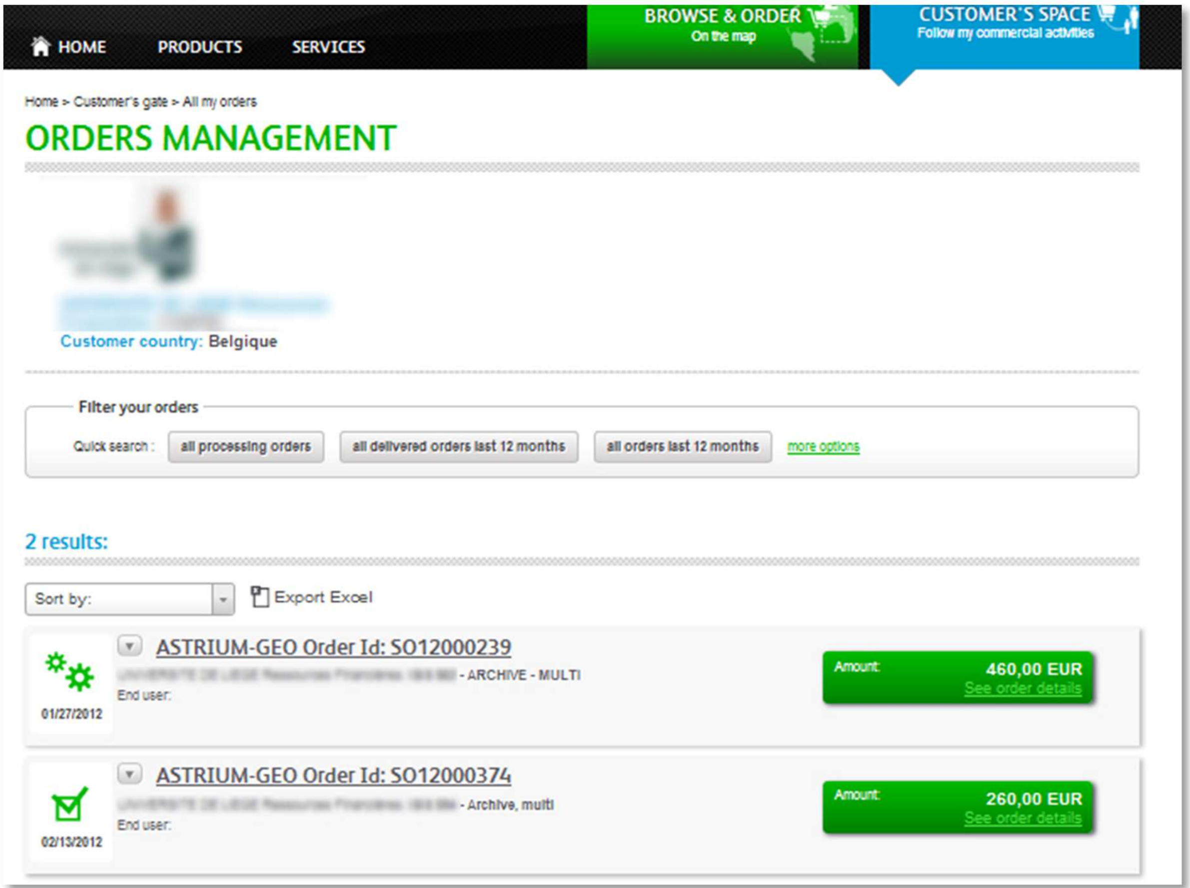


FIGURE 16: GEOSTORE ORDER MANAGEMENT PAGE – LIST VIEW

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

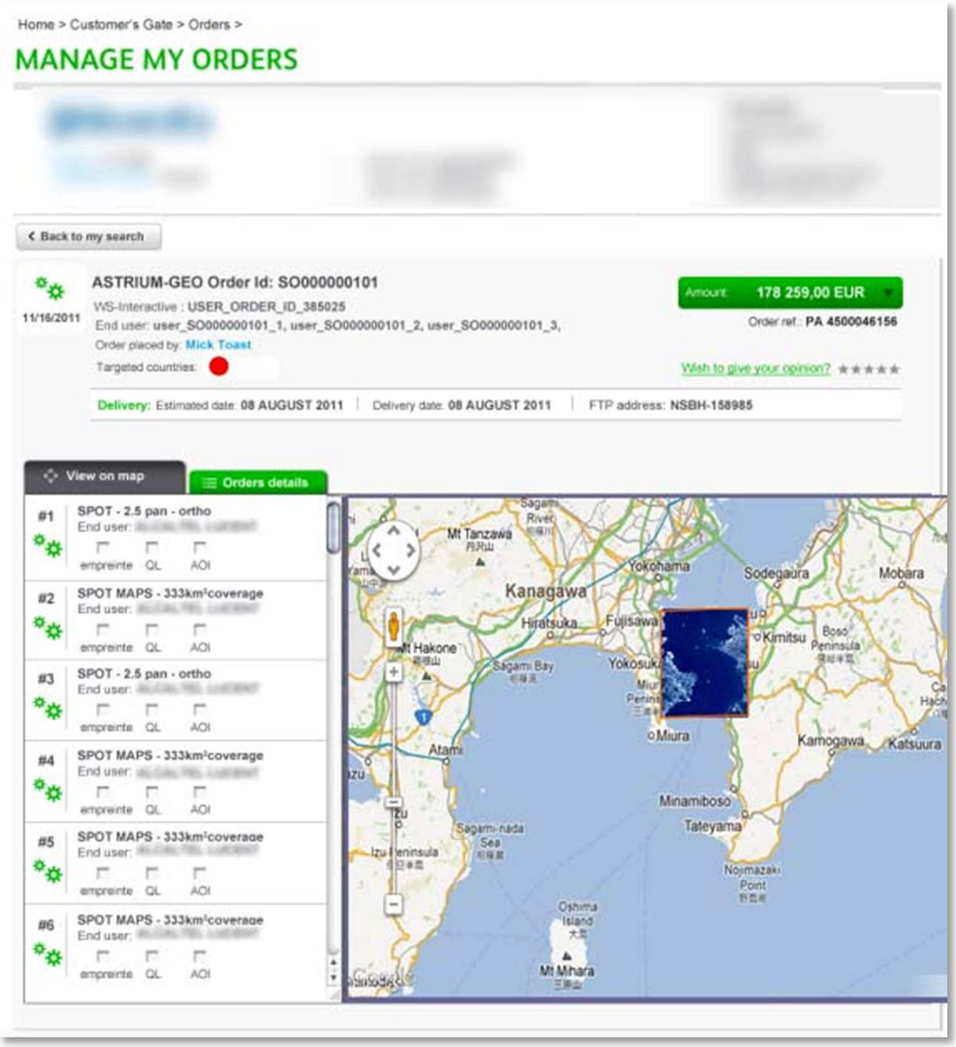


FIGURE 17: GEOSTORE ORDER MANAGEMENT PAGE – MAP VIEW

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

TABLE 11: 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 1.5-m, Pan-sharpened 4-band, 3,600 sq.km product.

JPEG 2000	GeoTIFF
Bit-Depth 12 bits • Optimized: 2.6 GB • Regular: 6 GB (max)	**Bit-Depth 12 bits** *(storage 16 bits)* • 12 GB
Bit-Depth 8 bits • Optimized: 2.6 GB • Regular: 6 GB (max)	**Bit-Depth 8 bits** • 6 GB

TABLE 12: 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 16-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, 1.5m)	1	1
Pan-sharpened 3-Band (Natural Color, 1.5m)	1	3
Pan-sharpened 3-Band (False Color, 1.5m)	1	3
Pan-sharpened 4-Band (Color, 1.5m)	1	4
Multispectral 4-Band (Color, 6m)	1	4
Bundle (Panchromatic, 1.5m + 4-Band Color, 6m)	1 + 1	1 + 4

(*) Regardless of tiling

TABLE 13: 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 18: 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_SPOT6_P_201210250959306_SEN_605179101_R1C1.JP2
IMG_SPOT6_P_201210250959306_SEN_605179101_R1C2.JP2
IMG_SPOT6_P_201210250959306_SEN_605179101_R1C3.JP2
IMG_SPOT6_P_201210250959306_SEN_605179101_R2C1.JP2
IMG_SPOT6_P_201210250959306_SEN_605179101_R2C2.JP2
IMG_SPOT6_P_201210250959306_SEN_605179101_R2C3.JP2
```

A ESRI worldfile J2W (or TFW for GEOTIFF products) is associated to each image tile (tile assembling for Primary products or georeferencing for Ortho products)

```
IMG_SPOT6_P_201210250959306_SEN_605179101_R1C1.J2W
IMG_SPOT6_P_201210250959306_SEN_605179101_R1C2.J2W
IMG_SPOT6_P_201210250959306_SEN_605179101_R1C3.J2W
IMG_SPOT6_P_201210250959306_SEN_605179101_R2C1.J2W
IMG_SPOT6_P_201210250959306_SEN_605179101_R2C2.J2W
IMG_SPOT6_P_201210250959306_SEN_605179101_R2C3.J2W
```

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

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, 3,600 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

SPOT 6 and SPOT 7 products are delivered in DIMAP V2 format.

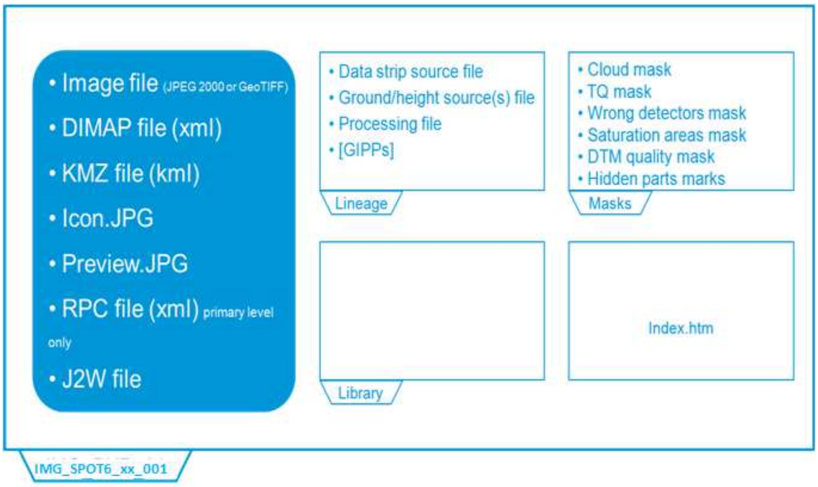


FIGURE 19: DIMAP V2 STRUCTURE

4.2.2 Example

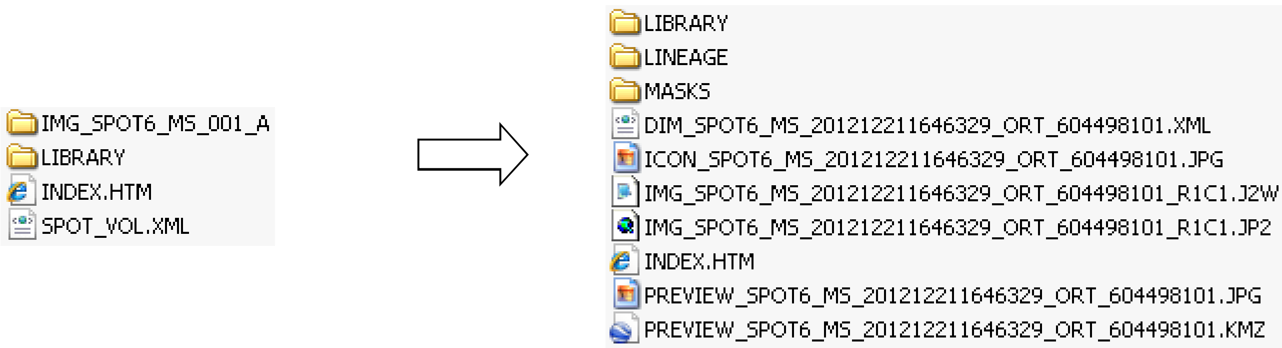


FIGURE 20: EXAMPLE OF DIMAP V2 STRUCTURE

Delivery File

A delivery file in pdf format will provide 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:

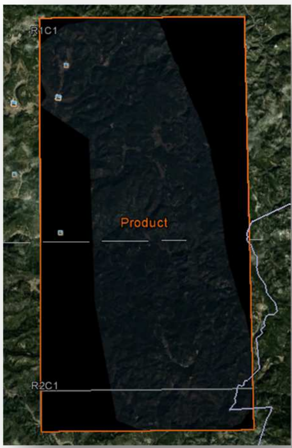


FIGURE 21: KMZ PREVIEW, FOOTPRINT

- Click on different objects to get more information:

FIGURE 22: KMZ PREVIEW, BUBBLE

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

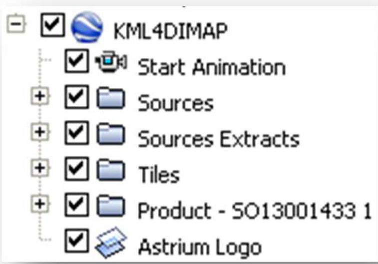


FIGURE 23: KMZ PREVIEW, LAYERS

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

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

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

Tiles: This layer shows the footprint and information (name, Volume ID) 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>9.9225</GAIN>
<BIAS>0</BIAS>
```

- Geometric values: Acquisition angles :

```
<AZIMUTH_ANGLE>61.4816816459</AZIMUTH_ANGLE>
<VIEWING_ANGLE_ACROSS_TRACK>-5.24525959689</VIEWING_ANGLE_ACROSS_TRACK>
<VIEWING_ANGLE_ALONG_TRACK>4.68608489805</VIEWING_ANGLE_ALONG_TRACK>
<VIEWING_ANGLE>7.01737330178</VIEWING_ANGLE>
<INCIDENCE_ANGLE_ALONG_TRACK>-3.81165895086</INCIDENCE_ANGLE_ALONG_TRACK>
<INCIDENCE_ANGLE_ACROSS_TRACK>6.8246901863</INCIDENCE_ANGLE_ACROSS_TRACK>
<INCIDENCE_ANGLE>7.70697203876</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 Ortho images or to assembly tiles 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 SPOT 6 or SPOT 7 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.) SPOT 6 and SPOT 7 products. The various software packages use different methods to georeference SPOT 6 and SPOT 7 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, use XML or RPC metadata files.

For any question regarding image processing software and versions able to integrate SPOT 6 and SPOT 7 products feel free to contact the technical support 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 Ortho products. For Tailored Ortho products, the physical format is shared with other sensors and is based on the standard described hereafter.

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
PROD_	X		Encapsulation directory of all acquisitions of a same pass	One to three linked acquisitions of a same pass
VOL_	X		Single acquisition directory (volume)	One per acquisition
IMG_	X	X	Single imagery directory, or image file(s), or associated georeferencing file(s)	Folder: One per spectral imagery
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, one per source
HEIGHT_		X	DIMAP, Height Source metadata file	If Vertical reset, one per source
PROCESSING_		X	DIMAP, processing lineage file	
CLD_		X	Cloud vector mask	

Prefix	Folder	File	Subject	Remark
DET_		X	Out of order detectors vector mask	
DTM_		X	DTM quality vector mask (water area)	Ortho only
QTE_		X	Synthetic QT vector mask	
ROI_		X	Region of Interest vector mask	
SLT_		X	Straylight and saturation vector mask	Optional
SNW_		X	Snow vector mask	
VIS_		X	Hidden part vector mask	Ortho only

TABLE 14: NAMING - PREFIXES

The suffixes are:

Suffix	Folder	File	Subject	Remark
_LIST		X	Dataset packaging index file	
_PROD	X	X	Index file of products related to acquisitions of a same pass	
_VOL		X	Index file of products related to a single acquisition	
_DIM		X	Various DIMAP metadata files (different from the main product metadata file)	
_R*i*C*j*		X	Image product file, possibly tiled	*ij*, Row (R) and Col (C) tile indexes
_MSK		X	Mask, raster or vector	Vector, GML format

TABLE 15: NAMING - SUFFIXES

The following files/directories have fixed naming:

Names	Folder	File	Subject	Remark
DELIVERY		X	Delivery note	
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 16: NAMING - MAIN DIRECTORIES

The file extensions are:

Extension	File	Subject	Remark
.GML	X	GML vector files	Mask file
.HTM	X	HTML file	
.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 17: NAMING - EXTENSIONS

A.1.1.2 Variable Key Information

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

The image directory name is comprised of:

<DirImage_ID>

SPOT<SAT_NUMBER>_<SPECTRAL_PROCESSING>_<PROD_ID>_<VOL_ID>

Example: **SPOT6_PMS_001_A**

Where: <SAT_NUMBER> = {6, 7}, SPOT 6 or SPOT 7
<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 18: NAMING – SPECTRAL PROCESSING

<PROD_ID> = {001, 002, 003}, single acquisition index (PROD_SPOTx_*PROD_ID*). Format is three digits increased by one

<VOL_ID> = {A, B}, single imagery index (VOL_SPOT*x_PROD_ID_VOL_ID*). Format is one letter increased by one

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

<Product_ID>

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

Example: **SPOT6_PMS_201006181052299_ORT_123456789**

Where: <SAT_NUMBER> = see previous section
<SPECTRAL_PROCESSING> = see previous section
<IMAGING_TIME> = UTC strip source acquisition start time. Format = "YYYYMMDDHHMMSSS"
<PROCESS_LEVEL> = {SEN, ORT}

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

TABLE 19: NAMING – PROCESSING LEVELS

<JOB_ID> = Internal production identifier. Format = variable string

Name(s) of SPOT 6/7 Data Strip Source metadata file(s) is comprised of:

<DATA_STRIP_ID>

DS_SPOT<n>_<YYYYMMDDHHMMSSS>_<AAA>_<aaa>_<RRR>_<rrr>_<XxxxYyy>_<TTTTT>

Example: **STRIP_DS_SPOT6_201212051035424_FR1_FR1_FR1_FR1_E002N41_01174**

Where: <n> = satellite number {6, 7}

<YYYYMMDDHHMMSSS> = UTC strip source acquisition start time
<AAA> = effective archiving center acronym
<aaa> = planned archiving center acronym
<RRR> = effective receiving center acronym
<rrr> = planned receiving center acronym
<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)
<TTTTT> = Number of PAN source frames

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 complete layout is as follow:

Primary, Ortho Imagery

SPOT_LIST.XML	Root packaging layout level
INDEX.HTM	
DELIVERY.PDF	
LIBRARY	
PROD_SPOT***x***_<***PROD_ID***> [1:n]	pass level (n=1)
SPOT_PROD.XML	
INDEX.HTM	
LIBRARY	
VOL_SPOT***x***_<***PROD_ID***>_<***VOL_ID***> [1:3]	acquisition level
<MISSION>_VOL.XML [1:1]	
INDEX.HTM [1:1]	
LIBRARY	
IMG_**<DirImage_ID>** [1:2]	spectral imagery level
INDEX.HTM	
DIM_<***Product_ID***>.XML [1:1]	
….	
LINEAGE	
MASKS	
LIBRARY	

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 The packaging layout

The packaging layout allows collecting several acquisitions of a same pass in a single delivery:

- One acquisition for Panchromatic, Multispectral, Pan-Sharpened or bundle for single orders
- Two acquisitions or three acquisitions for stereo pair or stereo triplet orders

	PROD directory	VOL directory	IMG directory
One Panchromatic	1	1	1
One Multispectral	1	1	1
One Pan-sharpenend	1	1	1
One Bundle	1	1	2
One stereo pair	1	2	2 or 4 (bundle case)
One stereo triplet	1	3	3 or 6 (bundle case)

Depending of the ordering system, stereo pair and stereo triplet should also be packaged separately.

The case of acquisitions of different passes (meaning several PROD directories) is not provided in standard delivery.

A.1.2.2 The imagery layout

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

- A root level index
- An spectral imagery level (1 to 2)
- Inside an imagery level, a set of sub-levels with additional information like striping masks

The usual file structure is as follows (primary and ortho products):

<MISSION>_VOL.XML [1:1]	
INDEX.HTM [1:1]	
LIBRARY	
VOL_LOGO.JPG	
VOL_STYLE.XSL	
IMG_**<DirImage_ID>** [1:2]	
INDEX.HTM	
DIM_<***Product_ID***>.XML [1:1]	
RPC_<***Product_ID***>.XML [0:1]	*for Primary Product only*
PREVIEW_<***Product_ID***>.KMZ [1:1]	
PREVIEW_<***Product_ID***>.JPG [1:1]	
ICON_<***Product_ID***>.JPG [1:1]	
IMG_<***Product_ID***>_R*i*C*j*.{JP2, TIF} [1:*n*]	*n if image is physically tiled*
IMG_<***Product_ID***>_ R*i*C*j*.{J2W,TFW} [1:*n*]	*n if image is physically tiled*
LINEAGE [1:1]	
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*]	if *ground reset*
HEIGHT_**R3D_DT2_*<Ref3D_Tile_ID>***_DIM.XML [0:*n*]	nor
HEIGHT_**SRTM_DT1**_DIM.XML [0:*n*]	nor
HEIGHT_**GLOBE**_DIM.XML [0:*n*]	if *vertical reset*
MASKS [1:1]	
CLD_<***Product_ID***>_MSK.GML [1:1]	
DET_<***Product_ID***>_MSK.GML [1:1]	
DTM_<***Product_ID***>_*MSK*.GML [0:1]	*for ortho product only*
QTE_<***Product_ID***>_MSK.GML [1:1]	
ROI_<***Product_ID***>_MSK.GML [1:1]	
SLT_<***Product_ID***>_MSK.GML [1:1]	
SNW_<***Product_ID***>_MSK.GML [1:1]	
VIS_<***Product_ID***>_*MSK*.GML [0:1]	*for ortho product only*
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 a physical Media

The type of media for physical delivery (DVD, Blue-ray, USB, Hard Disk Drive) is selected according to the product size.

A.2 Levels of Information and File Short Contents

File name	Standard Products	
	Primary	Ortho
XML Dataset Index File	Y	Y
HTML Dataset Index File	Y	Y
Delivery File	Y	Y
XML Index File	Y	Y
HTML Index File	Y	Y
XML Index File	Y	Y
HTML Index File	Y	Y
Product File	Y	Y
RPC File	Y	N
World File	Y	Y
KMZ File	Y	Y
Preview File	Y	Y
Thumbnail File	Y	Y
Data Strip Source File	Y	Y
Ground Source File	N	If set
Height Source File	N	Y
Processing File	Y	Y
Mask File	Y	Y

TABLE 20: OVERVIEW OF AVAILABLE INFORMATION VS. PROCESSING LEVELS

A.2.1 The Dataset Packaging Root Level

The root level provides information on all products collected by the delivery order. 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 Dataset Index Metadata File

SPOT_LIST.XML: file encoding = XML, metadata format = DIMAP V2

The Dataset Index metadata file, lists all components of the delivery order (i.e. all unitary products on the media): the access path to next level index metadata files.

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, product metadata files and imagery 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 imagery, a selection of information, and possibly for standard products, the histograms of each spectral band and quicklook.

A.2.2 The Pass Acquisitions Level

The Pass Acquisition level encapsulated all imagery acquired in a same pass. The delivery contains one or several spectral products. Each is a component of the full delivery.

A.2.2.1 Index Acquisition Pass Metadata File

SPOT_PROD.XML: file encoding = XML, metadata format = DIMAP V2

This index file is a subset of the Dataset index file, limited of all acquisitions of a same pass: mono acquisition (Bundle or one of PAN or MS or Pan-sharpened) or stereo pair or stereo triplet.

A.2.3 The Acquisition Level

A.2.3.1 Index Acquisition Metadata File

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

The Index Acquisition metadata file, or Volume file, lists all components of a single acquisition (i.e. all unitary products on the medium): the access path to spectral product metadata files and associated thumbnail images.

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.2.4 The Spectral Imagery Product Level

IMG_<DirImage_ID>

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

A.2.4.1 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: each vertex located using the rigorous model of the image at the elevation values given by the system DEM (possibly coarse)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 EPSG. It includes five single entities: - 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 Projected and geodetic are the common ones for image mapping. Conventionally, Primary image are recorded with WGS84 geodetic CRS CRS are recorded to EPSG registry if known. Subsequent parameters are only given if no identifier is found in the registry (commonly known

	as a "user-defined" definition)
Geoposition	Easiest relationship between the dataset coordinates and the CRS coordinates: - Georectified data (Ortho): insertion point and dimension - Raw image (Primary): link to RPC analytic model
Processing_Information	Information on production facility, level of processing, processing settings: geometric, radiometric, sampling, MTF
Raster_Data	Raster file path(s) and tiling size organization, encoding and displaying
Radiometric_Data	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
Geometric_Data	Geometric information: - 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	Quality information. Should be: - Planimetric accuracy (Ortho Product) - Vertical accuracy (DEM product) - Link to various data giving quality information: lineage masks
Dataset_Sources	Original data identification from which the current dataset was made and a link to the corresponding lineage metadata file(s)

TABLE 21: METADATA ORGANIZATION

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.2.4.2 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).

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

TABLE 22: RPC METADATA FILE

A.2.4.3 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 A.6).*

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 World File is adapted to assemble raster tile files, if any. At this level World File has no ability to georeference the image (sensor geometry), please use XML metadata files (Dimap or RPC).

A.2.4.4 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. Meanwhile the content would be unified with Pléiades, the current different layer contents 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. Double-click on the iconic to locate the satellite at acquisition
Sources Extracts	The outline extract(s) performed by the data production system for the current product Could be ignored and turned-off by end user (will be simplified, current is one feature = one subswath per band)
Tiles	The footprint of each image tile
Product	The footprint of the whole product (produced polygon from the ordered polygon) and its PREVIEW image
Logos Layer	

TABLE 23: KML METADATA FILE

FIGURE 24: KMZ OVERVIEW

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 necessary located at the true Ground Surface, but positioning with the following estimated positioning:

- Sources - the source strip extent(s), vertex positions using the rigorous model of the image with a possibly coarse DEM.

- Source extracts - the outline extract(s), vertex positions using the rigorous model of the raw strip with a possibly coarse DEM.
- Tiles - the footprint of each tile 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.
- Product - the footprint of the product is positioned:
  - For Primary products, using the rigorous model of the image 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.2.4.5 Preview Raster File

PREVIEW_*<Product_ID>*.JPG: file format = JPEG

The sub-sampled image (also called a quicklook), is compressed. The PREVIEW image is sub-scaled from the full resolution image to fit a fixed size of nearly 1000 columns.

A radiometric enhancement is planned before end of 2013

A.2.4.6 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 nearly 128 columns.

A.2.5 Sub-Levels With Additional Information

A.2.5.1 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.2.5.1.1 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 if any.
Geometric_Data	Acquisition time and date of the full strip
Catalog	Coordinate of the strip as stored in the catalogue system

TABLE 24: DATASTRIP SOURCE METADATA FILE

A.2.5.1.2 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 Primary or Ortho level to reset the native location of the image on GCP, if requested and available when placing the imagery order. This file is not supplied for products with no reset applied (native location of the sensor data).

For Standard 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 25: GROUND SOURCE METADATA FILE

A.2.5.1.3 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 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.

For Primary products, this file is not used.

DIMAP groups: same as Ground Source metadata file.

A.2.5.1.4 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 26: PROCESSING METADATA FILE

A.2.5.2 The Mask Sub-level

MASKS

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

A.2.5.2.1 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 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):

flush_period=2048 Stiles=\{2048,2048\} Sprecision=12 (or 8) Cycc=yes (except for PAN) Creversible=yes/no Qstep=0.000244 (or 0.0039) Cblk=\{64,64\} Clevels=5 Cuse_precincts=yes Cprecincts=\{256,256\},\{256,256\},\{256,256\},\{256,256\},\{256,256\},\{256,256\} Corder=RPCL ORGgen_plt=yes Clayers=10.

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 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 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 Raster file Band Index

JPEG2000 and TIFF files are both organized in multi-band files (one single file for all spectral bands). According a direct RGB load and go at screen. The raster loader at screen should follow the default order:

Spectral Processing	Nbands	RGB (Red)	RGB (Green)	RGB (Blue)	Extra Channel	Intensity Channel
PAN	1	-	-	-	-	1
MS	4	1(B2)	2(B1)	3(B0)	4(B3)	-
PMS	4	1(B2)	2(B1)	3(B0)	4(B3)	-
PMS-N	3	1(B2)	2(B1)	3(B0)	-	-
PMS-X	3	1(B3)	2(B2)	3(B1)	-	-

TABLE 27: RASTER FILE INDEX FOR DEFAULT RGB DISPLAY

A.4.4 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

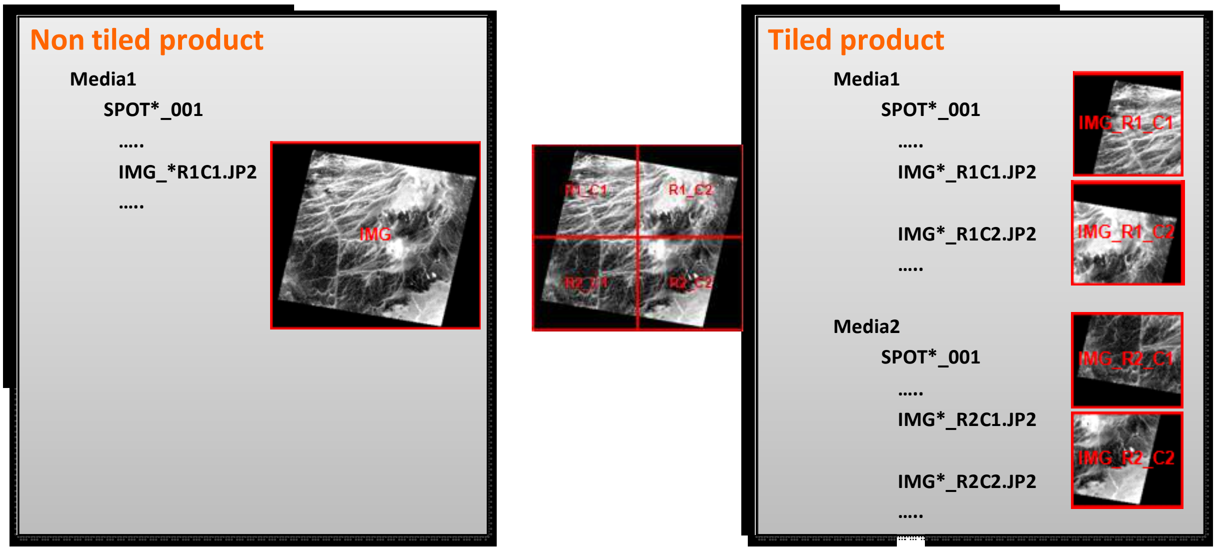


FIGURE 25: TILING

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 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 with 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 with a unique constant sampling step, identical on both Northing and Easting Axis.

As Coordinate Axis are in angular unit (preserves only angles not distance), we do not recommend Geographic projection for visualization applications (anamorphosis effect along Easting Axis).

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 28: 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
GeoDETIC_CRS_CODE	GeographicTypeGeoKey	attribut SrsName	n/a
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 29: 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.
  - 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 dedicated for image is in map geometry (Ortho).

For image in sensor geometry (Primary) georeferencing must be performed though a geometric model. Please 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
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 Ortho product, the CRS is the one formatted with the product.

For Primary products the World File is adapted to assemble raster tile files, if any. The CRS is the raster Coordinate System (column,row).

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 tilled images, are the location of the center of the upper left pixel for each 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
B	0
E	-20.17541308822119
C	424178.11472601280548
F	4313415.90726399607956

TABLE 30: ORTHO WORLDFILE

Parameter	Example
A	1
D	0
B	0
E	-1
C	1
F	-1

TABLE 31: PRIMARY WORLDFILE

APPENDIX B: IMAGE QUALITY

B.1 Design Specification vs. Performances

The following table gives Image Quality performances (measured in Dec 2012) significant for the user. They are compared with the original design specification of the S6/7 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: 600m LE95 Along track: 1000m LE95	Across track: 50m LE95 Along track: 260m LE95	
Dynamic Effect (high frequency jittering)	Along Lines: 0.2pixel PAN LE95 Along columns: 0.1 pixel PAN LE95	Along Lines: <0.1pixel PAN LE95 Along columns: < 0.1 pixel PAN LE95	
Static effect (regularity of resampling between adjacent pixels due to focal plan design)	0.2 pixel CE99.7	0.2 pixel CE99.7	-Intra-array: 0.05 pixel CE99.7
GEOMETRY (Rigorous Geometric Model accuracy without GCP: all products)			
Location Accuracy	50m CE90@30°	20m CE90@30°	
Length Distortion	1/1000 CE90	0.5/1000 CE90	Between 2 points distant of 1000 pixels Panchromatic
MS Registration	0.25 pixel MS CE99.7	<0.15 pixel MS CE99.7	
MS and Pan Co-registration	1 pixel PAN CE99.7	<0.4 pixel PAN CE99.7	
Global RPC Discrepancy vs. Rigorous Model	-	<0.25 pixel PAN	

Image Quality Item	Design Specification	Up-to-Date Performance	Remark
GEOMETRY (Rigorous Geometric Model accuracy reset on (perfect) GCP and DEM)			
Planimetric Accuracy (Panchromatic)	1 pixel CE90	0.9 pixel CE90 (1.35mCE90)	
Planimetric Accuracy (Multispectral)	1 pixel CE90	0.4 pixel CE90 (2.4mCE90)	
Vertical Accuracy (absolute error)	B/H = 0.8 within radius of 9km: ≤20%: 4mLE90 20 to 40%: 8mLE90	At B/H=0.5 for slopes: ≤20%: 2.4mLE90 20 to 40%: 2.6mLE90	Operational case is close to B/H=0.5
RADIOMETRY (Radiometric Model accuracy (DN conversion to Radiance) known accuracy performance with pre-launch measurement			
Absolute Calibration	≤6%	Preliminary values: PAN: <5% Blue: <5% Green: <5% Red: <5% NIR: <10%	
Relative Cross-band Calibration	≤3%	3%	
Relative Multi-temporal Calibration	≤5%	5%	
RESOLUTION			
Satellite MTF (X/Y axis): Panchromatic	PAN: 0.10/0.10	PAN: 0.18/0.16	
Satellite SNR: Panchromatic	PAN: 100	PAN: 126	
IQF (MTF x SNR): Panchromatic	PAN: 10	PAN: 22/20	
Restored MTF (target): Panchromatic	0.30	0.3	
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: 0.4/0.26 Green: 0.4/0.26 Red: 0.4/0.26 NIR: 0.4/0.26	
Satellite SNR: Multispectral	Blue: 150 Green: 150 Red: 150 NIR: 150	Blue: 259 Green: 254 Red: 267 NIR: 293	
IQF (MTF x SNR): Multispectral	Blue: 30/30 Green: 30/30 Red: 30/30 NIR: 30/30	Blue: 103/67 Green: 101/66 Red: 106/69 NIR: 118/76	

TABLE 32: SPECIFICATIONS AND PERFORMANCES

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

C.1.1 Focal plane

SPOT 6/7 raw products are very complex and not user-friendly, due in particular to the complexity of the focal plane. Indeed, the full swath focal plane is a combination of two individual focal planes belonging to two individual cameras.

Moreover, each raw focal plane is composed on two detectors separated along the satellite track within the field of view.

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 on a virtual line corresponding to the average of the four panchromatic TDI arrays.

Hereunder Figure 26 describes the whole focal plane. This is a virtual representation as far as both cameras are physically independent.

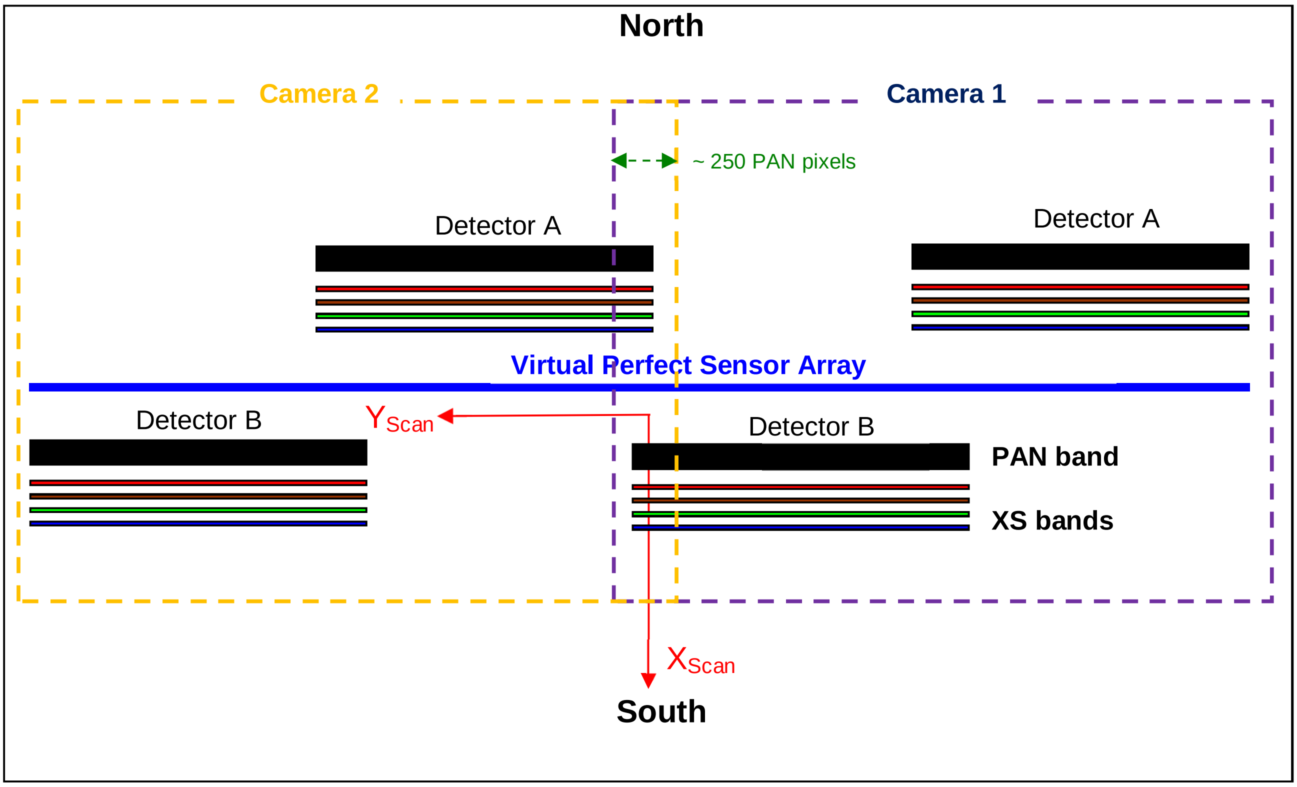


FIGURE 26: FULL FOCAL PLANE LAYOUT (SWATH) AND LOCATION OF PRIMARY VIRTUAL ARRAY.

Both cameras of previous figure are strictly identical. Each individual focal plane is designed as shown hereunder:

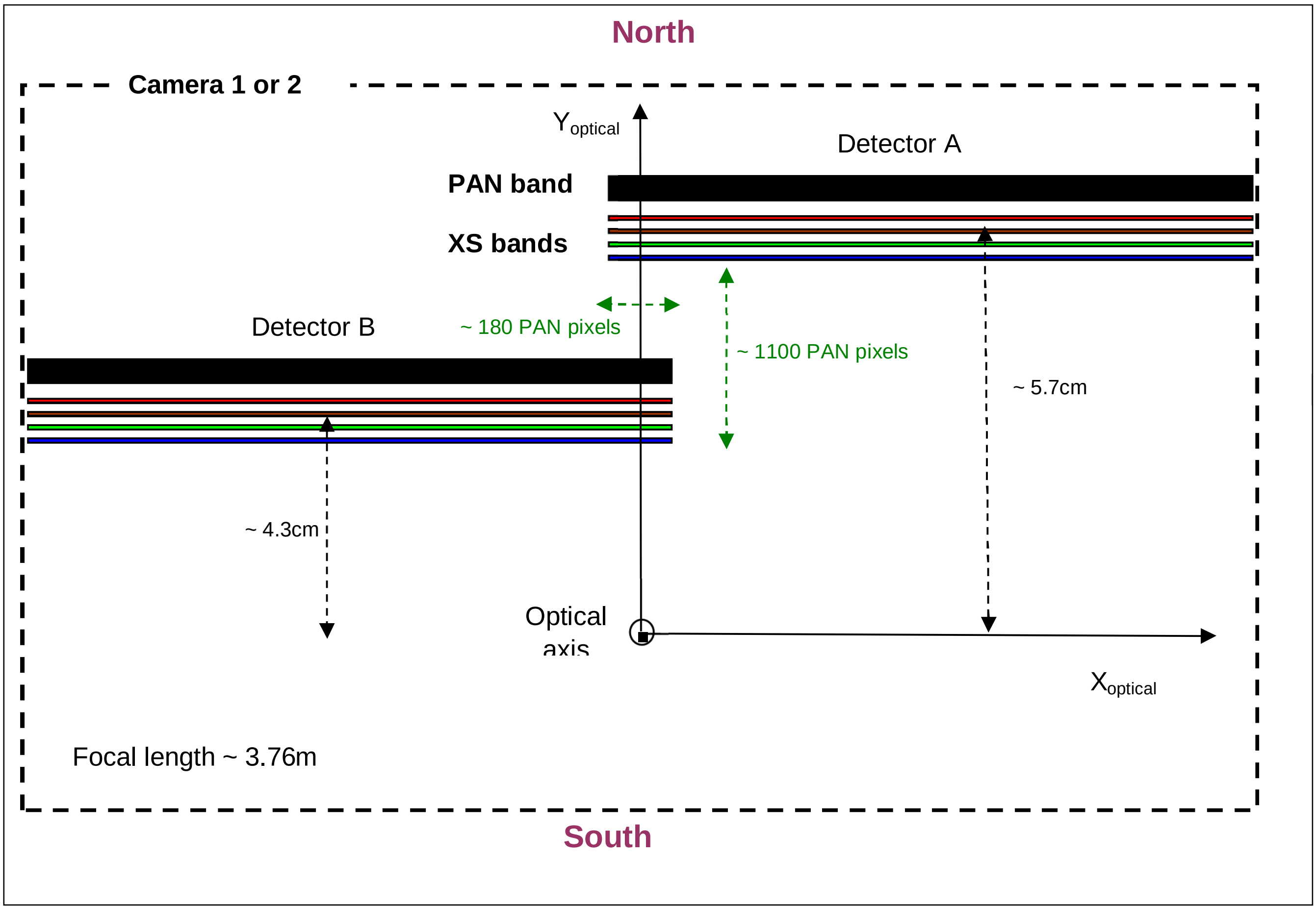


FIGURE 27: RAW FOCAL PLANE LAYOUT AND LOCATION OF PRIMARY VIRTUAL ARRAY

C.1.2 Primary product geometrical properties

Besides, this ideal array is supposed to belong to a perfect instrument with no optical distortion and carried by a platform with no high attitude perturbations. This attitude variation correction (made with a polynomial fitting) allows for both simple attitude modelling and more accurate precision of the imaging geometry by the rational functions sensor model.

The pixel reference is the centre of the pixel ("pixel is point").

C.1.2.1 GSD

The Primary product resolution is related to the raw imagery GSD, which varies according to the viewing angle (see Table 33).

Global viewing angle from satellite α(°)	PAN GSD (m)	MS GSD (m)	SWATH (km) width	PAN GSD_c (m)	MS GSD_c (m)	$SWATH_c$ (km) width	*GSD_c-GSD (m)*	*GSD Error (%)*
*Please refer to part **C.4.1** for more details*	*Without taking into the rotundity of the Earth*			*Taking into the rotundity of the Earth*				
0	2.19	8.77	84.6212	2.19	8.77	84.6212	*0.00*	*0.00%*
5	2.21	8.83	85.2689	2.21	8.85	85.3804	*0.00*	*0.13%*
10	2.26	9.04	87.2522	2.27	9.09	87.7179	*0.01*	*0.53%*
15	2.35	9.40	90.6968	2.38	9.51	91.8237	*0.03*	*1.23%*
20	2.48	9.93	95.8314	2.54	10.16	98.0547	*0.06*	*2.27%*
25	2.67	10.67	103.022	2.77	11.09	107.012	*0.10*	*3.73%*
30	2.92	11.69	112.828	3.10	12.40	119.687	*0.18*	*5.73%*
35	3.27	13.07	126.11	3.57	14.27	137.763	*0.30*	*8.46%*
40	3.74	14.94	144.202	4.25	17.02	164.256	*0.52*	*12.21%*
45	4.38	17.53	169.243	5.31	21.25	205.067	*0.93*	*17.47%*
50	5.30	21.22	204.807	7.08	28.33	273.45	*1.78*	*25.10%*

TABLE 33: GSD VS. VIEWING ANGLE

Notes:

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

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

With:

h_{sat} (km)	699
PAN IFOV (rad)	3.14E-06
MS IFOV (rad)	1.25E-05
Earth	
Semi-major axis (km)	6378.14
Semi-minor axis (km)	6356.75
R_E (km) (mean)	*6367.45*

C.1.2.2 Primary Grids Alignment (Bundle)

With Primary bundle delivery PAN and MS bands sampling grid are phased as shown on Figure 28.

FIGURE 28 PRIMARY BUNDLE GRIDS ALIGNMENT

Centre of the first MS pixel corresponds exactly to the centre of the third column (or third line) PAN pixel centre. PAN image is larger than MS image by 0.5 pixel “all around” MS image footprint.

C.1.3 Ortho product geometrical properties

The pixel reference is the upper left corner of the pixel ("pixel is area").

C.1.3.1 GSD

The Ortho product resolution is also related to the raw imagery GSD (see Table 33). To ensure perfect radiometric accuracy and image restoration, the Ortho end product is zoomed with a fix sampling of 1.50m for Panchromatic and 6.0m for Multispectral imagery (or equivalent angular value at equator for geographic projection).

C.1.3.2 Ortho Grids Alignment (Bundle)

On an Ortho bundle delivery PAN and MS bands sampling grid are phased as shown on Figure 29.

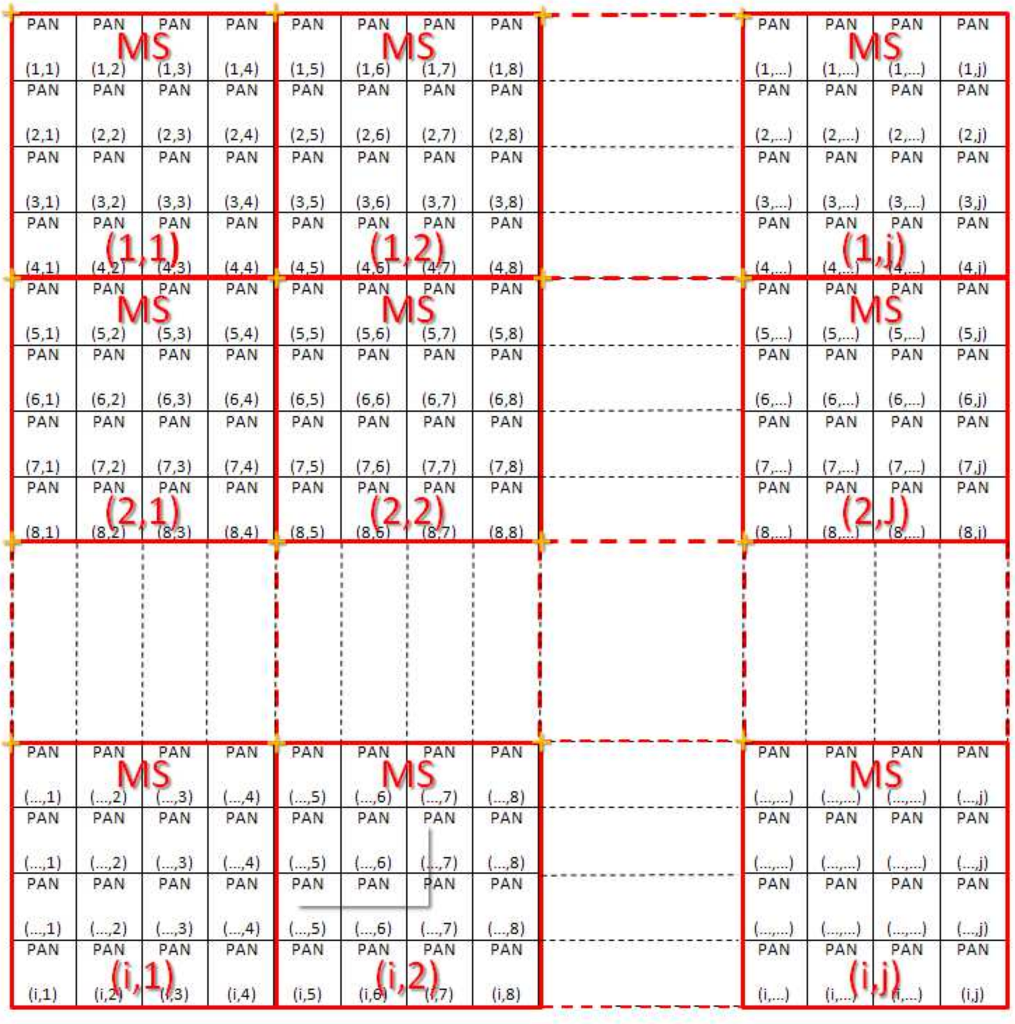


FIGURE 29 ORTHO BUNDLE GRIDS ALIGNMENT

Upper-left corner of the first MS pixel corresponds exactly to upper left corner of the first column (or first line) PAN pixel.

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.

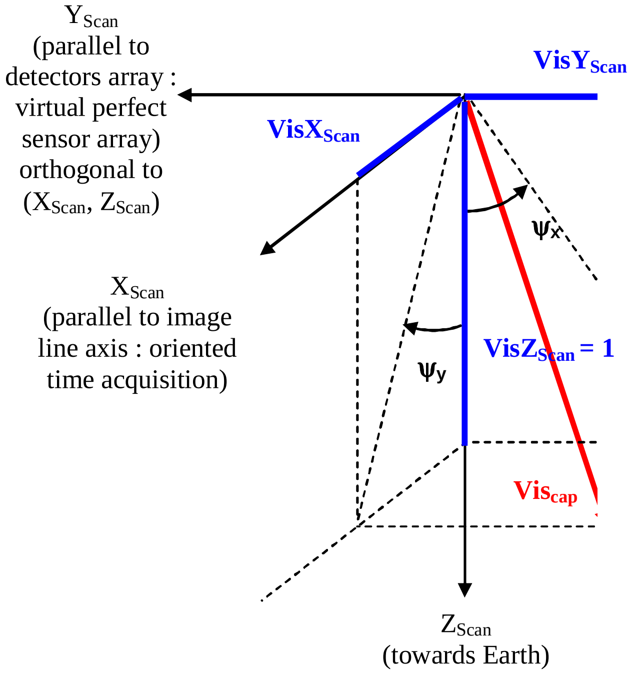


FIGURE 30: IMAGE FOCAL PLANE FRAME

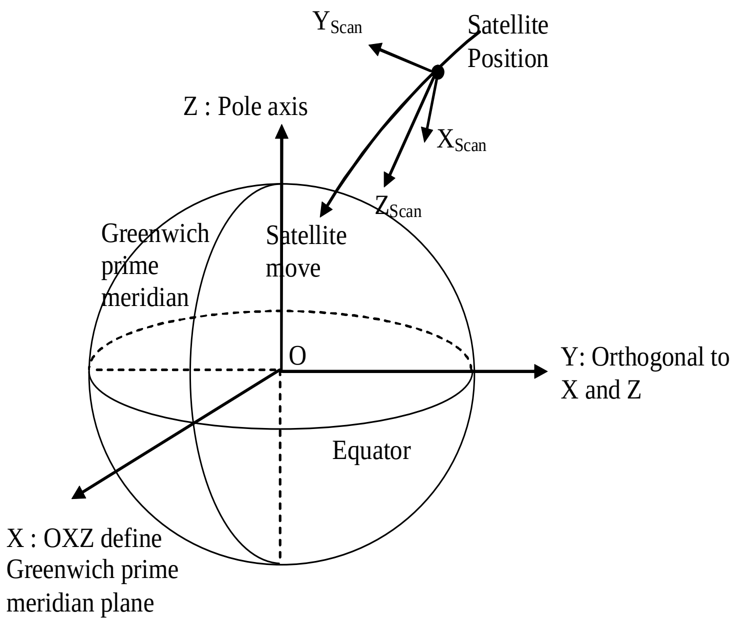


FIGURE 31: GEOCENTRIC EARTH FRAME (WGS84)

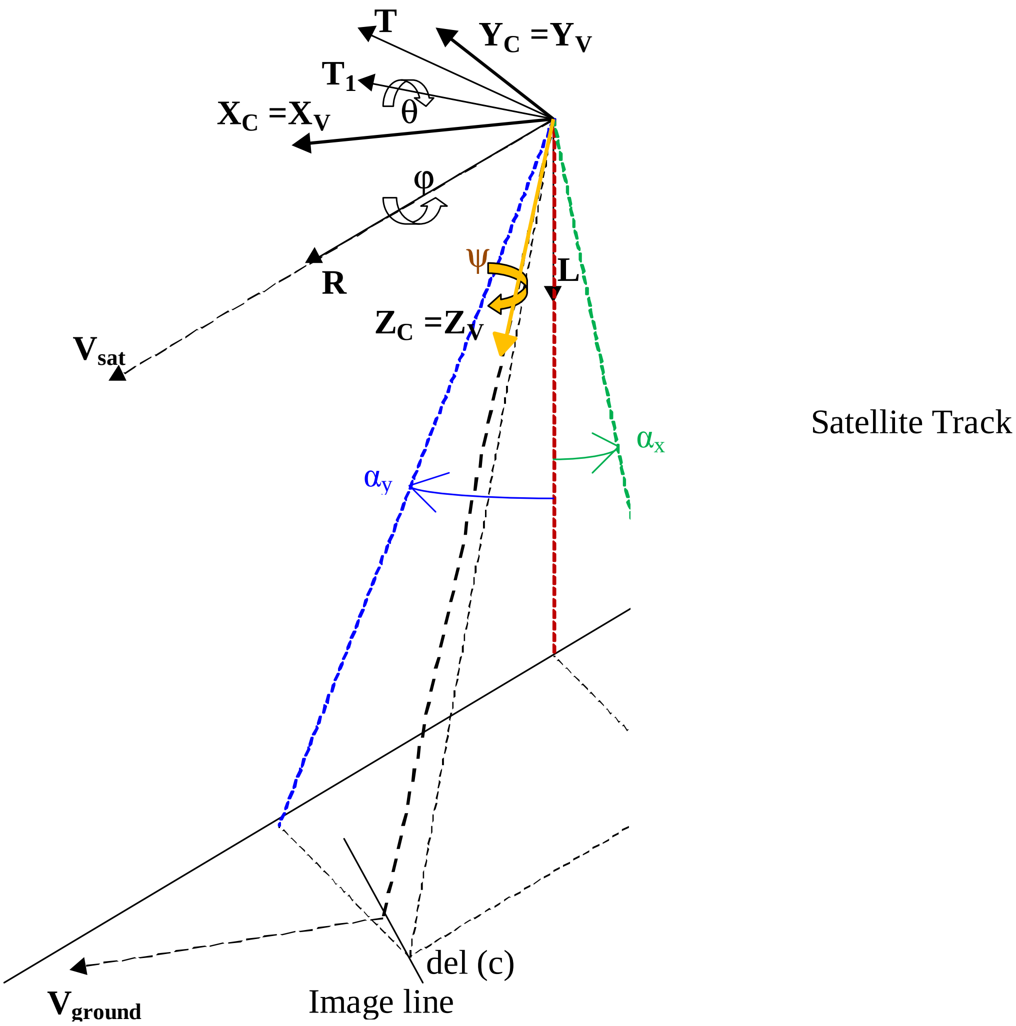


FIGURE 32: FRAMES SUMMARY

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 (Xv, Yv, Zv) are identical
- A set of quaternions sampled at 16Hz 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:

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

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

By convention for SPOT 6/7 Primary product $TanPsiY = 0$ and first column index is 0;

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

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

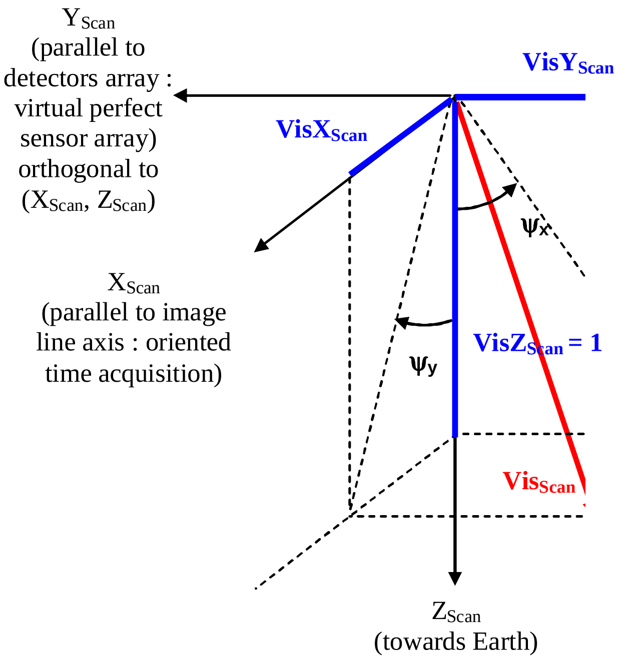


FIGURE 33: VIEWING ANGLE IN IMAGE FOCAL PLANE FRAME

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

Sattelite orientation for a given time is deduced from the quaternion list. Quaternions components Q1, Q2, and Q3 are respectively the three rotation vector component and Q0 is the rotation angle component. Each quaternion comes along with a time stamp.

Quaternion components must be interpolated at the time of interest. Each component must be interpolated individually. A cubic interpolation is recommended.

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:

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

Calculation of the viewing angle in the geocentric Earth frame.

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

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

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

Given

Satellite location at a given time:

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

Viewing angle in geocentric Earth frame:

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

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 34).

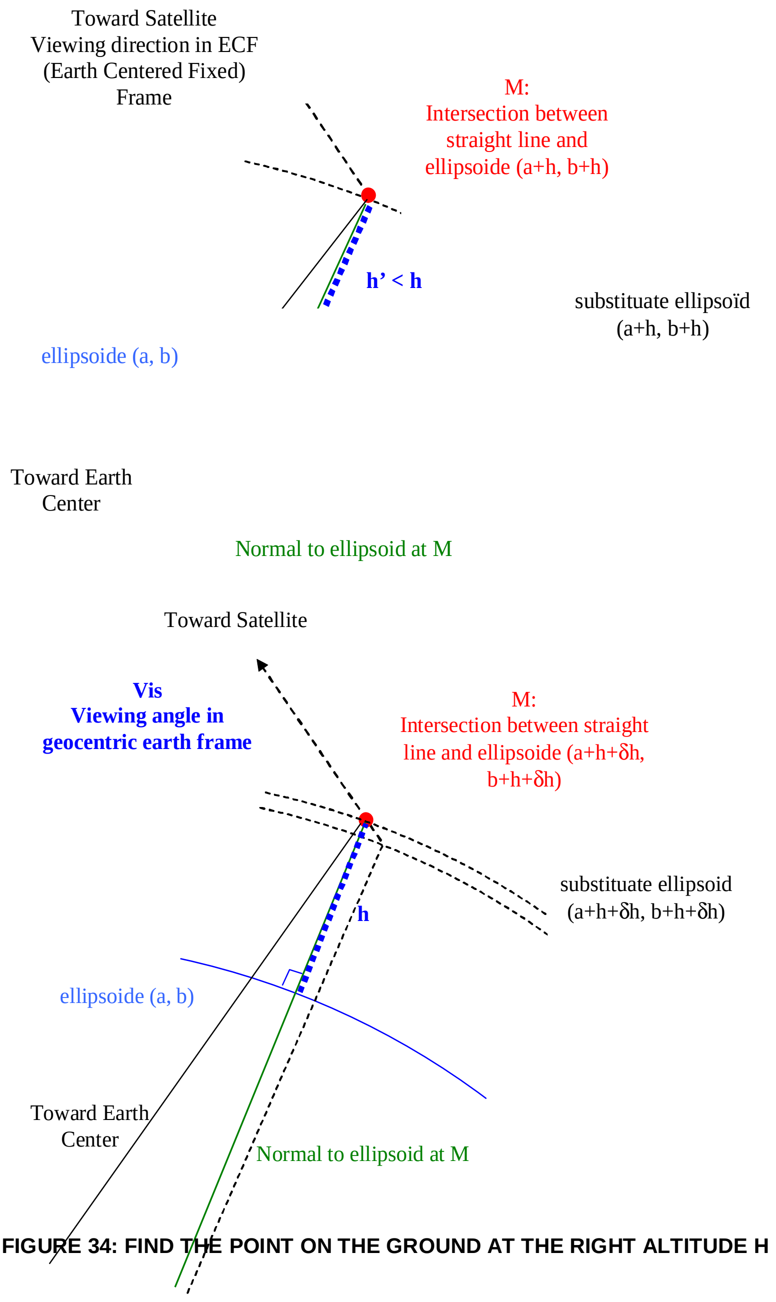


FIGURE 34: FIND THE POINT ON THE GROUND AT THE RIGHT ALTITUDE H

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:

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

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

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 to geographic coordinates and height above ellipsoid (λ, φ, h').

See: 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 += δh

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

Note that preceding algorithm does not take into account neither the atmospheric refraction nor the light transmission delay. Nevertheless, the corresponding geolocation error is about 2.5m at 30° viewing angle and 5m at 40° viewing angle which is one order of magnitude below SPOT 6 geolocation performance.

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.
(col, lin) ➔ $(\lambda, \varphi)_{h1}$ $(\lambda, \varphi)_{hi}$ $(\lambda, \varphi)_{hn}$

For each altitude, compute an inverse localization predictor by least-squares using grid samples (col, lin, λ, φ):

$col_{hi} = f_{hi}(\lambda, \varphi)$
$lin_{hi} = g_{hi}(\lambda, \varphi)$

Compute an approximation of the image position.

Apply the polynomial at different altitudes:

$col_{h1} = f_{h1}(\lambda, \varphi)$ $col_{hi} = f_{hi}(\lambda, \varphi)$.$col_{hn} = f_{hn}(\lambda, \varphi)$

$lin_{h1} = g_{h1}(\lambda, \varphi)$ $lin_{hi} = g_{hi}(\lambda, \varphi)$.$lin_{hn} = g_{hn}(\lambda, \varphi)$

Interpolate the approximate image position at the given altitude h:

col_app_h = Interpolate (col_{h1}, … col_{hi} , …col_{hn})
lin_app_h = Interpolate (lin_{h1}, … lin_{hi} , …lin_{hn})

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

$col_{cur} = col\_app_h$
$lin_{cur} = lin\_app_h$

Do {

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

DirLoc (col_{cur}, lin_{cur}, h) ➔ (λ_{cur}, φ_{cur})

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

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

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

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

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

Apply the correction to the current image coordinates:

col_{cur} += dcol

lin_{cur} += dlin

}

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:

col_{CN} = (col – SAMP_OFF) / SAMP_SCALE
lin_{CN} = (lin – LINE_OFF) / LINE_SCALE
lon_{CN} = (lon – LONG_OFF) / LONG_SCALE
lat_{CN} = (lat – LAT_OFF) / LAT_SCALE
alt_{CN} = (h_{ground} – HEIGHT_OFF) / HEIGHT_SCALE

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:

col_{CN} = (col – SAMP_OFF) / SAMP_SCALE
lin_{CN} = (lin – LINE_OFF) / LINE_SCALE

Transform altitude coordinate into center-normalized altitude coordinate:

alt_{CN} = (alt – HEIGHT_OFF) / HEIGHT_SCALE

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

$$lon_{CN} = \frac{\sum_{i=1}^{20} SAMP\_NUM\_COEFF_i \bullet \rho_i(lin_{CN}, col_{CN}, alt_{CN})}{\sum_{i=1}^{20} SAMP\_DEN\_COEFF_i \bullet \rho_i(lin_{CN}, col_{CN}, alt_{CN})}$$

$$lat_{CN} = \frac{\sum_{i=1}^{20} LINE\_NUM\_COEFF_i \bullet \rho_i(lin_{CN}, col_{CN}, alt_{CN})}{\sum_{i=1}^{20} LINE\_DEN\_COEFF_i \bullet \rho_i(lin_{CN}, col_{CN}, alt_{CN})}$$

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

$$\sum_{i=1}^{20} C_i \bullet \rho_i(lin_{CN}, col_{CN}, alt_{CN}) =$$

$$\begin{aligned}
&C_1 \ldots\ldots\ldots\ldots + C_6 \bullet col_{CN} \bullet alt_{CN} + C_{11} \bullet lin_{CN} \bullet col_{CN} \bullet alt_{CN} + C_{16} \bullet lin_{CN}^3 \\
&+ C_2 \bullet col_{CN} \ldots\ldots + C_7 \bullet lin_{CN} \bullet alt_{CN} + C_{12} \bullet col_{CN}^3 \ldots\ldots\ldots\ldots + C_{17} \bullet lin_{CN} \bullet alt_{CN}^2 \\
&+ C_3 \bullet lin_{CN} \ldots\ldots + C_8 \bullet col_{CN}^2 \ldots\ldots + C_{13} \bullet col_{CN} \bullet lin_{CN}^2 \ldots\ldots + C_{18} \bullet col_{CN}^2 \bullet alt_{CN} \\
&+ C_4 \bullet alt_{CN} \ldots\ldots + C_9 \bullet lin_{CN}^2 \ldots\ldots + C_{14} \bullet col_{CN} \bullet alt_{CN}^2 \ldots\ldots + C_{19} \bullet lin_{CN}^2 \bullet alt_{CN} \\
&+ C_5 \bullet col_{CN} \bullet lin_{CN} . + C_{10} \bullet alt_{CN}^2 \ldots\ldots + C_{15} \bullet col_{CN}^2 \bullet lin_{CN} \ldots\ldots + C_{20} \bullet alt_{CN}^3
\end{aligned}$$

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:

$lon = lon_{CN}$ * 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:

$$col_{CN} = \frac{\sum_{i=1}^{20} SAMP\_NUM\_COEFF_i \bullet \rho_i(lat_{CN}, lon_{CN}, alt_{CN})}{\sum_{i=1}^{20} SAMP\_DEN\_COEFF_i \bullet \rho_i(lat_{CN}, lon_{CN}, alt_{CN})}$$

$$lin_{CN} = \frac{\sum_{i=1}^{20} LINE\_NUM\_COEFF_i \bullet \rho_i(lat_{CN}, lon_{CN}, alt_{CN})}{\sum_{i=1}^{20} LINE\_DEN\_COEFF_i \bullet \rho_i(lat_{CN}, lon_{CN}, alt_{CN})}$$

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

$$\begin{aligned}
&\sum_{i=1}^{20} C_i \bullet \rho_i(lat_{CN}, lon_{CN}, alt_{CN}) = \\
&C_1 .... + C_6 \bullet lon_{CN} \bullet alt_{CN} + C_{11} \bullet lat_{CN} \bullet lon_{CN} \bullet alt_{CN} + C_{16} \bullet lat_{CN}^3 \\
&+ C_2 \bullet lon_{CN} .... + C_7 \bullet lat_{CN} \bullet alt_{CN} + C_{12} \bullet lon_{CN}^3 .... + C_{17} \bullet lat_{CN} \bullet alt_{CN}^2 \\
&+ C_3 \bullet lat_{CN} .... + C_8 \bullet lon_{CN}^2 .... + C_{13} \bullet lon_{CN} \bullet lat_{CN}^2 .... + C_{18} \bullet lon_{CN}^2 \bullet alt_{CN} \\
&+ C_4 \bullet alt_{CN} .... + C_9 \bullet lat_{CN}^2 .... + C_{14} \bullet lon_{CN} \bullet alt_{CN}^2 .... + C_{19} \bullet lat_{CN}^2 \bullet alt_{CN} \\
&+ C_5 \bullet lon_{CN} \bullet lat_{CN} . + C_{10} \bullet alt_{CN}^2 .... + C_{15} \bullet lon_{CN}^2 \bullet lat_{CN} .... + C_{20} \bullet alt_{CN}^3
\end{aligned}$$

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 “Inverse Model” in the RPC file.

Transform center-normalized image coordinates into image coordinates

col = col_{CN} * SAMP_SCALE + SAMP_OFF
lin = lin_{CN} * LINE_SCALE + LINE_OFF

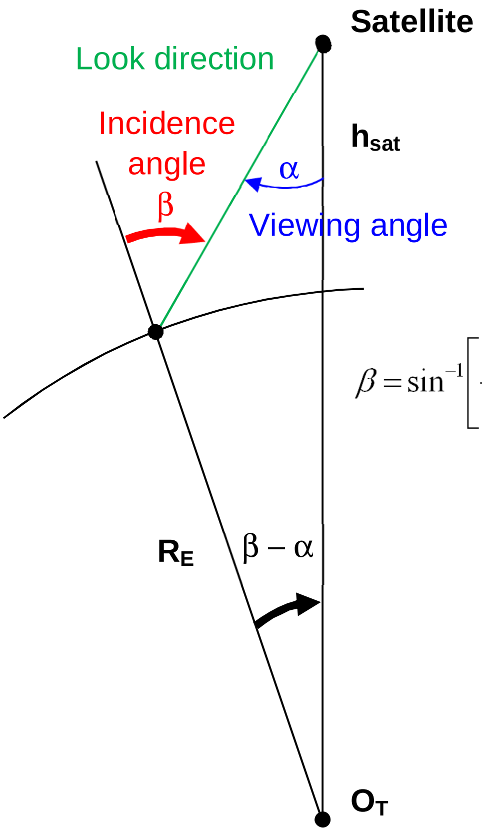
C.4 Other Informative Geometric Data

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



$$\beta = \sin^{-1}\left[\frac{R_E + h_{sat}}{R_E} * \sin(\alpha)\right] \geq 0$$

FIGURE 35: 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 SPOT 6/7, the range for the incidence angle is [0, 55 degrees].

The satellite azimuth angle is the angle between the meridian passing through the centre of raw scene and the line passing through the centre of raw scene and the satellite nadir point. The range for the azimuth angle is [0, 360 degrees], clockwise positive. As shown on Figure 36.

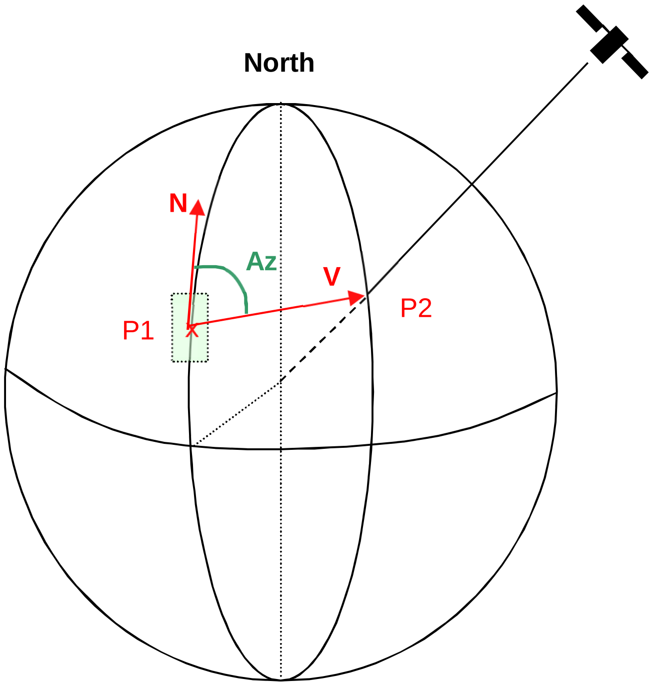


FIGURE 36: AZIMUTH ANGLE

Azimuth angle is computed as described hereunder:

- Position P1 of swath center pixel is computed
- North direction **N** is computed for this point
- Satellite nadir point P2 is computed
- Direction **V** between nadir point P2 and centre swath P1 is computed
- Direct angle between **N** and **V** is the azimuth

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

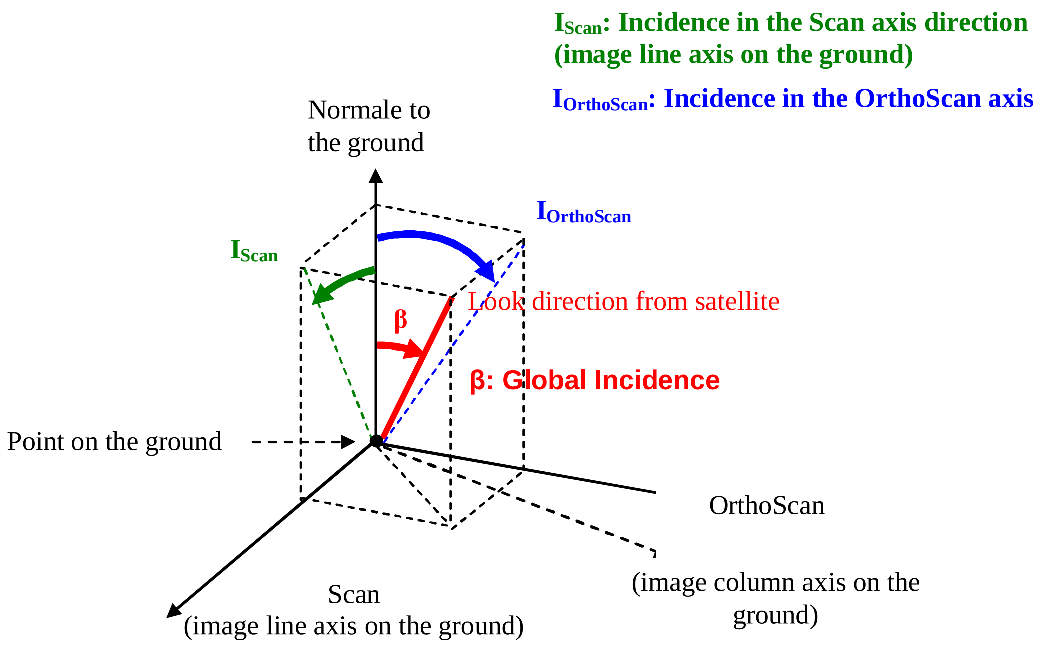


FIGURE 37: INCIDENCE ANGLE PROJECTED ON TWO PLANES

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 SPOT 6/7 the range for the viewing angle is generally [0, 35 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 38

Thus, viewing may be measured in both planes:

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

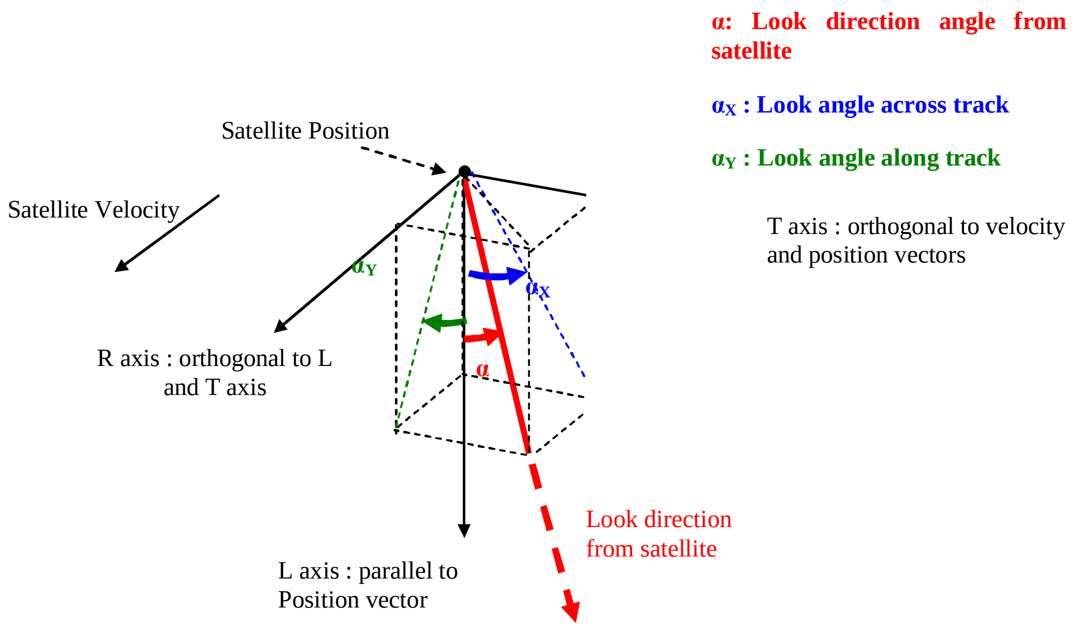


FIGURE 38: VIEWING ANGLE ALONG AND ACROSS TRACK

C.4.2 Solar Angles

The following angles (see Figure 39) are calculated in a local Earth frame (Normal to the ground, North, East):

- SUN_AZIMUTH
- SUN_ELEVATION

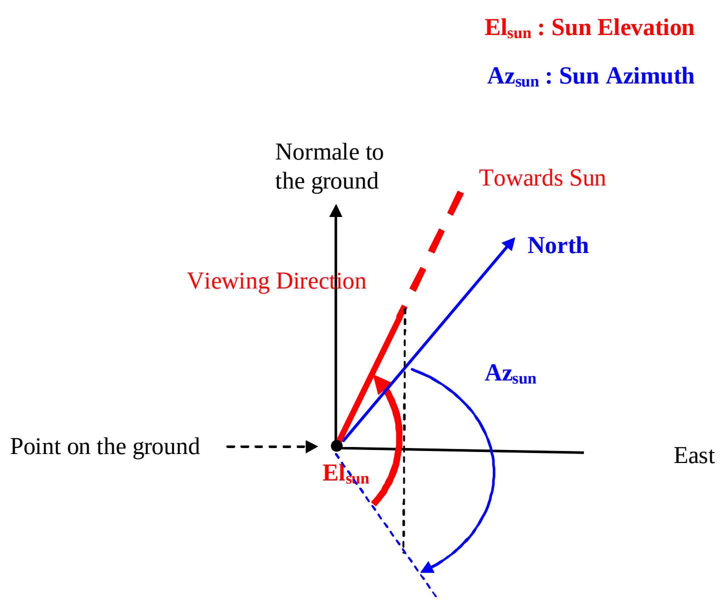


FIGURE 39: SOLAR INCIDENCES

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

Pixel values are raw Digital Counts numbers (DN) representing quantity of photons measured by the on-board sensor. Integrating many contributors at instrument level (detector efficiency, filters, optical effect on mirrors...) these Digital Counts are relative to a physical spectral measure like spectral radiance. They are not cross-band neither physically normalized.

Physical applications require conversion of raw Digital Count numbers to physical units. Current physical measurements include radiance (at-Ground or at-Top Of Atmosphere), reflectance, or albedo. The conversion to such physical values is explained hereunder.

D.1 SPOT 6 Spectral Bands

SPOT 6 acquires images in five spectral ranges. Compared to the spectral ranges specification (see Table 3) following spectral ranges are based on a rejection measurement at 1%:

Spectral ranges	λmin	λmax
PAN - Panchromatic	0.455 µm	0.744 µm
B0 – Blue	0.454 µm	0.519 µm
B1 - Green	0.527 µm	0.587 µm
B2 - Red	0.624 µm	0.694 µm
B3 - Near Infrared	0.756 µm	0.880 µm

TABLE 34: SPOT 6 SPECTRAL BANDS

D.2 Spectral Sensitivity of the SPOT 6 Sensor

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 SPOT 6 sensor are represented on Figure 40:

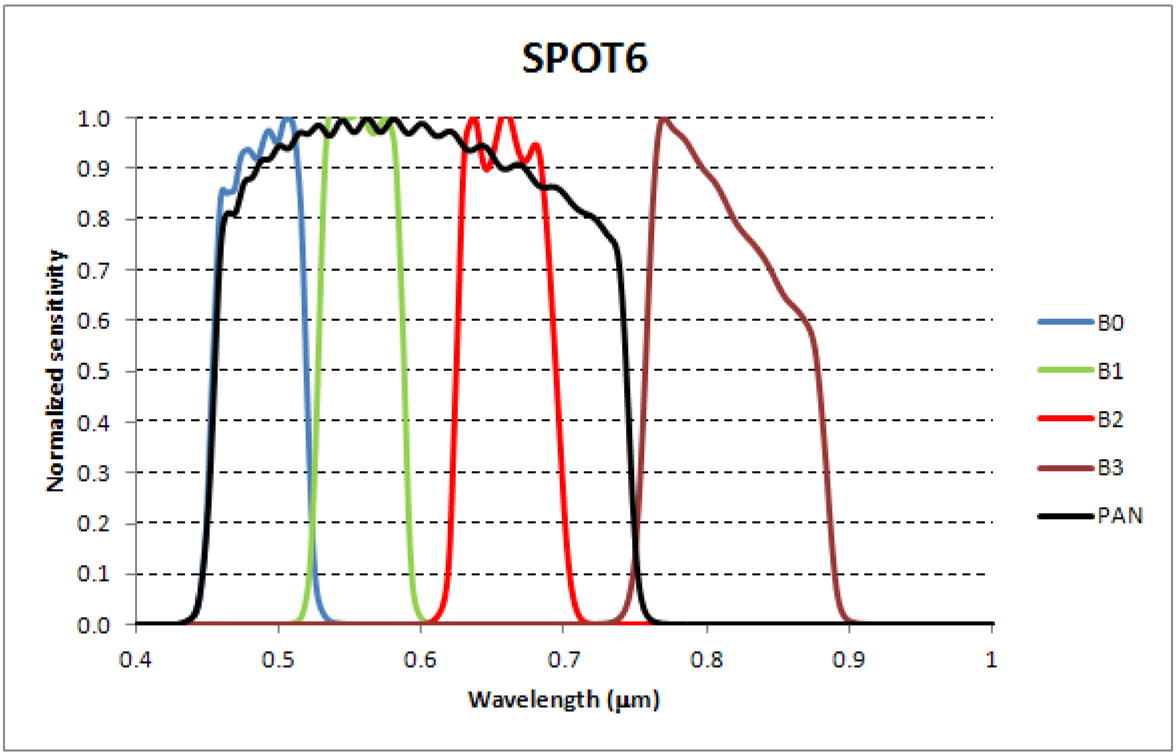


FIGURE 40: SPECTRAL NORMALIZED SENSITIVITIES OF SPOT 6 SENSORS

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

D.3 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 coefficients are recomputed for products ranged to 8 bit-depth with a linear adjustment, meaning a non-zero BIAS value.

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

D.4 TOA Spectral Reflectance

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

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

User may complete this basic equation with additional terms like variation of solar illumination with Earth-Sun distance, etc.

To take into account the spectral sensitivity of the sensors (see D.2), an equivalent spectral radiance will be computed:

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

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 41, 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 34 for more details about how to select the right B/H ratio.

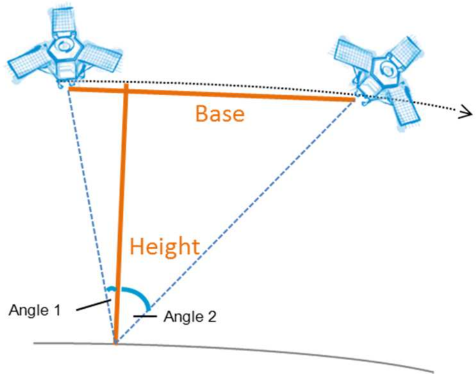


FIGURE 41: STEREOSCOPIC - B/H

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 35: APPROXIMATE MAPSCALE EQUIVALENCIES BASED ON THE US NMAS[3]

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

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

thanks to a cardan gimbaled mechanism. The CMGs are used both for the maneuver guidance to ensure transitions between image acquisitions and for the acquisition guidance in order to guarantee the image quality.

FIGURE 42: 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.

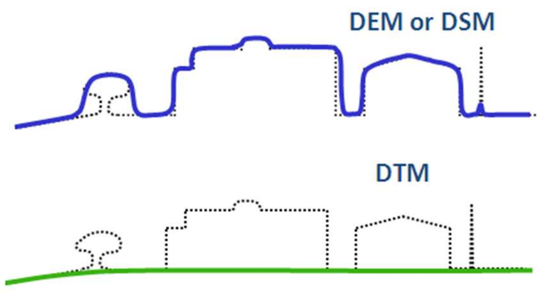


FIGURE 43: DEM VS. DTM

DRS – Direct Receiving Station: An antenna and a terminal enabling a given partner to receive SPOT 6/7 telemetry directly at their facility. *More about the DRS at* www.astrium-geo.com/en/211-spot-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
Posting values decrease towards the poles to cope with meridian convergence.				
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 36: 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.

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 44*.*

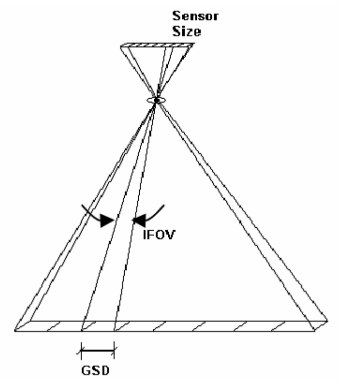


FIGURE 44: IFOV AND GSD

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 SPOT 6/7 products..

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 colour 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.

OVR – Optimized Visualization Rendering: An algorithm used to enhance the imagery histogram (like DRA, etc). It modifies the luminosity and contrast of the imagery. Through this enhancement, the initial radiometric properties of the imagery are lost, but the colour balance is adjusted to get an aesthetically pleasing image on a screen. With OVR 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. OVR is different from linear adjustment (see below).

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 (colour) product.

Panchromatic (PAN): Detectors that are sensitive to visible colours of the spectrum. SPOT 6/7 have a Panchromatic band that extends into the near-IR and covers the spectral region between 0.45 - 0.74 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 45*.*

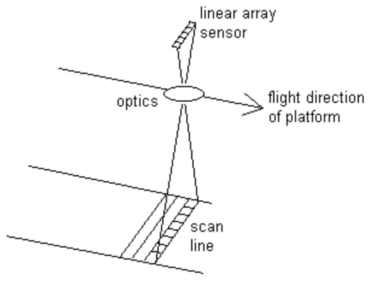


FIGURE 45: PUSHBROOM SENSOR

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 catalogue. Basically, the quicklook is a sub-sampled image..

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:* *www.astrium-geo.com/en/2788-reference3d-your-geographic-reference-system*

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. SPOT 6 blue band covers an area between 0.45 and 0.52 µm).

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

Sun-synchronous: A satellite orbit in which the orbital plane remains at a fixed angle with respect to the Sun, processing through 360° during the period of a year. The SPOT 6/7 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. SPOT 6/7 swath is 60 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 instrument's 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.

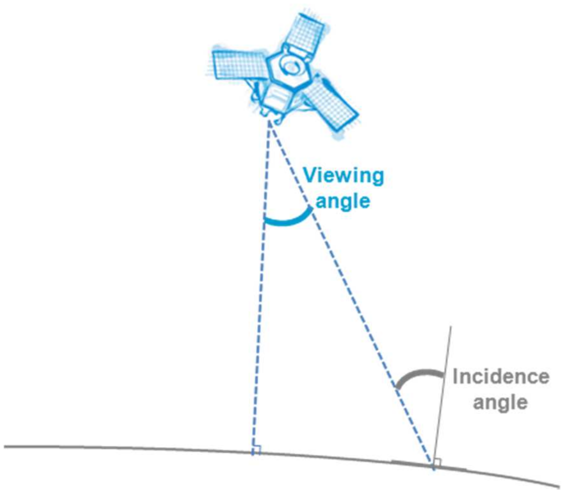


FIGURE 46: VIEWING ANGLE

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 SPOT 6/7) 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 (°). <Geometrice_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: TanPsiX = f(col –colref). <Geometric_Data><Refined_Model><Geometric_Calibration><Instrument_Calibration><Polynomial_Look_Angles><XLOS_(i)>
CoeffPsiY(i)	Polynomial model coefficients: TanPsiY = g(col –colref). <Geometric_Data><Refined_Model><Geometric_Calibration><Instrument_Calibration><Polynomial_Look_Angles><YLOS_(i)>
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.
$E_o(\beta)$	Eo(β) is the mean Top of Atmosphere (TOA) solar irradiance for the band (b) in W/m²/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. <Rational_Function_Model><Global_RFM><RFM_Validity><Direct_Model_Validity_Domain><…>
FIRST_ROW **LAST_ROW**	Validity domain for line image coordinate (row) available for Global RFM. <Rational_Function_Model><Global_RFM><RFM_Validity><Direct_Model_Validity_Domain><…>
FIRST_LAT **LAST_LAT**	Validity domain for latitude coordinate available for Global RFM <Rational_Function_Model><Global_RFM><RFM_Validity><Inverse_Model_Validity_Domain><…>
FIRST_LON **LAST_LON**	Validity domain for longitude coordinate available for Global RFM. <Rational_Function_Model><Global_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. <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.
(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 $\vec{T} = \frac{\vec{Vit} \wedge \vec{Pos}}{\left\| \vec{Vit} \wedge \vec{Pos} \right\|}$)
R	Roll axis : $\vec{R} = \vec{T} \wedge \vec{L}$
L	Yaw axis (build with Satellite Position : $\vec{L} = -\frac{\vec{Pos}}{\left\| \vec{Pos} \right\|}$)
(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, Xc, Yc, Zc)	"Pointing" frame. (Xc, Yc, Zc) = (Xv, Yv, Zv) when attitude control is perfect.
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)	Satellite locations at different times $t_{i.}$

PosY(t_i) **PosZ(t_i)**	<Geometric_Data><Refined_Model><Ephemeris><Point_List><Point(i)> < LOCATION_XYZ>
Q0	Quaternion component: Q0. <Geometric_Data><Refined_Model><Attitudes><Quaternion_List><Quaternion><Q0 >
Q1	Quaternion component: Q1. <Geometric_Data><Refined_Model><Quaternion_List><Quaternion><Attitudes><Q1 >
Q2	Quaternion component: Q2. <Geometric_Data><Refined_Model><Quaternion_List><Quaternion><Attitudes><Q2 >
Q3	Quaternion component: Q3. <Geometric_Data><Refined_Model><Attitudes><Quaternion_List><Quaternion><Q3 >
R_E	Mean Earth Radius ($R_E \approx$ 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_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_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.
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.
$trel_i$	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.

DOCUMENT CONTROL AND DATA SHEET

1.	Report No. and date:	SI/DC/13034-v1.0 July 8th, 2013
2.	Title:	SPOT 6/7 Imagery - User Guide
3.	Type:	Technical, Reference
4.	No. of pages:	120
5.	Compiled and Edited by:	Laurent Coeurdevey, Image Quality Manager Jérôme Soubirane, SPOT Product Manager
6.	Originating Unit:	Astrium Services, France
7.	Abstract:	A reference document containing information regarding SPOT 6/7 mission, sensors, data reception, orbit and coverage, data processing, products, services, and dissemination.
8.	Security Classification:	Unrestricted
9.	Distribution:	SPOT 6/7 data users' community

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