DEFENCE AND SPACE
Intelligence

Pléiades Neo

User Guide

Version 4 – February 2023

AIRBUS

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1 Introduction

With two identical Pléiades Neo optical satellites launched in 2021, Airbus Defence and Space Intelligence brings its constellation to the next level, and enters the very high-resolution market, at 30cm resolution.

The genesis of Pléiades Neo comes from the success of its predecessor, Pléiades. This new constellation guarantees continuity and the quality of service that we provide to our customers, with increased performance to meet tomorrow’s application requirements.

Ensuring permanence of Airbus’ Earth optical imaging service until 2031, the two satellites operate as a constellation, combining a daily visit frequency capability anywhere at very high resolution.

Pléiades Neo satellites are state-of-the-art optical satellites delivering 0.3m resolution Ortho products as a standard. They are phased on the same orbit, with an optimised and smart-tasking system, and with an improved weather forecast management, they provide the highest quality images with unprecedented reactivity.

Entirely funded by Airbus Defence and Space, the constellation resource is fully available commercially.

The Pléiades Neo satellites have been launched on board Arianespace’s rocket in 2021, from Europe’s space port in Kourou, French Guiana.

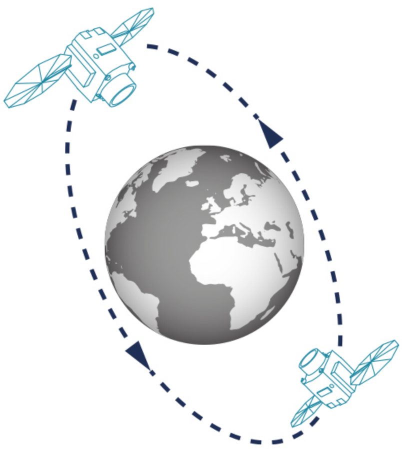


Figure 1: Pléiades Neo in orbit

1.1 The Best Constellation Available since 2021

Pléiades Neo is a constellation of two identical, very high-resolution optical satellites launched in 2021 on board Arianespace's Vega rockets. With a 10-year expected lifetime, they will ensure the provision of 30cm resolution imagery until at least 2031, and consequently the continuity of Airbus Intelligence's high standard geo-information services.

Number of satellites	Two identical satellites in constellation, named: • Pléiades Neo 3 • Pléiades Neo 4
Launch mass	Body: ~1 ton for each satellite
Launch	April 2021 for Pléiades Neo 3 and August 2021 for Pléiades Neo 4
Mission lifetime	10 years for each satellite

Table 1: General characteristics of the constellation

Pléiades Neo operates as a genuine constellation on the same orbit and phased at 180° from each other. Added to their oblique incidence capability (up to 52° angle) and exceptional agility, this orbit phasing allows the satellites to visit any point on the globe daily – ideal for monitoring sensitive sites, anticipating risks, effectively managing crises and for coverage of large areas.

Orbit	Sun-synchronous, 10:30 a.m. descending node
Altitude	620km
Cycle	26 days
Period/Inclination	97.2'/97.9°
Frequency of visit (with four satellites)	Daily, anywhere
Acquisition capability	Up to 1 million km² per day (with two satellites)
Nominal imaging mode	14km-swath strips oriented along North-South axis
Stereo capability	Single-pass stereo and tri-stereo (fore, nadir and aft mode)

Table 2: Orbital characteristics and viewing capability

The daily visit capacity anywhere is backed by a very reactive operational loop. Work plans are updated every 25 minutes and pooled: when an image is to be collected by one satellite, the related acquisition request is removed from the tasking plans of the other satellite. These multiple and synchronised daily work plans enable easy handling of last-minute tasking requests, as well as integration of the latest weather information for an improved data collection success rate.

In addition, Airbus Defence and Space Intelligence's network of ground receiving stations enables an all-orbit contact and ensures near real-time performances worldwide and rapid data-access, to deliver the highest standards in our service response times. Images are downlinked at each orbit, automatically processed and quickly delivered to the customer, allowing faster results in emergency situations.

For the user, this results in:

- More image collection opportunities.
- Improved map update capacity (coverage).
- Rapid access to data after acquisition.
- Unprecedented capacity for disaster response, regular or intensive monitoring, or change detection.

Main X-band receiving stations	Toulouse (France) Kiruna (Sweden) Inuvik (Canada)
S-band uplink stations	Kiruna (Sweden) Inuvik (Canada)
Programming centre	Airbus DS - Connected Intelligence – Toulouse (France) Airbus DS - Connected Intelligence – Herndon, VA (USA)
Production centre	Airbus DS - Connected Intelligence – Toulouse (France)
Tasking plans refresh frequency	Every orbit: ~15 times/day/satellite (almost 30 times a day in total)
Update of weather forecast	4 times a day for global weather forecast + at each orbit: weather update for the next 2 hours
Satellite Control Centre	Airbus DS - Toulouse (France)

Table 3: Key attributes of the Pléiades Neo Constellation

The Pléiades Neo satellites benefit from exceptional performance in terms of agility (roll/pitch: 10° in 7 seconds, 30° in 12 seconds, 60° in 20 seconds). The time required to slew 200 kilometres (17°) is reduced to 10 seconds, including stabilisation time. This kind of performance results in a reduced average acquisition window for the users, allowing more images to be collected during the same pass. Collection opportunities are more numerous, conflicts between contiguous requests are minimised, and the acquisition on the same pass of either big AOIs or several targets at the same latitude is improved.

The Pléiades Neo constellation offers a wide range of products and services featuring different options to match as closely as possible to any customer requirements. Combining the Panchromatic and multispectral bands, images can be visualised as either black and white (30 cm product resolution), natural colours, false colours (1.2m product resolution) or as merged product (Pan-sharpened colour image) with the resolution of a Panchromatic image.

Optical system	Korsch telescope, TDI instrument
Spectral bands	Panchromatic: 450-800nm Multispectral channels: • Deep Blue: 400-450nm • Blue: 450-520nm • Green: 530-590nm • Red: 620-690nm • Red-Edge: 700-750nm • Near Infrared: 770-880nm
Ground sampling distance (nadir)	Panchromatic 0.3m Multispectral 1.2m
Product resolution	Panchromatic 0.3m Multispectral 1.2m
Swath width	14km at nadir
Dynamic range at acquisition	12 bit per pixel
Viewing angle	± 52°
Pointing agility	Roll/pitch: 10° in 7 seconds, 30° in 12 seconds, 60° in 20 seconds
Slew time@200km*	10 s
Onboard storage*	14-Tbits store and forward capability
Instrument TM link rate	1.2 Gbps dual polarity

Table 4: Instrument technical specifications and performances

GSD-PAN @nadir	0.3m
GSD-Multispectral @nadir	1.2m
Location accuracy at nadir PRIMARY/PROJECTED product levels (residual bias error)	(X,Y): 5m CE90 Expected: 3.5m with refined data
Planimetric accuracy **Standard ORTHO product (residual errors, standard GCP and DEM)**	(X,Y): 5m CE90
Planimetric accuracy **Customised ORTHO product (residual errors, nearly perfect GCP and DEM)**	(X,Y): 0.3m CE90
Vertical accuracy **Customised ORTHO product (residual errors, nearly perfect GCP, slope <20%)**	Z: 0.6m LE90
NIIRS	5.8 (GIQE V5)

Table 5: Main performances and image quality commitments

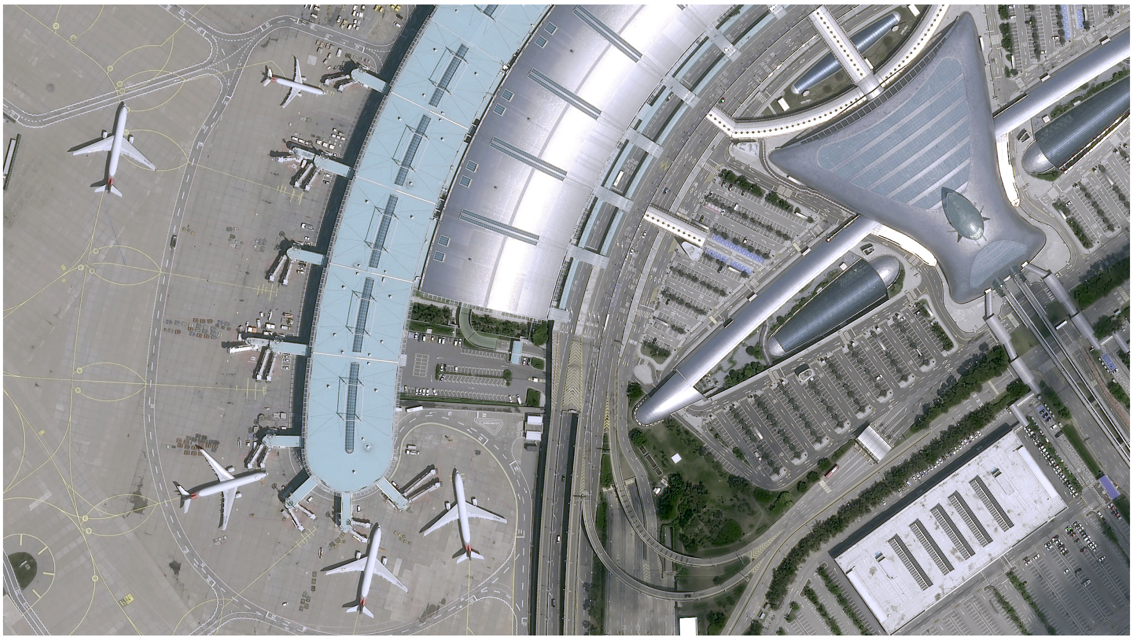


Figure 2: Image at 30cm resolution of Seoul Incheon Airport

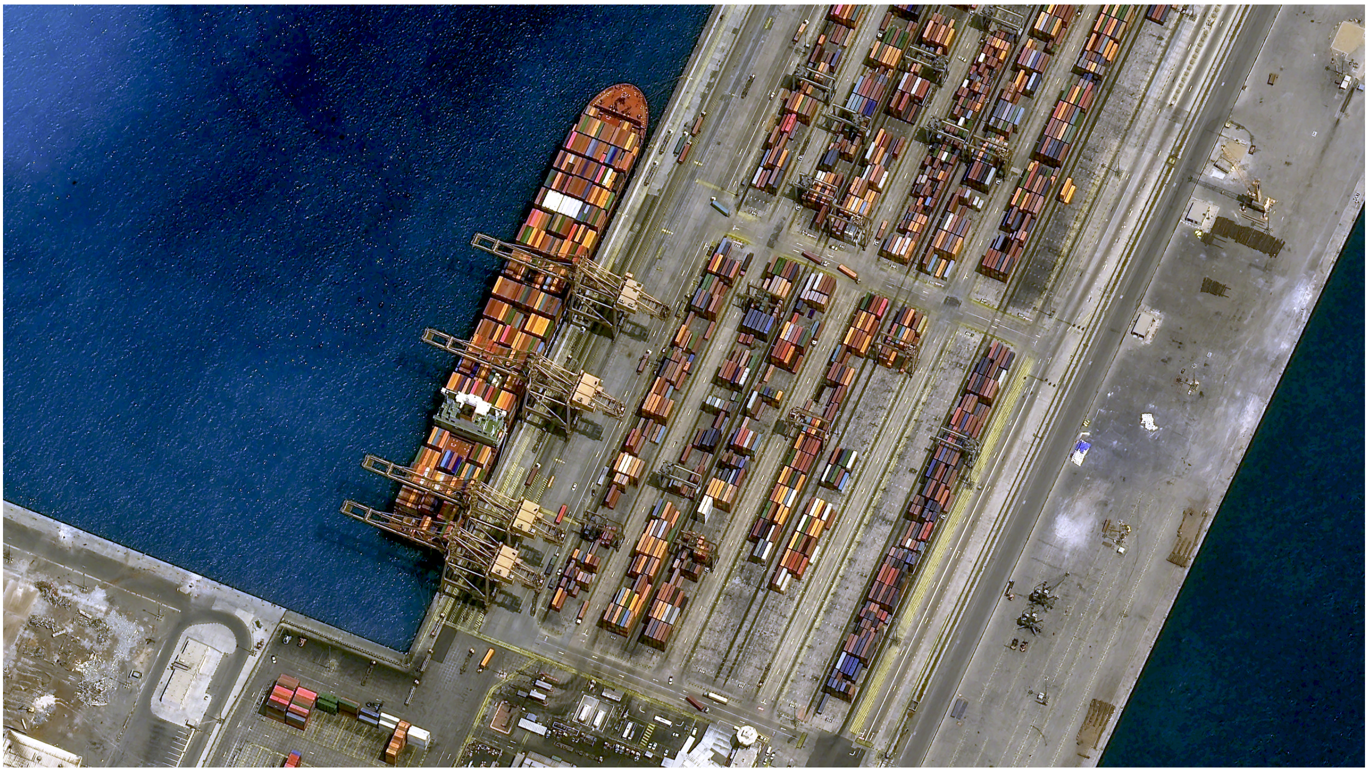


Figure 3: Image at 30cm resolution of the port of Djeddah

Entirely funded by Airbus Defence and Space, Pléiades Neo is built in-house, benefiting from many years of experience and proven capabilities in Earth observation systems manufacturing.

Bus supplier	Airbus Defence and Space - Space Systems
Payload supplier	Airbus Defence and Space - Space Systems
Sensor supplier	Airbus Defence and Space - Space Systems

Table 6: Main information on the manufacturer

1.2 Ground Segment

The design of the space segment is fully linked with the development of a new generation of ground segment. Use of cloud technology is embedded in the architecture of the system with immediate access to the massive archive database for product delivery in the shortest timeframe.

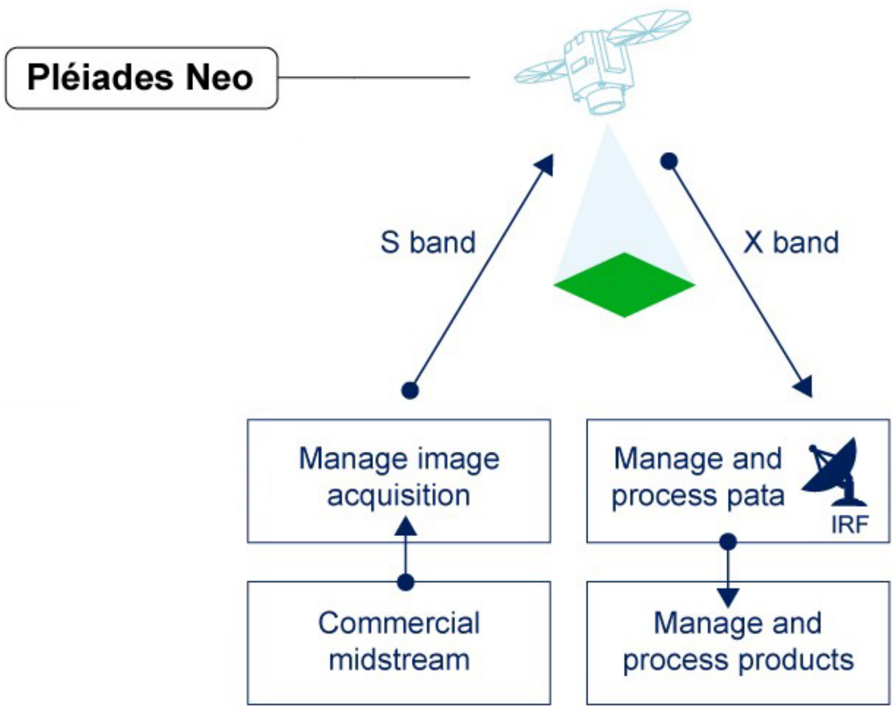


Figure 4: Pléiades Neo overall system

1.2.1 Tasking

The tasking of the whole constellation is optimised, with command and control of satellites from Toulouse via a network of S-band polar stations.

A new tasking plan is uploaded at every orbit for each satellite, which means a new plan every 50 minutes to the constellation. This allows integration of new requests for urgent acquisitions and factors in the latest weather forecast, so focuses are over areas where success rate is higher.

The pooling of the tasking plans for the two satellites means that when an image is to be collected by one of them, the related acquisition request is removed from the tasking plans of the other satellite. This optimises the resource allocated to a coverage task.

S-band uplink stations	Kiruna (Sweden) Inuvik (Canada)
Programming Centre	Airbus DS – Connected Intelligence – Toulouse (France) Airbus DS – Connected Intelligence – Chantilly VA (USA)
Tasking plans refresh frequency	30 times a day (15 times/day/satellite)
Update of weather forecast	Four times a day for global weather forecast + at each orbit: weather update for the next 2 hours
Satellite Control Centre	Airbus DS - Toulouse (France)
TC frequency (uplink)	S-band

Table 7: Tasking attributes of the Pléiades Neo Constellation

1.2.2 Downlink

With a download rate tripled compared to SPOT 6/7 mission, the system is designed to deliver acquired data in a timely way. At each orbit, download is triggered when crossing visibility circles of the anchor stations the Northern Pole and in Toulouse, France – namely the Main Operating Centre (MOC). In addition, imagery download relies on a network of direct receiving partners (DRS MM Neo), able to serve local users in near real time.

Main X-band receiving stations	Toulouse (France) Kiruna (Sweden) Inuvik (Canada)
Production centre	Airbus DS - Connected Intelligence – Toulouse (France)
TM frequency (downlink)	X-band

Table 8: Downlink attributes of the Pléiades Neo Constellation

1.3 **Acquisition Capacity**

With an acquisition capacity of up to 500,000 km² per satellite and per day, the Pléiades Neo constellation has a global daily collection of up to 1 million km² per day at 30cm resolution.

The multi-strip acquisition mode allows collection of a wider surface area – typically 7,500 km² in a single pass to cover complete urban areas.

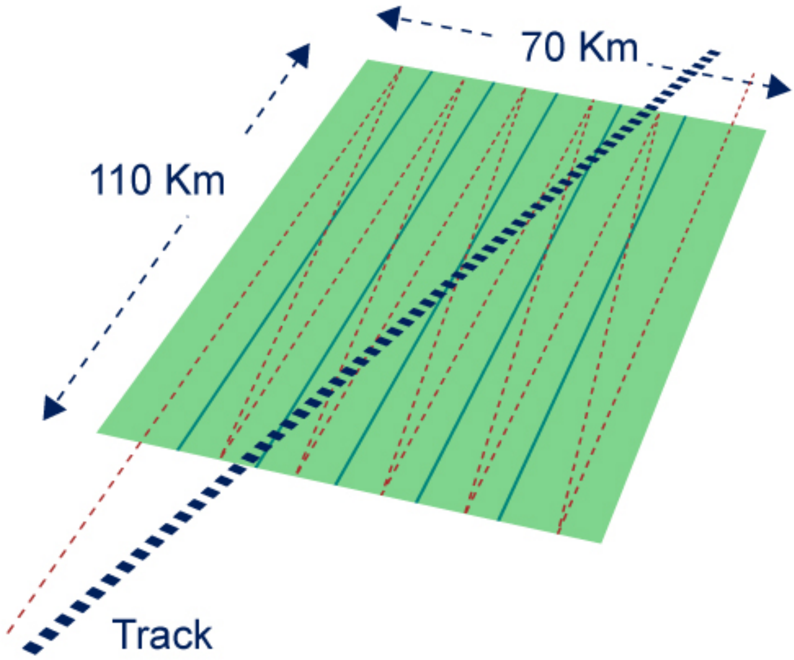


Figure 5: Pléiades Neo multi-strip acquisition mode and capacity in a single pass

1.3.1 Swath and Coverage

Pléiades Neo coverage capacity is also due, in part, to its swath (14 km), the largest in this class of resolution – providing a larger native image footprint.

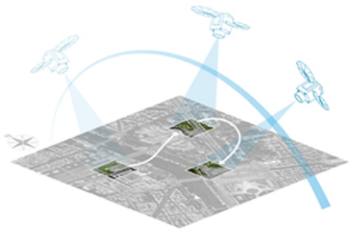
This results in maximised information on a target and its surroundings and optimised production with a reduced requirement for cutlines and mosaicking work over large areas, as well as easier data handling, with fewer folders and products to manipulate for a given large AOI.

1.3.2 Single Pass Collection Scenarios – Overview

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

- **Target collection**: image multiple targets (1 and 2): up to 13 targets within a 100 x 200 km area, in a corridor of +/-30 degrees.
- **Strip mapping**: large mosaics in a single pass (3): up to 70 x 110 km in the same pass (7,500 km²).
- **Stereo and Tri-stereo acquisition** (4): for accurate 3D applications.
- **Corridor acquisition** (5): follow linear features such as coastlines, borders, pipelines, rivers, roads, etc.

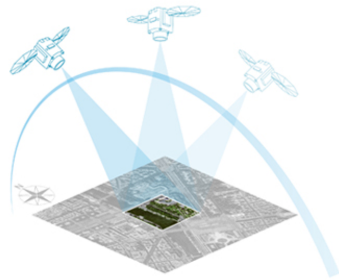
The daily revisit anywhere allows detection of changes and the collection of wide areas in the shortest timeframe, typically 7,500km² areas can be covered in a single pass.



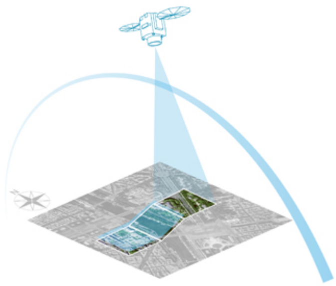
Target collection
Multiple close targets during the same pass, typically 20 targets over a 1,000 x 1,000 km area inside a +/-30° corridor

Multiple acquisitions
Multiple acquisitions over a given area, typically ten images over an area of 100 x 200 km

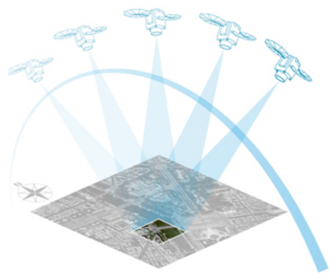
Single pass strip mapping
Strip mapping over large areas, typically up to five contiguous strips of 110 km each



Stereo and tri-stereo
Stereo and Tri-stereo acquisitions for 3D applications



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



Multiple acquisitions over a single pass
Persistent surveillance mode, for moving targets and/or improved photointerpretation

Figure 6: Single pass collection scenarios

Typical daily point target collection capability	Up to 1 million km² per day (with two satellites)
Retargeting agility	Up to 13 targets for 100*200 km theatre

Table 9: Pléiades Neo daily collection capacity

1.3.3 Mosaics Acquired in a Single Pass

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

Swath cover	Maximum length	Km²
Incidence angle ±30°		
5 strips (14 km)	➔110 km	7,700
6 strips	80 km	6,700
7 strips	60 km	5,900
8 strips	40 km	4,500

Table 10: Strip mapping coverage

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

1.3.4 Stereoscopic Cover Capabilities

Thanks to their agility, each Pléiades Neo satellite offers high resolution stereoscopic cover capability. A stereoscopic cover is achieved within a single pass over the area of interest.

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 to get tri-stereoscopic vision where necessary.

Stereo		Tri-stereo	
B/H	**Length**	**B/H**	**Length**
0.15	15 km	0.3	20 km
0.2	30 km	0.4	40 km
0.3	60 km	0.5	60 km
0.4	90 km	0.6	80 km
0.5	110 km	0.7	100 km

Table 11: Pléiades Neo Stereo/Tristero B/H

Tri-stereo images can be used to create more accurate 3D models, compared to what is possible with basic stereo, as the near nadir acquisition minimises the risk of missing hidden items. This is ideal for dense urban and mountainous areas.

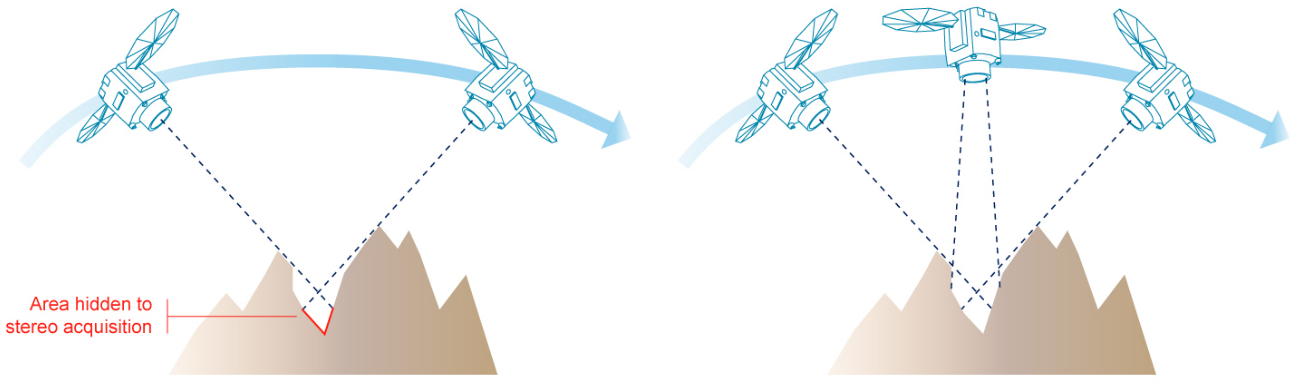


Figure 7: Pléiades Neo-stereo/Tri-stereo acquisition capabilities

2 Products, Services and Options

Pléiades Neo delivers ready-to-use products, which can be easily integrated in GIS and/or transformed into thematic information when combined with other satellite, airborne or ground information. Pléiades Neo satellites always acquire images simultaneously in two modes:

- **Panchromatic:** one band (black and white)
- **Multispectral:** six bands (colour)

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

The Pléiades Neo constellation offers a wide range of products and services featuring different options to match as closely as possible to any customer requirements.

Geometric processing options	Primary Projected Ortho
Radiometric processing options	Basic Reflectance Display
Imagery format	JPEG 2000 Regular GeoTIFF JPEG 2000 Optimized *[1] NITF *
Product encoding	12 bits 16 bits 8 bits
Spectral combinations	• **PAN:** Panchromatic (1 band) • **Bundle:** PAN + MS (4 bands RGB+NIR) • **Full Bundle:** PAN + Full MS (6 bands) • **MS:** Multispectral (4 bands RGB+NIR) • **Full MS:** Multispectral (6 bands) • **PMS_N:** Pansharpening in natural colour (3 bands RGB) • **PMS_X:** Pansharpening in false colour (3 bands RGNIR) • **PMS:** Pansharpening (4 bands RGB+NIR) • **Full PMS:** Pansharpening (6 bands)

Table 12: Standard product options delivered by Image Production Facility

[1] * Unavailable at the commercial launch

2.1 Spectral Band Combinations

Combining the Panchromatic and Multispectral bands, images can be visualised as black and white (30 cm product resolution), natural colours, false colours (1.2m product resolution) or as merged product (Pan-sharpened colour image) with the resolution of a Panchromatic image.

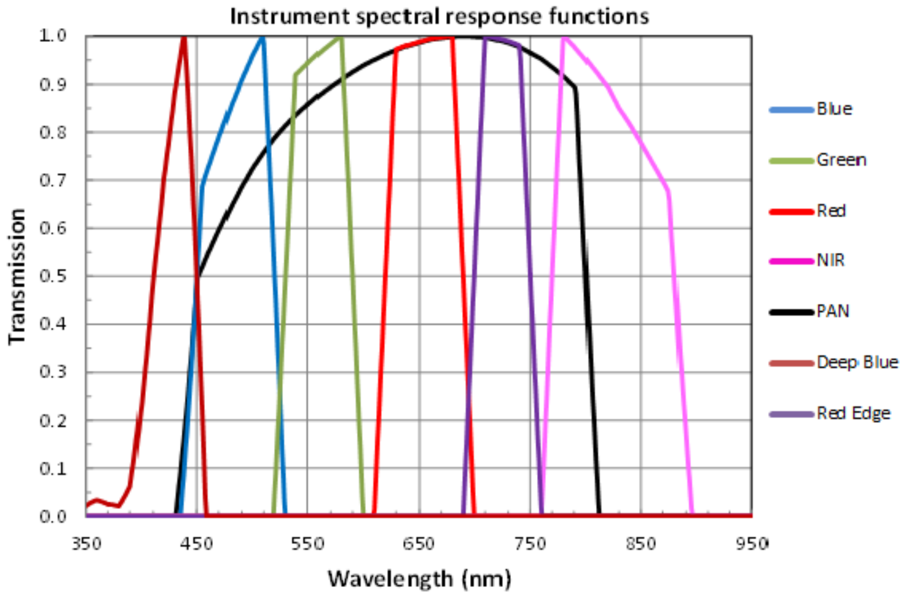


Figure 8: Typical representative spectral bands

2.1.1 Panchromatic Product

The Pléiades Neo Panchromatic product includes only one black and white band. It covers wavelengths between 450–800nm of the visible spectrum. The product pixel size is 0.3m (Ortho).

Spectral bands	Panchromatic: 450–800nm
Ground Sampling Distance (nadir)	Panchromatic 0.3m
Product resolution	Panchromatic 0.3m

Table 13: Panchromatic band technical specifications

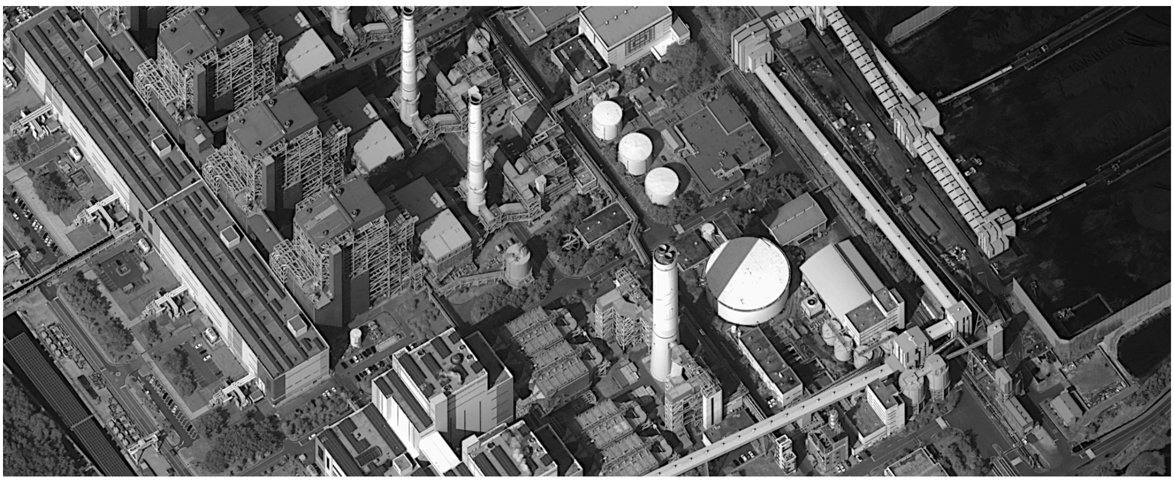


Figure 9: Panchromatic Image at 30cm resolution of industrial site

2.1.2 Multispectral Product

The Multispectral product includes six Multispectral (colour) bands: deep blue, blue, green, red, red edge, near infrared. The product pixel size is 1.2m (Ortho).

Spectral bands	Multispectral channels: Deep Blue: 400-450nm Blue: 450-520nm Green: 530-590nm Red: 620-690nm Red Edge: 700-750nm Near Infrared: 770-880nm
Ground Sampling Distance (nadir)	Multispectral 1.2m
Product resolution	Multispectral 1.2m

Table 14: Multispectral bands technical specifications

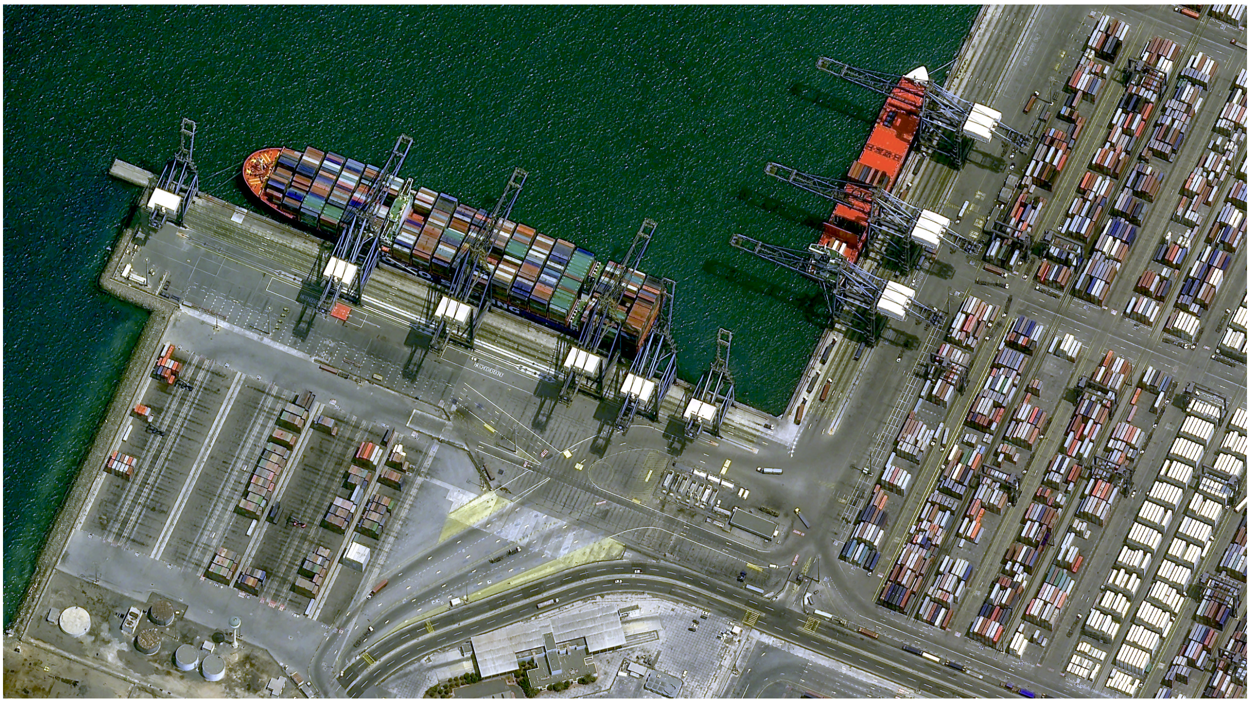


Figure 10: Image at 30cm resolution of Djeddah

Compared to Pléiades, Pléiades Neo has two additional multispectral bands:

- **Deep-blue:** allows deeper penetration into water bodies, and is very useful in bathymetric studies, and has better characterisation of atmospheric conditions and discrimination in shadows.
- **Red-edge:** is particularly useful for agricultural and vegetation-related applications as it provides crop and vegetation status through photosynthesis characterisation. Once canopy closure is reached (NDVI is saturating), Red-edge can differentiate between the various densities of canopy.

The Multispectral products are offered as four or six-band products:

- **MS:** Multispectral (4 bands RGB+NIR)
- **Full MS:** Multispectral (6 bands)

2.1.3 Bundle Products

The Panchromatic (0.3m) and Multispectral (1.2m) products simultaneously acquired are delivered together separately (not merged) for a single delivery (one file for Panchromatic and one file for Multispectral).

Bundle products are offered as five or seven-band products:

- **Bundle:** PAN + MS (4 bands RGB+NIR)
- **Full Bundle:** PAN + Full MS (6 bands)

2.1.4 Pansharpened Products

Pansharpened products combine the visual coloured information of the Multispectral data with the details provided by the Panchromatic data, resulting in a higher resolution 0.3m colour product.

For Pansharpened products, Airbus Defence and Space Intelligence uses its proprietary fusion processing. Performing its own pan-sharpening is a fine process.

Pansharpened products are offered as three, four or six-band products:

- **PMS_N:** Pansharpening in natural colour (3 bands RGB)
- **PMS_X:** Pansharpening in false colour (3 bands NIRRG)
- **PMS:** Pansharpening (4 bands RGB+NIR)
- **Full PMS:** Pansharpening (6 bands)

Figure 10: Pansharpened, NED bands image (NIR, Red Edge, Deep Blue) from FULL PMS at 30cm resolution of Arcachon

The natural and false colour images are derived from Multispectral combinations, all bands have been acquired simultaneously.

2.2 Geometric Processing Levels

Pléiades Neo core imagery products are available in three different geometric processing levels: Primary, Projected and Ortho.

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

Standard products offer the Panchromatic channel (product resolution: 0.3m) or the Multispectral channels (six bands, product resolution: 1.2m) already registered and possibly merged.

2.2.1 Primary Level Products

The Primary product is the geometric 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. This product is optimal for those clients familiar with satellite imagery processing techniques who want to apply their own production methods (orthorectification or 3D modelling 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 level product is:

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

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

The main geometric processing includes:

- The combination of all sub-swaths across the field of view (14km nadir condition): synthesis in a virtual focal plane represented by a single linear array for all spectral bands.
- Correction of instrumental and optical distortions: viewing angles adjusted to the single linear array model.
- Co-registration of all spectral bands: Multispectral and Panchromatic.
- Attitudes and ephemeris data are refined at ground on the mean estimation:
  - Adjustment of the time stamp sampling (along scan line).
  - Attitudes filtering over time of acquisition.
- Consistent alignment of the physical location model ancillary data and RPC analytic model data.
- When appropriate the image location can be improved by Ground Control Points from the Airbus Intelligence worldwide Space Reference Points database.

The main radiometric corrections/enhancements include:

- Inter-detector equalisation: correction of differences in sensitivity between the detectors (on-board correction).
- Aberrant detectors correction (none at that time).
- Panchromatic band restored and de-noised.

The final format includes:

- Masking of pixels (black fill) outside the AOI polygon.
- Physical tiling: images beyond a certain size are split into several files.

The user selects:

The spectral band combinations: PAN, Bundle, Full Bundle, MS, Full MS, PMS, PMS_N, PMS_X, Full PMS (for more details, see *Table 12: Standard product options delivered by Image Production Facility*).

The radiometric processing: Basic or Reflectance or Display.

The bit-depth in Basic processing: 12-bit native (4096 values) or reduced to 8 bits (adjusted linearly to 256 values) for screen display without adaptation.

The raster file format: JPEG 2000or GeoTIFF.

2.2.2 Projected Level Products

Compared to Primary level, the Projected level results from an additional process to map the image onto an Earth cartographic system at an iso-altitude value. The image is georeferenced without correction from acquisition and terrain off-nadir effects. This image-to-map transformation is directly compatible with GIS environment, for example to overlay the image on other data.

The Projected image cannot be superimposed on a map, the effects of the true relief being preserved in the image. Just like Primary images, data processed at projected level can be used for geometric modelling, orthorectification or 3D extraction, for example. This is possible thanks to the RPC model provided with the product, which is supported by many software programs available on the market, from standard Geographic Information System (GIS) to expert photogrammetry ones.

Key benefits

Directly compatible with GIS environments.

Easier orthorectification by users who use their own reference layers (Ortho, GCPs and DEM), thanks to the geometric model described in the embedded RPC file.

For users looking for ultimate geometric performances, generally speaking, the sensor model (Primary only) is more focused on image strip and large bundle adjustment, while the RPC analytic model has the same level of accuracy with shorter images.

The Projected product is mapped on the Earth onto a projection system at a constant terrestrial altitude, with respect to the reference ellipsoid. By default, the ellipsoid and map projection is WGS84/UTM, and the altitude is the mean altitude computed over the image area. The user also has the choice to select a projection system on WGS84 from the many offered by Airbus Defence and Space Intelligence and to customise the altitude value.

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

The Projected level inherits same geometric corrections from the Primary level, with additional adjustments:

- Image projected in a map projection or geographic projection at an iso-altitude value with respect to the WGS84 reference ellipsoid.
- Alignment of the RPC analytic model on this Earth projection geometry.

The Projected product inherits same radiometric corrections and enhancements from the Primary level, with additional adjustments:

- Pixel sampling (Spline kernel) at a regular resolution of 1.2m for Multispectral products and 0.3m for Panchromatic and Pansharpened products.

The final format includes:

- Masking of pixels (black fill) outside the AOI polygon.
- Physical tiling: images above a certain size are split into several files.

The user selects:

- The spectral band combinations: PAN, Bundle, Full Bundle, MS, Full MS, PMS, PMS_N, PMS_X, Full PMS (for more details, see Table 12: Standard product options delivered by Image Production Facility).
- The radiometric processing level: Basic, Reflectance or Display.
- The bit-depth in basic processing: 12-bit native (4096 values) or 8-bits (adjusted linearly to 256 values) for screen display without adaptation.
- The raster file format: JPEG 2000 or GeoTIFF.

2.2.3 Orthoimages

2.2.3.1 Standard Orthoimages

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 can be superimposed on a map. In addition to 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 localisation gaps that can be caused by different viewing angles or relief between the various layers. In order to improve the accuracy of the product, Airbus Intelligence uses its own worldwide 3D reference layers to perform ground corrections: Space Reference Point Ground Control Points (GCP) and WorldDEM4Ortho hybrid DTM/DSM for orthorectification.

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 level product inherits same geometric corrections from the Primary level, with additional adjustments:

- Planimetric reset: if ground reference data is available and will enhance the native location accuracy if relevant, reset on Ground Control Points. By default, Space Reference Points are used, otherwise PAS ortho tiles are used where available.
- Altimetric reset: with a Digital Elevation Model (DEM) to correct acquisition angles and relief off-nadir effects (as a vertical shot) for the orthorectification resampling process. By default, the WorldDEM4Ortho layer is used where available, otherwise Reference3D DEM or SRTM is used.
- Map projection or geographic projection.

The Ortho product inherits same radiometric corrections and enhancements from the Primary or Projected processing level, with additional adjustments:

- Pixel sampling (Spline kernel) at a regular resolution of 1.2m for Multispectral products and 0.3m for Panchromatic and Pansharpened 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.

The user selects:

- The spectral band combinations: PAN, Bundle, Full Bundle, MS, Full MS, PMS, PMS_N, PMS_X, Full PMS (for more details, see Table 12: Standard product options delivered by Image Production Facility).
- The radiometric processing level: Basic, Reflectance or Display.
- The bit-depth in Basic processing: 12-bit native (4096 values) or reduced to 8 bits (adjusted linearly to 256 values) for screen display without adaptation.
- The raster file format: JPEG 2000, with Optimised or Regular compression, or GeoTIFF.

Main characteristic	Information
Geographic projections	WGS84 – latitude/longitude sampling according to DTED2 zoning standards (please refer to A.5.1 for more details)
Mapping projections	Most of the projections registered by EPSG, in metres (please refer to A.5.2 for more details)
GCP	Space Reference Points (SRP), PAS Ortho tiles
DEM	WorldDEM4Ortho DSM/DTM, Reference3D DEM layer (DTED2), SRTM (DTED1), GLOBE (DTED0)

Table 15 : Geometric details of the Ortho product

2.2.3.2 Tailored Ortho

Apart from the standard Ortho product, when different specifications are needed, Airbus Intelligence can also provide on-demand, custom orthorectification, with a more precise 3D model provided by the client or acquired for 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.

2.3 Radiometric Processing Levels

Pléiades Neo core imagery products are available in three different radiometric processing levels: Basic, Reflectance and Display.

2.3.1 Basic Radiometric Processing

Basic imagery corresponds to raw data without any radiometric processing. Each pixel is given in digital numbers (DN), i.e. native pixel values from the sensor acquisition (after equalisation). Those digital numbers quantify the energy recorded by the detector, corrected relative to the other detectors to avoid non-uniformity noise.

The sensor absolute calibration aims to turn back the DN value into a physical unit value (radiance, light power) at the input of the camera. 'Top-of-Atmosphere' (TOA) is not applied to the image bands. The absolute calibration coefficients are provided in the DIMAP metadata file, ensuring spectral corrections from space to ground by the user.

The source DN values at sensor level range from 0-4095. These Basic values are maintained to the original 12 bit-depth, also for byte-oriented format as GeoTIFF needing 16 bits integer storage.

In order to minimise the image file volume, the user can order Basic in 8 bit-depth. The conversion to 8 bits coding (range 0-255) is performed by a linear stretch on the effective histogram of the source image.

Key benefits

For experts used to pure data and familiar with satellite imagery applications and image processing tools.

Ideal to carry up own calibration and own spectral analysis.

2.3.2 Reflectance Radiometric Processing

Reflectance imagery is radiometrically corrected from sensor calibration and systematic atmospheric effects of the atmosphere (molecular or 'Rayleigh' diffusion). Image values are provided in normalised reflectance values with a 1/10,000 ratio.

In clear sky conditions (no dynamic factors affecting the low atmosphere as veils), the reflectance value is directly assimilated to the ground surface reflectance. Otherwise Cloud, cloud veil, haze, aerosol (pollution, sand wind) remain.

Reflectance is more straightforward and easier to use than the Basic radiometric processing. Such benefits are, for example, on spectral and monitoring analysis to ensure direct comparison between images at different dates or different calibrated sensors and on image processing to correct the bluish effects from atmosphere to achieve reliable true colour.

In addition, the product with Reflectance radiometric option provides an XML file of colour curves (Look-Up Table, LUT) for true colour image rendering. LUT uses GDAL and MapServer form to ease integration in display applications. The colour curve is optimised by a stretch taking care of sensor calibration and atmospheric correction. The rendering is the same as the Display radiometric option but without altering the original imagery spectral physical values.

Reflectance and Basic have the same spectral capability. The reflectance model is a universal atmospheric correction addressing the most common user needs. The model is also reversible back to radiance or DN through coefficients provided in the DIMAP metadata file. It allows expert users with locally accurate atmospheric measurements to refine the correction.

The image values are given in 1/10,000 reflectance, having range 1–10,000, possibly overcome on specular targets. A quantisation on 8-bit would revoke the benefit of a direct readable count in physical unit and is not proposed.

Key benefits

Calibrated image correcting the bluish effects from atmosphere, so that colours are reliable and true.

Ensures better stability of luminosity/contrast on screen.

Prepares end users for spectral analysis and seamless coverage (e.g. mosaicking).

2.3.3 Display Radiometric Processing

Display products are generated on an algorithm based on the Reflectance product.

In the Display radiometric option, a true colour curve has been applied to the image directly usable for visualisation on screen. The colour curve is the LUT computed by the Reflectance processing. The image true colour is properly retrieved from sensor calibration and correction of systematic effects of the atmosphere.

Display processing is to be used when imagery needs to be immediately usable with optimised visual rendering. The imagery values are 8-bit numbers optimised for a direct rendering on the screen. The values are not reversible to spectral physical unit.

The image values are encoded in 8-bit depth per band, addressing the 16.78 million colours of RGB space for Multispectral, plus an extra channel for four-band delivery. A larger encoding would not have extra values for display purposes. 8-bit pixel coding should be requested since 16-bit pixel coding does not provide any additional information.

Key benefits

Ideal radiometric processing level when imagery needs to be immediately usable with optimised visual rendering.

Optimised for display on screen (8-bit).

2.4 Product and Image Format

Pléiades Neo imagery is available in different products and image formats:

- DIMAP – Regular JPEG 2000
- DIMAP – GeoTIFF

Pléiades Neo products are, by default, delivered in DIMAP V2, just like Pléiades and SPOT 6/7:

- The image can be output in different raster formats, either GeoTIFF or JPEG 2000.
- Rational Polynomial Coefficients (RPCs) are provided for easier orthorectification and geometric processing.
- A KMZ is included for a rapid, easy and user- friendly display of the main metadata in a Google Earth environment.
- Quality and cloud cover masks are included.

Within the products, the imagery file is available in two formats, GeoTIFF or JPEG 2000.
Compared to GeoTIFF, JPEG 2000 saves on file space. JPEG 2000 files can be up to five times smaller than GeoTIFF files, making data warehouse management, handling, post-processing and streaming much easier. Depending on your needs, you can choose between two compression rates:

- **JPEG 2000 Optimised** is intended for those looking for fast download and easy data sharing:
  - 3.5 bits/pixel compression.
  - Lossy compression: the compression rate is optimised to avoid any spatial effect but is not reversible.
  - A spectral effect of 1/1000 is tolerated.

- **JPEG 2000 Regular** is perfect for users who plan to do high precision post-processing:
  - 8 bits/pixel compression (average from different landscapes).
  - 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 GeoTIFF format is free of any compression. 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. As Pléiades Neo acquires images with a 12-bit depth, there is no benefit to the GeoTIFF 16-bit products storing 4 bits.

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 16 – Image format options

Combinations	JPG 2000 Regular	JPG 2000 Optimised	GeoTIFF 16 bits
Panchromatic (PAN) – 1 band – 30 cm	1818	909	4154
Multispectral VNIR (MS) – 4 bands – 1.2 m	455	228	1039
Multispectral Full Spectrum (Full MS) – 6 bands – 1.2 m (2)	682	341	1558
Bundle VNIR (Bundle) – 5 bands – 30 cm + 1.2 m (2)	2273	1137	5193
Bundle Full Spectrum (Full Bundle) – 7 bands – 30 cm + 1.2 m (3)	2500	1250	5712
Pansharpening (PMS_N or PMS_X) – 3 bands – 30 cm	5452	2726	12462
Pansharpening (PMS) - 4 bands – 30 cm	7270	3635	16616
Pansharpening (Full PMS) – 6 bands – 30 cm (2)	10904	5452	24923

Table 17 – Image size according to image format (image 14x14km, values in Mb)
(2): 2 image files (regardless of tiling)
(3): 3 image files (regardless of tiling)

Please refer to **Products Delivery,** for assistance in selecting the appropriate options.

Most of the software providers have eased the ingestion of Pléiades Neo data into their systems. The detailed status, per software and version, is available upon request at technicalsupport@intelligence-airbusds.com.

2.5 Licensing

To find the licences that fit your needs, please visit the following page:

https://www.intelligence-airbusds.com/legal/licence

3 Products Delivery

3.1 Deliverable

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

Streaming access to Pléiades Neo data is also available as a standard delivery mode or through diverse existing or to- come digital offers.

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 30 cm resolution, Pan- sharpened 4-band, 196 km² product.

JPG 2000 Regular	GeoTIFF
Bit-depth 12 bits Optimised: 3.6 GB Regular: 7.3 GB	**Bit-depth 12 bits** (storage 16 bits) 16.7 GB
Bit-depth 8 bits Optimised: 3.6 GB Regular: 7.3 GB	**Bit-depth 8 bits** (storage 8 bits) 8.4 GB

Table 18 – Examples of typical file sizes

For 12-bit products, a JPEG 2000 file is two times smaller with a Regular compression, and around five times smaller with an Optimised 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.

- JPEG 2000 12-bits vs. JPEG 2000 8-bits:
  the image features a larger dynamic, but the file size is comparable.
  Theoretically, for JPEG 2000, file sizes are the same for 8 and 12 bits in Optimised and Regular compression. This is related to the fact that the JPEG2000 compression process determines a same targeted bit- rate (3.5 bits/pixel for Optimised compression, 8 bits/pixel (average) for Regular), which can be directly linked to a target file size, whether the dynamic range is 8 or 12 bits. In fact the real dynamic range affects more or less the binary length encoding. Practically the file size is decreasing according the proper dynamic range.

Image Files
The product contains one image file (regardless of tiling) for each spectral mode less than 4 bands, containing one or several bands:

Band Combination products	Image files (regardless of tiling)	Number of band
Panchromatic (PAN) – (Black and White, 30 cm)	1	1
Multispectral VNIR (MS) – (4 Band Colour, 1.2 m)	1	4
Multispectral Full Spectrum (MS-FS) – (6 Band Colour, 1.2 m)	1+1	6
Bundle VNIR (PAN+MS) – (Panchromatic, 30cm + 4 Bands, 1.2 m)	1+1	1+4
Bundle Full Spectrum (PAN+MS-FS) – (Panchromatic, 30cm + 6 Bands, 1.2 m)	1+1+1	1+3+3
Pansharpening (PMS-N) – (Natural Colour – 30 cm)	1	3
Pansharpening (PMS-X) – (False Colour – 30 cm)	1	3
Pansharpening VNIR (PMS) - (4 Band Colour, 30 cm)	1	4
Pansharpening Full Spectrum (PMS-FS) – (6 band Colour, 30 cm)	1+1	3+3

Table 19 - Number of image files and of bands per product type

Band Naming and Band Order
Pléiades Neo spectral bands are defined as:

- PAN = Panchromatic spectral band
- DB = Deep Blue spectral band
- B = Blue spectral band
- G = Green spectral band
- R = Red spectral band
- RE = Red Edge spectral band
- NIR = NIR spectral band

For visible spectrum the band order in the image file is defined to have directly a consistent colour display with RGB system:

- 4 bands (PMS, MS):
  - 1st channel in JPEG200/TIFF = Red spectral band (R)
  - 2nd channel in JPEG200/TIFF = Green spectral band (G)
  - 3rd channel in JPEG200/TIFF = Blue spectral band (B)
  - 4th channel in JPEG200/TIFF = NIR spectral band (NIR)

- 3 bands Natural Colour (PMS-N, MS and PMS-FS, MS-FS first imagery file RGB):
  - 1st channel in JPEG200/TIFF = Red spectral band (R)
  - 2nd channel in JPEG200/TIFF = Green spectral band (G)
  - 3rd channel in JPEG200/TIFF = Blue spectral band (B)

- 3 bands False Colour (PMS-X):
  - 1st channel in JPEG200/TIFF = NIR spectral band (NIR)
  - 2nd channel in JPEG200/TIFF = Red spectral band (R)
  - 3rd channel in JPEG200/TIFF = Green spectral band (G)

For additional spectrum the band order in the image file is defined to have a False Colour display as close to the RGB system:

- second NED bands imagery file (Full PMS, Full MS):
  - 1st channel in JPEG200/TIFF = NIR spectral band (NIR)
  - 2nd channel in JPEG200/TIFF = Red Edge spectral band (RE)
  - 3rd channel in JPEG200/TIFF = Deep Blue spectral band (DB)

Image Tiling

Products exceeding a certain size limit are broken up into smaller pieces called 'tiles' constituting the whole product.

Figure 11 – Product Tiling

If a product is not tiled, the image file name is: 'IMG_product_R1C1. JP2'

If a product is tiled, there are as many image files as tiles, named 'IMG_product_RiCj.JP2'. The tiles are delivered without overlap. Please refer to A.4.3 for detailed information.

IMG_PNEO3_202007131011476_PMS-N_PRJ_4562984101_RGB_R1C1.JP2
IMG_PNEO3_202007131011476_PMS-N_PRJ_4562984101_RGB_R1C2.JP2

A georeferencing World File J2W (or TFW for GEOTIFF products) is associated to each image tile to assemble all image files.

IMG_PNEO3_202007131011476_PMS-N_PRJ_4562984101_RGB_R1C1.J2W
IMG_PNEO3_202007131011476_PMS-N_PRJ_4562984101_RGB_R1C2.J2W

All other metadata (RPC XML and DIM XML) are not tiled and are applicable to the full extent product. This means that the product can be visualised and processing into software using the metadata file (DIM_product.XML).

The tiling is applied automatically depending on the file size, which rely on the AOI production size and the following production options:

- Image file format (TIF/JP2)
- Spectral mode (PAN, MS, MS-FS, PMS, PMS-FS, PMS-X, PMS-N)
- Bands number and image encoding.

It is not possible to customize the tiling parameters. Tile size limit is approximately:

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

Since the product size depends on the image format, the same product will be cut into more tiles in GeoTIFF than in JPEG 2000. For example, for one Pan- sharpened, 4-band, 200 sq.km product, a JPEG 2000 12- bit (Optimised) product will be 3.7 GB: no tiling is needed. A GeoTIFF 12- bit product will be approximately 17 GB, with 6 image tiles.

3.1.1 Overview of the Product in DIMAP V2 format

Pléiades products are delivered in DIMAP V2 format.

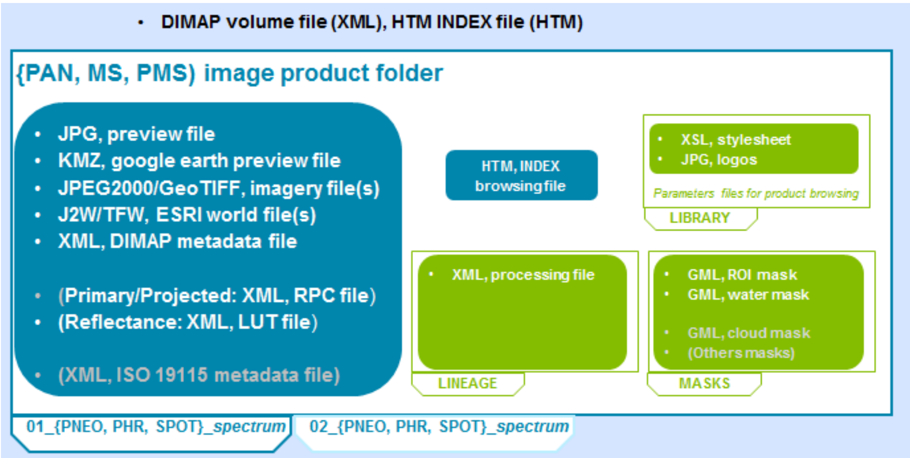


Figure 12 - DIMAP V2 Structure

3.1.2 Example

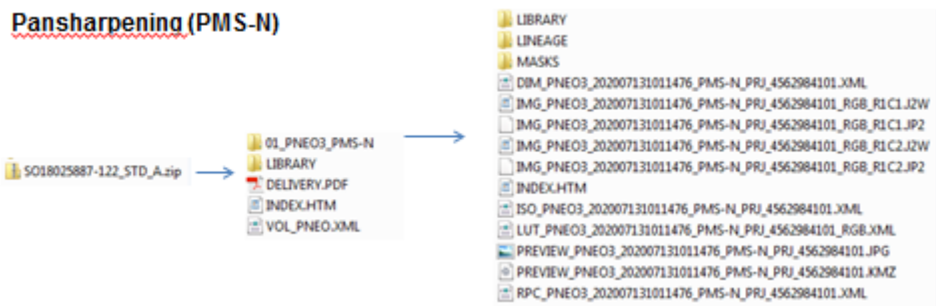


Figure 13 - Example of DIMAP V2 Structure

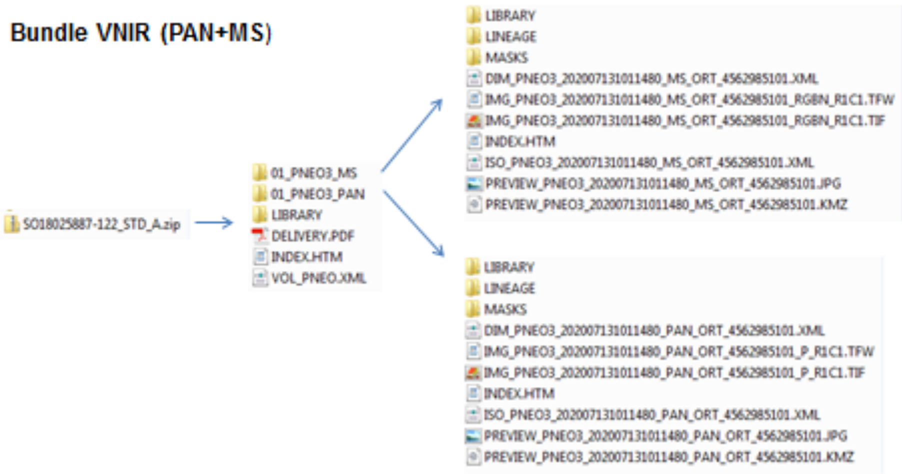


Figure 14 – Example of DIMAP V2 Structure

Primary, Projected and Ortho products can be discovered with the following files:

- The image file, including The ‘PREVIEW’ quicklook files, either in KMZ or JPEG
- The index file named ‘INDEX.HTM’, that allows an easy display of the main information about the product extracted from the metadata file.

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 15 – KMZ Preview, Footprint

Click on different objects to get more information:

Figure 16 – KMZ Preview, Bubble

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

Figure 17 - KMZ Preview, Layers

- **AOI**: This layer shows the order footprint of the whole product.
- **Product**: This layer gives the footprint performed by the data production, and preview of the whole product.
- **Tiles**: This layer shows the footprint and name of each tile contained in the product.
- **Sources**: This layer displays the entire footprint of all source strips, necessary for the production of the 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, such as Internet Explorer or Mozilla Firefox: product description, quick look, coordinate system.

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

Examples:

- **Radiometric values:** gain and offset calibration value to radiance count:


```
<Band_Radiance>
  <BAND_ID>B</BAND_ID>
  <CALIBRATION_DATE>2020-10-16T11:32:43Z</CALIBRATION_DATE>
  <MEASURE_DESC>Reflectance (RHO) to TOA Radiance (L). Formulae L=RHO/GAIN+BIAS</MEASURE_DESC>
  <MEASURE_UNIT>watt/m2/steradian/micrometer</MEASURE_UNIT>
  <MEASURE_UNCERTAINTY>5</MEASURE_UNCERTAINTY>
  <GAIN>0.002263123</GAIN>
  <BIAS>28.902443927827285</BIAS>
</Band_Radiance>
```


- **Geometric values:** acquisition angles :


```
<Acquisition_Angles>
  <IMAGE_ORIENTATION unit="deg">180</IMAGE_ORIENTATION>
  <AZIMUTH_ANGLE unit="deg">15.4102361844</AZIMUTH_ANGLE>
  <VIEWING_ANGLE_ACROSS_TRACK unit="deg">-0.433780671611</VIEWING_ANGLE_ACROSS_TRACK>
  <VIEWING_ANGLE_ALONG_TRACK unit="deg">15.6467044437</VIEWING_ANGLE_ALONG_TRACK>
  <VIEWING_ANGLE unit="deg">15.6527918199</VIEWING_ANGLE>
  <INCIDENCE_ANGLE_ALONG_TRACK unit="deg">-16.6387065477</INCIDENCE_ANGLE_ALONG_TRACK>
  <INCIDENCE_ANGLE_ACROSS_TRACK unit="deg">4.85171724873</INCIDENCE_ANGLE_ACROSS_TRACK>
  <INCIDENCE_ANGLE unit="deg">17.2490968165</INCIDENCE_ANGLE>
</Acquisition_Angles>
```


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 Projected and ortho images or to assembly tiles for Primary products.
Please refer to Appendix A for a complete DIMAP V2 description.

3.2 How to Open Your Product

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

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

* Not applicable for Primary products.
** In row/column for Primary products.

For more than a year before Pléiades Neo launch, Airbus has been working with the main image processing software providers to ease the ingestion of Pléiades Neo data into their systems. The detailed status, per software and version, is available upon request at technicalsupport@intelligence-airbusds.com.

3.3 Technical Support and Claims

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 a 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: technicalsupport@intelligence-airbusds.com.

Appendix A. File Format – DIMAP V2

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. Fixed Names

The prefixes are as shown in the table below:

Prefix	Folder	File	Subject	Remark
VOL_		X	Index volume file of products contained in the delivery	
IMG_	X	X	Product directory, or image file(s), or associated georeferencing file(s)	
DIM_		X	DIMAP, main product metadata file	
ISO_		X	ISO 19115/19139 metadata file	(optional)
LUT_		X	DIMAP, LUT colour curves metadata files	Reflectance processing only
RPC_		X	DIMAP, RPC metadata file	Primary and Projected Products only
PREVIEW_		X	Quicklook raster file, or associated KMZ file	
GROUND_		X	DIMAP, GROUD Source metadata file	If Ground reset at Ortho level, one per source (specific delivery)
HEIGHT_		X	DIMAP, HEIGHT Source metadata file	If Vertical reset at Ortho level, one per source (specific delivery)
PROCESSING_		X	DIMAP, PROCESSING lineage file	
GIPP_		X	Ground Image Processing Parameters file	(specific delivery)
ROI_		X	GML, Region Of Interest mask, vector	
CLD_		X	GML, CLouD mask, vector	if cloud coverage > 0
QTE_		X	GML, Synthetic TEchnical Quality mask, vector	if non nominal quality
VIS_		X	GML, Hidden area mask, vector	Projected and Ortho Products only

Prefix	Folder	File	Subject	Remark
WAT_		X	GML, WATer areas mask, vector	(if available on area)
CUT_		X	Shapefile, CUTline mask, vector	Mosaic Product only
PPM_		X	Planimetric accuracy Performance assessment Mask, raster	Ortho (if available on area)

Table 20 - Naming – Prefixes

The suffixes are:

Suffix	Folder	File	Subject	Remark
_RiCj		X	Image file(s), possibly tiled	ij, Row (R) and Col (C) image tile indexes

Table 21- Naming – Suffixes

The following files/directories have fixed naming:

Name	Folder	File	Subject	Remark
DELIVERY		X	Delivery note	(specific delivery)
LICENSE		X	License file	(specific delivery)
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 files	
STYLE		X	XSLT style sheet files	Short metadata content for discovering purpose

Table 22 - Naming – Main Directories

The file extensions are:

Extension	File	Subject	Remark
.GML	X	GML vector files	Mask file
.HTM	X	HTML file	Short metadata content for discovering purpose
.JPG	X	JPEG raster file	Quicklook discovering file
.JP2	X	JPEG 2000 raster file(s)	Full resolution image file(s)
.J2W	X	ESRI World file(s) for JPEG 2000	Simple assembling/georeferencing file(s)
.KMZ	X	KML file (archived in zip format)	Preview discovering file
.SHP	X	ESRI Shapefile file	(Plus .DBF, .PRJ. SHX), Mosaic cutline
.TIF	X	TIFF/GeoTIFF raster file(s)	Full resolution image file(s)
.TFW	X	ESRI World file(s) for TIFF/GeoTIFF	Simple assembling/georeferencing file(s)
.XML	X	DIMAP file encoding in XML or simple XML file	Metadata files
.XSL	X	XML style sheet file	

Table 23 - Naming – Extensions

A.1.1.2. Variable Key Information

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

At root the product volume directory name is comprised of:

<DirVolume_ID>

<ORDER_ID>_<PRODUCT_CODE><DELIVERY_INDEX>
Example: **SO18025887_121_STD_A**

Where:

<ORDER_ID> = Commercial order and item identifier. Format =variable string (example SO1180258887_123)
<DELIVERY_INDEX> = Delivery item within a complete order delivery = Capital letter, from A to Z

PRODUCT_CODE Standard or uplift processing
STD STandarD processing, Primary, Projected, Ortho
STE STEreo Series, Primary, Projected
SER Geometrically Consistent SERies, Ortho
MOS Ortho, automatic MOSaic processing

The image product directory name for unitary Primary, Projected and Ortho is comprised of:

<DirImage_ID>

<NUM_PRODUCT>_<MISSION><MISSION_INDEX>_<SPECTRAL_PROCESSING>
Example: **01_PNEO3_PMS**

Where:

<NUM_PRODUCT> = Incremental product index within the Volume. Format is two digits from 01 to 99
<MISSION><MISSION_INDEX> = Mission name and satellite number {PNEO, SPOT}{1,2,3,4,5,6…}
<SPECTRAL_PROCESSING> = {PAN, MS, MS-FS, PMS, PMS-N, PMS-X, PMS-FS}, see Table 24.

SPECTRAL_PROCESSING	Spectral Mode
PAN	Panchromatic 1 band
MS	Multispectral 4 bands VNIR (Red, Green, Blue plus one extra band NIR)
MS-FS	Multispectral 6 bands Full Spectrum (MS bands>4, plus Red-Edge and Deep Blue bands)
PMS	Pan-sharpened 4 bands VNIR (Red, Green, Blue plus one extra band NIR)
PMS-N	Pan-sharpened 3 bands (visible spectrum: Red, Green, Blue bands)
PMS-X	Pan-sharpened 3 bands (false colour: Green, Red, NIR bands)
PMS-FS	Pan-sharpened 6 bands Full Spectrum (MS bands>4, plus Red-Edge and Deep Blue bands)

Table 24 - Naming – spectral processing

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

<DirMOS_ID>
<NUM_PRODUCT>_<MISSION>_<SPECTRAL_PROCESSING>
Example: **01_PNEO_PMS**

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

<Imagery_ID>

<MISSION><MISSION_INDEX>_<IMAGING_DATE><IMAGING_TIME>_<SPECTRAL_PROCESSING>_<PROCESS_LEVEL>_<JOB_ID>
Example: **PNEO4_202202191022416_PMS_ORT_PWOI_000007394_1_1_F_1**

Where:
<MISSION><MISSION_INDEX> = see previous section
<IMAGING_DATE><IMAGING_TIME> = Image date and time acquisition at center product (YYYYMMDDHHMMSSs)
<SPECTRAL_PROCESSING> = see previous section
<PROCESS_LEVEL> = {SEN, PRJ, ORT, MOS}, see Table 25
<JOB_ID> = Internal production identifier. Format =variable string

PROCESS_LEVEL	Product processing level
SEN	Primary (abbreviation for SENSOR)
PRJ	Projected
ORT	Ortho, unitary
MOS	Ortho, mosaic image

Table 25 - Naming – processing levels

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

<Mosaic_ID>
<MISSION>_<ORDER_ID>_<SPECTRAL_PROCESSING>_<PROCESS_LEVEL>_<JOB_ID>
Example: PNEO_SO18025887_121_PMS_MOS_PWOI_000007394_1_1_F_1

Where:

<MISSION> = see previous section
<ORDER_ID> = see previous section
<SPECTRAL_PROCESSING> = see previous section
<PROCESS_LEVEL> = see previous section
<JOB_ID> = see previous section

Generally not provided for standard delivery, the name(s) of Pléiades Neo Image Archive Source metadata file(s) can comprised of:

<IAP_ID>
IAP_SAT<n>_<YYYYMMDDHHMMSSS>_<EEE>_<PPP>_<RRR>_<rrr>_<ORBIT>_<SEGM>_<START>_<END>_<XxxxYyy>
Example: **IAP_PNEO3_202202191022416_BK1_FR1_FR1_FR1_00000020_00000081_002151_W030N30**

Where:
SAT = satellite code {PNEO}
<n> = satellite number {1, 2, 3, 4, 5, 6…}
<YYYYMMDDHHMMSSs> = UTC strip source acquisition start time
<EEE> = effective inventory center acronym
<PPP> = programmed inventory center acronym
<RRR> = first effective reception center acronym
<rrr> = programmed effective reception station
<ORBIT> = orbit number on 8 digits, with left-padding zeros
<SEGM> = Segment number on 8 digits, with left-padding zeros
<START> = First source packet on 6 digits, with left-padding zeros
END> = Last source packet on 6 digits, with left-padding zeros
<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)

Generally not provided for standard delivery, the name(s) of Ground and Height Source metadata file(s) for product set on a reference or rectified with a DEM is comprised of:

<Ground_Source_ID>

Ground_Source_ID	**Ground reference source**
SRP_*{N|S}xx{E|W}yyy*	GCPs Space Reference Points, *{N|S}xx{E|W}yyy* = lower left block corner (example N44E001)
PAS_OR_*{N|S}xx{E|W}yyy*	Ortho image PAS, *{N|S}xx{E|W}yyy* = lower left block corner (example N44E001)
R3D_OR_*{N|S}xx{E|W}yyy*	Ortho image R3D, *{N|S}xx{E|W}yyy* = lower left block corner (example N44E001)
EXCH_OR_*{ID}*	External ortho reference image, *{ID}* = free optional identifier (example: CAPITOLE)

Table 26 - Naming – Ground Sources

<DEM_Source_ID>

DEM_Source_ID	DEM/DTM reference source
WD4O_*{N|S}xx{E|W}yyy*	WorldDEM4Ortho DSM/DTM, *{N|S}xx{E|W}yyy* = lower left block corner (example N44E001)
PAS_DT2_*{N|S}xx{E|W}yyy*	PAS DEM/DTED2, *{N|S}xx{E|W}yyy* = lower left block corner (example N44E001)
R3D_DT2_*{N|S}xx{E|W}yyy*	R3D DEM/DTED2, *{N|S}xx{E|W}yyy* = lower left block corner (example N44E001)
SRTM_DT1	SRTM DEM/DTED1 (nine arc seconds posting)
GLOBE	Global DEM (DTED0) (thirty arc seconds posting)
EXCH_DEM_*{ID}*	External Ortho image, *{ID}* = free optional identifier (example: DT2_CAPITOLE)

Table 27 - Naming – DEM Sources

Derived from SPECTRAL_PROCESSING the band combination set or subset in an imagery file is comprised of:

<BandSet>

SPECTRAL_PROCESSING	BandSet	Spectral Bands
PAN	P	Panchromatic (1 band file)
MS	RGBN	Red, Green, Blue plus one extra band NIR (4 bands file)
PMS	RGBN	Red, Green, Blue plus one extra band NIR (4 bands file)
MS-FS	RGB	Red, Green, Blue (3 bands file)
	NED	NIR, Red Edge, Deep Blue (3 bands file)
PMS-FS	RGB	Red, Green, Blue (3 bands file)
	NED	NIR, Red Edge, Deep Blue (3 bands file)
PMS-N	RGB	Red, Green, Blue (3 bands file)
PMS-X	NRG	NIR, Red, Green (3 bands file)

Table 28 - Naming – Band Set identification

A.1.2 Tree Structure

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

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

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

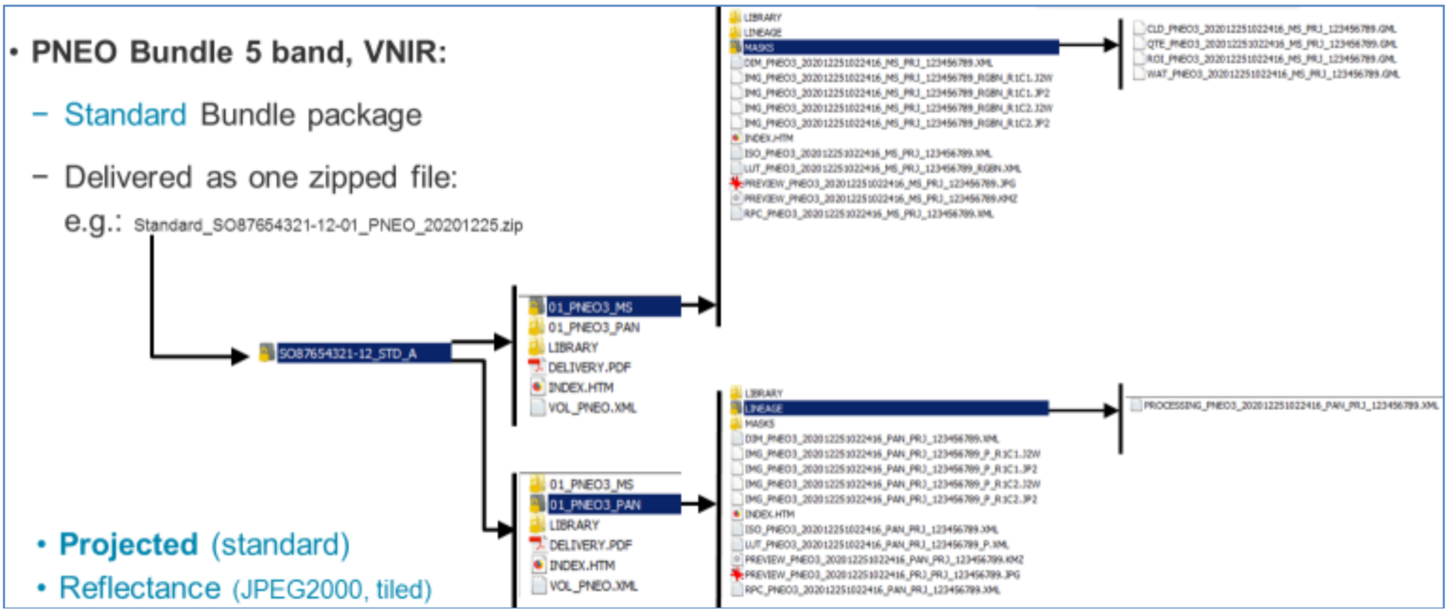


Table 29 - Example of Pléiades Neo layout

A.1.2.1. Primary, Projected or Single Ortho Level Image Products

The file naming convention is detailed in the previous section. The usual file structure is as shown below.
For products delivered in TIFF/GeoTIFF format instead of JPEG 2000 format, file extensions TIF and TFW replace file extensions JP2 and J2W.

Single Primary, Projected or Ortho Level Image

<DirVolume_ID> [1:1]
INDEX.HTM [1:1]
LICENSE.PDF [0:1]
VOL_***<MISSION>***.XML [1:1]

LIBRARY
VOL_LOGO.JPG
VOL_STYLE.XSL

IMG_***<DirImage_ID>*** [1:*n*]
INDEX.HTM [1:1]
DIM_***<Imagery_ID>***.XML [1:1]
IMG_***<Imagery_ID>***_*<BandSet>*_RiC*j*.{J2W,TFW} [1:*n*] — *n* if image is physically tiled x 2 if Full Spectrum
IMG_***<Imagery_ID>***_*<BandSet>*_RiC*j*.{JP2,TIF} [1:*n*] — *n* if image is physically tiled x 2 if Full Spectrum
ISO_***<Imagery_ID>***.XML [1:1]
LUT_***<Imagery_ID>***_*<BandSet>*.XML [0:2] — for Reflectance processing option only
PREVIEW_***<Imagery_ID>***.KMZ [1:1]
PREVIEW_***<Imagery_ID>***.JPG [1:1]
RPC_***<Imagery_ID>***.XML [0:1] — for Primary and Projected Products only

LINEAGE [1:1]
*GROUND_**<Ground_Source_ID>**.XML [0, n]* — *for specific delivery if ground reset only*
*HEIGHT_**<Height_Source_ID>**.XML [0:n]* — *for specific delivery, Ortho Products only*
PROCESSING_***<Imagery_ID>***.XML [1:1]
*STRIP_**<IAP_ID>**.XML [0:1]* — *for specific delivery only*

MASKS [1:1]
CLD_<***Imagery_ID***>.GML [0:1]   if cloud coverage > 0 only
QTE_<***Imagery_ID***>.GML [0:1]   if degraded quality only
ROI_<***Imagery_ID***>.GML [1:1]
VIS_<***Imagery_ID***>.GML [0:1]   for Ortho Products only
WAT_<***Imagery_ID***>.GML [0:1]   if available on area
PPM_<***Imagery_ID***>.TIF [0:1]   for Ortho Products if available on area

EXPERT [0:1]   *for specific delivery only*

LIBRARY
LOGO.JPG
STYLE.XSL

Figure 18 – Pléiades Neo Single Primary, Projected or Ortho layout

A.1.2.2. Mosaic Ortho Image Products

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

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

Mosaic Level Image

<***DirVolume_ID***> [1:1]
INDEX.HTM [1:1]
LICENSE.PDF [0:1]
VOL_<***MISSION***>.XML [1:1]

LIBRARY
VOL_LOGO.JPG
VOL_STYLE.XSL

IMG_<***DirMOS_ID***> [1:*n*]
INDEX.HTM [1:1]
DIM_<***Mosaic_ID***>.XML [1:1]
IMG_<***Mosaic_ID***>_<*BandSet*>_Ri*C*j.{J2W,TFW} [1:*n*]   *n* if mosaic is physically tiled x 2 if Full Spectrum
IMG_<***Mosaic_ID***>_<*BandSet*>_Ri*C*j.{JP2,TIF} [1:*n*]   *n* if mosaic is physically tiled x 2 if Full Spectrum
ISO_<***Mosaic_ID***>.XML [1:1]
LUT_<***Mosaic_ID***>_<*BandSet*>.XML [0:2]   for Reflectance processing option only
PREVIEW_<***Mosaic_ID***>.KMZ [1:1]
PREVIEW_<***Mosaic_ID***>.JPG [1:1]
RPC_<***Mosaic_ID***>.XML [0:1]   for Primary and Projected Products only

LINEAGE [1:1]
DIM_<***Imagery_ID***>.XML [2:*n*]   Dimap file, 1 per mosaic source images
PROCESSING_<***Mosaic_ID***>.XML [1:1]

MASKS [1:1]
ROI_<***Mosaic_ID***>.GML [1:1]
CUT_<***Mosaic_ID***>.SHP [0:1]   if available on area

EXPERT [0:1] *for specific delivery only*

LIBRARY
LOGO.JPG
STYLE.XSL

Figure 19 - PNEO Mosaic layout

A.1.2.3. Product Delivered on Several Media

When the product image size exceeds the delivery medium capacity, the tree structure is duplicated on every medium. Each medium gets a subset of image raster tiles up to the media limit. The complete product can be gathered with the information provided into index, metadata and KMZ files. The same rule applies to electronic delivery via FTP, considered here to have the same capacity as a DVD (4 GB).

A.2. Levels of Information and File Short Contents

	Standard Products		Other Products
Mandatory Files	**Primary/ Projected**	**Ortho/Mosaic**	
Root Level			
Volume Index Metadata File	Y	Y	Y
Product Level			
Product Metadata File	Y	Y	Y
RPC File	Y	N	
LUT file	If Reflectance	If Reflectance	
World File	Y	Y	
KMZ File	Y	Y	
Preview File	Y	Y	Y
Lineage Sub-Level			
Processing File	Y	Y	
Mask Sub-Level			
Mask File(s)	Y	Y	

Table 30 - Overview of standard available Information vs Processing Levels

A.2.1 The Root Level Index

<DirVolume_ID>

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

A.2.1.1. Volume Index Metadata File

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

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

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.2.2 The Product Level

IMG_<{DirImage_ID, DirMOS_ID}>

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

A.2.2.1. Product Metadata File

DIM_<{Imagery_ID, Mosaic_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. See Table A.11 overleaf.

Metadata_ Identification	Metadata format and language identification.
Dataset_Identification	Brief text and links for 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	Localisation of the dataset and geometric extent. User should use this information for cataloguing 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 four 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. Projected and geodetic are the most common for image mapping. Conventionally, Primary images are recorded with WGS84 geodetic CRS. CRS are recorded to EPSG registry, if known. Subsequent parameters are only given if no EPSG identifier is found (commonly known as a «user-defined» definition).
Geoposition	Easiest relationship between the dataset coordinates and the CRS coordinates: • Georectified image (Projected, Ortho and Mosaic): insertion point and dimension. • Sensor 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 organisation, 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, reflectance solar irradiance.
Geometric_Data	Geometric information: • Sensor 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, see Appendix C: Geometric Modelling). • 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.

Table 31 - 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.2.2.2. ISO 19115 Metadata File

ISO_<{Imagery_ID, Mosaic_ID}>.XML: file encoding = XML, metadata format = ISO19115:2003/Cor.1:2006/19139:2007 (GMD 1.0 application schema)

The ISO19115/19139 product metadata file provides the set of ISO metadata extracted or derived from the DIMAP metadata file content. The ISO 19115 metadata are mainly relating to product discovery and cataloguing purposes. The implementation of ISO follows the GMD (GeographicMetaData) XML application Schema.

The ISO19115/19139 product metadata file is conform to the International Profile Regulations defined on ISO 19115 corpus, mandatory to delivery at numerous institutional entities: INSPIRE (European Community, Commission Regulation), NAP (North American Profile), ANZLIC (Australian/New Zealand Profile).

A.2.2.3. LUT metadata File

```
LUT_<Imagery_ID>.XML: file encoding = XML, metadata format = DIMAP V2
```

For Reflectance radiometric option only, the colour curves for true colour image rendering, in Look-Up-Table form. The LUT level values for:
- Red, Green Blue and Deep Blue bands are strictly the same targeting a RGB rendering.
- Red Edge and NIR bands differ slightly from RGB bands targeting a false colour rendering.

The LUT has the same syntax of VRT files (Raster Virtual format) adopted by GDAL or MapServer.

A.2.2.4. RPC Metadata File

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

The RPC file contains the coefficients and Normalisation 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 geometric model (Primary and Projected product).

The RPC file provides the following functions estimated for the whole image (Global):

- Ground → Image analytic model (Inverse)

- Image → Ground analytic model (also called Direct)

RPC is a generalised 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 (Primary product, metadata file).

The specific metadata are in the following DIMAP groups:

Global_RFM	Global model defining the best fit model to the whole dataset, as delimited by the RFM validity
GroundtoImage	Rational function polynomial coefficients from ground to image (inverse model)
ImagetoGround	Rational function polynomial coefficients from image to ground (direct model)

Table 32 - RPC Metadata File

The GroundtoImage (inverse) model is the one's used by the COTS software. The metadata names are those specified by by the Controlled Extension (CE) of NITF V2.1 applicable to inverse model only. The coefficients are arranged in the RPC00B order.
The ImagetoGround (direct) model is not covered by NITF or other standard, thus DIMAP uses its own metadata names with a closed NITF scheme. Coefficients are also ranged like RPC00B. Please note compared to previous SPOT and Pléiades RPC these metadata names are renamed to improve consistency.

A.2.2.5. World File

IMG_<{Imagery_ID, Mosaic_ID}>_RiCj.J2W/TFW: file encoding = ASCII, metadata format = ESRI

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

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

For Primary products the World File is adapted to assemble raster tile files, if any. At Primary level, World File has no ability for georeferencing the image (sensor geometry); please use XML metadata files (Dimap or RPC files).

A.2.2.6. KMZ File

PREVIEW_<{Imagery_ID, Mosaic_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 email or web server.

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

AOI	The contractual footprint of the whole product (order polygon)
Product	The footprint performed by the data production system for the whole product and its PREVIEW image
Tiles	The footprint of each image tile
Sources	The acquisition extent of sources images
Logos Layer	The logos) of the data provider

Table 33 - KML Metadata File

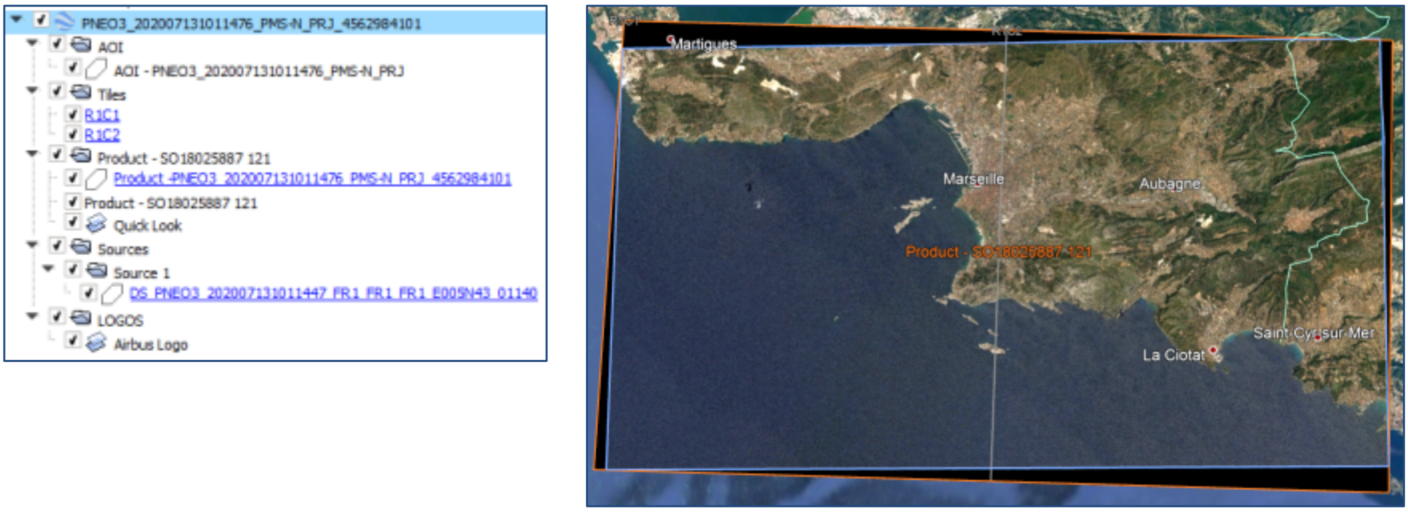


Figure 20 - KMZ Overview

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 conventions:

- Product – the footprint of the product is positioned:
  - For Primary products, at the elevation values given at each vertex by an internal DEM (possibly coarse).
  - For Ortho products, at Ground surface, according to planimetric accuracy of the product.

- Tiles – the footprint of each tile is positioned:
  - For Primary products, at a mean elevation value over the whole product footprint.
  - For Ortho products, at Ground surface, according to planimetric accuracy of the product.

- Sources – the source extent(s) at a mean elevation value over the complete source footprint, using a rigorous or RPC geometric model.

For products with a significant acquisition angle and/or on significant relief, some misalignments between KML features may happen, especially with Primary products. Thus, alignments should be made through a coarse projection on- ground. In Google Earth, we recommend to deactivate the 'Show terrain' option to avoid incorrect mapping.

A.2.2.7. Preview Raster File

PREVIEW_<{Imagery_ID, Mosaic_ID}>.JPG: file format = JPEG The subsampled image (also called a quicklook).

Typically, the PREVIEW image is subsampled by a ratio of 40 towards the original image sampling (10 towards XS), i.e. approximately 12 m, and compressed. The visual rendering depends on the radiometric option:

- Basic: original dynamic stretched by threshold (by default 2%).
- Reflectance and Display: true RGB colour (on Reflectance application of the LUT file).

A.2.3 Sub-Levels with Additional Information

A.2.3.1. The Lineage Sub-Level

LINEAGE

The lineage directory deals with information about the processing history.

a. Processing Metadata File

PROCESSING_<Imagery_ID>.XML: file encoding = XML, metadata format = DIMAP V2

The processing file describes the processing steps and for traceability the processing parameter identifiers activated 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 (GIPP) activated at the moment of the production launch

Table 34 - Processing Metadata File

b. Image Source Metadata File (Mosaic)

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

For Mosaic product the metadata files of images input in the mosaic can be added at this lineage level. Format is the ones introduced above at Product Metadata File section.

c. The Mask Sub-level

MASKS

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

d. Mask Files

ROI}_<{Product_ID, Mosaic_ID>.GML: file encoding = XML, metadata format = GML V3.1.1
{CLD, QTE, VIS, WAT}_<Product_ID>.GML: file encoding = XML, metadata format = GML V3.1.1
{CUT}_<Mosaic_ID>.SHP: file encoding = binary, vector format = ESRI Shapefile
{PPM}_<Product_ID>.TIF: file encoding = -binary, 8bit Colour palette, raster format = GeoTIFF

All masks are registered with the whole image product (same geometry and CRS) for overlaying purposes.

GML vector masks are available for standard products. They include:

- Masks related to an ordering parameter: cloud cover (CLD), technical quality rate (QTE). Masks are not delivered for non-cloudy or nominal quality products.
- Masks built by the data process:
  - Product footprint (ROI, Region Of Interest).
  - Image quality masks: hidden areas (VIS, visibility), water areas (WAT).

For Mosaic products the cutline mask (CUT) is available in ESRI Shapefile format (DBF, PRJ, SHP, SHX files).

For Ortho products the Planimetric Performance assessment Mask (PPM) is planned for some productions. The assessment is rather estimation than a measurement. This assessment is performed by an automatic way inputting the a priori accuracies of planimetric and vertical reference data. No independent control or ground truth data are used.
The mask is formatted in 8-bits with a Look Up Table (LUT) colour index to display the values in homogeneous class between a min and a max meter values.

A.3. Metadata Contents and Organisation

The metadata is 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. DIMAP V2 is the standard used for Pléiades 1A, Pléiades 1B, SPOT 6 and SPOT 7 products, and other Airbus missions of earth observation imagery. Minor adaptations may happen.

For an overview of the main improvements brought by DIMAP V2, please refer to section 2.4 Product and Image

Format.

A.4. Image Format

Products are available in two raster formats:

- TIFF (including GeoTIFF)
- JPEG 2000

The file sizing is managed by image tiling.
With the Basic radiometric option, 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. It can be expressed as (informative):

Name	Value	Description
Stiles	{2048,2048}	Tiles sizes
flush_period	2048	Flush period
Ssigned	no	Signedness
Cblk	{64,64}	Codeblock size
Clevels	5	Wavelet decomposition level
Corder	RPCL	Order
ORGgen_plt	yes	Marker (used to allow optimized decompression)
SPrecision	coding dynamic (8 or 12)	SPrecision
Qstep	1/2^(coding dynamic)	Qstep
Clayers	10	Quality layers
Cuse_precincts	yes	Precinct
Cprecincts	{256,256\},{256,256\},{128,128\},{128,128\},{64,64\}	
Cycc	yes	YCC (used for PAN-Sharpened images)
Creversible	yes	For lossless compression only (Regular)

Table 35 - JPEG200 CODEC

Two compression schemes are available:

- JPEG 2000 Optimised is meant for users looking for fast download and easy data sharing. It uses the so-called lossy compression: the compression rate is optimised to avoid any spatial effect but is not reversible. A spectral effect of 1/1000 is tolerated. The compression rate is set at 3.5 bits/pixel (informative).

- JPEG 2000 Regular is perfect for users willing to do some high precision post-processing. 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. Depending of the landscape the compression rate is around 8 bits/pixel (informative).
- 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 Optimised compression file size.

A.4.2 TIFF

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

A.4.3 Image Tiling

Products exceeding a certain imagery size limit are broken in several image pieces, called images tiles, paving the effective product extent. Per tile, this limit is approximately (informative):

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

This limit could change as software capabilities progress.

For bundle products the tile size and tile number are driven by the highest resolution band (Panchromatic). The tiles will have the same extent for Panchromatic and Multispectral bands.

The tiling is based on an orthonormal (as a matrix): y-axis for each row (Ri) and x-axis for each column (Cj) of the grid. The tiles of the first row begin at the upper and left borders of the entire image product.

The nominal tiles are adjusted equal rectangles (possibly squared), except the tiles of last row and (C) ranges maybe rounded to the product extent. Tiles are not overlapping.

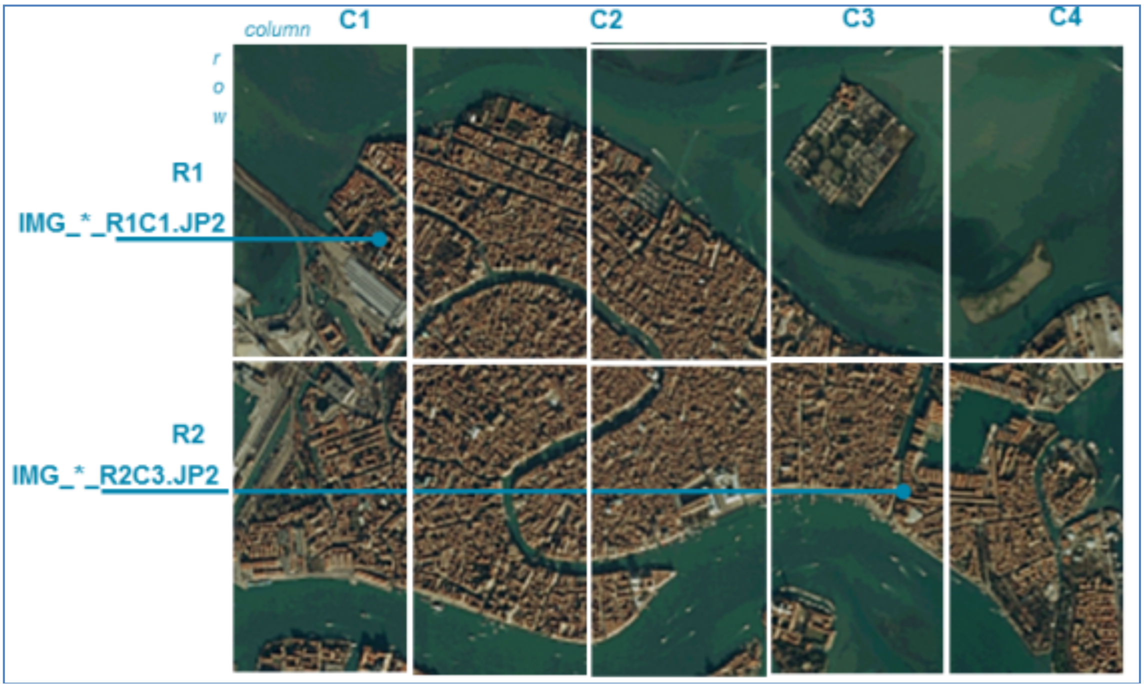


Figure 21 – Pléiades Neo image tiling

Even if the product is not tiled the imagery file is always named IMG_*_R1C1.

At discovery level the KMZ file provides the tile positioning. The product metadata file describes:

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

A.5. Available Geographic and Cartographic Projections

Airbus DS Intelligence offers orthorectification in nearly any geodetic parameters and National Mapping System registered in the EPSG database.

A.5.1 Geographic Projections

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

The default geographic projection is related to WGS84 geodetic datum/ellipsoid in decimal degree angular unit (EPSG::4326). The pixels are regularly posted in latitude/longitude angle according the following DTED2 zoned system:

- 5 zones: [0° to 50°], [50° to 70°], [70° to 75°], [75° to 80°], [80° to 90°] North or South latitude

A.5.2 Mapping Projections

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

Mapping projections are related to National Mapping Agencies or International Authorities. The default parameters values are those registered in EPSG. The linear unit is the meter.

The default CRS mapping projection is UTM/WGS84 (EPSG::32601 to 32760). 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.

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

Table 36 – Georeferencing
(1) GML: counting from 0 (gml:high = NROWS-1 NCOLS-1); DIMAP & GeoTIFF: counting from 1
(2) GML: offset; DIMAP & GeoTIFF: dimension

Each image tile has a GMLJP2 or TIFF header and World File consistent with its extent.

A.6.1 GMLJP2

The GMLJP2 format is used to store information as geocoding into the JPEG2000 imagery file. The encoding uses GMLJP2 V2.1 following the Defence Geospatial Information Working Group (DGIWG-104(2-1)) and OGC (OGC 08-085r8 V2.1) specifications.

The GMLJP2 header is stored in the XML box embedded in the JPEG 2000 file: JPEG 2000 Part I (XML BOX) and II (label BOX and association BOX).

The GMLJP2 V2.1 encoding is consistent with the product geometric level to provide self-contained image files for autonomous distribution:

- ORTHO and MOSAIC levels imagery:
  - The header uses the GMLJP2RectifiedGridCoverage 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, excepted WGS84 geographic projection.
      - WGS84 geographic projection (EPSG::4326), EPSG definition is axis 1=Geodetic latitude, axis 2=Geodetic longitude (y then x). According limitation of most software packages EPSG::4326 is ordered in a lon/lat order (x then y).
    - Coordinate Reference System (CRS) encoding in conformance with the EPSG standard.

- PRIMARY level imagery:
  - The image being in sensor geometry the header has no geocoding information and uses a simple gml:GridEnvelope feature scheme (column, row axis).
  - For positioning the header give the RPC model (lat,long,h) -> (col,row) (GroundtoImage, inverse model) using the gmlcovrgrid:SensorModel feature scheme. The RPC model applies to the entire imagery even in case of image tiling. This implementation is planned in the short future.

- PROJECTED level imagery:
  - PROJECTED has the both properties of a regular grid map geometry for a coarse positioning (at iso-altitude) and a virtual sensor model for an accurate positioning. Therefore the GMLJP2 header implemented the both ORTHO and PRIMARY RPC encoding sequentially. This implementation is planned in the short future.

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 sensor geometry, no GeoTIFF information (column, row axis).

- Projected and 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 images in map geometry: Projected, Ortho.

For an image processed in sensor geometry processing level (Primary), the georeferencing must be performed though a geometric model. Please refer to the RPC metadata file or the geometric modelling 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:

$$x1 = A_x + B_y + C$$
$$y1 = D_x + E_y + F$$

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

E = negative of y-scale; dimension of a pixel in CRS units in y direction (YDIM)

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 always set to zero value (meaning no rotation needed).

The translation terms C and F, are the location of the centre of the upper left pixel for each tile.

The World File is an ASCII file containing six lines, giving the six parameters in the A, D, B, E, C, F order (one per line).

For the Projected and Ortho products, the CRS is the one formatted with the product.

Parameter	Example
A	20.17541308822119
D	0.00000000000000
B	0.00000000000000
E	-20.17541308822119
C	424178.11472601280548
F	4313415.90726399607956

Table 37 - Projected or Ortho Worldfile

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

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

Table 38 - Primary Worldfile

Appendix B. Image quality

Image Quality Commitments

Table 39 provides Image Quality performances worldwide commitments being significant for the product end-user.

The measurements are expressed for:

- Geometry - inside the cone of 30° pointing angles around nadir
- Radiometry - at nearly 100 W/m²/sr/microns (L2)
- Resolution - no sampling factor. Overall bpp target = 2.5 for Pan and 3.4 for MS

Abbreviations:

MTF: Modulation Transfer Function
SNR: Signal to Noise Ratio
IQF: Image Quality Factor
bpp: bit per pixel
MTF/SNR:
Satellite = on RAW satellite image data
Restored = on PRIMARY delivery product after deconvolution and denoising processing

Image Quality Item	IQ Commitment	Remark
GEOMETRY		
Dynamic Effect	< 0.2 pixel Pan LE99.7	*Line of sight stability (jittering micro-vibrations)*
MS Registration	< 0.25 pixel MS CE99.7	
MS and Pan Co-registration	< 0.25 pixel MS CE99.7	
RPC vs. Rigorous Modelling	< 0.1 pixel PAN CE90	*Over a length of one scene (14km)*
GEOMETRY - Rigorous/RPC Model accuracy without GCP: with ancillary data only		
Location Accuracy	5m CE90 @ Nadir	*PRIMARY and PROJECTED product levels*
GEOMETRY - Rigorous/RPC Model accuracy refined with Airbus reference auxiliary data		
Location Accuracy	3.5m CE90 @ Nadir	*PRIMARY and PROJECTED product levels.* *GCPs from Airbus Space Reference Points (SRP) database*
Planimetric Accuracy	5m CE90	*ORTHO product level, slopes < 20%* *GCPs from Airbus Space Reference Points database (SRP) and WorldDEM4Ortho DEM*
GEOMETRY – Rigorous/RPC Geometric Model accuracy refined with (perfect) GCP and DEM auxiliary data		
Planimetric Accuracy: Panchromatic	0.3m CE90	*ORTHO product level, slopes < 20%* *Relative error (linear errors corrected)*
Vertical Accuracy: Panchromatic, B/H=0.5	0.5m LE90	*DEM product, slopes < 20%* *Relative error (linear errors corrected)*

Table 39: Commitments to image quality Performances

Appendix C. GSD

The Primary product GSD is related to the raw imagery resolution, which varies according to the viewing angle.

The GSD values estimated with a simplified Earth model on a sphere are summarized in Table 40, upon the nominal and extended angular domains.

Roll angle α (°)	PAN GSD_{ALT} (cm)	PAN GSD_{ACT} (cm)	MS GSD_{ALT} (m)	MS GSD_{ACT} (m)	PAN GSD_{MEAN} (cm)	MS GSD_{MEAN} (m)	SWATH width (km)
Please refer to section D.5.2.1 for more details	*Taking into account the rotundity of the Earth*						
Nominal angular domain							
0	30	30	1.20	1.20	**30**	**1.20**	**14.000**
5	30	30	1.21	1.21	**30**	**1.21**	**14.124**
10	31	31	1.22	1.24	**31**	**1.23**	**14.505**
15	31	33	1.25	1.30	**32**	**1.27**	**15.172**
20	32	35	1.29	1.39	**33**	**1.34**	**16.184**
25	33	38	1.34	1.51	**36**	**1.42**	**17.635**
30	35	42	1.41	1.69	**39**	**1.54**	**19.679**
Extended angular domain							
35	*38*	*48*	1.50	*1.94*	**43**	**1.71**	***22.577***
40	*41*	*57*	1.63	*2.30*	**48**	**1.93**	***26.790***
45	*45*	*71*	1.79	*2.85*	**56**	**2.26**	***33.194***
50	*51*	*94*	2.02	*3.74*	**69**	**2.75**	***43.691***
55	*59*	*136*	2.36	*5.43*	**90**	**3.58**	***63.312***

Table 40: GSD projected on Earth vs. Viewing Angle

The GSD value significant for end users is the mean GSD (between along and across track directions). The GSD variation is mainly representative for the roll angle in across track direction (ACT). For the pitch angle the GSD is a combination of the velocity, the sampling time, the guidance profile, thus the variation is negligible.

Notes:

With:

h_{sat} (reference altitude, km)	630
IFOV PAN (rad)	4.76E-07
IFOV MS (rad)	1.90E-06
Earth	
Mean equatorial (km)	6367.45

Appendix D. Geometric modeling

The geometric modelling describes the relationships between the sensor image pixels and the ground coordinates. The geometric model is accessible for PRIMARY and PROJECTED product levels. Either:

- The physical model (also called rigorous or photogrammetric model): positions <Ephemeris>, external orientation <Attitudes> and inner orientation <Polynomial_Look_Angles>.
    - Primary level posted in the DIMAP product Metadata file.
- The analytic RPC model: normalized coordinates and 3rd order rational polynomial coefficients.
    - Primary and Projected levels posted in the RPC product Metadata file.

Once the geometric model is applied at Ortho level, this information is no more relevant in the product.

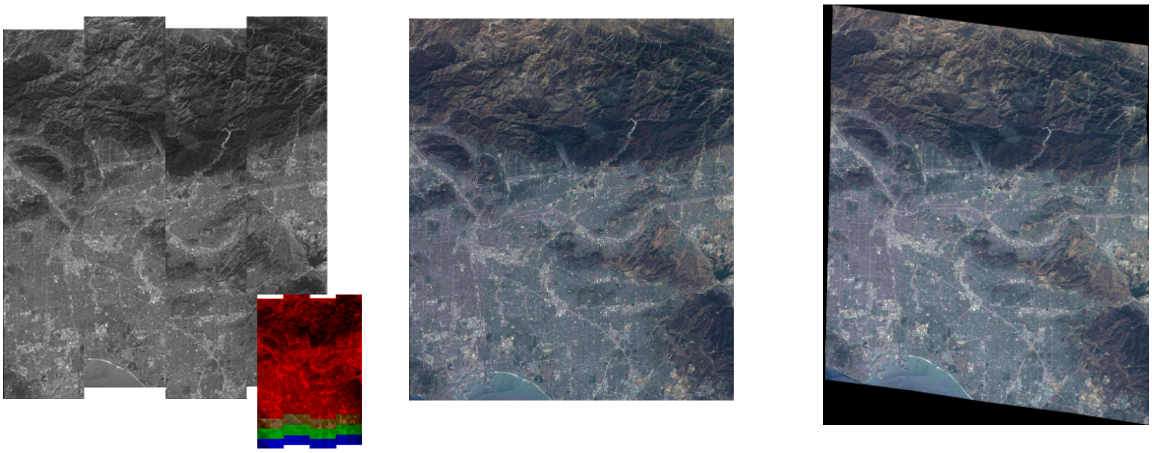


Figure 22: From left to right: typical RAW image, Primary and Ortho levels

In the Raw image, sub-swaths and bands are separated. The sub-swaths are merged into a single image for the Primary level. Ortho and Projected levels are resampled into a ground geometry (North / South orientation).

	The Pléiades Neo physical model is the same as provided for SPOT products, whereas with Pléiades products (attitudes given through a polynomial form). Pléiades Neo RPC file: compared to previous Pléiades and SPOT RPC files the tag names of direct model were renamed to ensure a better consistency. The scheme remains the same.

D.1. Raw and Primary level image

D.1.1 Focal Plan

The Pléiades Neo sensor image geometry (RAW image) is not proposed to end-users, in particular due to the complexity of the detector layout in the focal plane. Moreover, the Pléiades Neo full swath focal plane is composed of six detectors (six sub-swaths) separated along the satellite track within the field of view.

The Primary product level is designed to remove this complexity. The Primary level offers to 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 Primary imagery geometric reference frame simulates the imaging geometry of a single push-broom linear array, located on a virtual line corresponding to the average of the six panchromatic TDI arrays.

D.1.2 Geometric Imagery Properties at Primary Level

Besides, this ideal array is supposed to belong to a perfect instrument with no optical distortion and carried by a platform with no high frequency 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 RPC (rational function) geometric model.

D.1.2.1. Primary Grids Alignment (Bundle)

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

For Primary bundle delivery PAN and MS bands sampling grids are registered as shown on Figure 23.

Figure 23 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.

D.2. Projected and Ortho Levels image

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

For all Projected and Ortho standard imagery files the upper-left corner (insertion point) is adjusted on a position being a Least Integer Common Multiple (LCM) of Panchromatic and MS pixel size. Considering future generalization the nominal LCM linear value is 6m. In geographic projections these linear value and position are converted in angular unit and adjusted accordingly.

The imagery file is sampled with a step of 30cm for Panchromatic and 1.2m for Multispectral imagery (or equivalent angular value at equator for geographic projection).

D.2.1.1. Projected and Ortho Grids Alignment (Bundle)

For Projected or Ortho bundle standard delivery PAN and MS bands sampling grids are registered as shown on Figure 24.

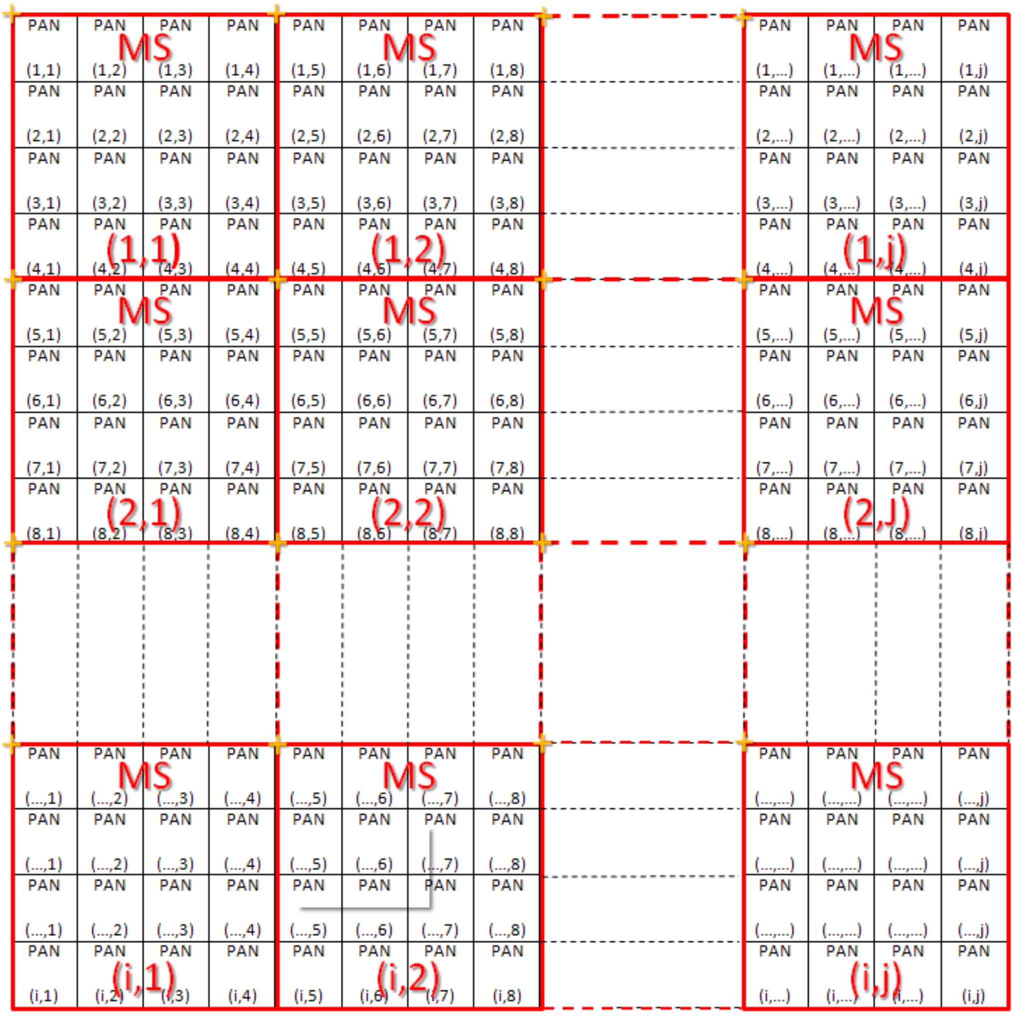


Figure 24 Projected or Ortho Bundle Grids Alignment

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

D.3. Primary Products: Using the Physical Model

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

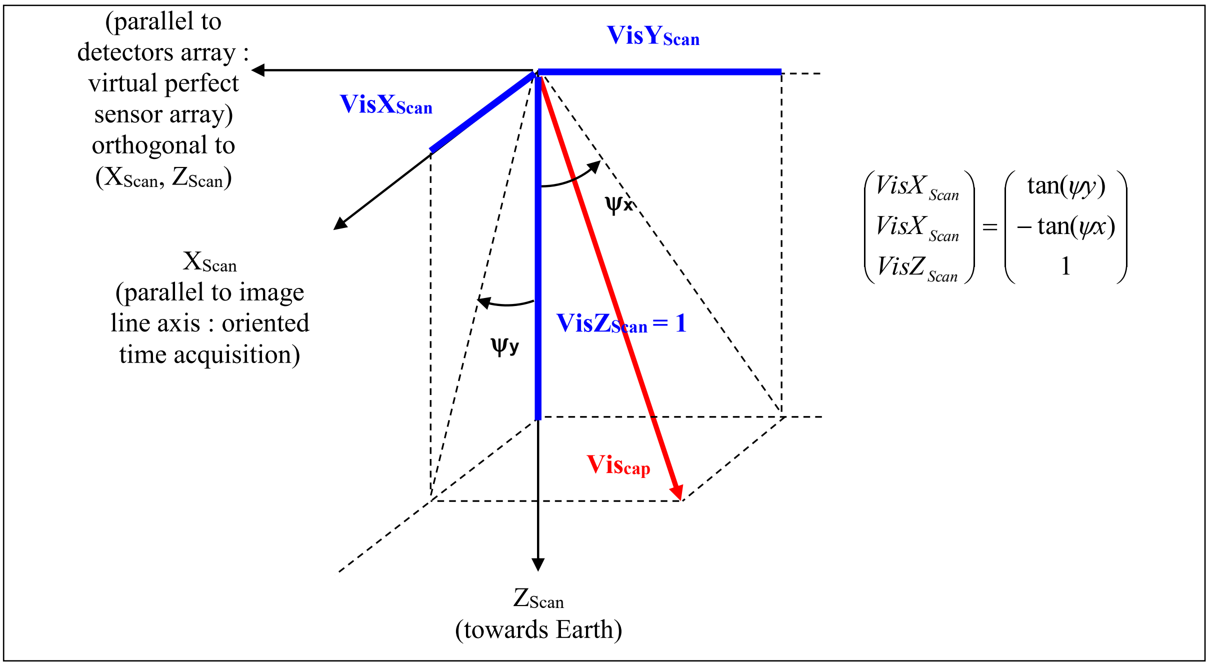


Figure 25: Image Focal Plane Frame and viewing angles

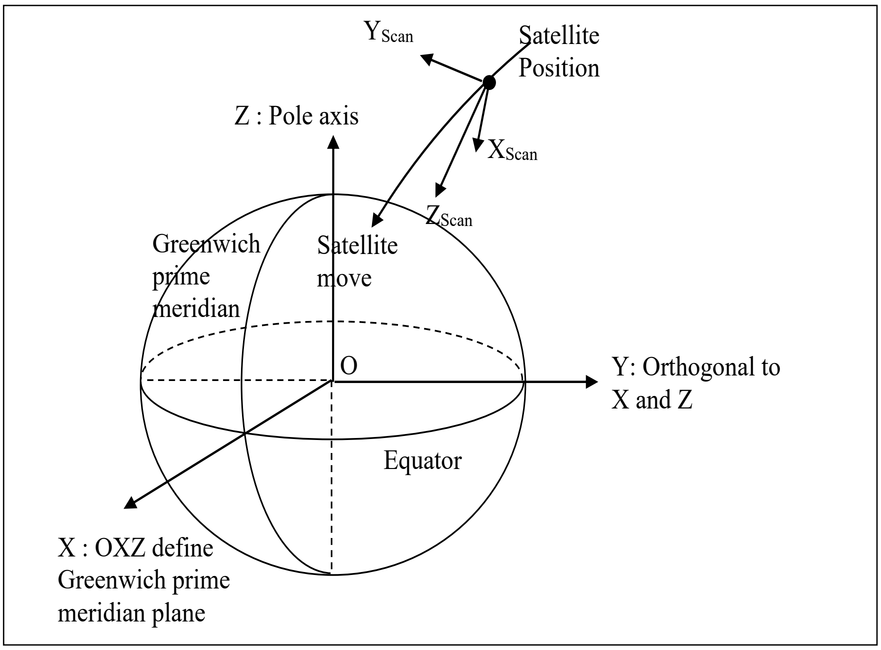


Figure 26: Geocentric Earth Frame (WGS84)

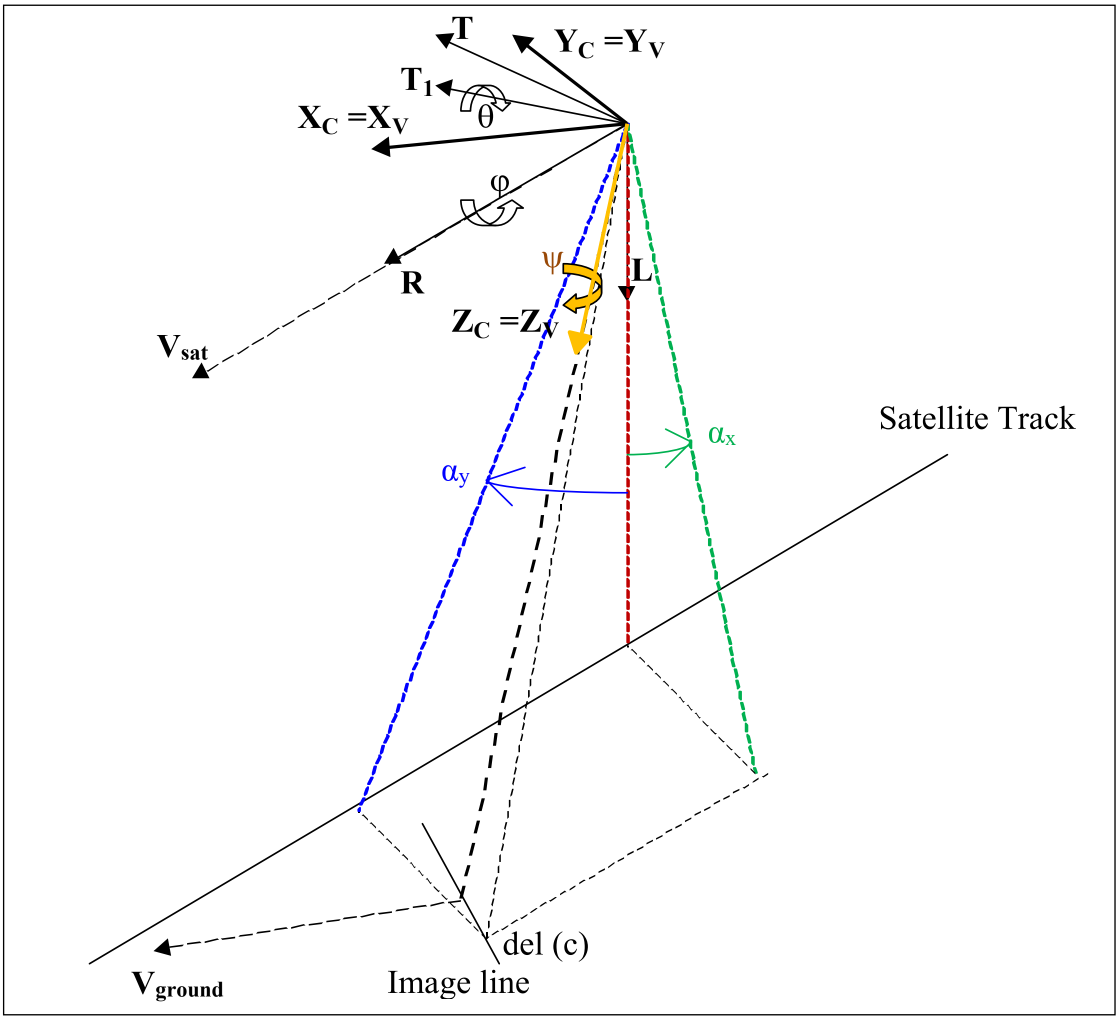


Figure 27: Frames Summary

Notes:

- Image orientation and satellite track are different
- On Primary Sensor Array, the image focal plane frame (X_{Scan}, Y_{Scan}, Z_{Scan}) and the frame to pilot (Xv, Yv, Zv) are identical
- All the data needed by the physical model is in the "DIM_*.XML" metadata file under the node <Refined_Model>
    - All satellite positions are expressed in Cartesian coordinates (O, X, Y, Z) in the ECF frame WGS84
    - Quaternions describing satellite attitude are sampled on-board at 16Hz and at higher frequency into the product for refining. At a given time, one can compute the quaternion and directly build the transformation matrix between image focal plane frame and geocentric earth frame (WGS84)
    - All acquisitions times and dates are expressed in UTC
- In the dataset extent, the ground coordinates of vertex are expressed in geographic coordinates (unit degrees) related to the WGS84 geodetic system. These values are computed at their estimated elevations on ellipsoid. The center value is an average of the vertex values.

D.3.1 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 follow:

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 line of sight models:

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

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

The columns shall be counted from the value given by the tag <PIXEL_ORIGIN>:

PIXEL_ORIGIN=1 => col_{ref} =1

Calculation of the viewing angle in the image focal plane frame (see Figure 25):

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

SATELLITE POSITION 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 position component (PosX, PosY, PosZ) is calculated by an interpolation with n samples:

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

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

On Pléiades Neo satellites positions are sampled at 8Hz. At this frequency a complex interpolator as Lagrange is not needed, user can choice a simple interpolator as cubic or spline.

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 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). Velocity data is not necessary for viewing direction orientation as speeds of light corrections have been already integrated (see section D.5.1.1).

SATELLITE ORIENTATION INTERPOLATION FOR A GIVEN TIME

The satellite orientation for a given time is deduced from the quaternion list. The quaternions components Q1, Q2, and

Q3 are respectively the three rotation vector components 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 28).

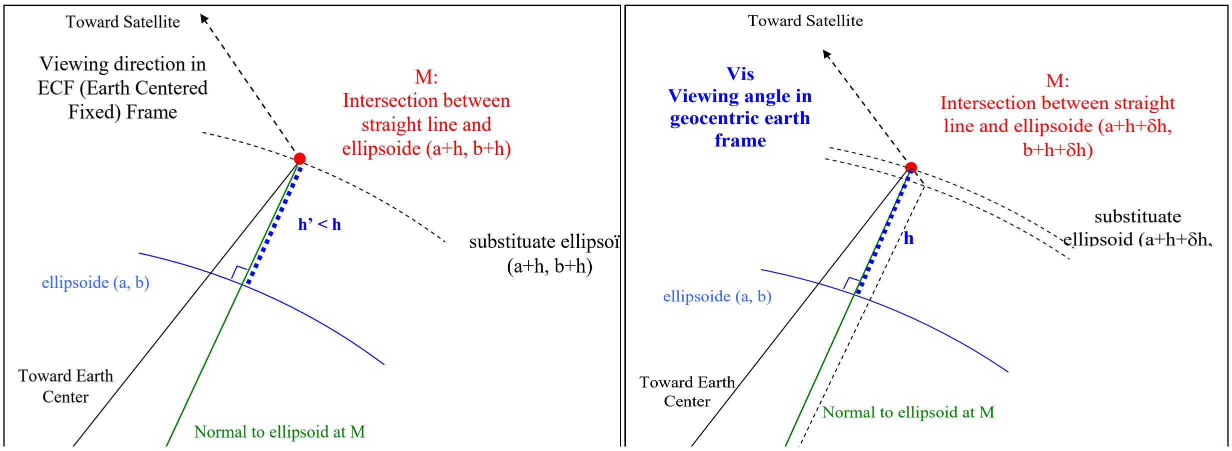


Figure 28: Find the Point on the Ground at the Right Altitude H

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: http://geodesie.ign.fr/contenu/fichiers/documentation/algorithmes/notice/NTG_80.pdf
- ALG0012 - Coordinate transformation: Cartesian coordinates ➔ Geographic coordinates

Calculate the height difference: δh = h – h'

Continue with he += δh

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

The parameters of the physical model provided in the metadata are already corrected of light transmission delay and relativist effects. Please refer to section D.5.1.1 for end-user guidance.

Please refer to section D.5.1.2 for atmospheric refraction effect and end-user guidance.

D.3.2 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).

D.4. Primary and Projected Levels: Using the RPC Analytical Model

The RPC file (RPC_*.xml) contains the coefficients and normalization parameters for the Rational Polynomial Coefficients (also called Rapid Positional Capability, Rational Function Model). RPC is a generalized analytical model (3rd order polynomial) independent of the sensor data handling. RPC is the most popular method in COTS.

The RPC model and the rigorous physical model shall provide the same positioning when the same geometric settings are applied. This remark explicitly concerns the atmospheric refraction correction applied by default on RPC values at each altimetric level and not on physical attitude values in Primary level to preserve the sensor image model. For detailed information please refer to section D.5.1.2.

For very long acquisitions a discrepancy of RPC model may appear due to the limitation of the polynomial approach.

The RPC file gives two relationships:

- image ➔ ground: the so-called direct model (Image coordinates + altitude to ground coordinates)
- ground ➔ image: the so-called inverse model (Ground coordinates + altitude to image coordinates)

The coordinates are related to WGS84 geodetic system. The altitude is height above ellipsoid.

Most of the software is only handling the ground ➔ image relationship (inverse model) following the definition of NITF specification (STDI-0006). The image ➔ ground relationship (direct model) is added in the file for completeness.

The inverse model metadata names - under the node <GroundtoImage_values> - are those specified by the NITF V2.1 Controlled Extension (CE). The coefficients are arranged in the RPC00B order.

NITF or other standard do not cover the direct model. DIMAP uses its own metadata names - under the node <ImagetoGround_values>- using a scheme similar to NITF. Coefficients are also arranged like RPC00B.

All coordinates must be center-normalized input 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

D.4.1 Ground to Image (Inverse) Localization Algorithm

The user supplies geographic coordinates (lon, lat) and an altitude (alt). The results of the invers model application 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

The rational function polynomial equations are defined as:

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

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

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

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

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

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, under the node <GroundtoImage_Values> 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

D.4.2 Image to Ground (Direct) Localization Algorithm

The user supplies image coordinates (col, lin) and an altitude (alt). The results of the direct model application 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

The rational function polynomial equations are defined as:

$$lon_{CN} = \frac{\sum_{i=1}^{20} LON\_NUM\_COEFF_i \cdot \rho_{i(lin_{CN}, col_{CN}, alt_{CN})}}{\sum_{i=1}^{20} LON\_DEN\_COEFF_i \cdot \rho_{i(lin_{CN}, col_{CN}, alt_{CN})}}$$

$$lat_{CN} = \frac{\sum_{i=1}^{20} LAT\_NUM\_COEFF_i \cdot \rho_{i(lin_{CN}, col_{CN}, alt_{CN})}}{\sum_{i=1}^{20} LAT\_DEN\_COEFF_i \cdot \rho_{i(lin_{CN}, col_{CN}, alt_{CN})}}$$

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

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

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

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

LON_NUM_COEF_n, LON_DEN_COEF_n, LAT_NUM_COEF_n, LAT_DEN_COEF_n, under the node <ImagetoGround_Values> 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

D.4.3 Validity domain and Estimated Accuracy

<Global_RFM> means that the RPC model is available for the whole image. The <GroundtoImage_Validity_Domain> and <ImagetoGround_Validity_Domain> are provided for information only.

The estimated errors of the analytic 3rd order polynomial are posted in nodes “ERR_BIAS_*”. This error is corresponding to 3 * standard deviation given for each model (99.7 % of evaluation samples).

D.5. Other Informative Geometric Data

D.5.1 A posteriori Corrections

D.5.1.1. Relativist Corrections

The relativist and light transmission delay corrections due to the speed of light are always applied in product. It means that these effects have been included into the attitude profile, and must not be taken into account again by the end-user.

D.5.1.2. Atmospheric Refraction Effect

Due to the variation of air density and composition along the atmosphere, light is not a straight but a deflected line. This implies localization errors if the atmospheric refraction is not considered. The magnitude of the correction is a function of the viewing angle (null at nadir) and the local altitude.

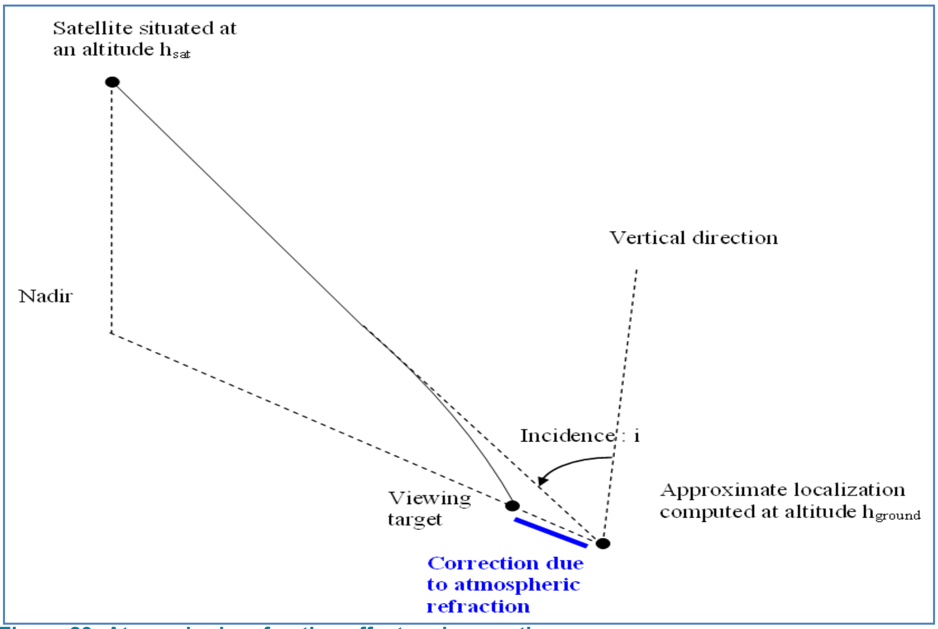


Figure 29: Atmospheric refraction effect and correction

The correction is typically input by a LUT of refractive index depending on the altitude thus interpolated at the real altitudes in the image. This correction is only accessible through the physical model.

For Primary and Projected levels the application (or not) of refraction correction is reported by two flags (true/false), under the node <Processing_Information><Geometric_Settings>:

- ATMOSPHERIC_REFRACTION_SETTING: related to sensor physical model (Primary level only)
- ATMOSPHERIC_REFRACTION_SETTING_RPC: related to RPC analytical model (Primary or Projected levels)

ATMOSPHERIC_REFRACTION_SETTING = true (default value): The sensor model data are not corrected (<Ephemeris>, <Attitudes>, <Polynomial_Look_Angles>). Only the image corners coordinates are corrected (<Vertex> of <Dataset_Extent>). In Primary sensor geometry, the imagery file resampling due to the correction is negligible thus the refraction is remaining.

- Note to end-users using Primary sensor model: whatever the flag value you are free to apply a refraction correction a posteriori in your own processing.

ATMOSPHERIC_REFRACTION_SETTING_RPC = true (default value): since in this analytical model the real sensor is lost the RPC coordinates and coefficients have been computed to include the effects of the atmospheric refraction. At Projected level the imagery file resampling due to the correction is consistent with the fixed rectification altitude of the product.

- Note to end-users: a posteriori correction is no more possible with the RPC analytical model.

D.5.2 Acquisition Angles and Located Values

Acquisition angles associated to the image area are under the node:

<Geometric_Data><Use_Area><Located_Geometric_Values>

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

D.5.2.1. Viewing and Incidence Angles

D.5.2.2. Viewing angles

The viewing angles, also called pointing angles, are the roll and pitch angles to the central pixel with respect to the local orbital frame and measured with respect to the satellite position. These angles are reported on the two following tags named by convention:

- VIEWING_ANGLE_ACROSS_TRACK (α_x): the roll (φ) acquisition angle [-90, 90 degrees]
- VIEWING_ANGLE_ALONG_TRACK (α_y): the pitch (θ) acquisition angle [-90, 90 degrees]

The combined viewing angle is VIEWING_ANGLE (α), computed on the sphere: $\propto = \mathrm{acos}\left(\cos(\propto_x).\cos(\propto_y)\right)$

The nominal range for the viewing angle is [-30, 30 degrees] but can be opened to increase the revisit frequency over a given target.

D.5.2.3. Incidence Angles

The (global) incidence angle INCIDENCE_ANGLE (β), also called the Observation Zenith Angle (OZA), is the angle between the local normal to the ellipsoid surface (approximated by a spherical Earth) and the look direction from the satellite: in other words the image angle affecting the spherical Earth surface. The incidence angle can be decomposed into two orthogonal components corresponding to the along track and across track directions. These angles are reported on the two following tags named by convention:

- INCIDENCE_ANGLE_ACROSS_TRACK (β_x): the angle in the image column axis on the ground [-90, 90 degrees]
- INCIDENCE_ANGLE_ALONG_TRACK (β_y): the angle in the image line axis on the ground [-90, 90 degrees]
- INCIDENCE_ANGLE (β): the global incidence angle [-90, 90 degrees]

D.5.2.4. Relationship between Viewing and Incidence Angles

Considering a spherical representation of the Earth, incidence angle on any point of the earth is given by the following formula:

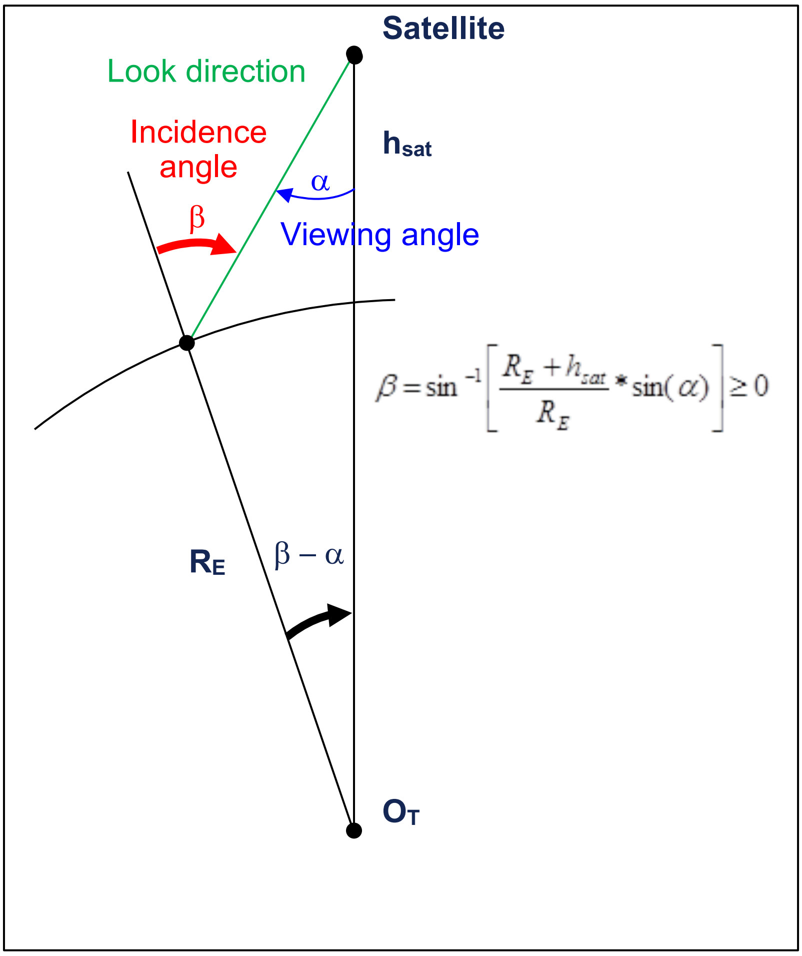


Figure 30: Relation between Incidence Angle and Viewing Angle

Where:

□is the incidence angle from the earth

α is the viewing angle from the satellite

R_E is the mean value of ellipsoid semi-axes

h_{sat} is the altitude of satellite above ellipsoid

The viewing angles are right oriented (see Figure 25), with opposite sign to incidence angles. The following Figure 31 illustrates this sign convention for descending orbits (daylight acquisitions).

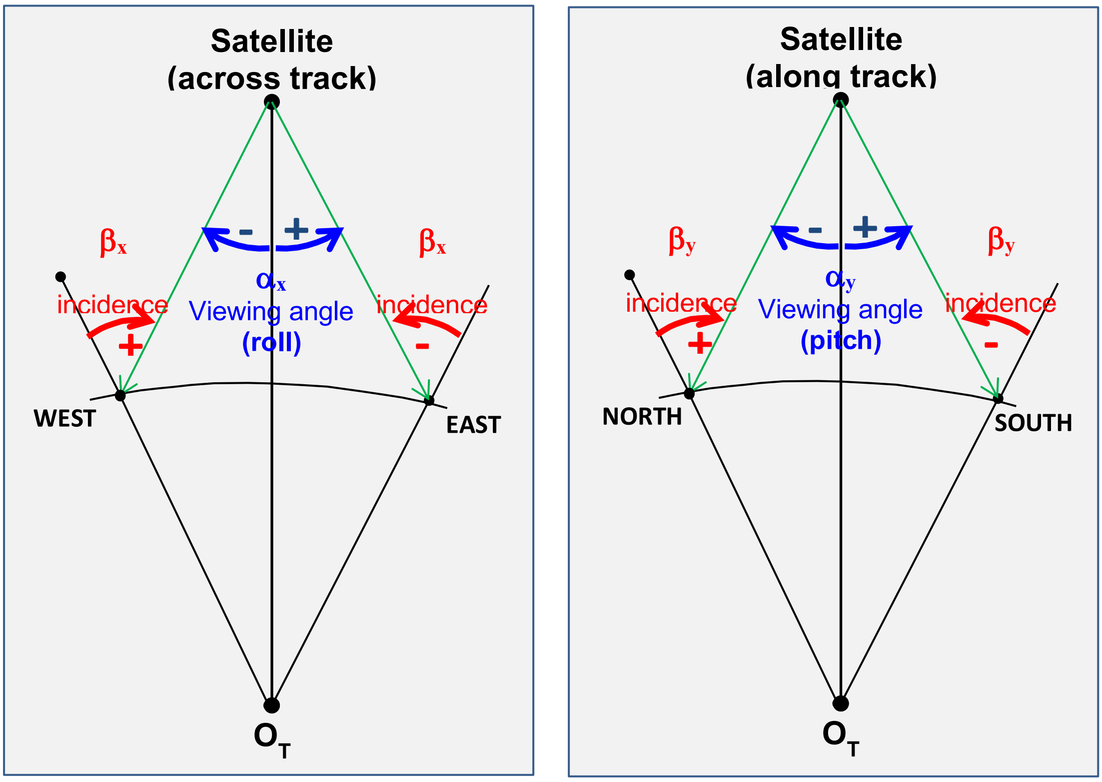


Figure 31: descending orbit case: Incidence and Viewing Angles sign convention

D.5.2.5. Satellite Azimuth angle

The satellite azimuth angle AZIMUT_ANGLE (Az_{sat}) is the angle between the meridian indicating the north passing through an image point and the line passing through this image point and the satellite nadir point. The range for the satellite azimuth angle is [0, 360 degrees], clockwise positive. As shown on Figure 32.

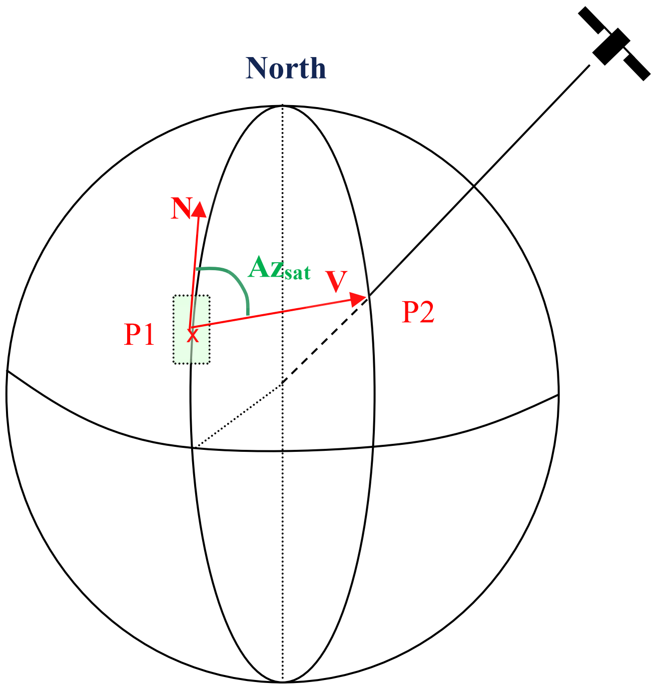


Figure 32: Satellite azimuth angle

Where :

P1 is the position of the image point
N is the north direction for this point
P2 is the satellite nadir point
V is the direction between nadir point P2 and image point P1
Direct angle between **N** and **V** is the satellite azimuth

D.5.2.6. Image Orientation Angle

The image orientation angle IMAGE_ORENTATION (Az_i), also called image cap, is the angle between the north direction and the image scan line direction on the ground. The range for the image orientation angle is [0, 360 degrees], clockwise positive.

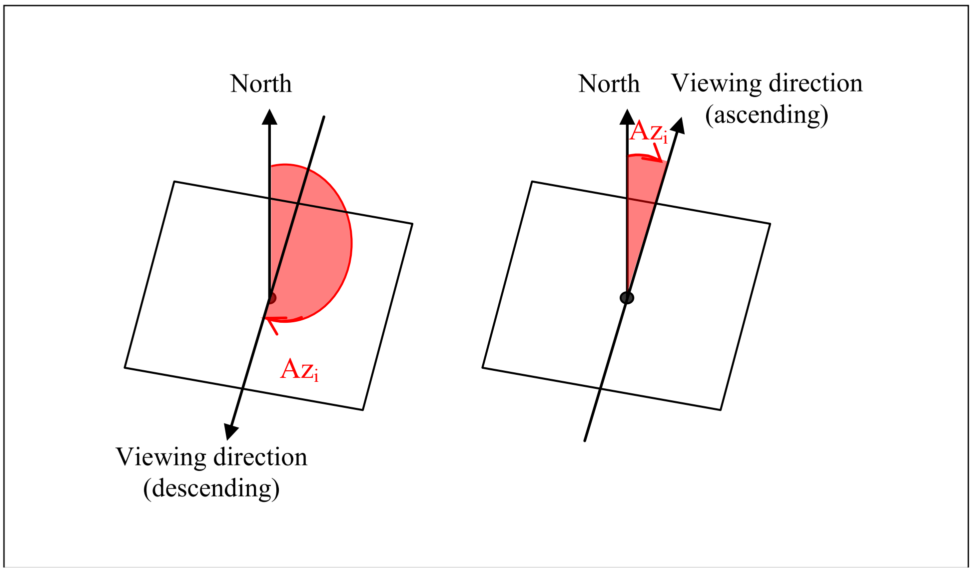


Figure 33: image orientation angle: left descending orbit, right ascending orbit

For descending orbit (daylight) the common orientation angle is around 180°.

D.5.2.7. Solar Angles

The solar elevation and azimuth angles are commonly referred to as the solar incidence angles.

The solar elevation angle SUN_ELEVATION (El_{sun}) is the angle between the geometric center of the sun's apparent disk and the idealised horizon.

The solar azimuth angle SUN_AZIMUTH (Az_{sun}) is the angle from due north measured clockwise positive.

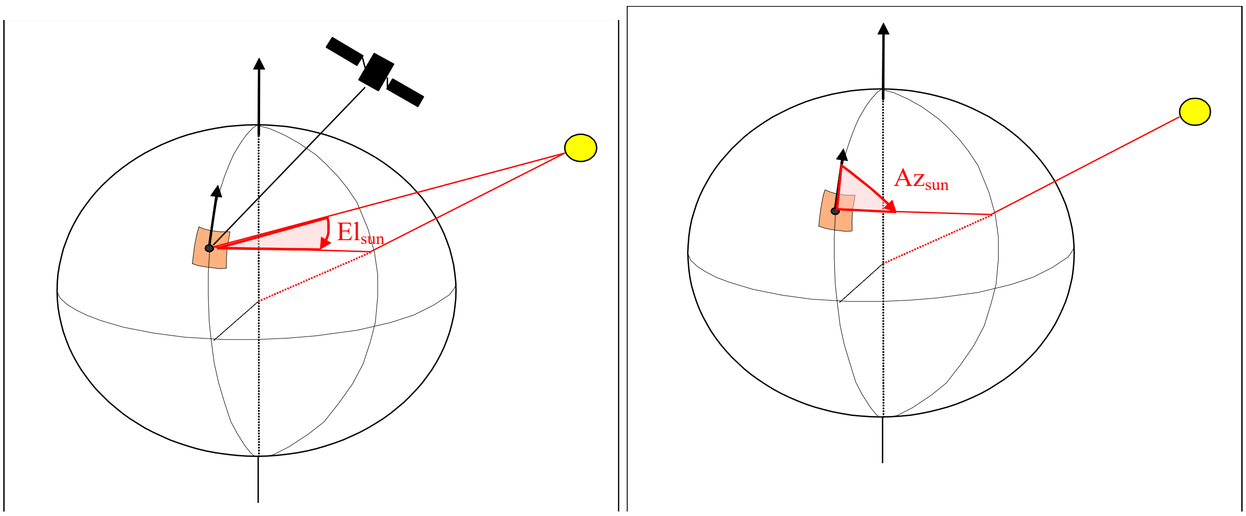


Figure 34: Sun elevation and Azimuth angles (Solar incidences)

- Note to end users: Sun zenith angle (θ_s) = 90° - SUN_ELEVATION (El_{sun})

D.5.2.8. 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 line direction
- GSD_ALONG_TRACK: pixel size along image column direction

Table 40 gives the GSD variation according to the viewing angle.

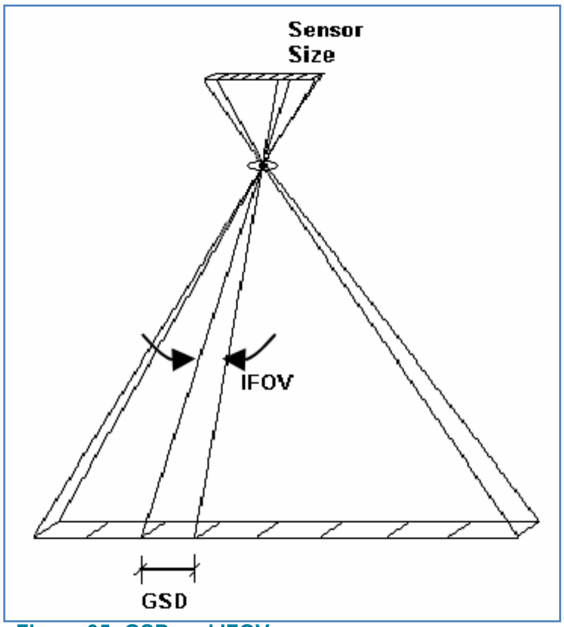


Figure 35: GSD and IFOV

Appendix E. Spectral modeling and rendering

E.1. Pléiades Neo Spectral Bands

The Pléiades Neo satellites acquire simultaneously one panchromatic band and six multispectral bands. Table 41 below provides the typical spectral domain of each band, according to the Full Width at Half Maximum (FWHM) expression.

Spectral bands (µm)	FWHM	Central wavelength	λmin	λmax
Panchromatic (PAN)	0.358 µm	0.638 µm	0.459 µm	0.817 µm
Deep Blue (DB)	0.04 µm	0.436 µm	0.416 µm	0.456 µm
Blue (B)	0.074 µm	0.483 µm	0.446 µm	0.52 µm
Green (G)	0.057 µm	0.562 µm	0.533 µm	0.59 µm
Red (R)	0.071 µm	0.654 µm	0.618 µm	0.689 µm
Red Edge (RE)	0.053 µm	0.723 µm	0.696 µm	0.749 µm
Near Infrared (NIR	0.12 µm	0.828 µm	0.768 µm	0.888 µm

Table 41: Pléiades Neo Spectral Bands

This realization is close to the specified band spectral domains. One can notice a marginal difference for the deep blue low cut-off wavelength.

The differences between each of the four sensors are negligible.

E.2. Pléiades Neo Spectral Responses

The spectral response at a particular wavelength is the ratio of light power measured in the sensor band to the light power input at the telescope entrance. The spectral normalized responses differences between the two Pléiades Neo satellites are negligible.

For applications requiring really accurate response profiles, tabulated values for each Pléiades Neo satellite are available upon request at technicalsupport@intelligence-airbusds.com.

E.3. Standard Radiometric Options

Applications based on advanced spectral analysis need to convert image raw Digital Numbers (DNs) to physical information such as spectral radiance, reflectance, or albedo.

This measurement performed by the satellite can be first converted to a radiance value thanks to sensor calibration. Then to "Top-Of-Atmosphere" (TOA) reflectance expressing the fact this is exo-atmospheric reflectance as measured from space, thus considering measurement at terrestrial level filtered by the atmosphere.

It may be then further corrected from the transfer through the atmosphere down to the ground level to obtain direct spectral information. An illustration of such correction steps is given in Figure 36.

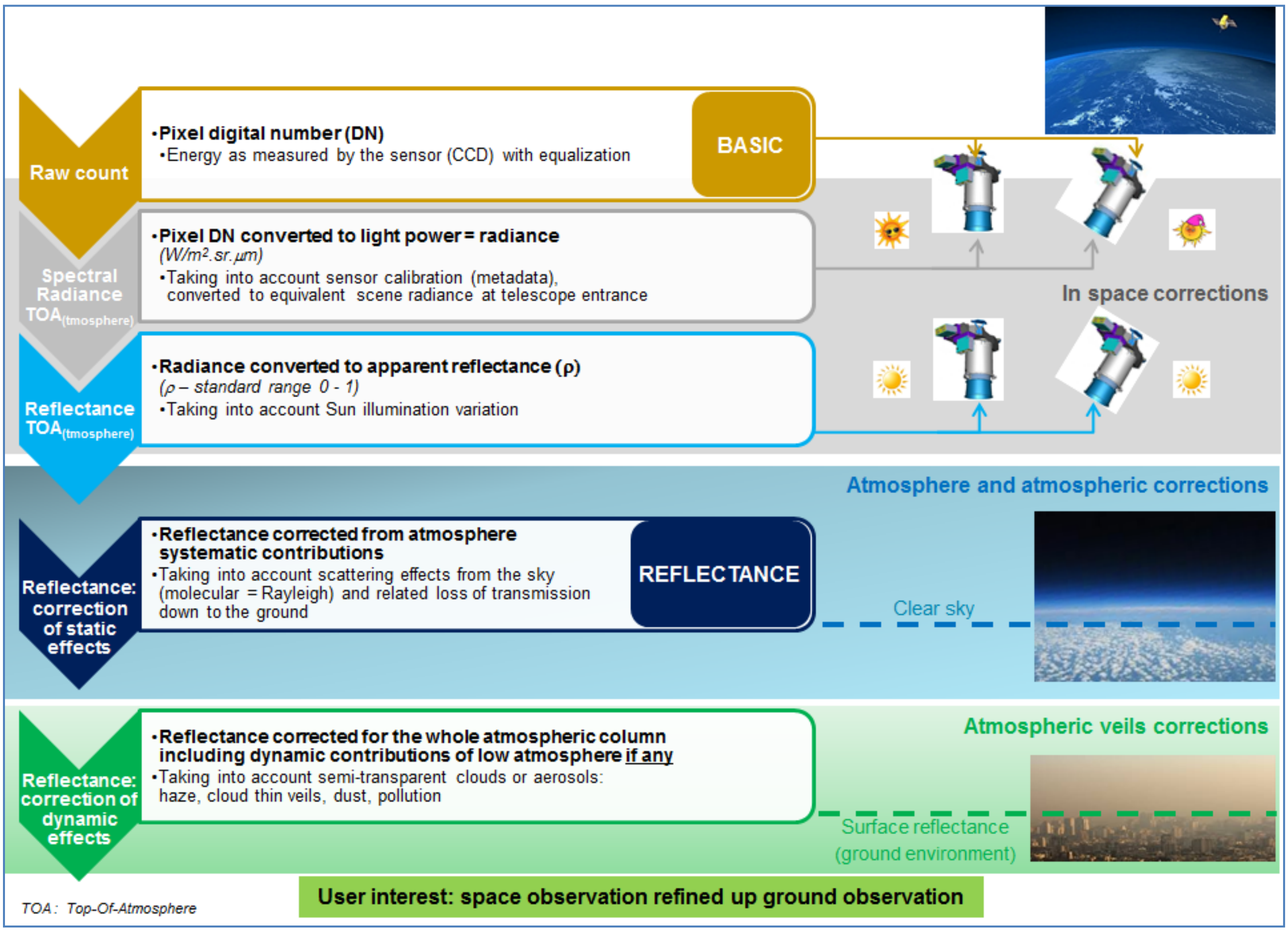


Figure 36: Sensor to ground physical spectral corrections

Ultimately, for the visual exploitation of the image product, some optimized image rendering can be applied to the reflectance image to provide a reliable true color image in the visible domain (RGB) for direct display.

Three standard spectral options are proposed. One of the following Radiometric Processing Options is selected at order placement:

- BASIC
- REFLECTANCE
- DISPLAY

Each of these radiometric selections appears in the product metadata file (DIMAP) under the RADIOMETRIC_PROCESSING tag. Two additional values may appear:

- LINEAR_STRETCH: relates to the BASIC option at 8-bit depth.
- SEAMLESS: relates to a Mosaic level product. Here the spectral properties cannot be retrieved since the initial images having undergone several radiometric adjustments for aesthetic rendering.

E.3.1 BASIC option

RADIOMETRIC_PROCESSING tag = ‘BASIC’ or ‘LINEAR_STRETCH’ (8-bit depth)

In the BASIC radiometric option the imagery values are digital numbers (DN) quantifying the energy recorded by the detector corrected relative to the other detectors to avoid non-uniformity noise.

E.3.1.1. Processing

Different radiometric artefacts may affect the raw image on-board. The main ones are high frequency noise due to the differential sensitivities between detectors (pixel equalization) and low frequency variations in the field of view (vignetting, etc.). After correction of the detector PRNU (Photo Response Non-Uniformity) the dark signal and relative gain of each detector are fully characterized and monitored at regular intervals throughout the satellite’s life to maintain a fine equalization according to the nominal TDI level or electronic gain. This “relative” correction is performed on-board and refined on-ground.

Other radiometric corrections can be performed on-ground such as: crosstalk correction, defective pixel (if identified), image restoration (denoising and deconvolution).

A DN value does not account for the light power in the space environment at the time of input at telescope entrance. In fact, part of the light power is lost during transmission at different stages of the acquisition chain (optic, filters, etc.). Basically, the loss is homogeneous on each sensor band with an evolution during the satellite life. Thus the related correction is simply modeled by a linear function on each band. This “absolute” calibration or sensor calibration includes an offset and a gain for each band, updated at regular intervals throughout the satellite’s life to maintain a fine restitution of the light power.

The absolute calibration aims to convert the DN value into a radiance value at the input of the camera (TOA). Absolute calibration coefficients are updated periodically, typically 4 times per year.

The BASIC radiometric option is the most untouched from a sensor point of view. Thus the absolute calibration is not applied to the image bands, and the linear coefficients are provided in the DIMAP metadata file (see section E.4.1.1). Substantial expertise is required to ensure spectral corrections from space to ground.

E.3.1.2. Encoding

Quantization performed at sensor level is 12 bit-depth. Thus source DN values have range 1-4095. For byte oriented format as GeoTIFF these values are encoded into a 16 bit unsigned integer image file. RADIOMETRIC_PROCESSING tag is set to ‘BASIC’.

To minimize the image file volume, the user can order BASIC in 8 bit-depth. The conversion to 8 bits coding (range 1-255) is performed by a linear stretch on the effective histogram of the source image. RADIOMETRIC_PROCESSING tag is set to ‘LINEAR_STRETCH’.

E.3.2 REFLECTANCE option

RADIOMETRIC_PROCESSING tag = ‘REFLECTANCE’

In the REFLECTANCE radiometric option the imagery values are corrected from radiometric sensor calibration and systematic effects of the atmosphere (molecular or Rayleigh diffusion and given in reflectance physical unit).

E.3.2.1. Processing

The reflectance (ρ) for a given spectral band (ρ_b) is the ratio of reflected light to the incident Sun illumination (or irradiance). A value 0 represents full absorption (black), and a value of 1 represents full reflection (perfect white). Apparent reflectance may exceed a value of 1 on specular targets or on slopes facing towards the Sun.

Absolute calibration coefficients, as obtained from the sensor regular absolute calibration, are applied to the DN values to convert into radiance (light power) information. This is referred as TOA radiance (see section E.4.1.1).

In general, in-situ measurements of the atmosphere are unavailable to process the satellite imagery, so determining the best atmospheric correction is a complex matter. Various methodologies are discussed in the scientific community; debate will go beyond the scope of this document. The aim of the REFLECTANCE option is a universal atmospheric correction addressing the most common user needs and allowing the users to locally refine the correction:

- (a) To revert without loss to the source DN image (BASIC) and TOA radiance
- (b) To further correct reflectance down to the ground level.

Atmospheric correction may address two factor categories:

- The systematic contribution of the atmosphere, corresponding to the sky effect as observed from ground - This part is rather predictable and results from the gaseous nature of atmosphere at its different layers therefore the molecular (or Rayleigh) scattering and corresponding loss of Sun illumination. The first order effect is the Rayleigh scattering, in inverse relation with the wavelength (law in $1/\lambda^4$) responsible for the bluish rendering in TOA imagery. Spatially, the static contribution is nearly uniform over the whole image scene and can be physically computed f²rom an atmospheric model, e.g. the LOWTRAN family (MODTRAN, ATCOR, etc.) or the 5S-6S (SMAC, etc.).
- Various dynamic factors affecting the low atmosphere - This part consist in various phenomena that are much more unstable, such as the presence of aerosols (haze) of different types and with varying load, and the presence of cloud thin veils. The correction is only relevant for semi-transparent phenomena; opaque clouds obviously cannot be corrected. This contribution is never homogeneous over the whole image scene and the knowledge of this optical thickness is often investigated on the pixel level rather than physical approaches.

To meet user needs as referred in (a), the REFLECTANCE product does not implement any correction of the dynamic atmospheric phenomena in the image (considered in a future product).

The systematic contribution of the atmospheric effects is corrected by the REFLECTANCE processing. Whereas no auxiliary data is available (i.e. in-situ measurements), the atmospheric model is estimated with a priori average parameters as standard pressure and at image level mean terrestrial altitude, average sun illumination and satellite viewing. The nearly homogeneous contribution resulting from these effects is represented by a linear correction in each spectral band. With respect to the condition (a) this linear formulation is reversible without loss with the opportunity to refine the model if accurate auxiliary data becomes available (see section E.4.1.2).

In clear sky conditions (no veils), the reflectance value given by the REFLECTANCE product can be directly assimilate to the ground surface reflectance.

In conclusion, REFLECTANCE is more straightforward and easier to use than BASIC for spectral analysis and several image processing techniques. Both have the same spectral capability.

E.3.2.2. Encoding

The reflectance values are encoded into integer values by a fixed scale factor of 10000, thus image values are given in 1/10 000 reflectance. The scale factor can be found in the DIMAP metadata file:

<Radiometric_Data><Radiometric_Calibration><Instrument_Calibration><Band_Measurement_List><Band_Reflectance><GAIN + BIAS> (respectively 10000 and 0).

The BIAS and GAIN formula given at section E.4.1 is appropriate to convert the reflectance values scaled in integer to the reflectance range values in real number.

The 1/10 000 unit sets a standard range of 0-10000. The upper limit is not predictable, notably on specular conditions. For byte oriented format as GeoTIFF these values are encoded into a 16 bit unsigned integer image file. A quantization on 8 bit would revoke the benefit of a direct readable count in physical unit and is not proposed.

In addition to the imagery data, REFLECTANCE option provides a Look Up Table (LUT) for each band that properly retrieves the true color from sensor calibration and atmospheric correction processing for RGB rendering. The LUT is optimized for the display by an adaptive stretching to 8-bit range per RGB channel, so the user can achieve DISPLAY rendering (see section E.5.2).

The LUT is common for bands in the visible domain, Red (R), Green (G), Blue (B), Deep Blue (DB), and Panchromatic (PAN), to ensure RGB visualization. The Red Edge (RE) and Near Infra-Red (NIR) band have their own LUTs for composite rendering, for instance false color for NIR band.

E.3.3 DISPLAY option

In the DISPLAY radiometric option, the imagery values are 8-bit numbers optimized for a direct rendering on the screen. The scene true color in the visible domain is properly retrieved from sensor calibration and correction of systematic effects of the atmosphere. The values are not reversible to spectral physical unit.

E.3.3.1. Processing

The aim of the DISPLAY option is to provide imagery that has been spectrally corrected and easy to display in true color in their software applications. The imagery is intended for visualization purposes rather than spectral applications.

The DISPLAY processing consists of the application of the LUTs computed for REFLECTANCE to the imagery file. Therefore imagery values are stretched to RGB values, and are no longer reversible to physical values (reflectance, radiance). Thus spectral information is not stated in the DIMAP metadata file.

E.3.3.2. Encoding

The image values are encoded in 8-bit depth, addressing the 16.78 million colours of RGB space plus an extra channel for 4-band delivery. A larger encoding would not have extra values for display purposes.

E.4. Radiometric and Atmospheric Corrections

E.4.1 Top-Of-Atmosphere (TOA) Spectral Radiance

BASIC or REFLECTANCE radiometric options provide information for converting the pixel values *X(p)* into TOA spectral radiance values (*L*). The formulation is linear for each band (*b*) set with coefficients GAIN and BIAS. The GAIN and BIAS values are posted in the DIMAP metadata file.

For each band *b* the formula is:

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

The physical unit of TOA spectral radiance is $W \cdot sr^{-1} \cdot m^{-2} \cdot \mu m^{-1}$

In same acquisition conditions by several Pléiades Neo the TOA spectral radiance is similar. Users looking for very accurate spectral information should consider the respective spectral responses aboard Pléiades 1A and 1B sensors (see section E.2).

E.4.1.1. From BASIC

The pixel values X(p) are DN values. The GAIN and BIAS are the absolute radiometric coefficients of the sensor calibration routinely performed during the satellite life cycle. The absolute calibration recovers the spectral response into TOA radiance unit (E.3.1.1). Inputs are as follows:

X= DN pixel values (band image file)

GAIN:
<Radiometric_Data><Radiometric_Calibration><Instrument_Calibration><Band_Measurement_List<>Band_Radiance><GAIN>
(DIMAP metadata file)

BIAS:
<Radiometric_Data><Radiometric_Calibration><Instrument_Calibration><Band_Measurement_List><Band_Radiance><BIAS>
(DIMAP metadata file)

Note that products in the sensor native radiometric range (12 bit quantization) have a BIAS value set to zero. For 8-bit products, the image DNs are reduced to the 8-bit range, which means a non-zero BIAS value.

E.4.1.2. From REFLECTANCE

The pixel values *X(p)* are reflectance values (ρ). The GAIN and BIAS are the coefficients of the linear law to reverse the atmospheric correction back to TOA radiance unit. Inputs are as follows:

X= reflectance (ρ) pixel values (band image file)

GAIN:
<Radiometric_Data><Radiometric_Calibration><Instrument_Calibration><Band_Measurement_List><Band_Radiance><GAIN>
(DIMAP metadata file)

BIAS:
<Radiometric_Data><Radiometric_Calibration><Instrument_Calibration><Band_Measurement_List><Band_Radiance><BIAS>
(DIMAP metadata file)

This conversion may be used to initiate an atmospheric model with user-defined parameter values, for instance in-situ measurements in capacity to refine the standard ones.

E.4.1.3. Converting TOA Radiance to TOA Reflectance

TOA radiance to TOA reflectance conversion is mainly for users using BASIC radiometric option.

TOA radiance of the acquired scene will directly vary with the Sun illumination, i.e. with the local elevation of the Sun at the time of image acquisition. Converting to TOA reflectance minimizes this dependency.

The TOA reflectance (□) for a given spectral band (□$_b$) is the ratio of reflected light filtered by the atmosphere to the incident Sun illumination. A value 0 represents full absorption (black), and a value of 1 full reflection (perfect white). Apparent reflectance may exceed the 1 value on specular targets or on slopes facing towards to the Sun.

TOA spectral radiance $L_b(p)$ can be converted to TOA spectral reflectance $\rho_b(p)$ with the following formula

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

Where

- $E_0(b)$ is the solar spectral irradiance in the considered band
- □$_s$ is the Sun zenith angle.
- *d* is a correction coefficient with respect to mean Earth-Sun distance

The DIMAP metadata file provides parameter values for the solar irradiance given per spectral band $E_o(b)$, and the Sun elevation angle (EL_{sun}). Sun zenith angle θ_s is 90°-El_{sun} (user can choose by default the value indicated at the center of the product).

The correction coefficient of the Earth-Sun distance (*d*) can be computed from formulas available in the literature, or may be approximated to 1 (varies of few % along the year).

E.4.2 Atmospheric Corrections

Some spectral image data analyses may be performed on TOA spectral reflectance, for example, if using only bands on which atmosphere has limited impact (e.g. Red, Red Edge and NIR bands). However, in many cases, to properly retrieve the scene true color in the visible domain, there is the need to apply further atmospheric corrections. Please refer to section E.3.2.1 for more information.

E.4.2.1. Correction of the atmosphere stable contribution

To initialize atmospheric models the DIMAP metadata file provides the following parameters:

- Sun parameters as Sun elevation (ELsun) and azimuth (AZsun) angles
- Viewing parameters as acquisition incidence angle (□□□and satellite azimuth angle (AZsat).

Atmosphere composition, local altitude values, etc. are typically auxiliary data or set to average values.

E.4.2.2. Correction of variable phenomena in the low atmosphere

In contrast with the stable contribution (Rayleigh scattering, etc.), correction of other atmospheric effects cannot be uniform as they may vary rapidly in the image. Atmospheric models include modelling of aerosols haze and clouds, and related parameters are difficult to assess. Many dehazing approaches use relationships between spectral bands to estimate locally these parameters from the image data, by reference to what should be the pixel reflectance in clear sky conditions (e.g. the Dark Dense Vegetation – DDV – method) and apply some spatial filtering to generalize this correction to the whole image. This correction will recover reflectance over hazy areas. Please refer also to section E.3.2.1 for more information.

E.5. Image Rendering

E.5.1 BASIC option

As discussed at section E.3.1.1 the colors are not calibrated and would need substantial effort to achieve a pleasant colour rendering with a manual stretch. First we recommend converting the DN pixel values in TOA radiance (E.4.1.1), especially for 8-bit- products. Then a threshold at histogram base plus a stretch per band can simulate an empiric correction of atmospheric effects.

E.5.2 REFLECTANCE option

We recommend using the Look-Up-Table for each band posted in the XML LUT file under the tag LUT:

<Raster_Data><Raster_Index_List><Raster_Index><LUT>

The LUT has the same syntax of VRT files (Raster Virtual format) adopted by GDAL or MapServer. Both are internally supported by many software.

All bands of visible domain have the same LUT: Red, Green, Blue, Deep Blue and Panchromatic bands. The LUT for the Red Edge and NIR bands are adapted for false color.

The rendering will be exactly the same as the DISPLAY option and remains neutral for the imagery values themselves. The rendering can partially absorb homogeneous haze effects.

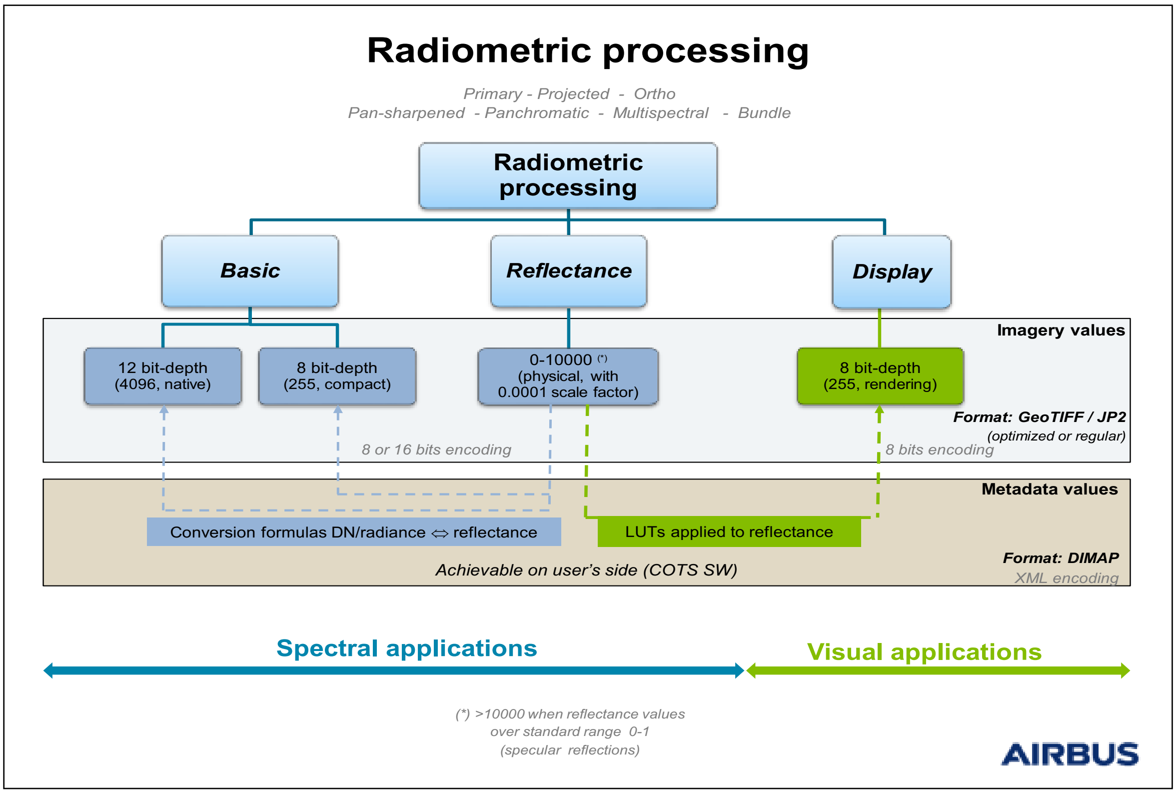
E.5.3 DISPLAY option

The image is immediately usable with optimized visual rendering. In Commercial off-the-Shelf software (COTS), we recommend switching the automatic stretching tools off.

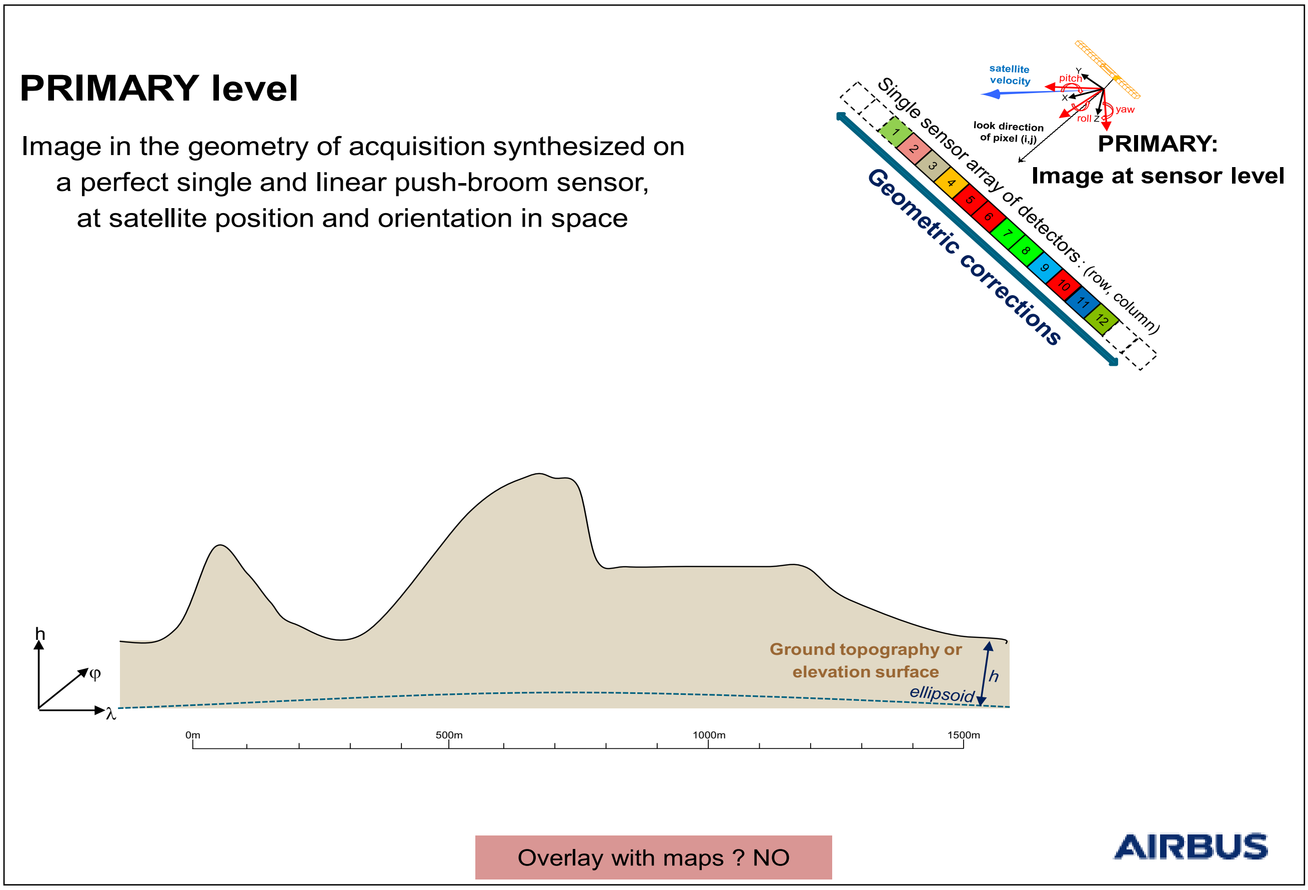
The brightness is a function of the reflectance value at ground level. For scenes acquired in low luminosity conditions or with low reflected objects, the luminosity level can be slightly increased at a same magnitude of the three RGB channels. Keep in mind the color balance may be a subjective notion as well as dependent of the calibration of the monitor.

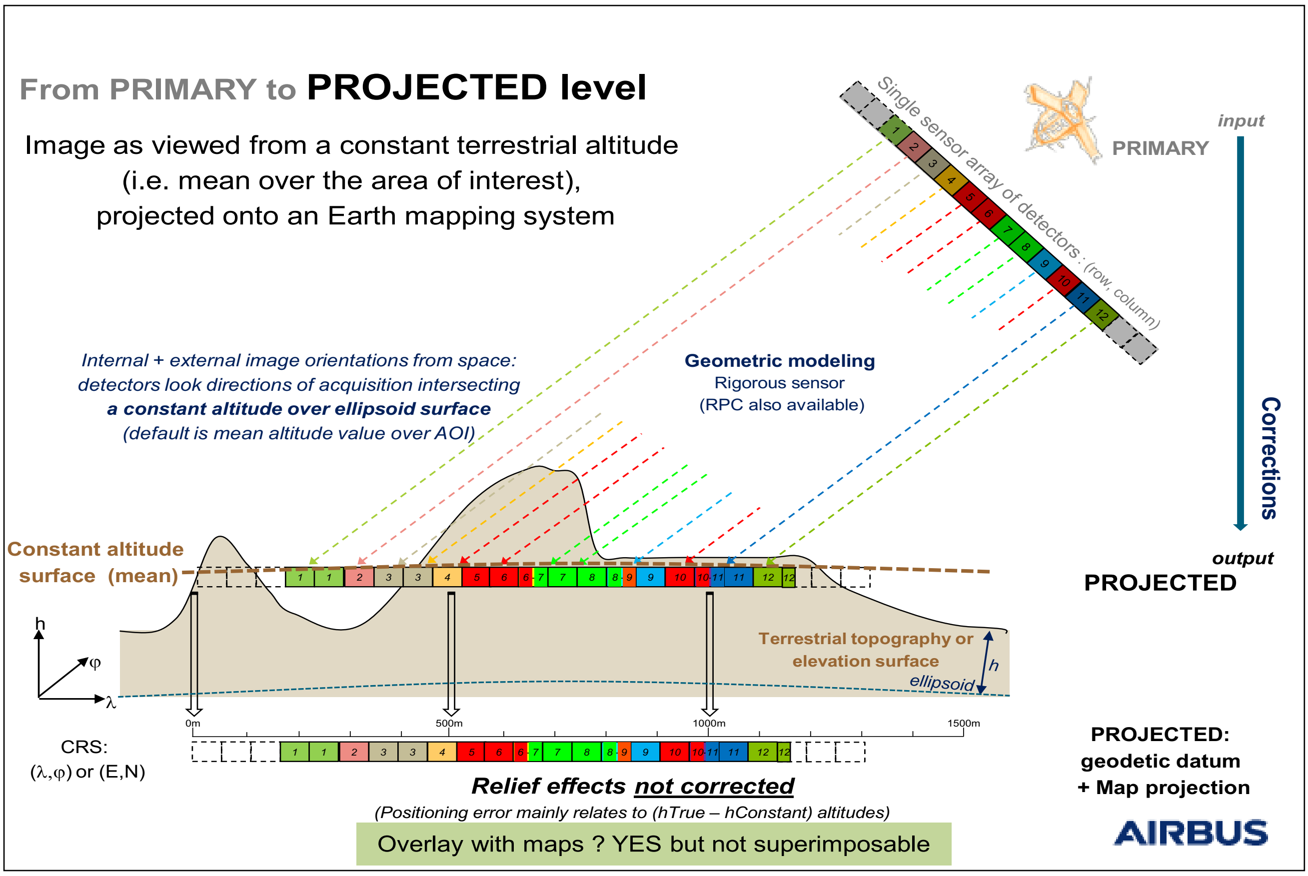
Appendix F. Schematic overview of processing

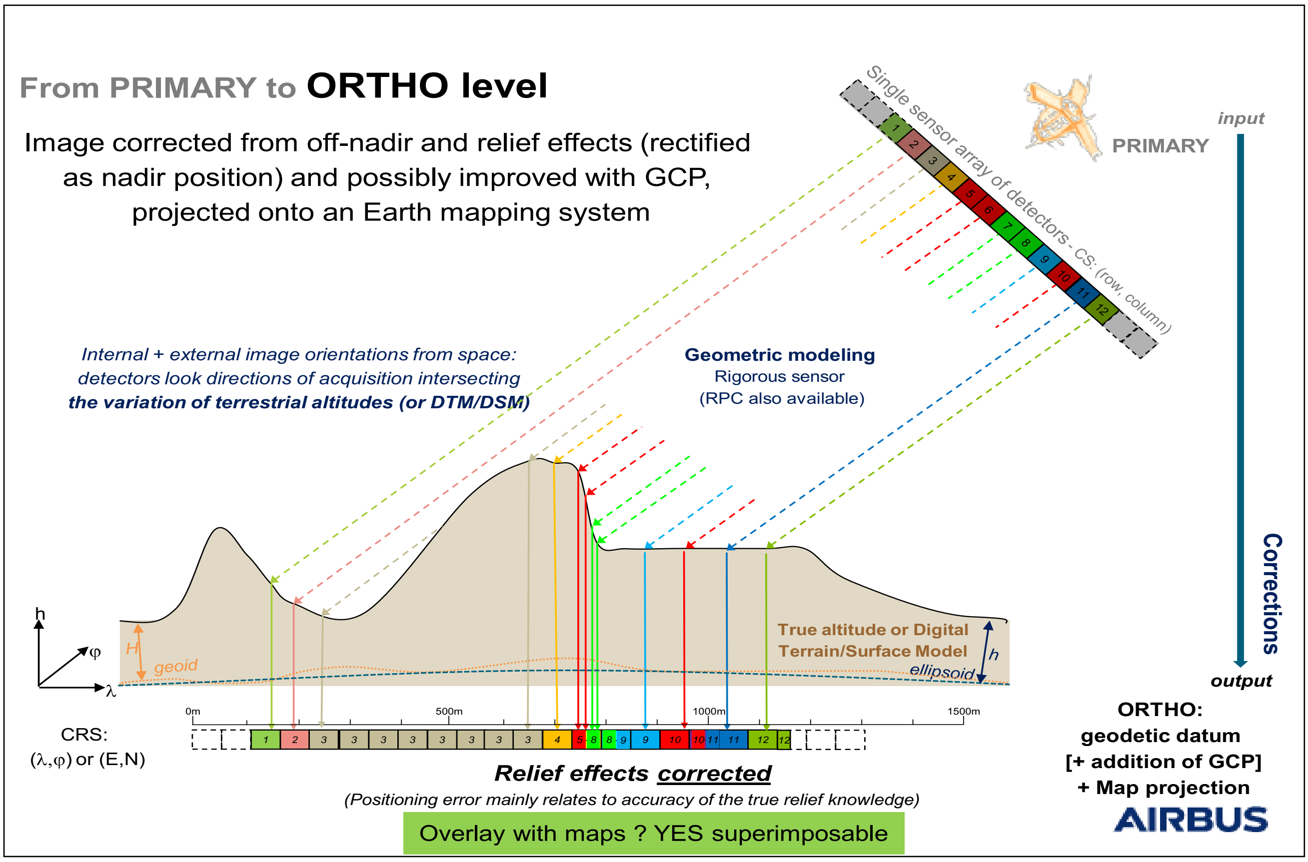
F.1. Radiometric Processing options

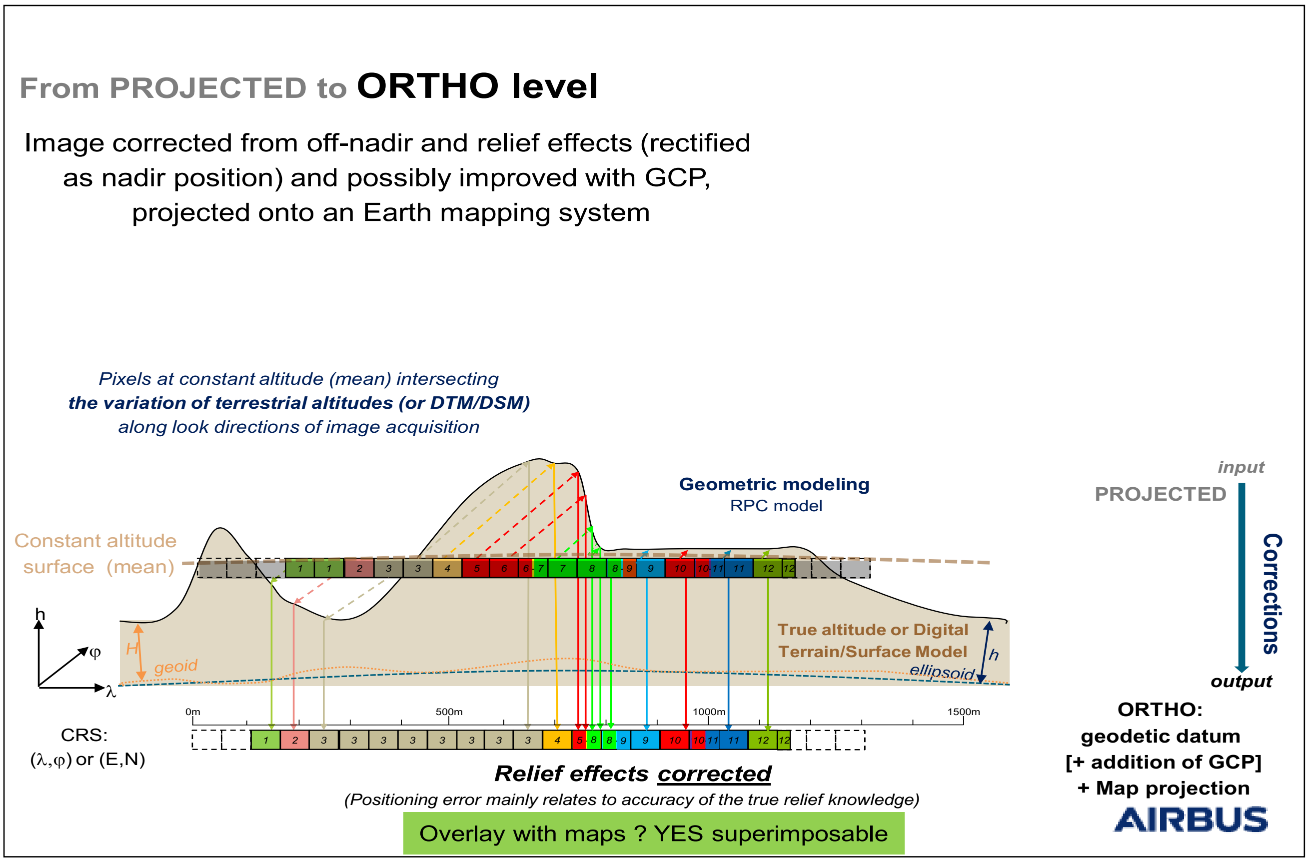


F.2. Geometric Processing options






From PRIMARY to ORTHO level
Image corrected from off-nadir and relief effects (rectified as nadir position) and possibly improved with GCP, projected onto an Earth mapping system
Single sensor array of detectors - CS: (row, column)
input
PRIMARY
Internal + external image orientations from space: detectors look directions of acquisition intersecting the variation of terrestrial altitudes (or DTM/DSM)
Geometric modeling
Rigorous sensor
(RPC also available)
Corrections
h
φ
λ
H
geoid
True altitude or Digital Terrain/Surface Model
ellipsoid
h
output
0m
500m
1000m
1500m
CRS:
(λ,φ) or (E,N)
Relief effects corrected
(Positioning error mainly relates to accuracy of the true relief knowledge)
Overlay with maps ? YES superimposable
ORTHO:
geodetic datum
[+ addition of GCP]
+ Map projection
AIRBUS


From PROJECTED to ORTHO level
Image corrected from off-nadir and relief effects (rectified as nadir position) and possibly improved with GCP, projected onto an Earth mapping system
Pixels at constant altitude (mean) intersecting the variation of terrestrial altitudes (or DTM/DSM) along look directions of image acquisition
Geometric modeling
RPC model
input
PROJECTED
Corrections
Constant altitude surface (mean)
h
φ
λ
H
geoid
True altitude or Digital Terrain/Surface Model
ellipsoid
h
output
0m
500m
1000m
1500m
CRS:
(λ,φ) or (E,N)
Relief effects corrected
(Positioning error mainly relates to accuracy of the true relief knowledge)
Overlay with maps ? YES superimposable
ORTHO:
geodetic datum
[+ addition of GCP]
+ Map projection
AIRBUS

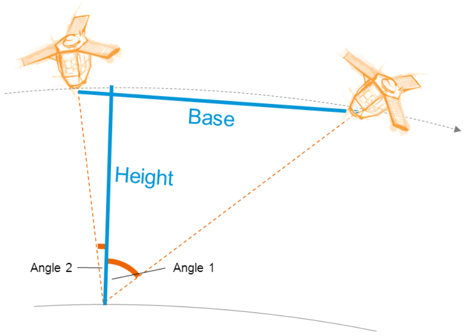
Abbreviations, Acronyms and Terms

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 (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.



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

Approximate Map scale Equivalencies Based on the US NMAS[2]

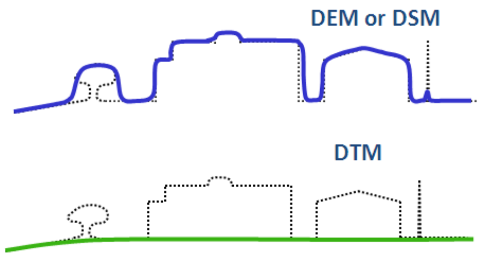
See also Geolocation accuracy, RMSE.

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 Earth altitude model, including the maximum altitude in every point: include human superstructures and canopy.

[2]. US NMAS: Unitied States National Map Accuracy Standard.



DEM vs. DTM

DRS – Direct Receiving Station: An antenna and a processing terminal enabling a given partner to receive telemetry directly at their facility.

DTM – Digital Terrain Model: A digital Earth altitude (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

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 the sensor model with 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 – 5m) 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 using it geometric model (rigorous or analytical).

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 35*.

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 Airbus imagery 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 from one viewpoint on the same orbit.

Mosaic: A mosaic is the 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 on short spectrum (and less than 20 bands), such as visible and infrared. Multispectral capacity enables a sensor to deliver color images.

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

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

Orthogonal: Having three right angles.

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

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

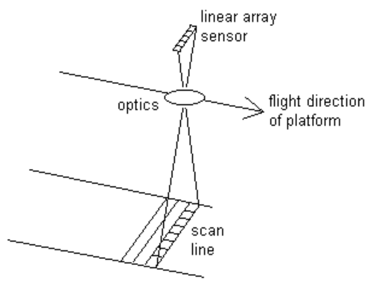
Panchromatic (PAN): Detectors that are sensitive to a large spectrum over mainly the visible.

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 reset with a DEM (vertical reset) and possibly with GCPs (horizontal reset). Unlike Location 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.



Pushbroom Sensor

Quicklook: Sometimes called a browse or preview 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 catalog. Basically, the quicklook is a sub-sampled image. It is compressed and dynamically stretched.

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) at sensor input, 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.

Reference layer: a global geographic coverage with qualified accuracy designed for registration and orthorectification of input images. The main use is to improve sensor model data of input images by massive automatic image algorithms such as matching registration or orthoimages rectified with a DSM. The historical Airbus reference layers were a dual endogenous layer composed of a continuous orthoimage layer and a vertical DSM layer sharing quality masks: the Reference**3D**® and PAS worldwide databases. The current Airbus reference layers are 3D feature points (GCP) extracted from images with a high accuracy location and a global DSM specifically designed to avoid orthorectification artefacts: respectively the Space Reference Points (SRP) database and the WorldDEM4Ortho (WD4O) hybrid DSM/DTM. *See SRP and WD4O.*

Reflectance: The ratio of the reflected radiance divided by the incoming radiance. 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 and has a directional aspect. 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. blue band covers an area between 0.43 and 0.55 µm).

SRP – Space Reference Points: a worldwide location reference layer of 3D GCPs built by massive multi-stereo Airbus imagery. The database is covering the entire Earth land surface except icefields with an intrinsic accuracy of 3mCE90 and an average density of 1 GCP / 2km². *For more information: [https://doi.org/10.5194/isprs-annals-V-2-2020-15-2020.](https://doi.org/10.5194/isprs-annals-V-2-2020-15-2020)*

Stereo(scopic): Which has been obtained by imaging from at least two viewpoints on the same orbit (mono-date) or several orbits (multi-date).

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

Swath: The width of an image. Pléiades Neo' swath is 14 km at nadir. The swath increases proportionally with the roll angle.

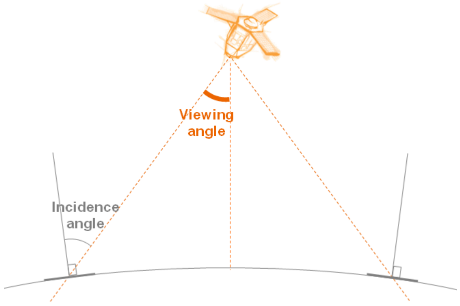
Time Delay Integration (TDI): A time delay integration detector is widely used for observation of high speed moving objects undetectable by classic detector. This technique senses charge patterns and shifts them across the detector array in sync with the movement of the image, to integrate more light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

UTC: Universal Time Coordinated.

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

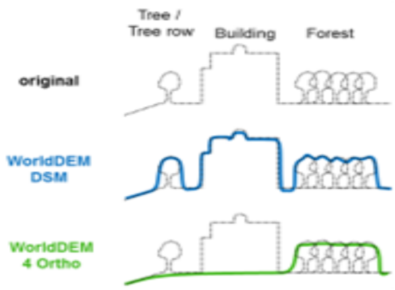
VHR – Very High Resolution: Imagery with a resolution below 1m.

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



Viewing Angle

WD4O - WorldDEM4Ortho a worldwide Airbus altimetric reference layer derivate of global WORLDEM™ dataset. The coverage is natively pole to pole with an intrinsic vertical accuracy of 4m LE90 and a posting of 24 meter. WD4O is a specific DEM designed as a hybrid DTM/DSM. This hybrid DEM (also called DEM / NUS – non-urbanized surface) excludes the anthropic superstructures near bare-ground and includes the vegetation canopy, preserving the altimetric accuracy and preventing orthorectification artefacts on very high resolution images. *For more information: https://www.airbus.com/newsroom/press-releases/en/2017/07/airbus-releases-worlddem4ortho--the-most-accurate-elevation-mode.html.*



WorldDEM4Ortho DTM/DSM hybrid design

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 the symbols involved within this document.

Symbol	Description <Location of values in DIMAP V2 format>
Az_i	The image orientation angle of the image line axis between the geographic north and the scan line direction. Degree unit (°). <Geometric_Data><Use_Area><Located_Geometric_Values><Acquisition_Angles><IMAGE_ORIENTATION>
Az_{sat}	The satellite azimuth angle. Degree unit (°). <Geometric_Data><Use_Area><Located_Geometric_Values><Acquisition_Angles><AZIMUT_ANGLE>
Az_{sun}	The sun azimuth angle (°). <Geometric_Data><Use_Area><Located_Geometric_Values><Solar_Incidences><SUN_AZIMUTH>
B	Spectral band identifier. Examples PAN, DB, B, G, R, RE, NIR = Resp. Panchromatic, Deep Blue, Blue, Green, Red, Red Edge and Near Infrared bands. <Radiometric_Data><Histogram_Band_List><Histogram_Band><BAND_ID> <Radiometric_Data><Radiometric_Calibration><Instrument_Calibration><Band_Measurement_List><{Band_Spectral_Range, Band_Radiance, Band_Reflectance, Band_Digital_Number, Band_Solar_Irradiance}><BAND_ID>
BIAS	A bias value. <Radiometric_Data><Radiometric_Calibration><Instrument_Calibration><Band_Measurement_List><{Band_Radiance, Band_Reflectance, Band_Digital_Number}><BIAS>
C	Light speed.
CoeffPsiX(i)	Polynomial line of sight model coefficients: TanPsiX = f(col –colref). <Geometric_Data><Refined_Model><Geometric_Calibration><Instrument_Calibration><Band_Calibration_List><Band_Calibration><Polynomial_Look_Angles><XLOS_(i)>
CoeffPsiY(i)	Polynomial line of sight model coefficients: TanPsiY = g(col –colref). <Geometric_Data><Refined_Model><Geometric_Calibration><Instrument_Calibration><Band_Calibration_List><Band_Calibration><Polynomial_Look_Angles><YLOS_(i)>
Col	Image column coordinate.
col_{ref}	Reference column for line of sight polynomial models. <Geometric_Data><Refined_Model><Geometric_Calibration><Instrument_Calibration><Band_Calibration_List><Band_Calibration><Swath_Range><FIRST_COL>
$E_o(b)$	The mean Top of Atmosphere (TOA) solar irradiance for the band (b) in W/m^2/micrometer. <Radiometric_Data><Radiometric_Calibration><Instrument_Calibration><Band_Measurement_List><{Band_Solar_Irradiance}><VALUE>
El_{sun}	The sun elevation angle <Geometric_Data><Use_Area><Located_Geometric_Values><Solar_Incidences><SUN_ELEVATION>
ERR_BIAS_LON	Error at 99.7% (corresponding to 3 * standard deviation) for the longitude (unit meter) between RPC model and physical model. <Rational_Function_Model><Global_RFM><ImagetoGroundValues><ERR_BIAS_LON>
ERR_BIAS_LAT	Error at 99.7% (corresponding to 3 * standard deviation) for the latitude (unit meter) between RPC model and physical model. <Rational_Function_Model><Global_RFM><ImagetoGroundValues><ERR_BIAS_LAT>

ERR_BIAS_COL	Error at 99.7% (corresponding to 3 * standard deviation) for the column (sample) (unit pixel) between RPC model and physical model. <Rational_Function_Model><Global_RFM><GroundtomageValues><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. <Rational_Function_Model><Global_RFM><GroundtomageValues><ERR_BIAS_ROW>
FIRST_COL **LAST_COL**	RPC validity domain for column image coordinate (sample). <Rational_Function_Model><RFM_Validity><ImagetoGround_Validity_Domain><…>
FIRST_ROW **LAST_ROW**	RPC validity domain for line image coordinate (row). <Rational_Function_Model><Global_RFM><RFM_Validity><ImagetoGround_Validity_Domain><…>
FIRST_LAT **LAST_LAT**	RPC validity domain for latitude coordinate. <Rational_Function_Model><Global_RFM><RFM_Validity><GroundtoImage_Validity_Domain><…>
FIRST_LON **LAST_LON**	RPC validity domain for longitude coordinate. <Rational_Function_Model><Global_RFM><RFM_Validity><GroundtoImage_Validity_Domain><…>
GAIN	A gain value. <Radiometric_Data><Radiometric_Calibration><Instrument_Calibration><Band_Measurement_List><{ Band_Radiance, Band_Reflectance, Band_Digital_Number }><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	The Incidence angle.
Lin	Image line coordinate.
lin_{ref}	Reference line to line-timing model.
lat, long	Geographic coordinates.
LAT_DEN_COEFF_i	Polynomial coefficients used to calculate the denominator (Q) in order to obtain centre-normalized latitude (i from 1 until 20). <Rational_Function_Model><Global_RFM><ImagetoGround><LAT_DEN_COEFF_i>
LAT_NUM_COEFF_i	Polynomial coefficients used to calculate the numerator (P) in order to obtain centre-normalized latitude (i from 1 until 20). <Rational_Function_Model><Global_RFM><ImagetoGround><LAT_NUM_COEFF_i>
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 line (i from 1 until 20). <Rational_Function_Model><Global_RFM><GroundtoImage_Values><LINE_DEN_COEFF_i>
LINE_NUM_COEFF_i	Polynomial coefficients used to calculate the numerator (P) in order to obtain centre-normalized line (i from 1 until 20). <Rational_Function_Model><Global_RFM><GroundtoImage_Values><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>
LON_DEN_COEFF_i	Polynomial coefficients used to calculate the denominator (Q) in order to obtain centre-normalized longitude (i from 1 until 20). <Rational_Function_Model><Global_RFM><ImagetoGround><LON_DEN_COEFF_i>
LON_NUM_COEFF_i	Polynomial coefficients used to calculate the numerator (P) in order to obtain centre-normalized longitude (i from 1 until 20). <Rational_Function_Model><Global_RFM><ImagetoGround><LON_NUM_COEFF_i>
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 $\vec{T} = \frac{\overrightarrow{Vit} \wedge \overrightarrow{Pos}}{\left\Vert \overrightarrow{Vit} \wedge \overrightarrow{Pos} \right\Vert}$)
R	Roll axis : $\vec{R} = \vec{T} \wedge \vec{L}$
L	Yaw axis (build with Satellite Position : $\vec{L} = -\frac{\overrightarrow{Pos}}{\left\Vert \overrightarrow{Pos} \right\Vert}$)
(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>
PIXEL_ORIGIN	Initialization pixel (image column) value with regard to values provided in the metadata file. <Geoposition><Raster_CRS><PIXEL_ORIGIN>
PosX(t) **PosY(t)** **PosZ(t)**	Satellite location at the given time.
PosX(t_i) **PosY(t_i)**	Satellite locations at different times 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 ($R_E \approx 6367{,}45$km).
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 column (i from 1 until 20). <Rational_Function_Model><Global_RFM><GroundtoImage_Values><SAMP_DEN_COEFF_i>
SAMP_NUM_COEFF_i	Polynomial coefficients used to calculate the numerator (P) in order to obtain centre-normalized column (i from 1 until 20). <Rational_Function_Model><Global_RFM><GroundtoImage_Values><SAMP_NUM_COEFF_i>
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.
α	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>
β	Incidence angle (°). <Geometric_Data><Use_Area><Located_Geometric_Values><Acquisition_Angles><INCIDENCE_ANGLE>
β_x	Incidence angle in the OrthoScan axis direction. <Geometric_Data><Use_Area><Located_Geometric_Values><Acquisition_Angles><INCIDENCE_ANGLE_ACROSS_TRACK>
β_y	Incidence angle in the Scan axis direction (image line axis on the ground). <Geometric_Data><Use_Area><Located_Geometric_Values><Acquisition_Angles><INCIDENCE_ANGLE_ALONG_TRACK>
θ_s	The sun zenith angle (sun zenith angle = 90°– sun elevation angle)
θ	Pitch angle.
ρ	Reflectance
φ	Roll angle.
ψ	Yaw angle.
ψ_x	Viewing direction angle in the Y_{Scan} direction (parallel to detector array).
ψ_y	Viewing direction angle in the X_{Scan} direction (parallel to image line axis).
Ω	Earth rotation angular speed.

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