PLANET IMAGERY PRODUCT SPECIFICATION

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Glossary

The following list defines terms used to describe Planet's satellite imagery products.

Alpha Mask

An alpha mask is an image channel with binary values that can be used to render areas of the image product transparent where no data is available.

Application Programming Interface (API)

A set of routines, protocols, and tools for building software applications

Bayer Mask Color Filter Array

The Bayer mask filters light reaching the CCD. At the time of image capture, each CCD photosensor measures one of the Red, Green, or Blue wavelengths. These values are interpolated to assign a red, green, and blue value to each image pixel.

Blackfill

Non-imaged pixels or pixels outside of the buffered area of interest that are set to black. They may appear as pixels with a value of "0" or as "noData" depending on the viewing software.

Charged-Coupled Device (CCD) Sensor

CCD sensors use capacitors to represent pixels. Each capacitor allows for the conversion of incoming photons into a digital number. CCD's are commonly used for the acquisition of professional, medical, and scientific imagery.

Digital Elevation Model (DEM)

A digital model of the elevation of the Earth's terrain surface relative to an ellipsoid. A DEM is used to remove terrain distortions from the imagery for the geo-corrected products.

Digital Number (DN)

The value assigned to a pixel in a digital image. This gray density value represents the intensity of reflected light from a feature collected by the sensor for a particular spectral range.

Dynamic Range

The number of possible DN values for each pixel in a band of an image.

GeoTIFF

Georeferenced tagged image file format. A GeoTIFF file is a version of the TIFF file format that contains embedded geographic positioning data.

Ground Control Point (GCP)

A point on the ground with known geographic coordinates. GCPs can be planimetric (latitude, longitude) or vertical (latitude, longitude, elevation). GCPs can be collected from ground survey, maps, or orthorectified imagery.

Ground Sample Distance (GSD)

The distance between pixel centers, as measured on the ground. It is mathematically calculated based on optical characteristics of the telescope, the altitude of the satellite, and the size and shape of the CCD sensor.

Graphical User Interface (GUI)

The web-based graphical user interfaces allows users to browse, preview and download Planet's imagery products.

International Space Station (ISS) Orbit

International Space Station (ISS) orbits at a 51.6°inclination at approximately 400 km altitude. Planet deploys satellites from the ISS, each having a similar orbit.

Metadata

Data delivered with Planet's imagery products that describes the products content and context and can be used to conduct analysis or further processing.

Mosaic

A composite of many individual images into a single layer.

Nadir

The point on the ground directly below the satellite.

Near-Infrared (NIR)

Near Infrared is a region of the electromagnetic spectrum.

Off-nadir Angle

The angle between the nadir point and the actual point on the ground where the satellite is pointed.

Orthorectification

The process of removing and correcting geometric image distortions introduced by satellite collection geometry, pointing error, and terrain variability.

Ortho Tile

Ortho Tiles are Planet's core product lines of high-resolution satellite images. Ortho tiles are available in two different product formats: Visual and Analytic , each offered in GeoTIFF format.

PlanetScope

The first three generations of Planet's optical systems are referred to as PlanetScope 0, PlanetScope 1, and PlanetScope 2.

Quad

A single square GeoTIFF, many of which together comprise a mosaic.

Radiometric Correction

The correction of variations in data that are not caused by the object or image being scanned. These include correction for relative radiometric response between detectors, filling non-responsive detectors and scanner inconsistencies.

RapidEye

RapidEye refers to the five-satellite constellation in operation since 2009.

Resolution

The resampled image pixel size derived from the GSD.

Revisit Time

The time interval between successive opportunities to image the same point on the Earth's surface.

Rational Polynomial Coefficient (RPC)

RPCs provide a generic geolocation model which, in combination with an elevation datasource, can be used to georeference or ortho-correct a Basic scene.

Sensor Correction

The correction of variations in the data that are caused by sensor geometry, attitude and ephemeris.

Sun Azimuth

The angle of the sun as seen by an observer located at the target point, as measured in a clockwise direction from the North.

Sun Elevation

The angle of the sun above the horizon.

Sun Synchronous Orbit (SSO)

A geocentric orbit that combines altitude and inclination in such a way that the satellite passes over any given point of the planet's surface at the same local solar time.

Swath Width

The width of the ground area that is recorded by one image acquisition.

Tile Grid System

Ortho tiles are based on a worldwide, fixed UTM grid system. The grid is defined in 24 km by 24 km tile centers, with 1 km of overlap (each tile has an additional 500 m overlap with adjacent tiles), resulting in 25 km by 25 km tiles. More details about the tile grid system in Appendix B.

Time Delayed Integration (TDI)

Time Delayed Integration (TDI) is an image capture technique that uses multiple stages of exposure combined into a single composite exposure.

1. OVERVIEW OF THIS DOCUMENT

This document describes Planet satellite imagery products. It is intended for users of satellite imagery interested in working with Planet's product offerings.

1.1. Company Overview

Planet uses an agile aerospace approach for the design of its satellites, mission control and operations systems; and the development of its web-based platform for imagery processing and delivery. Planet is a fully integrated company that designs, builds, and actively operates satellites while also delivering data to customers via a web-based platform. Planet employs an "always on" image-capturing method as opposed to the traditional tasking model used by most satellite companies today.

1.2. Data Product Overview

Planet operates the PlanetScope (PS) and RapidEye (RE) Earth-imaging constellations. Imagery is collected and processed in a variety of formats to serve different use cases, be it mapping, deep learning, disaster response, precision agriculture, or simple temporal image analytics to create rich information products.

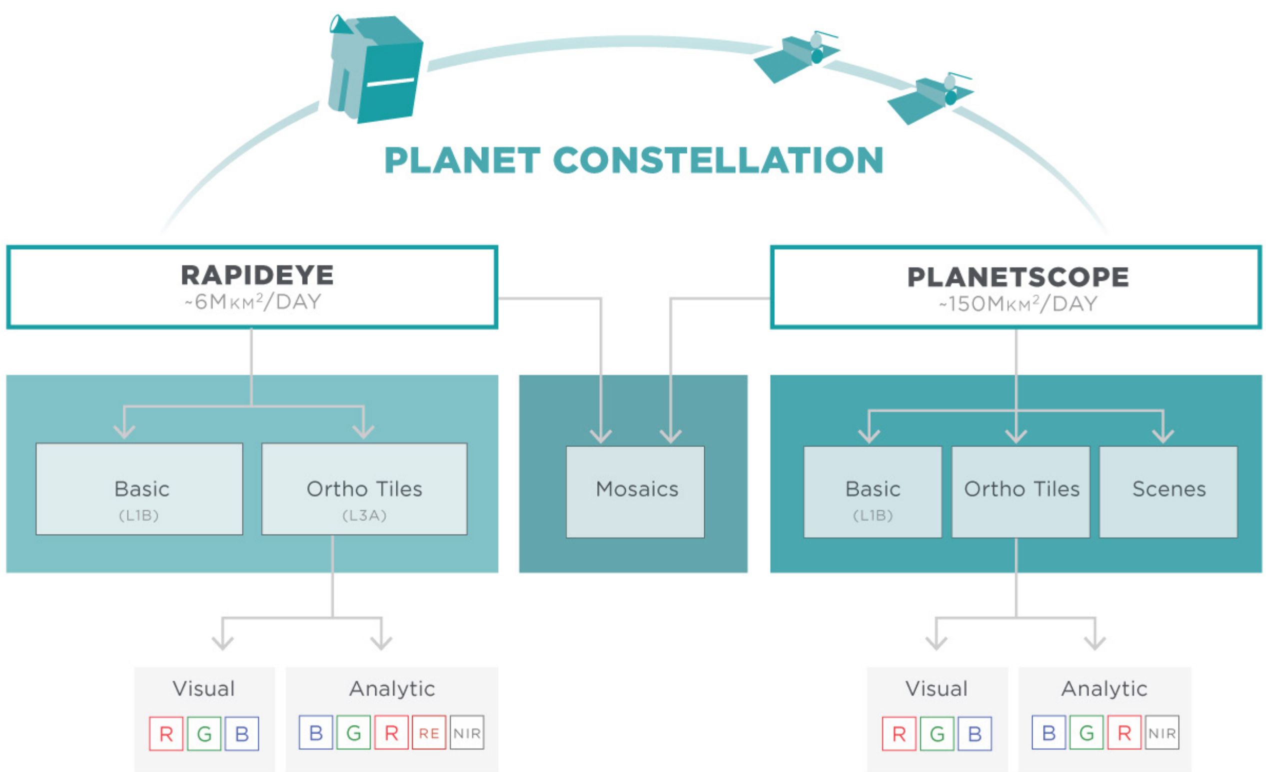
PlanetScope satellite imagery is captured as a continuous strip of single frame images known as "scenes." Scenes may be acquired as a single RGB (red, green, blue) frame or a split-frame with a RGB half and a NIR (near-infrared) half depending on the capability of the satellite.

Planet offers three product lines for PlanetScope imagery: a Scene product, an Ortho Tile product and a Basic product. Scenes represent the single-frame image captures as acquired by a PlanetScope satellite but with additional post processing. Ortho Tiles are multiple split-frame Scenes in a single strip that have been merged and then split according to a defined grid. The Basic product is not orthorectified or corrected for terrain distortions.

RapidEye satellite imagery is acquired using a push broom sensor that is capable of capturing strips in RGB, NIR and red-edge wavelengths. There are two product lines for RapidEye imagery: an Ortho Tile product and a Basic product. Ortho Tiles are built from strips that have been split according to a defined grid. The Basic product is not orthorectified or corrected for terrain.

More information on all these products may be found in Sections 3 and 4.

Figure A: Planet Imagery Product Offerings



All data will be available by 2017 through the Planet API and web-based Graphical User Interface (GUI) tool built on top of the API.

2. SATELLITE CONSTELLATIONS AND SENSOR OVERVIEW

2.1 PlanetScope Satellite Constellation and Sensor Characteristics

The PlanetScope satellite constellation consists of multiple launches of groups of individual satellites. Therefore, on-orbit capacity is constantly improving in capability or quantity, with technology improvements deployed at a rapid pace. Each PlanetScope satellite is a CubeSat 3U form factor (10 cm by 10 cm by 30 cm). The complete PlanetScope constellation of approximately 120 satellites will be able to image the entire Earth every day (equating to a daily collection capacity of 150 million km²/day).

Table A: PlanetScope Constellation and Sensor Specifications

Mission Characteristic	Sun Synchronous Orbit	International Space Station Orbit
Orbit Altitude (reference)	475 km (~98° inclination)	400 km (51.6° inclination)
Max/Min Latitude Coverage	±81.5° (depending on season)	±52°
Equator Crossing Time	9:30 - 11:30 am (local solar time)	Variable
Sensor Type	Three-band frame Imager or four-band frame Imager with a split-frame NIR filter	Three-band frame Imager or four-band frame Imager with a split-frame NIR filter
Spectral Bands	Blue 455 – 515 nm Green 500 – 590 nm Red 590 – 670 nm NIR 780 – 860 nm	Blue 455 – 515 nm Green 500 – 590 nm Red 590 – 670 nm NIR 780 – 860 nm
Ground Sampling Distance (nadir)	3.7 m (at reference altitude 475 km)	3.0 m (approx.)
Swath Width	24.6 km x 16.4 km (at reference altitude)	20 km x 16.4 km (at reference altitude)
Maximum Image Strip per orbit	20,000 km²	8,100 km²
Revisit Time	Daily at nadir (early 2017)	Variable
Image Capture Capacity	150 million km²/day (early 2017)	Variable
Camera Dynamic Range	12-bit	12-bit

Planet's image capture capacity forecasts are strongly driven by successful completion of launch. Launch manifests are subject to change.

2.2 RapidEye Satellite Constellation and Sensor Characteristics

The RapidEye satellite constellation consists of five satellites collectively able to collect over 6 million square kilometers of data per day at 6.5 meter GSD (at nadir). Each satellite measures less than one cubic meter and weighs 150 kg (bus + payload). All five satellites are equipped with identical sensors and are located in the same orbital plane.

Table B: RapidEye Constellation and Sensor Specifications

Mission Characteristic	Information
Number of Satellites	5
Orbit Altitude	630 km in Sun-Synchronous Orbit
Equator Crossing Time	11:00 am local time (approximately)
Sensor Type	Multispectral push broom imagery
Spectral Bands	Blue 440 – 510 nm Green 520 – 590 nm Red 630 – 685 nm Red Edge 690 – 730 nm NIR 760 – 850 nm
Ground Sampling Distance (nadir)	6.5 m
Swath Width	77 km
Maximum Image Strip per orbit	Up to 1500 km of image data per orbit
Revisit Time	Daily (off-nadir) / 5.5 days (at nadir)
Image Capture Capacity	>6 million km^2/day
Camera Dynamic Range	12-bit

3. PLANETSCOPE IMAGERY PRODUCTS

PlanetScope imagery products are available as either individual Scenes or as coregistered Basic or Ortho Tile products.

Table C: PlanetScope Satellite Image Product Processing Levels

Name	Description	Product Level
PlanetScope Scene Product	Radiometric and sensor corrections applied to the data. Imagery may either be orthorectified (Ortho Scenes) and projected to a UTM projection or un-orthorectified (Unrectified Scenes) projected to a WGS84 projection.	Ortho Scenes: Level 3 Unrectified Scenes: Level 1
PlanetScope Ortho Tile Product	Radiometric and sensor corrections applied to the data. Imagery is orthorectified and projected to a UTM projection.u	Level 3
PlanetScope Basic Productt	Radiometric and sensor corrections applied to the data.	Level 1

3.1 PlanetScope Scenes Product Specification

The PlanetScope Scene products refers to a single image as taken by one of the PlanetScope satellites. Scenes may either be orthorectified (Ortho Scenes) or un-orthorectified (Unrectified Scenes).

PlanetScope satellites collect imagery as a series of overlapping framed scenes, and the Ortho Scene products are not organized to any particular tiling grid system. The Ortho Scene products enable users to create seamless imagery by stitching together PlanetScope Ortho Scenes of their choice.

The PlanetScope Unrectified Scene product offers PlanetScope satellite imagery that is designed for advanced users who wish to perform their own orthorectification. The PlanetScope Unrectified products have been radiometrically- and sensor-corrected.

The PlanetScope Ortho Scene product offers PlanetScope satellite imagery that has been orthorectified. This product was designed for a wide variety of applications that require imagery with an accurate geolocation and cartographic projection. It has been processed to remove distortions caused by terrain and can be used for cartographic purposes. They are delivered as visual (RGB) and analytic products. Ortho Scenes are radiometrically-, sensor-, and geometrically-corrected and aligned to a cartographic map projection. The geometric correction uses fine DEMs with a post spacing of between 30 and 90 meters.

Ground Control Points (GCPs) are used in the creation of every image and the accuracy of the product will vary from region to region based on available GCPs.

Table D: PlanetScope Scene Product Attributes

Product Attribute	Description
Product Components and Format	PlanetScope Scene product consists of the following file components: • Image File – GeoTIFF file that contains image data and geolocation information • Metadata File – GeoJSON metadata available • Thumbnail File – PNG/JPEG format
Product Orientation	Map North up
Product Framing	N/A
Bit Depth	Visual: 8-bit | Analytic: 12-bit | Unrectified: 12-bit
Product Size	Nominal tile size is approximately 24 km by 8 km, but varies by altitude.
Geometric Corrections	Sensor-related effects are corrected using sensor telemetry and a sensor model. Orthorecti-fication uses GCPs and fine DEMs (30 m to 90 m posting).
Horizontal Datum	WGS84
Map Projection	UTM
Resampling Kernel	Cubic Convolution

3.1.1 PlanetScope Visual Ortho Scene Product Specification

The PlanetScope Visual Ortho Scene product is orthorectified and color-corrected (using a color curve). This correction attempts to optimize colors as seen by the human eye providing images as they would look if viewed from the perspective of the satellite. It has been processed to remove distortions caused by terrain and can be used for cartographic mapping and visualization purposes. It eliminates the perspective effect on the ground (not on buildings), restoring the geometry of a vertical shot. Additionally, a correction is made to the sun angle in each image to account for differences in latitude and time of acquisition.

The Visual Ortho Scene product is optimal for simple and direct use of the image. It is designed and made visually appealing for a wide variety of applications that require imagery with an accurate geolocation and cartographic projection. The product can be used and ingested directly into a Geographic Information System.

Table E: PlanetScope Visual Ortho Scene Product Attributes

Product Attribute	Description
Information Content	
Visual Bands	3-band natural color (red, green, blue)
Ground Sample Distance	3.7 m (at reference altitude 475 km)
Processing	
Pixel Size (orthorectified)	3 m
Bit Depth	8-bit
Geometric Corrections	Sensor-related effects are corrected using sensor telemetry and a sensor model. Space-craft-related effects are corrected using attitude telemetry and best available ephemeris data. Orthorectified using GCPs and fine DEMs (30 m to 90 m posting) to <10 m RMSE positional accuracy.
Positional Accuracy	Less than 10 m RMSE
Color Enhancements	Enhanced for visual use and corrected for sun angle

3.1.2 PlanetScope Analytic Ortho Scene Product Specification

The PlanetScope Analytic Ortho Scene product is orthorectified, multispectral data from the satellite constellation. Analytic products are calibrated multispectral imagery products that have been processed to allow analysts to derive information products for data science and analytics. This product is designed for a wide variety of applications that require imagery with an accurate geolocation and cartographic projection. It has been processed to remove distortions caused by terrain and can be used for many data science and analytic applications. It eliminates the perspective effect on the ground (not on buildings), restoring the geometry of a vertical shot. The orthorectified analytic scene is optimal for value-added image processing such as land cover classifications. In addition to orthorectification, the imagery has radiometric corrections applied to correct for any sensor artifacts and transformation to at-sensor radiance.

Table F: PlanetScope Analytic Ortho Scene Product Attributes

Product Attribute	Description
Information Content	
Analytic Bands	3-band natural color (red, green, blue).
Ground Sample Distance	3.7 m (at reference altitude 475 km)
Processing	
Pixel Size (orthorectified)	3 m
Bit Depth	12-bit

Product Attribute	Description
Geometric Corrections	Sensor-related effects are corrected using sensor telemetry and a sensor model. Spacecraft-related effects are corrected using attitude telemetry and best available ephemeris data. Orthorectified using GCPs and fine DEMs (30 m to 90 m posting) to <10 m RMSE positional accuracy..
Positional Accuracy	Less than 10 m RMSE
Radiometric Calibration Accuracy	Initial availability • No correction applied • Pixel values are digital numbers

3.1.3 PlanetScope Unrectified Scene Product Specification

The PlanetScope Unrectified Scene product is a minimally processed version of the available PlanetScope Ortho Scene imagery products. This product is designed for customers with advanced image processing capabilities and a desire to geometrically correct the product themselves. This product line is available in the GeoTIFF format.

The PlanetScope Unrectified Scene product is radiometric and sensor corrected, providing imagery as seen from the spacecraft without correction for any geometric distortions inherent in the imaging process, and is not mapped to a cartographic projection. The imagery data is accompanied by RPCs to enable orthorectification by the user.

The radiometric corrections applied to this product are:

- Correction of relative differences of the radiometric response between detectors
- Non-responsive detector filling which fills nulls values from detectors that are no longer responding

The geometric sensor corrections applied to this product correct for:

- Optical distortions caused by sensor optics
- Co-registration of bands

Table G: PlanetScope Unrectified Scene Product Attributes

Product Attribute	Description
Information Content	
Analytic Bands	3-band natural color (red, green, blue).
Ground Sample Distance	3.7 m (at reference altitude 475 km)
Processing	
Pixel Size (orthorectified)	3 m
Bit Depth	12-bit
Positional Accuracy	Less than 10 m RMSE
Radiometric Calibration Accuracy	Initial availability • No correction applied • Pixel values are digital numbers
Map Projection	WGS84

3.2 PlanetScope Ortho Tile Product Specification

The PlanetScope Ortho Tile products offer PlanetScope Satellite imagery orthorectified as individual 25 km by 25 km tiles referenced to a fixed, standard image tile grid system. This product was designed for a wide variety of applications that require imagery with an accurate geolocation and cartographic projection. It has been processed to remove distortions caused by terrain and can be used for cartographic purposes.

For PlanetScope split-frame satellites, imagery is collected as a series of overlapping framed scenes from a single satellite in a single pass. These scenes are subsequently orthorectified and an ortho tile is then generated from a collection of consecutive scenes, typically 4 to 5. The process of conversion of framed scene to ortho tile is outlined in the figure below.

The PlanetScope Ortho Tile products are radiometrically-, sensor-, and geometrically-corrected and aligned to a cartographic map projection. The geometric correction uses fine DEMs with a post spacing of between 30 and 90 meters. Ground Control Points (GCPs) are used in the creation of every image and the accuracy of the product will vary from region to region based on available GCPs.

Figure B: PlanetScope Scene to Ortho Tile Conversion

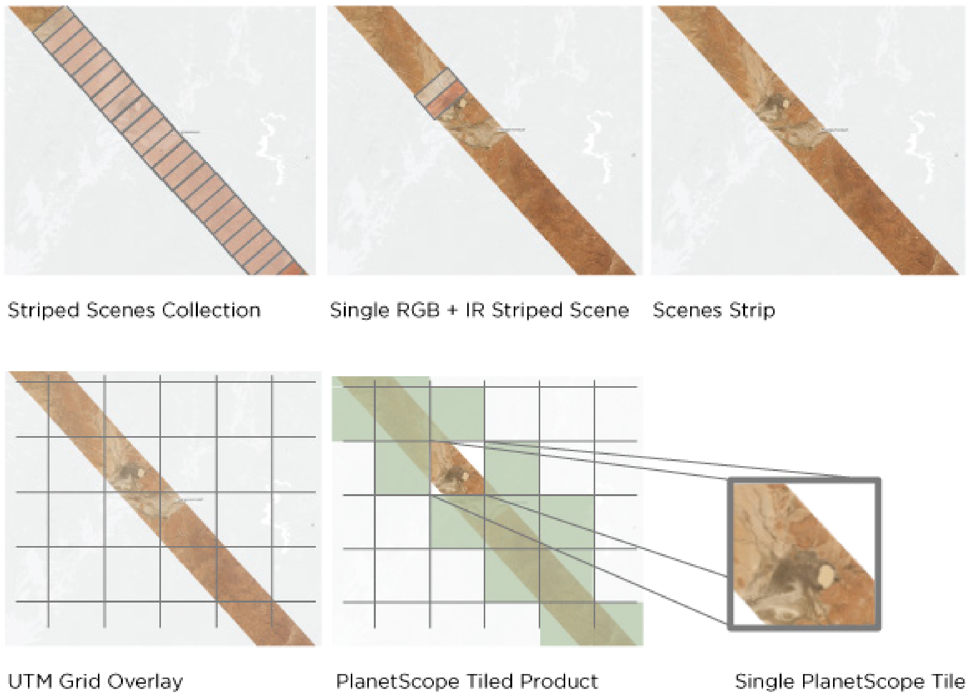


Table H: PlanetScope Ortho Tile Product Attributes

Product Attribute	Description
Product Components and Format	PlanetScope Ortho Tile product consists of the following file components: • Image File – GeoTIFF file that contains image data and geolocation information • Metadata File – XML format metadata file and GeoJSON metadata available • Thumbnail File – GeoTIFF format • Unusable Data Mask (UDM) file – GeoTIFF format
Product Orientation	Map North up
Product Framing	PlanetScope ortho tiles are based on a worldwide, fixed UTM grid system. The grid is defined in 24 km by 24 km tile centers, with 1 km of overlap (each tile has an additional 500 m overlap with adjacent tiles), resulting in 25 km by 25 km tiles. More details about the Planet API in Section 8 and the tile grid system in Appendix B .
Pixel Size (orthorectified)	3.125 m
Bit Depth	16-bit unsigned integers
Product Size	Tile size is 25 km (8000 lines) by 25 km (8000 columns). 5 to 500 Mbytes per Tile for 4 bands at 3.125 m pixel size after orthorectification.
Geometric Corrections	Sensor-related effects are corrected using sensor telemetry and a sensor model. Orthorectified using GCPs and fine DEMs (30 m to 90 m posting).

Product Attribute	Description
Horizontal Datum	WGS84
Map Projection	UTM
Resampling Kernel	Cubic Convolution

3.2.1 PlanetScope Visual Ortho Tile Product Specification

The PlanetScope Visual Ortho Tile product is orthorectified and color-corrected (using a color curve). This correction attempts to optimize colors as seen by the human eye providing images as they would look if viewed from the perspective of the satellite. It has been processed to remove distortions caused by terrain and can be used for cartographic mapping and visualization purposes. It eliminates the perspective effect on the ground (not on buildings), restoring the geometry of a vertical shot. Additionally, a correction is made to the sun angle in each image to account for differences in latitude and time of acquisition.

The Visual product is optimal for simple and direct use of the image. It is designed and made visually appealing for a wide variety of applications that require imagery with an accurate geolocation and cartographic projection. The product can be used and ingested directly into a Geographic Information System.

Table I: PlanetScope Visual Ortho Tile Product Attributes

Product Attribute	Description
Information Content	
Visual Bands	3-band natural color (red, green, blue).
Ground Sample Distance	3.7 m (at reference altitude 475 km)
Processing	
Pixel Size (orthorectified)	3.125 m
Bit Depth	8-bit
Geometric Corrections	Sensor-related effects are corrected using sensor telemetry and a sensor model, bands are co-registered, and spacecraft-related effects are corrected using attitude telemetry and best available ephemeris data. Orthorectified using GCPs and fine DEMs (30 m to 90 m posting) to <10 m RMSE positional accuracy..
Positional Accuracy	Less than 10 m RMSE
Color Enhancements	Enhanced for visual use and corrected for sun angle

3.2.2 PlanetScope Analytic Ortho Tile Product Specification

The PlanetScope Analytic Ortho Tile product is orthorectified, multispectral data from the satellite constellation. Analytic products are calibrated multispectral imagery products that have been processed to allow analysts to derive information products for data science and analytics. This product is designed for a wide variety of applications that require imagery with an accurate geolocation and cartographic projection. It has been processed to remove distortions caused by terrain and can be used for many data science and analytic applications. It eliminates the perspective effect on the ground (not on buildings), restoring the geometry of a vertical shot. The orthorectified visual imagery is optimal for value-added image processing including vegetation indices, land cover classifications, etc. In addition to orthorectification, the imagery has radiometric corrections applied to correct for any sensor artifacts and transformation to at-sensor radiance.

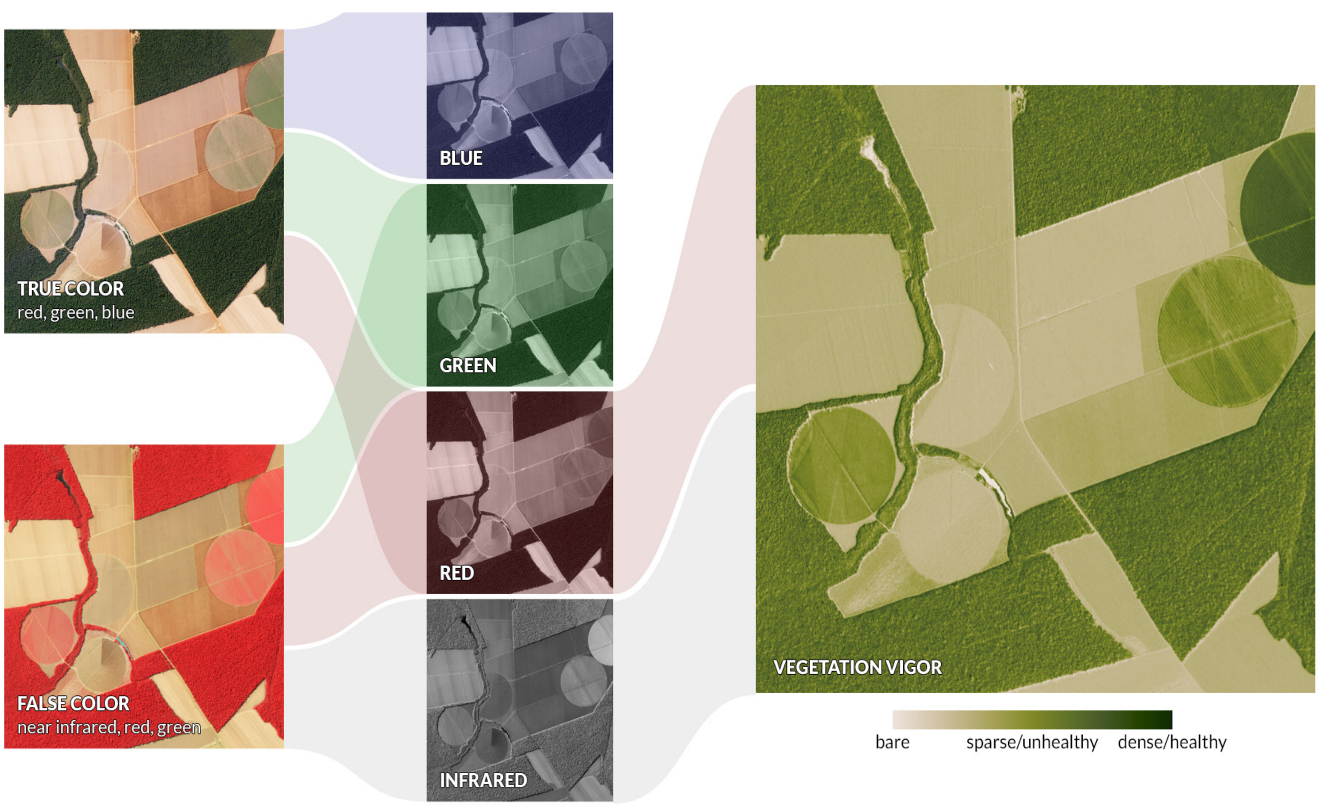
Given the 3.125 m product resolution, the daily revisit cycle, and multispectral bands, users are enabled to perform advanced analytics, this imagery can be used to check the health of agricultural fields, the latest update on a natural disaster, burn scar assessment, or the progression of deforestation.

Figure C: PlanetScope Analytic Ortho Tiles with RGB (left) and NIR False-Color Composite (right)

Table J: PlanetScope Analytic Ortho Tile Product Attributes

Product Attribute	Description
Information Content	
Analytic Bands	4-band multispectral image (blue, green, red, near-infrared).
Ground Sample Distance	3.7 m (at reference altitude 475 km)
Processing	
Pixel Size (orthorectified)	3.125 m
Bit Depth	16-bit
Geometric Corrections	Sensor-related effects are corrected using sensor telemetry and a sensor model, bands are co-registered, and spacecraft-related effects are corrected using attitude telemetry and best available ephemeris data. Orthorectified using GCPs and fine DEMs (30 m to 90 m posting) to <10 m RMSE positional accuracy.
Positional Accuracy	Less than 10 m RMSE
Radiometric Calibration Accuracy	Initial availability • No correction applied • Pixel values are digital numbers

Figure D: PlanetScope Analytic Bands



3.3 PlanetScope Basic Product Specification

The PlanetScope Basic product is the least processed of the available PlanetScope imagery products. This product is designed for customers with advanced image processing capabilities and a desire to geometrically correct the product themselves. This product line will be introduced in September of 2016, and will be available in the GeoTIFF format.

The PlanetScope Basic product is radiometric and sensor corrected, providing imagery as seen from the spacecraft without correction for any geometric distortions inherent in the imaging process, and is not mapped to a cartographic projection. The imagery data is accompanied by RPCs to enable orthorectification by the user.

The radiometric corrections applied to this product are:
- Correction of relative differences of the radiometric response between detectors
- Non-responsive detector filling which fills nulls values from detectors that are no longer responding

The geometric sensor corrections applied to this product correct for:
- Optical distortions caused by sensor optics
- Co-registration of bands

4. RAPIDEYE IMAGERY PRODUCTS

RapidEye imagery products are available in two different processing levels to be directly applicable to customer needs.

Table K: RapidEye Satellite Image Product Processing Levels

Name	Description	Product Level
RapidEye Ortho Tile Product	Radiometric and sensor corrections applied to the data.Imagery is orthorectified using the RPCs and an elevation model	Level 3A (L3A)
RapidEye Basic Product	Radiometric and sensor corrections applied to the data. Onboard spacecraft attitude and ephemeris applied to the data.	Level 1B(L1B)

4.1 RapidEye Ortho Tiles Product Specification

The RapidEye Ortho Tile products offer RapidEye Satellite imagery orthorectified as individual 25 km by 25 km tiles. This product was designed for a wide variety of applications that require imagery with an accurate geolocation and cartographic projection. It has been processed to remove distortions caused by terrain and can be used for many cartographic purposes.

The RapidEye Ortho Tile products are radiometrically-, sensor- and geometrically-corrected and aligned to a cartographic map projection. The geometric correction uses fine DEMs with a post spacing of between 30 and 90 meters. Ground Control Points (GCPs) are used in the creation of every image and the accuracy of the product will vary from region to region based on available GCPs. RapidEye Ortho Tile products are output as 25 km by 25 km tiles referenced to a fixed, standard RapidEye image tile grid system.

Table L: RapidEye Ortho Tile Product Attributes

Product Attribute	Description
Product Components and Format	RapidEye Ortho Tile product consists of the following file components: • Image File – GeoTIFF file that contains image data and geolocation information • Metadata File – XML format metadata file and GeoJSON metadata • Thumbnail File – GeoTIFF format • Unusable Data Mask (UDM) file – GeoTIFF format
Product Orientation	Map North up
Product Framing	RapidEye ortho tiles are based on a worldwide, fixed UTM grid system. The grid is defined in 24 km by 24 km tile centers, with 1 km of overlap (each tile has an additional 500 m overlap with adjacent tiles), resulting in 25 km by 25 km tiles. More details about the Planet API in Section 8 and the tile grid system in Appendix B .
Pixel Size (orthorectified)	5 m

Product Attribute	Description
Bit Depth	16-bit unsigned integers
Product Size	Tile size is 25 km (5000 lines) by 25 km (5000 columns). 250 Mbytes per Tile for 5 bands at 5 m pixel size after orthorectification.
Geometric Corrections	Sensor-related effects are corrected using sensor telemetry and a sensor model, bands are co-registered, and spacecraft-related effects are corrected using attitude telemetry and best available ephemeris data. Orthorectified using GCPs and fine DEMs (30 m to 90 m posting).
Horizontal Datum	WGS84
Map Projection	UTM
Resampling Kernel	Cubic Convolution

4.1.1 RapidEye Visual Ortho Tile Product Specification

The RapidEye Visual Ortho Tile product is orthorectified and color-corrected (using a color curve). This correction attempts to optimize colors as seen by the human eye providing images as they would look if viewed from the perspective of the satellite. It has been processed to remove distortions caused by terrain and can be used for cartographic mapping and visualization purposes. It eliminates the perspective effect on the ground (not on buildings), restoring the geometry of a vertical shot. Additionally, a correction is made to the sun angle in each image to account for differences in latitude and time of acquisition.

The Visual product is optimal for simple and direct use of the image. It is designed and made visually appealing for a wide variety of applications that require imagery with an accurate geolocation and cartographic projection. The product can be used and ingested directly into a Geographic Information System.

Below is a sample of a RapidEye ortho tile:

Figure E: RapidEye Visual Ortho Tile

Table M: RapidEye Visual Ortho Tile Product Attributes

Product Attribute	Description
Information Content	
Visual Bands	3-band natural color (red, green, blue)
Processing	
Pixel Size (orthorectified)	5 m
Geometric Corrections	Sensor-related effects are corrected using sensor telemetry and a sensor model, ban are co-registered, and spacecraft-related effects are corrected using attitude telemetry and best available ephemeris data. Orthorectified using GCPs and fine DEMs (30 m to 90 m posting) to <10 m RMSE positional accuracy.
Positional Accuracy	Less than 10 m RMSE
Radiometric Corrections	• Correction of relative differences of the radiometric response between detectors • Non-responsive detector filling which fills nulls values from detectors that are no longer responding • Conversion to absolute radiometric values based on calibration coefficients
Color Enhancements	Enhanced for visual use and corrected for sun angle

4.1.2 RapidEye Analytic Ortho Tile Product Specification

The RapidEye Analytic Ortho Tile product is orthorectified, multispectral data from the RapidEye satellite constellation. This product is designed for a wide variety of applications that require imagery with an accurate geolocation and cartographic projection. It has been processed to remove distortions caused by terrain and can be used for many data science and analytic applications. It eliminates the perspective effect on the ground (not on buildings), restoring the geometry of a vertical shot. The orthorectified visual imagery is optimal for value-added image processing including vegetation indices, land cover classifications, etc. In addition to orthorectification, the imagery has radiometric corrections applied to correct for any sensor artifacts and transformation to at-sensor radiance.

Table N: RapidEye Analytic Ortho Tile Product Attributes

Product Attribute	Description
Information Content	
Analytic Bands	5-band multispectral image (blue, green, red, red edge, near-infrared)
Processing	
Pixel Size (orthorectified)	5 m
Bit Depth	16-bit
Geometric Corrections	Sensor-related effects are corrected using sensor telemetry and a sensor model, bands are co-registered, and spacecraft-related effects are corrected using attitude telemetry and best available ephemeris data. Orthorectified using GCPs and fine DEMs (30 m to 90 m posting) to <10 m RMSE positional accuracy.
Positional Accuracy	Less than 10 m RMSE
Radiometric Corrections	• Correction of relative differences of the radiometric response between detectors • Non-responsive detector filling which fills nulls values from detectors that are no longer responding • Conversion to absolute radiometric values based on calibration coefficients

4.2 RapidEye Basic Product Specification

The RapidEye Basic product is the least processed of the available RapidEye imagery products. This product is designed for customers with advanced image processing capabilities and a desire to geometrically correct the product themselves. This product line will be available in the Planet Platform in early 2017, and will be available in GeoTIFF and NITF formats.

The RapidEye Basic product is radiometrically- and sensor-corrected, providing imagery as seen from the spacecraft without correction for any geometric distortions inherent in the imaging process, and is not mapped to a cartographic projection. The imagery data is accompanied by all spacecraft telemetry necessary for the processing of the data into a geo-corrected form, or when matched with a stereo pair, for the generation of digital elevation data. Resolution of the images is 6.5 meters GSD at nadir. The images are resampled to a coordinate system defined by an idealized basic camera model for band alignment.

The radiometric corrections applied to this product are:

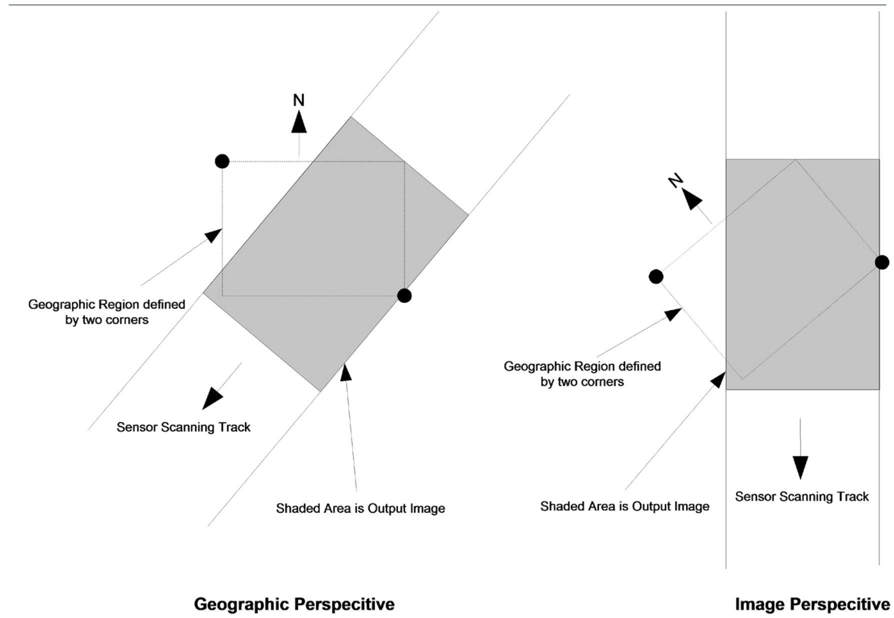
- Correction of relative differences of the radiometric response between detectors
- Non-responsive detector filling which fills null values from detectors that are no longer responding
- Conversion to absolute radiometric values based on calibration coefficients

The geometric sensor corrections applied to this product correct for:

- Internal detector geometry which combines the two sensor chipsets into a virtual array
- Optical distortions caused by sensor optics
- Registration of all bands together to ensure all bands line up with each other correctly

The table below lists the product attributes for the RapidEye Basic product.

Table O: RapidEye Basic Product Attributes

Product Attribute	Description
Product Components and Format	RapidEye Basic product consists of the following file components: • Image File – Image product delivered as a group of single-band NITF or GeoTIFF files with associated RPC values. Bands are co-registered. • Metadata File – XML format metadata file. Metadata file contains additional information related to spacecraft attitude, spacecraft ephemeris, spacecraft temperature measurements, line imaging times, camera geometry, and radiometric calibration data. • Thumbnail File – GeoTIFF format • Unusable Data Mask (UDM) file – GeoTIFF format
Product Orientation	Spacecraft/sensor orientation
Product Framing Geographic based framing – a geographic region is defined by two corners. The product width is close to the full image swath as observed by all bands (77 km at nadir, subject to minor trimming of up to 3 km during processing) with a product length	
Ground Sample Distance (nadir)	6.5 m
Bit Depth	16-bit unsigned integers
Pixel Size (orthorectified)	Variable number of pixels (less than 11980 per line) and up to a maximum of 46154 lines per band. 462 Mbytes/25 km along track for 5 bands. Maximum 5544 Mbytes.
Geometric Corrections	Idealized sensor, orbit and attitude models. Bands are co-registered.
Horizontal Datum	WGS84
Map Projection	N/A
Resampling Kernel	Cubic Convolution

5. PRODUCT PROCESSING

5.1 PlanetScope Processing

Several processing steps are applied to PlanetScope analytic imagery products, listed below. For analytic products, we expect to have an Radiance product which accounts for nominalization in early Q3 2016.

- Darkfield/Offset Correction : Corrects for sensor bias and dark noise. Master offset tables are created by averaging on-orbit darkfield collects across 5-10 degree temperature bins and applied to scenes during processing based on the CCD temperature at acquisition time.

- Flat field Correction : Flat fields are collected for each optical instrument prior to launch. These fields are used to correct image lighting and CCD element effects to match the optimal response area of the sensor.

- Camera Acquisition Parameter Correction : Determines a common radiometric response for each image (regardless of exposure time, TDI, gain, camera temperature and other camera parameters).

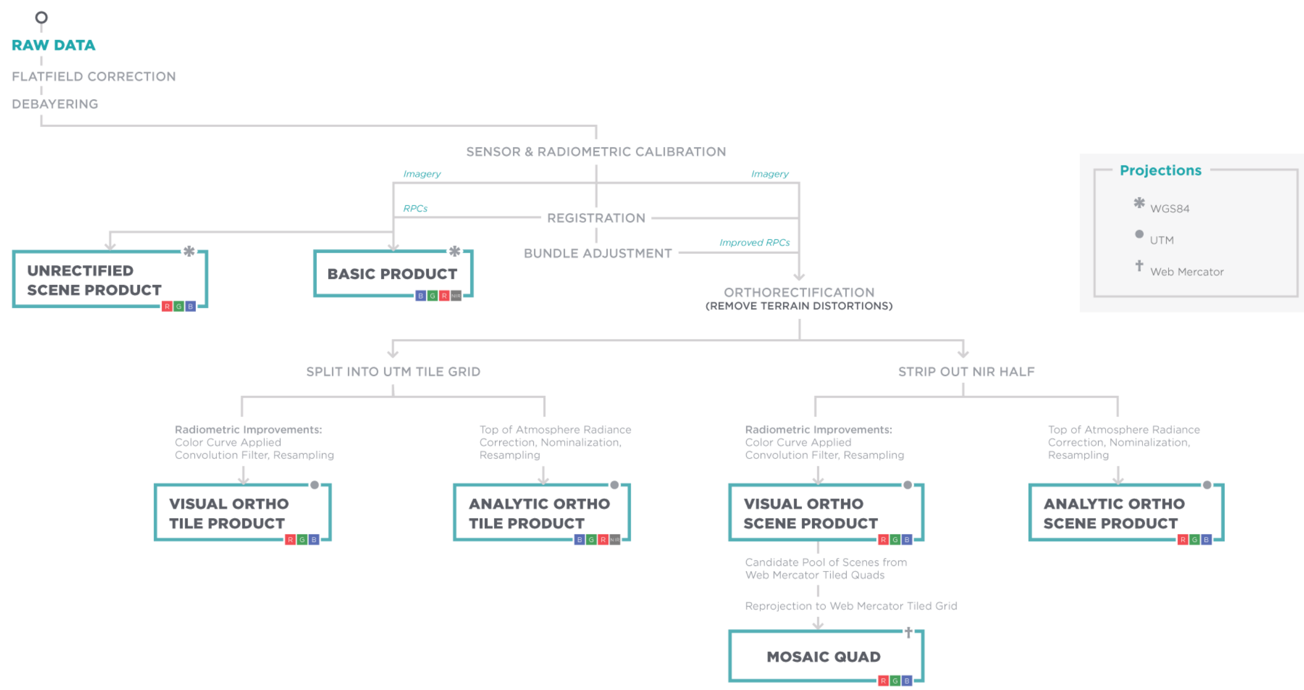
- Absolute Calibration : as a last step the spatially and temporally adjusted datasets are transformed from digital number values into physical based radiance values (scaled to $W/(m^2*str*\mu m)*100$).

- Visual Product Processing : Presents the imagery as natural color, optimize colors as seen by the human eye. This process is broken down into 4 steps:
    - Flat fielding applied to correct for vignetting.
    - Nominalization - Sun angle correction, to account for differences in latitude and time of acquisition. This makes the imagery appear to look like it was acquired at the same sun angle by converting the exposure time to the nominal time (noon).
    - Unsharp mask (sharpening filter) applied before the warp process.
    - Custom color curve applied post warping.

- Orthorectification : Removes terrain distortions. This process is broken down into 2 steps:
    - The rectification tiedown process wherein tie points are identified across the source images and a collection of reference images (NAIP, OSM, Landsat, ALOS) and RPCs are generated
    - The actual orthorectification of the scenes using the RPCs, to remove terrain distortions. The terrain model used for the orthorectification process is derived from multiple sources (SRTM, Intermap, and other local elevation datasets) which are periodically updated. Snapshots of the elevation datasets used are archived (helps in identifying the DEM that was used for any given scene at any given point.

The figure below illustrates the processing chain and steps involved to generate each of Planet's imagery products. Each processing step is detailed in Section 6.

Figure F: PlanetScope Image Processing Chain



5.2 RapidEye Processing

For RapidEye analytic imagery products, the processing steps are listed below:

- Flat Field Correction (also referred to as spatial calibration) : Correction parameters to achieve the common response of all CCD element when exposed to the same amount of light have been collected for each optical instrument prior to launch. During operations, these corrections are adjusted on an as-needed basis when effects become visible or measurable using side slither or statistical methods. This step additionally involves statistical adjustments of the read-out channel gains and offsets on a per image basis.

- Temporal Calibration: Corrections are applied so that all RapidEye cameras read the same DN (digital number) regardless of when the image has been taken in the mission lifetime. Additionally with this step a cross calibration between all spacecraft is achieved.

- Absolute Calibration: as a last step the spatially and temporally adjusted datasets are transformed from digital number values into physical based radiance values (scaled to $W/(m^2*str*\mu m)*100$).

- Visual Product Processing : Presents the imagery as natural color, optimize colors as seen by the human eye. This process is broken down into 4 steps:
  - Flat fielding applied to correct for vignetting.
  - Nominalization - Sun angle correction, to account for differences in latitude and time of acquisition. This makes the imagery appear to look like it was acquired at the same sun angle by converting the exposure time to the nominal time (noon).
  - Unsharp mask (sharpening filter) applied before the warp process.
  - Custom color curve applied post warping.

- Orthorectification : Removes terrain distortions. This process is broken down into 2 steps:
  - The rectification tiedown process wherein tie points are identified across the source images and a collection of reference images (NAIP, OSM, Landsat, ALOS) and RPCs are generated.
  - The actual orthorectification of the scenes using the RPCs, to remove terrain distortions. The terrain model used for the orthorectification process is derived from multiple sources (SRTM, Intermap, and other local elevation datasets) which are periodically updated. Snapshots of the elevation datasets used are archived (helps in identifying the DEM that was used for any given scene at any given point.

6. IMAGERY QUALITY ATTRIBUTES

6.1 Product Geometric Positional Accuracy

The locational accuracy of all the imagery products depends on the quality of the reference data used (GCPs and DEMs). Additionally, the roll angle of the spacecraft during the image acquisition and the number as well as the distribution of GCPs within the image will impact the final product accuracy.

All ortho tiles are orthorectified using high resolution control image raster data, a global DEM which is generated from a variety of elevation sources. Orthorectification results are less than 10 m RMSE accuracy.

6.2 Cloud Cover

PlanetScope

The cloud estimation for PlanetScope is based off of the expected luminosity of pixels for a given time of year. A historical per-pixel database has been built from the Landsat 8 archive. If the luminosity of a PlanetScope pixel is significantly higher than expected for that time of year, the pixel is marked as 'cloudy'.

This method is fast and simple, but has limitations:
1. If a region may be covered by snow at a given time of year, clouds are much less likely to be identified.
2. Darker clouds are less likely to be identified. This includes both thin clouds and self-shadowed clouds.
3. Brighter areas, such as desert surfaces, sands, and salt flats, are less likely to be identified as containing clouds.
4. Specular reflection and noon local time are more likely to be marked as clouds.

RapidEye

Cloud detection for the RapidEye satellite imagery products is done at two different stages of image processing with the results being used to create the Unusable Data Mask (UDM) file that accompanies every image product (see Appendix A for a detailed description of the UDM file). The two stages in the processing chain where the cloud cover is determined are:

1. **Cataloging** : For each acquired image received on the ground, the system performs a cloud detection and provides an Unusable Data Mask (UDM) for each tile in the image (see Appendix B for a description of the tile grid system); the result of this assessment is used to determine whether each tile can be accepted or whether a new collection is required and the area re-tasked.
2. **Processing** : For each product generated, the system performs cloud detection and produces a UDM file for that product. This is provided to the Customer as part of the Image Support Data (ISD) metadata files.

The cloud cover algorithm used in the RapidEye processing system has been specifically developed for RapidEye imagery and detects clouds based on complex pattern recognition algorithms which use information from all available spectral bands. This cloud cover algorithm is an improvement over previous versions and further improvements are being pursued on an ongoing basis.

This cloud detection technique has a number of known limitations:

1. Haze and cloud shadow are not reported.
2. Snow/ice may be incorrectly classified as clouds.
3. Overly bright surfaces, such as some desert surfaces, sands and salt flats.
4. “Darker” and/or smaller “popcorn” clouds may be undetected.

Due to the vast amount of imagery collected on a daily basis, the cloud detection in both stages is the result of a fully automatic process and thus there is no “manual” quality control of the UDMs.

6.3 Band Co-Registration

PlanetScope

The RGB and the NIR “stripes” are 2 separate acquisitions (approximately 0.5 seconds apart). The imagery is first rectified to the ground and any adjacent rectified scenes with high accuracy. All tiepoints from this rectification solution (geographic and image coordinate tuples) are saved for future use, typically ~4,000 tiepoints to the ground and as many to each adjacent image. After all scenes in a complete strip (roughly 1,000 acquisitions depending on landmass extent) are individually rectified, all of the metadata files are loaded into a single non-linear solver program, along with the corresponding RPCs. Using the RPCs and the tiepoint files, the solver can calculate cost functions for both ground error and adjacency error simultaneously for all scenes being considered.

Using the constructed cost functions, the program is then able to quickly perform an operation similar to bundle adjustment over all scenes in a strip, optimizing for ground alignment and band co-registration. If one is familiar with the traditional bundle adjustment workflow, think of it as replacing the camera models with RPC equations, with the added benefit of ground tiepoints. The non-linear solver package that is used (Ceres) was actually designed for true bundle adjustment work.

RapidEye

The focal plane of the RapidEye sensors is comprised of five separate CCD arrays, one for each band. This means that the bands have imaging time differences of up to three seconds for the same point on the ground, with the blue and red bands being the furthest apart in time. During processing, every product is band co-registered using a DEM to roughly correlate the bands to the reference band (Red Edge); a final alignment is done using an auto-correlation approach between the bands. For areas where the slope is below 10°, the band co-registration should be within 0.2 pixels or less (1-sigma). For areas with a slope angle of more than 10° and/or areas with very limited image structure (e.g. sand dunes, water bodies, areas with significant snow cover) the co-registration threshold mentioned above may not be met.

The separation between the RapidEye spectral bands leads to some effects that can be seen in the imagery. In a regular RapidEye scene with clouds, the cloud may show a red-blue halo around the main cloud. This is due to the Red and Blue bands being furthest apart on the sensor array, and the cloud moving during the imaging time between the two bands. Also, clouds are not reflected within the DEM which may lead to mis-registration. The same effect is visible for jet exhaust trails and flying planes. Bright vehicles moving on the ground will also look like colored streaks due to the image time differences.

6.4 Radiometry and Radiometric Accuracy

PlanetScope

Significant effort is made to ensure radiometric image product quality of all PlanetScope Satellite Imagery Products. This is achieved through a vigorous sensor calibration concept that is based on lab calibration, regular checks of the statistics from all incoming image data, acquisitions over selected temporal calibration sites, and absolute ground calibration campaigns.

The current product release will include calibrated radiance values using a limited set of pre-launch calibration data in the Analytic Ortho Tiles. This preview release is intended to expose users to the format of the radiance product. Our objective is to keep the calibration accuracy of the PlanetScope constellation consistent over time with on-orbit calibration techniques.

RapidEye

Significant effort is made to ensure radiometric image product quality of all RapidEye Satellite Imagery Products. This is achieved through a vigorous sensor calibration concept that is based on regular checks of the statistics from all incoming image data, acquisitions over selected temporal calibration sites, and absolute ground calibration campaigns.

The long term stability and inter-comparability among all five satellites is done by monitoring all incoming image data, along with frequent acquisitions from a number of calibration sites located worldwide. Statistics from all collects are used to update the gain and offset tables for each satellite. These statistics are also used to ensure that each band is within a range of +/- 2.5% from the band mean value across the constellation and over the satellite's lifetime.

All RapidEye satellite images are collected at a bit depth of 12 bits and stored on-board the satellites with a bit depth of up to 12 bits. The bit depth of the original raw imagery can be determined from the "shifting" field in the XML metadata file. During on-ground processing, radiometric corrections are applied and all images are scaled to a 16-bit dynamic range. This scaling converts the (relative) pixel DNs coming directly from the sensor into values directly related to absolute at sensor radiances. The scaling factor is applied so that the resultant single DN values correspond to 1/100th of a W/(m^2*sr*μm). The DNs of the RapidEye image pixels represent the absolute calibrated radiance values for the image.

Results from an on-orbit absolute calibration campaign have been used to update the pre-launch absolute calibration of all five sensors. This calibration change applies to all imagery acquired after 1 January, 2010, but was only effective on or after 27 April, 2010.

The radiometric sensitivity for each band is defined in absolute values for standard conditions (21 March, 45° North, Standard Atmosphere) in terms of a minimum detectable reflectance difference. This determines the already mentioned bit depth as well as the tolerable radiometric noise within the images. It is more restrictive for the Red, Red Edge, and NIR bands, compared with the Blue and Green bands. During image quality control, a continuous check of the radiometric noise level is performed.

Converting to Radiance and Top of Atmosphere Reflectance

To convert the pixel values of the Analytic products to radiance, it is necessary to multiply the DN value by the radiometric scale factor, as follows:

RAD(i) = DN(i) * radiometricScaleFactor(i) , where radiometricScaleFactor(i) = 0.01

The resulting value is the at sensor radiance of that pixel in watts per steradian per square meter ($W/m^2*sr*\mu m$). Reflectance is generally the ratio of the reflected radiance divided by the incoming radiance. Note, that this ratio has a directional aspect. To turn radiances into a reflectance it is necessary to relate the radiance values (e.g. the pixel DNs) to the radiance the object is illuminated with. This is often done by applying an atmospheric correction software to the image, because this way the impact of the atmosphere to the radiance values is eliminated at the same time. But it would also be possible to neglect the influence of the atmosphere by calculating the Top Of Atmosphere (TOA) reflectance taking into consideration only the sun distance and the geometry of the incoming solar radiation. The formula to calculate the TOA reflectance not taking into account any atmospheric influence is as follows:

$$REF(i) = RAD(i)\frac{\pi * SunDist^2}{EAI(i) * \cos(SolarZenith)}$$

with:

- i = Number of the spectral band
- REF = reflectance value
- RAD = Radiance value
- SunDist = Earth-Sun Distance at the day of acquisition in Astronomical Units. Note: This value is not fixed, it varies between 0.983 289 8912 AU and 1.016 710 3335 AU and has to be calculated for the image acquisition point in time.
- EAI = Exo-Atmospheric Irradiance
- SolarZenith = Solar Zenith angle in degrees (= 90° – sun elevation)

For RapidEye, the EAI values for the 5 bands are:

- Blue: 1997.8 $W/m^2\mu m$
- Green: 1863.5 $W/m^2\mu m$
- Red: 1560.4 $W/m^2\mu m$
- RE: 1395.0 $W/m^2\mu m$
- NIR: 1124.4 $W/m^2\mu m$

For PlanetScope, the EAI values will be published online.

7. PRODUCT METADATA

As mentioned in Sections 3 and 4, all Ortho Tile data in the Planet API will contain metadata in machine-readable GeoJSON and supported by standards-compliant GIS tools (e.g. GDAL and derivatives, JavaScript libraries). The product metadata is also provided in XML format.

The table below describes the GeoJSON metadata schema for PlanetScope and RapidEye ortho tile products:

Table P: Ortho Tile GeoJSON Metadata Schema

Parameter	Description	Type
catalog::acquired	The RFC 3339 acquisition time of underlying imagery	string
catalog::black_fill	Ratio of image containing artificial black fill due to clipping to actual data	number (0 - 1)
catalog::cloud_cover	Ratio of the area covered by clouds	number (0 - 1)
catalog::grid_cell	The grid cell identifier of the gridded item	string
catalog::provider	Name of the imagery provider	string (“planetscope”,”rapideye”)
catalog::resolution	Pixel resolution of the imagery in meters	number
catalog::satellite_id	Globally unique identifier of the satellite that acquired the underlying imagery	string
catalog::strip_id	The imaging strip from which the ortho tile originated	number
catalog::sun_azimuth	Angle from true north to the sun vector projected on the horizontal plane in degrees	number (0 - 360)
catalog::sun_elevation	Elevation angle of the sun in degrees	number (0 - 90)
catalog::usable_data	Ratio of the usable to unusable portion of the imagery due to cloud cover or black fill	number (0 - 1)
catalog::view_angle	Spacecraft across-track off-nadir viewing angle used for imaging, in degrees with + being east and - being west	number (-25 - +25)
published	The RFC 3339 timestamp at which this item was added to the catalog	string

The tables below describe the GeoJSON metadata schema for PlanetScope and RapidEye scene products, respectively::

Table Q: PlanetScope Scene GeoJSON Metadata Schema

Parameter	Description	Type
acquired	The time that image was taken in ISO 8601 format, in UTC.	string
camera.bit_depth	Bit depth with which the image was taken onboard the satellite. Currently 8 or 12.	number (0 - 1)
camera.color_mode	The color mode of the image as taken by the satellite. Currently "RGB" or "Monochromatic".	number (0 - 1)
camera.exposure_time	The exposure time in microseconds.	string
camera.gain	The analog gain with which the image was taken.	number
camera.tdi_pulses	The number of pulses used for time delay and integration on the CCD. Currently 0 (if TDI was not used), 4, 6, or 12.	number (+1)
cloud_cover.estimated	The estimated percentage of the image covered by clouds. Decimal 0-100.	number (0 - 100)
image_statistics.gsd	The ground sample distance (distance between pixel centers measured on the ground) of the image in meters.	number
image_statistics.image_qulaity	Image quality category for scene. One of 'test,' 'standard,' or 'target.'	string ("test","standard", "target")
image_statistics.snr	The estimated signal to noise ratio. Values greater than or equal to 50 are considered excellent quality. Values less than 50 and greater than or equal to 20 are considered adequate quality. Values less than 20 are considered poor quality..	number (>0)
published	The time the image was first exposed in the API, in ISO 8601 format, in UTC. Note that this can vary by user.l	string
sat.alt	The altitude of the satellite when the image was taken in kilometers.	number
sat.id	A unique identifier for the satellite that captured this image.	string
sat.lat	The latitude of the satellite when the image was taken in degrees.	number
sat.lng	The longitude of the satellite when the image was taken in degrees.	number
sat.off_nadir	The angle off nadir in degrees at which the image was taken.	number
strip_id	A unique float identifier for the set of images taken sequentially be the same satellite.	string

Parameter	Description	Type
sun.altitude	The altitude (angle above horizon) of the sun from the imaged location at the time of capture in degrees.	number
sun.azimuth	The azimuth (angle clockwise from north) of the sun from the imaged location at the time of capture in degrees..	number
sun.local_time_of_day	The local sun time at the imaged location at the time of capture..	number (0-24)

Table R: RapidEye Scene GeoJSON Metadata Schema

Parameter	Description	Type
acquired	The time that image was taken in ISO 8601 format, in UTC.	string
cloud_cover.estimated	The estimated percentage of the image covered by clouds. Decimal 0-100.	number (0 - 100)
image_statistics.gsd	The ground sample distance (distance between pixel centers measured on the ground) of the image in meters.	number
strip_id	The base RapidEye Level 1B catalog id.	string
area	Area covered by the image (excluding black_fill) in square kilometers	number
sat.alt	The altitude of the satellite when the image was taken in kilometers.	number
sat.id	A unique identifier for the satellite that captured this image.	string
sat.off_nadir	The angle off nadir in degrees at which the image was taken (absolute view angle)..	number
sat.view_angle	The view angle in degrees at which the image was taken.	number
sun.azimuth_angle	The azimuth of the satellitefrom the imaged location at the time of capture in degrees..	number
sun.altitude	The altitude (angle above horizon) of the sun from the imaged location at the time of capture in degrees..	number
sun.azimuth	The azimuth (angle clockwise from north) of the sun from the imaged location at the time of capture in degrees..	number
rapideye.black_fill	The percent of image pixels without valid image data	number (0 - 100)
rapideye.tile.id	The RapidEye tile id - corresponds to a fixed footprint.	string
rapideye.catalog_id	The base RapidEye Level 3A catalog id...	string

8. PRODUCT DELIVERY

8.1 File Format

The Basic product is available as NITF and GeoTIFFs; the Visual and Analytic Ortho Tile products are GeoTIFFs.

The Ortho Tile product GeoTIFFs are resampled at 3.125 m, and projected in the UTM projection using the WGS84 datum. An alpha mask is provided as a binary color channel. The alpha mask can be used to remove or hide low-image-quality pixels near the periphery of a given scene. The alpha mask compensates for effects due to vignetting, low SNR, or hot or cold pixels.

The Ortho Scene product GeoTIFFs are resampled at 3 m, and projected in the UTM projection using the WGS84 datum. An alpha mask is provided as a binary color channel. The alpha mask can be used to remove or hide low-image-quality pixels near the periphery of a given scene. The alpha mask compensates for effects due to vignetting, low SNR, or hot or cold pixels.

The Unrectified Scene product is available as GeoTIFFs.

8.2 Naming

The name of each acquired image is designed to be unique and allow for easier recognition and sorting of the imagery. It currently includes the date and time of capture, as well as the id of the satellite that captured it. The name of each downloaded product is composed of the following elements:

PlanetScope: <strip_id><itt_tileid>_<pass_at date>_<satellite_id>_RGBNIR.<extension>
RapidEye: <tileid>_<acquisition_date>_<satellite_id>_<productType>.<extension>

Example: **2328007_2010-09-21_RE4_3A_visual.tif**
TileId: Item's unique tile id (ex: 2328007)
productType: 'visual' or 'basic' (ex: 'visual')
fileExtension: 'tif', 'json', or 'zip' (ex: 'tif')

8.3 Planet API

The Planet API offers REST API access that allows listing, filtering, and downloading of data to anyone using a valid API key. The metadata features described above are all available in the responses to API queries. The full TIFF / GeoTIFF image data files are accessible (in the different product formats) at the /full URL endpoints.

The metadata can be requested through the API endpoint: api.planet.com/v1/.

8.4 Bulk Delivery Folder Structure

Sets of imagery products can be ordered through the Planet API. The name of the parent folder is:

- `planet_order_[id]`

Bulk deliveries are delivered in a .zip folder file format. Each .zip file contains:

- A README file with information about the order.
- A subfolder for each scene requested named with the scene id.
- Each subfolder contains the TIFF or GeoTIFF requested and an associated metadata file.
- If basic data is requested, the subfolder will also contain an RPC text file.

APPENDIX A – IMAGE SUPPORT DATA

All PlanetScope and RapidEye Ortho Tile Products are accompanied by a set of image support data (ISD) files. These ISD files provide important information regarding the image and are useful sources of ancillary data related to the image. The ISD files are:

A. General XML Metadata File
B. Unusable Data Mask File

Each file is described along with its contents and format in the following sections.

1. General XML Metadata File

All PlanetScope and RapidEye Ortho Tile Products will be accompanied by a single general XML metadata file. This file contains a description of basic elements of the image. The file is written in Geographic Markup Language (GML) version 3.1.1 and follows the application schema defined in the Open Geospatial Consortium (OGC) Best Practices document for Optical Earth Observation products version 0.9.3, see http://www.opengeospatial.org/standards/gml.

The contents of the metadata file will vary depending on the image product processing level. All metadata files will contain a series of metadata fields common to all imagery products regardless of the processing level. However, some fields within this group of metadata may only apply to certain product levels. In addition, certain blocks within the metadata file apply only to certain product types. These blocks are noted within the table.

The table below describes the fields present in the General XML Metadata file for all product levels.

Table A - 1: General XML Metadata File Field Descriptions

General Metadata File Field Contents

Field	Description
“metaDataProperty” Block	
EarthObservationMetaData	
Identifier	Root file name of the image
status	Status type of image, if newly acquired or produced from a previously archived image
downlinkedTo	
acquisitionStation	X-band downlink station that received image from satellite
acquisitionDate	Date and time image was acquired by satellite
archivedIn	
archivingCenter	Location where image is archived
archivingDate	Date image was archived
archivingIdentifier	Catalog ID of image.

General Metadata File Field Contents

Field	Description
processing	
processorName	Name of ground processing system
processorVersion	Version of processor
nativeProductFormat	Native image format of the raw image data
license	
licenseType	Name of selected license for the product
resourceLink	Hyperlink to the physical license file
versionIsd	Version of the ISD
orderId	Order ID of the product
tileId	Tile ID of the product corresponding to the Tile Grid
pixelFormat	Number of bits per pixel per band in the product image file.
"validTime" Block	
TimePeriod	
beginPosition	Start date and time of acquisition for source image take used to create product, in UTC
endPosition	End date and time of acquisition for source image take used to create product, in UTC
"using" Block	
EarthObservationEquipment	
platform	
shortName	Identifies the name of the satellite platform used to collect the image
serialIdentifier	ID of the satellite that acquired the data
orbitType	Orbit type of satellite platform
instrument	
shortName	Identifies the name of the satellite instrument used to collect the image
sensor	
sensorType	Type of sensor used to acquire the data.
resolution	Spatial resolution of the sensor used to acquire the image, units in meters
scanType	Type of scanning system used by the sensor
acquisitionParameters	

General Metadata File Field Contents

Field	Description
orbitDirection	The direction the satellite was traveling in its orbit when the image was acquired
incidenceAngle	The angle between the view direction of the satellite and a line perpendicular to the image or tile center.
illumination AzimuthAngle	Sun azimuth angle at center of product, in degrees from North (clockwise) at the time of the first image line
illumination ElevationAngle	Sun elevation angle at center of product, in degrees
azimuthAngle	The angle from true north at the image or tile center to the scan (line) direction at image center, in clockwise positive degrees.
spaceCraftView Angle	Spacecraft across-track off-nadir viewing angle used for imaging, in degrees with "+" being East and "-" being West
acquisitionDateTime	Date and Time at which the data was imaged, in UTC. Note: the imaging times will be somewhat different for each spectral band. This field is not intended to provide accurate image time tagging and hence is simply the imaging time of some (unspecified) part of the image.
"target" Block	
Footprint	
multiExtentOf	
posList	Position listing of the four corners of the image in geodetic coordinates in the format: ULX ULY URX URY LRX LRY LLX LLY ULX ULY where X = latitude and Y = longitude
centerOf	
pos	Position of center of product in geodetic coordinate X and Y, where X = latitude and Y = longitude
geographicLocation	
topLeft	
latitude	Latitude of top left corner in geodetic WGS84 coordinates
longitude	Longitude of top left corner in geodetic WGS84 coordinates
topRight	
latitude	Latitude of top right corner in geodetic WGS84 coordinates
longitude	Longitude of top right corner in geodetic WGS84 coordinates
bottomLeft	
latitude	Latitude of bottom left corner in geodetic WGS84 coordinates
longitude	Longitude of bottom left corner in geodetic WGS84 coordinates

General Metadata File Field Contents

Field	Description
bottomRight	
latitude	Latitude of bottom right corner in geodetic WGS84 coordinates
longitude	Longitude of bottom right corner in geodetic WGS84 coordinates
“resultOf“ Block	
EarthObservationResult	
browse	
BrowseInformation	
type	Type of browse image that accompanies the image product as part of the ISD
reference SystemIdentifier	Identifies the reference system used for the browse image
fileName	Name of the browse image file
product	
fileName	Name of image file.
size	The size of the image product in kbytes
productFormat	File format of the image product
spatialReferenceSystem	
epsgCode	EPSG code that corresponds to the datum and projection information of the image
geodeticDatum	Name of datum used for the map projection of the image
projection	Projection system used for the image
projectionZone	Zone used for map projection
resamplingKernel	Resampling method used to produce the image. The list of possible algorithms is extendable.
numRows	Number of rows (lines) in the image
numColumns	Number of columns (pixels) per line in the image
numBands	Number of bands in the image product
rowGsd	The GSD of the rows (lines) within the image product
columnGsd	The GSD of the columns (pixels) within the image product
radiometric CorrectionApplied	Indicates whether radiometric correction has been applied to the image
geoCorrectionLevel	Level of correction applied to the image
atmosphericCorrec-tionApplied	Indicates whether atmospheric correction has been applied to the image

General Metadata File Field Contents

Field	Description
atmosphericCorrectionParameters	
autoVisibility	Indicates whether the visibility was automatically calculated or defaulted
visibility	The visibility value used for atmospheric correction in km
aerosolType	The aerosol type used for atmospheric correction
waterVapor	The water vapor category used
hazeRemoval	Indicates whether haze removal was performed
roughTerrainCorrection	Indicates whether rough terrain correction was performed
bRDF	Indicates whether BRDF correction was performed
mask	
MaskInformation	
type	Type of mask file accompanying the image as part of the ISD
format	Format of the mask file
referenceSystemIdentifier	EPSG code that corresponds to the datum and projection information of the mask file
fileName	File name of the mask file
cloudCoverPercentage	Estimate of cloud cover within the image
cloudCoverPercentageQuotationMode	Method of cloud cover determination
unusableDataPercentage	Percent of unusable data with the file
The following group is repeated for each spectral band included in the image product	
bandSpecificMetadata	
bandNumber	Number (1-5) by which the spectral band is identified.
startDateTime	Start time and date of band, in UTC
endDateTime	End time and date of band, in UTC
percentMissingLines	Percentage of missing lines in the source data of this band
percentSuspectLines	Percentage of suspect lines (lines that contained downlink errors) in the source data for the band
binning	Indicates the binning used (across track x along track)

General Metadata File Field Contents

Field	Description
shifting	Indicates the sensor applied right shifting
masking	Indicates the sensor applied masking
radiometricScale-Factor	Provides the parameter to convert the pixel value to radiance (for radiance product) or reflectance (for a reflectance product). To convert to radiance/reflectance engineering units, the pixel values should be multiplied by this scale factor. Hence the pixel values in the product are: **Radiance product:** (W/m^2 sr µm) / (Radiometric Scale Factor). The Radiometric Scale Factor is expected to be 1/100. For instance, a product pixel value of 1510 would represent radiance units of 15.1 W/m^2 sr µm. **Reflectance product:** Percentage / (Radiometric Scale Factor). The Radiometric Scale Factor is expected to be 1/100. For instance, a product pixel value of 1510 would represent 15.1% reflectance.
The remaining metadata fields are only included in the file for L1B RapidEye Basic products	
spacecraftInformationMetadataFile	Name of the XML file containing attitude, ephemeris and time for the 1B image
rpcMetadataFile	Name of XML file containing RPC information for the 1B image

File Naming

The General XML Metadata file will follow the naming conventions as in the example below.

Example: **2328007_2010-09-21_RE4_3A_visual_metadata.xml**

2. Unusable Data Mask File

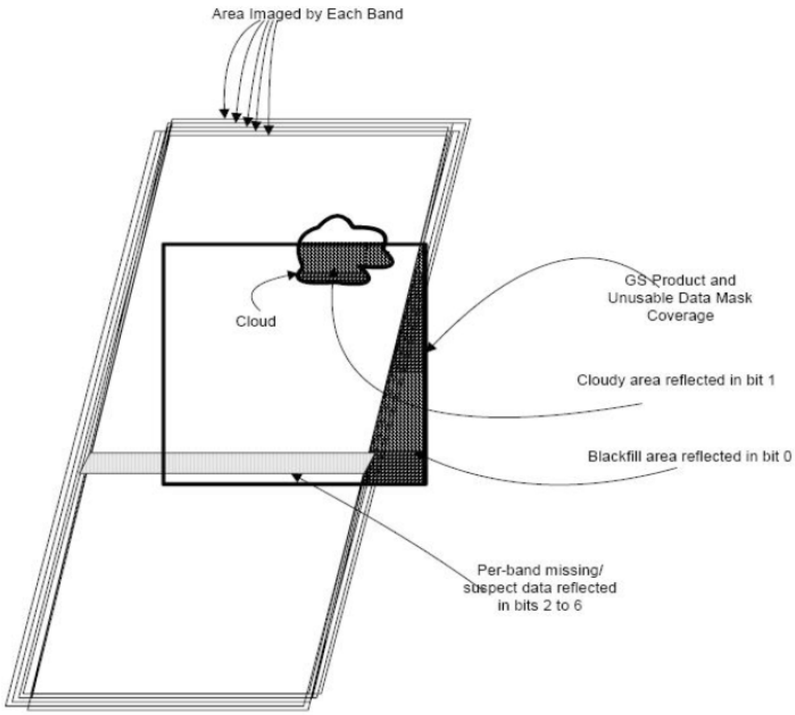
All PlanetScope and RapidEye Ortho Tile products will be accompanied by an unusable data mask file.

The unusable data mask file provides information on areas of unusable data within an image (e.g. cloud and non-imaged areas). As mentioned previously, the pixel size after orthorectification will be 3.125 m for PlanetScope and 5 m for RapidEye. It is suggested that when using the file to check for usable data, a buffer of at least 1 pixel should be considered. Each bit in the 8-bit pixel identifies whether the corresponding part of the product contains useful imagery:

- Bit 0: Identifies whether the area contains blackfill in all bands (this area was not imaged by the spacecraft). A value of "1" indicates blackfill.
- Bit 1: Identifies whether the area is cloud covered. A value of "1" indicates cloud covered. Cloud detection is performed on a decimated version of the image (i.e. the browse image) and hence small clouds may be missed. Cloud areas are those that have pixel values in the assessed band (Red, NIR or Green) that are above a configurable threshold. This algorithm will:
  - Assess snow as cloud;
  - Assess cloud shadow as cloud free;
  - Assess haze as cloud free.
- Bit 2: Identifies whether the area contains missing (lost during downlink) or suspect (contains downlink errors) data in the Blue band. A value of "1" indicates missing/suspect data. If the product does not include this band, the value is set to "0".
- Bit 3: Identifies whether the area contains missing (lost during downlink and hence blackfilled) or suspect (contains downlink errors) data in the Green band. A value of "1" indicates missing/suspect data. If the product does not include this band, the value is set to "0".
- Bit 4: Identifies whether the area contains missing (lost during downlink) or suspect (contains downlink errors) data in the Red band. A value of "1" indicates missing/suspect data. If the product does not include this band, the value is set to "0".
- Bit 5: Identifies whether the area contains missing (lost during downlink) or suspect (contains downlink errors) data in the Red Edge band. A value of "1" indicates missing/suspect data. If the product does not include this band, the value is set to "0".
- Bit 6: Identifies whether the area contains missing (lost during downlink) or suspect (contains downlink errors) data in the NIR band. A value of "1" indicates missing/suspect data. If the product does not include this band, the value is set to "0".
- Bit 7: Is currently set to "0".

The figure below illustrates the concepts behind the Unusable Data Mask file.

Figure A-1: Concepts behind the Unusable Data Mask File



File Naming

The General XML Metadata file will follow the naming conventions as in the example below.

Example: **2328007_2010-09-21_RE4_3A_visual_udm.tif**

APPENDIX B – TILE GRID DEFINITION

Ortho Tile imagery products are based on the UTM map grid as shown in Figure B-1 and B-2. The grid is defined in 24km by 24km tile centers, with 1km of overlap, resulting in 25km by 25km tiles.

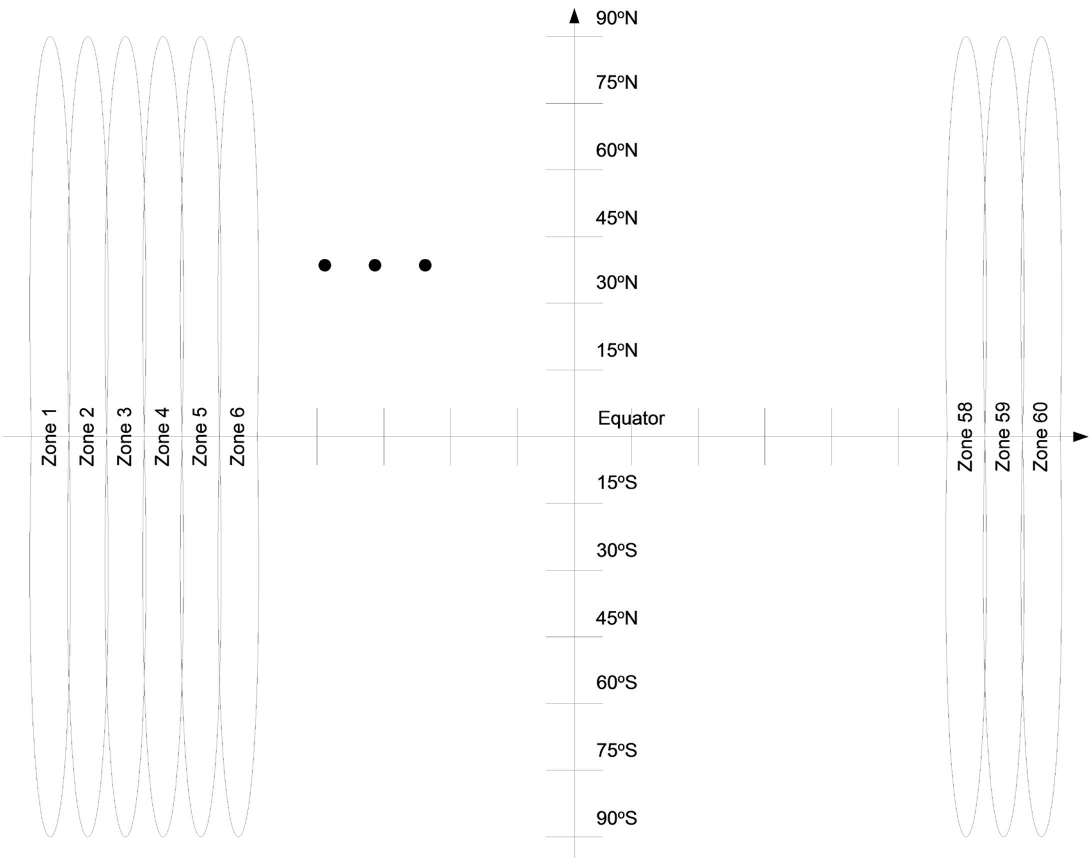


Figure B-1 Layout of UTM Zones

An Ortho Tile imagery products is named by the UTM zone number, the grid row number, and the grid column number within the UTM zone in the following format:

`<ZZRRRCC>`

where:

```
ZZ =   UTM Zone Number (This field is not padded with a zero for single digit zones in the
       tile shapefile)
RRR =  Tile Row Number (increasing from South to North, see Figure B-2)
CC =   Tile Column Number (increasing from West to East, see Figure B-2)
```

Example: **Tile 547904 = UTM Zone = 5, Tile Row = 479, Tile Column = 04**
Tile 3363308 = UTM Zone = 33, Tile Row = 633, Tile Column = 08

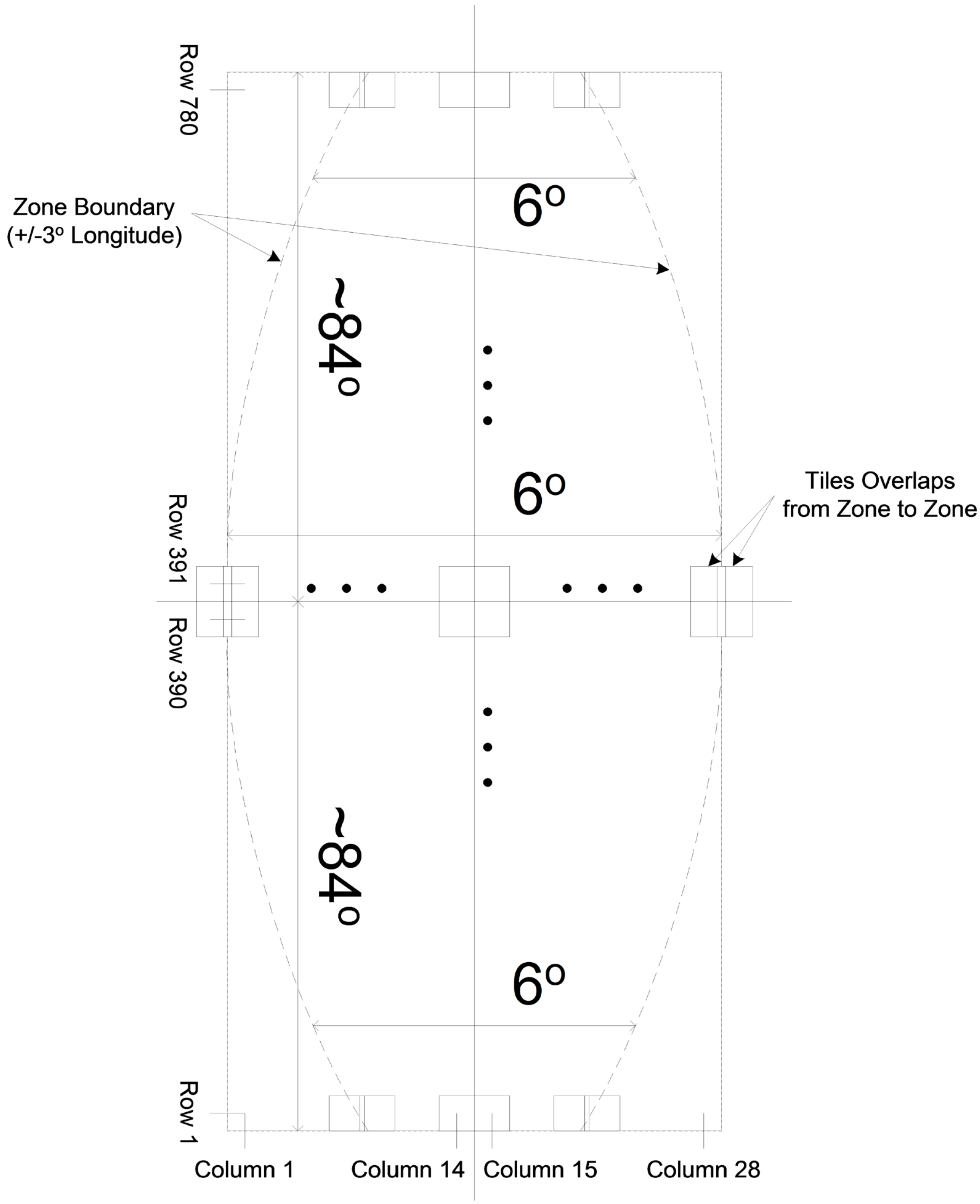


Figure B-2 Layout of Tile Grid within a single UTM Zone

Due to the convergence at the poles, the number of grid columns varies with grid row as illustrated in Figure B-3.

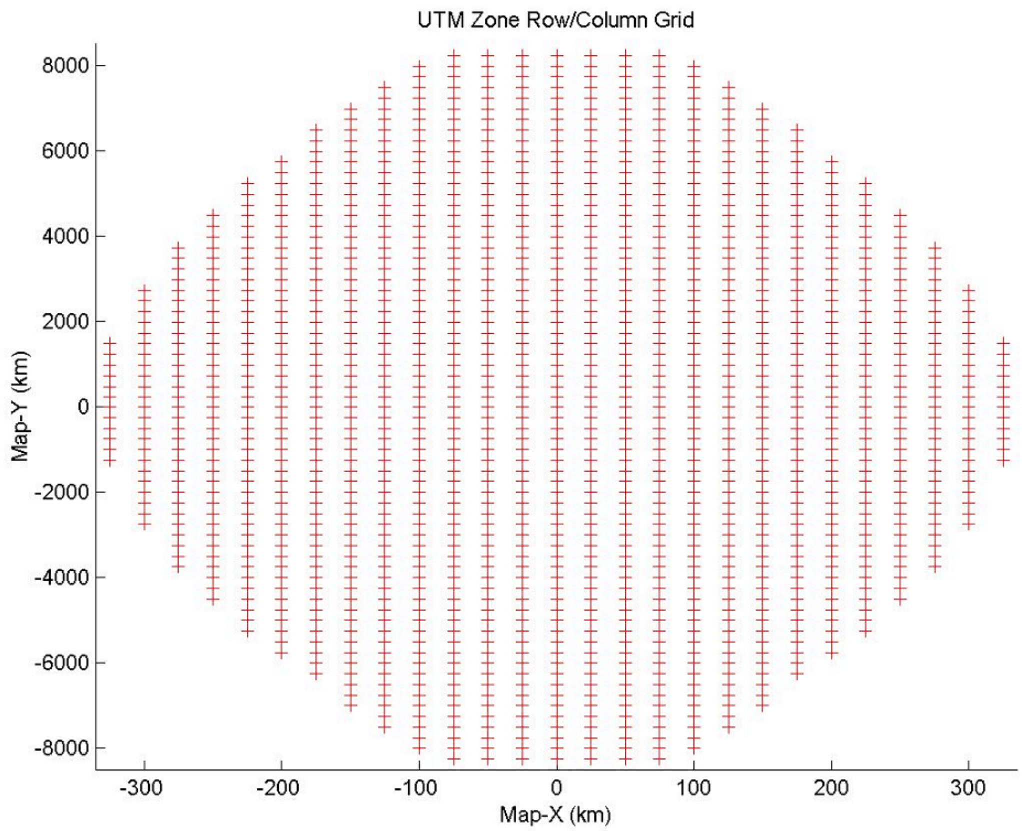


Figure B-3 Illustration of grid layout of Rows and Columns for a single UTM Zone

The center point of the tiles within a single UTM zone are defined in the UTM map projection to which standard transformations from UTM map coordinates (x,y) to WGS84 geodetic coordinates (latitude and longitude) can be applied.

```
col = 1..29
row = 1..780
Xcol = False Easting + (col –15) x Tile Width + Tile Width/2
Yrow = (row – 391) x Tile Height + Tile Height/2
```

where:

X and Y are in meters

False Easting	=	500,000m
Tile Width	=	24,000m
Tile Height	=	24,000m

The numbers 15 and 391 are needed to align to the UTM zone origin.

APPENDIX C – POSITIONAL ACCURACY TIMELINE

Planet is currently validating the positional accuracy of our imagery across the globe. We will be gradually updating data in different regions to ensure that we meet our target of having a positional accuracy of less than 10m RMSE in each of them.

See the following table with the schedule for when validated data will be available:

Table C-1: Positional Accuracy Availability

Month	Region
July	<10m RMSE in USA, Mexico and Australia
August	<10m RMSE in North and South America, Australia
September	<10m RMSE in North and South America, Europe and Australia
October	<10m RMSE globally

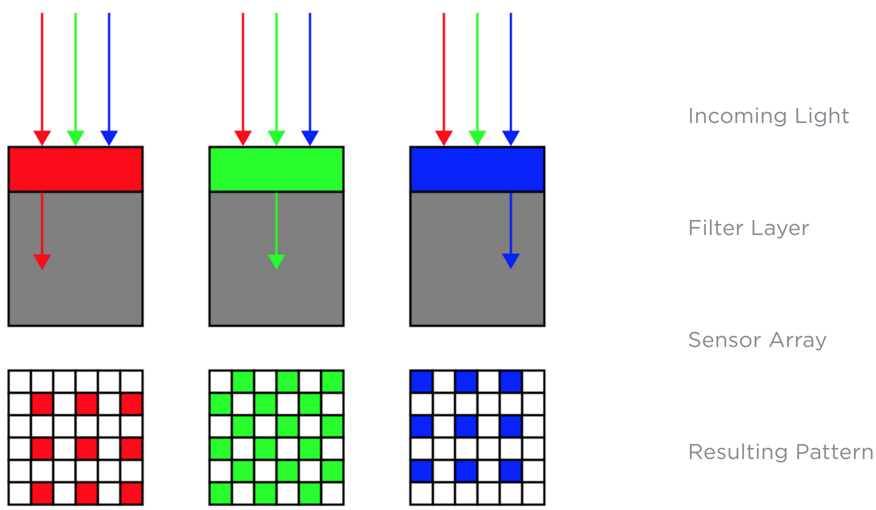
Supplemental Information

Detail on PlanetScope Camera Operations:

PlanetScope Color Array Filter (CFA)

PlanetScope satellites have a CCD camera equipped with a Bayer mask style Color Filter Array (CFA). This means that at the time of image capture, each sensor well measures one of red, green, or blue wavelengths. These values are interpolated to assign a red, green, and blue value to each pixel. A similar interpolation is used in the presentation of Near Infrared data collected by the PlanetScope Constellation .

Figure A: Bayer Mask



PlanetScope Time Delay Integration (TDI)

Time Delay Integration (TDI) is a technique designed to increase the effective exposure time of images. TDI is a default configuration for PlanetScope image capture. It works by shifting the rows of pixels within the CCD (Charge-Coupled Device) at the same rate as the ground motion of the scene. The number of lines (or pulses) of TDI is limited by the well capacity of the detector. The specific TDI mode used to capture each scene is avail- able in that scene's metadata.