PAZ Image Product Guide

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Ref.:	PAZ-HDS-GUI-001

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PAZ Image
Product Guide

Ref: PAZ-HDS-GUI-001
Issue: 2.0
Date: 10th May 2021
Page: 2/44

Distribution List

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Page	Issue	Changes
-	1.1	Review for corrections
All document	2.0	Staring Spotlight and Wide ScanSAR new modes included
All document	2.0	New polarization combinations for SAR modes included
All document	2.0	ScanSAR SCC product characteristics included

PAZ Image
Product Guide

Ref: PAZ-HDS-GUI-001
Issue: 2.0
Date: 10th May 2021
Page: 3/44

TABLES

FIGURES

PAZ Image
Product Guide

Ref: PAZ-HDS-GUI-001
Issue: 2.0
Date: 10th May 2021
Page: 4/44

INDEX

PAZ Image
Product Guide

Ref: PAZ-HDS-GUI-001
Issue: 2.0
Date: 10th May 2021
Page: 5/44

PAZ Image
Product Guide

Ref: PAZ-HDS-GUI-001
Issue: 2.0
Date: 10th May 2021
Page: 6/44

1. Documentation

RD-01   PZ-DLR-ID-3003 SAR Level 1b Product Format Specification for PAZ SAR Processor

2. Acronyms

AD	Applicable Document
DAS	Direct Acess Station
DEM	Digital Elevation Model
DN	Digital Number
DRA	Dual Receive Antenna
EEC	Enhanced Ellipsoid Corrected product
EO	Earth Observation
EPSG	European Petroleum Survey Group
EULA	End User License Agreement
GEC	Geocoded Ellipsoid Corrected product
GIM	Geocoded local Incidence angle Mask
GPS	Global Positioning System
GS	Ground Segment
HDS	Hisdesat
HS	High resolution Spotlight mode
ISLR	Integrated SideLobe Ratio
MGD	Multi look Ground Detected product
NEBN	Noise Equivalent Beta Nought
NESZ	Noise Equivalent Sigma Zero
NRT	Near Real Time
OGC	Open Geospatial Consortium
PRF	Pulse Repetition Frequency
PRI	Pulse Repetition Interval
PSLR	Peak to SideLobe Ratio
RE	Radiometrically Enhanced product
SAR	Synthetic Aperture Radar
SC	ScanSAR mode
SE	Spatially Enhanced product
SL	SpotLight mode
SM	StripMap mode
SRA	Single Receive Antenna
SSC	Single look Slant range Complex product
ST	Staring Spotlight
TIFF	Tagged Image File Format
UPS	Universal Polar Stereographic
USP	User Services Provider
UTC	Coordinated Universal Time
UTM	Universal Transverse Mercator
WMS	Web Map Service

PAZ Image
Product Guide

Ref: PAZ-HDS-GUI-001
Issue: 2.0
Date: 10th May 2021
Page: 7/44

3. Introduction

3.1 Hisdesat Company Profile

HISDESAT Servicios Estratégicos, S.A. was founded in 2001 as a governmental satellites services operator to act primarily in the areas of defense, security, intelligence and foreign affairs. Since 2005, HISDESAT has been providing secure satellite communications services to government agencies for various countries (Spain, USA, Denmark, Norway, Belgium, etc.). This governmental communications system is based in two geostationary satellites (SPAINSAT launched in 2006 and XTAR-EUR, launched in 2005); both cover two thirds of the earth.

Regarding governmental and secure communications, Hisdesat is currently developing the SPAINSAT NG program, composed of two new satellites, SPAINSAT NG I and SPAINSAT NG II, that will be located in two different orbital positions (30°W and 29°E), and will operate in X-Band, military Ka and UHF.

HISDESAT shareholder responds to a capital public-private partnership model to provide strategic services of excellence and efficiency criteria. HISDESAT has established several collaboration agreements with other companies and agencies to offer his services to a market more and more global.

Regarding the Earth Observation market, HISDESAT is the owner and operator of the PAZ satellite, which offers precise information for multiple applications from its polar orbit around the Earth. The launch of the satellite was entrusted to the rocket Falcon 9, following the signing of the contract with the North American company Space X. PAZ satellite was successfully launched on 22nd of February of 2018.
In 2012 , Hisdesat signed an agreement with Airbus Defense and Space (formerly Astrium GEO Services) for the creation of a constellation of satellites using radar coordinated resources of PAZ, TerraSAR -X and TanDEM –X, available to customers.

Finally, HISDESAT has developed a new satellite constellation for maritime traffic information (AIS), through the Canadian company, exactEarth, a joint venture between COMDEV and HISDESAT. Currently, the five satellites of this new constellation (will be nine satellites within the next one and half year) receive AIS signals from more than 80,000 vessels and allow knowing the situation of the world maritime traffic in real time.
Despite HISDESAT is not formally a consultancy firm, the three main fields of activities of the company have been created through a National Space program where formally the different Ministries are the responsible but HISDESAT has been a key player from the conceptual design till the actual elaborations of the plans.

The importance to sovereign nations of dedicated, secure communications has never been greater than it is now in the 21st century. Accurate and timely information is needed to make proper decisions that affect all aspects of national interest – military, economic, diplomatic – and for operations with friendly and allied nations. Very often, this critical information flow is into or out of regions not serviced by traditional terrestrial communications infrastructure. As a result, satellite communications have become the essential link for governments around the world.

3.2   PAZ Mission

PNOTS (from Spanish Earth Observation National Program) employs two satellites, PAZ and INGENIO (currently in development) and featuring two space observation techniques: radar (SAR) and optical. They will offer nighttime and daytime images in any weather conditions. With this program, Spain becomes the first European country to have a dual-observation, dual-use system.

Both satellites allow for earth observation for multiple purposes: border control, intelligence, environmental monitoring, protection of natural resources, military operations, enforcement of international treaties, surface monitoring, city and infrastructure planning, monitoring of natural catastrophes and high-resolution mapping, among many others.

3.2.1   PAZ satellite

The PAZ (Spanish for "peace") satellite is intended primarily to address civilian needs with multiple applications.

HISDESAT is the owner and operator of the PAZ satellite, which offers precise information for multiple applications from its polar orbit around the Earth. The launch of the satellite was entrusted to the rocket Falcon 9, following the signing of the contract with the North American company Space X. PAZ satellite was successfully launched on 22nd of February of 2018.

Figure 1 – PAZ satellite

PAZ Image
Product Guide

Ref: PAZ-HDS-GUI-001
Issue: 2.0
Date: 10th May 2021
Page: 9/44

In September 2018, PAZ was declared fully operational, once the commissioning phase had successfully finished.

In 2012 , Hisdesat signed an agreement with Airbus Defense and Space (formerly Astrium GEO Services) for the creation of a constellation of satellites using radar coordinated resources of PAZ, TerraSAR -X and TanDEM –X, available to customers.

Among the advantages, the constellation provides are:

- Significant reduction of the revisit time (will be between 4 and 7 days), important for interferometric processes and applications with strict timing requirements.
- Improving procurement capacity for surveillance applications and map generation.
- Ease of making requests through a single portal requests and a single catalog.

The creation of the constellation responds to the growing demand of the industry's earth observation based on radar technology for coordinating private missions to market products that comply fully with the expectations of existing applications and provide benefits for new ones.

From the start, the manufacture of the PAZ satellite has given Spain's aerospace industry a significant return on the investments made by the companies involved, allowing them to develop new capabilities that will improve their competitiveness in the global aerospace marketplace. This new satellite also significantly improves Spain's standing within Europe's Global Monitoring for Environment and Security (GMES) program, Copernicus, a key initiative in ground monitoring led by the European Union and the European Space Agency (ESA).

PAZ is intended to not only address security and defense needs, but also other needs of a civilian nature.

PAZ satellite has been designed for a seven years of nominal mission. It orbits the Earth fifteen times a day at an altitude of 514 kilometers in a speed of seven kilometers per second, and cover an area of over 300,000 square kilometers a day. Thanks to its slightly inclined quasi-polar orbit, PAZ covers the entire Earth with an average revisit time of 24 hours.

Its total weight is 1400 kg with 5 m high and 2.4 m diameter. The radar has been designed to be very flexible and is able to operate in a wide array of configurations depending on the desired image performance. It has a 256-GB image storage capacity and an X-band transmission speed of 300 Mbits/sec for relaying its images to the ground.

3.2.2   PAZ Ground Segment

The Nominal PAZ ground segment facility is located at the INTA-Torrejón (Madrid) premises. Spain's National Institute for Aerospace Technology (INTA) is the developer and owner of the Ground Control segment. This facility is the prime and nominal site for PAZ mission. It is fully equipped for the control, command, monitoring, planning, processing, calibration, storing, cataloguing and services functionalities for the ground segment.

This center was also used during commissioning phase for planning, execute and analyze all the on-flight tests.

The backup PAZ ground segment facility is located in the INTA-Maspalomas (Canary Islands) premises.

PAZ Image
Product Guide

Ref: PAZ-HDS-GUI-001
Issue: 2.0
Date: 10th May 2021
Page: 10/44

3.2.3   PAZ Service Segment

The USP (User Service Provider) is the service segment of PAZ mission with the main functional activities showed below. It is a meeting point for the use of remote sensing information acquired by Spanish satellites and commercialization of derived products from these sensors.

The USP will work in conjunction with TerraSAR-X and Tandem-X missions through the Airbus' commercial services, forming a constellation with an outstanding response time for image acquisitions worldwide. This is a geoportal to:

- Provide access of catalogued products of GS
- Provide planning services to acquire new data in GS
- Deliver GS and USP products via World Wide Web
- Support business processes of Hisdesat
- Offer collaborative tools for EO fields
- Support of DAS stations worldwide
- Management of third ground station services

USP provides a central access to the Hisdesat's customers bringing services corresponding to the TerraSAR-X, Tandem (through GEO Airbus Defense & Space) and PAZ mission that conforms the constellation. The EO derived products also are included as services and suppose an important added value product that can be adapted to the market needs.

In addition, the portal serves as a communication tool with customers and ordinary public showing documentation, news, or videos representing the company's products and services.

4. PAZ Instrument

PAZ instrument is a side-looking X-Band synthetic aperture radar (SAR) using the active phased array antenna technology.

The SAR instrument comprises the back-end and the front-end, with an operational instantaneous bandwidth up to 300 MHz. It allows the operation in the following imaging modes: Spotlight, HR Spotlight, Staring Spotlight, StripMap, ScanSAR and Wide ScanSAR, with various polarizations (single, dual).
The instrument back-end is based on the TerraSAR-X one, and the front-end, which consists of 12 active antenna panels based on dual polarized subarrays (multilayer printed technology), is a Spanish development.

PAZ Image
Product Guide

Ref: PAZ-HDS-GUI-001
Issue: 2.0
Date: 10th May 2021
Page: 11/44

The following table shows the system parameters for PAZ satellite:

Orbit and attitude	
Operational life	7 years
Orbit	Sun-synchronous repeat orbit
Orbits / day	15 $^2/_{11}$
Repeat period	11 days
Nominal orbit height at the equator	514 Km
Inclination	97.44°
Ascending node equatorial crossing time	18:00 ± 0.25h (local time)
SAR instrument	
Radar carrier frequency	9.65 GHz
Chirp bandwidth	100 MHz, 150 MHz, 300 MHz
Antenna type	Active phased array antenna
Antenna size	4.8 m length, 0.7 m width
Polarizations	HH, HV, VV, VH
PRF	2.0 KHz – 6.5 KHz
Nominal acquisition direction	Right looking
Number of elevation beams in StripMap	27 for SM-S 54 for SM-D
Number of elevation beams in ScanSAR	14
Number of elevation beams in Wide ScanSAR	10
Number of elevation beams in Spotlight, HR Spotlight and Staring Spotlight	122
Number of azimuth beams	209

Table 1 – PAZ System Parameters

4.1 PAZ Imaging Modes

The instrument timing and pointing of the electronic phased array antenna is designed allowing a numerous sensing mode combinations to support a variety of SAR applications, ranging from medium up to very high-resolution mapping. Making use of that, four basic imaging modes have been defined:

- StripMap mode (SM), in single or dual polarization
- ScanSAR mode (SC), in single polarization
- Spotlight mode (SL), in single or dual polarization
- High Resolution Spotlight mode (HS), in single or dual polarization
- Staring Spotlight mode (ST), in single polarization
- Wide ScanSAR mode (WS), in single polarization

In the following chapters, the previous basic imaging modes will be defined.

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PAZ Image
Product Guide

Ref: PAZ-HDS-GUI-001
Issue: 2.0
Date: 10th May 2021
Page: 12/44

4.1.1   StripMap mode (SM)

This is the basic SAR imaging mode. The ground swath is illuminated with a continuous train of pulses while the antenna beam is pointed to a fixed angle both in elevation and in azimuth. This results in an image strip with constant image quality in azimuth. Figure 2 sketches the StripMap mode acquisition geometry.
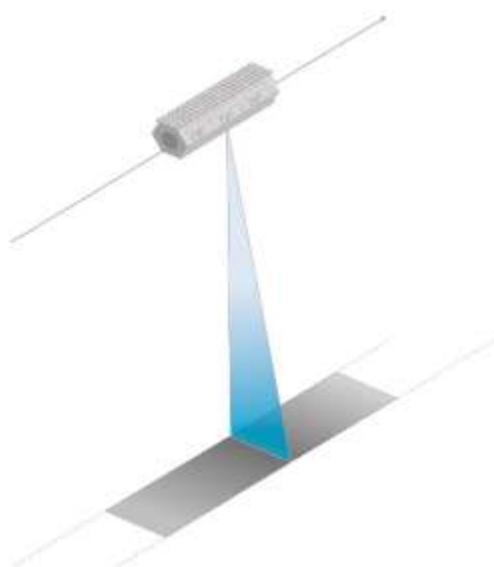
Figure 2 – StripMap mode acquisition geometry

StripMap mode can be performed in single (SM-S) or in dual (SM-D) polarization mode resulting in one or two image layers, respectively.

The dual polarization mode is implemented by toggling the transmit and/or receive polarization from PRI to PRI, e.g. HH-HV so the same part of the Doppler spectrum is recorded by both polarizations and, finally, two polarization images are acquired by the instrument. In this case the "effective" PRF of each polarimetric channel is half of the transmit PRF. In order to sample the antenna azimuth spectrum properly in each channel, the transmit PRF has to be increased and so the maximum ground swath width is shorter w.r.t the single polarization one.

For SM-D mode, a convenient selection of the swath width is 15 km, thus a halved swath width if compared to the SM-S one. Table 2 includes a summary of the main StripMap mode characteristics.

Parameter	Value
Swath width (ground range)	30 Km for SM-S 15 Km for SM-D
Nominal product length	50 Km
Full performance incidence angle range	20° - 45°
Data access incidence angle range	15° - 60°
Polarizations	HH, VV, HV, VH for SM-S HH/VV, HH/HV, VV/VH for SM-D

Table 2 – StripMap mode characteristics

PAZ Image
Product Guide

Ref: PAZ-HDS-GUI-001
Issue: 2.0
Date: 10th May 2021
Page: 13/44

The following figure shows an example of a StripMap image:
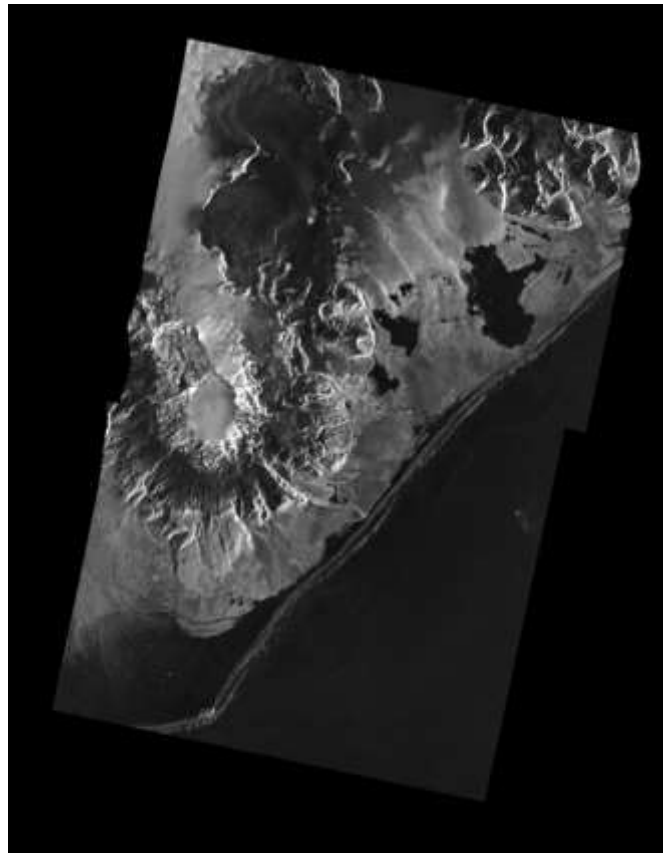
Figure 3 – StripMap image (Öræfajökull, Island)

4.1.2   ScanSAR mode (SC)

The purpose of a ScanSAR (SC) mode is to increase the swath width respect to the StripMap mode by splitting the total integration time between four different sub-swaths oriented at consecutive along-track positions. We can observe in Figure 4 how the sub-swaths are acquired during the flight of the satellite.
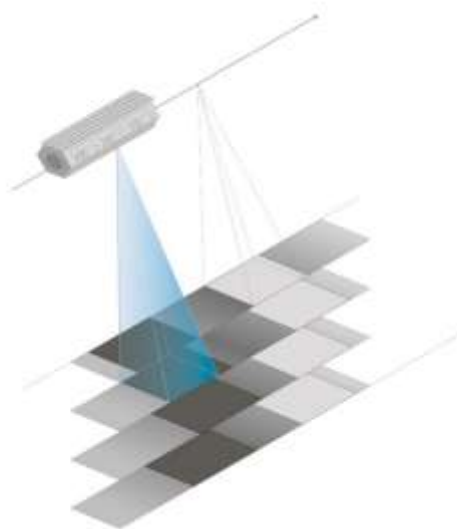
Figure 4 – ScanSAR mode acquisition geometry

PAZ Image
Product Guide

Ref: PAZ-HDS-GUI-001
Issue: 2.0
Date: 10th May 2021
Page: 14/44

An enhanced swath width is composed by sub-swaths, which are obtained by antenna steering in elevation direction. The steering in elevation has to be selected properly in order to avoid gaps between the sub-swaths while the total burst duration is selected based on the required resolution and also to achieve a continuous illumination in along-track direction. Each sub-swath is only illuminated during a small part of the synthetic aperture length (a limited number of pulses are transmitted and a different number of echoes are received due to the switching geometry), which inevitably results in a reduced azimuth resolution of the imaged area. Table 3 includes a summary of the main ScanSAR mode characteristics.

Parameter	Value
Swath width (ground range)	100 Km
Nominal product length	150 Km
Full performance incidence angle range	20° - 45°
Data access incidence angle range	15° - 60°
Polarizations	HH, VV, HV, VH

Table 3 - ScanSAR mode characteristics

The following figure shows an example of a ScanSAR image:

Figure 5 – ScanSAR image (Norway Coast)

PAZ Image
Product Guide

Ref: PAZ-HDS-GUI-001
Issue: 2.0
Date: 10th May 2021
Page: 15/44

4.1.3 Spotlight (SL) & HR Spotlight (HS) modes

Spotlight modes take advantage of the beam steering capability in the azimuth plane to illuminate for a longer time the area of interest. This results in an increased synthetic aperture length (i.e. increased integration time), thus a sensible improvement of the azimuth resolution is achieved at the expense of a shorter scene size. More than one hundred beams are defined to adjust the scene center in small increments so that the required scene can be placed in the middle of the area of interest.
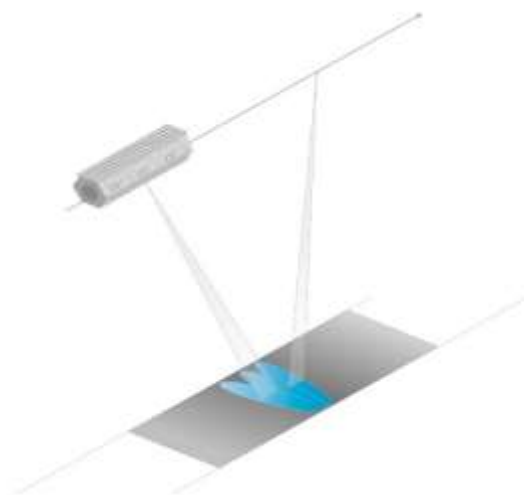
Figure 6 – Spotlight modes acquisition geometry

As depicted in Figure 6, the Spotlight modes can be easily described using a virtual rotation point, which is normally further away from the area being illuminated. During the data acquisition time, the radar antenna is "virtually" steered about this auxiliary point and the center of the beam moves along the azimuth direction in order to increase the illuminated area (swath length). Whereas for Spotlight this rotation point coincides with the center of the beam, so the image length in the flight direction is constrained by the projection on-ground of the azimuth beamwidth.

As previously stated, two variants of Spotlight mode are designed with different values of the azimuth resolution and scene size:

*   Spotlight mode (SL) is designed to take advantage of squint angle to maximize the azimuth scene extension at the expense of the spatial resolution, and

*   High Resolution Spotlight mode (HS) is designed to maximize the spatial resolutions at the expense of the scene extension.

Both modes can be performed in single or in dual polarization mode. HR Spotlight mode products can be ordered with 150 MHz or 300 MHz transmitted bandwidth. The modes characteristics can be seen in Table 4.

Parameter	Value	
	SL	**HS**
Swath width (ground range)	10 Km	5 – 10 Km
Nominal product length	10 Km	5 Km
Full performance incidence angle range	20° - 55°	20° - 55°
Data access incidence angle range	15° - 60°	15° - 60°
Polarizations	HH, VV, HV, VH for SL-S HH/VV, HH/HV, VV/VH for SL-D	HH, VV, HV, VH for HS-S HH/VV, HH/HV, VV/VH for HS-D

Table 4 – Spotlight & HR Spotlight modes characteristics

PAZ Image
Product Guide

Ref: PAZ-HDS-GUI-001
Issue: 2.0
Date: 10th May 2021
Page: 16/44

The following figures show two examples of HR Spotlight and a Spotlight images (detail of a part of the image):

Figure 7 – Detail of a HR Spotlight image (Sidney, Australia)
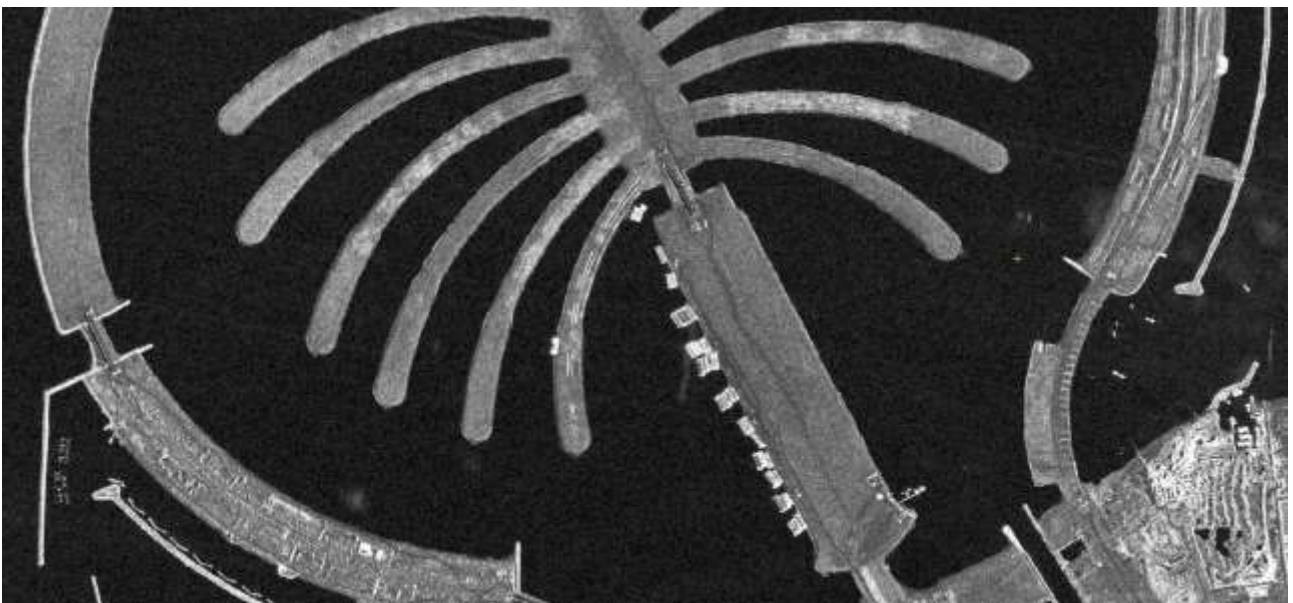
Figure 8 – Detail of a SL image (Dubai, United Arab Emirates)

![hisdeSAT logo]

PAZ Image
Product Guide

Ref: PAZ-HDS-GUI-001
Issue: 2.0
Date: 10th May 2021
Page: 17/44

4.1.4 Wide ScanSAR mode

In order to cover the demand of higher swath coverage products, Wide ScanSAR mode is defined, using six sub-swaths, instead of the four used in the ScanSAR mode:
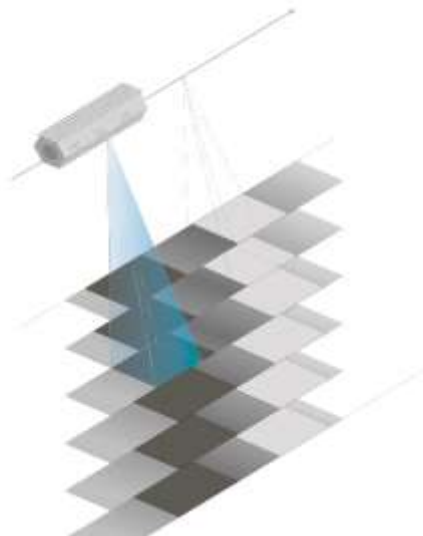
Figure 9 Wide ScanSAR mode acquisition geometry

Table 5 includes a summary of the main Wide ScanSAR mode characteristics.

Parameter	Value
Swath width (ground range)	196 - 273 Km
Nominal product length	208 Km
Full performance incidence angle range	15.6° - 49°
Data access incidence angle range	15.6° - 49°
Polarizations	HH, VV, HV, VH

Table 5 Wide ScanSAR mode characteristics

PAZ Image
Product Guide

Ref: PAZ-HDS-GUI-001
Issue: 2.0
Date: 10th May 2021
Page: 18/44

The following figure shows an example of a Wide ScanSAR image:

Figure 10 Wide ScanSAR image (Panama Canal)

PAZ Image
Product Guide

Ref: PAZ-HDS-GUI-001
Issue: 2.0
Date: 10th May 2021
Page: 19/44

4.1.5   Staring Spotlight mode

In order to obtain the best achievable azimuth resolution, the Staring Spotlight mode was defined for PAZ. For Staring Spotlight mode, the virtual rotation point coincides with the center of the beam, so the image length in the flight direction is constrained by the projection on- ground of the azimuth beamwidth. It leads to a target azimuth illumination time increment (i.e. azimuth resolution improvement).

Parameter	Value
Swath width (ground range)	9 – 4.6 Km
Nominal product length	2.7 – 3.6 Km
Full performance incidence angle range	20° - 45°
Data access incidence angle range	15° - 60°
Polarizations	HH, VV, HV, VH

Table 6 Staring Spotlight mode characteristics

The following figures show two examples of Staring Spotlight images:

Figure 11 Staring Spotlight image (Uluru – Australia)

PAZ Image
Product Guide

Ref: PAZ-HDS-GUI-001
Issue: 2.0
Date: 10th May 2021
Page: 20/44
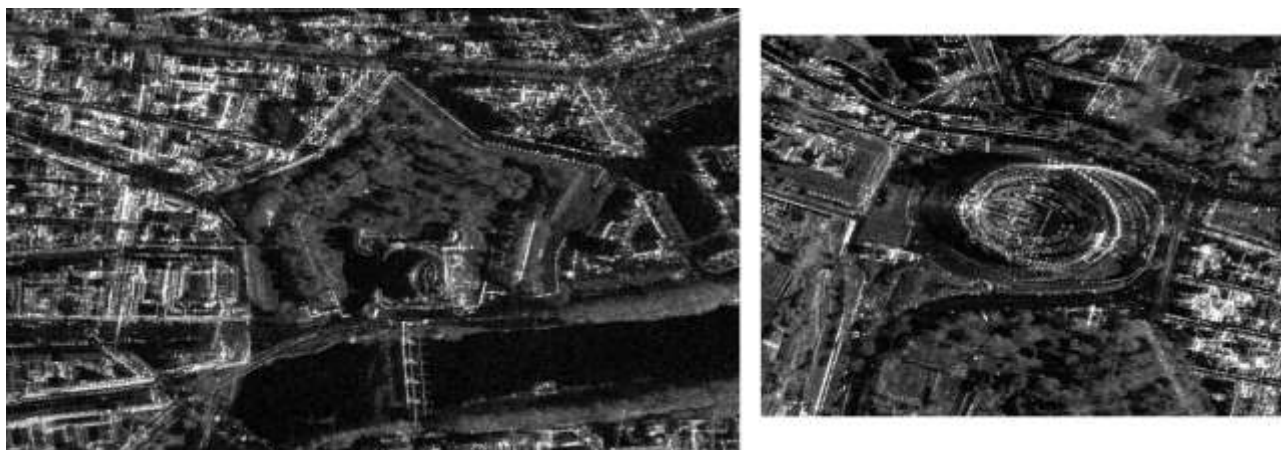
Figure 12 Details of a ST image (Sant'Angelo – left-, and Colosseum –right-, Rome, Italy)

4.2 Data access and full performance incidence angles range

The PAZ basic products performance (included in chapter 6) is specified within the so-called full performance incidence angles range; out of this range, the expected performance could be reduced. The following table summarizes both the data access and the full performance incidence angles range:

Imaging mode	Data access		Full performance	
	Beams	Incidence angles range	Beams	Incidence angles range
SM-S	strip_001 – strip_027	15° - 60°	strip_003 – strip_014	20° - 45°
SM-D	stripNear_001 – stripFar_027	15° - 60°	stripNear_003 – stripFar_014	20° - 45°
SC	scan_001 – scan_014	15° - 60°	scan_003 – scan_011	20° - 45°
SL-S	spot_001 – spot_122	15° - 60°	spot_010 – spot_100	20° - 55°
SL-D	spot_001 – spot_122	15° - 60°	spot_010 – spot_100	20° - 55°
HS-S	spot_001 – spot_122	15° - 60°	spot_010 – spot_100	20° - 55°
HS-D	spot_001 – spot_122	15° - 60°	spot_010 – spot_100	20° - 55°
WS	wide_001 – wide_010	15.6° - 49°	wide_001 – wide_005	15.6° - 49°
ST	spot_001 – spot_122	15° - 60°	spot_010 – spot_067	20° - 45°

Table 7 – Data access and full performance incidence angles range

The previous if for right looking acquisitions, but the spacecraft may also be operated in left-looking mode or with a wider range of incidence angles defining the data access range. These operations improve the access time to a scene. However, due to reduced performance these products are not open for general access.

PAZ Image
Product Guide

Ref: PAZ-HDS-GUI-001
Issue: 2.0
Date: 10th May 2021
Page: 21/44

4.3 Revisit time

PAZ satellite offers a global coverage with an average access time (full performance beams) of less than 70 hours, which can be reduced up to 35 hours if the area of interest is located out of the latitudes range of [+35°, -35°].
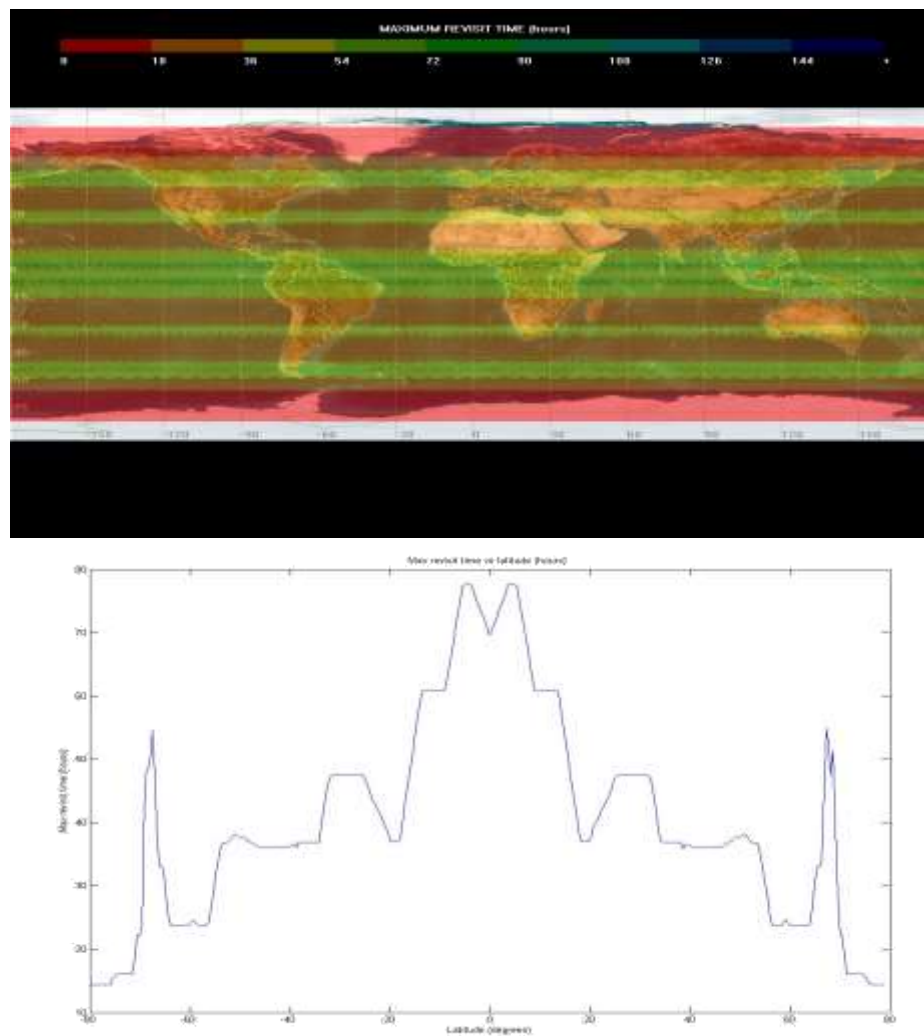
Figure 13 – PAZ revisit times

PAZ Image
Product Guide

Ref: PAZ-HDS-GUI-001
Issue: 2.0
Date: 10th May 2021
Page: 22/44

As previously stated, PAZ orbit cycle is 11 days, with four contacts per day (44 per cycle) with the main Ground Station, distributed in two consecutive contacts in the morning session and other two consecutive contacts in the evening session, as depicted in the following figure:
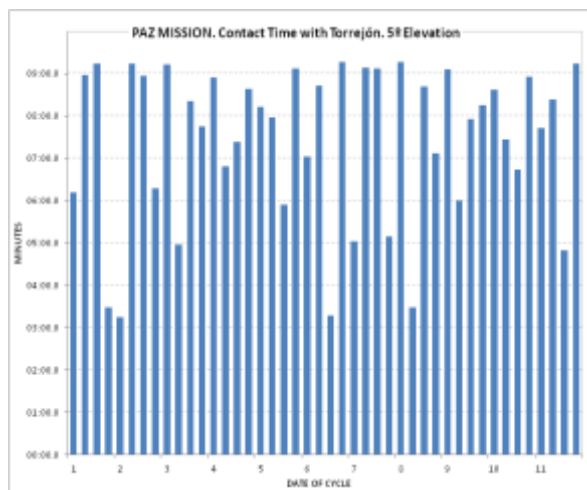
Figure 14 - Distribution of contact time with Torrejón station in one cycle

5. Basic Products

The first part of the chapter describe the main performance parameters of SAR products, and then the following parts include the geometric projections and the processing options available for each product.

5.1 SAR products main performance parameters

5.1.1 Spatial resolution

PAZ SAR instrument maximum bandwidth is 300 MHz (which is used in HR Spotlight mode and Staring Spotlight), so the theoretical maximum slant range resolution in single polarization is 0.5 meter, with no spectral weighting applied. For all PAZ products (complex and detected), the maximum resolution is deliberately reducing both in range and azimuth using a Hamming window (coefficient $\alpha = 0.6$) in order to reduce the sidelobes of the impulse response function (ambiguity ratios reduction consequently).

In the case of StripMap, ScanSAR and Wide ScanSAR modes, the maximum bandwidth used is 150 MHz, and due to instrument timing limitations, the previous bandwidth cannot be achieved for all beams. Depending on the actual timing parameters, far range beams in StripMap and ScanSAR mode are operated with a reduced range bandwidth setting of 100 MHz.

In azimuth, the theoretical resolution (StripMap mode, single polarization) is half the antenna length (2.4 meter), with no spectral weightening; as it was said, in the processor, a bandwidth reduction and spectral shaping (Hamming) is performed in order to reduce the ambiguities caused by aliasing. In dual polarization mode, the effective PRF per polarization channel is reduced as well as the azimuth resolution.

PAZ Image
Product Guide

Ref: PAZ-HDS-GUI-001
Issue: 2.0
Date: 10th May 2021
Page: 23/44

Note, that for the complex products the resolution is given in azimuth and slant range while for all detected products the geometric resolution is given in ground range.

In the detected product variants the resolution is reduced (the number of looks is increased accordingly) in order to reduce speckle and thermal noise, i.e. to improve the radiometric resolution. Therefore, two different strategies have been followed in order to design two variants of detected products. One is optimized for spatial resolution (spatially enhanced, SE) and one is optimized for radiometry (radiometrically enhanced, RE). In both variants, a square sized ground resolution cell is implemented.

5.1.1.1   *Spatially Enhanced products (SE)*

The spatially enhanced products are designed with the target of maximize the spatial resolution in pixels with squared size, so the larger resolution value of azimuth or ground range determines the square pixel size, and the smaller resolution value is adjusted to this size and the corresponding reduction of the bandwidth is used for speckle reduction.

Note: SE products are not available in ScanSAR and Wide ScanSAR modes

5.1.1.2   *Radiometrically Enhanced products (RE)*

The radiometrically enhanced products are designed with the target of maximize the radiometry, so the range and azimuth resolutions are intentionally decreased to significantly reduce speckle by averaging several looks.

5.1.2   **Radiometric performance**

5.1.2.1   *NESZ*

In the products annotations, instead of the NESZ (sigma nought) value, the expected NEBN (beta nought) is annotated in form of polynomials over range with azimuth time tags that describe the image data noise power (requiring the identical k_s as the imaging DNs for conversion to beta naught, as explained in chapter 5.1.2.3) as a function of range.

Noise expressed in sigma nought (NESZ) can be obtained from NEBN through the following expression:

$$NESZ = NEBN \cdot \sin \theta_i$$

being θ_i the local incidence angle (contained in the incidence angle mask of EEC products, see chapter 5.2.4.1) at the pixel.

5.1.2.2   *Radiometric accuracy*

The overall PAZ products radiometric accuracy is defined through two parameters:

- Relative radiometric accuracy: this parameter is the standard deviation of the radiometric error of known targets within one acquisition. Antenna pattern and antenna pointing knowledge are the main parameters which contribute to the relative radiometric accuracy.
- Absolute radiometric accuracy: this parameter is the root mean square error between the measured and the real radar cross section at different locations within one scene and also over time.

PAZ Image
Product Guide

Ref: PAZ-HDS-GUI-001
Issue: 2.0
Date: 10th May 2021
Page: 24/44

5.1.2.3   *Derivation of backscatter coefficient for distributed targets*

PAZ products are calibrated to radar brightness β_0 (beta nought), and the conversion from digital image data pixel values (DN, digital number) shall be done through the calibration factor, k_s (included in the product annotations).

In order to obtain a fully calibrated and noise corrected image in sigma nought (σ_0), the noise power must be taken into account. The thermal noise power estimation is annotated in PAZ products, and has to be scaled with the same calibration factor as the according image data to obtain the noise equivalent beta nought, NEBN. Then, this local NEBN has to be subtracted from each pixel's β_0 value through the following expression:

$$\sigma_0 = (k_s \langle |DN|^2 \rangle - NEBN) \sin \theta_i$$

Where θ_i is the local incidence angle (contained in the incidence angle mask of EEC products, see chapter 5.2.4.1) at the pixel, k_s is the calibration factor for SAR signals annotated in each product, and the local calibrated noise power *NEBN,* which is only to be used for uncorrected products and derived from the noise profiles. For flat terrain or sea surfaces, the incidence angles annotated in the geo grid file are sufficiently accurate for this conversion – otherwise the local slopes from a terrain model have to be taken into account.

5.1.3   Pixel localization accuracy

The pixel localization accuracy defines how accurate a pixel in PAZ basic products can be transformed to a ground position. For complex products (SSC) only the systems errors are relevant, taking into account that there is no ground projection performed by the processor. The main parameter that contributes to the pixel localization accuracy is the GPS orbit determination. For that reason, depending on the customer needs, three different orbit products can be used for image processing, as shown in the next table:

Orbit product type	Orbit product accuracy	Use
Predicted	700 m	Only used for NRT products processing
Rapid	2 m	Standard processing of basic products
Science	0.2 m	Processing for high accuracy purposes

Table 8 – Orbit products

Delivery times for PAZ products are strongly linked to the type of orbit product chosen during the product ordering, as can be seen in chapter 5.4.

5.2   *Geometric projections and data representation*

PAZ basic products can be ordered using the following four geometric projections (one complex type and three detected ones).

5.2.1   Single Look Slant Range Complex (SSC)

Geometric projection: azimuth – slant range (time domain).

The SSC product is a single look product of the focused radar signal. The pixels are spaced equidistant in azimuth (according to the pulse repetition interval PRI=1/PRF) and in slant range (according to the range sampling frequency). The data are represented as complex numbers containing amplitude and phase information. Each image pixel is processed to zero Doppler coordinates in range direction, i.e. perpendicular to the flight track. Due to the nature of azimuth/slant range coordinates, no geocoding is available. The SSC is delivered in the DLR-defined binary COSAR format (see [RD-01] PAZ Level1B Product Format Specification). The SSC product is intended for applications that require the full bandwidth and phase information, e.g. for

PAZ Image
Product Guide

Ref: PAZ-HDS-GUI-001
Issue: 2.0
Date: 10th May 2021
Page: 25/44

SAR interferometry and polarimetry. Depending on the required application, this product may be preferred to geocoded data, since it does not include any radiometric artifacts, which may be introduced during spatial resampling and geocoding.

5.2.2   Multi Look Ground Range Detected (MGD)

Geometric projection: azimuth – ground range (without terrain correction)

The MGD product is a detected multi look product with reduced speckle and approximately square resolution cells on ground. The image coordinates are oriented along flight direction and along ground range. The pixel spacing is equidistant in azimuth and in ground range. A simple polynomial slant to ground projection is performed in range using a WGS84 ellipsoid and an average, constant terrain height parameter. The advantage of this product is that no image rotation to a map coordinate system is performed and interpolation artifacts are thus avoided. Consequently, the pixel localization accuracy is lower than in geocoded products. As for the rest of PAZ products, a coarse grid of coordinates is annotated in the product. The grid coordinates are calculated using a coarse DEM, while the projection of the image data is performed using an ellipsoid with one elevation determined for the scene.
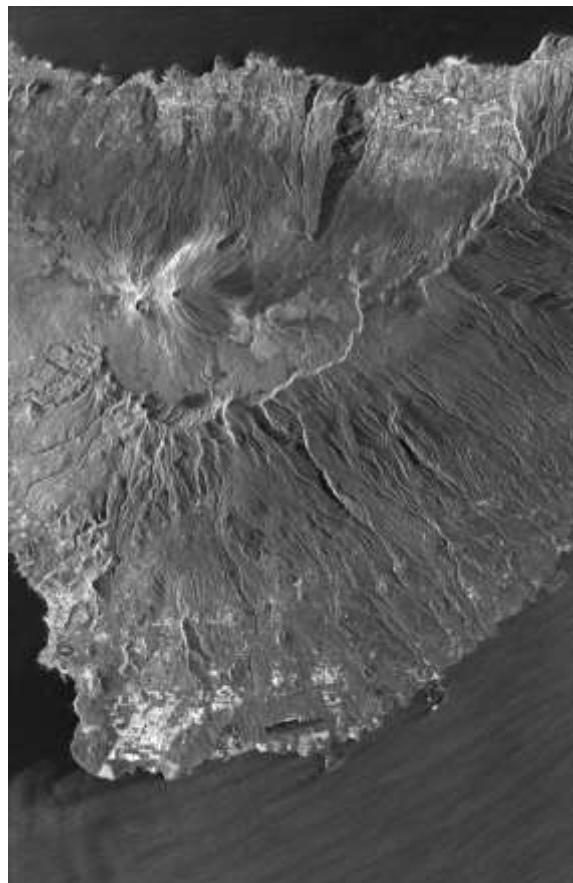
Figure 15 – PAZ image MGD (Teide, Canary Islands, Spain)

PAZ Image
Product Guide

Ref: PAZ-HDS-GUI-001
Issue: 2.0
Date: 10th May 2021
Page: 26/44

5.2.3   Geocoded Ellipsoid Corrected (GEC)

Geometric projection: map geometry with ellipsoidal corrections only (no terrain correction performed)

The GEC product is a multi look detected product. It is projected and re-sampled to the WGS84 reference ellipsoid assuming one average terrain height. Available grid formats are UTM and UPS.

As the ellipsoid correction does not consider a DEM, the pixel location accuracy varies due to the terrain.
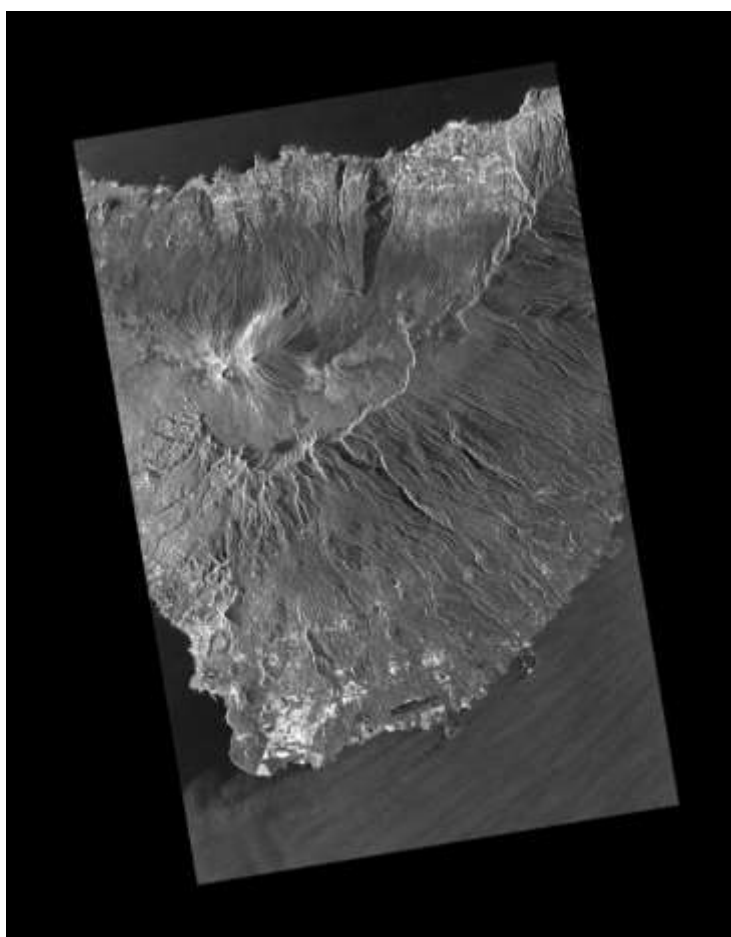
Figure 16 – PAZ image GEC (Teide, Canary Islands, Spain)

![hisdeSAT logo]

PAZ Image
Product Guide

Ref: PAZ-HDS-GUI-001
Issue: 2.0
Date: 10th May 2021
Page: 27/44

5.2.4   Enhanced Ellipsoid Corrected (EEC)

Geometric projection: map geometry with terrain correction, using a DEM

The EEC is a multi look detected product. It is projected and re-sampled to the WGS84 reference ellipsoid. The image distortions caused by varying terrain height are corrected using an external DEM. Available grid formats will be either UTM or UPS.

Terrain induced distortions are corrected using a DEM. Therefore the pixel localization in these products is highly accurate. The accuracy still depends on the type of terrain as well as the quality and resolution of the DEM and on the incidence angle.

Figure 17 – PAZ image EEC (Teide, Canary Islands, Spain)

hisdeSAT

PAZ Image
Product Guide

Ref: PAZ-HDS-GUI-001
Issue: 2.0
Date: 10th May 2021
Page: 28/44

5.2.4.1 Incidence angle mask (GIM)

EEC products will optionally be complemented with a geocoded incidence angle mask (GIM). The GIM provides information about the local incidence angle for each pixel of the geocoded SAR scene and about presence of layover and shadow areas.

The local incidence angle is the angle between the radar beam and a line perpendicular to the slope at the point of incidence. For its determination, it is necessary to know the slant range vector and the local surface normal vector.

Areas of SAR shadow are determined via the off-nadir angle, which in general increases for a scan line from near to far range. Shadow occurs as soon as the off-nadir angle reaches a turning point and decreases when tracking a scan-line from near to far range. The shadow area ends where the off-nadir angle reaches that value again, which it had at the turning point.

The GIM product shows the same cartographic properties like the geocoded output image with regard to output projection and cartographic framing. The content of the GIM product component is basically the local terrain incidence angle and additional flags indicate whether a pixel is affected by shadow and/or layover or not.

The following coding of the incidence angles into the GIM data is specified:
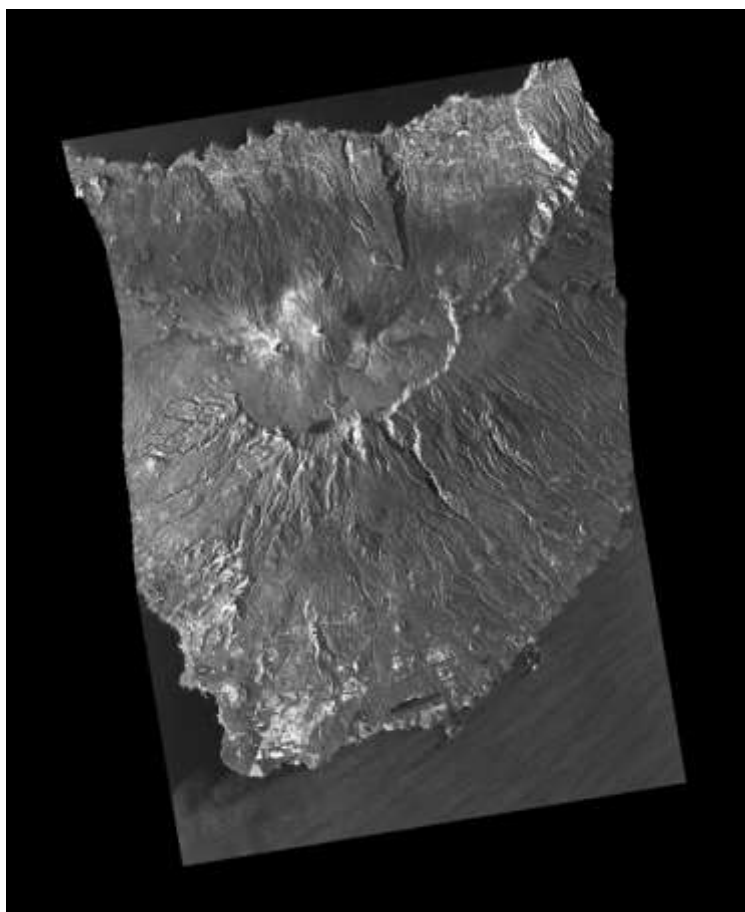
- Incidence angles are given as 16 bit integer values in tenths of degrees, e.g. 10.1° corresponds to an integer value of 1010.
- The last digit of this integer number is used to indicate shadow and/or layover areas as follows:
  - '1': indicates layover (ex. 1011)
  - '2': indicates shadow (ex. 1012)
  - '3': indicates layover and shadow (ex. 1013)

5.3 Map projections and grid formats

For PAZ products, WGS84 is used as geodetic datum. Universal Transverse Mercator (UTM) is the standard projection, and for polar regions, Universal Polar Stereographic (UPS) will be applied.

Map projection can be selected by user. If not, the projection and zone are derived from the scene center coordinates. Whenever the scene center latitude crosses 84° north or 80° south, UPS projection is selected. The UTM-zones are 6° wide with e.g. 3° (UT31), 9° (UT32), 15° (UT33),... as central meridians. The scene center longitude determines the zone of the entire scene.

5.4 Summary of processing options

The user shall select the following processing options:

1. Resolution mode: SE/RE
2. Geometric projection: SSC/MGD/GEC/EEC (with/without GIM; please, note that without GIM is selected by default)

PAZ Image
Product Guide

Ref: PAZ-HDS-GUI-001
Issue: 2.0
Date: 10th May 2021
Page: 29/44

Taking into account the previous resolution mode and geometric projection selection, the following combinations will be available:

Mode	SSC	RE			SE		
		MGD	GEC	EEC	MGD	GEC	EEC
SM-S	✓	✓	✓	✓	✓	✓	✓
SM-D	✓	✓	✓	✓	✓	✓	✓
SC	✓	✓	✓	✓	✗	✗	✗
SL-S	✓	✓	✓	✓	✓	✓	✓
SL-D	✓	✓	✓	✓	✓	✓	✓
HS-S	✓	✓	✓	✓	✓	✓	✓
HS-D	✓	✓	✓	✓	✓	✓	✓
WS	✓	✓	✓	✓	✗	✗	✗
ST	✓	✓	✓	✓	✓	✓	✓

Table 9 – Basic product combinations

3. Map projection (not mandatory): UTM/UPS
4. Type of order: there are three types of orders, depending on the priority of download and processing:
   a. Emergency: the highest priority of download and processing. It is linked to NRT products.
   b. Urgent: medium priority of download and processing.
   c. Nominal: the lowest priority of download and processing.
5. Type of product:
   a. NRT (only in Emergency orders): acquisition data will be downloaded and processed with the highest priority, using a predicted orbit product, and with no instrument internal calibration applied. Associated L1b product (when rapid orbit product is available) will be also delivered.
   b. L1b: nominal processing with selected orbit precision product and instrument internal calibration applied (if telemetry available).
   c. From archive:
      i. Direct dissemination: if the L1b product is available with the same processing options.
      ii. Processing: if the L1b is not available or the processing options are different from the original order.
6. Orbit measurement precisions: Predicted/Rapid/Science

As previously stated, three different orbit products can be used for image processing, as shown in the next table:

Orbit product type	Orbit product accuracy	Use
Predicted	700 m	Only used for NRT products processing
Rapid	2 m	Standard processing of basic products
Science	0.2 m	Processing for high accuracy purposes

Table 10 Orbit product types

Note: for NRT products, only the Predicted orbit product will be available for processing.

PAZ Image
Product Guide

6. Basic Product Tables

The following tables include the main parameters that characterize the PAZ basic products for each SAR mode.

6.1 StripMap Single (SM-S)

Parameter	Value		
Polarizations	HH, VV, HV, VH		
Data Collection Range	15° - 60°		
Full Performance Range	20° - 45°		
Scene size (Range x Azimuth) [Km]	30 x 50		
Absolute Radiometric Accuracy [dB]	0.57		
Relative Radiometric Accuracy [dB]	0.35		
NESZ [dB]	< -16.8 [3]		
Ambiguity Ratios [dB]	< -17		
Pixel Localization Accuracy [m] (SSC)	0.65		
	Detected (MGD, GEC, EEC), SE	Detected (MGD, GEC, EEC), RE	Complex (SSC)
Range Resolution [m]	Ground Range: 2.99 … 3.52 @ (45°…20°)	Ground Range: 6.53 … 7.65 @ (45°…20°)	Slant Range: 1.1 [1]
Azimuth Resolution [m]	3.05	6.53 … 7.60 @ (45°…20°)	3.01
Approx. Range Pixel Spacing [m]	1.25	3.25	0.91 [2]
Approx. Azimuth Pixel Spacing [m]	1.25	3.25	2

Table 11 – SM-S Basic Products Table

[1] Slant range resolution value valid for beams with 150 MHz bandwidth; for beams with 100 MHz bandwidth, it changes into 1.76 m.

[2] Approximated range pixel spacing value valid for beams with 150 MHz bandwidth; for beams with 100 MHz bandwidth, it changes into 1.36 m.

[3] NESZ value is defined as the worst case within the whole full performance incidence angles range

PAZ Image
Product Guide

Ref: PAZ-HDS-GUI-001
Issue: 2.0
Date: 10th May 2021
Page: 31/44

6.2   StripMap Dual (SM-D)

Parameter	Value		
Polarizations	HH/VV, HH/HV, VV/VH		
Data Collection Range	15° - 60°		
Full Performance Range	20° - 45°		
Scene size (Range x Azimuth) [Km]	15 x 50		
Absolute Radiometric Accuracy [dB]	0.3		
Relative Radiometric Accuracy [dB]	0.24		
NESZ [dB]	< -18.5 [1]		
Ambiguity Ratios [dB]	< -22.5		
Pixel Localization Accuracy [m] (SSC)	0.7		
	Detected (MGD, GEC, EEC), SE	Detected (MGD, GEC, EEC), RE	Complex (SSC)
Range Resolution [m]	Ground Range: 6	Ground Range: 7.51 … 10.43 @ (45°…20°)	Slant Range: 1.18
Azimuth Resolution [m]	6.11	7.52 … 10.4 @ (45°…20°)	6.04
Approx. Range Pixel Spacing [m]	2.75	3.5 … 4.75 @ (45°…20°)	0.91
Approx. Azimuth Pixel Spacing [m]	2.75	3.5 … 4.75 @ (45°…20°)	2.99

Table 12 - SM-D Basic Products Table

[1] NESZ value is defined as the worst case within the whole full performance incidence angles range

PAZ Image
Product Guide

Ref: PAZ-HDS-GUI-001
Issue: 2.0
Date: 10th May 2021
Page: 32/44

6.3   ScanSAR (SC)

Parameter	Value	
Polarizations	HH, VV, HV, VH	
Data Collection Range	15° - 60°	
Full Performance Range	20° - 45°	
Scene size (Range x Azimuth) [Km]	100 x 150	
Absolute Radiometric Accuracy [dB]	0.41	
Relative Radiometric Accuracy [dB]	0.33	
NESZ [dB]	< -18 [1]	
Ambiguity Ratios [dB]	< -22	
	Detected (MGD, GEC, EEC), RE	**Complex (SSC)**
Range Resolution [m]	Ground range: 16.79 … 18.19 @ (45°…20°)	Slant range: 1.17 - 3.4 (depending on range bandwidth)
Azimuth Resolution [m]	17.66 … 18.18 @ (45°…20°)	18.5
Approx. Range Pixel Spacing [m]	8.25	-
Approx. Azimuth Pixel Spacing [m]	8.25	-

Table 13 - SC Basic Products Table

[1] NESZ value is defined as the worst case within the whole full performance incidence angles range

PAZ Image
Product Guide

Ref: PAZ-HDS-GUI-001
Issue: 2.0
Date: 10th May 2021
Page: 33/44

6.4 Wide ScanSAR (WS)

Parameter	Value	
Polarizations	HH, VV, HV, VH	
Data Collection Range	15.6° - 49°	
Full Performance Range	15.6° - 49°	
Scene size (Range x Azimuth) [Km]	[273 … 196] x 208	
Absolute Radiometric Accuracy [dB]	0.41	
Relative Radiometric Accuracy [dB]	0.33	
NESZ [dB]	< -24 [1]	
Ambiguity Ratios [dB]	Not specified	
Pixel localization accuracy [m]	0.97	
	Detected (MGD, GEC, EEC), RE	**Complex (SSC)**
Range Resolution [m]	Ground range: 35	Slant range: 1.75 - 3.18 (depending on range bandwidth)
Azimuth Resolution [m]	39	38.27
Approx. Range Pixel Spacing [m]	15	1.36
Approx. Azimuth Pixel Spacing [m]	15	14.21

Table 14 WS Basic Products Table

[1] NESZ value is defined as the worst case within the whole full performance incidence angles range

PAZ Image
Product Guide

Ref: PAZ-HDS-GUI-001
Issue: 2.0
Date: 10th May 2021
Page: 34/44

6.5 Spotlight Single (SL-S)

Parameter	Value		
Polarizations	HH, VV, HV, VH		
Data Collection Range	15° - 60°		
Full Performance Range	20° - 55°		
Scene size (Range x Azimuth) [Km]	10 x 10		
Absolute Radiometric Accuracy [dB]	0.63		
Relative Radiometric Accuracy [dB]	0.25		
NESZ [dB]	< -18.7 [1]		
Ambiguity Ratios [dB]	< -17		
Pixel Localization Accuracy [m] (SSC)	0.6		
	Detected (MGD, GEC, EEC), SE	**Detected (MGD, GEC, EEC), RE**	**Complex (SSC)**
Range Resolution [m]	Ground Range: 1.55 … 3.43 @ (55°…20°)	Ground Range: 3.51 … 5.43 @ (55°…20°)	Slant Range: 1.18
Azimuth Resolution [m]	1.56 … 2.9 @ (55°…20°)	3.51 … 5.4 @ (55°…20°)	1.46
Approx. Range Pixel Spacing [m]	0.75 … 1.25 @ (55°…20°)	2.25	0.91
Approx. Azimuth Pixel Spacing [m]	0.75 … 1.25 @ (55°…20°)	2.25	1.14

Table 15 - SL-S Basic Products Table

[1] NESZ value is defined as the worst case within the whole full performance incidence angles range

PAZ Image
Product Guide

Ref: PAZ-HDS-GUI-001
Issue: 2.0
Date: 10th May 2021
Page: 35/44

6.6 Spotlight Dual (SL-D)

Parameter	Value		
Polarizations	HH/VV, HH/HV, VV/VH		
Data Collection Range	15° - 60°		
Full Performance Range	20° - 55°		
Scene size (Range x Azimuth) [Km]	10 x 10		
Absolute Radiometric Accuracy [dB]	0.37		
Relative Radiometric Accuracy [dB]	0.32		
NESZ [dB]	< -16.5 [1]		
Ambiguity Ratios [dB]	< -22 (<-16 @>45°)		
Pixel Localization Accuracy [m] (SSC)	0.75		
	Detected (MGD, GEC, EEC), SE	Detected (MGD, GEC, EEC), RE	Complex (SSC)
Range Resolution [m]	Ground Range: 3.09 … 3.5 @ (55°…20°)	Ground Range: 4.98 … 7.63 @ (55°…20°)	Slant Range: 1.17
Azimuth Resolution [m]	3.53	4.99 … 7.64 @ (55°…20°)	3.1
Approx. Range Pixel Spacing [m]	1.5	2.25 … 3.5 @ (55°…20°)	0.91
Approx. Azimuth Pixel Spacing [m]	1.5	2.25 … 3.5 @ (55°…20°)	1.43

Table 16 – SL-D Basic Products Table

[1] NESZ value is defined as the worst case within the whole full performance incidence angles range

Ref: PAZ-HDS-GUI-001
Issue: 2.0
Date: 10th May 2021
Page: 36/44

PAZ Image
Product Guide

6.7 HR Spotlight Single (HS-S)

Parameter	Value		
Polarizations	HH, VV, HV, VH		
Data Collection Range	15° - 60°		
Full Performance Range	20° - 55°		
Scene size (Range x Azimuth) [Km]	10/6 [1] x 5		
Absolute Radiometric Accuracy [dB]	0.47		
Relative Radiometric Accuracy [dB]	0.33		
NESZ [dB]	< -16.2 [2]		
Ambiguity Ratios [dB]	< -16		
Pixel Localization Accuracy [m] (SSC)	0.62		
	Detected (MGD, GEC, EEC), SE	Detected (MGD, GEC, EEC), RE	Complex (SSC)
Range Resolution [m]	Ground Range: 1 ... 1.76 @ (55°...20°)	Ground Range: 2.83 ... 3.11 @ (55°...20°)	Slant Range: 0.6
Azimuth Resolution [m]	1 ... 1.49 @ (55°...20°)	2.83 ... 3.13 @ (55°...20°)	1.05
Approx. Range Pixel Spacing [m]	0.5	1.25	0.45
Approx. Azimuth Pixel Spacing [m]	0.5	1.25	0.82

Table 17 - HS-S Basic Products Table

[1] Depending on the incidence angle
[2] NESZ value is defined as the worst case within the whole full performance incidence angles range

PAZ Image
Product Guide

Ref: PAZ-HDS-GUI-001
Issue: 2.0
Date: 10th May 2021
Page: 37/44

6.8   HR Spotlight Dual (HS-D)

Parameter	Value		
Polarizations	HH/VV, HH/HV, VV/VH		
Data Collection Range	15° - 60°		
Full Performance Range	20° - 55°		
Scene size (Range x Azimuth) [Km]	10 x 5		
Absolute Radiometric Accuracy [dB]	0.38		
Relative Radiometric Accuracy [dB]	0.24		
NESZ [dB]	< -16.8 [1]		
Ambiguity Ratios [dB]	< -16		
Pixel Localization Accuracy [m] (SSC)	0.68		
	Detected (MGD, GEC, EEC), SE	Detected (MGD, GEC, EEC), RE	Complex (SSC)
Range Resolution [m]	Ground Range: 2 … 3.5 @ (55°…20°)	Ground Range: 4 … 6.2 @ (55°…20°)	Slant Range: 1.17
Azimuth Resolution [m]	2.38 … 2.93 @ (55°…20°)	4 … 6.25 @ (55°…20°)	2.16
Approx. Range Pixel Spacing [m]	1 … 1.25 @ (55°…20°)	1.75 … 2.75 @ (55°…20°)	0.91
Approx. Azimuth Pixel Spacing [m]	1 … 1.25 @ (55°…20°)	1.75 … 2.75 @ (55°…20°)	1.77

Table 18 – HS-D Basic Products Table

[1] NESZ value is defined as the worst case within the whole full performance incidence angles range

PAZ Image
Product Guide

Ref: PAZ-HDS-GUI-001
Issue: 2.0
Date: 10th May 2021
Page: 38/44

6.9 Staring Spotlight (ST)

Parameter	Value		
Polarizations	HH, VV, HV, VH		
Data Collection Range	15° - 60°		
Full Performance Range	20° - 45°		
Scene size (Range x Azimuth) [Km]	[9 … 4.6] x [2.7 … 3.6]		
Absolute Radiometric Accuracy [dB]	0.47		
Relative Radiometric Accuracy [dB]	0.33		
NESZ [dB]	< -19 [1]		
Ambiguity Ratios [dB]	Not specified		
Pixel Localization Accuracy [m] (SSC)	0.2		
	Detected (MGD, GEC, EEC), SE	Detected (MGD, GEC, EEC), RE	Complex (SSC)
Range Resolution [m]	Ground Range: 0.96 … 1.78 @ (45°…20°)	Ground Range: 0.97 … 1.78 @ (45°…20°)	Slant Range: 0.59
Azimuth Resolution [m]	0.38 … 0.7 @ (45°…20°)	0.97 … 1.42 @ (45°…20°)	0.22
Approx. Range Pixel Spacing [m]	0.2 … 0.38 @ (45°…20°)	0.54 … 0.74 @ (55°…20°)	0.45
Approx. Azimuth Pixel Spacing [m]	0.2 … 0.38 @ (45°…20°)	0.54 … 0.74 @ (55°…20°)	0.17

Table 19 ST Basic Products Table

[1] NESZ value is defined as the worst case within the whole full performance incidence angles range

Ref: PAZ-HDS-GUI-001
Issue: 2.0
Date: 10th May 2021
Page: 39/44

PAZ Image
Product Guide

hisdeSAT

7. Basic Products Data Structure

7.1 Product delivery package

The main folder that host the level 1b products are named using a fixed name convention, as explained in the following figure:
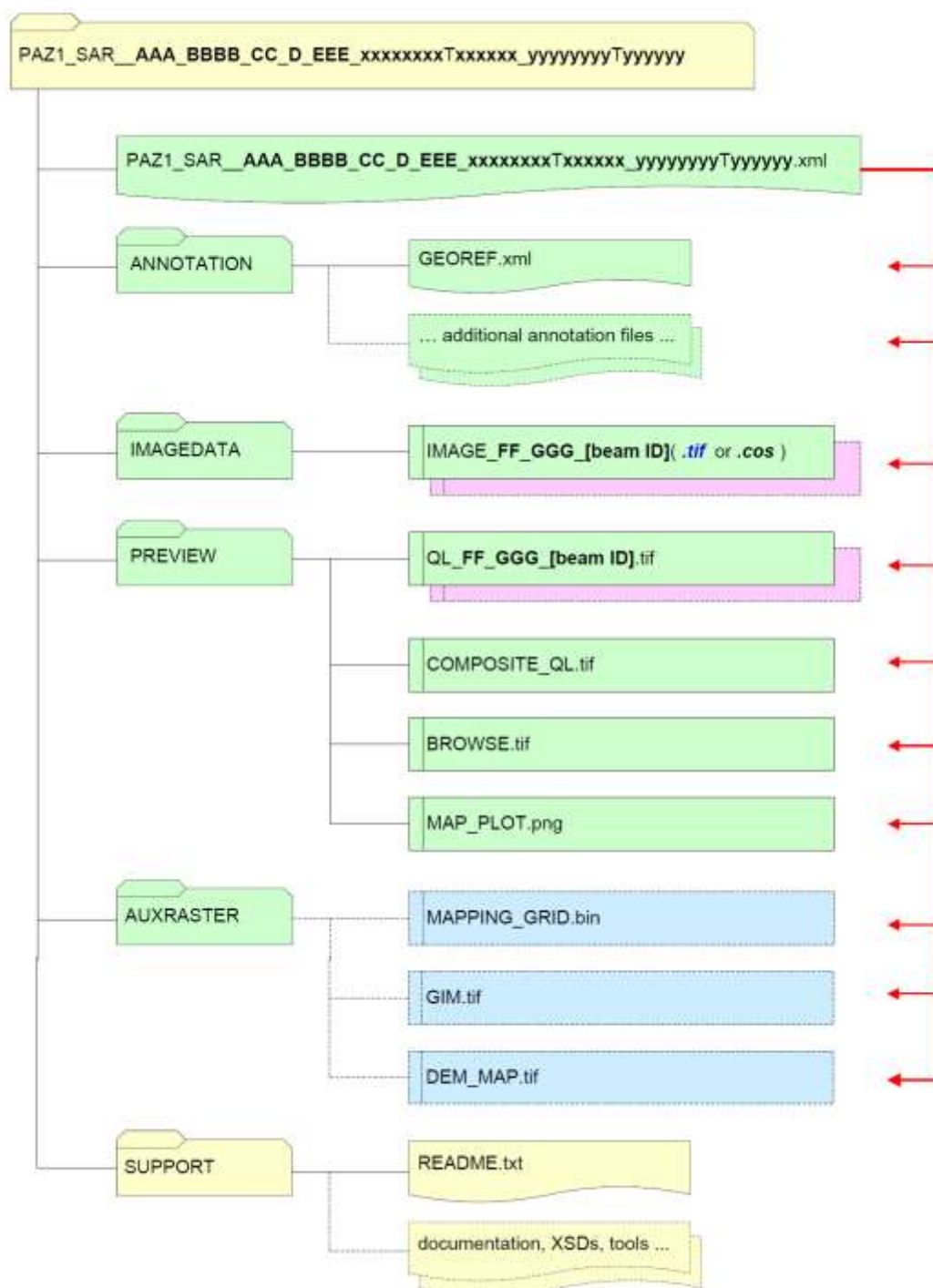

Figure 18 – PAZ L1b products folders

PAZ Image
Product Guide

Ref: PAZ-HDS-GUI-001
Issue: 2.0
Date: 10th May 2021
Page: 40/44

The file name components are depicted in the following table:

Constituent ID	Constituent name	Values/Example	Remark
L1b product names			
-	Mission & satellite ID	PAZ1	Three letters + number
-	sensor	SAR_	fixed
AAA	Product variant	SSC, MGD, GEC, EEC	Product class
BBBB	Resolution variant	SE__, RE__	Product sub-class: spatially or radiometrically enhanced. No entry for SSCs (____).
CC	Imaging mode	SM, SC (*), SL, HS, ST	Example: HS for High resolution Spotlight
D	Polarization mode	S, D	S for Single and D for Dual polarization mode
EEE	Antenna receive configuration	SRA, DRA	SRA for Single-Receive Antenna and DRA for Dual-Receive Antenna
xxxxxxxxTxxxxxx	UTC start time	-	Format: YYYYMMDDThhmmss
yyyyyyyyTyyyyyy	UTC stop time	-	Format: YYYYMMDDThhmmss
Variable parts of the product component file names			
FF	Polarization channel image layer	HH, HV, VH, VV	TxRx polarization
GGG	Geometric (antenna receive channel) image layer	SRA, FWD, AFT	Geometric layers for DRA mode
[beam ID]	Elevation beam configuration ID	e.g. strip_007, scan_009…	

Table 20 – PAZ products file name components

(*) Note: Wide ScanSAR products uses the same mnemonic for the imaging mode as ScanSAR (SC)

There are the file name extensions used in PAZ product package elements:
- ".xml" for the annotation files
- ".tif" for TIFF and GeoTIFF images
- ".cos" for the COSAR images
- ".bin" for a binary raster file
- ".png, .txt" for standard PNG and TXT files

PAZ Image
Product Guide

Ref: PAZ-HDS-GUI-001
Issue: 2.0
Date: 10th May 2021
Page: 41/44

7.2   SAR image raster files

The individual polarization layers of the image data of projected products (MGD, GEC, EEC) are given as separate files in the GeoTIFF file format in unsigned 16 bit representation.

GeoTIFF is an extension of the TIFF (Tagged Image File Format) standard, which defines additional tags concerning map projection information. It is readable with standard image processing and GIS software packages.

Complex products (SSC) are given in DLR-defined COSAR (Complex SAR) file format. One COSAR file contains all focused complex SAR data of one beam in a burst.

For more information, see [RD-01] PAZ Level 1B Product Format Specification.

7.3   Auxiliary raster files

The following auxiliary raster files can be given within the product package:

- The **geocoded incidence angle mask** (GIM) for EEC products (see chapter 5.2.4.1)
- The **DEM map** for EEC products: the reference to the DEM used during the geocoding of this pixel. Its format and its extent are identical to the image files (GeoTIFF). Its resolution depends on the best available DEM for the geocoding.

7.4   Image preview files

Two image preview files are given:

- **Quicklook images**: one image quicklook rescaled to a height of approximately 2000 pixels (depending on the imaging mode and product size) is provided for each image layer in TIFF format, thus readable with common display tools. Targeted pixel spacings for detected products are approx. 25m for StripMap, 10m for SpotLight and 50m for ScanSAR. The quicklooks use an unsigned 16 bit per sample greyscale representation.
- **Map plot**: a coarse geographical map showing the footprint of the scene as a low-resolution image.

7.5   Level 1b product annotation

PAZ L1b products annotations file is delivered in XML format, including all the relevant information associated to the delivered product.

For more information, see [RD-01] PAZ Level 1B Product Format Specification.

PAZ Image
Product Guide

Ref: PAZ-HDS-GUI-001
Issue: 2.0
Date: 10th May 2021
Page: 42/44

8. Ordering and Delivery

8.1 USP tool

The USP (User Service Provider) tool is the service segment of PAZ mission. It is a meeting point for the use of remote sensing information acquired by PAZ, and provides a central access to the Hisdesat's customers bringing services corresponding to PAZ mission as well as the EO derived products which are included as services and suppose an important added value product that can be adapted to the market needs.

In addition, the portal serves as a communication tool with customers and ordinary public showing documentation, news, or videos representing the company's products and services.

8.1.1 USP web portal

USP web portal can be access through the following link: www.geos.hisdesat.es
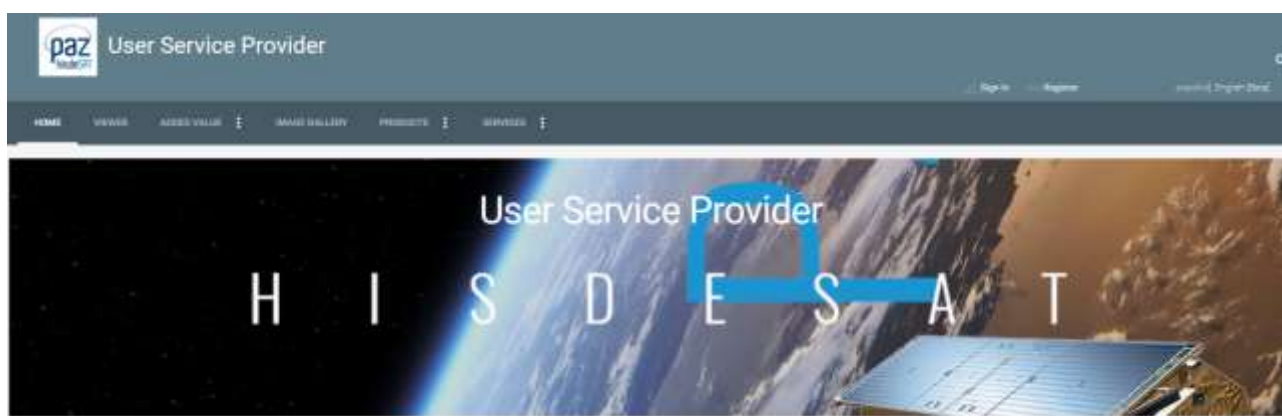

Figure 19 – USP web portal

8.1.2 USP users registration

There are two modalities for USP registration:

- Basic users: users that are only interested in using the USP tool and its functionalities but not in ordering. For basic users, only an email address and a name are required for registration.
- Advanced users: users that are interested in ordering products and services.

8.1.3 Web viewer

Viewer tool can be accessed both being a basic or an advanced user and it is a graphical interface, based on OGC, for display the geospatial information catalogued in the system. It also includes other functionalities such as simulating future acquisitions, displaying catalogued images, showing metadata information, etc. This tool includes a map area to display the geospatial information based on WMS protocol and a table of content to show the layer information; name legend, etc. This also involves a set of auxiliaries' tools to show the layer information; coordinates, coordinated reference system, and map projections based on EPSG.
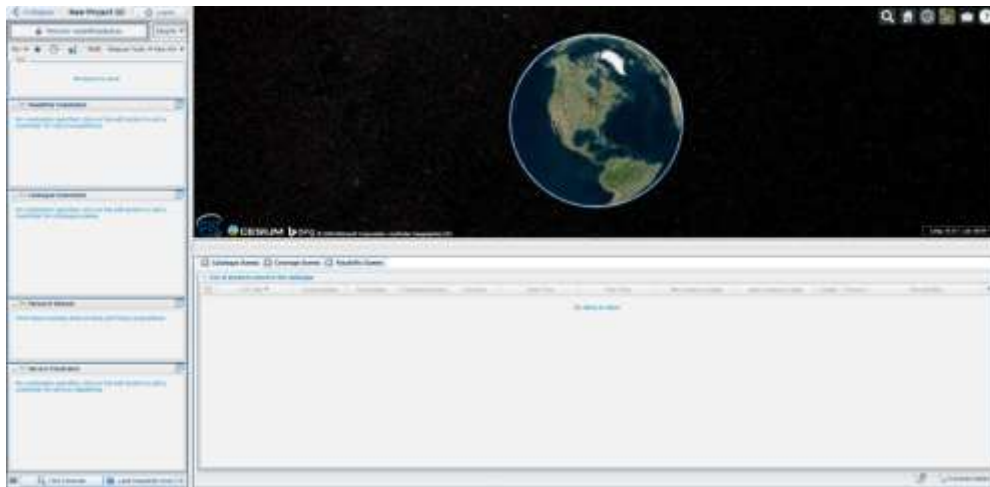
PAZ Image
Product Guide

Ref: PAZ-HDS-GUI-001
Issue: 2.0
Date: 10th May 2021
Page: 43/44

Figure 20 – USP web viewer

8.2   Ordering process. Priority

The acquisition of PAZ images is subjected to a priority concept, which is defined through the type of order:

- Emergency: the highest priority of download and processing.
- Urgent: medium priority of download and processing.
- Nominal: the lowest priority of download and processing.

There are two submission deadlines each day: 8:30h and 21:30h (both UTC), which are related to the uplink window for satellite tasking.

8.3   Legal aspects

8.3.1   License to the users

The end user must accept the End User License Agreement (EULA), provided by Hisdesat, in advance to any usage. It applies to each PAZ data from an acquisition, or to any derived products or services provided by Hisdesat.

The current version will be delivered to the customer by request.

8.4   Delivery process.

8.4.1   Delivery media and file sizes

PAZ products will be delivered via FTP. The customer will be informed via e-mail once the links is available, and can be found in the USP tool.

PAZ Image
Product Guide

Ref: PAZ-HDS-GUI-001
Issue: 2.0
Date: 10th May 2021
Page: 44/44

PAZ products file sizes depends on the acquisition mode, the polarization mode, the processing type (complex, detected, SE, RE…), and the near or far range position of the image. The following table shows a brief description of the file dimensions of PAZ basic products:

	SSC product size (MB)	MGD/GEC/EEC product size (MB)
StripMap	900 to 1500	100 to 1400[1]
ScanSAR	~ 3500-4500	200 to 350
SpotLight	200 to 270	30 to 300[1]
HR SpotLight	120 to 220	20 to 300[1]
Wide ScanSAR	~ 4000-5000	270 to 650
Staring Spotlight	340 to 420	70 to 420 [1]

Table 21 – PAZ products file sizes

[1] Typically, the lower sizes correspond to RE products, and the higher to the SE ones.

9. Contact Information

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