

Sentinel-1 Overview

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Satellite Applications Catapult - Electron Building, Harwell, Oxfordshire

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Copernicus: A New Generation of Data Sources



- Copernicus is a European space flagship programme led by the European Union
- ESA coordinates the space component
- Copernicus provides the necessary data for operational monitoring of the environment and for civil security
- Free and open data policy
- Websites:

<https://sentinel.esa.int/web/sentinel/home>

<https://sentinel.esa.int/web/sentinel/user-guides/sentinel-1>



Sentinel-1: C-band SAR mission

✓ Copernicus radar imaging mission for ocean, land and emergency services

✓ Applications:

- monitoring sea ice zones and the arctic environment
- surveillance of marine environment (e.g. oil spill monitoring)
- maritime security (e.g. ship detection)
- wind, wave, current monitoring
- monitoring of land surface motion (subsidence, landslide, tectonics, volcanoes, etc.)
- support to emergency / risk management (e.g. flooding, etc.) and humanitarian aid in crisis situations
- mapping of land surfaces: forest, water and soil, agriculture, etc.

✓ Data continuity of ERS and ENVISAT missions

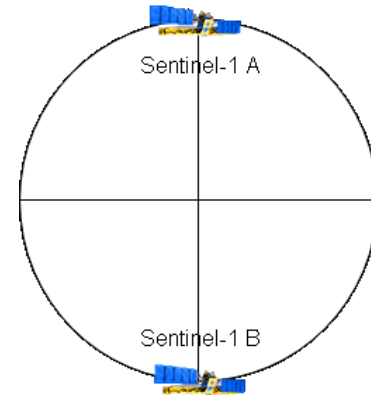
✓ Constellation of 2 satellites

- Sentinel-1A launched on 3 April 2014
- Sentinel-1B launch scheduled for Mid 2016



Sentinel-1 Mission Facts

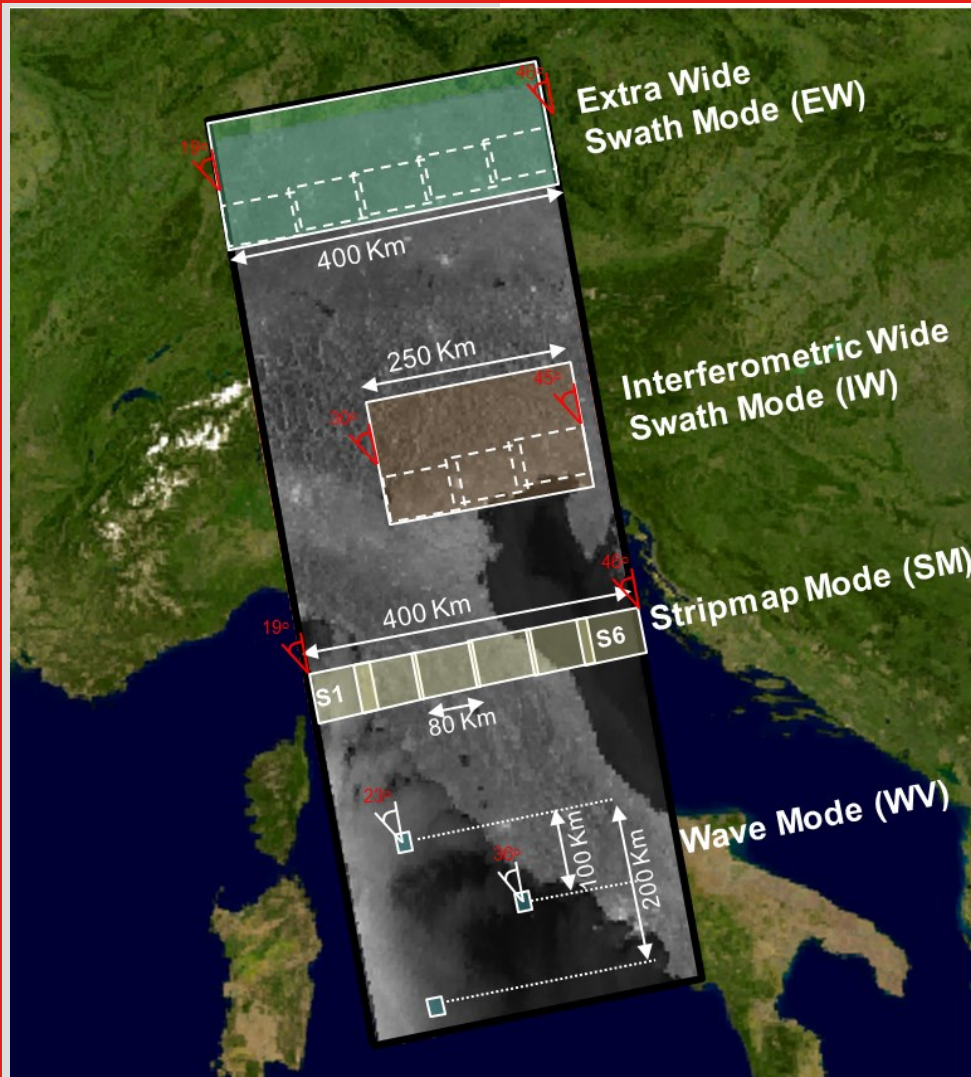
- Constellation of two satellites (A & B units)
- C-Band Synthetic Aperture Radar Payload (at 5.405 GHz)
- 7 years design life time with consumables for 12 years
- Near-Polar sun-synchronous (dawn-dusk) orbit at 698 km
- 12 days repeat cycle (1 satellite), 6 days for the constellation
- Both Sentinel-1 satellites in the same orbital plane (180 deg phased in orbit)
- On-board data storage capacity (mass memory) of 1400 Gbit
- Two X-band RF channels for data downlink with 2 X 260 Mbps
- On-board data compression using Flexible Dynamic Block Adaptive Quantization (FDBAQ)
- Optical Communication Payload (OCP) for data transfer via laser link with the GEO European Data Relay Satellite (ERDS)



Instrument operations constraints:

- ✓ SAR modes exclusivity (incl. polarisation schemes)
- ✓ SAR mode transition time (2.4 sec.)
- ✓ SAR duty cycle (25 min/orbit for the 3 high rate modes)
- ✓ Huge volume of data, potentially up to 2.4 TB/day with the two satellites

Sentinel-1 SAR Modes



Sentinel-1 SAR can be operated in **4 exclusive imaging modes** with different resolution and coverage:

Mode Rate	SAR Mode
High Bit Rate (HBR)	IW
	EW
	SM (S1 → S6)
Low Bit Rate (LBR)	WV

Polarisation schemes for IW, EW and SM:

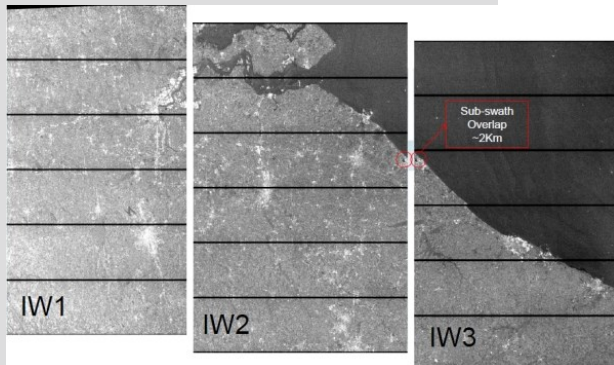
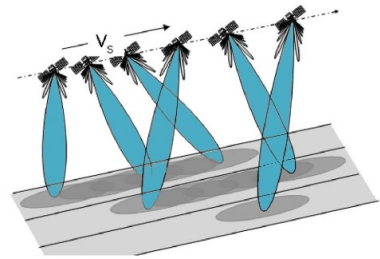
- single polarisation: HH or VV
- dual polarisation: HH+HV or VV+VH

For Wave mode: HH or VV

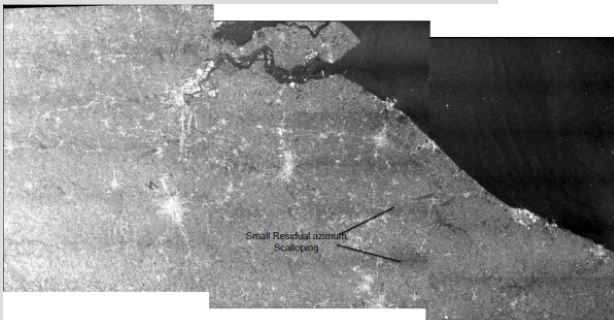
Sentinel-1 Mission Performance

Mode	Access Angle	GR <u>Single Look</u> Resolution	Swath Width	Polarisation
Strip Map	20-45 deg.	Range 5 m Azimuth 5 m	> 80 km	HH or VV or HH+HV or VV+VH
Interferometric Wide Swath	> 25 deg.	Range 5 m Azimuth 20 m	> 250 km	HH or VV or HH+HV or VV+VH
Extra Wide Swath	> 20 deg.	Range 20 m Azimuth 40 m	> 400 km	HH or VV or HH+HV or VV+VH
Wave mode	23 deg. & 36.5 deg.	Range 5 m (TBC) Azimuth 5 m (TBC)	> 20 x 20 km Vignettes at 100 km intervals	HH or VV
For All Modes				
Radiometric accuracy (3 σ)				1 dB
Noise Equivalent Sigma Zero				-22 dB
Point Target Ambiguity Ratio				-25 dB
Distributed Target Ambiguity Ratio				-22 dB

Terrain Observation with Progressive Scans SAR (TOPSAR) Interferometric Wide Swath



IW Sub-Swaths with Minimal Overlap



Resulting **De-Burst** and **Merged** IW Product

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- The Interferometric Wide swath mode is the main acquisition mode over land.
- 250 km swath at 5 m (Range) by 20 (Azimuth) m spatial resolution (single look).
- IW mode captures three sub-swaths using TOPS mode and a IW SLC product contains one image per sub-swath (1 or 2 polarisations)
- Each sub-swath image consists of a series of bursts, where each burst has been processed as a separate SLC image.
- The individually focused complex burst images are included, in azimuth-time order, into a single sub-swath image with black-fill demarcation in between (overlap in azimuth by just enough to provide contiguous coverage of the ground)
- The images for all bursts in all sub-swaths are resampled to a common pixel spacing grid in range and azimuth while preserving the phase information (de-burst and merge)

<https://sentinel.esa.int/web/sentinel/user-guides/sentinel-1-sar/acquisition-modes/interferometric-wide-swath>

Main characteristics of the Interferometric Wide swath mode

Characteristic	Value
Swath width	250 km
Incidence angle range	29.1° - 46.0°
Sub-swaths	3
Azimuth steering angle	± 0.6°
Azimuth and range looks	Single
Polarisation options	Dual HH+HV, VV+VH Single HH, VV
Maximum Noise Equivalent Sigma Zero (NESZ)	-22 dB
Radiometric stability	0.5 dB (3 σ)
Radiometric accuracy	1 dB (3 σ)
Phase error	5°

Beam	IW1	IW2	IW3
Off-nadir angles at min orbit altitude	27.53-32.48	32.38-36.96	36.87-40.40
Incidence angles at min orbit altitude	30.86-36.59	36.47-41.85	41.75-46.00
Off-nadir angles at max orbit altitude	26.00-30.96	30.86-35.43	35.35-38.88
Incidence angles at max orbit altitude	29.16-34.89	34.77-40.15	40.04-44.28

ESA Operational Products available to users

LEVEL-0 PRODUCTS

Compressed, unprocessed instrument source packets, with additional annotations and auxiliary information to support the processing.

LEVEL-1 PRODUCTS

Level-1 Slant-Range Single-Look Complex Products (SLC):

Focused data in slant-range geometry, single look, containing phase and amplitude information.

Level-1 Ground Range Detected Geo-referenced Products (GRD):

Focused data projected to ground range, detected and multi-looked.

Data is projected to ground range using an Earth ellipsoid model, maintaining the original satellite path direction and including complete geo-reference information.

LEVEL-2 PRODUCTS

Level-2 Ocean products

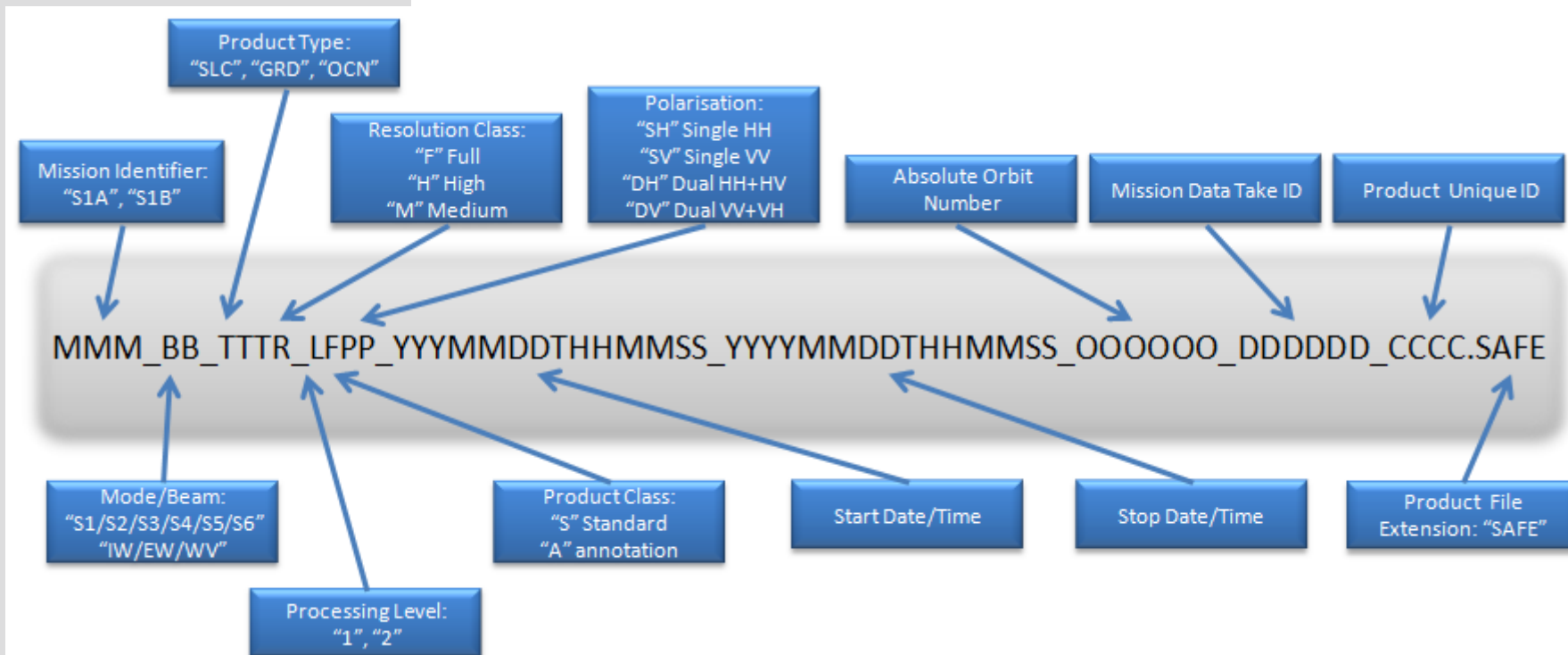
Ocean wind field, swell wave spectra and surface radial velocity information as derived from SAR data.

Operational ESA Sentinel-1 products - L1 characteristics

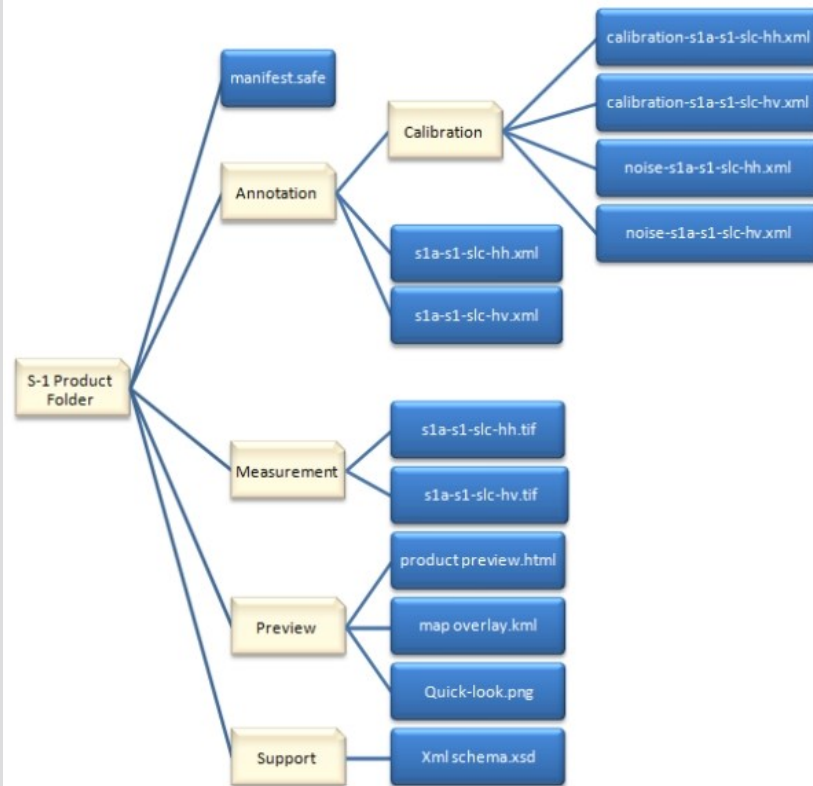
Acq. Mode	Product Type	Resolution Class	Resolution [Rng x Azi] [m]	Pixel Spacing [Rng x Azi]	No. Looks [Rng x Azi]	ENL
SM	SLC	-	1.7 x 4.3 to 3.6 x 4.9	1.5 x 3.6 to 3.1 x 4.1	1 x 1	1
	GRD	FR	9 x 9	4 x 4	2 x 2	3.9
		HR	23 x 23	10 x 10	6 x 6	34.4
		MR	84 x 84	40 x 40	22 x 22	464.7
IW	SLC	-	2.7 x 22 to 3.5 x 22	2.3 x 17.4 to 3 x 17.4	1	1
	GRD	HR	20 x 22	10 x 10	5 x 1	4.9
		MR	88 x 89	40 x 40	22 x 5	105.7
EW	SLC	-	7.9 x 42 to 14.4 x 43	5.9 x 34.7 to 12.5 x 34.7	1 x 1	1
	GRD	HR	50 x 50	25 x 25	3 x 1	3
		MR	93 x 87	40 x 40	6 x 2	12
WV	SLC	-	2.0 x 4.8 and 3.1 x 4.8	1.7 x 4.1 and 2.7 x 4.1	1 x 1	1
	GRD	MR	52 x 51	25 x 25	13 x 13	139.7

- For Ground Range Products, the resolution corresponds to the mid range value at mid orbit altitude, averaged over all swaths.
- For SLC SM/IW/EW products, the resolution and pixel spacing are provided from lowest to highest incidence angle.
- For SLC WV products, the resolution and pixel spacing are provided for beams WV1 and WV2.
- For SLC products, the range coordinate is in slant range. All the other products are in ground range.

Naming Conventions



SENTINEL-SAFE format



The SENTINEL-SAFE format wraps a folder containing image data in a binary data format and product metadata in XML.

A SENTINEL product refers to a directory folder that contains a collection of information. It includes:

- a 'manifest.safe' file which holds the general product information in XML
- subfolders for measurement datasets containing image data in various binary formats
- a preview folder containing 'quicklooks' in PNG format, Google Earth overlays in KML format and HTML preview files
- an annotation folder containing the product metadata in XML as well as calibration data
- a support folder containing the XML schemes

<https://sentinel.esa.int/web/sentinel/user-guides/sentinel-1-sar/data-formats/safe-specification>

Orbit impact

Geolocation accuracy



- Precise geolocation has been assessed over dedicated site deployed by UZH over Torny-le-Grand and Dubendorf
- Assessment of the geolocation accuracy was performed using:
 - Different state vector sources
 - atmospheric path delay correction (3m)
 - plate tectonics (~cm)
 - Solid earth tides (~cm)

SM SLC	Slant range offset [m]	Azimuth offset [m]	SM GRDF	Slant range offset [m]	Azimuth offset [m]	
Internal (SSP)	5.45±24.32	2.19±58.2	Internal (SSP)	5.37±2.59	0.49±59	Fix under implementation
Reconstituted	1.30±0.06	2.03±0.58	Reconstituted	1.30±0.19	1.95±0.51	User product
Precise	1.27±0.06	1.96±0.41	Precise	1.27±0.19	1.89±0.40	

Credit: S-1 instrument and product performance status @ Fringe 2105, March 2015, ESA-Esrin, Frascati, Rome (Italy)

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Precise geolocation accuracy

S2

4 asc., 8 desc.

Mean \pm standard deviation:

Δ_{rg} 1.27 ± 0.07 m

Δ_{az} 1.57 ± 0.18 m

S4

7 asc., 3 desc.

Mean \pm standard deviation:

Δ_{rg} 1.27 ± 0.06 m

Δ_{az} 2.07 ± 0.13 m

IW

7 asc., 3 desc.

Mean \pm standard deviation:

Δ_{rg} 1.47 ± 0.23 m

Δ_{az} 2.45 ± 0.49 m

IW

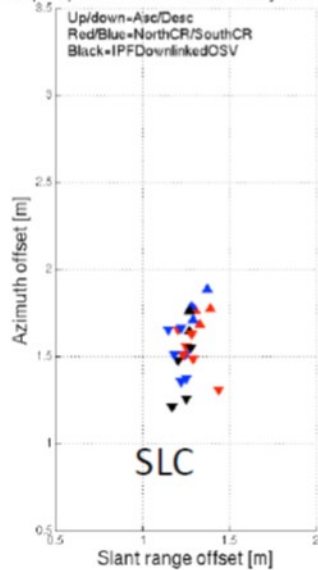
7 asc., 3 desc.

Mean \pm standard deviation:

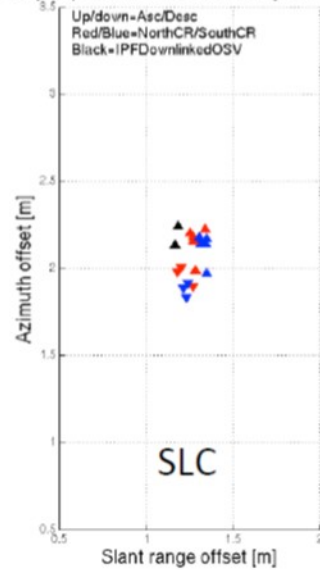
Δ_{rg} 1.47 ± 0.25 m

Δ_{az} 2.40 ± 0.8 m

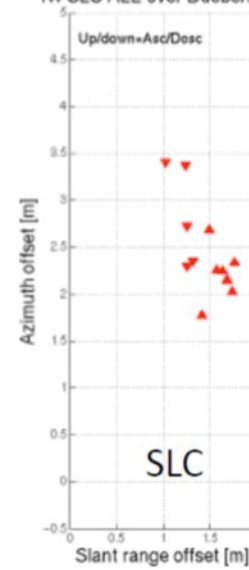
Stripmap S2 SLC ALE over Torny-le-Grand



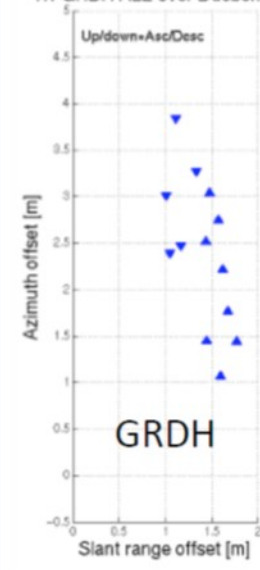
Stripmap S4 SLC ALE over Torny-le-Grand



IW SLC ALE over Duebendorf



IW GRDH ALE over Duebendorf

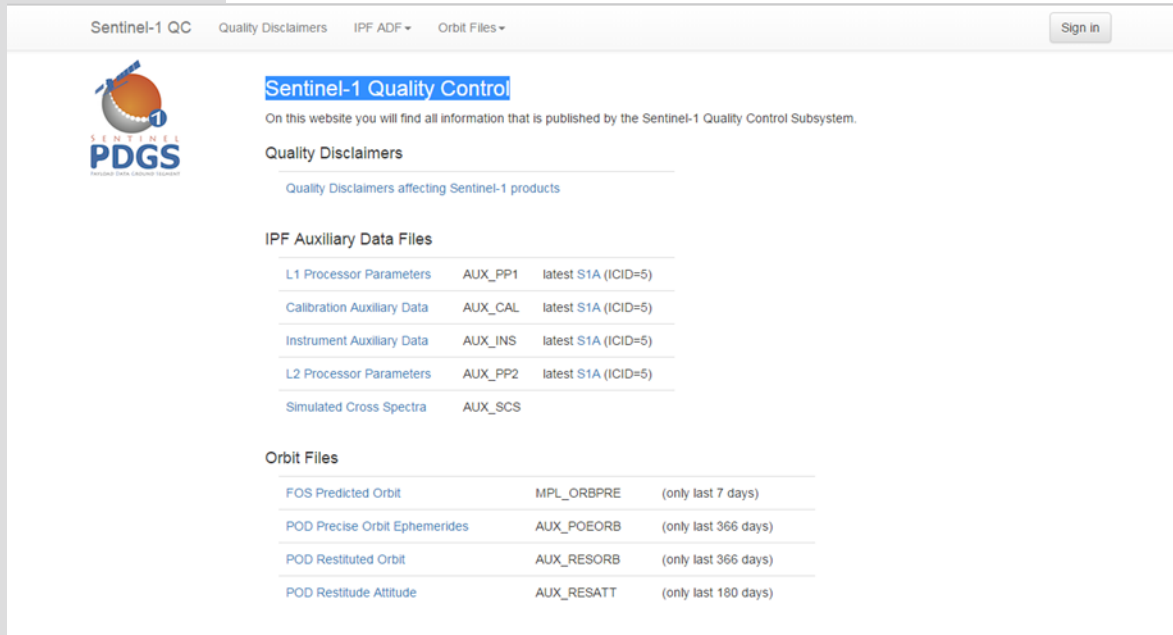


Credit: S-1 instrument and product performance status @ Fringe 2105, March 2015, ESA-Esrin, Frascati, Rome (Italy)

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Sentinel-1 Quality Control

Website: <https://qc.sentinel1.eo.esa.int>



The screenshot shows the Sentinel-1 Quality Control website. The header includes navigation links: Sentinel-1 QC, Quality Disclaimers, IPF ADF, and Orbit Files, along with a Sign in button. The main content area features the Sentinel-1 PDGS logo and a heading 'Sentinel-1 Quality Control'. Below this, it states: 'On this website you will find all information that is published by the Sentinel-1 Quality Control Subsystem.' The 'Quality Disclaimers' section lists 'Quality Disclaimers affecting Sentinel-1 products'. The 'IPF Auxiliary Data Files' section contains a table with the following data:

File Name	File ID	Version
L1 Processor Parameters	AUX_PP1	latest S1A (ICID=5)
Calibration Auxiliary Data	AUX_CAL	latest S1A (ICID=5)
Instrument Auxiliary Data	AUX_INS	latest S1A (ICID=5)
L2 Processor Parameters	AUX_PP2	latest S1A (ICID=5)
Simulated Cross Spectra	AUX_SCS	

The 'Orbit Files' section contains a table with the following data:

File Name	File ID	Version
FOS Predicted Orbit	MPL_ORBPRED	(only last 7 days)
POD Precise Orbit Ephemerides	AUX_POEORB	(only last 366 days)
POD Restituted Orbit	AUX_RESORB	(only last 366 days)
POD Restituted Attitude	AUX_RESATT	(only last 180 days)

POD Restituted Orbit [AUX_RESORB]

POD Precise Orbit Ephemerides [AUX_POEORB] (more accurate than POD)

Mission Status

<https://sentinel.esa.int/web/sentinel/missions/sentinel-1/mission-status>

Sentinel-1 observation scenario

Implement a **pre-defined** and **conflict-free** observation plan, aiming at fulfilling, to the maximum feasible extent, the observation requirements from:

- the **Copernicus services**
- the **use by ESA / EU Member States**

In addition, on best effort basis and in order to ensure some **continuity of ERS/ENVISAT**, requirements from the **science** community are also considered, as well as contribution to **international cooperation** activities.

→ Need to find *a priori* the **solutions on the potential conflict** among users (e.g. different SAR operation modes / polarisation required over same geographical area)

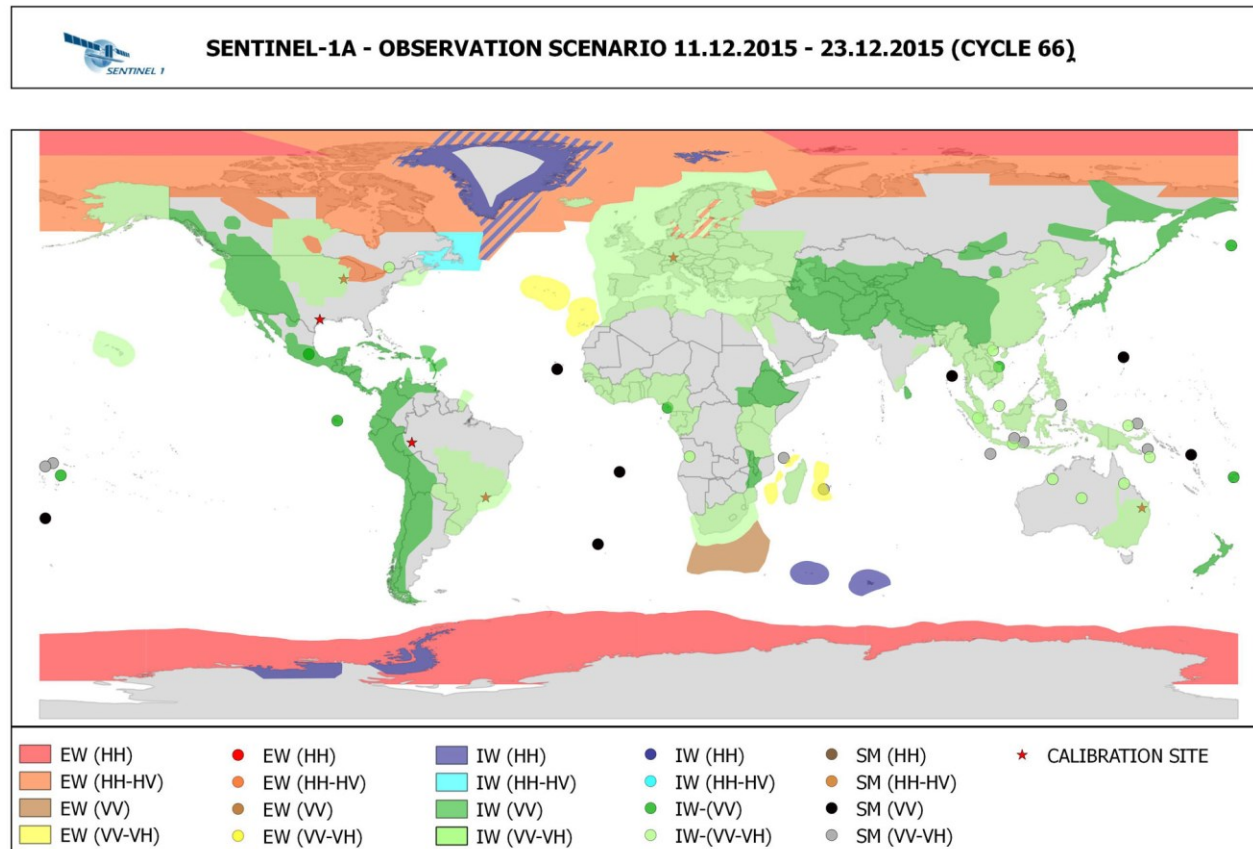
<https://sentinel.esa.int/web/sentinel/missions/sentinel-1/observation-scenario>

Sentinel-1 observation scenario

High level strategy during Full Operations Capacity

- Optimum use of SAR duty cycle (25 min/orbit for 1 satellite), taking into account the various constraints (e.g. limitation in number of X-band RF switches, mode transition times)
- **Wave Mode** continuously operated **over open oceans**, with lower priority w.r.t. the other high rate modes
- IW or EW modes operated over pre-defined geographical areas:
 - ✓ **Over land**: pre-defined mode is **IWS**
 - ✓ **Over seas and polar areas, and ocean relevant areas**: pre-defined mode is either **IWS** or **EWS**
- The **Full Operations Capacity** is reached with the 2-satellite constellation (potentially up to **2.4 TB/day** with the two satellites)

Sentinel-1 observation scenario



KML files are available to provide detailed information about the planned Sentinel-1 acquisitions:

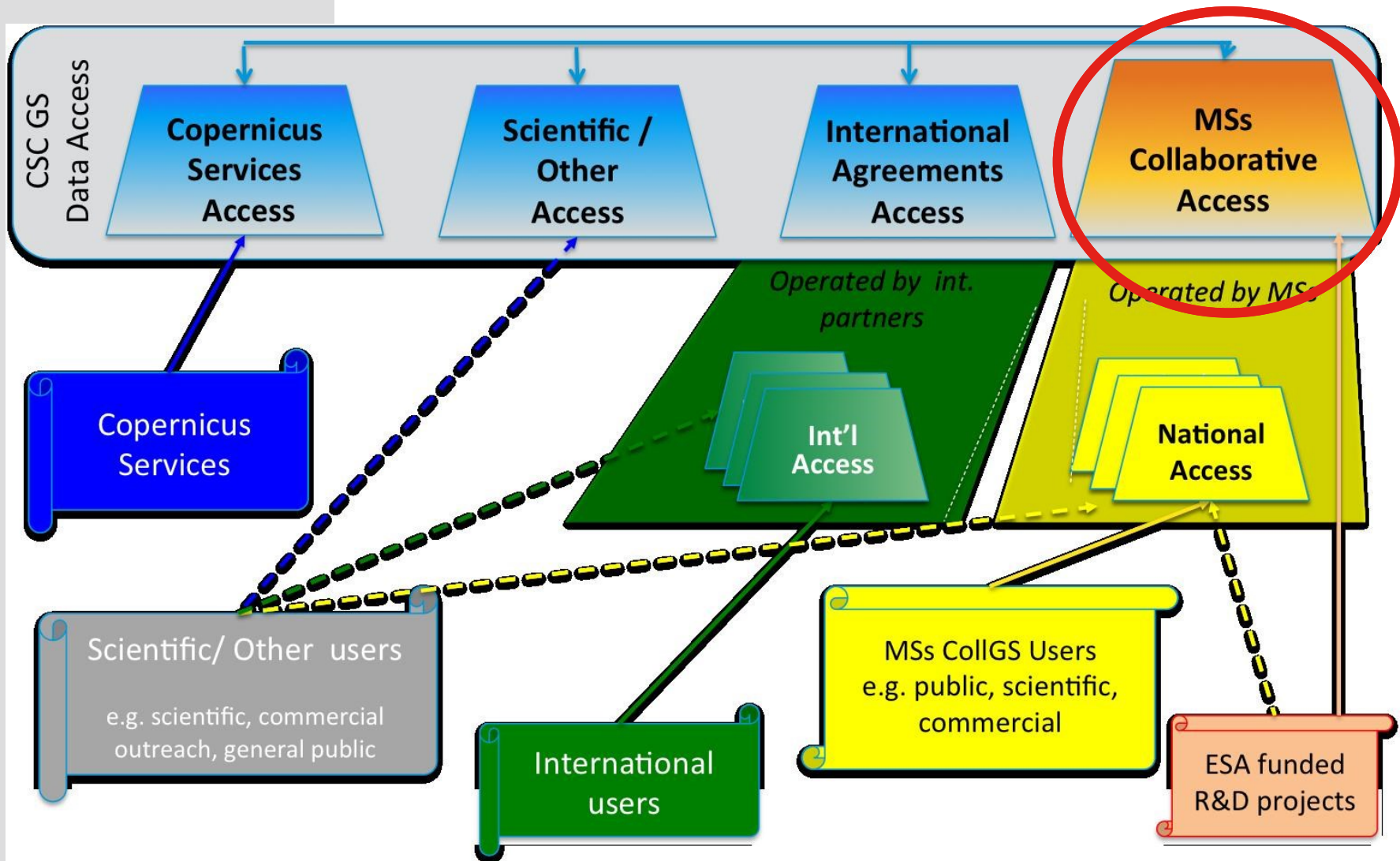
<https://sentinel.esa.int/web/sentinel/missions/sentinel-1/observation-scenario/acquisition-segments>

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SEDAS

UK Collaborative Ground Segment for Sentinel Data Access

ESA Copernicus Data Access



ESA-UKSA Collaboration agreement

Understanding for the Sentinel
Collaborative Ground
Segment

Signed 18th March 2015

Enables UK Collaborative GS
data access

- Direct access to Sentinel data
- Technical advice and data processing and archival software



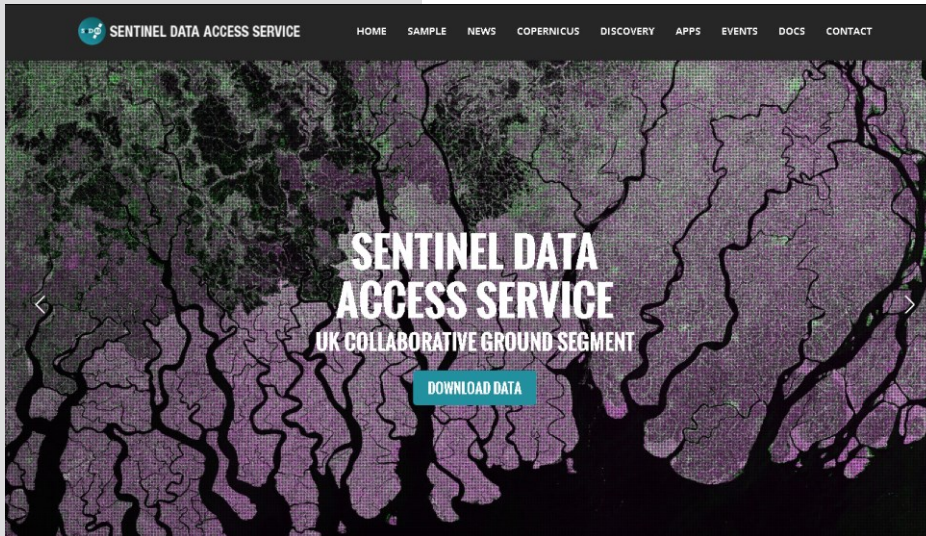
SEDAS: Background



- **Airbus DS Geo-intelligence** (Farnborough) operates the Processing and Archiving facilities for Sentinel 1 and Sentinel 2
- **Satellite Applications Catapult** responsible for managing and disseminating the data to UK commercial users
- **STFC-CEDA** responsible for managing and disseminating the data to UK academic users

& other UK partners involved in CGS development

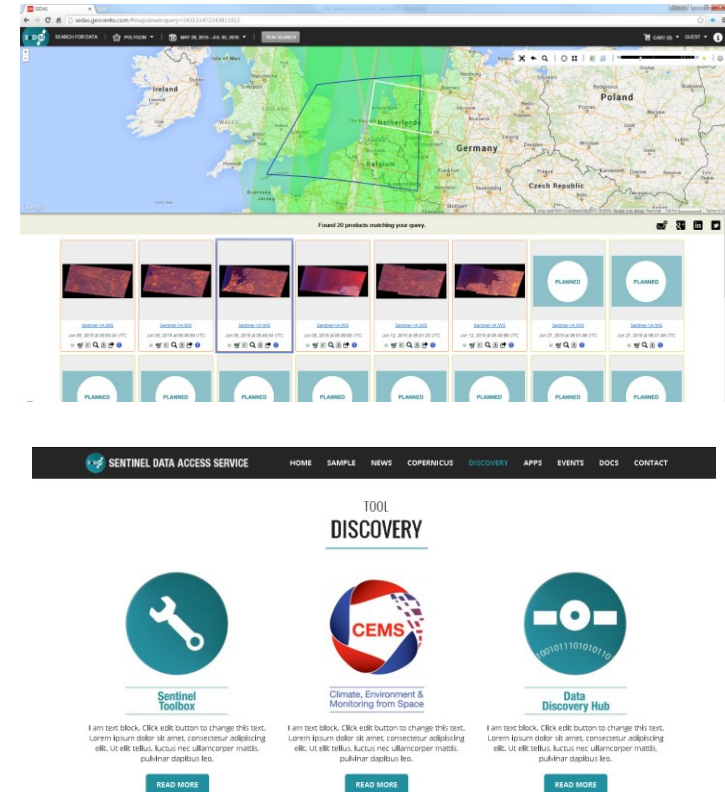
SEDAS - SENTINEL DATA ACCESS SERVICE



Website: <http://sedas.satapps.org/>

- 1 month term rolling archive
- Access via spatial or temporal searches
- Automatic notification
- Full archive availability

Classification: CATAPULT OPEN



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Satellite Applications

Any Question?

