Sentinel High Level Operations Plan (HLOP)

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Table of contents:

1 INTRODUCTION

1.1 Scope

The Sentinel High Level Operations Plan (HLOP) provides the top-level operations plan of the Sentinel missions, including space and ground segment. The HLOP is applicable to all operational entities of Sentinels and Sentinel facilities.

The HLOP is part of the Copernicus Space Component system technical baseline as defined in the EU-ESA Copernicus Agreement ([RD4] and [RD18]). It is based upon a number of documents as listed in Chapter 2, and in particular on the CSC System Requirements Document (SRD) [RD13], the Declaration on the Copernicus Space Component (GSC) Programme [RD1], the Sentinel Data Policy as defined in [RD2], the Copernicus Space Component Operations Concept [RD3], the Data Warehouse requirements [RD11] as well as the Sentinel Mission Requirements Documents.

The HLOP is applicable to the Sentinel missions for the operational phase (phase E2), i.e. after completion of respective satellite commissioning phases.

The aim of the HLOP is:

- to identify the main constraints, limitations and potential conflicts related to the high-level operations of the Sentinel missions
- to define the rules for resource allocation and for resolving conflicts, with the definition of a priority scheme
- to describe the measures and the strategy to cope with these constraints, reducing to the maximum the potential conflicts during operations.

The HLOP is implemented through a set of detailed rules and operational directives defined in the detailed operations plans of the respective Sentinel missions.

1.2 Validity, approval and procedure for future revisions

The first version of the HLOP (ESA/PB-EO(2013)1, rev. 1) became applicable after approval by ESA Member States (PB-EO) in February 2013.

The European Commission (EC), as Programme Manager of Copernicus and owner of the Sentinels, endorses the Sentinel HLOP and its revisions, including the Sentinel observation scenarios, based on the process described in Chapter 8.

The version 3 of the Sentinel HLOP released in July 2019 reflected the Full Operational Capacity (FOC) of the Sentinel-1, Sentinel-2, Sentinel-3 and Sentinel-5 Precursor missions with high level operations principles and technical constraints, as well as the rules and strategy for resource allocation with the related priority scheme, where relevant.

This new version (Issue 3 Rev 1) provides updates to the document, including:

- the update of the Sentinel-1 and Sentinel-2 observation scenario with the implementation of new observation needs requested by Copernicus Participating States and Copernicus Services, as a result of the 2021 revision process
- the addition of details related to the Sentinel-4 and Sentinel-5 operations provided by EUMETSAT.
- the addition of details related to the Sentinel-6 operations provided by EUMETSAT.

The Sentinel HLOP is regularly updated to make reference to the evolution of the operational scenarios. In this process, EC, DOSTAG and the Copernicus User Forum and/or Copernicus Committee / Copernicus Configuration are consulted (typically every 2 years or as needed in case of major changes) on the Sentinels observation scenarios, elaborated based on the process described in this document (chapter 8).

The high-level definition of the observation plan relevant to the on-going Sentinels operations is provided for complementary information in the Annexes of this document.

1.3 Structure of the document

Following a high-level overview of the Sentinel missions (chapter 3), the document addresses the key elements that drive the operations baseline and related strategy.

For each Sentinel, common and mission specific strategies are described in terms of observation and instrument planning, data acquisition, data production and data dissemination.

In each of these areas, the document provides a description of the relevant constraints and of the adopted high-level strategy (chapter 4) that, taking into account the priorities for resource allocation (described in chapter 6) and based on the observation needs, result in the baseline operations scenario.

2 REFERENCE DOCUMENTS

RD1	Declaration on the GMES Space Component (GSC) Programme	ESA/PB-EO/CXI/Dec. 1, rev. 9 (Final) attached to ESA/C(2015)33
RD2	Commission Delegated Regulation (EU) No 1159/2013 (of 12 July 2013 supplementing Regulation (EU) No 911/2010 of the European Parliament and of the Council on the European Earth monitoring programme (Copernicus) by establishing registration and licensing conditions for Copernicus users and defining criteria for restricting access to Copernicus dedicated data and Copernicus service information, 19 Nov 2013	
RD3	CSC Operations Concept Document	GMES-GSEG-EOPG-PD-12-0056, iss. 1, rev. 1, 19 August 2013
RD4	Agreement between the European Union, represented by the European Commission and the European Space Agency on the Implementation of the Copernicus Programme including the transfer of ownership of Sentinels (Copernicus Agreement)	Updated consolidated version 22 January 2019
RD6	Sentinel-1 Mission Requirement Document	ES-RS-ESA-SY-0007, issue 1 rev.4
RD7	Sentinel-2 Mission Requirement Document	EOP-SM/1163/MR-dr, issue 2 rev.0
RD8	Sentinel-3 Mission Requirement Document	EOP-SMO/1151/MD-md, issue 2 rev.0
RD11	Data Warehouse Requirements – Version 2.4: “Copernicus Data Access Specifications of the space-based Earth Observation needs for the period 2014-2020"	
RD12	Copernicus Contributing Mission - Data Access Portfolio (formerly Copernicus Space Component Data Access Portfolio - Data Warehouse 2014-2020)	COPE-PMAN-EOPG-TN-15-0004 Issue 2 rev 7, 16 December 2019
RD13	Copernicus Space Component System Requirements Document	EOP-E/GSC-SRD-01 Issue 1 Rev. 9

RD14	GMES Sentinel 4 and 5 Mission Requirement Document	EOP-SMA/1507/JL-dr, iss. 1, rev. 0, 2 April 2007
RD15	The Copernicus Space Component: Sentinel Data Products List	COPE-GSEG-EOPG-PD-14-0017 Issue 1 Rev.1
RD16	Regulation (EU, Euratom) No 2021/696 of the European Parliament and of the Council of 28 April 2021 establishing the Union Space Programme and the European Union Agency for the Space Programme and repealing Regulations (EU) No 912/2010, (EU) No 1285/2013, (EU) No 377/2014 and Decision 541/2014/EU1	
RD17	Agreement between the EU, represented by the European Commission, and EUMETSAT on the implementation of the Copernicus Programme, including the transfer of ownership of certain assets, the Copernicus Agreement	Signed on 7 November 2014
RD18	Contribution Agreement between the European Commission, representing the European Union, and the European Space Agency on the Implementation of the Union Space Programme and Horizon Europe (Pillar II, Cluster 'Digital, Industry and Space', Space Section) under the Financial Framework Partnership Agreement (FFPA)	Signed on 22 June 2021
RD19	Contribution Agreement between the European Union, represented by the European Commission and the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT) on the implementation of the Copernicus Component of the Space Programme of the European Union	Signed on 22 July 2021
RD20	Copernicus Space Component Sentinels User Level Data Portfolio	ESA-EOPG-EOPGC-TN-20, Issue 1 rev. 0, 18/01/2021
RD21	CSC Operations - ESA Framework - Sentinels User Level Data Services Portfolio	ESA-EOPG-EOPGC-TN-36, Issue 1 rev. 0, 18/01/2021
RD22	Copernicus Space Infrastructure Architecture and Operations Concept	*To be released*

3 SENTINEL MISSIONS BACKGROUND

3.1 Sentinel missions overview

The Sentinel series, complemented by relevant National, EUMETSAT and other Third Party Missions, have been designed in order to satisfy the user requirements for the implementation of Copernicus and National services. These services expressed the need for observation continuity and seamless access to data, redundancy in the context of an operational system and increased frequency of observations.

The Copernicus Space Component currently comprises the following series of Sentinel missions:

- Sentinel-1: High-resolution radar imaging
- Sentinel-2: High-resolution multispectral imaging
- Sentinel-3: Medium-resolution multispectral imaging and altimetry
- Sentinel-4: Atmospheric composition monitoring from geostationary orbit
- Sentinel-5, and Sentinel-5 Precursor: Atmospheric composition monitoring from low-Earth orbit
- Sentinel-6 Michael Freilich: High precision radar altimeter mission

This space observation infrastructure ensures the continuity of observations enabling the gradual implementation of services in the area of land monitoring, operational oceanography, atmospheric composition monitoring, emergency response, security and climate change monitoring.

3.2 Sentinel missions objectives overview

3.2.1 Sentinel-1

The Sentinel-1 mission is based on a constellation of two satellites (A and B units). Sentinel-1 carries a C-band Synthetic Aperture Radar (SAR), and provides continuity of ERS and ENVISAT SAR types of missions. It allows all-weather and day/night imaging capability. SAR observations are key for operational applications over ocean, seas and polar areas (oil slick monitoring, sea-ice monitoring, ship traffic monitoring, ship routing, etc.). SAR observations are also used for land applications and provide data for emergency response and security, in particular under adverse weather conditions. SAR interferometry has proven scientific and operational value for terrain motion monitoring.

3.2.2 Sentinel-2

The Sentinel-2 mission provides enhanced continuity to services relying on optical multi-spectral high spatial resolution observations over global land and coastal regions. The Sentinel-2 mission is based on a constellation of two satellites (A and B units). Well beyond its initial objectives, Sentinel-2 is used for a large range of applications. In the land domain, Sentinel-2 is for instance used for smart farming, ecosystems protection, in-land waters quality monitoring. In the marine domain, Sentinel-2 is for instance used for coastal waters quality and sea-ice charting. In the emergency management domain, Sentinel-2 is for instance used for rapid mapping of burnt areas or volcanoes. In the security domain, the mission is for instance used for oil spills detection and polluter identification. In the climate change domain, Sentinel-2 is used for glaciers mapping and flow velocities measurement. In the atmospheric domain, the mission is for instance used for oil/gas industry methane emissions monitoring.

3.2.3 Sentinel-3

The Sentinel-3 mission is based on a constellation of two satellites (A/B units and C/D units providing continuity). Sentinel-3 provides continuity of MERIS (ENVISAT), ATSR/AATSR (ERS/ENVISAT) and radar altimetry (ERS/ENVISAT/Cryosat) missions. The Sentinel-3 mission measures sea surface topography, sea and land surface temperature, and ocean and land surface colour. Sentinel-3 observations also support applications based on vegetation as well as fire, river and lake height and atmospheric products.

3.2.4 Sentinel-4

The Sentinel-4 mission is based on a payload to be embarked on EUMETSAT Meteosat Third Generation (MTG) satellites. Sentinel-4 instruments will be accommodated on board the two MTG-S satellites (sounding mission satellites). Sentinel-4 is used for atmospheric composition monitoring from the geostationary orbit.

3.2.5 Sentinel-5 Precursor and Sentinel-5

The Sentinel-5 Precursor mission is used for atmospheric composition monitoring from a low-Earth polar orbit and extends data sets as provided by the ENVISAT/SCIAMACHY, EPS/GOME-2 and NASA's AURA/OMI instruments.

The Sentinel-5 Precursor mission will be followed by the Sentinel-5 mission which is a payload to be embarked on the EUMETSAT Polar System Second Generation (EPS-SG) satellites.

3.2.6 Sentinel-6 Michael Freilich

Sentinel-6 and Sentinel-3 form a complementary pair in which both are needed to provide the necessary accuracy for Copernicus. The Sentinel-6 spacecraft, that ensures continuity of Jason series, is based on a platform derived from CryoSat-2 adjusted to the specific requirements of the mission, including the much higher orbit. The instrument suite comprises a radar altimeter based on Sentinel-3 SRAL, a Microwave Radiometer AMR-C (based on AMR on Jason-3), a GPS device (recurrent from Sentinel-3), a DORIS receiver (recurrent from CryoSat-2) and a Laser Reflector (recurrent from CryoSat-2).

3.3 Data Policy

The main objective of the Sentinel Data Policy, as described in the Commission Delegated Regulation [RD2], is to establish full and open access to Sentinel data of the currently defined Sentinel missions, with free of charge license for the Sentinel data itself.

Such an approach aims at maximising the beneficial use of Sentinel data for the widest range of applications and intends to stimulate the uptake of information based on Earth Observation data for end users.

The principles of the Sentinel Data Policy have a substantial impact on the Sentinel overall operation strategy, as described in the following chapters.

4 OPERATIONS STRATEGY

4.1 Scope

This chapter describes the Sentinel's operations strategy and the measures taken to cope with the main constraints, limitations and potential conflicts related to the Sentinel missions, which have an impact on the operations.

Technical constraints, limitations and conflicts for Sentinel operations may occur due to:

- spacecraft design, e.g. instrument modes, on-board data management, downlink design
- ground segment design, e.g. related to facilities for data acquisition, product generation, product distribution
- operations conflicts across the Sentinels
- governance and funding approach, e.g. change of technical operations concept, budget limitation.

For each of the main relevant areas, including instrument observation/planning, acquisition, processing and dissemination, the following chapters (from 4.3 to 4.6) describe first the technical constraints and potential conflicts and second, the operations strategy.

4.2 Overall Sentinel operations strategy

The main objectives of the Sentinel operations strategy, which is based on the Sentinel Data Policy and the CSC Operations Concept, and for the various set of HLOP relevant activities (including planning, acquisition, production, dissemination) are:

- to provide data to Copernicus and National services according to their specified requirements
- to ensure systematic and routine operational activities with a high level of automation and with pre-defined operations to the maximum extent possible
- to minimize the number of potential conflicts during operations, therefore to solve anticipated conflicts a priori, in particular in the elaboration of the mission observation scenarios.

The Operations phase of Sentinel-1, -2, -3 and -5P has been based on a ramp-up approach in terms of exploitation capacity that has gradually increased over time. The ramp-up phase started at completion of the first spacecraft launch and commissioning, and continued until the Full Operational Capacity is reached, with the constellation of the Sentinel-1, -2, - 3 A and B-models as well as Sentinel-5P. For the Sentinel-4, Sentinel-5 and Sentinel-6 missions a similar strategy is applied.

4.3 Observation and instrument planning

4.3.1 General

a) Sentinel instrument operations constraints

The main instrument constraints that have an impact on the operations, and require the elaboration of a planning strategy, are typically the exclusivity of instrument modes (for Sentinel-1) and the instrument operations time limitations or sensing constraints.

b) Sentinel observation and instrument planning strategy

A robust baseline Sentinel's observation strategy is the tool to ensure predictable repetitive coverage and continuous data flow required by the Copernicus services. While by nature the instruments on board Sentinel-3, Sentinel-5P and Sentinel-6, as well as the Sentinel-4 and Sentinel-5 instruments hosted on MTG-S and MetOP-SG, are continuously operated and feature relatively low to medium data rates, the implementation of a baseline observation strategy for the Sentinel-1 and Sentinel-2 missions requires careful analysis of the user needs and optimisation of the related space and ground resources. This is necessary due to the various constraints related to these missions, in particular the high data rates and volume generated, the instrument duty cycle, and other constraints and conflicts as identified below (SAR modes exclusivity, limitations in number of X-band switches, available core ground stations network for data downlink, etc.), as well as requirements in terms of timeliness between sensing and downlink (real time, near real time, etc.).

A major objective in the operations of the Sentinel-1 and Sentinel-2 missions is therefore to implement, to the maximum feasible extent, a conflict-free instrument observation and planning scenario, aiming at fulfilling the observation requirements from the Copernicus and National services. These observations and planning scenarios are based on the requirements as derived from the mission MRDs, and complemented by the recurrent versions of the Data Access Portfolio (DAP) document [RD12] responding to the Copernicus Data Access Data Warehouse requirements [RD11], which develops in more detail the observation requirements as expressed by the individual Copernicus services. The process for collecting Sentinel observation requirements and for elaborating the observation scenarios is further detailed in Chapter 8.

Emergency observation requests in support to related Copernicus and National services are foreseen to mainly be accommodated via data supplied by the better tailored Copernicus Contributing Missions providing specifically developed functions with high agility of the satellite to address this kind of needs. Furthermore, it is expected that such requests will also be satisfied by data already foreseen to be acquired as part of the baseline Sentinels observation scenario (see chapter 6.3). As a consequence, it is not foreseen to frequently alter the Sentinels stable observation scenario in support of such emergency requests (this may occur in exceptional cases only). This approach allows to implement an efficient use of the available Copernicus Space Component infrastructure resources. In practice and by experience at the stage of Full Operations Capacity, due to the added-value of the Sentinel-1 mission to the Copernicus Emergency Management Service as well as to the International Charter Space and Major Disasters, since the respective launches of Sentinel-1A and Sentinel-1B satellites, specific Sentinel-1 observation tasking activities are regularly performed to support emergency situations, floods in particular, with very limited impact on the baseline observation plan.

4.3.2 Sentinel-1

a) Sentinel-1 instrument operation constraints

Mode exclusivity
The Sentinel-1 SAR features four exclusive imaging modes of operations:

- Interferometric Wide Swath (IW)
- Extra Wide Swath (EW)
- Strip Map (SM), with 6 possible incidence angles
- Wave (WV).

The first three modes can be operated in 4 different schemes of polarisation (2 in single and 2 in double): HH, VV, HH+HV or VV+VH. The Wave mode can operate only in single polarisation, either in HH or VV. Overall this represents 34 possible sub-modes of operations.

SAR mode and data takes transition times

A transition time, in the order of 3.6 seconds is necessary to switch from a SAR measurement mode to another measurement mode, or to perform a change of polarisation. An additional time between 3 and 3.5 seconds is necessary before and after each SAR data take due to warmup, “preamble” and “postamble”. In addition, each SAR data take must start coinciding with tie points defined along the orbit with an interval corresponding to a SAR burst duration, in the order of 3 seconds (this allows to synchronise bursts from one repeat cycle to the next, necessary for interferometry). Adding these figures, the interval between 2 consecutive data takes is therefore in practise in the order of 10 seconds, corresponding to about 70 km. No data are acquired during this time interval.

Duty cycle

The Sentinel-1 SAR is capable of operating up to a total of 25 min per orbit (within a moving window of a 100 min. orbit period duration) in any combination of the IW, EW or SM modes, and up to the rest of the orbit in Wave mode.

Due to the above constraints, conflicts may therefore take place if different modes are required over the same (or adjacent) geographical area, or if the duty cycle limitation does not allow accommodating instrument mode (IW, EW or SM) over a geographical area. The transition time constraint to switch from one measurement mode to another measurement mode may result in some imaging gaps of geographical areas.

This constraint of 25 min per orbit period (sliding window of 100 min) corresponds to the sizing of the power system during eclipse period, that takes place indicatively from early May to early August each year. Outside this period, a slight relaxation of this constraint is possible and has been implemented, with a constraint of 30 min per orbit period. This mainly allows for a higher stabilisation of the standard observation plan.

b) Sentinel-1 observation and planning strategy

Based on the above constraints, the elaboration of a baseline Sentinel-1 mission observation scenario requires solving, a priori and systematically, the identified conflicts between the observations requirements.

This scenario makes optimum use of SAR duty cycle, taking into account its limitation, as well as potential limitation in the number of X-band switches (see chap 4.4.2) and the constraint of transition times between measurement modes / data takes.

The Sentinel-1 mission observation scenario during full operations capacity is based on the following principles for each satellite:

- Wave Mode continuously operated over ocean, with lower priority w.r.t. the other modes
- IW or EW modes operated (for a total duration of up to 25 min per orbit or 30 min outside eclipse period) over pre-defined geographical areas:
    - Over land: the baseline mode is IW

- Over oceans, seas and polar areas: the baseline mode is either IW or EW. The EW mode (featuring a 400 km swath) is the preferred mode for services providing monitoring activities over large areas with frequent revisiting requirements and not having specific needs for high resolution products (such as the sea-ice monitoring operations performed by the Copernicus Marine Environment Monitoring Service)
- If possible, use of single polarisation is adopted in order to give priority to the coverage extent and, if relevant, to facilitate the data acquisition strategy. Note: it is recognised that the use of dual polarisation improves some applications such as sea-ice monitoring or ship detection, however using dual polarisation in real time (which require the use of both RF channels – see chap 4.4.2.a)) has a strong impact on the overall acquisition scenario.

The observation scenario takes into account the preliminary status of the mission with the Sentinel-1A in orbit, and then the Full Operational Capacity with both Sentinel-1A and Sentinel-1B in orbit.

During routine operations, in order to optimise the average revisiting and coverage frequency, the two satellites are placed in the same orbit but with a mean anomaly delta of 180 deg. This results in a repeat cycle of 6 days for the 2-satellite constellation. This phasing is of particular benefit for InSAR applications (interferometric pairs every 6 days) and for maritime surveillance and sea-ice monitoring applications (increased average revisit time).

A high level description of the Sentinel-1 observation scenario is provided in the Annex of this document.

4.3.3 Sentinel-2

a) Sentinel-2 instrument operation constraints

The Sentinel-2 Multispectral Instrument (MSI) data are systematically acquired during daylight portions of the orbit where the target surface has a Sun Zenith Angle (SZA) below a certain threshold (currently being specified by default at 82 deg and at 85 deg over specific regions, e.g. over Europe). Different illumination conditions will hence derive seasonal patterns and lead to varying acquisition scenarios during the periods between summer solstice, winter solstice and autumn/spring equinoxes.

The MSI duty cycle is limited to 48 min per orbit period.

The number of MSI Detectors & Front End Electronics ON/OFF cycles has been qualified for 40,000 switches. Following a detailed review of the matter in order to limit the impact of this constraint as life limited item, whatever the number of observations performed by the MSI during the illuminated part of the orbit, the number of switches in full operations capacity is limited to one cycle per orbit (a switch corresponding to the instrument being put in “Idle” mode).

b) Sentinel-2 observation and planning strategy

The Sentinel-2 instrument has been designed based on a baseline observation scenario as required in the MRD [RD7], to cover all land and coastal regions (up to 20 km from the coastline) between 56° South latitude (Cape Horn in South America) and 83° North latitude (north of Greenland) including major islands (greater than 100 km2 size), EU islands and the whole Mediterranean Sea, as well as all inland water bodies and closed seas. The actual Sentinel-2 observation scenario full operations capacity for each satellite is elaborated starting from these requirements, and completed based on further requirements from the Copernicus and National services, to derive associated continental to regional observation areas and priorities, coverage repetitiveness (e.g. systematic or with a specific mapping frequency), seasonal variations, as well as timeliness for various areas etc. The current observation scenario goes well beyond the initial mission requirements, including acquisitions between 83° North and 83° South latitude.

During routine operations, in order to optimise the average revisiting and coverage frequency, the two Sentinel-2 satellites are placed in the same orbit but with a mean anomaly delta of 180 deg. This results in a repeat cycle of 5 days for the 2-satellite constellation, which, due to swath overlaps, translates in a coverage up to 2-3 days in mid-latitudes.

This scenario accounts for the limitation in the number of X-band switches (see 4.4.3). The observation scenario at any given stage takes into account the status of the mission currently in FOC with both Sentinel-2A and Sentinel-2B in orbit.

The observation scenario accounts for the limitation in the number of X-band switches (cf. section 4.4.3).

A high-level description of the Sentinel-2 observation scenario is provided in Annex 2 of this document.

4.3.4 Sentinel-3

a) Sentinel-3 instruments operation constraints

There are no major relevant constraints on the operations of the Sentinel-3 instruments, other than operating the OLCI and the visible channels of the SLSTR based on specific solar illumination conditions:

- OLCI operates during daylight, therefore during the descending part of the orbits, with a Sun Zenith Angle of the sub-satellite point of less than 80 deg. (and taking into account the seasonal variations), representing 44% of the time
- The SLSTR visible channels acquired data out of eclipse only (all infrared and SWIR channel acquired data permanently).

b) Sentinel-3 observation and planning strategy

The Sentinel-3 mission is based on the simultaneous operation of a pair of identical 3-axis stabilised satellites phased by 140 degrees (note: amended from the original phasing of 180 degrees), following a change request from the Commission. The 140 degrees phasing allows to optimise the topography mission for CMEMS with a minor impact on the optical and temperature mission, in a common orbital plane, with a polar, sun-synchronous orbit at an altitude of 814.5 km, an inclination of 98.65°, an orbital cycle of 27 days (14+7/27 orbits per day, 385 orbits per cycle) and a mean local solar time at descending node of 10:00 hours.

The spacecraft routine operation is highly autonomous in the sense that no frequent space to ground dialogue is required by the nominal missions of Sentinel-3. The Sentinel-3 instruments provide the sensing of the data autonomously on-board the spacecraft on the basis of predefined geographic data and selection of observation mode depending on the surface over which the spacecraft is flying. This mode of operation does not require any specific request from users, and ground-based routine operations planning of the spacecraft is relatively straightforward. The Sentinel-3 instruments autonomously perform systematic and continuous sensing as follows:

- The OLCI instrument acquires data over daylight part of the orbit (i.e. for a Sun Zenith Angle below 80 deg)
- The SLSTR instrument operates the infra-red and SWIR channels over the whole orbit, and the visible channels out of eclipse only
- The SRAL instrument acquires data over the whole orbit in the SRAL SAR mode.
- The MWR instrument operates over the whole orbit.

These autonomous operations are based on on-board mechanisms controlling the various instrument mode transitions as a function of the satellite orbital position.

4.3.5 Sentinel-5 Precursor

a) Sentinel-5 Precursor instrument operation constraints

There are no major relevant constraints on the operations of the Sentinel-5 Precursor instrument TROPOMI. The autonomous operations are based on a stable orbit scenario and a periodic execution of the TROPOMI instrument calibration and atmospheric target measurements in line with the instrument specific repeat cycle.

b) Sentinel-5 Precursor observation and planning strategy

The operations of the Sentinel-5 Precursor payload TROPOMI are performed in accordance with a set of pre-defined planning rules and constraints based on an instrument specific planning repeat cycle of 360 orbits. The following observation strategy is followed:

- Radiance measurements will be taken on the whole day-side part of each orbit plus some few additional minutes at both ends of the day side part to cover the terminator crossing.
- Background measurements will be taken on the eclipse part of each orbit.
- Solar irradiance measurements will be performed approximately every 15 orbits.
- Calibration (e.g. radiometric and spectral lamp) measurements will be taken outside the South Atlantic Anomaly before spacecraft midnight.

The Sentinel-5 Precursor satellite is operated in a so-called loose formation with the NOAA Suomi-NPP satellite. The difference of the overpass time between Sentinel-5 Precursor and Suomi-NPP after launch was about 5 minutes, which has been reduced by the end of commissioning phase to about 3.5 minutes. The main driver for the loose formation flying is the cloud clearing for the Sentinel-5 Precursor Methane product using the high spatial resolution data from the Visible/Infrared Imager Radiometer Suite aboard Suomi-NPP. The technical coordination is performed through the exchange of planning files (e.g. orbits) between ESA and NOAA.

During summer 2019 the TROPOMI operations have been changed to improve the spatial resolution of the measurements along track from 7 km to 5.5 km.

4.3.6 Sentinel-4

a) Sentinel-4 instrument operation constraints

The Sentinel-4 mission consists of an Ultraviolet-Visible-Near-Infrared (UVN) light imaging spectrometer instrument embarked on the Meteosat Third Generation Sounder (MTG-S) satellite. The main objective of the Sentinel-4 mission is to monitor key air quality trace gases and aerosols over Europe at high spatial resolution and with a fast revisit time. The Ground Segment of Sentinel-4 is fully integrated in the EUMETSAT MTG Core Ground Segment.

b) Sentinel-4 observation and planning strategy

The Sentinel-4 instrument monitors the Earth's radiance over Europe, parts of North Africa, and parts of the Atlantic from 30°N to 65°N in latitude and 30°W to 45°E in longitude.
The area covered includes only areas with full day illumination conditions, thus excluding morning and evening.

The instrument has an instantaneous field of regard of 4.0° that covers the north-south range of the area covered. For the east-west range a scan mirror is used, that scans continuously from east to west over a range of about +/- 4.5°. After each east-west scan the scan mirror moves back slowly to its eastern starting position in about 20 seconds.

The instrument measures the earth radiance on the illuminated part of the earth's surface. During night, when no earth radiance measurements are possible, specific calibration measurements are performed, such as Dark, LED, White Light Source, Moon and Star measurements.

The instrument is operated with fixed scan duration of 60 minutes. During this time, a spatial subset of the geographical area referred to as ‘scan window' is covered. In the course of a day, this scan window is shifted in two steps from its easternmost position to its westernmost position, in order to optimise the number of observations with favorable illumination conditions. During a large part of the day the scan window is optimised to cover continental Europe. The coverage of the Atlantic in the evening provides valuable observations of long lived constituents that are transported toward continental Europe, and offers clean reference observations for short lived species.

4.3.7 Sentinel-5

a) Sentinel-5 instrument operation constraints

The main objective of the Sentinel-5 mission is to perform atmospheric measurements, with high spatio-temporal resolution, relating to air quality, climate forcing, ozone and UV radiation and providing a daily global coverage.

Sentinel-5 is an instrument onboard the METOP-SG A series and is fully integrated in the EPS-SG ground segment. The EPS-SG ground segment allows all Sentinel-5 data to be systematically acquired, processed and distributed. It includes elements for monitoring and controlling the Sentinel-5 instrument and for downloading, processing and disseminating data to users. It also has mechanisms for monitoring and controlling the quality of data products, as well as for data archiving.

b) Sentinel-5 observation and planning strategy

Sentinel-5 is operating in nadir looking push broom mode from sun synchronous low earth orbit. The wide across-track field-of-view (FoV) of 108° provides a wide swath of about 2670km on earth and thus almost globally allows for daily coverage of the earth surface.

Observation is performed over the complete sunlit (with respect to the sub-satellite point) part of the orbit while the instrument calibrations are done during the dark part of the orbit.
The following observation strategy is followed:

- Radiance measurements will be taken on the whole day-side part of each orbit.

- Background as well as Deep Space View measurements will be taken on the eclipse part of each orbit.
- Solar irradiance measurements will be performed once per day, during the South Pole crossing.
- Calibration (White Light Source, LED, Laser diodes) measurements will be performed regularly, during the night side crossing of selected orbits, avoiding those orbits affected by the Southern Atlantic Anomaly.

4.3.8 Sentinel-6

a) Sentinel-6 instrument operation constraints

There are no major relevant constraints on the operations of the Sentinel-6 instruments, except specific scenarios performed for calibration.

b) Sentinel-6 observation and planning strategy

Sentinel-6 is operating the POS-4 altimeter. The instruments follow specific mode transitions each orbit repeat cycle, based on planned scenarios. These different scenarios include LRM (Low Resolution Mode), LRMC (LRM + reduced SAR) or LX (LRM + raw SAR) modes, in closed loop or open loop, depending on the surface. The final scenario for routine operations will be selected at the end of the commissioning phase. Each repeat cycle, a pre-defined sequence of internal calibrations is executed over desert zones and regular transponder calibrations are executed each repeat cycle over transponders.

Sentinel-6 also operates the microwave radiometer AMR-C everywhere over the globe. AMR deep sky calibration are performed on a regular basis, approximately every 30 days.

4.4 Data acquisition

4.4.1 General

a) Data acquisition constraints

The main constraints related to acquisition and on-board data management system are:

- Volume of data generated on-board and to be downlinked and acquired, especially in the case of Sentinel-1 and Sentinel-2, and to some extent in the case of the other Sentinels (which feature a lower generated data volume than Sentinel-1 and -2 and therefore a less complex data download strategy).
- Possible conflict between parallel downlink of real time data and of on-board recorded data (for Sentinel-1)
- Limitation of the number of X-band downlink switches, maximum downlink time per orbit and maximum consecutive downlink time

- Number and geographic location of ground stations, concurrent use of the stations by the Sentinel satellites and possible downlink frequency interferences between the Sentinel satellites (and potentially with other satellites making use of the same X-band frequencies for data downlink)
- Capacity and availability of the EDRS system, concurrent use of the EDRS system by the Sentinel-1A, -1B, -2A and -2B satellites, simultaneous downlink via EDRS and X-band.

b) Data acquisition strategy

The data acquisition for each of the Sentinel missions relies on a network of X-band core ground stations and, regarding the Sentinel-1 and Sentinel-2 missions, is complemented by the use of the EDRS system. The current network of core stations for Sentinel-1, -2 and -3 includes Matera (e-GEOS), Maspalomas (INTA), Svalbard (KSAT), Inuvik (SSC) and Neustrelitz (DLR).

For the Sentinel-1 and Sentinel-2 missions, the data acquisition strategy heavily depends on the respective mission observation scenarios, and reversely, constraints related to the data acquisition capacity may affect and require refinement of the observation scenarios.

The sizing of data acquisition and downlink takes into account the available operations funding resources, impacting the deployment and use of the core stations network and the overall downlink capacity, which, in turn, will affect the affordable observation scenario.

4.4.2 Sentinel-1

a) Sentinel-1 data acquisition constraints

Data volume
The potential operation of up to 25 min of SAR data per orbit among IW, EW or SM modes (30 min outside eclipse period), with instant average data rate in the order of 430 Mbps (i.e. for IW mode with the use of dual polarisation), leads to a very large amount of data to be recovered on ground (corresponding to about 3 TBytes of compressed raw data per day in FOC with both Sentinel-1A and Sentinel-1B operating in parallel at the maximum duty cycle). The use of single polarisation and/or EW mode leads to a decrease in the overall data volume.

Data rate versus X-band downlink capacity
The spacecraft X-band downlink system comprises two X-band channels at 260 Mbps (each) of useful data. The FDBAQ (Flexible Dynamic Block Adaptative Quantisation) on-board data compression allows reducing the SAR data rates from all modes. Swath 1 of the SM mode features however, in dual polarisation, a data rate greater than the total X-band channel capacity. This constraint requires buffering the data in the on-board memory. The SM mode Swath 1 is however not planned to be normally used as

part of the baseline observation scenario (see 4.3.2. b)) and will be commanded only in specific exceptional cases (e.g. emergency situation, specific campaigns potentially).

Downlink conflict
Conflict may occur between real time downlink and downlink of recorded data, in case of real time downlink of dual polarisation data (requiring the use of both X-band RF channels, i.e. one assigned to each polarisation).

On-board data management
The on-board data management allows prioritising data downlink. However it does not provide a precise ground control of data to be downlinked at each ground station, due to the necessary use of the FDBAQ compression.

On-board memory sizing
The total available on-board memory size (1410 Gbits) allows the storage of more than all SAR data that could be acquired within one orbit (considering a total of 25 min (30 min outside eclipse) of SAR operations per orbit from IW, EW or SM modes and the rest of the orbit in Wave mode). This sizing requires, as a general rule, to avoid accumulating recorded data over several orbits, i.e. the dumping strategy should permit the dump of all recorded data of an orbit during the following orbit.

X-band duty cycle
As per the current baseline, the spacecraft thermal and power/energy accommodation of the X-Band System allows a maximum downlink time per orbit of 30 min, with the possibility to perform 30 consecutive minutes.

Limited number of X-band downlink switches
The X-Band system is specified for an overall number of operation cycles (from standby to operation and back) equal to 150,000 for the mission lifetime. This constraint results in an average number of maximum 4 switches per orbit considering 7 years lifetime (and maximum average of 2.4 switches per orbit considering the extended lifetime of 12 years). This constraint has an impact on the number of non-overlapping downlink passes per orbit and on the detailed definition of the observation scenario, i.e. on an orbit basis. In addition, specific real time downlink requests over local stations might not be satisfied due to this constraint.

Network of ground stations
The network of selected ground stations and their effective use may constrain the final achievable downlink capacity, thus the maximum effective instrument duty cycle operations, resulting in an impact on the observation scenario. The capability to ensure real time or near real time timeliness also depends from the ground station network.

b) Sentinel-1 data acquisition strategy

The Sentinel-1 data acquisition strategy is performed in accordance with the general Sentinel data acquisition strategy (chapter 4.4.1) tailored to take into account the specific Sentinel-1 constraints listed above. It is closely linked to the systematic and baseline observation scenario (chapter 4.3.2.b), and, naturally, to the network of core ground stations.

The current data download strategy to X-band core stations and through EDRS takes into account the timeliness of the core product, i.e. NRT or Fast-24h.

The core stations Svalbard, Matera, Maspalomas and Neustrelitz are currently used to acquire Sentinel-1 data.

On-board memory packet-stores containing NRT data are allocated a high priority for download to X-band core stations or through EDRS, and are therefore sent in the next X-band station visibility or EDRS link opportunity. Download of packet-stores containing Fast-24h data are performed chronologically to the next visibility opportunities of the core stations or EDRS, some of them may be retained on-board during several orbits. The adopted approach depends on various parameters such as the size of the data in the packet-store (which in turn varies according to the sensing segment duration and the SAR mode), the available downlink resource time of the next X-band visibilities, etc. For Fast-24h data, since all data products must be made available at the latest within 24 hours (this includes download, production and dissemination), a maximum retention time in the on-board memory of a few hours is configured in the ground segment mission planning system as a configuration parameter used to define the downlink plan.

For data to be transmitted in real-time, the so-called “pass-through” concept is followed, i.e. the data transit through the on-board memory and are immediately transmitted to the ground, with the possibility for ground to perform “data retain”, i.e. the same data can be kept in the on-board memory for later download.

The data acquisition scenario also requires taking into account the real-time transmission of data to the EMSA CleanSeaNet stations and other collaborative local ground segment, i.e. beyond the core ground segment downlink facilities. To this end the current CSC operations concept baseline assumes that local stations are only allowed to listen-in to downlinks from the Sentinels to the X-band core ground stations. As such the local stations activities have no impact on the spacecraft resources and lifetime, the downlink plan or operations. In this respect, the operations concept baseline makes no distinction between local station within or outside Europe, as long as they can listen-in to data downlinks to core stations.

4.4.3 Sentinel-2

a) Sentinel-2 data acquisition constraints

Data volume

The combination of the large swath (290km), spectral range (13 bands from the visible to the short-wave infrared), spatial resolution (10/20/60m), coupled with the global and continuous acquisition requirement with high-revisit frequency, leads to an average daily generation of 1.3 TB of orthorectified top-of-atmosphere reflectance products

(L1C) per satellite unit and a slightly higher volume of bottom-of-atmosphere reflectance products (L2A). This corresponds to an average continuously sustained raw-data supply rate of 160Mbps.

Downlink conflict

- The observation and downlink strategy for Sentinel-2 needs to be able to consider 3 types of data downlink: The MSI data may be buffered on-board at the same time to allow for a repeated downlink by playback at a later stage (nominal First-In First-Out (FIFO) mode);
- The MSI data recorded on-board may be prioritised as Near-Real-Time (NRT) data into the playback queue so as to ensure it is downlinked as early as possible, rather than following the regular FIFO nominal approach;
- A Real-Time (RT) downlink may be commanded so as to forward the MSI real-time 490 Mbps data stream directly to the transmission system.

Contemporaneous operations of real time downlink and downlink of recorded data is not permitted, as all downlink modes make use of the 2 X-band RF channels at 260 Mbps in parallel.

X-band duty cycle

The satellite thermal and power/energy accommodation of the X-Band System shall not exceed operations of 25 min in a sliding window of one orbit.

Limited number of X-band downlink switches

The constraint is the same as for Sentinel-1 (see previous chapter).

Network of ground stations

This constraint is the same as in the case of Sentinel-1 (see previous chapter).

b) Sentinel-2 data acquisition strategy

The Sentinel-2 data acquisition strategy during full operations is closely linked to the systematic and baseline observation scenario (chapter 4.3.3.b).

In order to simplify the operations concept, all MSI data are buffered on-board to allow for a repeated downlink by playback at a later stage, i.e. the mission uses the nominal First-In First-Out (FIFO) mode.

The core stations Svalbard and Inuvik are currently used to acquire Sentinel-2 data.

4.4.4 Sentinel-3

a) Sentinel-3 data acquisition constraints

There are no major relevant constraints for Sentinel-3 data acquisition, apart from the appropriate selection of the X-band core stations in order to support the required contact time for data download. The X-band system used for Sentinel-3 is identical as for

Sentinel-1 and Sentinel-2; the simple downlink strategy to the core ground segment implemented for Sentinel-3 is not affected by the limited number of X-band downlink switches like in the case of Sentinel-1 and -2.

b) Sentinel-3 data acquisition strategy

The data acquisition and recovery strategy is based on recording the instrument data over a complete orbit and dumping the recorded data to one or several core ground stations, without making use of the real time transmission of the data. Considering the X-band RF channel capacity, there is a need for one station contact time per orbit to download the recorded data from all instruments.

The current constraints allow for the use of a single core ground station at high latitude to download routinely all instrument data. The Svalbard core station is currently used for this function.

4.4.5 Sentinel-5P

a) Sentinel-5P data acquisition constraints

There are no major relevant constraints for Sentinel-5P data acquisition, apart from the appropriate selection of the X-band core stations in order to support the required contact time for data download.

Based on the improved spatial resolution of TROPOMI from [7 km x 3.5 km] to [5.5 km x 3.5 km] the data volume for the Sentinel-5P mission has been increased by about 20% since mid 2019.

In order to guarantee Level 2 NRT data delivery, the baseline network currently comprises the S-/X-band acquisition stations in Svalbard and Inuvik which are used for the downlink of up to 139 Gbit per orbit. Both stations are located at high latitudes thus ensuring that at least one downlink opportunity of sufficient visibility duration exists for each orbit.

b) Sentinel-5P data acquisition strategy

The X-band data acquisition and recovery strategy is based on a ‘resume/dump’ concept, ensuring that science data contained in a given dump cover the sensing time interval from the start of the previous dump up to the start of the actual dump. The spacecraft automatically switches off the X-band transmission when all measurement data acquired up to the start of the actual dump have been transmitted. The required dump time is approx. 520 s, exceeding the visibility time of mid latitude stations.

This is based on recording the instrument data over a complete orbit and dumping the recorded data to the ground stations. Note that Sentinel-5 Precursor has no direct downlink capabilities, i.e. no pass-through mode.

4.4.6 Sentinel-4

Sentinel-4 is fully integrated in the MTG ground segment. The MTG Ground Station Facilities include the telemetry, tracking and control facility (TTCF) and the Mission Data acquisition facility (MDAF).

The TTCF will monitor and control all MTG satellites using the S band. The facility will simultaneously monitor the two closely-located MTG satellites from one site with one antenna, pointing the antenna at a virtual point in between the two spacecraft. There will be a number of S-band antennas at various locations in Europe to perform the telemetry, tracking and commanding of the satellites.

The MDAF will acquire mission data using the Ka band frequency from the MTG imaging (MTG-I) and sounding (MTG-S, including Sentinel-5) satellites, and route them, once decrypted, to the EUMETSAT headquarters. The MDAF includes two remote sites in Lario, Italy and Leuk, Switzerland, processing functions (including the consolidation and decryption functions) and the monitoring and control sub-system (M&C) allowing full control of the unmanned sites from the EUMETSAT main control room. Each site has one receiving antenna per operational MTG satellite.

4.4.7 Sentinel-5

Sentinel-5 is fully integrated in the EPS-SG ground segment.

The Payload Data Acquisition and Processing (PDAP) acquires the Ka band signal from the satellites that contains the payload data, including the Sentinel-5 instrument data, and transforms this into Level 1 and Level 2 data sets.

The Mission Control and Operations (MCO) acquires the satellite's housekeeping telemetry and transmits telecommands, tracking and ranging data on S-band. The MCO supports the planning of the mission, monitors the space segment, and performs the flight dynamics functions. In general EPS-SG instrument planning, including Sentinel-5, is based on orbital dynamics predictions calculated on ground which are translated into instrument observing events scheduled on-board the satellite.

4.4.8 Sentinel-6

a) Sentinel-6 data acquisition constraints

Sentinel-6 flies in the same orbit as their predecessors, TOPEX/Poseidon and the Jason missions. This is a non-sun-synchronous orbit with a nominal altitude of 1336 km and 66° inclination. The ground track cycle repeats approximately every 10 days. The mission operational availability (completeness and latency) condition the location of the core X-band core science telemetry acquisition stations for this orbit: at least two core ground stations are required in order to meet the performance requirements. This is achieved by the two ground stations in Fairbanks and Kiruna.

b) Sentinel-6 data acquisition strategy

In order to meet the operational availability, the data acquisition and recovery strategy is based on recording the instrument data over a complete orbit and dumping the recorded data to either of the core ground stations. Considering the X-band RF channel capacity, there is a need for one station contact time per orbit to download the recorded data for the High Resolution telemetry.

However, higher operational availability requirements are applicable in this mission for the Low Resolution off-line products, justified by the continuity of the service provided by Jason-3. This higher performance is achieved by enabling the archiving of Low Resolution data on board and commanding this Archive Dump at selected ground station passes, typically every 12 hours.

4.4.9 Sentinel concurrent access to X-Band stations

a) Downlink conflicts between Sentinels

Potential conflicts among Sentinels occur for the share of X-Band resources considering that the CSC operations concept aims at maximising common and interoperable usage of ground segment resources. This particularly applies to the common use of X-Band ground stations among the Sentinels, as the data rates introduced by the Sentinel missions and the dual spacecraft approach for each mission require, overall, a large number of X-Band station contacts to recover the data on-ground.

b) Strategy

The Sentinel ground segment plans the X-band downlinks taking into account the above described potential conflicts. Considering these conflicts are fully deterministic (for a given station network) and the conflict pattern repeats after a given number of cycles, this conflict-free coordination among Sentinels is static to a large extent (e.g. on a six months basis).

4.4.10 EDRS service

a) System and data flow overview

The baseline service required by the Sentinels from EDRS is the data relay service, linking the Sentinels satellites via one or several EDRS geostationary satellites (or embarked payload) to the ground. This service is provided for Sentinel-1 and -2 missions.

Sentinel-1 and -2 satellites host an OCP (Optical Communication Payload), including a Laser Communication Terminal (LCT), an LCT Adaptation Unit (LIAU) and a radiator. Sentinel-1 and -2 communicate with the EDRS GEO satellite(s) via an optical link, Sentinel data are then relayed from the Geostationary satellites through a Ka-Band RF downlink to a set of Ka-band ground stations. See Figure 1.

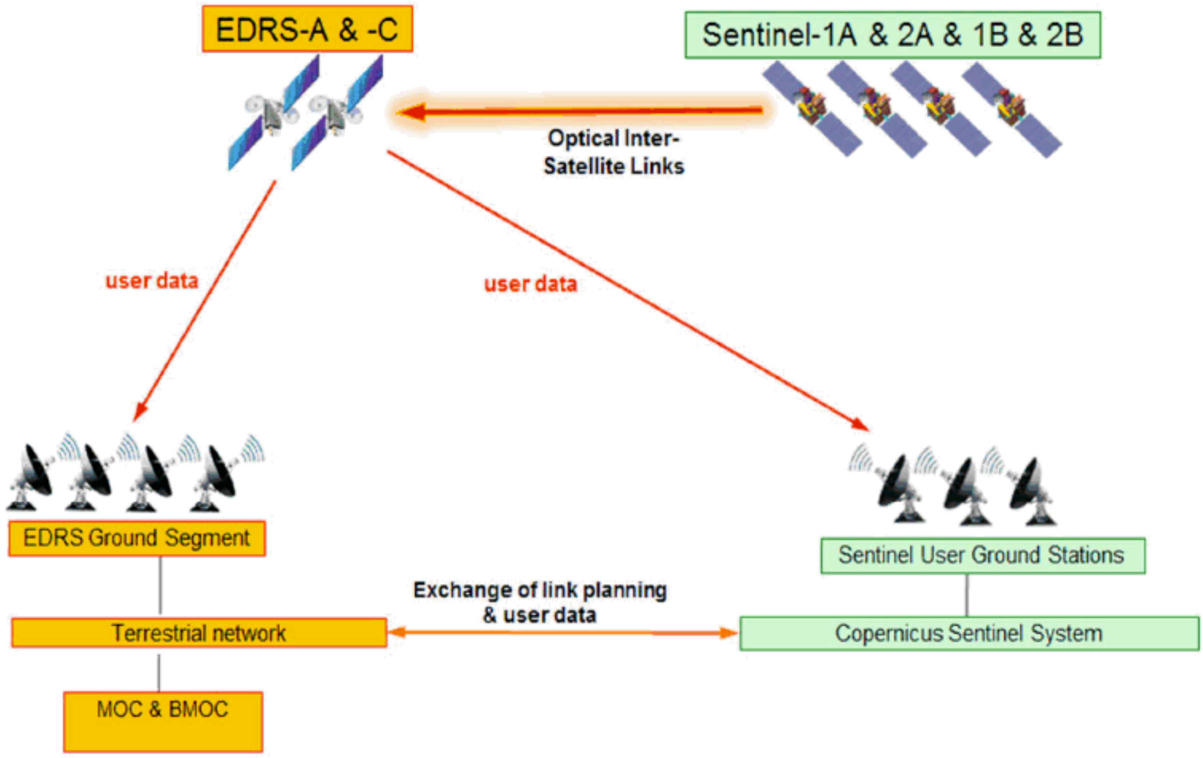


Figure 1 – EDRS – Sentinel service interfaces

OCP operations on-board the Sentinels are under CSC Mission Management and Operations responsibility. Interfaces between the EDRS Mission and Operation Centre and the Sentinels Ground Segment are required to exchange necessary management data, including exchange of orbit data, mission plans and reporting.

Sentinel data can be encrypted by the EDRS satellites before downlink to the ground. On the ground, the Ka-band Ground Stations perform reception, demodulation, decoding, and decrypting functions.

An overview of the overall architecture is illustrated on Figure 2.

The Sentinel data acquired by the Ka-band ground stations are transferred to the Sentinel-1 and Sentinel-2 Payload Data Ground Segment (PDGS), through the high capacity Copernicus ground network.

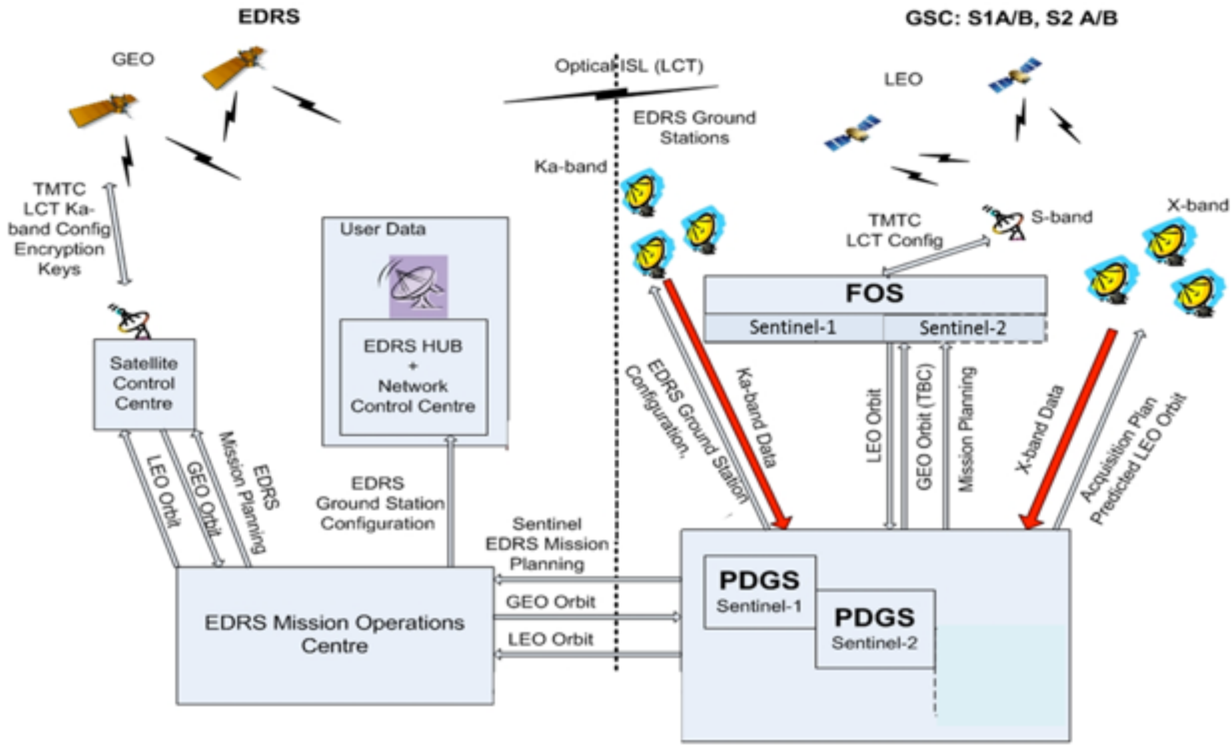


Figure 2 – EDRS – Sentinel System Architecture overview

b) Operations constraints for EDRS service use

The high level operation constraints related to the use of the EDRS service by the Sentinel-1 and Sentinel-2 missions takes into account among others:

- number and location of EDRS GEO terminals (currently including EDRS-A and EDRS-C)
- available data rates / channels / time slots provided by the EDRS service, as defined in the applicable SLA.
- on-board memory data downlink through either X-band or through EDRS service, refer to section 4.4
- coordination related to concurrent access between Sentinel-1 and Sentinel-2 satellites, which are managed by the Sentinels ground segment as part of the service requests sent to the EDRS provider
- time to establish the link between a Sentinel-1 or Sentinel-2 satellite and an EDRS terminal, which typically required less than one and a half minutes.

c) Operations strategy for EDRS service use

The use of the EDRS service for data downlink for the Sentinel-1 and Sentinel-2 missions represents an important complementary capacity with respect to the X-band stations network. It brings flexibility in the elaboration of the downlink scenarios and in order to support real-time services (in particular for Sentinel-1).

In particular, the use of the EDRS service for the Sentinel-1 and -2 missions observations is managed according to the following observation strategy:

- inclusion of acquisition and downlink capacity in support of Copernicus operational services outside Europe (within EDRS coverage) making use of Sentinel-1 data in near real time (NRT) and quasi real time (QRT), i.e. defined as data being made available in less than 1 hour from sensing.

Note: European initiatives are taking shape to organise maritime surveillance activities outside EU waters, e.g. over African coasts. EDRS represents a major asset for such services as it will on one hand avoid to set up direct receiving X-band stations over the related critical areas and on the other hand allows to get the data immediately in Europe. In such scenario, the related responsible entities (e.g. EMSA, Member State representative) will be able to receive the Sentinel data via an own Ka-band local receiving station, via a Ka-band local receiving station operated by own service provider, data provided by ESA via terrestrial network (Level-0 product).

- Considering the fact that some operational services require the pass-through mode to be used over Europe for data transmission in quasi real-time via the two X-band channels, the EDRS service is used to download to Europe the recorded data (sensed elsewhere in the world) outside X-band core stations visibilities.

Note: Sentinel-1 orbital segments in visibility of EDRS over the southern hemisphere (within EDRS visibility from the geostationary orbit) are in particular useful for this purpose.

- increase of the overall Sentinel-1 and -2 downlink capacity and provision of flexibility and redundancy for the mission data download scenarios, being complementary to the X-band core station network.

Note: in particular for Sentinel-1, the use of EDRS supports the data acquisition associated to the full SAR duty cycle capacity, considering in particular the potential constraints in Europe with respect to X-band stations (see above).

Note: for Sentinel-2, in providing additional downlink capacity, the use of EDRS also allows to improve the overall data timeliness performance.

- Download of data in encrypted mode from the EDRS GEO terminals to the Ka-band receiving station for subsequent decryption.

Note: encryption of sensitive data is considered useful in the framework of the above mentioned security-related services.

The resulting operational coordination with the EDRS service provider establishes the detailed planning of the EDRS service for the Sentinel-1 and Sentinel-2 missions. This results in pre-defined available EDRS time slots at static times along the orbits of the

Sentinel-1 and -2 satellites. In addition, technical procedures for short term allocation of EDRS slots to support emergency activities are also available as part of the service (please refer also to the ‘EDRS-Sentinels service high level description document, reference ESA-EOPGS-0018, for further details).

4.4.11 Long term performance monitoring of OCPs

Long term performance monitoring of the Sentinel-1 and Sentinel-2 Optical Communication Payload (OCP) is also done by downlinking dedicated OCP telemetry through Alphasat-TDP1. This encompasses a small number of statistical links (no data transfer) via Alphasat, from the four OCPs on Sentinel-1A/B and Sentinel-2 A/B satellites, allowing to monitor the performance of these OCPs over time and to derive statistics. This activity, that started in May 2018 through a cooperation with DLR, does not interfere with the Sentinel-1 and Sentinel-2 operations with EDRS.

4.5 Data production

4.5.1 General

a) Data production constraints

The main constraint on data production is related to the requirement to systematically generate and make available products from all acquired data within specific timeliness. A subset of data products, corresponding to specific geographical areas, is to be made available within 3 hours from sensing, or less in very specific cases, as defined in [RD15], [RD20] and [RD21].

b) Data production strategy

All acquired Sentinel data are systematically processed to a pre-determined product level for each sensor type (typically Level 1), and archived. The sizing and the timeliness of the production as well as the online retention time will take into account the available operations budget. The systematic character of the production allows achieving a stable and deterministic production scenario. See details in [RD15], [RD20] and [RD21].

The exceptions to this baseline scenario are:
- for Sentinel-1, the handling of specific, on-demand and urgent production request related to a rush emergency situation
- campaigns of data re-processing, necessary following major updates of processing algorithms or auxiliary data for all Sentinel missions.

4.5.2 Sentinel-1

a) Sentinel-1 data production constraints

Sentinel-1 data production constraints include:

- High volume of data to be processed and large processing resources needs
- Systematic and short processing timeliness
- Need for reprocessing campaigns.

b) Sentinel-1 data production strategy

The systematic processing approach allows the systematic generation of a set of Level-1 and Level-2 products (see details in [RD15], [RD20] and [RD21]) after acquisition (either in NRT or within 24h i.e. NTC, Non-Time Critical), with no ordering required for each product to be generated. The set of products to be systematically generated respond to the different requirements of the Copernicus services and allows generating several products with different characteristics for the same data take. This systematic processing approach is also used in case of a reprocessing campaign, to update the Level-1 and Level-2 products archive, after major processing algorithm changes to ensure a long-term harmonised data set quality. On-demand production capability from historical Level 0 products (greater than 24 h) for product different than those systematically generated (e.g. level 1 SLC products generated from past level 0, before the systematic SLC product generation was generalised – see below) is available and has been sized (in terms of resources and users having access to them) according to the evolving requirements.

Systematic product generation is based on the following types of processing:

- systematic NRT 10 min. processing to Level 0. Currently such timeliness is implemented by collaborative ground segment local stations operating e.g. in support of EMSA. As part of a future evolution this could be achieved within the CSC ground segment via use of the EDRS service outside Europe in particular, and by relevant core ground stations, for provision of the resulting QRT data stream.

- systematic NRT 1h/3h processing for a subset of the acquired data, based on geographical areas

- systematic NTC (24h) processing for all other data acquired, to a pre-defined Level-1 and -2 products.

The areas related to systematic regional production of level 1 SLC products, to support interferometric applications in particular, were published online at: https://sentinels.copernicus.eu/web/sentinel/missions/sentinel-1/production-scenario

The Sentinel-1 operations concept initially foresaw the generation of SLC over a limited set of areas over land. Since 21 July 2015, 100% of the IW and SM data over land were systematically produced to level 1 SLC. From 14 April 2016, all SLC IW and SM production has then been operationally extended to all data at global level, i.e. acquired over seas and sea-ice areas as well. This represented a major enhancement of the initial processing and dissemination concept, with an associated increase in the overall

ground segment processing load and core products volumes. Backward processing of IW SLC over areas not included in the initial SLC processing scenario started in summer 2016, and was completed in November 2016: all Sentinel-1 data acquired in IW over land and ice masses since the Sentinel-1A data access opening are now available as SLC products on-line to all users.
Such SLC production increase has allowed to foster the exploitation of Sentinel-1 data for an increasing number of applications and over an increasing number of areas worldwide.

4.5.3 Sentinel-2

a) Sentinel-2 data production constraints

The main Sentinel-2 data production constraints include:
- High volume of data to be processed and large processing resources needs
- Systematic and short processing timeliness
- Need for reprocessing campaigns, driven by improvements of the processor baseline.

b) Sentinel-2 data production strategy

The production strategy is similar as for Sentinel-1. Differences may occur for reprocessing in the case of Sentinel-2 with regard to orthorectified products, in cases where e.g. new auxiliary data (e.g. reference maps or Digital Elevation Models) become available or where improvements were done in the processing baseline or format changes (e.g. geometric refinement).

All data acquired by the MSI from the Sentinel-2 constellation are systematically processed up to Level-2A. The systematic and operational global generation of Level-2A products has been implemented and is operational since 13 December 2018. See details in [RD15], [RD20] and [RD21].

4.5.4 Sentinel-3

a) Sentinel-3 data production constraints

The Sentinel-3 main data production constraints include:
- Flow of data from 4 different instruments and requirements related to production timeliness
- Need for reprocessing campaigns.

b) Sentinel-3 data production strategy

The systematic processing approach allows the systematic generation of Level-0 products and of a pre-defined set of Level-1 products after acquisition (see [RD15], [RD20] and [RD21]). No ordering from users is required for each product to be generated.

The production is split between the land part operated by ESA and the marine part operated by EUMETSAT. For the atmospheric products, namely Aerosol Optical Depth (AOD) and Fire Radiative Power (FRP), EUMETSAT is responsible for the NRT and ESA for the STC/NTC production.

The set of products systematically generated responds to the different requirements of the Copernicus services and allows generating land and marine Level-2 products with different geophysical parameters from the same Level-1 input data (see details in [RD15], [RD20] and [RD21]). This systematic processing approach is also used in case of a reprocessing campaign, to update the Level-1 or higher level products archive, after major processing algorithm changes to ensure a long-term harmonised data set.

4.5.5 Sentinel-5P

a) Sentinel-5P data production constraints

The data production constraints include:

- High volume of data to be processed and large processing resources needs
- Systematic and short processing timeliness
- Need for reprocessing campaigns.

b) Sentinel-5P data production strategy

The data acquired at the ground stations are systematically processed as follows (see details in [RD15], [RD20] and [RD21]):

- systematic Level 2 NRT production with delivery of the Level 2 within 3 hours (all Level 2 except Methane and tropospheric ozone)
- systematic Level 1 production based on consolidated calibration and auxiliary data with delivery of the Level 1 generally within 1 day
- systematic Level 2 production based on consolidated calibration and auxiliary data (including Level 2 Methane and tropospheric ozone products) within 14 days
- systematic full mission reprocessing upon major processing baseline changes

Similar than the other Sentinels, no ordering from users is required for core products to be generated.

4.5.6 Sentinel-4

a) Sentinel-4 data production constraints

The data production constraints include:

- High volume of data to be processed and large processing resources needs.

- Systematic and short processing timeliness

- Level-1b data with full spectral coverage for the large data assimilation centres and Level-2 data for other NRT users shall be delivered regularly one hour after sensing with full spatial coverage.

- Need for reprocessing campaigns, driven by improvements of the processor baseline.

b) Sentinel-4 data production strategy

The data acquired at the mission data acquisition (MDA) ground stations is provided to the MTG-S Level 1 instrument data processing facility - Sounders (IDPF-S) for systematic Level 0 to Level 1 processing. The following higher-level data production is generated by the Level 2 processing facility (L2PF), for the extraction of centrally generated products.

No ordering from users is required for core products to be generated.

The set of products systematically generated responds to the different user requirements and allows generating different geophysical Level-2 products from the same Level-1 input data. This systematic processing approach is also used in case of a reprocessing campaign, to update the Level-1 or higher level products archive, after major processing algorithm changes to ensure a long-term harmonised data set.

4.5.7 Sentinel-5

a) Sentinel-5 data production constraints

The data production constraints include:

- High volume of data to be processed and large processing resources needs.

- Systematic and short processing timeliness

    - Level-1b data with full spectral coverage shall be available 2h 15’ after sensing and Level-2 data shall be available 2h 45’ after sensing

- Need for reprocessing campaigns, driven by improvements of the processor baseline.

b) Sentinel-5 data production strategy

The EPS-SG Payload data acquisition and processing (PDAP) block will ensure the end-to-end chain from Sentinel-5 data acquisition to the systematic generation of level 1 and level 2 products.

No ordering from users is required for core products to be generated.

The set of products systematically generated responds to the different user requirements and allows generating different geophysical Level-2 products from the same Level-1 input data. This systematic processing approach is also used in case of a reprocessing campaign, to update the Level-1 or higher level products archive, after major processing algorithm changes to ensure a long-term harmonised data set.

4.5.8 Sentinel-6

a) Sentinel-6 data production constraints

The Sentinel-6 main data production constraints include:
- Flow of data from the altimeter POS-4 and microwave radiometer AMR-C and requirements related to production timeliness (Near Real Time in 3 hours, Short Time Critical in 36 hours and Non Time Critical in 60 days);
- Need for regular reprocessing campaigns with strong requirements related to climate applications (sea level).

b) Sentinel-6 data production strategy

The systematic processing approach allows the systematic generation of Level-0 products and of a pre-defined set of Level-1 products after acquisition (no Level-1 in NRT, Level-1A and 1-B in STC and NTC). No ordering from users is required for each product to be generated.

The Level-2 products contain Low Resolution Mode and High Resolution Mode parameters (mainly sea surface height, wind speed and significant wave height), provided at two different sampling rates (1 and 20 Hz).

These Level-2 products allow the generation of higher level products L2P and L3 used mainly by the Copernicus Marine and Climate Services.

Regular reprocessing campaigns are planned, to update the Level-1 or higher level products archive, after major processing algorithm changes to ensure a long-term harmonised data set.

4.6 Data dissemination

a) Data dissemination constraints

The main constraint related to data dissemination is related to the huge volume of processed Sentinel data, to be widely accessible on-line by the users (see data policy, chapter 3.3). Measures must be taken to avoid conflicts and network congestions in downloading the products.

b) Data dissemination strategy

All acquired Sentinel-1, -2, -3 (land) and -5P data are systematically disseminated by ESA with on-line access by users, according to the principles of the Sentinel data policy. Sentinel-3 (marine and atmosphere NRT) data are disseminated by EUMETSAT, as well as Sentinel-4, Sentinel-5P, Sentinel-5 and Sentinel-6 data. Sentinel data are made available for Copernicus and National use and, in line with the Sentinel data policy and within available operational budget, for other use (e.g. scientific, international, etc.). More information regarding data access is available at: https://sentinels.copernicus.eu/web/sentinel/sentinel-data-access/typologies-and-services for ESA, and https://www.eumetsat.int/access-our-data for EUMETSAT.

The Copernicus Space Component Ground Segment data access implements an open and free data policy ensuring that all Sentinels products are accessible to all users online.

Access to Sentinel-1, -2, -3 (land) and -5P latest products is made available via dedicated data hubs:

- User can self-register to the data hubs
- Data provision via rolling archives
- Data download via terrestrial network (connectivity to internet at e.g. 20 Gbps)

In addition, access to full Sentinels long-term archive is made available to all users online.

Sentinel-3 (marine), Sentinel-4, Sentinel-5 and Sentinel-6 user level data is made available through the EUMETSAT Data Store, EUMETcast and the Copernicus Online Data Access. Archived data can be retrieved from the EUMETSAT data centre (https://www.eumetsat.int/eumetsat-data-centre). Users can register via the Earth observation portal (https://www.eumetsat.int/data-registration).

The distributed implementation of the product dissemination during FOC, involving several core centres, allows decentralising the dissemination function. Regular review of the dissemination performance is a pre-requisite for the evolution of the infrastructure in charge of dissemination, avoiding problem of network bottleneck in particular.

Enhanced data dissemination, including e.g. Centralised Data Pick Up Points on data hubs, mirror sites, additional distribution nodes as part of e.g. the collaborative ground segment, further ease the access to data by end users. This concept has been implemented during the CSC ramp-up phase and is regularly consolidated during the FOC phase, with the support of partners for:

- National or regional re-distribution by partners within Member States
- regional re-distribution (e.g. by partners with whom international cooperation agreements have been established by the EU)
- specific user community or large research projects
- Copernicus Data Access and Information service platforms.

5 INTERNATIONAL TECHNICAL COOPERATION

Specific international technical cooperation is planned with missions having similar mission characteristics and data policy compared to the Sentinels, as well as a similar way to operate (e.g. baseline observation scenario). A high-level description of the relevant cooperation is the object of the following sub-chapters regarding Sentinel-1, Sentinel-2, Sentinel-3, Sentinel-4, Sentinel-5, Sentinel-5P and Sentinel-6.

Note: such cooperation is in addition to the involvement of Copernicus Contributing Missions for which data access contracts are placed (more information at: https://spacedata.copernicus.eu/web/cscda/data-offer/missions).

5.1 Roles and responsibilities

In accordance with the EU-ESA Copernicus Agreement ([RD4] and [RD18]) and the EU-EUMETSAT Copernicus Agreement [RD19], the EU represents Copernicus and manages relationships with third countries and international organisations, ensuring the coordination of Copernicus with activities at national, Union and international levels.

ESA and EUMETSAT provide support to the EU for the matters concerning the international technical cooperation of the Copernicus Programme. In particular, ESA and EUMETSAT assess the impact of international technical cooperation requests and implements and is responsible for technical actions with international partners subject to prior consultation with the Commission.

To date, technical arrangements have been established between ESA and respectively NASA, NOAA, USGS, Geoscience Australia, Brazil, Serbia, India and Ukraine, and more recently with respective organisations from Chile and Colombia. The content of these agreements is available at:
https://sentinels.copernicus.eu/web/sentinel/missions/international-cooperation/partners

For EUMETSAT, technical arrangements have been established with NOAA, Geoscience Australia, India and Chile.

5.2 Cooperation on the Sentinel-1 mission

The cooperation between the Sentinel-1 mission and the Radarsat Constellation Mission is addressed as part of the on-going EU – Canada cooperation discussions on Copernicus. The main objective is to define and implement complementary observation scenarios between Sentinel-1 and RCM for the respective benefits of the Canadian and European users in particular.

5.3 Cooperation on the Sentinel-2 mission

Cooperation is on-going between the Sentinel-2 mission and Landsat mission by USGS and NASA. The cooperation includes the improvement of the missions' interoperability in terms of products geometric and radiometric properties as well as metadata.

Great progress has been achieved in terms of aligning the image geometries with Landsat using Sentinel-2 Global Reference Image (GRI) as sources of ground control points. The usage of Copernicus DEM is also being considered by Landsat team and this would strongly improve the interoperability.

As well, the top and bottom-of-atmosphere radiometries of both missions are being cross-compared to characterise the differences. These activities are carried in the framework of the Committee on Earth Observation Satellites (CEOS), in particular for the bottom-of-atmosphere measurements under the so-called ACIX (Atmospheric Correction Inter-comparison Exercise) activity.

Cloud masks from both missions have as well been compared as part of the CEOS CMIX (Cloud Masking Inter-comparison Exercise) activity.

5.4 Cooperation on the Sentinel-3 mission

The long-term time-series comparability from SPOT VGT, PROBA-V and Sentinel-2 to Sentinel-3 products in particular for land surface and vegetation parameters is on-going.

An agreement for the provision of marine data to key marine regional centres in Africa is in place between EUMETSAT and the African Union. This agreement also covers the re-distribution of ESA-provided Sentinel-3 Land data for Africa through EUMETCast.

5.5 Cooperation on the Sentinel-5 Precursor mission

A cooperation agreement between ESA and NOAA regarding the Sentinel-5 Precursor mission and Suomi-NPP has been signed. The two satellites are maintained in loose formation flying, with about 3.5-minutes separation.

Sentinel-5P delivers key data relevant to the Atmospheric Composition Virtual Constellation (AC-VC) of CEOS – see more details on this CEOS activity in chapters 5.6 and 5.7 below.

5.6 Cooperation on the Sentinel-4 mission

The Atmospheric Composition Virtual Constellation (AC-VC) of CEOS strives to coordinate existing and future international space assets and to bring about technical/scientific cooperation and collaboration among space agencies.

In the framework of the AC-VC, the geostationary missions Sentinel-4, TEMPO (NASA) and GEMS (NIER, Republic of Korea) missions are regarded as the Geostationary Air Quality (Geo-AQ) constellation. In order to enhance the relevance of the Geo-AQ constellation missions for science and policy, AC-VC pursues coordination of algorithm development, harmonization of content and format of the mission products, as well as coordination of calibration and validation activities.

5.7 Cooperation on the Sentinel-5 mission

Similar to the case of Sentinel-4, Sentinel-5 is regarded a key element of the Atmospheric Composition Virtual Constellation (AC-VC). The goal is to collect and deliver data to improve monitoring, assessment, and predictive capabilities for changes in the ozone layer, air quality, and climate forcing associated with changes in the environment through coordination of existing and future international space assets.

5.8 Cooperation on the Sentinel-6 mission

Sentinel-6 is a collaborative mission implemented and co-funded by the European Commission, the European Space Agency, EUMETSAT and the US, through NASA and the National Oceanic and Atmospheric Administration.

6 PRIORITIES FOR ACCESSING SENTINEL RESOURCES

6.1 Scope

The extent of the Sentinel data access is constrained by:

- the technical constraints of the space and ground segments (see chapter 4 for high level constraints)
- the limitations in financial resources during the development and operations phase.

The access to Sentinel data is complemented by the contributions by collaborative centres or local stations, including national ground segment functionalities, and by Copernicus services.

One main objective of the Sentinel operations strategy is to ensure systematic and routine operational activities with pre-defined operations to the maximum extent possible, anticipating and avoiding conflicts during operations through the Sentinel observation scenarios. Priorities are used for the definition of the observation scenario and for the implementation of exceptional emergency requests in the case of Sentinel-1.

6.2 Priority scheme

The priority scheme relies on the Copernicus Regulation [RD16], the GSC Programme Declaration [RD1] and the EU-ESA Copernicus Agreement [RD4] and is used for managing conflicting user requirements for accessing Sentinel missions' resources. Today most of the potential conflicts can be solved by appropriate planning of shared resources among the 2-spacecraft Sentinels constellation.

The following Sentinel data use is foreseen:

- Copernicus service use: this data use is related to Copernicus service providers, responding to the Copernicus governance. It consists of all "Copernicus services" approved by the EC.

- National utilisation by Copernicus Participating States and ESA Participating States in accordance with the Copernicus Regulation [RD16] and the GMES Space Component Programme Declaration [RD1], and utilisation by the following EU institutions: European Parliament, European Council, Council of European Union, European Commission, European External Action Service (EEAS)

- Other use:
  - i. Cooperation agreements between EU and international partners, responding to present and future data requirements.
  - ii. Scientific use
  - iii. Other use.

Cooperation agreements, such as the ones envisaged under "other use" i), are subject to the applicable EU and ESA approval procedures.

The following priorities, in descending order, are assigned:

Priority	**Data use**
1 (first priority)	Copernicus service use
2	National utilisation by Participating States in accordance with the Copernicus Regulation [RD16] and the GMES Space Component Programme Declaration [RD1] and utilisation by the following EU institutions: European Parliament, European Council, Council of European Union, European Commission, European External Action Service (EEAS)
3	Other

The process to solve any remaining conflict is based on the adoption of the above priority scheme, defined in line with the provisions of the EU-ESA Copernicus Agreement. Therefore, a simple procedure is applied to solve these cases, whereby the requirement from the use typology with higher priority takes precedence. It is not expected that the priority scheme will vary over the course of the mission, thus allowing adoption of such straightforward and robust approach. In case a conflict cannot be unequivocally resolved based on the above priority scheme (e.g. a conflict within a single priority group) the mission manager will decide on a case-by-case basis, in consultation with the European Commission.

In all cases, the Sentinel data are available free of charge and following acceptance of the Terms and Conditions for the use of the data.

6.3 Handling of Sentinel-1 emergency observations

In the case of the Sentinel-1 mission only, emergency observations are regularly handled. The Sentinel-1 observation strategy is based on a baseline observation scenario, fulfilling the Copernicus and national user needs known and agreed in advance, based on the priority scheme described in chapter 6.2. The concept of planning specific observations for emergency support is not applicable to the other Sentinels.

The Sentinel-1 baseline observation scenario is set up anticipating observations on a systematic basis for the main types of disasters over land, i.e. earthquakes, volcanoes and flooding. As part of the overall CSC operations, it is indeed assumed that on-demand ad-hoc requirements for emergency and security purpose, user requests are fulfilled by very high resolution observation (typically less than 5 meters) from optical and SAR (X-band in particular) Copernicus contributing missions.

In practice and by experience at the stage of Full Operations Capacity, due to the added-value of the Sentinel-1 mission to the Copernicus Emergency Management Service since the respective launches of Sentinel-1A and Sentinel-1B satellites, specific Sentinel-1 observation tasking activities are regularly performed to support emergency situations, floods in particular.

Users entitled to submit Sentinel-1 emergency / security requests are:
- the Copernicus Emergency Management Service
- the Copernicus Security Services.

In addition, in the event of urgent observation requirements arising in association with a disaster and in case this event is not supported by the baseline observation scenario, the Sentinel-1 Mission Manager may allocate specific requests for SAR operation and product generation. This may include specific requests from ESA/EU Member States or National services, the Commission via its formal point of contact to ESA (as defined in the EU-ESA Copernicus Agreement), EMSA or from the International Charter for Space and Major Disasters.

The following criteria shall be met and assessed by the Mission Manager for deciding that a particular event should be supported in an exceptional basis by specific Sentinel-1 observations, if not yet in the baseline observation scenario:

1. The satellite data is not foreseen to be acquired by the Sentinel-1 baseline observation scenario

2. The satellite data are required by disaster management authorities with short response time with respect to the event.

3. The event is recognised as a disaster (e.g. may induce danger on human life, may have important environmental or security consequences, etc.)

4. The satellite data are of help during the crisis phase of the event.

In these cases, the required Sentinel operations will have priority over the baseline observation scenario.

Effort shall be made to minimize these observations to the strict necessary duration and to avoid overriding the baseline observation scenario.

The following priorities, in descending order, are assigned for the Sentinel-1 mission operations:

Priority	Originator/category
1 (first priority)	Spacecraft safety
2	Emergency Observations (no specific priority is applied among the items of the list below): - Copernicus Emergency Management Service - Copernicus Security Services - Other cases as defined above, handled through the mission management. Note: Copernicus services shall have precedence in case of conflicts within this priority level
3	Baseline observation scenario

The Mission Manager will decide in case of such exceptional cases and inform the Commission (via the standard reporting mechanism). In addition, in case the exceptional tasking affects the baseline scenario, the user community at large is informed through the release of resulting detailed planned acquisitions segments.

As part of these on-demand tasking activities, tropical cyclone observations over seas / oceans are regularly supported, upon request from France. This is performed based on an agreed planning procedure that considers forecasted tracks of relevant tropical cyclones covering several days. In the current status of these operational activities, the agreed number of specific planning actions to support tropical cyclone observations over seas and oceans is 4 per month.

7 MISSION MANAGEMENT

The following principles apply for the management of the Sentinel mission operations:

- The HLOP provides the ground rules for the allocation of Sentinel resources, within the mission operations constraints. The detailed definition of these activities and therefore the detailed planning of spacecraft and ground segment operations are implemented accordingly

- Problems of interpretation of the HLOP documentation, appearing in the day-to-day planning of the mission, will be solved by the relevant Mission Managers[1] as required, and confirmation sought from the Commission or any other body (e.g. Copernicus User Forum, Copernicus Committee) according to the Copernicus governance rules

- If deviations are required with respect to HLOP rules and dispositions, two cases should be considered:
  - occasional deviations, which do not imply a revision of the HLOP: the Mission Managers can authorise such deviations
  - deviations which require a (permanent) revision of the HLOP. If required, as a matter of urgency, the Mission Managers can authorise the implementation of such deviations, establishing a temporary rule to be applied.

Once the full operations capacity of the mission is reached, the Mission Managers will inform the Commission in case of exceptional or occasional deviations of the Observation Scenario prior to their implementation.

The reporting and consultation mechanism with the Commission is based on the provisions defined in the EU-ESA Copernicus agreement covering the CSC operations. The consultation mechanism related to the Sentinel observation scenarios is defined in this document under chapter 1.2 and chapter 8.

Whenever deviations are implemented, be it occasional or a (permanent) revision of the observation scenario, the user community at large is informed through the release of resulting detailed planned acquisitions segments and through a dedicated news item or weekly mission reports (e.g. for Sentinel-1 specific tasking in support of emergency activations).

8 PROCESS FOR DEFINING, REVISING AND APPROVING THE SENTINEL OBSERVATION SCENARIOS

[1] Note that for Sentinel-3, Mission Management is shared between ESA and EUMETSAT, and that the Sentinel-4, Sentinel-5 and Sentinel-6 missions are operated and managed by EUMETSAT

8.1 Scope

The process for collecting Sentinel observation requirements and for elaborating the observation scenarios is established in accordance with the Copernicus Regulation [RD16], the Declaration of the GMES Space Component Programme [RD1], the Sentinel Data Policy as defined in [RD2], the Copernicus Space Component Operations Concept [RD3], the Data Warehouse requirements [RD11] as well as the Sentinel Mission Requirements Documents. Based on the operations guidelines and constraints described in Chapter 4, the elaboration of observation scenarios is required for the Sentinel-1 and -2 missions. Considering the nature of the missions and instruments operations, the definition of the Sentinel-3, Sentinel-5P, Sentinel-4, Sentinel-5 and Sentinel-6 observation scenario is straightforward and therefore this process can be simplified.

8.2 Collection of observation requirements

The objective of this exercise is to discuss and collect the observation requirements from the various user groups, starting with the Copernicus services, National requirements and relevant EU institutions. This allows further detailing the requirements as derived from the Mission Requirements Documents (MRDs).

Five main groups of requirements are identified as follows:

- Copernicus services use
- National services and use by ESA and EU Member States, Copernicus Participating States, in accordance with the Copernicus Regulation and GSC Programme Declaration, and by the following EU institutions: European Parliament, European Council, Council of European Union, European Commission, European External Action Service (EEAS)
- Other use, including:
  - International public use based on international agreements, contribution to international initiatives
  - Scientific use
  - Other use including use for commercial value-adding.

Table 1 below summarises these categories and indicates the mechanisms and main forum for collecting the requirements.

Group	Source of Requirements
Copernicus services	- Copernicus Data Access Data Warehouse requirements - Direct discussions, operational progress meetings with Copernicus services and user questionnaires in the frame of CSCDA operations

Group	Source of Requirements
National services and use by Participating States in accordance with the Copernicus Regulation [RD16] and the GMES Space Component Programme Declaration [RD1] and by the following EU institutions: European Parliament, European Council, Council of European Union, European Commission, European External Action Service (EEAS)	- Discussions with Member States Delegations, European Commission, Copernicus User Forum and Copernicus Integrated Ground Segment Task Force Members - Interactions in the frame of the Sentinel Collaborative Ground Segment - Provision of new requirements as part of the Sentinel HLOP revision process
International public use based on international agreements, contribution to international initiatives	- EU agreements with international partners - GEO/CEOS (e.g. FCT, GFOI, Geo-hazard Supersites), IGOS, FAO, REDD, PSTG, IICWG, GCOS, IRRI, CliC, TIGER, DRAGON, etc.
Scientific use	- Recommendations from scientists at key SAR workshops (FRINGE, SEASAR), Sentinels workshops, SEN4SCI, etc. - Extrapolation of ESA GSE Projects (e.g. Polar View, MARISS, Terrafirma, GMFS, etc.) - Glob-series projects, CCI, SEOM, etc. - Extrapolation of ERS/ENVISAT projects
Other use	- Any other use, including use for commercial value-adding

Table 1 – Source of Sentinel observation requirements

8.3 Elaboration of the observation scenarios

Based on the collected observation requirements, a series of simulations are performed to elaborate the Sentinels observation scenarios, taking into account the priority scheme as defined in Chapter 6.2. In addition to the instrument planning and coverage maps, the simulations also cover the elaboration of the data downlink scenarios within the technical constraints described in Chapter 4 (satellite, instrument, ground segment, EDRS). Detailed optimisations are performed with the operational mission planning systems with the resulting observation plans published online at sentinels.copernicus.eu.

8.4 Consultation and approval mechanism

The consultation of the European Commission and ESA/EU Member States on both the collection of observation requirements and the resulting observation plans is planned to take place once a year typically, or as needed in case of major changes. A time interval of 3 to 6 months indicatively is necessary between the submission of requirements and the effective definition of the observation plans, in order to perform the necessary analyses, simulations and optimisation in the use of mission resources.

The approval mechanism with the Commission is based on the following principles:

- before issuing a new version of the HLOP and/or a baseline observation scenario update (see Annexes), ESA will submit the draft of the document to the Commission for review and endorsement, indicating the reasons for the suggested updates and allowing sufficient time to review the proposal

- on request by the Commission, ESA will support the presentation of HLOP updates to the relevant Copernicus boards (e.g. User Forum, Committee, Integrated Ground Segment Task Force)

- the gradual extension of the observation scenario during the ramp-up phase (in line with the increasing operational capacity), as well as day-to-day routine changes during full operations (e.g. due to technical reasons) will be done at the discretion of ESA.

8.5 Evolution of the Sentinel observation scenarios

It is planned to define and implement a stable observation plan for the benefit of the (operational) users. Nevertheless, regular revisions and adaptations of the observation scenarios are necessary, both within the ramp-up phase and during the full operations phase, as follows:

From Space Segment Commissioning phase to full routine operations capacity of the first A satellites:

- an observation / operations scenario allowing to carry out the satellite commissioning activities supports the phase E1
- ramp-up phase: the scenario gradually evolves in line with the ground segment operational capacity and incorporating the priority user requirements (Copernicus, National) to reach the routine exploitation of the first satellite.

Evolution during CSC operational phase, to cope in particular with:

The main system capacity scenarios, including:
  - o the inclusion of the second Sentinel satellite leading to the Full Operational Capacity of the missions with the 2-satellite constellation
  - o for Sentinel-1 and -2, the gradual use of the European Data Relay System (EDRS) to e.g. enhance the data download capacity
- The evolution of the requirements from the Copernicus services, the evolution of the "perimeter" of the Copernicus services as defined by the European Commission, the inclusion of new Commission projects (e.g. under H2020)

- The evolution of national requirements from ESA/EU Member and Participating States, to satisfy in particular the collaborative ground segment activities
- The evolution of the requirements from the other sources as defined in Table 1
- The constraints on the use of the space and ground segment resources (e.g. core and collaborative local ground station networks).

ANNEX 1

Sentinel-1 baseline observation scenario

1. Scope

The scope of this annex is to describe the principles based on which the Sentinel-1 observation scenario is established. These principles have been applied during the ramp-up phase of Sentinel-1A and also constitute the basis for the routine phase. This annex also addresses the high level approach that is followed with Sentinel-1B in operations.

The Sentinel-1 observation scenario is based on the current best knowledge of the Sentinel-1 observation requirements (from Copernicus, ESA/EU Member States, scientific communities, etc.). The scenario has been established on the basis of the requirements collected over the past and in the frame of the Sentinel HLOP revision process. This list is provided in the Appendix to this Annex 1.
The observation scenario is anticipated to evolve during the course of routine operations, based on the revision process described in Chapter 8.

2. Assumptions and constraints

The current observation scenario, at the stage of Full Operations Capacity, is based on the following assumptions and constraints:

- The availability of the Matera, Svalbard, Maspalomas and Neustrelitz core ground stations, as well as the operational use of EDRS.
- A priority given to Copernicus services, as well as to National services and use by Copernicus and GSC/CSC Participating States, and by relevant EU institutions, as stipulated in Chapter 6.

3. Sentinel-1 baseline observation scenario description

3.1 Observations

Europe, European waters, and Arctic

- A full coverage of European land (EEA-39 countries) and surrounding seas (Exclusive Economic Zones - EEZ) is performed at each constellation repeat cycle (6 days) to support many Copernicus and national activities. A careful selection of the passes is made to ensure an optimisation of the coverage reducing the overlaps between passes in order to save satellite resources, in particular at high latitudes. A full coverage is ensured every constellation repeat cycle both in ascending and descending passes, thus providing a very good revisiting frequency. The selected mode and polarisation is IWS VV+VH, which adequately supports the various land cover applications. This regular and frequent mapping of European land supports the Copernicus Global Land service soil moisture / hydrology component, noting that Europe is the area defined as Priority 1 by the service partner. This high coverage frequency also provides a possibility to support the Copernicus Land Monitoring Service over Europe with SAR imagery. The Copernicus Ground Motion Service also benefits from this high coverage frequency, as well as the new emergency service related to automated flood detection. Long segments are acquired over Europe and the Mediterranean Sea / adjacent EEZs without SAR mode switches to avoid data gap either on the coasts or on the water coastal areas (with few exceptions, see below). The polarisation VV+VH is also essential for wind / wave monitoring and suitable for oil spill monitoring, while for land key applications based on InSAR, the difference is minor between vertical and horizontal polarisation.

- On the western European waters outside both the EEZs and the sea-ice monitoring areas, the background selected mode is EWS VV+VH to allow oil spill monitoring. This mode, which features a larger swath, is better suited (with respect to the IWS mode) to the support to EMSA CleanSeaNet activities. It also supports the wind-wave monitoring activities, based on national requirements as well as for the extension of the Copernicus Marine Environment Monitoring Service with SAR-based sea-state activities.

- The principle of the European continental land coverage is replicated over minor European islands in the open ocean (e.g. Azores, Canaries) with a set of IWS (VV+VH) tracks covering the islands and their associated EEZs, and a set of EWS (VV+VH) tracks covering the wider EEZ area of the islands in accordance with maritime surveillance requirements.

- For sea-ice and iceberg monitoring (Copernicus Marine Environment Monitoring Service and national services) the most suitable mode is EWS HH+HV (GRD product in medium resolution at 90 m ensuring a very high radiometric resolution). The EWS is preferred to the IWS mode in order to privilege the coverage capability (400km swath with EWS, 250km swath with IWS). It is systematically used for most passes in both ascending and descending to get the maximum revisit time. In routine operations with the constellation, all relevant sea-ice polar areas are now covered in EWS HH+HV polarisation. In the particular case of the Baltic Sea surrounded almost completely by land territories of EU/ESA Member States, sea-ice monitoring activities require as well data in EWS mode, HH+HV polarisation (activities performed during winter for typically 7-8 months in the Northern part and 2-3 months in the southern part). For this specific case of the Baltic Sea, in order to address at best the conflicting requirements of the European Land coverage (IW VV+VH, mostly free of gaps) and the seasonal sea-ice monitoring (EW HH+HV), a spatially optimised set of passes has been selected for the service of sea-ice monitoring in EWS HH+HV (with Sentinel-1B only), while a complete coverage for the land services in IW VV+VH is maintained (mainly using Sentinel-1A), exploiting the spatial overlap between neighbouring passes at high latitudes. In order to limit the impact on some land activities when using the EW mode, a switch between EW and IW mode is implemented for some specific orbits, EW being used over seas, IW over land. The scenario takes into account the variations of the sea-ice monitoring areas of interest during the year. This particular scheme, previously implemented with Sentinel-1A during the winter period to support the Baltic sea-ice monitoring, is currently implemented with Sentinel-1B only. For Sentinel-1A, IW VV+VH observations are made over the Baltic, in the same mode used for the mapping of the whole Europe EEA-39 and coastal waters, to ensure full consistency and continuity during the year.

- A specific strategy is adopted regarding Greenland ice sheets monitoring, allowing users to derive, among others, glacier velocity maps, very relevant for climate change monitoring (e.g. estimation of contribution to global sea-level rise); this activity has been included in the Copernicus Climate Change Service. At least one campaign per year during winter season covering the whole Greenland ice sheet is planned in IW HH in both ascending and descending passes, made of 4 to 6 consecutive repeat cycles at 6 days interval, using both Sentinel-1A and Sentinel-1B. This also includes coverage of surrounding waters – without mode switch to avoid data gap – also used by the Copernicus Marine Environment Monitoring Service (CMEMS) for sea-ice and iceberg monitoring. A similar strategy is implemented for monitoring Svalbard glaciers, on top of which regular observations are performed in both ascending and descending passes. In addition and in agreement with CMEMS, 6 long passes in IW HH+HV, specifically selected to cover almost completely the Greenland margins are systematically acquired every 6 days using both satellites, starting at the beginning of the routine operations phase, with the objective of ensuring a very regular monitoring of the highly changing outlet glaciers of the Greenland ice sheet. These passes in IW mode are also of interest for CMEMS for Greenland inshore areas and for fast ice detection, as well as iceberg monitoring in relevant areas. In addition and outside the 3-month eclipse period, a regular mapping at 12 days of the inner part of Greenland is performed, to support activities of the Copernicus Climate Change Service as well as observation needs from Denmark, in particular. Specific care is made on the transition between the EW mode segments and the IW mode segments, so that the IW mode use is maximised over Greenland and the EW mode use over the surrounding waters; one objective is to minimize the number of passes where both IW and EW segments are used and therefore limit the data gaps due to the mode transition.

Outside Europe, outside European Waters / Arctic

Sentinel-1 resources are available to complement the European observations and support in particular some Copernicus services activities outside Europe, some national services / use on national territories outside Europe (e.g. Canada or French and UK overseas territories / departments) and some national services / use outside national territories (e.g. Antarctica), as well as to support international cooperation. Additional observations are performed to support key activities only possible with SAR data (e.g. InSAR related applications for geo-hazard and tectonic areas monitoring). Regarding the operational services requiring data in quasi or near real time, the detailed observations will be adjusted depending on the readiness of the relevant users to acquire and process the QRT data.

The following observations are included in the Sentinel-1 observation scenario:

- Copernicus Marine Environment Monitoring Service sea-ice / iceberg operational service in Southern Ocean around Antarctica (EWS HH, and for a major part in HH+HV with the routine use of the 2-satellite constellation, NRT 3 hours), also covering national requirements on the subject areas. The revisit frequency is similar to Envisat past regular activities over key areas, as starting point, then an increase has been gradually implemented with Sentinel-1B in operations

- For Northern / Western polar areas, of lower priority for the Copernicus Marine Environment Monitoring Service (i.e. “Western Arctic”), a regular mapping is performed as well, although due to satellite resource constraints, at a lower frequency w.r.t what is ensured for CMEMS priority areas, taking into account seasonal conditions. The 2-satellite constellation has allowed to increase the repeat coverage frequency to a full mapping every 3 days typically, slightly better or worse depending on the areas and related system constraints.

- Background observations to provide reference map for Copernicus Emergency Management Service and Copernicus Security Service (IW VV+VH or IW HH+HV depending on the area). These observations represent limited SAR resources as 1 or 2 reference product is to be provided per year. Some of the areas are covered by the mapping of tectonic and volcanic areas at global level – see below

- Regular observations in IW VV+VH to support the Copernicus Global Land Service, for identified priority areas on all continents except Antarctica. The requirement for soil moisture monitoring asks for a short revisiting in the order of 1 to 2 weeks. With the start of the constellation operations, a full mapping of global land areas every 12 days (except Antarctica which is subject to specific campaigns) in IW VV+VH has been reached, with a combined use of S1A and S1B. Before reaching the full operations capacity, the Boreal forest, in a first step, was covered every 24 days. It shall be noted that during mission ramp-up some global tectonic areas have been observed in single polarisation VV. As indicted above, Europe EEA-39 is covered every 6 days in both ascending and descending passes. This European scheme has been extended to Ukraine, to mainly support agriculture monitoring, performed in cooperation with the European Commission (DG-JRC, DG-NEAR). The European scheme has also been implemented on a limited area over Russia near the Finish border (within 200 km), upon request from Finland.

- During mission ramp-up, regular coverage of global tectonic and volcanic active areas in a stable full two-pass IW mode, VV polarization, with a revisit frequency of 24 days per pass (alternating ascending and descending passes, i.e. a particular area is observed every 12 days, interferometric pairs are available every 24 days) has been implemented. With the routine operations of the constellation, tectonic and volcanic active areas located within Europe are revisited every 6 days per pass in IW mode, VV-VH polarization, giving the possibility to perform InSAR in both ascending and descending geometry every 6 days. Outside Europe, the routine operations of the constellation now allows a repeat frequency every 12 days or better in both ascending and descending passes in IW VV+VH. Critical areas, for instance subject to recent earthquakes or volcano eruptions, are covered with both satellites, allowing to perform interferometry at 6 days.

Note: for a number of small volcanic islands worldwide, from May 2015 onwards, the Stripmap mode (SM) is used for the regular coverage. This is implemented in the case a SM swath fully covers the island in one pass, and no maritime surveillance activities take place around the island. The SM mode features (at a comparable system resource consumption) a smaller swath w.r.t the IW mode (in the order of 80 km vs 250 km) but ensures a higher spatial resolution, of particular interest for volcano monitoring.

- Regular observations to support Canadian operational services, in particular sea-ice monitoring services (EW HH+HV or EW HH) and the sea-state monitoring activities (EW VV+VH), as well as monitoring of Canadian lake and river ice. Substantial observations in support of CMEMS activities also support the needs from Canada, in particular as regards Baffin Bay, Davis Strait, Labrador Sea and the Arctic Ocean.

- Regular observations to support French overseas territories / dept. operational services (maritime surveillance, illegal fisheries monitoring) including Kerguelen and Crozet Islands (IW HH), La Réunion, the Iles Eparses (Mayotte, Geyser, Juan de Nova, Bassas da India, Tromelin, Glorieuse, Europa, in EW VV+VH and/or IW VV+VH), French Guiana waters (IW VV+VH), and starting end Nov. 2017 St Paul & Amsterdam (IW HH+HV). Based on provided requirements, a specific strategy has been adopted since the start of the mission operations for La Reunion Island, for which a coverage is ensured every repeat cycle (as for Europe), but alternating the use of the SM mode and the IW mode, to support both land monitoring (incl. volcano) and maritime surveillance. The regular coverage of the following areas was implemented mid 2018: Clipperton, New Caledonia / Pacific (Marquises, Wallis & Futuna, Matthew, Hunter, Walpole). An extended coverage off the coast of Martinique Island and the Antilles Arc, to support the detection and monitoring of potential Sargasso algae, has been implemented routinely.

- Regular observations to support United Kingdom overseas territories monitoring (illegal fisheries monitoring) including BIOT (British Indian Ocean Territory) starting end Nov. 2017 (IW HH+HV), Ascension (campaign Feb-Mar 2018, IW HH, to be potentially re-conducted with permanent observations). British Antarctic Territories (BAT) are regularly substantially covered (EW HH or HH+HV) with CMEMS observation needs, as well as the southern waters of South Georgia and South Sandwich Islands. The St. Helena and Tristan da Cunha islands are regularly covered in SM for volcano monitoring.

- Regular observations to support the maritime surveillance activities of the Indian Ocean Commission (IOC) in EW VV+VH and/or IW VV+VH (IOC members: Comoros, France/La Réunion, Madagascar, Mauritius and Seychelles).

- A specific strategy has been adopted regarding Antarctica ice sheets monitoring, allowing experts to derive, among others, glacier velocity maps. During mission ramp-up, at least one campaign per year during local winter season covering the Antarctica ice sheet margins was performed in IW HH, made of 4 to 6 consecutive repeat cycles of 12 days or if possible 6 days. Considering the large extent of the areas to be covered, the campaign was organised by sectors of the Antarctica coastal zone. The Antarctica ice sheet wide acquisition campaign (visible interior) is performed every 3 to 4 years for 3 to 4 consecutive passes, using both satellites. Contribution from other SAR missions is however assumed, as discussed in the frame of the Polar Space Task Group. The decision by NASA to operate NISAR in left-looking geometry will allow for the regular complete coverage of the inner part of Antarctica, which is not ensured by the flying SAR missions. A continuous coverage of the Antarctic Peninsula and the major outlet glaciers of the Antarctic ice shield flowing into Pine Island bay is provided in IW HH every constellation cycle (6 days), outside the campaign seasons. This region currently undergoing drastic changes is very relevant for climate change monitoring (e.g. estimation to contribution to global sea-level rise). With the routine operations of the constellation, most of the Antarctica ice sheet margins is now observed at 6 days repeat in IW HH, the rest (lower priority) at 12 days.

- Upon request from Norway, a specific campaign is planned during local winter every year (during the period June-August) over Bouvet Island in the South Atlantic Ocean, made of consecutive passes at 6 or 12 days in IW HH, in both ascending and descending geometries.

- During mission ramp-up, campaigns to support forest monitoring international activities (IW VV+VH), as part of GFOI activities in particular, in support of REDD, were organised. GFOI sites include areas in Vietnam, Ecuador, Colombia, Peru, Amazon, Tanzania and Lake Victoria region.
  With the routine operations of the constellation, these areas are now covered every 12 days in IW VV+VH, as part of the global land systematic mapping. Some key areas, of limited extent, like the Vietnam Mekong delta are observed every constellation cycle, i.e. every 6 days.

- During mission ramp-up, regular observations of key acquisition zones (with a 12-day revisit) in IW VV+VH focusing on the world`s most important agricultural production areas were performed. This also included campaigns to support agriculture / crop monitoring activities worldwide in the frame of GEOGLAM actions, among others. GEOGLAM-SIGMA sites include areas in Taiwan, Malaysia, Indonesia, Thailand, Philippines, Laos, China and Pakistan. Observations also include priority areas established by IRRI for rice monitoring in the following countries (some being the same as the GEOGLAM sites): India (Tamil Nadu and

Odisha states), Vietnam, Philippines, Thailand and Cambodia. Similarly than for GFOI / REDD supporting activities, unless they require a repeat frequency less than 12 days, these campaigns are no longer necessary due to the fact that in routine operations of the constellation, a full mapping of global land areas has now been implemented every 12 days in IW VV+VH. For some critical areas of limited extent and if necessary, a repeat frequency of 6 days may be envisaged, within the system resources constraints.

- Observations in Africa in IW (now systematically in dual-pol VV+VH) to support in particular GMES-Copernicus Africa activities, EC Copernicus Projects, as well as TIGER follow-on activities. The 12-day global land coverage in IW VV+VH now in routine operations is a key asset to support such activities. Increased revisit frequency or complementary observations in the other geometry (ascending or descending) has been implemented to support the needs of the H2020 Project TWIGA, targeted to some African countries / areas (Kenya, Uganda, Ghana, South Africa, Lake Kivu).

- Systematic observations in IW VV+VH or EW VV+VH of "super-sites" for current / wave monitoring, including the Gulf of Maine, key areas along the US West coast and the waters around Hawai.

- Additional areas outside European waters have been identified by EMSA to be covered in NRT or possibly QRT, and include: La Reunion, French Guiana and West Indies, Greenland waters (middle east & west and southern waters), Kerguelen, Newfoundland, New Caledonia, Sao Tome e Principe, areas near Antarctica, Gulf of Guinea, ad-hoc areas in the Atlantic, Caspian Sea. Availability of related data in QRT (potentially using EDRS if feasible) was assessed and could be considered on "best effort" (QRT data provision from core ground segment is not formally part of the Sentinel-1 operations baseline).

- Specific Sentinel-1 observations were planned to support the following campaigns, limited in time, that took place between the release of version 3 of the Sentinel HLOP in July 2019 and the current version 3.1 of the document:
  - MOSAiC experiment: largest polar expedition in history, consisting in spending a year (from Nov 2019) drifting through the Arctic Ocean with the icebreaker Polarstern. The MOSAiC experiment was terminated in October 2020
  - EUREC4A campaign: International initiative in support of the World Climate Research Programme's Grand Science Challenge on Clouds, Circulation and Climate Sensitivity. EUREC4A took place between 20 January and 20 February 2020 with operations based out of Barbados.
  - Vendée Globe sailing race. The purpose was to perform a one-off mapping of relevant areas before the passage of the boats in the Southern Ocean, allowing to detect icebergs and therefore consolidate the exclusion zones. The main use of radar data is for safety purpose. Specific planning was

performed using both satellites between 11 November and 23 December 2020.

- AMAZOMIX: an international oceanographic measuring campaign of 30 days between 27 August and 29 September 2021, off the Amazon River mouth and continental shelf.
- S-MODE oceanography campaign, from 18 October to 8 November 2021. The main objective is to test the hypothesis that submesoscale (1-10 km) ocean dynamics make important contributions to vertical exchange in the upper ocean. The subject area near San Francisco was of very limited extent and already covered by existing passes, few additional passes were added to increase the revisit frequency.

Calibration – Validation activities

Aiming at the best achievable data quality of Sentinel-1 products, calibration and validation activities are routinely performed during the routine operations phase. These priority activities may locally and temporarily interfere the delivery of coverage in consistent mode-polarization combination. During mission ramp-up, the major regions affected by these activities were Northern Alpine Lowlands (Germany, Austria and Switzerland) and the narrow surroundings of Sao Paulo (Brazil), Houston and Chicago (USA). Limiting the consistency of static mode–polarization coverage and causing small observation gaps due to instrument switches, these activities bring the opportunity to explore the variety of the Sentinel-1 image modes to data users of the affected areas. During routine operations of the constellation, only the above sites located outside Europe are subject to specific acquisitions for cal-val purpose.

3.2 Production

The production scheme, gradually implemented during the ramp-up phase, is established in accordance with the production strategy as described in chapter 4.5.2 of the Sentinel HLOP.

The following processing approach is planned:

- NRT3h acquisition and processing timeliness has been gradually put in operations during the ramp up phase, in line with available operations resources

- The most demanding timeliness provided by the core ground segment is the 1h/3h-from-sensing requirement for generating level 1 GRD products for the CMEMS sea-ice monitoring services over Northern Europe waters. More stringent timeliness, not part of the MRD, in support of specific user needs (e.g. 10 min from sensing for e.g. EMSA or national maritime surveillance services) are implemented through collaborative local passive X-band stations and can also potentially be supported by the CSC ground segment by provision of Quasi-Real Time data stream (via e.g.

EDRS service and/or X-band core stations). This is however not part of the operations baseline and as far as EDRS QRT is concerned, is performed on best-effort basis. At the stage of Full Operations Capacity, most of Europe is covered in pass-through mode, allowing operational services (e.g. from EMSA or from national activities) to generate information products within minutes from sensing, with the acquisition of Sentinel-1 data by the respective collaborative stations.

- For all other areas of interest, systematic processing to level 1 GRD products for all data acquired is available within 24h from sensing (at the exception of SLC products, originally planned to be generated over regional areas of interest only – see below)

- Systematic generation of SLC products, relevant to InSAR applications, is provided at least over relevant tectonic areas and in Europe. Since July 2015, the generation of SLC products is systematically performed at global level for IW and has been subsequently performed for SM acquisitions as well (see more details in chapter 4.5.2).

- Provision of level 0 data, available in less than 1 day typically

- Gradual increase of systematic wave mode data processing into Level-2 products. Since July 2015, Wave Mode data are regularly acquired over open oceans and systematically processed to Level-2 OCN products. Sentinel-1 IW and EW Level-2 OCN products over regional ocean areas are also available to users. The implementation of the systematic generation and distribution of Sentinel-1 level-2 OCN products derived from IW, EW and SM modes over seas at global level has been completed on 15 November 2017 (relevant for the Wind component - OWI).

It should be noted that during the routine phase, the activities of operational user products quality verification, calibration and validation are pursued, aiming at ensuring delivery of fully calibrated and validated products for the routine operations.

4. Remarks

- SAR Polarisation

Over land, the same SAR polarisation scheme is systematically used over a given area, to guarantee data series in the same sensing conditions for routine operational services and to allow frequent InSAR. Depending on the area, the selection is either vertical or horizontal, the choice being made according to the main application behind. The reason for selecting the VV polarisation over land is explained in section 3.1 above. Conflicts may occur during winter season with snow monitoring activities (though these services are less developed) for which the horizontal polarisation is preferred. Over large ice sheets (Greenland and Antarctica) and polar areas, the HH polarisation is more suitable.

- SAR Mode

The default mode over land is the IW mode. Specific requirements (some of them part of national requirements and Copernicus projects) ask for the use of the SM mode over some particular areas (e.g. volcanoes or zones of special interest in Antarctica like the Peninsula or the other Antarctica ice shields) or even at global level (e.g. one mapping per year of all land areas in SM). It should be noted that while some exceptional campaigns may be performed in SM mode, the Sentinel-1 observation plan is established with the goal to ensure systematic and routine provision of data allowing operational services to run on a routine basis, with stable observation conditions. As a general principle, the use of the SM mode in the standard observation plan is limited to the specific cases where there is no other use in competition (e.g. a small volcanic island in the middle of an ocean, see section 3.1 above). Having reached full operational capacity, an increase in utilisation of the SM mode is not envisaged, except for very specific needs like the ones from Copernicus Security Services over land. Users will otherwise be invited to make use of data from other missions if a higher resolution than the one provided by the IWS mode is required.

5. Sentinel-1B

The Sentinel-1 mission relies on a 2-satellite constellation, which, together with the use of EDRS and a 4th core station, permits to reach the Full Operations Capacity (FOC). The availability of the 2-satellite constellation is a pre-requisite to remove the vast majority of remaining conflicts that arise with one satellite only, and to fulfil the necessary revisiting requirements of the key operational services. It also allows performing InSAR every 6 days over extended areas, resulting in great progress expected in the operational application, operational science and scientific domains in general.

The inclusion of Sentinel-1B was assessed in details to optimize the use of the 2-satellite constellation resources. Further consolidation activities have been conducted to optimize the exploitation of the full operations capacity. This additional capacity is largely used to increase the revisiting frequency and enlarge the worldwide areas regularly covered. Related benefits include (not exhaustive):

- The increase of revisiting frequency for the Copernicus Marine Environment Monitoring Service. The CMEMS requirement is to provide information maps on a daily coverage basis. Sentinel-1B allows increasing the revisiting frequency by a factor 2, w.r.t Sentinel-1A alone. For the lower latitudes areas, the 2-satellite constellation is still not be sufficient for achieving this daily mapping, as evidenced in the Sentinel-1 Mission Requirements Document [RD6]. Contribution from other SAR missions may therefore be still necessary

- The possibility, for critical areas, to perform interferometry every 6 days. This is implemented for Europe EEA-39, in both ascending and descending passes. This is particularly relevant for a number of applications, such as landslide monitoring. Another example is the monitoring of fast moving glaciers. In some cases the 12-day revisit is not short enough to get InSAR coherence between two acquisitions due to the speed of the glacier (other effects during winter for ice sheets are snowfall and redistribution of surface snow due to wind, causing temporal decorrelation).

- For an identified set of tectonic areas at global level, the revisiting has been increased with Sentinel-1B by a factor 2 as an extension of what was achieved with Sentinel-1A (see section 3.1 above), allowing performing InSAR every 12 days both in ascending and descending.

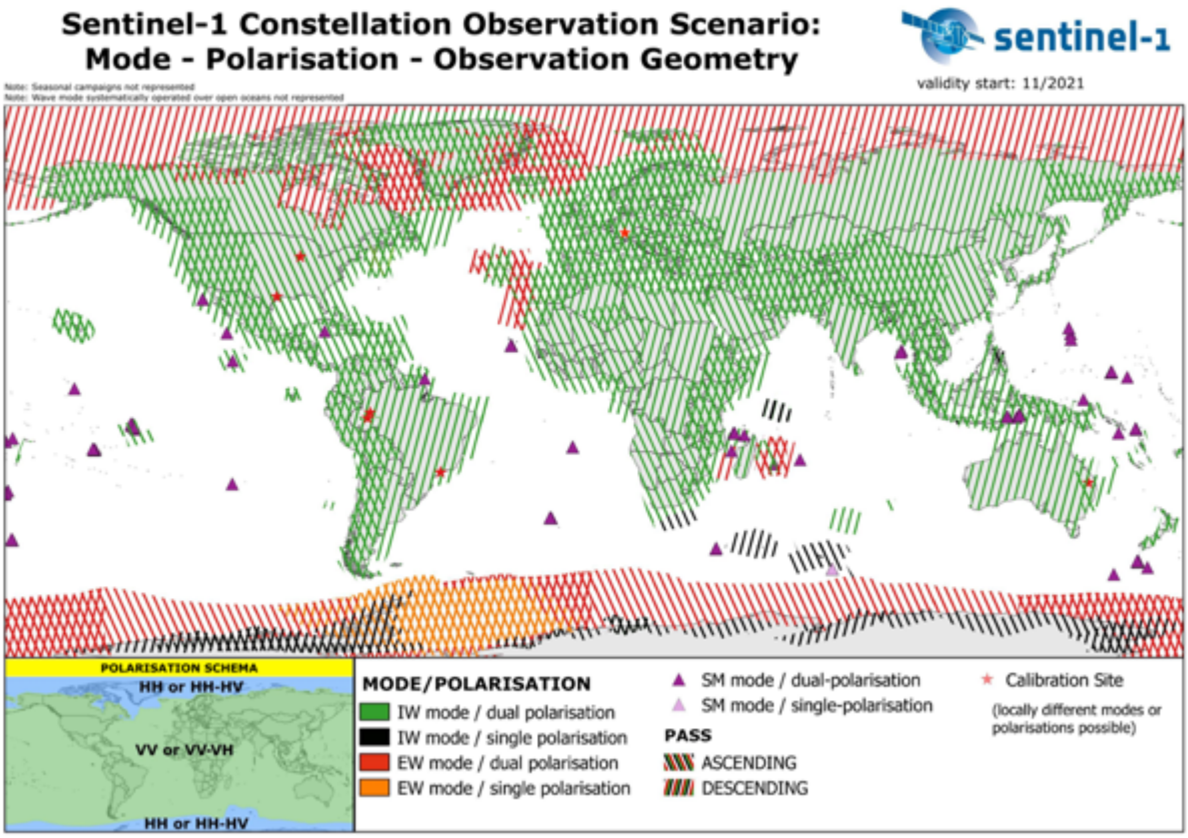
- Increase of global land mapping frequency, in particular in support activities of the Copernicus Global Land service, but also crop monitoring activities that requires short revisit time, e.g. rice monitoring in key areas worldwide (see earlier)

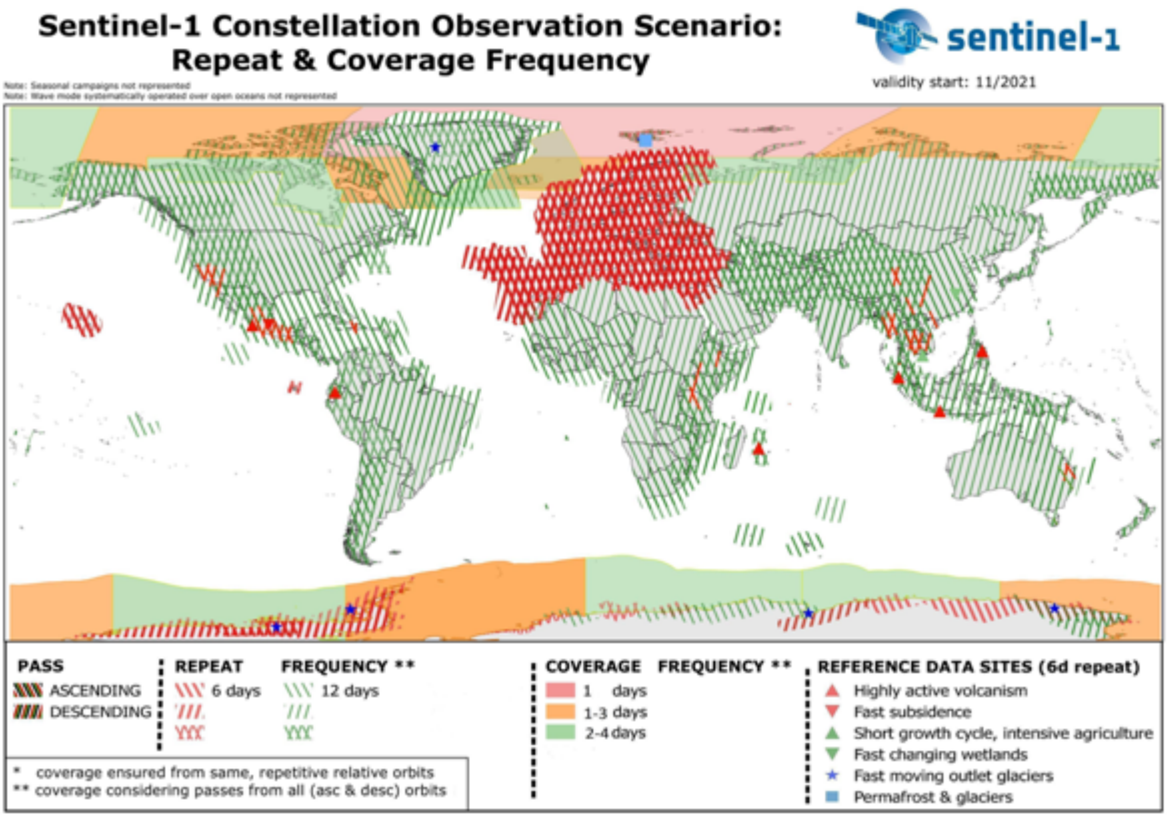
- Extension of regular coverage of some EEZs at continent level (e.g. Africa) and of EEZs from member states overseas territories.

6. Resulting detailed observation plan

The Sentinel-1 constellation observation scenario resulting from the above is published in the form of coverage maps, including modes, polarisation, ascending / descending passes, revisit and coverage frequency at: https://sentinels.copernicus.eu/web/sentinel/missions/sentinel-1/observation-scenario

An overview of the observation scenario is provided in the following two maps (status: starting November 2021).


Sentinel-1 Constellation Observation Scenario:
Mode - Polarisation - Observation Geometry
sentinel-1
validity start: 11/2021
Note: Seasonal campaigns not represented
Note: Wave mode systematically operated over open oceans not represented
POLARISATION SCHEMA
HH or HH-HV
VV or VV-VH
HH or HH-HV
MODE/POLARISATION
IW mode / dual polarisation
IW mode / single polarisation
EW mode / dual polarisation
EW mode / single polarisation
SM mode / dual-polarisation
SM mode / single-polarisation
PASS
ASCENDING
DESCENDING
Calibration Site
(locally different modes or polarisations possible)


Sentinel-1 Constellation Observation Scenario:
Repeat & Coverage Frequency
sentinel-1
validity start: 11/2021
Note: Seasonal campaigns not represented
Note: Wave mode systematically operated over open oceans not represented
PASS
ASCENDING
DESCENDING
REPEAT
6 days
FREQUENCY **
12 days
COVERAGE
FREQUENCY **
1 days
1-3 days
2-4 days
REFERENCE DATA SITES (6d repeat)
Highly active volcanism
Fast subsidence
Short growth cycle, intensive agriculture
Fast changing wetlands
Fast moving outlet glaciers
Permafrost & glaciers
* coverage ensured from same, repetitive relative orbits
** coverage considering passes from all (asc & desc) orbits

In addition, the detailed planned acquisitions segments including information of mode, polarisation, date, start and stop times, orbit number etc. for both Sentinel-1A and Sentinel-1B are published in the form of kml files at (see example below): https://sentinels.copernicus.eu/web/sentinel/missions/sentinel-1/observation-scenario/acquisition-segments

Appendix to Annex 1:

Overview of Sentinel-1 observation needs collection considered for the definition of the observation scenario

The following tables provide an overview of the various Sentinel-1 observation needs collected in the past and as part of the HLOP revision process, used for the consolidation of the observation scenario defined in Annex 1. Detailed additional information, not reported below, is available for some of them (shape files, period of the year, etc.). These needs are considered for the Sentinel-1A and Sentinel-1B routine operations, some of them can only be fulfilled during the Full Operations Capacity phase. This list has been included with the main purpose to provide full transparency to all stakeholders on the needs expressed by relevant use typologies.

The list includes a number of past projects (e.g. from FP7), their potential extensions or initiatives that have not necessarily provided observation needs but which are assumed to be served by Sentinel-1 observations.

Notes:

- The collection of observation needs is a continuous process, managed in close coordination with the Commission, and allowing capturing evolving user scenarios. Future revisions of the HLOP will include new observation needs as well as an historical view of observation needs collected in the past.

- some of the projects listed in the first column has been completed or are limited in time (e.g. FP7 projects, ESA GMES Service Element projects, etc.). They are intentionally kept in the list as reference for relevant Sentinel-1 observation needs and examples of Sentinel-1 based applications.

- in case of inconsistency between the user typologies definition and order reported in the tables below and the definition of the categories of source of requirements provided under chapter 8.2, the latter takes precedence.

OVER OCEANS & SEAS, SEA-ICE					
Source of requirements	**Indicative Geographic Area**	**Latency - Availability of (level 1) product**	**Mode / Polarisa-tion**	**Temporal coverage, revisit frequency**	**Comment**
Sea-ice and iceberg monitoring					
Copernicus services / projects and Copernicus use					
Copernicus Marine Environment Monitoring Service (CMEMS), MONARCH-A, SIDARUS Polar Ice SWARP	CMEMS: Sea-ice and iceberg monitoring in Baltic Sea, Eurartic Waters, Greenland waters (incl. South), Davis Strait, Labrador Sea, Baffin Bay, Antarctica (Southern Ocean)	1 hour to 3 hours, depending on the areas	EWS HHHV or IWS HHHV (iceberg)	Every Opportunity or Daily coverage, in some cases sample strategy. Seasonal acquisition scheme. Coverage around Antarctica at least 1 every 3 days	Single polarisation (HH) is acceptable for ice drift monitoring in the Arctic Ocean and Antarctica winter season. Seasonal variation of extent.
National services and use by ESA and EU Member States					
National requirements from Canada, Denmark, Estonia, Finland, France, Norway, Sweden, UK Consolidated needs provided by Canada in the frame of HLOP revision process 2017	Baltic Sea, Northwest Atlantic, Greenland waters, Faroe Islands waters, Barents Sea, Beaufort Sea, Mid-West Arctic, High Arctic, Davis Strait, Labrador Sea, Great Lakes, Baffin Bay, Hudson Strait, Eastern Canadian Coast, Kara Sea, North East Passage, Bering Strait, Gulf of St. Laurence, Antarctica (around Antarctica and between -45 and -55 deg. latitude in Southern Ocean)	1 hour to 3 hours, depending on the areas	EWS HHHV or IWS HHHV depending on coverage require-ment / areas	Every opportunity or daily coverage, in some cases sample strategy. Seasonal acquisition scheme. Coverage around Antarctica at least 1 every 3 days	Single polarisation (HH) is acceptable for ice drift monitoring in the Arctic Ocean and Antarctica winter season. Seasonal variation of extent.
Scientific use, on-going ESA projects, continuity of ERS/ENVISAT					

Polar View	Davis Strait, Labrador Sea, Baffin Bay, Eastern Canadian Coast	NRT	EWS HHHV or IWS HHHV (iceberg)	Every opportunity or daily coverage, in some cases sample strategy. Seasonal acquisition scheme. Coverage around Antarctica at least 1 every 3 days	
Science Requirement	Beaufort Sea and Arctic Waters	not NRT	EWS HHHV	Regular mapping at daily to weekly frequency	ESA Beaufort Sea, Envisat BRM
International Initiatives, International cooperation					
IICWG NOAA (US coordinated requirements)	NOAA requirements: Ice concentration, ice type, ice depth, ice motion, ice extent, All ice covered regions of world, including the Great Lakes	IICWG: no NRT NOAA: NRT	EWS or IWS or SM (SM not selected)	Daily to weekly	
PSTG SAR Coordination Group (& NOAA)	Polar floating ice (scientific use)	No NRT	EWS or IWS	3-day repeat coverage frequency ideally	
Other use including commercial use					
Polar View, Support to oil and gas industry	Barents Sea, Greenland Sea, South and West Greenland waters, Norwegian Sea, Beaufort Sea	NRT	EWS HHHV	Daily to weekly coverage	During relevant seasons only

Oil spill monitoring and polluter identification					
Copernicus services / projects and Copernicus use - EMSA					
EMSA, SeaU	Large coverage of European waters. Areas of interest extended outside European waters, incl: areas near Iceland, Canary Islands, Greenland (middle east & west and southern waters), Sao Tome and Principe, New Caledonia, Caspian Sea	10 min	EWS VVVH or HHHV - or IWS VVVH or HHHV	Frequent observations but not necessarily every opportunity (sampling concept)	CleanSeaNet station network (part of collaborative GS): Matera, Brest, Azores, Tromsö, Svalbard, Puertollano
National services and use by ESA and EU Member States					
National requirements from Denmark, Finland, France, Germany, Italy, Norway, Portugal, Romania, UK, Canada	National / European waters (incl. Back Sea), Atlantic NE Region, Greenland waters, Faroe Islands waters, Canadian waters (East Coast, Gulf of ISTOP), French overseas territories / dept.	10 to 60 min (depen-ding on areas)	EWS VVVH or HHHV - or IWS VVVH or HHHV	Frequent observations but not necessarily every opportunity (sampling concept)	Coordination with EMSA wherever relevant. Collaborative stations: Brest, Matera, Neustrelitz, Tromsoe/Svalbard, Kiruna (TBC), Sodankylä, Azores.
National requirements from Canada	Canadian Waters	60-120 min	EWS VVVH or HHHV - or IWS VVVH or HHHV	Every opportunity, all year	
Scientific use, on-going ESA projects, continuity of ERS/ENVISAT					
Science Requirement	Global shipping and drilling areas	Not NRT	EWS VVVH or HHHV	TBD	former Envisat SDS BRM
International Initiatives, International cooperation					

INPE, IBAMA (Brazil)	Brazilian Coast near Rio / Sao Paolo	Quasi-real time	TBD	Frequent observations but not necessarily every opportunity (sampling concept)	former Envisat SDS BRM
NOAA (US coordinated requirements)	EEZ US, Gulf of Mexico north of 25 deg. N, and occasionally other regions globally	Quasi-real time	IWS, EWS or SM (SM not selected)	Daily to 3-days	

Maritime surveillance, maritime security information services (incl. ship detection, illegal fisheries monitoring)

Copernicus services / projects and Copernicus use + EMSA and EU bodies					
EMSA, SeaU, DOLPHIN, NEREIDS SAGRES LOBOS	Large coverage of European waters	10 min	EWS VVVH or HHHV, or IWS VVVH or HHHV	Frequent observations but not necessarily every opportunity (sampling concept)	CleanSeaNet station network (part of collGS): Matera, Brest, Azores, Tromsö, Svalbard, Puertollano
EMSA	East African Coast (Somalia Coast, Gulf of Aden, etc.), La Reunion, French Guiana and West Indies, Greenland, Kerguelen, Newfoundland, New Caledonia, Sao Tome e Principe, Antarctica, Gulf of Guinea, ad-hoc areas in the Atlantic.	60 min, NRT3h, or QRT	EWS VVVH or HHHV, or IWS VVVH or HHHV	Frequent observations but not necessarily every opportunity (sampling concept)	EDRS could be used in QRT for relevant areas, on best effort basis.

National services and use by ESA and EU Member States					
National requirements from Denmark, Finland, France, Germany, Italy, Norway, Portugal, Romania, UK, Canada	Atlantic Approaches (Biscay, UK & Ireland), European waters (up to 1000 NM from national coasts), Mediterranean Sea, Black Sea, Greenland waters, Faroe Islands waters, French overseas territories / dept (Indian Ocean, Northern part of South American Coast), Eastern and Western African coasts.	10 to 30 min	EWS VVVH or HHHV, or IWS	Very frequent observations, sampling strategy	Potential collaborative stations: Brest, Matera, Neustrelitz, Tromsoe/ Svalbard, Kiruna (TBC), Sodankylä, Azores, Use of EDRS outside Europe in QRT if feasible, on best effort basis
National requirements from Finland, France, Germany, Italy, Norway, Spain, UK, Canada	Activities with international partners and/or outside Europe & National territories: East and West African coastal areas, NE-passage / Siberia, North Polar Ocean/ NW-passage, Canadian waters, Caribbean, Antarctic Peninsula polar ocean, western coasts of South America	10 min to 3 hours	EWS VVVH or HHHV – or IWS VVVH or HHHV depending on the areas	Very frequent observations, sampling strategy	
Monitoring and protection of UK Overseas Territories. Request from the UK Centre for Environment, Fisheries, and Aquaculture Science (CEFAS). Needs provided in the frame of HLOP revision process 2017	Extended water areas around various UK Overseas Territories, including: Ascension, St. Helena, Tristan de Cunha, BIOT (British Indian Ocean Territory), South Georgia, Pitcain, BAT (British Antarctic Territory)	Few hours from sensing	IW	Depending on area and seasonal needs	Specified areas are very large and require careful analysis, as potentially affecting the S1 observation plan already in place.

Maritime surveillance over France Overseas Territories, for the "Direction des Affaires Maritimes" (DAM) and the "Marine Nationale"). Needs provided in the frame of HLOP revision process 2017	Extended water areas around various France Overseas Territories, including: Kerguelen, Crozet, St Paul et Amsterdam, Clipperton, Guyane, Iles Eparses, Mayotte, Geyser, Juan de Nova, Bassas da India, Tromelin, Glorieuse, Europa, Reunion, Marquises, Nouvelle Caledonie, Antilles.	Few hours from sensing	IW, EW, SM depending on areas	Depending on area and seasonal needs	
(Scientific use,) on-going ESA projects, continuity of ERS/ENVISAT					
MARISS	Mediterranean, North Sea, Baltic Sea, Open Atlantic, Portugal, Black Sea, Canaries/West Africa, Red Sea, East Africa, Caribbean	10 to 60 min	IWS HHHV or VVVH	Very frequent observations, sampling strategy	
International Initiatives, International cooperation					
NOAA (US coordinated requirements)	Approaches to major U.S. ports, major fishing grounds, U.S./Russia Maritime Border in Bering Sea, south of western Aleutian islands (illegal drift nets), Northwest Hawaiian Islands. Secondary - North Atlantic and Pacific	Quasi to near real time	SM (not selected), IWS	Hourly to 3 days	

Sub-Regional Fisheries Commission (SRFC), inter-governmental fisheries cooperation organization including: Cabo Verde, The Gambia, Guinea, Guinea-Bissau, Mauritania, Senegal and Sierra Leone. Activity: illegal fisheries monitoring.	At least all EEZs of involved countries, extended towards west of Guinea, Guinea-Bissau, The Gambia, Senegal and Sierra Leone	TBD, could be NRT if the service materialises	IW VV+VH is most suitable to avoid mode switch / data gap vs. land observation	Regular coverage	
Indian Ocean Commission (IOC) – Maritime surveillance	Specific maritime areas of interest from IOC members: Comoros, France/La Réunion, Madagascar, Mauritius, Seychelles	Few hours from sensing	IW or EW VV+VH is most suitable	Regular coverage	
CSIRO (Australia) Aquatic Remote Sensing team CSIRO Oceans and Atmosphere Flagship	All EEZs of Australia	No specific need	Not specified, but IW VV+VH is the appropriate mode to be extended from land to surrounding seas (EEZ)	Regular coverage	Specified areas (all Australian EEZ) are very large and cannot be implemented as requested. Australian EEZ in the north of Australia are covered by the plan.

Sea-state monitoring (wind, wave, current)					
Copernicus services / projects and Copernicus use					
Copernicus Marine Environment Monitoring Service (CMEMS) MyWave SWARP	Use of Ocean Product (for Wave information)	Global and regional scale, few hours from sensing	WM, EWS, IWS (OCN product)	Where OCN product is available	Start of use of Wave data by CMEMS in Q4 2017
National services and use by ESA and EU Member States					
National requirements from Denmark, France, Germany, Portugal, UK	North and Baltic Seas, large coverage of European waters (all free of ice), Greenland waters, Faroe Islands waters	10 min to 3 hours	EWS VVVH or IWS VVVH	If possible every opportunity, all year	Note: quasi-real time requirements assumed to be implement-ted by collabora-tive GS or by QRT from core stations
National requirements from Canada	Canadian East and West coasts, Hudson Bay, Great Lakes, Northern Lakes and Southern Lakes	60 min	EWS VVVH or HHHV	Acquisition window according to AOI	
National requirements from France	All coastal waters worldwide, Supersites (Gulf Stream and Aghulas currents), Malakka Strait	3 hours	EWS VV	Routinely operated	
Scientific use, on-going ESA projects, continuity of ERS/ENVISAT					
Science Requirement	Global Open Ocean monitoring (incl. Sea State ECV)	not NRT	Wave mode and possibly high rate modes	Routine observations	
International Initiatives, International cooperation					

NOAA (US coordinated requirements)	All ocean products from ESA - Global Ocean, especially US EEZ, North Atlantic, entire Pacific, and global coastal. Top Priority: Gulf of Alaska, Gulf of Maine, Northwest US, Bering Sea, Tropical cyclone areas. Second Priority: The rest of the US EEZ, extra tropical cyclone areas, North Atlantic and Pacific	Quasi or near real time	Wave mode and high rate modes	Hourly to 3 days	

OVER LAND					
Source of requirements	**Indicative Geographic Area**	**Latency - Availability of (level 1) product**	**Mode / Polarisa-tion**	**Temporal coverage, revisit frequency**	**Comment**
Glacier, Snow and Permafrost monitoring					

Copernicus services / projects and Copernicus use					
CRYOLAND	Snow monitoring and Land ice monitoring. First phase: regions in Europe; e.g. Scandinavia and the Alps, Pyrenees, (including foothills)	12 hours for NRT service	IWS (preferably SLC products)	Frequent coverage during melting period (Mar to Aug for the Alps)	Ascending & descending passes
National services and use by ESA and EU Member States					
National requirements from Austria, Finland, Germany, Italy, Norway, Romania	Snow monitoring: Central/Eastern Europe, Alpine Arc, Northern Europe / Scandinavia, Baltic Sea (drainage)	3 hours	IWS HHHV (VVVH selected over land)	Frequent coverage during snow season	Ascending & descending passes
National requirements from Finland and UK	Snow cover: Northern Hemisphere and Global (Finland requirement)	NRT (Northern Hemisphere), not NRT (global)	EWS VVVH	Daily (Northern Hemisphere), weekly (global)	
National requirements from Norway and Canada New needs provided by Norway in the frame of HLOP revision process 2017	Glaciology: Svalbard glaciers, about 10 northern latitude glaciers (Canada) New need from Norway: provide an additional pass in IW to cover Svalbard in descending as well	Not NRT	IWS HHHV or HH (Svalbard) SM HHHV (IW used instead of SM)	Frequent coverage (Svalbard) (new need: Every 6-day constellation cycle) Once a year (Canada)	
Scientific use, on-going ESA projects, continuity of ERS/ENVISAT					

Polar View	Snow monitoring: Central Europe, Alpine Arc, Scandinavia, Baltic Sea area	NRT or not NRT depending on area	IWS HH TBC	Frequent coverage during snow season	
Science Requirement (climate change monitoring)	Global Glacier Areas	not NRT	IWS HH or SM HH	Typically twice a year	
Glob-Permafrost	Global permafrost monitoring	Not NRT	IWS or EW	Regular monitoring	See PSTG below

International Initiatives, International cooperation					
NOAA (US coordinated requirements)	Snow cover, depth, state: Global Land, priority for North America	NRT	EWS or IWS	3 to 120 h	
PSTG SAR Coordination Group	Permafrost monitoring.	not NRT	EWS or IWS	Regular coverage	At least one complete Sentinel-1 IW VV-VH coverage of global permafrost zone during relevant season + 2-3 local subsequent acquisitions over a total of 5+ cold spots

Ice sheets / shelves monitoring					
Copernicus services / projects and Copernicus use					
MONARCH-A CRYOLAND	Antarctica Ice Sheet, Greenland Ice Sheet	not NRT	IWS HH TBC	TBD	
National services and use by ESA and EU Member States					
National requirements from Denmark, Germany, Norway, Italy, UK	Antarctica Ice Sheet, Greenland Ice Sheet, Greenland & Antarctica outland glaciers / coastline	not NRT	IWS HH	Full and regular coverage	Observation scenario: see PSTG below
Scientific use, on-going ESA projects, continuity of ERS/ENVISAT					
CCI	Antarctica Ice Sheet, Greenland Ice Sheet	not NRT	IWS HH	Antarctica 1coverage/ year at least, Tentatively monthly coverage for Greenland	
International Initiatives, International cooperation					

PSTG SAR Coordination Group	Antarctica Ice Sheet, Greenland Ice Sheet, Svalbard	not NRT	IWS HH, SM HH	Full and regular coverage to be coordinated with other SAR National and international missions.	Observation strategy agreed with PSTG: Greenland: 1 campaign once a year with 4 to 6 passes at 6 days, plus 6 tracks systematically covering every 6-days the Greenland margins. Antarctica ice sheet margins: 1 coverage per year with 4 to 6 passes at 6 days. Areas of special interest in Antarctic: systematic coverage every 6 days Antarctica interior: 1 campaign every 3-4 years in cooperation with other SAR missions

River and Lake Ice monitoring					
National services and use by ESA and EU Member States					
National requirements Canada Consolidated needs provided by Canada in the frame of HLOP revision process 2017	Lake ice monitoring: hundreds of inland lakes across entire Canadian landmass and northern continental US and Alaska. Nunavik lake. Eastern / Western Canada River ice monitoring	NRT or not NRT depending on areas NRT (Nunavik) NRT	IWS HHHV, EWS HHHV. SM HHHV (Nunavik) (SM not selected) IWS HHHV	Weekly, from October to July. 2-3 times per week	
International Initiatives, International cooperation					
NOAA (US coordinated requirements)	Northern North America rivers (especially Yellowstone River and Alaska rivers), especially in spring.	NRT	EW, IWS or SM (SM not selected)	Daily	
Crisis Mapping, Emergency Support, GeoHazards, Terrain motion monitoring (subsidence, landslides), tropical cyclones monitoring					
Copernicus services / projects and Copernicus use					
Copernicus EMS, (incl. former SAFER) EFAS RASOR	Flooding: Europe Floodplains, Global Floodplain Background monitoring	NRT	IWS HH (VV actually used over land)	Every cycle in Europe, twice / year outside Europe	
Copernicus EMS, (incl. former SAFER)	Asset mapping: West Romania, West Central Bulgaria, North Central Bulgaria, North East Spain, South East France	not NRT	IWS VV or HH	Twice a year per area	ERSS_20- Assets mapping service Europe

Copernicus EMS (incl. former SAFER), DORIS, SubCoast RASOR PanGeo LAMPRE SENSUM INCREO MARSITE	Terrain motion in Europe and worldwide (based on relevant map of risks)	not NRT	IWS VV or HH	Frequent observations. Background mapping for global observations	Ascending / Descending
National services and use by ESA and EU Member States					
National requirements from Czech Republic, Italy, Germany, Greece, France, Norway, Romania, UK, Canada	Terrain motion: Italy, Germany, Mediterranean Sea relevant islands, Iceland, selected cities, South East Europe, Balkan and Middle East. Hotspot areas for natural hazards worldwide with special focus on Africa (esp. Western and Southern Africa), Indonesia, Chile, Bangladesh and Central America	NRT or not NRT depending on areas	IWS VV or HH	Max. revisit, every opportunity	Ascending & Descending, no land/sea discontinuities.
National requirements from Czech Republic, Germany, UK, Canada	Flood mapping in cities and at European continental level. Global flood mapping.	NRT	IWS HH (VV actually used over land)	Frequent observations	
National requirements from Greece, Italy	Fire monitoring, burn scar mapping at national / regional level in Europe	NRT or not NRT depending on application	IWS	Frequent observations	

Tropical cyclone monitoring over seas and oceans Request from France (Ifremer, Meteo-France, CLS).	Objective is to track relevant tropical cyclones in all ocean basins	Requirement: Sentinel-1 observation data and the cyclonic winds derived from it should be produced and made available in real time in an operational and sustainable manner	EW VV+VH in priority, IW VV+VH suitable as well	Period is all the year but different for each ocean basin. Systematic acquisition of S1 during cyclone periods: to be planned according to cyclone movement forecasts.	Acquisitions are performed on-demand In the current status of these operational activities, the agreed number of specific planning actions to support tropical cyclone observations over seas/ oceans is 4 per months
Scientific use, on-going ESA projects, continuity of ERS/ENVISAT					
Science Requirement	Global Subsidence background monitoring, focus on large urban areas	not NRT	IWS HH	Monthly, yearly	Details TBD
RESPOND	Africa, Latin America, South-East and Central Asia, Middle East	normal	TBD (IWS assumed)	Yearly	EGSE_036-Thematic mapping Medium Scale
Terrafirma	*Covered by national requirements*				
International Initiatives, International cooperation					
Former Cat 2 Envisat	East Asia: Flooding / Typhoon monitoring	NRT	Mode TBD, dual pol	During flooding / typhoon season	
Former Cat 2 Envisat	US East Coast, Caribbean, Gulf of Mexico (Miami station coverage): Hurricane monitoring	NRT	Mode TBD, dual pol	During hurricane season	

Geoscience Australia	Large area in south-east Australia to support InSAR applications	No specific need	IW VV+VH, i.e. the default mode / polarisation over land	Provide coverage in ascending geometry, in addition to existing descending observations	This request is quite demanding in terms of resources and cannot be accommodated as such. A subset of the area, located over mining areas and over Sydney area is supported (both asc & desc).

Tectonic Areas and Volcano Monitoring					
Copernicus services/ projects and Copernicus use					
EVOSS, Copernicus EMS (incl. former SAFER) APhoRISM FUTUREVOLC MEDSUV	Subset of volcanoes worldwide. EVOSS test sites: Jebel Zubair, El Hierro, Nabro, Grímsvötn, Eyjafjallajokull, Dalaffilla, Dabbahu, Erta'Ale, Manda Hararo, Ol'Doinyo Lengai, Jebel-al-Tair, Stromboli, Mt. Etna, Nyiragongo, Piton de la Fournaise, Karthala, Soufriere Hills, Nyamuragira.	NRT 1h or not NRT depending on volcano	IWS HH or VV	Every repeat cycle	Ascending and descending
National services and use by ESA and EU Member States					
National requirements from Italy, Germany, Greece, France, Norway, Romania, UK	Tectonic areas and volcanoes in Europe, South East Europe and Middle East - Global tectonic areas.	NRT or not NRT depending on areas	IWS VV or HH	Max. revisit, every opportunity	Ascending & Descending, no land/sea discontinue-ties.
Scientific use, on-going ESA projects, continuity of ERS/ENVISAT					
Science Requirement	Tectonic areas and volcanoes in Europe – Global tectonic areas and (subset of) worldwide volcanoes	Not NRT	IWS VV or HH	Every opportunity or every second cycle	Ascending & Descending
International Initiatives, International cooperation					
GEO Geohazard Supersites	Supersites worldwide: Los Angeles, Vancouver/Seattle, Hawaii, Istanbul, Tokyo-Mt Fuji, Mt Etna, Vesuvius, Haiti, Chile, Tohoku-oki, Wenchuan	Not NRT	SM (not selected) or IWS	Frequent revisit	Ascending and descending
Specific Copernicus Security Services (land), Critical Assets Monitoring, Illegal Mining					
Copernicus services and Copernicus use					

Former G-MOSAIC G-SEXTANT G-NEXT	G-Mosaic: Africa: DR Kongo (Kinshasa, Great Lakes Area, North and South Kivu province), Somalia, Chad, Sudan, Angola, Nigeria (Niger Delta), Algeria, Tanzania-Congo-Burundi borders Asia: Iraq, Kuwait, Odessa Port, Ukraina, Georgia, Baku-Tiflis-ceyhan pipeline Eastern Europe: Sofia region South America: Colombia (lower Magdlena river)	Not NRT	IWS HHHV or VVVH	3 times a year	SEC_002 – Crisis Indicators: Exploitation of natural resources. Note: these were test sites and should be reconsidered.
Copernicus security service	Specific targets in Africa and middle-east	Not NRT	SM VVVH	Repeat pass limited to a duration of few months	
National services and use by ESA and EU Member States					
TBD					
Forest monitoring, Agriculture monitoring, Crop Mapping					
Copernicus services / projects and Copernicus use					

Geoland-2 EUFODOS REDDAF ReCover REDD-FLAME REDDINESS ISAC Advanced_SAR IMAGINES ERMES North-State SEN3APP	Geoland-2: priority for Europe, potentially outside Europe, at global level. Focus on generally cloudy areas (Northern Europe, Equatorial regions for forest monitoring) Other EU projects related to REDD / Deforestation: focus on tropical and sub-tropical forests ISAC: agriculture and the agro-environment in Europe and Africa Advanced-SAR: Advanced Techniques for Forest Biomass and Biomass Change Mapping: test sites: Evo Finland and Remningstorp, Sweden IMAGINES: crop mapping demonstration. Test sites in Russia (Top left: 54.861° N, 35.900°E; Bottom right: 52.945°N, 38.952°E) and South Africa (Top left: 26.851°S, 24.548°E; Bottom right: 30.741°S, 29.770°E) ERMES: rice information service. 3 study areas in Europe (in Italy, Spain and Greece). Outside Europe: Gambia, South-East part of Senegal, to be extended to West Africa North State: Carbon and Water Balance Modelling of Northern Forest Ecosystems. 4 test sites: in Iceland, Finland (Sodankyla and Hyytiala) and Russia (Pechora-Llych) SEN3APP: Processing lines and operational services combining Sentinel and in situ data for Cryosphere terrestrial and boreal forest areas. S1 in complement of S2, in particular for cloudy regions	not NRT	IWS VVVH For Advanced_SAR project: SM with various sub-swath and narrow time window (in contradiction with S1 standard mapping based on IW mode) IMAGINES: SM VVVH (in contradiction with S1 standard mapping based on IW mode) ERMES: IW VVVH or HHHV North State: IW VVVH SEN3APP: IW SLC complete coverage of the northern hemisphere with IW SLC data	Regular coverage ERMES project: systematic every 12 days from beg. April to end Dec. IMAGINES: coverage every 2 weeks ERMES, North State projects: as frequent as possible SEN3APP: frequent coverage	
National services and use by ESA and EU Member States					

National requirement from Czech Republic, France, Germany, Italy, Norway, Romania, Spain, Switzerland, UK, Canada	Agriculture and forestry in Europe and Canada. Involvement in international partnership / projects at global level. Monitoring deforestation (special focus in South America).	not NRT	IWS VVVH or HHHV	Regular coverage, depending on growing season for agriculture / crop monitoring	
Scientific use, on-going ESA projects, continuity of ERS/ENVISAT					
GMFS	African territories involved in GMFS	not NRT	IWS VVVH or HHHV	Regular coverage, depending on season	
International Initiatives, International cooperation					
REDD, FCT, GFOI, GEOGLAM-SIGMA, IRRI	Tropical forest globally, UN REDD Participating Countries, potentially all forests worldwide GFOI sites: Vietnam, Ecuador, Colombia, Peru, Amazon, Tanzania, Lake Victoria region. GEOGLAM-SIGMA sites in Taiwan, Malaysia, Indonesia, Thailand, Philippines, Laos, China, Pakistan IRRI priority areas for rice monitoring in following countries: India (Tamil Nadu and Odisha states), Vietnam, Philippines, Thailand, Cambodia	not NRT	IWS VVVH or HHHV	4 coverage per year typically for forest. For rice monitoring: every 12-day repeat cycle 6-days for critical areas (e.g. Mekong Delta, Vietnam)	

Land Use, Hydrology, Soil Moisture					
Copernicus services and Copernicus use					
Geoland-2 HELM Copernicus Global Land	Land use in Europe – Copernicus Global Land: both Europe and Global components. Priority areas: 1- Europe, 2 – Africa, 3- rest of the world	No NRT – NRT for soil moisture/ hydrology in Europe)	Europe: IWS HH or VV (product GRD-HR) Global: IW HH or VV, MR (product GRD-MR)	Systematic / very high frequent coverage	Copernicus Global land component: (MR1_SAR_GLOBAL) assumes the service is provided by Sentinel-1 at low resolution (MR1: 30m/100m)) with a "daily composite": the mission design cannot technically cope with such coverage frequency, due to the orbit repeat cycle and onboard constraints. Proposal: 12-day at global level in IW VV+VH, 6 days over Europe EEA-39 in both asc and desc
National services and use by ESA and EU Member States					

National requirements from Austria, Czech Republic, France, Germany, Greece, Italy, Romania, UK, Canada New needs provided by Canada in the frame of HLOP revision process 2017	Land use and land cover changes at national and regional level, integrated water management, internal waters, etc. Regions in North Africa and Central Asia (for integrated water management). Sparsely vegetated regions (for soil moisture). Regional and global land areas (for soil moisture / hydrology). New needs from Canada related to land use, Hydrology, Soil moisture for areas in Canada (Central Mackenzie Valley, Northwest Territories, Oil sands region, Alberta), in Asia (Vietnam, Cambodia, Lao PDR, Thailand) and in Africa for flood monitoring (Caprivi strip, Namibia and Okavango Delta, Botswana)	Not NRT Potential-ly NRT	IWS HH or IWS HHHV	1 coverage during dry season for North Africa and Central Asia water management - Systematic / very frequent coverage for soil moisture / hydrology.	Coverage ensured as part of the global land regular mapping, at least every 12 days in IW VV+VH
Scientific use, on-going ESA projects, continuity of ERS/ENVISAT					
CCI Land Cover	Land use and land cover changes at global level	Not NRT	IWS VVVH	Regular global coverage, 12 days at least	
International Initiatives, International cooperation					
GEO, UN, EEA, etc.	Global land areas	Not NRT	SM (not selected) or IWS	One coverage / year	Details TBD
NOAA (US coordinated requirements)	Land topography, land cover, land use classes, burnt areas: Targeted Global, Coastal US, North America + US Territories Soil moisture / water surface: Global Land, North America, U.S. territories	NRT, not NRT depending on activities	IWS, SM (SM not selected)	3 to 120 h	

Cooperation with US SMAP mission	Support SMAP mission objectives with C-band radar data	Not NRT	IWS VV+VH	All passes (requirement)	The implementation of all S1A+S1B passes over the whole US is not technically possible. A 12-day repeat coverage (like for other global land areas outside Europe) is implemented, in ascending orbits with combined S1A + S1B acquisitions
H2020 Project TWIGA "Transforming Weather Water data into value-added Information services for sustainable Growth in Africa ", led by TU Delft, composed of 18 partners.	- Kenya + Uganda - Ghana - South Africa - Lake Kivu (West of Ruanda)	No specific need, i.e. Fast24h is sufficient	IW VV+VH, i.e. the default mode / polarisation over land	Provide 6-day repeat coverage in both ascending & descending geometry, over identified areas of the subject countries	

ANNEX 2

Sentinel-2 baseline observation scenario

Scope

The scope of this annex is to describe the Sentinel-2 baseline observation scenario as applicable at the date of issuing this document.

The Sentinel-2 observation scenario definition is based on the current best knowledge of the Sentinel-2 observation requirements (from Copernicus Services, Copernicus Participating States, ESA Member States, scientific community, etc.).

The scenario has been established progressively along the mission lifetime and on the basis of requirements collected according to the procedure described in Chapter 8.

Assumptions and constraints

The current observation scenario is based on the following assumptions and constraints:

- The availability of the Svalbard and Inuvik core ground stations plus the EDRS system (using EDRS-A geostationary satellite).
- A priority given to Copernicus Services, as well as to National services and use by Copernicus and GSC/CSC Participating States, and by relevant EU institutions, as stipulated in Chapter 6.

Sentinel-2 baseline observation scenario description

The Sentinel-2 observation scenario includes:

a) MSI nominal observations with 5-day revisit as requested by MRD [RD7];
b) MSI vicarious, sun-diffuser and dark observations for Cal/Val purposes as requested by Sentinel-2 Mission Performance Centre (MPC).
c) Additional MSI nominal observations following Copernicus Services, Copernicus Participating States and ESA Member States requests.

Beyond MRD baseline, the additional MSI nominal observations are listed in the following table (with changes with respect to HLOP version 3.0 underlined).

Observation Area	Requester and Application	Revisit for S2A	Revisit for S2B
Extended offshore coverage (e.g. Northern Sea, Gulf of Gascony).	Requested by CMEMS and EMSA for marine environment monitoring and maritime surveillance.	10 days	10 days
Coral reefs	Requested by ESA, GEO and other users for coral reef monitoring activities.	10 days	10 days
Antarctica	CMEMS (Copernicus Marine Environment Monitoring Service) for sea-ice monitoring.	Not acquired	Geographically selected tracks ensuring 10 days coverage [with SZA<85deg for a fraction of the Antarctic rim]
Baffin Bay	Requested by CMEMS for sea-ice monitoring.	10 days	10 days
Pacific Islands	Requested by Germany and UK for climate change studies.	10 days	10 days
France and UK overseas territories offshore	Requested by France and UK being their territories.	Not acquired	10 days
Arctic Seas (Beaufort Sea and Fram Strait)	Requested by CMEMS for sea-ice monitoring.	Not acquired	10 days
Bouvet Island	Requested by Norway being a Norwegian territory.	10 days	10 days
Europe and Greenland in low-illumination conditions	Requested by Sweden, Norway and CMEMS for extended observations around winter solstice over northern Europe, Artic Seas and Greenland.	10 days [with SZA<85deg]	10 days [with SZA<85deg]
Sargasso Sea	Requested by France for prediction, early warning and detection of sargassum seaweed standings.	10 days	10 days
Rest of land surfaces (including small islands and atolls)	Requested by several users (e.g. GEO, Geoscience Australia) for applications such climate change study.	10 days	10 days

The following map (Figure 3) illustrates the Sentinel-2 baseline observation scenario including all MSI nominal observations, which correspond to the observations distributed to users.

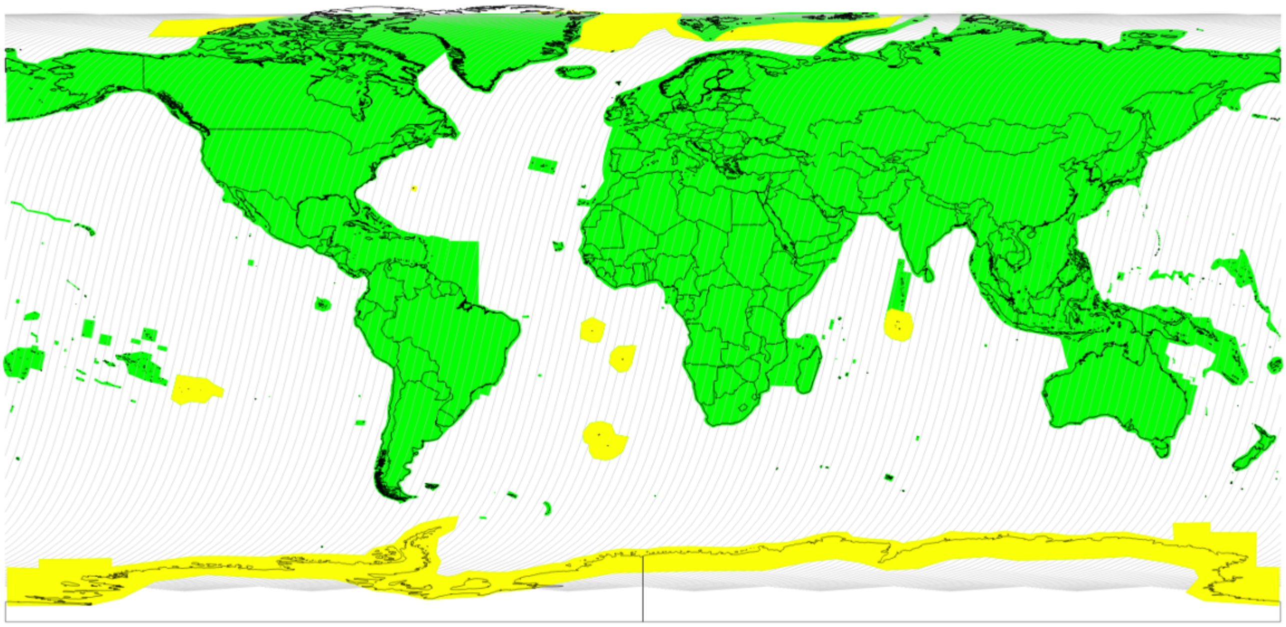


Figure 3 - Sentinel-2 mission observation scenario for MSI nominal observations. Green areas are covered with 5-day revisit, while yellow areas with 10-day revisit.

The following map (Figure 4) illustrates the regions acquired in low-illumination conditions, i.e. with a Sun Zenith Angle (SZA) up to 85 degree.

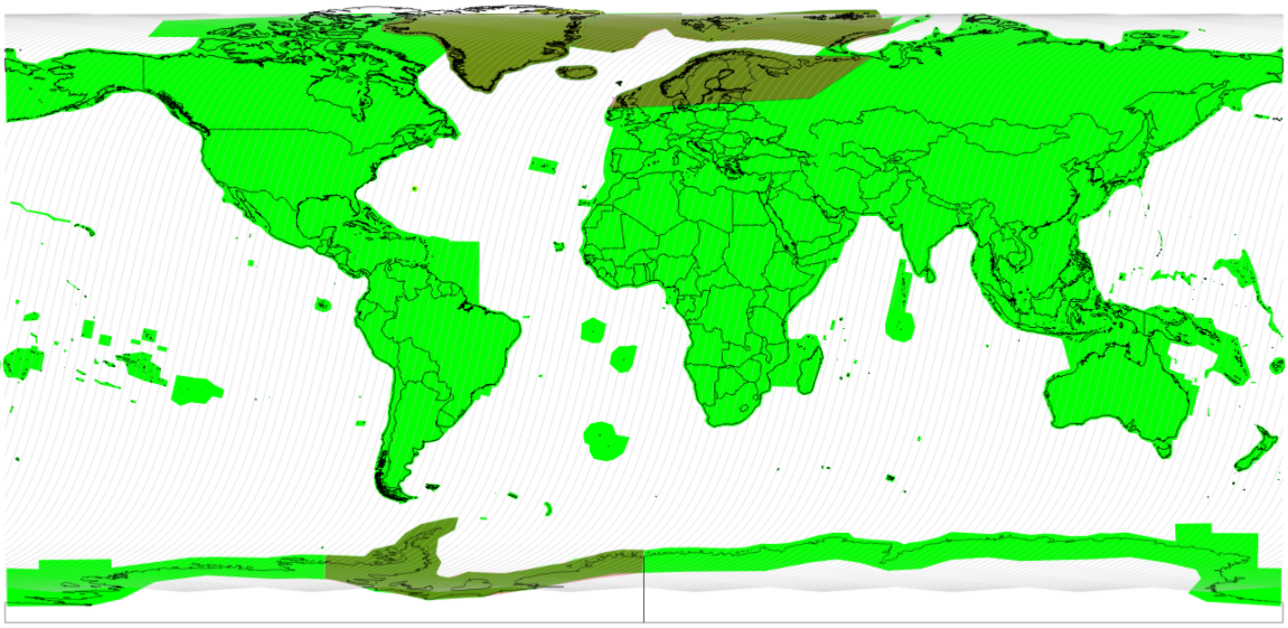


Figure 4 - Sentinel-2 mission observations with areas acquired in low-illumination conditions marked in dark green (Northern Europe, Greenland, Artic Seas and Antarctica ring fraction).

The detailed planned acquisitions segments per cycle are published in the form of kml files at: https://sentinels.copernicus.eu/web/sentinel/missions/sentinel-2/acquisition-plans

Finally, it is noted that the following observation requirements, received as part of the last HLOP revision process, could not be supported in this version of the HLOP:

- coverage of volcanoes at night (requested by Germany),
- extended offshore coverage in Africa (requested by EMSA),
- extended offshore Pacific Ocean coverage (requested by GEO) and
- coverage of northern Europe coverage in ascending orbits.

The requests above are at this stage rejected either because they are not compliant with certain system constraints, because they need more exhaustive feasibility checks, or because they require additional mission system resources. Would the context evolve, some of the requests above might be implemented operationally without necessarily waiting for the next version of the HLOP document.