Prepared by ESA
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Information Document

STATUS OF THE CURRENT AND FUTURE ESA EARTH OBSERVATION MISSIONS AND PROGRAMMES

CGMS is informed of the current status of the European Space Agency Earth Observation missions **currently** in-orbit. Three of them, MSG, MTG and MetOp are in co-operation with EUMETSAT.

The first new generation of Meteosat, MTG-I1 has been launched successfully in December 2022, and the first image has been revealed in May 2023.

Copernicus represents the major continuing initiative of European efforts in Earth Observation. The first Copernicus dedicated satellite ("Sentinel-1A") was launched on 3 April 2014, followed by series of satellites until Sentinel-6 Michael Freilich on 21 November 2020; other Sentinels will follow in the coming years from the next generation of Sentinels and the sixth expansion missions in preparation. Sentinel operations continued nominally apart from the major Sentinel-1B anomaly that occurred on 23 December 2021 affecting the satellite power system and causing the end of the mission. Sentinel-1C will replace the mission with a launch planned for the end of 2023 at the earliest.

Sentinel missions are developed, launched and operated in partnership with the European Union and EUMETSAT. The Sentinel-4 and 5 instruments developed by ESA will fly respectively on the MTG-S and Metop-SG missions also developed by ESA in cooperation with EUMETSAT.

The Earth Explorer missions SMOS, CryoSat and Swarm currently in orbit are performing extremely well and the related data exploitation is based on continuous data of excellent quality. The three missions all feature strong elements of international collaboration and a growing synergy between them. The Earth Explorer Aeolus will conclude all nominal operations on 30 April 2023 to prepare a series of end-of-life activities. The positive impact of Aeolus on the weather forecast has been seen by multiple Numerical Weather Prediction centres world-wide, in particular by ECMWF. It will pave the way for a follow-on mission already planned in collaboration with EUMETSAT.

The Proba-V small satellite was launched on 7 May 2013. Its coarse resolution imager has together with Sentinel-3, continued the data acquisition of the Vegetation payload on-board SPOT-4 and 5, during the reporting period. However, from July 2020, owing to its orbital drift, Proba-V Vegetation instrument has ended its operations on 31 October 2021 as planned. The foreseen launch date of Proba-V Cubesat Companion (PV-CC) developed within the GSTP programme is end July-August 2023 as part of the Small Satellites Mission Service (SSMS) rideshare mission, on board Vega flight VV23.

CGMS is further informed of the current status of the **future** European Space Agency Earth Observation missions. The Living Planet Programme has three lines of implementation: Earth Explorersatellites, Earth Watch satellites plus services and applications demonstration.

Progress in the preparation of the forthcoming Explorer missions, EarthCARE, Biomass, FLEX, FORUM and Harmony is described. Harmony was formally selected for implementation as Earth Explorer10 (EE-10) in September 2022.

The science requirement consolidation (SciReC) studies are continuing for the four Earth Explorer 11 (EE11) candidate missions selected for Phase 0: CAIRT, Nitrosat, SEASTAR, and WIVERN. Iterative changes to the MATER (Mission Assumptions and Technical Requirements Document) have been prepared by ESA and discussed with the MAG for each mission.
A call for ideas was issued for Earth Explorer 12 (EE12) on 20 February 2023.

Activities related to Aeolus-2, Arctic Weather Satellite (AWS) in cooperation with EUMETSAT, TRUTHS, SCOUTs and ALTIUS are ongoing. Each of these missions are planned contribute routine, operationalmonitoring data to improve our understanding of the Earth system and climate change.

Looking to the future, the six Copernicus Expansion missions are currently in phase B2/C/D/E1, addressing EU policy and gaps in Copernicus user needs, and each expanding the current capabilities of the Copernicus space component: CHIME, CIMR, CO2M, CRISTAL, LSTM, and ROSE-L. The Sentinel development activities, including Copernicus Expansion missions and Next Generation missions, continued in line with Segment 4 of the Copernicus Space Component (CSC) Programme, the FutureEO Programme and the CSC Long Term Scenario. The industrial activities are progressing according to plan with system and instrument PDRs for CIMR, CHIME, LSTM and ROSE-L successfully completed.

CGMS is also informed of the status of the Earth Watch Programme element, Global Monitoring of Essential Climate Variables (also known as the ‘ESA Climate Change Initiative’ or CCI). The CCI has continued to progress very well since. In 2016, a second phase of the programme, CCI+, was approved by ESA member states which is allowing to study and monitor 23 essential climate variables (ECV) derived from satellite data, fulfilling GCOS objectives. Out of these 23 ECVs, 16 have been handed over to the Copernicus Climate Change Service (C3S) lead by ECMWF, for operational use. The implementation of CCI phase 2 is on-going, with the majority of extensions to existing ECV projects, and the associated funding, being placed. The new climate initiative, CLIMATE-SPACE, was presented and oversubscribed at the Ministerial Council 2022 (CM22).

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STATUS OF THE CURRENT AND FUTURE ESA EARTH OBSERVATION MISSIONS AND PROGRAMMES

1 INTRODUCTION

This paper provides information on the status of the current and future European Space Agency Earth Observation missions. ESA's EO Programme comprises a science and research element, which includes the Earth Explorer missions, and an Earth Watch element, which is designed to facilitate the delivery of Earth observationdata for use in operational services. Earth Watch includes the well-established meteorological missions developed in coordination with the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT). These missions (MSG,MTG, MetOp and MetOp-SG) are not dealt within this report.

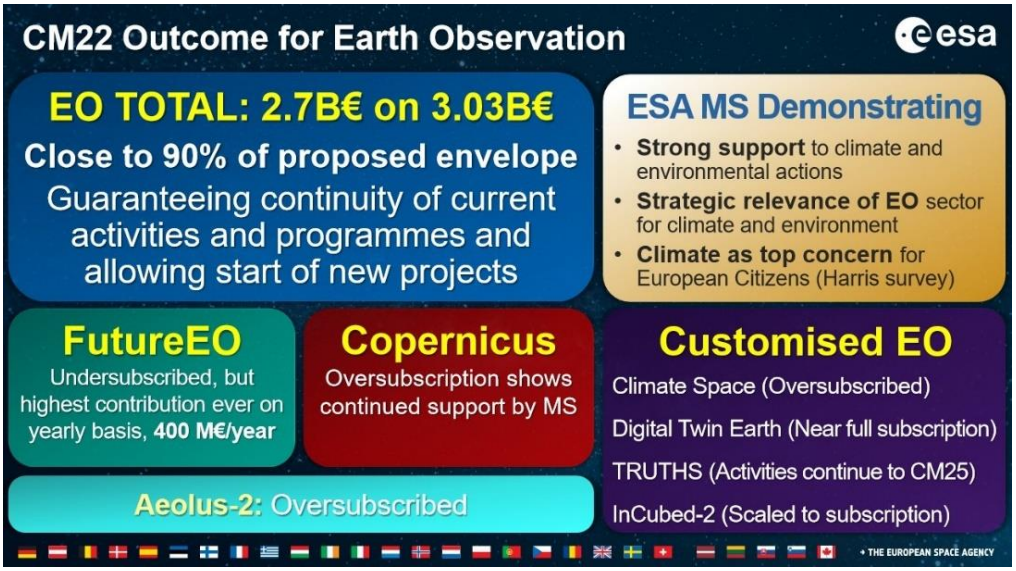
Current in-flight missions include four R&D satellites missions (6 satellites) from the Earth Explorer series, two small satellites of the Proba series, and seven Sentinel satellites. The status of future Earth Explorer and Earth Watch missions is presented,as well as the progress in the development of the ESA Climate Change Initiative (CCI).

Although the past ESA ERS-1, ERS-2, Envisat and GOCE missions are no longer operating, thousands of users still access the large ESA on-line archives to get products generated from their respective instrument complements.

2 ESA Council Meeting at Ministerial Level – 2022 (CM22)

ESA’s Ministerial Councils bring together ESA’s Member States and observers every three years to decide on new proposals and funding for ESA’s next years of work.

At the ESA Council at Ministerial level held in Paris on 22 and 23 November 2022, government ministers representing ESA’s Member States, Associate States and Cooperating States resolved to together strengthen Europe’s space ambitions, ensuring a continuous concerted effort to serve European citizens.



Responding to the proposals for the next three years, ministers confirmed that Europe's independent access to space is crucial to secure the benefits that space brings to life on Earth – including climate change monitoring and mitigation, and rapid and resilient responses to crises.

The delegations and the internal team at ESA highlighted the great success of the ESA Council meeting at ministerial level held in Paris on 22 and 23 November 2022 with Member States continuing to support investment in space programmes even under current difficult economic circumstances, notably due to inflation and the geo-political situation.

3 CURRENT ESA SATELLITE SYSTEMS

Satellites	Equator Crossing TimeAltitude	Launch date	Access to data or products	Instruments	Status, applications, and other information
Aeolus	97° 320 km	22/08/2018	Earthnet on line	ALADIN instrument (Atmospheric LaserDoppler Instrument)	Global observations of wind profiles from space to improve the quality of weather forecasts, and to advance our understanding of atmospheric dynamics and climate processes. **(end of operational activities 30/04/2023)**
PROBA-1	7:30 (D) 615 km	22/10/2001	Earthnet on line	CHRIS, SREM	The orbit is drifting from the original 10:30 desc. ECT.
SMOS (with CNES and CDTI)	06:00 (A) 755 km	2/11/2009	SMOS data centres	MIRAS (Microwave Imaging Radiometer using Aperture Synthesis), GPS, STA	L-band radiometer for salinity & soil moisture observation
PROBA-2	06:00 (A) 730 km	2/11/2009	Earthnet on line	SWAP, LYRA, TPMU, DSLP	2nd flight unit of the PROBA programme. Main mission: space weather
CryoSat-2	717 km (92° incl.)	8/04/2010	Earthnet on line	SIRAL (SAR Interferometric Radar Altimeter), DORIS, LRR	Polar ice monitoring
PROBA-V	10:30 (D) 820 km	5/07/2013	Earthnet on line	VEGETATION-P	2nd flight unit of the PROBA programme. Main mission: vegetation monitoring
Swarm A &C (with CNES and CSA)	87.35° 460 km	22/11/2013	Earthnet on line	ACC, SM, EFI (SWARM), GPS (ESA), LRR (DLR), STR (SWARM), VFM	Earth magnetic field
Swarm B	87.75° 530 km	22/11/2013	Earthnet on line		
Sentinel-1A (with EC)	06:00 (D) 693 km	03/04/2014	Copernicus Space component data access	SAR-C	Radar imagery
Sentinel-2A (with EC)	10:30 (D) 786 km	22/06/2015	Data available from centres of the Payload Data Ground Segment (PDGS). Real-time availability possible at appointedX-band stations.	MSI (Multispectralimager)	Land and vegetation observation
Sentinel-3A (with EC)	10:00 (D) 814.5 km	16/02/2016	Data available from centres of the Payload Data Ground Segment (PDGS). Real-time availability	DORIS, GPS, LRR, MWR, OLCI, SLSTR,SRAL	Primary mission: ocean observation. Secondary mission:atmosphere and land applications

			possible at appointedX-band stations.		

Satellites	Equator Crossing Time Altitude	Launch date	Access to data or products	Instruments	Status, applications, and other information
Sentinel-2B (with EC)	10:30 (D) 786 km	06/03/2017	Data available from centres of the Payload Data Ground Segment (PDGS). Real-time availability possible at appointedX-band stations.	MSI (Multispectralimager)	Land and vegetation observation
Sentinel-5P (with EC and NSO)	13:30 (D) 824 km	13/10/2017	Data available from centres of the Payload Data Ground Segment (PDGS). Real-time availability possible at appointed X-band stations.	TROPOMI	Atmospheric composition and airquality monitoring.
Sentinel-3B (with EC)	10:00 (D) 814.5 km	25/04/2018	Data available from centres of the Payload Data Ground Segment (PDGS). Real-time availability possible at appointed X-band stations.	DORIS, GPS, LRR, MWR, OLCI, SLSTR,SRAL	Primary mission: ocean observation. Secondary mission:atmosphere and land applications
Sentinel-6 Michael Freilich	non-Sun-synchronous orbit 1336 km	21 November 2020	Products are still not accessible to public during the ongoing commissioning phase	AMR-C, DORIS-NG, GNSS POD Receiver, GNSS-RO Receiver, LRA (Sentinel-6), Poseidon-4 Altimeter	Provides continuity of the reference, high-precision ocean topography service after Jason-3

4 STATUS OF CURRENT EARTH EXPLORER SATELLITES

Three ESA Earth Explorer missions are currently in operation, namely SMOS (launched in 2009), CryoSat-2 (launched in 2010) and the Swarm constellation of 3 satellites (launched in 2013). All three missions, as well as GOCE, have provided outstanding results of interest to the meteorological and climate research communities at large. The overall performance of the SMOS, CryoSat, Swarm missions remains excellent. Both ESA DOSTAG and PB-EO have endorsed the extension of the SMOS, CryoSat and Swarm missions until the end of 2025.

4.1 SMOS

Launched on 2 November 2009, SMOS is the second Earth Explorer Opportunity mission to be developed as part of ESA's Living Planet Programme. SMOS carries a novel microwave sensor to capture images of brightness temperature, from which information on soil moisture and ocean salinity is derived. The data acquired from the SMOS mission leads to better weather and extreme-event forecasting, and contribute to seasonal-climate forecasting.

4.1.1 Status of spacecraft

The platform is operated under CNES responsibility. No major anomalies or failureshave been identified since launch. There are no changes to the routine mission planning to be reported. A routine Orbit Correction Maneuver (OCM) was scheduled for Wednesday, 5 April 2023.The SMOS payload is operating nominally, except for some recurrent minor anomalies impacting the data availability. In total, all the anomalies in this period caused 29 min and 3 sec of on-board data losses and 59 min and 57 sec of on-board degraded data (0.07%), from 1 January 2023 to 1 April 2023.

MIRAS segment A1 reached its second expected temperature peak of 29.6 degrees at the end of the SMOS eclipse season in January 2023. This value is very similar to the one seen last season indicating a smaller degradation process. The temperature of the MIRAS on board computer also continues with an upward trend but still far from worrying limits.

The performance of the mission (i.e. 99.9%) is excellent and remains above the design specifications.

4.1.2 Performance and results

Performance:

Globally, 98.96% of the dumped passes have been acquired. The acquired data were successfully processed to 99.09% for all products Levels including near-real time (NRT) for the period between 15 December 2022 and 30 March 2023. The timeline of 165 minutes for the NRT products was meet in 97.36%.

SMOS - Earth Online (esa.int) https://earth.esa.int/eogateway/instruments/miras.

Data Access:

Since the opening of the ESA SMOS dissemination data service in March 2016, approximately 41.1 million products have been downloaded by more than 3550 active accounts (cumulative number of accesses), with an average of 42 new users per month in the last year, for a total volume of about 1820 TB (Figure 2.21-1) up to 28 February 2023.

Besides the ESA dissemination server and national data hubs, SMOS data can now also be accessed through the CREODIAS service (https://creodias.eu/).

Integration of SMOS products in the EuroDataCube is currently ongoing (https://eurodatacube.com/).

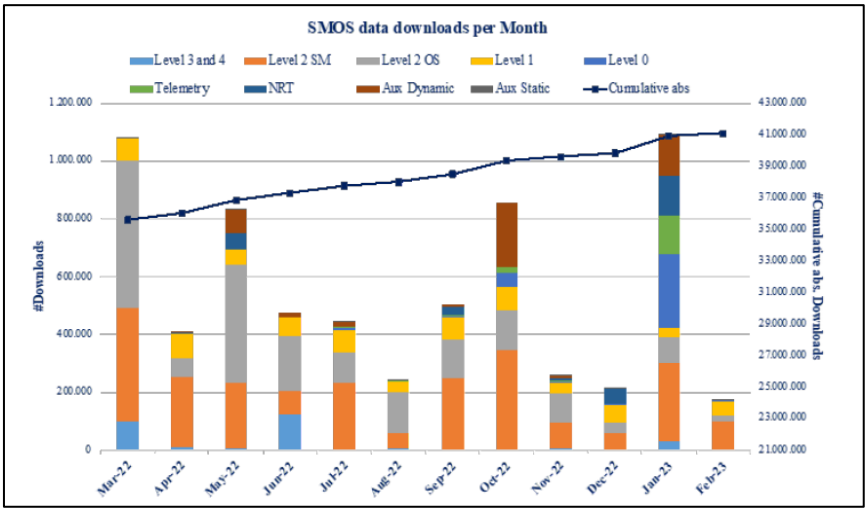


Figure 1: Performance of ESA SMOS data portal, which is operational since March 2016. Around 41.1 million products have been downloaded by more 3550 active accounts for a total volume of 1820TB.

The reprocessing Metric Campaign L1 v770 for the period 20 May 2016 to 30 June 2016 has been executed successfully in December 2022. The analysis of the dataset has shown some inconsistencies in the auxiliary file configuration that are now fixed in this quarter.

Radio Frequency Interference and Frequency Coordination:

Currently, there are 416 RFI (Radio Frequency Interference) sources worldwide active (status 28 February 2023), of which 36% are strong sources with brightness temperature (BT) between 1000 K and 5000 K, and 11% are very strong sources with brightness temperatures higher than 5000 K. The total number of RFI sources has decreased (-42) since the last quarter.

During the reporting period, formal contacts have been established via ANFR (French National Agency for Frequency issues who is acting on behalf of ESA), with the national authorities of Spain, Russian Federation, Serbia, China, Argentina, Uzbekistan, Mexico and South Soudan. Regular contacts have been made with the Argentine administration to update the status of interference in the country and confirm the shutdown of an RFI source by this administration.

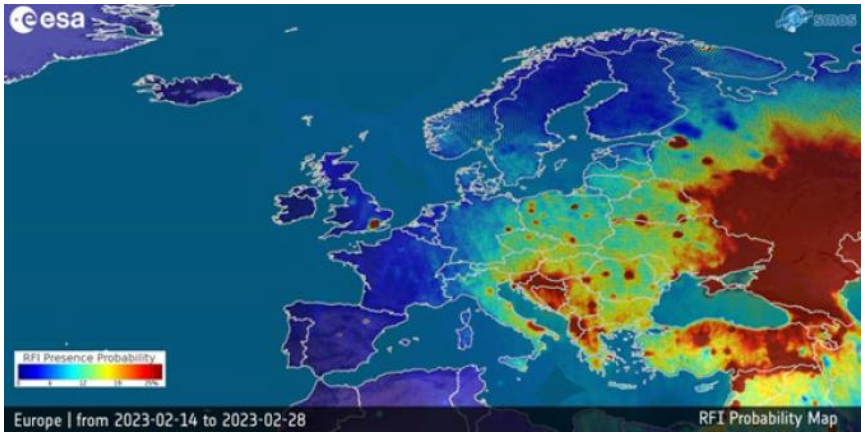


Figure 2: *Maps of Europe comparing the probability of SMOS persistent RFI occurrences in February 2023.*

(credits: SMOS RFI team at ESA ESAC)

SMOS Data Quality Evolution, Product Portfolio Evolution: **SMOS L1 and L2 Science data - Earth Online (esa.int)**

Level 1:

- Main outcomes from the last SMOS payload calibration meeting in March 2023 were:
    1. Further improvements in the definition of the antenna losses dependence with temperature
    2. Algorithms definition to mitigate the so called “bowl shape” in the Brightness Temperature image.
    3. Good stability of Brightness Temperature over different targets (Antartica icesheets and Oceans) and good agreement with SMAP measurements.
    4. Preliminary comparison between SMOS derived VTEC and SWARM VTECshows interesting results with differences explained by different sensor's pointing.
    5. SMOS derived Sun Brightness temperature provides good mitigation of Sun glint effect in sea surface salinity retrieval.

Level-2

Soil Moisture (SM)

- The next version (v730) of the L2 soil moisture processor delivery was delayed by few months, and it is now planned in Q2 2023. This version includes improvements in auxiliary data for land cover characterisation (ESA CCI 2015 Land Cover) and resolution of few software problem reports.
- Concerning algorithm evolution, activities are on-going to retrieve ground permittivity, snow parameters and to screen out frozen soil.
- The CCN for a special reprocessing with homogenous auxiliary data, such as ECMWF Reanalyses (overcoming the inherent operational constraints) has been

accepted. The kick-off of Phase-1 of the study (sensitivity analysis) is planned for Q2 2023.

Sea Surface Salinity (OS)

- A final set of analyses, methodologies, and metrics regarding the upcoming "BlindTest" 2023 exercise (to compare the novel DnB with the nominal algorithm) has been agreed at PM#49 in September 2022 and consolidated in the following months. The validation protocol overhaul will be performed in Q2 2023.
- The upcoming L2OS v730 processor, further delayed to Q2 2023, will focus on the DnB temporal correction and the nominal algorithm latitudinal/seasonal correction.

Sea ice thickness

- Real time production of the sea ice thickness product has been restarted as usual at mid of October. The ESL has continued to work on the validation of a similar product for the Antarctic region.
- A new version of the combined Cryosat-2/SMOS sea ice thickness products has been delivered as planned in Q1 2023 from the ESA dissemination service (New version of the SMOS-CryoSat level 4 sea ice thickness product is now available - Earth Online (esa.int))

Wind

- ESL has completed the work on refining the geophysical model function (GMF)based on Sentinel-1 dataset. Validation results are good and the new GMF will be implemented in the operational processor by the end of 2023.

Soil Freeze/Thaw

- Algorithm improvements have been validated. The operational processing chain at FMI is now under implementation. The new products will be available in Q2/2023.

Product portfolio evolution

- Nothing to report.

4.2 CryoSat-2

ESA's Earth Explorer CryoSat-2 mission, launched on 8 April 2010, is dedicated tothe precise monitoring of the changes in the thickness of marine ice floating in the polar oceans and variations in the thickness of the vast ice sheets that overlie Greenland and Antarctica.

4.2.1 Status of spacecraft and mission

Overall, the space segment performed nominally with no major issues.

- For the payload, no major issues to report. On 30 January 2023, 4 passes were lost, resulting in a loss of SIRAL science data of ~1 hour, due to a malfunction of the S-Band down converter at Kiruna ground station.

- For the platform, the propellant leakage rate is evolving in line with predictions. The latest estimation of fuel depletion is January 2025. The current plan foresees a switchover to the backup propulsion branch (RCS-B) in mid-November 2023 to extend the lifetime of the satellite until 2028. Six Orbit Control Manoeuvres (OCM) were executed during the reporting period to keep the satellite within the required ground track dead-band. The current high rate of manoeuvres is the result of the increased drag due to expansion of the atmosphere density approaching the peak of the 11-year solar cycle. At the time of the last minimum, 2018 to 2020, the annual average was 6 manoeuvres.
The overall performance of the CryoSat mission was in line with the previous reporting period. The performance of the mission (i.e. 98.64%) has been excellent and remains well above the design specifications. Since the start of the exploitation phase, the overall system availability has been 99.12%.

4.2.2 Performance and results

Ongoing efforts have been consistently made to enhance the stability, operability, and business continuity of the PDGS, with the aim of effectively supporting mission operations in the coming years. Specifically, plans are underway for deploying a new system architecture for data dissemination, which aligns with the ESA EOP Security Framework requirements. This is being executed simultaneously with the assessment and implementation of additional new security requirements.

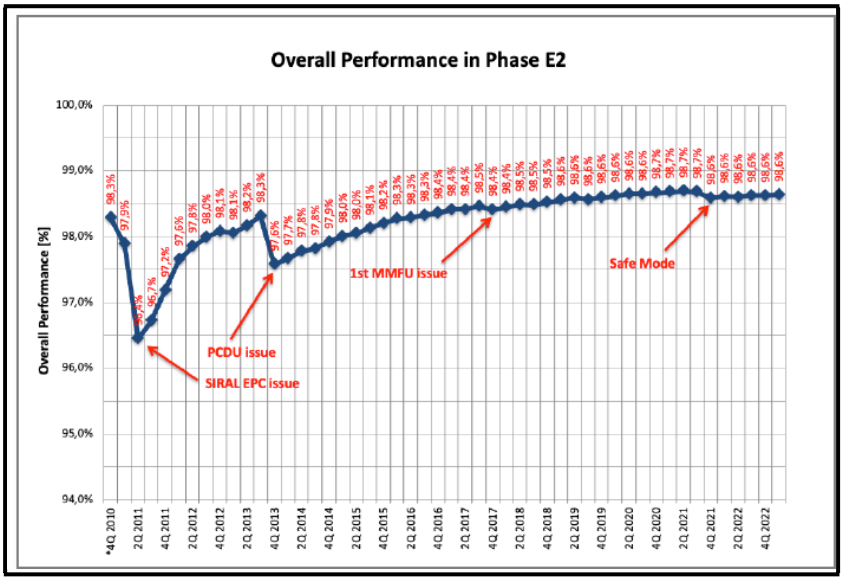


Figure 3: Historical Mission Performance in Phase E2

During the reporting period, the end-to-end mission performance, namely the overall mission data return that considers the planned (0.55%) and unplanned unavailability (0.13%) of the space and ground segments, was **99.32%**.

The CryoSat data availability page on the Earth web portal (https://earth.esa.int/web/guest/missions/cryosat/unavailability-periods) provides the entire of all the mission data gap since the start of the mission (CryoSat - Earth Online (esa.int)). This page is constantly updated, adding all the periods where the instrument is

unavailable.

Data Access:
Over the reporting period, an aggregate grand total of more than 42 TB of products were downloaded from the Science Server (CryoSat Data - Earth Online (esa.int)).

CryoSat-2 Data Quality Evolution, Product Portfolio Evolution:
The overall daily quality and operational control of the ice and ocean CryoSat products are carried by IDEAS+ (UK).
Detailed quality control of the L2 ice products was carried out by Mullard Space Science Laboratory (MSSL, UK). Reports are available on http://cryosat.mssl.ucl.ac.uk/qa/.

The Technical University of Delft (TUD, NL) carried out complementary quality control and long-term science validations of the L2 CryoSat Ocean products (COP) and CryoSat orbit solutions where the team currently tries to characterize the geographically correlated orbit error.
Long-term monitoring of the instrument performance is constantly carried out by ARESYS (IT) and periodically reported. During last quarter, no major issues were found. An analysis was carried out to measure the instrument Signal to Noise Ratio (SNR) from L1B ocean products. The analysis demonstrated that the SNR has not degraded significantly, and it is not a limiting factor for the CryoSat mission.

Product portfolio evolution
CRYO-TEMPO EOLIS (http://www.cryotempo-eolis.org): During the reporting period, the new EOLIS baseline-2 (V2) algorithm has been fully implemented and tested. A number of evolutions to the swath processing algorithm, EOLIS gridding and uncertainty determination improves the spatial coverage and quality of the EOLIS product V2 product is now live and back processing has started for all EOLIS regions.

CRYO-TEMPO: During the current reporting period, the new Phase 2.1 reprocessed and operational Baseline-B products were delivered to the ESA PDSservers. These products covered evolutions to the following Thematic Areas: LandIce, Sea Ice, Polar Ocean, Coastal Ocean and Inland Water. The updated version of the Evolutions Recommendation Report was also delivered to ESA. In parallel, Phase 2.2 work has now commenced, comprising the definition and implementation of the algorithm evolutions for Cryo-TEMPO cycle 3, which includes the new summer sea ice activity that will go into operation at the end of this year.
***Ocean Level-1 and Level-2 Baseline D*:** the one-year intermediate COP Baseline D TDS has been generated and CalVal activities have been completed. This TDS is currently being used to compute a new and more accurate SSB correction that will be used to generate a final 6-month TDS. This data will be shared with expert users for a thorough scientific assessment and results will be shown at the QWG meeting to be hosted by the University of Porto in September (planning has started). Transfer to operation is planned for the beginning of Q4 2023.

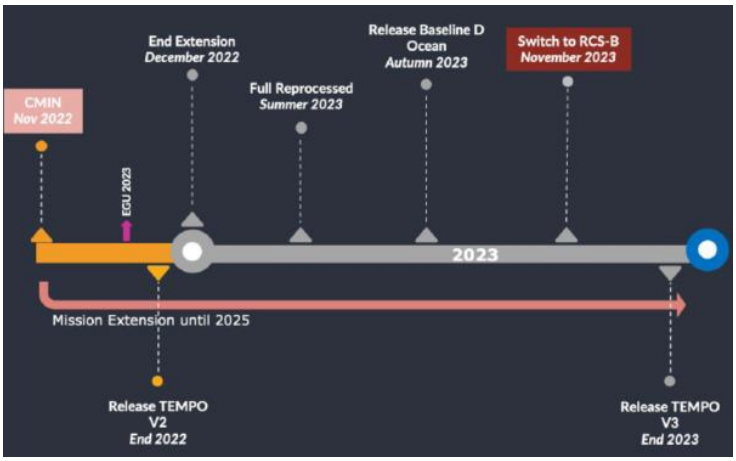


Figure 4: CryoSat-2 mission timeline.

4.3 SWARM

Swarm is the fourth Earth Explorer Opportunity Mission of ESA's Earth Observation Envelope Programme. This constellation of three satellites is designed to measure the magnetic signals that stem from Earth's core, mantle, crust, oceans, ionosphere, and magnetosphere.

4.3.1 Status of spacecraft

Overall, the three-spacecraft performed nominally during the reporting period.
For the platforms, the high trend of collision warnings continued in line with the previous quarters, with six escalated events in the first three months of the year.
A "double" collision warning involving Swarm-A and Swarm-C over two consecutive orbits was escalated by ESOC Space Debris Office on 4 January 2023. The chaser satellite, COSMOS-1544 (1984-027A) had multiple conjunctions with both Swarms over consecutive orbits, in two cases above the CAM threshold. Due to the risk, it was necessary to implement one CAM for Swarm-A and one for Swarm-C, both on 06/01/2023. This is the first time such manoeuvres are executed in each of the Swarm lower pair satellites due to a single object creating multiple conjunctions. The size of the manoeuvres was such that no return manoeuvre was necessary afterwards to tune the constellation separation.

The events continued with no additional CAMs being required, but four events being discussed. Two events were involving Swarm-A and TOMSAT R3 cubesat (2018-104A) on 17 January 2023 over two orbits, and two involving Swarm-B, on 6 March 2023 involving COSMOS-1300 (1981-082A) and on 25 March 2023 involving Flock-4x-39 (2022-002AX). In this last case, the CAM was avoided thanks to the efficient coordination between ESA's Space Debris Office and PLANET, who provided the chaser's operational ephemeris and informed about ongoing manoeuvres.

On 6 February 2023 the mass memory unit on Swarm-A was re-mapped in an attempt to solve a minor anomaly leading to detection of errors and seldom packet losses.

On 12 February 2023, due to a Single Event Upset on the Star Tracker unit, Swarm-A suffered a fallback to Coarse Pointing Mode: the anomaly implied the autonomous switch-off of all instruments, including STR, GPSR, VFM, ASM, ACC and EFI.

At the end of March, a first planning meeting about the Phase 2 of the Swarm-A and Swarm-C orbit raise campaign was held. Due to the effects of the Solar Cycle 25 on the drag and ultimately on the orbital decay during the first quarter, it was suggested and agreed to implement a series of manoeuvres to raise the orbits by ~27 km starting at the end of April.
For the payloads, The Swarm-B VFM instrument has suffered a bit locked in the PPS delta time field on 24 February: the uncompressed data sets of the magnetic field measurements were affected until the instrument was cured through power reset commanded by FOS on 3 March. The affected data has been corrected on ground by applying a mask. Apart from the above anomaly, all Vector Field Magnetometers (VFMs) as well as the Swarm Alpha and Bravo Absolute Scalar Magnetometers (ASMs) continue to perform extremely well, resulting in truly excellent magnetic field data.

- All accelerometers have been performing as usual during the reporting period.
- The Star Trackers have been performing well during the reporting period, with the exception of one spontaneous reboot and the Single Event Upset on 12 February 2023 causing the first of the two attitude packets to the AOCS subsystem to be corrupted
- Non-permanent degradation in image quality remains present on all Electric Field Instrument-TIIs, preventing continuous acquisition of highest-quality science data.
- The Langmuir probes continue to be investigated in detail to allow the production of well-calibrated measurements in various plasma regimes.
- A number of on-board software patches to improve the performance of GPSR have been implemented on-board since Commissioning Phase.

4.3.2 Performance and results

On 28 September 2022, the new Level-1 v3.24p4 and Level-2 Cat-2 v1.20 processing baseline was put into operation, simultaneously with the release of the 2nd full mission reprocessed products, providing fully consistent datasets from the beginning of the Mission to the present. Since then, the nominal processing chain has been fully operational.
All ingestion, Level 1 and Level 2 processing, archiving, and dissemination functions are running nominally. (Swarm - Earth Online (esa.int))
The actual data availability was 100% for both Level 1 and Level 2 products.

Data Access:
All data products (Swarm Data - Earth Online (esa.int)) are routinely made available to both Cal/Val teams and general users through the Swarm dissemination server. In addition, the Swarm dissemination server also provides to all users some advanced datasets, such as the ASM/VFM residuals dataset, the provisional results of Swarm plasma data for all three spacecraft - including the Langmuir probes extended dataset at 2 Hz, and the 16 Hz ionospheric electron density from faceplate measurements - thanks to a special effort from the Electric Field Instrument teams.

The production of the Level 2 Cat-1 fast-track magnetospheric field model, the precise science orbits and non-gravitational acceleration and thermosphere neutral densities determined solely from GPSR data is current and products are made available to users on a routine basis.
During the reporting period more than 21.5 TB of Swarm data products - corresponding to more than more than 2.4 million files - have been distributed to CalVal and general users. The ESA Swarm dissemination server also hosts under the Multimission folder CryoSat-2, CASSIOPE/e-POP, CHAMP, GRACE, and GRACE-FO data coming from several Swarm related projects.

SWARM Data Quality Evolution:
The data quality team of the Swarm DISC (Data Innovation and Science Cluster) provides essential services to ESA for the verification and validation of all data products, as well as the enhancement of processing algorithms.
The improved version of the Swarm Level 1B (L1BOP v03.24p4) and Level 2-Cat2 (L2-Cat2 v01.20) operational processors that have been successfully deployed into operations on 28/09/2022 operated nominally during the reporting period.
The Data Quality Team continue to work to implement further evolutions to be included in the L1BOP v03.25 release. The key improvements will be:

- New particle counter product based on Star Tracker data.
- Improved dB Sun model that takes into account the degree of Earths eclipse of the spacecraft and the direction towards the Sun in the Magnet processing chain.
- New parameters related to Ion density measures in Plasma products and error computation improvements.
- Flagging improvements on Plasma products.

An extensive summary report of Swarm Data Quality Workshop (SDQW) #12 and a list of recommendations that came out from the interaction with the community has been published in the reporting period.
(https://earth.esa.int/eogateway/documents/20142/37627/Swarm-DQW12-Summary-Recommendations-Report.pdf).

Product portfolio evolution

The figure below shows the status of projects initiated through “open call for ideas” and subsequent “invitations to tender” (ITTs) published by ESA and Swarm DISC.

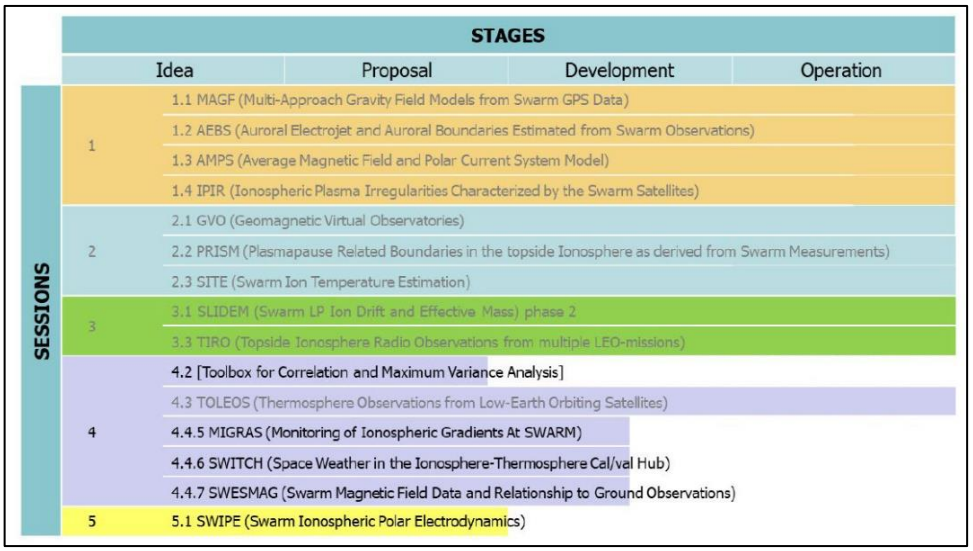


Figure 5: SWARM DISC projects' status

4.4 Aeolus

Launched on 22 August 2018, Aeolus is the first satellite mission to acquire profiles of Earth's wind on a global scale. The primary objective of the Aeolus mission is to demonstrate the Doppler Wind Lidar technique to measure wind profiles from space.The mission sets out to provide observations of global wind profiles along the instrument line of sight (LOS) direction over a minimum lifetime of 3 years. The data will be assimilated into NWP models, to improve the analyses and forecasting of the 3-D vector wind field. A secondary mission objective is to provide data sets suitable for the evaluation of climate models.

4.4.1 Status of spacecraft and mission

The performance of the Aeolus mission was in line with expectations.

D/EOP has authorised that Aeolus can be re-entered through an *assisted* approach, acknowledging the recommendations on the Aeolus Re-entry Working Group. Since then, the preparation and closure of open points with industry are progressing according to plan.
However, the increase of Solar Activity has forced the Aeolus team to anticipate the re-entry timeline and, for this reason, the **End of Aeolus Mission Operations** will be declared on **30 April 2023**.
The decay phase of Aeolus will start on **19 June 2023.** With current prediction of the Solar Activity, Aeolus **will re-enter between 18 July** and **18 August 2023.**

For the platform, there has been a significant increase in both the instances of GPS interference sand the geographical extent where these interferences take place, causing

the GPS to configure several times. A solution to mitigate this issue has been found in view also of making the GPS acquisitions more robust for the re-entry.

A collision risk with a Starlink satellite was raised at the beginning of March, forcing the Flight Control team to cancel and move a planned Orbit Control Manoeuvre (OCM) over to the weekend. The last active mitigation of a Collision Warning was carried out in September 2019.
Due to significant increase in solar activity, two OCMs per week are now performed to keep the ground track within the dead-band limits.
The platform consumables (i.e. spacecraft fuel and oxygen used for the instrument purging system) are in fair conditions. While the oxygen could cover a mission lifetime beyond 2027, the spacecraft fuel remains a driving factor for the platform lifetime, strongly depending on the behaviour of the solar activity.
The Aeolus preparations for the *assisted re-entry* operations are proceeding at full speed.

For the payload, the ALADIN instrument has been operating for more than 52 months, accumulating more than 6.7 billion laser shots. The switch-back to the nominal laser (FM-A) was carried out successfully in the last reporting period.
Compared to the condition in 2018-2019, the instrument appears to be more stable. No significant UV energy drifts have been observed since the resumption of the nominal operation.
There were two issues observed since the last reporting period. On 20 January, the UV energy jumped from **51 m**J to **48 m**J due to changes of the Q-switch discharge pressure conditions. Following the drop, the variations in the UV energy and the INT path signals were improved significantly, which brought positive impacts in terms of wind quality.
The ALADIN instrument was switched to the Standby mode by the Fault Detection, Isolation and Recovery (FDIR) on 21 February. It was triggered by an out of limit transient in the monitoring of MO energy (photodiode PD71). The instrument recovery took one week and the ALADIN was back in operation on 1 March. The performance remained very similar to that prior to the FDIR. Similar to the energy jump, this was most likely caused by the Q-switch discharge state (stray light).

Two successful on-ground verification tests were carried out at the Aeolus Laser Operations Verification Facility (LOVF) with the flight spare laser (FM-C) in February 2023. The first was the functional test of the CLCL ramp set point (closed loop cavity control for the MO) with the objective to improve the frequency stability, in preparation of the End-Of-Life Activities testing in-orbit (EOLA). The second one was the optimisation of FM-A setting by changing the Q-switch pulse width with the objective to provide further margins to increase the UV energy.

4.4.2 Performance and results

This reporting period was characterized by several anomalies occurred at satellite on-board and at ground segment acquisition levels that have affected the PDGS operations.

In two occasions, one on 18 January and one on 4 March, the jump in the on-board orbit counter, mentioned previously, produced an incorrect execution timing for the instrument acquisitions and x-band dump operations. This caused an impact for the ground segment on the data processing and degraded products quality, requiring wind products block-listing. Nominal operations were recovered on 19 January and on 6 March, respectively.
A second block-listing period for wind data products was configured from 20 February 2023 to 2 March 2023 during the ALADIN instrument recovery activity related to a mode switch to stand-by caused by an anomaly. This event caused a gap in the science data acquisition from the 21 February 2023 03:26:50 UTC to the 22 February 2023 07:21 UTC (in total 16 dumps were lost).

During the reporting period, and apart from the anomaly on the x-band acquisitions scheduling reported above, the Aeolus Ground Segment performed nominally.
Nominal mission planning operations continued during the reporting period in accordance with the recovery activities related to the issues mentioned above that were directly managed at Flight Segment level.
Since the last report, the 99,26% of the scheduled Aeolus passes were successfully acquired and the 98,77% of the available telemetry for L1B processing were systematically processed and made available to ECMWF and the Aeolus Cal/Val community in far less than 3 hours from sensing.
The overall production completeness of L2A (aerosol/cloud optical products) was 99,45% and 98,90% for the L2B wind products generated at ECMWF and distributed successfully to Aeolus data users in NRT within 3 hours from data sensing.

Data Access :

Users can access and discover Aeolus products through the following links and tools:

- Aeolus Online Dissemination http Service: http://aeolus-ds.eo.esa.int/oads/access/
- ESA Aeolus Online Dissemination ftp Service: ftps:// aeolus-ds.eo.esa.int
- WMO in BUFR format: https://acquisition.ecmwf.int/index.html
- VirES: https://aeolus.services & Aeolus - Earth Online (esa.int)

Aeolus Data Quality Evolution:

Monthly data quality reports for the publicly available L2B wind products are available via the Earth Online Aeolus site https://bit.ly/3ESsnIK, while the weekly statistics from NWP monitoring remain available via the ECMWF website.
The FM-A data quality continues to be among the best during the mission so far, underlining that this unit is hardly impacted by the cause of the signal decrease observed on FM-B previously. The Rayleigh random error remained at the same level, coming close to the MRD requirement (see Figure 2-4.5 and Table 2-4.1).
Wind data block-listing/flagging remained active during the re-switch-on of FM-A out of Stand-by at the end of Feb, until the data quality was assured again from 1 March.

New range bin settings to measure high quality winds in the tropical tropopause layer have been activate on 20 February.

Product portfolio evolution

The new Rayleigh cloudy wind product has been rolled out to users in March. Furthermore, L2A products covering the period from 9 October 2020 until 26 May 2021 are now fully accessible in Baseline 11, closing gap in the L2A time-series.
The Baseline 16 processing chain has been delivered by DISC and it currently expected to be rolled out in the next reporting period. It also forms the basis for the first reprocessing of the whole mission as reported in the previous paragraph. Highlights of this baseline will be advertised in the coming reporting period.

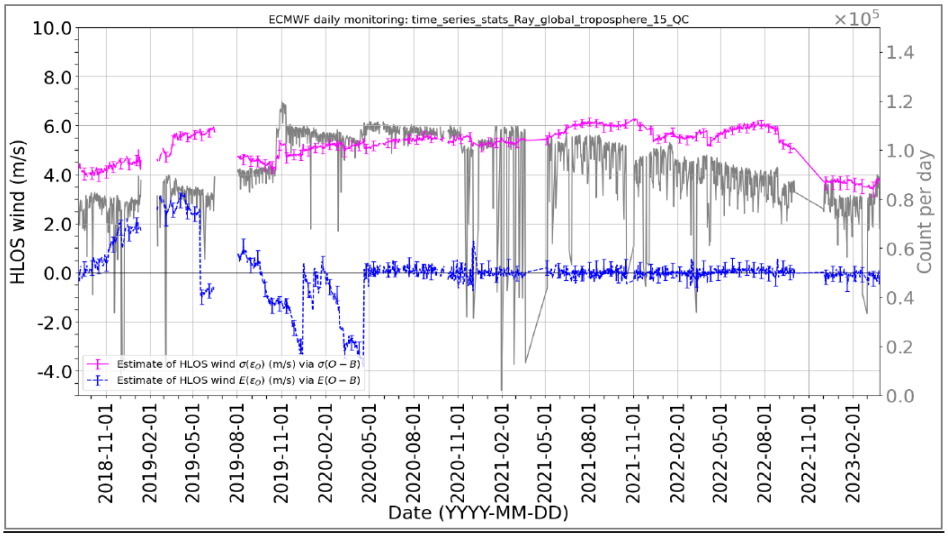


Figure 6: *Evolution of L2B Rayleigh-clear global random error for free troposphere (2-16km). The current random error is around 3.7 m/s*

Aeolus Re-entry

The Aeolus Re-entry Working Group (ARWG) completed its activities in January 2023 and documented in a report. The main conclusions are here recorded:
- Aeolus was not designed to re-enter in a controlled mode. Since its SRR was carried out before the entry into force of ESA's Space Debris Mitigation Policy, the Aeolus re-entry is only subject to a best effort obligation to minimise casualty risk.
- It was demonstrated that during re-entry, an average of 17 satellite debris may reach the Earth's surface with a total mass of about 223 kg (i.e. approx. 20% of satellite's dry mass). For an uncontrolled re-entry, it was confirmed that the casualty risk is 1.71·10-4, well above the target of 1 in 10,000.
- Different re-entry corridors compatible with Aeolus's orbit and design capabilities were reviewed and it was concluded that the Atlantic corridor (25W) has been identified to be the most robust in case of orbit dispersion (i.e. inaccuracy) during the re-entry. Two requirements were then set for the orbit dispersion around the defined location of re-entry: a target dispersion of σ = 1.0 revolution and a goal dispersion of σ = 0.5 revolutions.

- Based on previous research carried out by industry (Airbus), a solution has been identified for Aeolus using an *assisted* approach which significantly reduces the casualty risk. The solution was verified by several simulated cases based on Monte Carlo analyses and presented in a Technical Note by industry.
Out of several options, the ARWG recommends implementing a re-entry solution (i.e. *Decay+*) that foresees a natural decay from the operational orbit 320 km to 280km and the through different retrograde manoeuvres, the re-entry occurs within 2.5 revolutions after the last apogee burst.
- The dispersion for the *Decay+* is only 0.23 revolutions (+/- 9,200 km), 1σ, around the reference location, well below the goal requirement.
- The estimated casualty risk is 4.0·10-6, well below the target of 1/10,000 (i.e. a factor of 42 better than the uncontrolled case) and in line with current Policy. It has been demonstrated that any major anomaly or abortion, during the re-entry phases, would result in a casualty risk not worse than that of the uncontrolled case.
The re-entry will be proceeded by a set of EOL activities which will perform technological and science demonstrations to support EarthCARE and EPS-Aeolus missions.

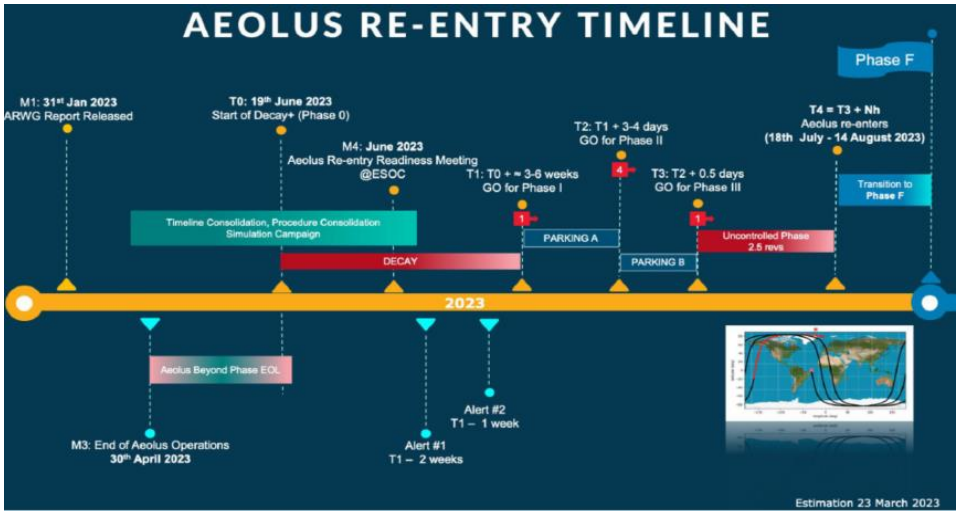


Figure 7: *Overview of the Aeolus Re-entry timeline*

5 STATUS OF CURRENT EARTH WATCH SATELLITES

The Earth Watch programme encompasses the development of the series of operational meteorological satellites of EUMETSAT **(not covered in this report)**, the Proba series of small satellites for medium-resolution imagery, and the Copernicus programme of Sentinel satellites designed to provide reliable, timely and accurate services to manage the environment, understand and mitigate the effects of climate change and help respond to crises.

5.1 Proba-V

Launched on 7 May 2013, Proba-V is tasked with a full-scale mission: to map land cover and vegetation growth across the entire planet every two days. Proba-V is flying a lighter

but fully functional redesign of the 'Vegetation' imaging instruments previously flown aboard France's full-sized Spot-4 and Spot-5 satellites, which have been observing Earth since 1998. The Spot Vegetation dataset had close to 10,000 registered users around the globe and has contributed to hundreds of scientific papers over 15 years. But with further Spot satellites lacking the capacity to carry Vegetation instruments, Proba-V has been designed to meet the future needs of thisgroup. Proba-V's Vegetation instrument boasts improved spatial resolution from its Spot predecessors: 350 m resolution compared to 1 km for Spot Vegetation, with 100 m resolution available within its central field of view. In fact, at that time the full Sentinel-3 constellation (A+B) is expected to be ready to ensure continuity to the SPOT-VGT and Proba-V long-term archive and to address the needs of the land community, in particular of the Copernicus Global Land Service (CGLS).

Proba-V provides data to the instrument's worldwide user community of scientists and service providers. Uses of Proba-V Vegetation data include day-by-day tracking of extreme weather, alerting authorities to crop failures, monitoring inland water resources and tracing the steady spread of deserts and deforestation.

The Vegetation instrument has ended its operations on 31 October 2021 as planned.

The Proba-V programme element is currently within a period of minimal activities, with regular operations of the Proba-V secondary instruments (e.g. EPT instrument) and with the Vegetation data reprocessing activities (Collection 2 dataset).

The Proba-V Cubesat Companion (PV-CC), under development within the GSTP programme, will be launched with Vega in July-August 2023.

5.1.1 Proba-V Operations

The Proba-V satellite remains healthy. The high Proba-V subsystem temperatures continued during the reporting period due to the natural long-term drift of the orbital plane. The higher tempertaures and associated memory error events caused continuing regular safe mode events with the result that the payload availability was reduced. The ESA-ESEC team at Redu carried out an extensive campaign testing alternative spacecraft orientations to lower the temperatures whilst maintaining sufficient electrical power and acceptable sensor fields of view. The result is that a new set of orientations is in use which reduce the temperatures to acceptable levels thus improving the payload availability. Work continues to fine tune the orientations.

The use of the Vegetation Instrument was limited to carrying out lunar calibration observation campaigns during the full moon periods plus a few acquisitions on a single test side for calibration purposes. The secondary instruments remain fully operational, in particular the Energetic Particle Telescope (EPT) which provides near real time and static radiation data products for the SSA Space Weather Service Network. The other instruments, ADS-B, SATRAM and HERMOD, are healthy and in semi-continuous operations.

The ESA Space Debris Office regularly informs the Proba-V Mission Control Centre at

Redu about any potential collision risks with space debris (Proba-V does not feature the capability to perform debris avoidance orbit manoeuvres).

5.1.2 Proba-V data products and quality

The reprocessing to Collection 2 (C2) was completed, including a thorough validation and intercomparison against benchmark datasets. The validation results were summarised in a report, which was presented during last QWG Meeting, held in VITO on 22-23 March. Overall, C2 reprocessing brings significant quality improvements with respect to previous collection, in particular in terms of cloud flagging and atmospheric correction accuracy. Furthermore, consistency with historical datasets, such as SPOT-VGT, AVHRR and MODIS is also slightly improved. Finally, C2 was formally endorsed by CEOS-LSI-VC as being CEOS-ARD compliant, see here: https://ceos.org/ard/. As a result of these positive outcomes, the QWG unanimously endorsed the release of C2 data to the users. The C2 was therefore officially disclosed to the community on March 28th and the news was published on VITO and ESA web sites.
The Contract Change Notice for Land Cover at 100 m was formally kicked off in November 2022 with Université Catholique de Louvain for one year duration. This project extension will be the first exploitation study of the C2 dataset. The objective is to generate cropland, irrigated cropland, and oil palm plantation annual global maps at 100 m resolution. Despite the recent advances in global mapping at high resolution, using combined Sentinel-1 and Sentinel-2 data, challenges remain in better discriminating cropland classes and very few studies have attempted to map oil palm plantation at global scale.
The SPAR@MEP project, led by Rayference, was formally closed in December 2022. The results are scientifically remarkable since they demonstrate, for the first time, the capability of retrieving both surface and aerosol properties from Proba-V data at kilometric scale resolution. The retrieved Aerosol Optical Depth (AOD) maps allow to accurately resolve known emission sources at regional scale and their temporal evolution, such as the biomass burning in African sub-tropical region. The AOD results were successfully validated against ground-based measurements.

5.1.3 Preparation of Proba-V Companion Smallsat operations

The activities on PV-CC satellite development (GSTP programme) are close to completion with Aerospacelab. The integration of the satellite is finishing with tests at ESTEC.
Aerospacelab has booked PV-CC launch as part of the Small Satellites Mission Service (SSMS) #5 rideshare mission, on board Vega flight VV23. At time of writing this report, the foreseen launch date is end July-August 2023 (booking has just been confirmed by Arianspace).
The integration of PV-CC with the deployer is currently planned during May 2023 at Aerospacelab. The delivery to the launch site of the PV-CC satellite integrated with the deployer is planned for end of June 2023.

The PV-CC LEOP campaign is under definition and will include the usage of 3 stations (Redu, Kiruna, Inuvik) in order to get frequent contact with the satellite (also in consideration of the rough orbit information – cubesats). LEOP shall make use of up to 10 S-band passes.
The PV-CC commissioning phase will include a first month of platform commissioning, followed by 2 months for the payload and platform. The PVCC operations during the commissioning will be performed from Aerospacelab premises in a first phase, then from ESA-ESEC in Redu by Aerospacelab people with ESEC witness. After IOCR the PV-CC operations will gradually be transferred to ESEC personnel.

Further information about Proba-V products can be found here : PROBA-V - Earth Online (esa.int)

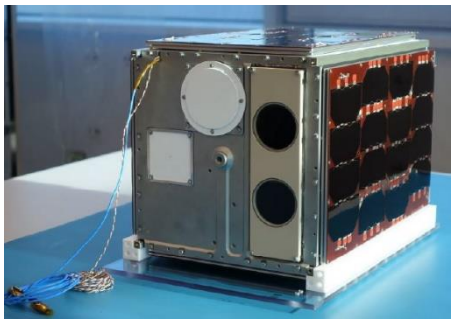


Figure 8: *PV-CC*

6 THE COPERNICUS SENTINEL PROGRAMME

Routine operations of Sentinel-1A continued during the reporting period. The contribution of the Sentinel-1 mission to the emergency activations, in particular from the International Charter Space and Major Disasters, and the Copernicus Emergency Management Service, for flood monitoring in particular, continued to be important during the reporting period. Regarding Sentinel-1B, and after the end of mission of the satellite, the preparation of the Sentinel-1B disposal phase has been completed. Due to the Sentinel-1C launch delay it has been decided, in agreement with COM, to anticipate the re-orbiting activities. Between February and March 2023, Sentinel-1B altitude has been successfully lowered by ~2Km to clear the nominal orbit. Active lowering will start in Q2 2023.
Operations of the Sentinel-2 mission continued nominally during the reporting period. The Sentinel-2 reprocessing campaign to generate Collection-1 continued during the reporting period, and the distribution of reprocessed data to users started in January 2023 through the DIAS (Data and Information Access Systems) CREODIAS, MUNDI and ONDA.
Both Sentinel-3A and Sentinel-3B are in routine operations and the overall performance is good. There was one minor anomaly during the reporting period as reported here after. During the last quarter, the 4th Sentinel-3 Mission Constellation Review (MCR#4) was organised jointly between ESA and EUMETSAT as a hybrid meeting, also involving representatives from COM and Copernicus Services. The S-3 MCR#4 board confirmed the excellent performances of both the space and ground segment elements, including

the on-going set of enhancements, which guarantees the continuous improvement of the associated optical, topography and atmospheric products and services.
Sentinel-5 Precursor operations continued nominally during the reporting period. A reprocessing campaign for all products over instrument lifetime is ongoing. During the reporting period the Aerosol Layer Height, Methane, Nitrogen Dioxide, and Level 1B products were published. It is planned to release the missing reprocessed products (Sulphur Dioxide, Formaldehyde, Ozone Profile, and Tropospheric Ozone) until end April 2023.
The Copernicus Data Space Ecosystem Service was open to users, as planned, on 24 January 2023 with an initial set of available functionalities, including a roadmap for the gradual availability of the foreseen services. The following key steps in the availability of the foreseen services are planned for April and July 2023. Users are kept informed about the planned evolutions concerning the Copernicus data access services and the need to migrate their data access activities from the Data Hub(s) to the new Copernicus Data Space Ecosystem by end of June and latest by end September 2023.

Activities related to the management of the overall CSC operations continued as planned, with the exception related to Sentinel-1B, following the anomaly of 23 December 2021 and the end of mission announced end July 2022.
Sentinel operations are performed in accordance with the Sentinel High Level Operations Plan (HLOP) document, with the exception related to the Sentinel-1B end of mission.

6.1 Sentinel-1A and 1B

The Sentinel-1 mission is a polar-orbiting satellite system for the continuation of Synthetic Aperture Radar (SAR) operational applications. Sentinel-1 is a C-band imaging radar mission to provide an all-weather day-and-night supply of imagery for GMES user services. The SAR will operate in two main modes: Interferometric WideSwath and Wave. The first has a swath width of 250 km and a ground resolution of 5×20 m.

The first Sentinel-1A satellite was successfully launched on 3 April 2014 and commissioned in September 2014. The second Sentinel-1 B was launched on 25 April 2016 and commissioned in September of the same year.

The Sentinel-1A routine operations continued and the overall performance was steady during the quarter. The occurrence of satellite anomalies and mission unavailability periods remained very limited.
The Sentinel-1B satellite unavailability started on 23 December 2021. The satellite remains under control, regular orbit control manoeuvres are routinely performed. On 3 August 2022, the end of exploitation was announced by ESA and COM with news released on the ESA Corporate and Sentinel Online portals and in parallel on the EU Copernicus portal.
The Sentinel-1B re-orbiting strategy (or more exactly the strategy for the re-orbiting to the disposal orbit) has been fully defined and agreed. It is based on an uncontrolled re-entry within 25 years.

As a consequence of the VV22 failure, it has been decided to anticipate the re-orbiting activities and to perform them before the Sentinel-1C launch. It was initially foreseen to perform the re-orbiting operations after the Sentinel-1C In-Orbit Commissioning Review. The re-orbiting plan devised aims at reaching the disposal orbit within the end of 2023 (in case of no major contingencies) with a full re-entry in the atmosphere estimated to be within 12 years, well within the 25 years re-entry requirement.

The re-orbiting will happen in several phases:

- February/March: nominal orbit clearing. Consisting in lowering the S/Cattitude by 2Km. This has been achieved according to the plan.
- April/June: Test campaign aiming at characterising the S/C attitude that willbe used for the re-orbiting. As a matter of fact, the re-orbiting will be performedusing a new attitude “Pitch slew attitude” that is a baseline for S-1C and Dunits but never experienced before.
- June/November: Bulk lowering
- November/December: Fuel depletion and passivation

It is to be noted that the schedule proposed is entirely dependent on the capacity to use and the performance of the “Pitch slew attitude” which will be assessed in Q2 2023. The approach and related schedule will be reviewed according to the need.

During the reporting period Sentinel-1 contributed again to several emergency events (floods mainly), in particular, in response to activations from the Copernicus Emergency Management Service and from the International Charter Space and Major Disasters. Sentinel-1A also contributed to image, on several occasions. the record-breaking Freddy Tropical Cyclone.

Regular Sentinel-1 mission status reports are released weekly on Sentinel Online (available at https://sentinels.copernicus.eu/web/sentinel/missions/sentinel-1/mission-status), with emphasis on the response to emergency situations, provision of mission unavailability information, and user / product statistics.

Figure 9: *Average SAR data sensing in minute per day*

6.2 Sentinel-2A and 2B

A pair of Sentinel-2 satellites routinely deliver high-resolution optical images globally, with 5-day revisit, providing enhanced continuity of SPOT- and Landsat-type data.

Sentinel-2 carries an optical payload with visible, near infrared and shortwave infrared sensors comprising 13 spectral bands: 4 bands at 10 m, 6 bands at 20 m and 3 bands at 60 m spatial resolution (the latter is dedicated to atmospheric corrections and cloud screening), with a swath width of 290 km.
The Sentinel-2A satellite was successfully launched by VEGA (VV05) on 22 June 2015 and the Sentinel-2B also by VEGA (VV09) on 6 March 2017. in accordance with the Copernicus data policy, Sentinel-2 data products are made available systematically and free of charge to all data users including the general public, scientific and commercial users.
During the quarter, the Sentinel-2 operations proceeded nominally, with a very good overall performance in all mission/system operational domains. Both satellites demonstrated good health, with no major anomalies detected or significant degradations observed.
An observation scenario, according to the latest HLOP (Sentinel High Level Operations Plan) version 3.1, is being operated for Sentinel-2A since 6 June 2022 and for Sentinel-2B since 11 June. This observation scenario includes all land surfaces within reach including the acquisition of all small islands and atolls worldwide.

The Sentinel-2 archive reprocessing continued during the reporting period. The distribution of the first reprocessed data started in January 2023 through the DIAS (Data and Information Access Systems) CREODIAS, MUNDI and ONDA.
The overall status of Sentinel-2A functional health is good, with few anomalies and little, if any, evidence of any long-term degradation. For Sentinel-2B, although the overall status is good, it shall be noted a new anomaly causing the loss of 20-30 Instrument Source Packets (ISP) per day (from a total of about 71 million per day). Initial investigations pointed to a potential issue with the Transfer Frame Generator Array 0&2 (TFG0&2). As tentative correction measure, a reboot of this sub-system was performed but did not resolve the anomaly. Investigations are ongoing to try to identify the cause of the anomaly and to solve it.
OCP units continue to suffer periodic outages due to radiation sensitivity, but mitigation measures are in place minimising unavailability periods. The Flight Operations Segment (FOS), ensuring the monitoring, control, and commanding of the satellites, operated nominally.
A Collision Avoidance Manoeuvre was executed for Sentinel-2B on 2 March 2023, and three other ones for Sentinel-2A on 1 January, 22 February and 4 March 2023.

The Copernicus Ground Segment operations continued nominally for Sentinel-2 during the quarter, ensuring regular planning of the Sentinel-2 observations as well as data acquisition on ground via X-Band and EDRS, systematic processing of acquired data into

User Level Data and long term archival of essential mission data. All data is available to users via the Data Hub(s) services and gradually though the new Copernicus Data Space Ecosystem services in line with the new service roadmap.
Product quality is routinely ensured by the Optical Mission Performance Cluster (MPC) service provider, that supports both Sentinel-2 and Sentinel-3.
The Sentinel-2 GRI (Global Reference Image) as a free & open product has been completed and will start being distributed to the public during Q2 2023.

Regular Sentinel-2 mission status reports are released weekly on Sentinel Online (https://sentinels.copernicus.eu/web/sentinel/missions/sentinel-2/mission-status).

6.3 Sentinel-3A and 3B

The main objective of the Sentinel-3 mission is to measure sea surface topography,sea and land surface temperature, and ocean and land surface colour with high accuracy and reliability to support ocean forecasting systems, environmental monitoring and climate monitoring. The mission definition is driven by the need for continuity in provision of ERS, Envisat and SPOT-Vegetation data, with improvements in instrument performance and coverage. Sentinel-3A was successfully launched on 16 February 2016 and the commissioning phase was terminated in August 2016. Sentinel-3A passed its Routine Operations Readiness Review on 16 October 2017 and is now officially in routine operations, having reached full operational capacity already in July 2017.

Currently all instruments, including OLCI, SRAL, SLSTR and MWR, on both satellites, are switched on and performing well. All Sentinel-3A and -3B Level 1 and Level 2 core data products have been released to the user community.
The joint ESA-EUMETSAT mission management is on-going, following the provisions in the Joint Operations Management Plan actions agreed at the 2nd Sentinel-3 Steering Group on 27 March 2019.
The Flight Operations Segment (FOS) for Routine Operations is operating according to plan, providing the required service to the EUMETSAT FOS, namely the S-Band TT&C ground station network.
On 24 February at 23:40:36 UTC, SLSTR Cooler Drive Electronics (CDE) entered Standby Refuse mode when Sentinel-3B was flying through the South Atlantic Anomaly. A power cycle followed by a decontamination of the unit has been performed to recover SLSTR to its nominal state. The instrument was turned back to ON_DUTY mode on 26 February at 23:11:33 UTC. All products are nominal from this time onward and the users have been informed accordingly through the regular channels.
The Copernicus Ground Segment operations continued nominally for Sentinel-3 during the quarter, ensuring data acquisition on ground via X-Band, systematic processing of acquired data into Sentinel-3 User Level Data and long term archival of essential mission data.
All data is available to users via the Data Hub(s) services and gradually though the new Copernicus Data Space Ecosystem services in line with the new service roadmap.

All Sentinel-3A and -3B Level 1 and Level 2 core data products have been released to the user community.
Efforts are also continuing to further improve the Sentinel-3 data quality, based on the results of the validation activities performed by the Optical & Altimetry Mission Performance Cluster (MPC), the feedback from the Quality Working Groups from previous Sentinel-3 Validation Team (S3VT) meetings. Due to Brexit, UK partners had to leave the MPCs end of 2022 but were replaced by continental partners without significant service disruption so that the Optical & Altimetry MPC services were nominal over the reporting period. The quality of the Sentinel-3 products is operationally monitored at the Optical & Altimetry MPC and the cyclic reports are published on the ESA Sentinel on-line web site. The performance of the Sentinel-3 core products is nominal. An Annual Performance Report covering the performance of the S-3 core products over the year 2022 was released on the ESA Sentinel online web pages.

On 4 August 2022, Pilot Level 2 Thematic Altimetry products with improved and tailored processing algorithms were released to the end users for the three surfaces: sea ice, land ice and hydrology. Reprocessing back to the beginning of the mission for both spacecraft with this new processing baseline has started during the last quarter. The quality of Thematic Sea Ice products shows very significant improvements over both the Arctic and Antarctic Sea ice domains, better matches that of CryoSat-2 and when compared with concurrent in-situ data. Clear improvements are also observed in terms of quality and coverage of the Thematic Land Ice and Hydro products.
During the last quarter, the 4th Sentinel-3 Mission Constellation Review (MCR#4) and the 6th Joint Steering Group (JSG#6) Meetings were organised jointly by ESA and EUMETSAT as a hybrid meeting, respectively on 28 and 29 March 2023 (on-site EUMETSAT with a remote access). The mission is recognized to be a mature mission with on-going set of enhancements, which guarantees the continuous improvement of the associated products and services over a wide range of surfaces and application domains.

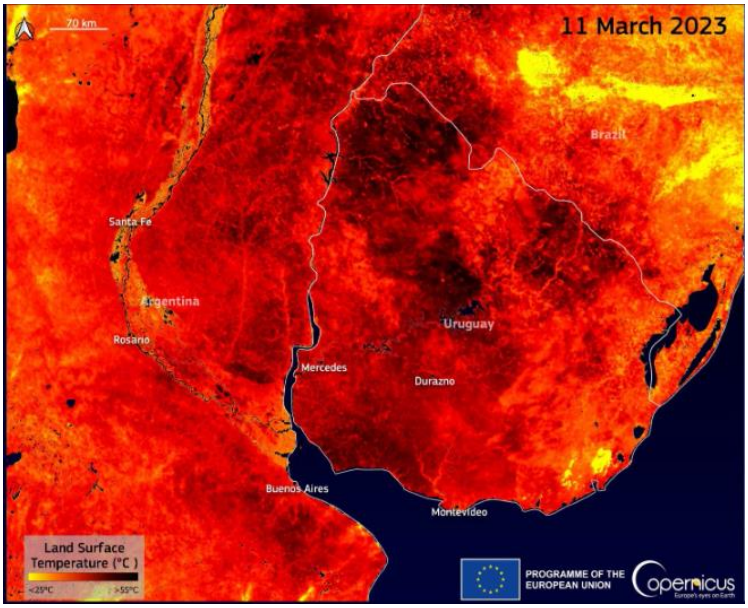


Figure 10: *Severe South America heatwave observed by Sentinel-3 Land Surface Temperature (March 2023)*

6.4 Sentinel-5P

The Sentinel-5P mission status is reported at:

https://sentinels.copernicus.eu/web/sentinel/missions/sentinel-5p/mission-status

The Sentinel-5 Precursor mission is a gap-filler, within the 2016-2023 timeframe,between the end-of-life of the current atmospheric chemistry mission (OMI on EOS/Aura) and the operational availability of Sentinel-5. As a joint initiative between ESA and the Netherlands, the mission will comprise a satellite and a UVNS instrument called TROPOMI.

The Sentinel-5P satellite has been launched by Rockot on 13 October 2017. Since April 2018, Sentinel-5P has been in routine operations, having reached full operational capacity in early March 2019.
The TROPOMI instrument continues measuring in nominal baseline with a 360 orbit repeat cycle and has been operated since 6 August 2019 with a spatial along-track resolution of 5.5 km (instead of 7 km), providing since then ~20% more science data to the user community. No major satellite anomalies occurred during the reporting period.
The Flight Operations Segment (FOS) is operating according to plan.
Due to a collision risk identified for the Sentinel-5P satellite a Collision Avoidance Manoeuvre (CAM) was executed on 10 January during the time period 17:43 – 20:09.
Sentinel-5P has been flying in loose formation with SUOMI-NPP since December 2017 and VIIRS cloud information is used operationally in the Methane retrieval algorithm.
Level 1B Radiance/Irradiance, Level 2 Methane, Tropospheric Ozone (Offline); Carbon Monoxide, Formaldehyde, Nitrogen Dioxide, Sulphur Dioxide, Total Ozone, Ozone Profile, Aerosol Absorbing Index, Aerosol Layer Height and Cloud products (Offline and NRT) are available to the public via the Copernicus Sentinel-5 Precursor Data Hub – s5phub.copernicus.eu.
A reprocessing campaign for all products over instrument lifetime is ongoing. During the reporting period the Aerosol Layer Height, Methane, Nitrogen Dioxide, and Level 1B products were published. It is planned to release the missing reprocessed products (Sulphur Dioxide, Formaldehyde, Ozone Profile, and Tropospheric Ozone) until end April 2023
Six pre-operational products (Aerosol Optical Thickness, Bromine Monoxide, Glyoxal, Sun-Induced Fluorescence, Water Vapour, and a Sulphur Dioxide product using the new Covariance-Based Retrieval Algorithm (COBRA)) are being provided to the public via https://data-portal.s5p-pal.com.
During the reporting period, Sentinel-5P MPC routine activities have been carried out nominally.

6.5 Sentinel-6 Michael Freilich (Jason-CS)

The Jason-CS satellites form the space component of the Jason Continuity of Service mission, within the Copernicus Space Component Segment 3. Jason-CS willextend high-accuracy ocean topography measurements well into the 2020s, thanks to the participation of all partners (EUMETSAT, ESA, CNES, NOAA and NASA/JPL).

The Poseidon-4 altimeter employs digital architecture and the simultaneous measurement in the advanced SAR mode as well as in the conventional pulse-width limited mode. The Advanced Microwave Radiometer, Climate Quality (AMR-C) will bean enhanced version of JPL's instrument used on Jason-2 and Jason-3. A major programmatic decision has been the abandonment of the High-Resolution Microwave Radiometer (HRMR) studies.

The GNSS receiver optimised for Precise Orbit Determination will be an instrument derived from the Sentinel-3b GNSS receiver, while Radio Occultation (RO) capabilitywill be satisfied by a NASA-provided GNSS-RO. Additionally a DORIS Receiver and a NASA-provided Laser Retro-Reflector Array will be embarked.

The Sentinel-6A Michael Freilich (Sentinel-6MF) has been launched from the Vandenberg Air Force Base, California, on 21 November 2020.NASA and NOAA jointly acting as the US party are responsible for providing the launch services for both Sentinel-6 A and B satellites, US payload instruments and ground segment support, and will contribute to the operations. The Sentinel-6 MF satellite was handed over to Mission Operations (Phase E2) after its successful In-Orbit Commissioning Review on 16 November 2021. EUMETSAT is responsible for the mission's operations. The mission's operational performance fully meets or exceeds expectations.

The Industrial Support Contract for phase E2 is running nominally (support to EUMETSAT by Industry through ESA, as per MOU). The Sentinel-6 industrial contract has been extended to include the B-unit long-term storage activities. NASA/JPL is procuring Space-X/Falcon-9 from Vandenberg for **Sentinel-6B** launch Phase E1 to be included in the contract when processing facility selection will be completed.

7 FUTURE ESA SATELLITE SYSTEMS

Important note: all the dates provided in this chapter 6 for launches and other activities in the future are indicative. They reflect the situation as of June 2023.

7.1 Future Earth Explorer and Earth Watch missions

The Earth Explorers are research missions designed to address key scientific challenges identified by the science community while demonstrating breakthrough technology in observing techniques. Involving the science community right from thebeginning in the definition of new missions and a peer-reviewed selection process ensures that a resulting mission is developed efficiently and provides the exact datarequired by the user.

7.1.1 EarthCARE : Earth Explorer 6th

ESA's EarthCARE (Cloud, Aerosol and Radiation Explorer) mission is the largest and most complex Earth Explorer to date, and will advance our understanding of the role that clouds and aerosols play in reflecting incident solar radiation back into space and trapping infrared radiation emitted from Earth's surface. EarthCARE is a joint venture between ESA and JAXA (Japan Aerospace Exploration Agency).

EarthCARE will advance our understanding of the role that clouds and aerosols playin

reflecting incident solar radiation back into space and trapping infrared radiation emitted from Earth's surface. By acquiring vertical profiles of clouds and aerosols, aswell as the radiances at the top of the atmosphere, EarthCARE aims to address these issues. The mission will employ high-performance lidar and radar technology that has never been flown in space before.
The mission has a design lifetime of three years, including a six-months commissioning phase.
Design modifications to the Vega-C launch system are progressing, although difficult due to very small margins of the fairing accommodation and impacts from the Vega-C launch failure. Compatibility study with backup launcher Falcon 9 ongoing with no showstopper identified. Launch is planned to take place in Q2-2024.

Satellite level environmental test campaign is progressing according to schedule with successful completion of thermal vacuum/thermal balance test campaign and EMC test campaign currently ongoing.
The EarthCARE Overall Ground Segment Verification phase is ongoing according to schedule with 2 major test runs (out of 4 planned) performed. Completion of L1 and L2 processors, including resolution of identified issues is ongoing. Good progress achieved on chaining of all L2 processors.

During the reporting period, the satellite level activities continued to progress very well. At the beginning of the year, the satellite was transferred into the LSS (Large Space Simulator – Thermal Vacuum/Thermal Balance chamber). The CPR reflector was opened and reflector heaters/thermal insulation (SLI – Single Layer Insulation) tent was installed by JAXA/NEC. All electrical connections and cooling loops for ATLID were installed. After a successful test readiness review, the LSS chamber was closed on 25 January, after which the thermal balance/thermal vacuum (TBTV) test was successfully performed by a joint Airbus, ESA, JAXA, NEC and ETS team over a period of 2 weeks of 24/7 testing. ESOC has been listening in to the satellite during the complete test, collecting all telemetry transmitted by the satellite and distributing it to the team with their operational tools. Thanks to the expertise and detailed knowledge of the satellite of the current AIT team (built up during the previous satellite level tests and operations System Validation Tests), all encountered unexpected results could be resolved very efficiently, resulting in completion of the test 1 day ahead of schedule.

- The platform level integration activities are considered complete.

- The ATLID instrument is integrated on the spacecraft. The Flight Spare Power Laser Head (PLH) remains in storage. Acceptance test campaign will only be initiated in case of need to replace the flight PLH on ATLID, which is a contingency case. With the successful completion of the thermal balance/thermal vacuum test, the likelihood of failure of ATLID PLH is considerably reduced.

- The BBR (Broadband Radiometer) instrument is integrated on the spacecraft and protected by environmental tent whenever possible during the environmental test campaign.
- MSI (Multi-Spectral Imager) is integrated on the EarthCARE satellite and protected by environmental tent whenever possible during the environmental test campaign.
- The CPR (Cloud Profiling Radar) instrument is integrated on the spacecraft. With the CPR successfully performing during the thermal vacuum/thermal balance tests at satellite level, JAXA declared the CPR with its current high power transmitter (HPT's) healthy and it was jointly decided that there was no need for replacement of one of the HPTs with the Spare HPT.
- The Ground Segment activities progressed well during the reporting period with the overall Ground Segment Verification phase running according to plan. Two major test runs (out of 4) were already successfully performed: (i) one processing run focussing on L0 and L1 data processing, data acquisition and data exchange between FOS, PDGS and JAXA PDGS; (ii) a mission planning run. Currently, preparations for processing run 2, covering data processing including L2 are ongoing with the processor activities described in the paragraphs below and integration of the tested processors into the PDGS. All ground segment activities are targeting the ground segment acceptance review scheduled in September-November 2023.

Regular coordination with the JAXA ground segment team continued during the reporting period and as well as regular coordination meetings with ECMWF.

Future Outlook

The satellite level EMC test campaign will be completed mid-April, to be followed by a number of functional, performance and software tests. System Validation Test SVT-3 is scheduled for execution in June 2023. In parallel, the satellite Qualification and Acceptance Review (QAR) will start. In June-July, propulsion system leak tests will be performed as one of the last tests in the satellite test campaign (with exception of the launcher separation/shock test which will be performed upon availability of the launcher adapter after QAR).
The Overall Ground Segment Verification Campaign will continue with the second processing test run and preparations of the final mission planning test run towards Ground Segment Acceptance Review starting at the end of September 2023.
Spare HPT test campaign is scheduled to be completed and delivery is foreseen in June 2023.
The decision between baseline and back-up launch will be taken and planning and preparations of the remaining activities will be adapted accordingly as well as negotiations of the consequences to the contractual baseline with satellite prime and ground segment contractors.

7.1.2 Biomass: Earth Explorer 7th

The Biomass mission was selected in May 2013 as the 7th Earth Explorer mission ofits

Living Planet programme. The satellite will be designed to provide, for the first time from space, P-band radar measurements optimised to determine the amount ofBiomass and carbon stored in the world's forests with greater accuracy than ever before. This information, which is poorly known in the tropics, is essential to understanding the role of forests in Earth's carbon cycle and in climate change. These objectives will be achieved by measuring Biomass and forest height at aresolution of 200 m and forest disturbances at a resolution of 50 m.

Reliable knowledge of tropical forest Biomass also underpins the implementation of the UN Reducing Emissions from Deforestation and forest Degradation (REDD+) initiative – an international effort to reduce carbon emissions from deforestation and land degradation in developing countries. In addition, the measurements made by Biomass offer the opportunity to map the elevation of Earth's terrain under dense vegetation, yielding information on subsurface geology and allowing the estimation ofglacier and ice-sheet velocities, critical to our understanding of ice-sheet mass loss ina warming Earth. Biomass also has the potential to evolve into an operational system, providing long-term monitoring of forests – one of Earth's most important natural resources.

The satellite mechanical test campaign was successfully completed. This is a major milestone of the system environmental test campaign and ensures that the satellite is qualified for the launch loads.
The DCU (Digital Control Units) proto flight model has successfully passed its qualification. Both units are now ready to be installed onto the satellite.
The schedule for the delivery of the Power Amplifier Assembly (PAS) could not be stabilised again. Quality issues in manufacturing and additional tuning further delayed the start of testing of the first SSPA. However, these have been finally overcome and this critical test is confirmed to start on 5 April. The Leonardo delivery date is now mid-September 2023. A review is ongoing to scrutinise all PAS, instrument and satellite activities to look for schedule improvements and avoid a one-to-one impact on the launch date.

The big structural elements of the ground calibration transponder, antenna, antenna positioner and radome, have arrived in New Norcia. Tests on the control electronics are still slower than expected due to persistent problems in the software development. The launcher situation remains volatile, but the Project remains focused to a launch readiness within the launch period that has been agreed with Arianespace from 1 July to 30 September 2024.

- During the reporting period the mechanical test campaign has been successfully completed. This campaign was comprised of the sine vibration test, acoustic test and shock tests. These were followed by the LDR pop and catch, a test to verify that the reflector can still move away from the satellite, and the solar array (SA) deployment. Following these tests, the LDR reflector and boom were dismounted and have been shipped back to L3Harris in Florida for a final deployment. The SA has also been dismounted and is being shipped back to ADS Leiden for its final checks and characterizations. Both the LDR and SA will be re-installed later in the AIT campaign and

after the thermal vacuum tests. The next major step that has just been achieved was the fit check with the launcher payload adapter.

- The post mechanical abbreviated functional test (AFT) has been completed and the ADS team at EVT are now preparing for the dismounting of the instrument panels. In parallel to the activities in the clean room, the preparations for the thermal vacuum test have continued with the test specification reviews and discussions. The Infra-Red Lamp CDR took place, and the manufacturing of the lamps is underway. In addition, the go ahead has been given to prepare the next version of the central software.
- Despite further delays during the reporting period, a very important milestone has been achieved with the completion of the first SSPA and its readiness for testing. Quality and manufacturing problems have led to the need of iterative additional tuning of the electrical circuitries and have again delayed the test readiness to 5 April. The tests are well prepared, and the next few weeks are crucial for the programme. The Qualification Review of other hardware elements of the PAS, the so-called mini equipment has been completed.
- The DCU PFM qualification campaign has been performed successfully and the consent to ship both DCUs for integration into the satellite in Toulouse has been given. This is another major step for the satellite programme. The investigations into the occurrence of read errors from a SRAM memory chip in one of the boards had to be concluded without finding the exact root cause of the problem. The read errors are however correctable by the onboard software. The use-as-is of the unit was justified based on the impact analysis of all potential failure hypotheses that the involved experts could identify. With the current knowledge and observables, none of them – if appearing - would lead to a permanent problem in orbit. The observed occurrences are very rare and only one of the two DCUs is affected.

Future Outlook

For the next reporting period the following main activities are planned:

• Removal of the instrument from the satellite and integration of the two DCUs
• Performance of Mission Integrated System Test (IST) on the satellite
• Completion of the test campaign of the first SSPA (“training unit”) and completion of the acceptance tests of the first three out of six flight SSPA units.
• Evaluation of the results of the simulation campaign with the E2E simulator version BEEPS v2.5.
• Completion of work on the calibration transponder site.
• Installation of the big hardware components of the calibration transponder in New Norcia and completion of the functional and performance tests of the calibration transponder control subsystem.
• Signature of the ISRO-ESA coordination arrangement with the Indian authorities.

7.1.3 FLEX: Earth Explorer 8th

On 19 November 2015, ESA’s Member States selected FLEX as the 8th Earth Explorer

mission upon recommendation from the Earth Science Advisory Committee. The Fluorescence Explorer (FLEX) mission will map vegetation fluorescence to quantify photosynthetic activity.

The conversion of atmospheric carbon dioxide and sunlight into energy-rich carbohydrates through photosynthesis is one of the most fundamental processes on Earth – and one on which we all depend. Information from FLEX will improve our understanding of the way carbon moves between plants and the atmosphere and how photosynthesis affects the carbon and water cycles. In addition, information from FLEX will lead to better insight into plant health and stress. This is of particular relevance since the growing global population is placing increasing demands on the production of food and animal feed.

So far, it has not been possible to measure photosynthetic activity from space, but FLEX's novel fluorescence imaging spectrometer will observe this faint glow, which serves as an indicator of photosynthesis. The FLEX satellite will orbit in tandem with one of the Copernicus Sentinel-3 satellites, taking advantage of its optical and thermal sensors to provide an integrated package of measurements. Launch is currently planned for mid-December 2025.

- FLORIS instrument PFM AIT is progressing well with the LR Spectrometer and LR Focal Plane System alignment achieved. LR chain finalisation in April.
- The HR Focal Plane System integration has been completed and tests have started. Its progress and finalisation are however hampered due to technical issues and delays on the Video Acquisition Units.
- The Polarisation Scrambler PFM integration has been completed and the transmission Wave Front Error (WFE) is still stable. A non-compliance on spot split measurements is being investigated.
- Instrument Control Unit (ICU) development is progressing, EM TRR has been held. Slow progress on the Application Software and FPGA validation activities. Flight Printed Circuit Board (PCB) manufacturing is delayed.
- The Payload Data Handling Unit is delayed due to PCB microvia issues. Remanufacturing has started.
- The propulsion subsystem assembly is completed, and testing has started and the solar array wing-level tests have started.
- The propulsion subsystem assembly (TAS, UK) has been completed and the TRR held. Tests are ongoing and so far all with nominal results.
- The Solar Array (STI, DE) panel-level electrical performance tests conducted at ESTEC have been completed successfully.
- The FLORIS PFM AIT progressed well for the Low-Resolution chain. The LR Spectrometer and Focal Plane System have been delivered by OHB to LDO and the final alignment on the optical bench has been achieved with excellent results.
- The assembly of the HR Focal Plane System (OHB, DE) with new detector units has been completed and testing has started with CMM measurements and Electro-Optical

tests already completed.
- The Polarisation Scrambler (SODERN, FR) PFM integration has been completed and testing has begun. An anomaly in the spot split measurements has been detected that looks like a 90 deg rotated scrambler and investigations are ongoing.
- At ground system (GS) level, the FOS and PDGS critical design reviews (CDRs) will be performed in October/ November 2023 and the FLEX GS CDR will be held in December 2023/ January 2024.

Future Outlook

Finalise the LR chain integration and alignment on the optical bench.
• Solve VAU problems (EMC and PCB/component malfunctioning).
• Complete the Polarisation Scrambler PFM TRB.
• Complete ICU PFM PCB board manufacturing.
• Complete the Propulsion subsystem test campaign and reach DRB.
• Complete the Solar Array wing-level test campaign.
• Initiate the assessment of FLEX launch on VEGA SSMS structure.

7.1.4 FORUM: Earth Explorer 9th

FORUM was selected on 23-25 September 2019 as Earth Explorer 9.
The Far-infrared Outgoing Radiation Understanding and Monitoring (FORUM) mission will provide new insight into the planet's radiation budget and how it is controlled, and therefore improve climate models. More than half of Earth's outgoinglongwave energy is in the far-infrared part of the electromagnetic spectrum, which has not been measured. FORUM will fill this gap.

Thanks to new technical developments, the Far-infrared Outgoing Radiation Understanding and Monitoring (FORUM) mission would measure radiation emittedfrom Earth across the entire far-infrared part of the electromagnetic spectrum.
Significantly, it measures in the 15–100 micron range, which has never been donefrom space before. These observations are important because Earth emits infrared radiation to space, which is affected by water vapour and cirrus clouds, which, in turn, play key roles in Earth's temperature.

FORUM's benchmark measurements would improve our understanding of the greenhouse effect and, importantly, contribute to the accuracy of climate change assessments that form the basis for policy decisions.

The focus of the technical activities in this reporting period has been the preparation of the Instrument PDR (I-PDR) data package which has been delivered by OHB (DE) to ADS(UK) and ESA, to start the review in April.

Relevant co-engineering activities have been conducted by ADS and OHB to consolidate the interface requirements between Platform and Instrument. The vibro-acoustic and acoustic analyses performed at instrument and Satellite level have brought encouraging

results. The road map followed by OHB and ADS allowed the reduction of the loads specified to the instrument units, now aligned with their heritage, pending the acceptance of the primary and secondary notching. This will be discussed in the frame of the I-PDR and System PDR (S-PDR).
A roadmap has been agreed for the revision of the micro-vibration requirements, considered critical for the Scanning Unit and Pointing Unit (SCU, POU). The outcome is expected for the I-PDR.
A relevant change in the instrument configuration has been required to avoid the damage of the Back Telescope and Detection Assembly (BTDA)detector, under non-nominal attitude conditions and launch phases due to the intrusion of the Sun in the secondary port of the interferometer. The performance impacts of the solution identified by OHB seem acceptable but are still under assessment and will be subject of the I-PDR.

- The Interferometer Assembly (IA) EM integration and the TRR for the functional and optical tests have been completed.

- The FORUM launch date is currently planned in Q3 2027 including margins distributed at instrument and satellite level before QAR and in Phase E1.

- On the Platform side, all contracts have been already implemented. Special agreements (i.e., advancing activities from Phase C into the Phase B2) have been reached to minimize inflation impacts, secure stock items, and safeguard the overall platform schedule in line with the mating planned between the PFM platform and instrument beginning of 2026.

Future Outlook

•Complete the Instrument PDR
•Start the System PDR
•Complete the IA EM alignment and the optical and vibration test campaign
•Close the SCU/POU and the IA PDR
•Complete the remaining Instrument Units PDRs.
•Complete the selection of the Instrument EGSE
•Hold the Risk and Schedule Control Board

7.1.5 HARMONY: Earth Explorer 10th

Harmony was selected on 22-23 September 2022 as Earth Explorer 10. Harmony will, in turn, also help address societal issues such as those laid out in the World Climate Research Programme's Grand Challenges and a number of the UN's Sustainable Development Goals. Harmony will provide a wealth of new information about our oceans, ice, earthquakes and volcanoes.

The mission will comprise two identical satellites orbiting Earth in convoy with a Copernicus Sentinel-1 satellite. Each Harmony satellite will carry a receive-only synthetic

aperture radar and a multiview thermal-infrared instrument. The launch is targeted for 2029.
Together with observations from Sentinel-1, Harmony will deliver a wide range of unique high-resolution observations of motion occurring at or near Earth's surface.
A grouped procurement proposal for the Phase B1 Studies of the Harmony Mission has been initiated.

As a result, the Phase B1 of the Harmony mission is currently on-going through parallel contracts for each of the above elements as defined below:

- Two parallel SAR Payload Phase B1 studies with Airbus Defence and Space GmbH (DE) and Thales Alenia Space Italia S.p.A (IT) initiated in October 2022.These studies will end with a dedicated Payload System Requirements Review currently planned in June 2023; Over the reporting period, the SAR Payload Phase B1 study previously engaged with Airbus Defence and Space (ES) has been novated to Airbus Defence and Space GmbH (DE);

- Two parallel TIR Phase B1 studies addressing the Optical Payload with Surrey Satellite Technology Limited (UK) and ABB Inc. (CA) initiated in October/November 2022. These studies will end with a dedicated Payload System Requirements Review planned in autumn 2023.

- Two parallel System Phase B1 studies addressing the System and satellites aspects with Airbus Defence and Space SAS (FR) and OHB System AG (DE) initiated in February 2023. Based on consolidated inputs from the payload Phase B1 studies, these System Phase B1 studies will end with a dedicated Intermediate System Requirements Review currently planned in October 2023.

One of the main tasks of the Phase B1 studies over the last period has been the harmonisation of the interfaces between Payloads and Platforms. The Agency organised and coordinated a series of Platform-Payload Interface Meetings (PPMs) during which the interfaces between the platform and the different Payloads were agreed while maintaining compatibility of the System with the combination of possible Payloads. Two Industry days have been organised in February and March 2023 to prepare for B2/C/DE1 procurement.

Future Outlook

- Finalise the parallel SAR Payloads Phase B1 Studies towards SRR by July 2023
- Prepare ITT data pack for initiation of SAR B2CDE1 procurement
- Mitigate technology risk and engage parallel activities for Antenna tile and Receive Module Unit for the SAR
- Progress the parallel TIR Payloads Phase B1 Studies towards SRR
- Progress the parallel System Phase B1 Studies towards ISRR
- Mitigate schedule for the TIR and engage procurement of pre-developments

7.1.6 Earth Explorer 11

The science requirement consolidation (SciReC) studies are continuing for the four Earth Explorer 11 (EE11) candidate missions selected for Phase0: CAIRT, Nitrosat, SEASTAR, and WIVERN. Iterative changes to the MATER (Mission Assumptions and Technical Requirements Document) have been prepared by ESA and discussed with the MAG for each mission. Consolidation of requirements is ongoing through the accompanying SciReC studies after completion of the Mid Term Reviews (MTR) of the Phase 0 system studies and parallel contracts for all of the 4 candidate missions.

In line with the recommendation of the ACEO-ESA EE10 Tiger Team, MAG representatives attended as observers to industry presentations during the MTR for each mission that were completed between November 2022 and mid-January 2023. Following MTR close-out, the initial ROM cost estimates provided by industry at PM3 for all missions were above the EE11 cost cap.

While cost estimate sand underlying assumptions made by industry are being scrutinised and challenged by the Executive, mission concept optimisations, cost reduction options and potential relaxation of requirements are being analysed with industry and discussed with the MAG in an iterative manner in view of the PM4 in March/April and of the upcoming Mission Architecture Review planned in May/June 2023.

At the end of this iterative process, the goal is to identify mission concepts for each mission candidate that optimise the science while being within the stringent and rigid EE11 cost cap.

For the End-to-End Performance Simulator (EEPS), proposals were received and evaluated for each candidate mission; kick-off meetings have been held in December 2022/January 2023 for CAIRT, Nitrosat and WIVERN, and on 31 March 2023 for SEASTAR.

7.1.7 Earth Explorer 12

The call for ideas for the next Earth Explorer 12 research mission opened on February 20th, the proposal submission deadline is on September 29th.

7.1.8 NGGM Gravity Mission

In orbit from March 2009 to November 2013, the Gravity field and steady-state Ocean Explorer (GOCE) measured the Earth's gravity field with unprecedented detailto advance our understanding of ocean circulation, sea-level change and Earth- interior processes.

GOCE successfully completed its last measurement cycle at an altitude of 223.88 kmon 19 October 2013. The satellite re-entered into the Earth atmosphere on 11 November 2013.

In the frame of Missions of Opportunity made possible by international cooperation, ESA and NASA have coordinated studies of optimal gravity monitoring constellations formed by two or more pairs of satellites to observe mass changes in the Earth system. In 2016 the ESA-NASA Science Working Group issued the document “Towards a sustained observing system for mass transport to understand global change and to benefit society”.

Programmatic discussions have also been held in March 2020 between ESA and NASA, based on a series of meetings and teleconferences in 2019, to identify the most suitable scenario for implementation of a joint mass change mission based on ajoint constellation of 2 pairs of satellites in an optimum orbit configuration, leveraging on technology developments, and technical and scientific expertise available both in Europe and in the US. The proposed mission architecture responds to user requirements previously established by the Interagency Gravity Science Working Group and builds upon the heritage from CHAMP, GOCE, GRACE, GRACE-FO.

The global science and user requirements were consolidated in a uniform traceable manner together with NASA. These requirements and a corresponding traceability matrix have been used to establish the mission requirements. The first issue of the Mission Requirements Document (Next Generation Gravity Mission as a Mass-change And Geosciences International Constellation (MAGIC) - A joint ESA/NASA double-pair mission based on NASA's MCDO and ESA's NGGM studies) was released on 18 December 2020, following signatures of ESA and NASA. The MRD was distributed to Delegations in early 2021. In close coordination with NASA the Joint Mass Change Mission Expert Group (JMCMEG), consisting of 9 European members and 9 US members, was established to support the Phase A.

An ESA/NASA Joint Engineering Team (JET) has been set up with the goal to support and coordinate the technical interaction between ESA and NASA to enable the implementation of an affordable, technically feasible and scientifically valuable observing architecture for MAGIC. The JET was kicked-off on 20 May 2021.

Preparation of the draft Concept Paper addressing roles and responsibilities of each cooperating party for the constellation implementation is on-going. This Concept Paper would be the first step towards an Implementing Arrangement between NASA and ESA for the constellation implementation. Further discussion on the way forward and the definition of the joint mission between ESA, NASA and other potential partner agencies will carry on during Q2 2023.

7.1.9 Aeolus-2

Aeolus-2 is a Doppler Wind Lidar designed to measure atmospheric winds through measurement of doppler shifts in the backscatter of emitted laser light from molecules, water droplets and aerosols in the atmosphere. The measurement principle has been successfully demonstrated on the first Aeolus mission and the Aeolus Doppler Wind Lidar instrument has been ranked by ECMWF as having the second highest impact on the accuracy of Numerical Weather Prediction of any single Satellite instrument.

The Aeolus-2 development will be based on an evolution of the Aeolus heritage, taking into account the lessons learned from the Aeolus development and in-orbit performances / operations, as well as from other similar spaceborne laser projects.

The objective of the Aeolus-2 mission is to provide Europe and, by extension, the

international community, with the unique capability to measure atmospheric winds for the support of Numerical Weather Prediction and to improve the understanding of atmospheric dynamics and associated processes.
Launch of the first Aeolus-2 Satellite is foreseen in 2030, with a series of two Satellites providing over ten years of operations.
The Aeolus-2 Space Segment consists of a series of two Satellites. The primary Payload is a Doppler Wind Lidar instrument operating in the ultra-violet spectrum (355 nm).
In addition, provided the accommodation is confirmed to be feasible, a Radio Occultation sounder (to provide high vertical resolution, all-weather atmospheric sounding by tracking Galileo, GPS and Beidou satellites) will also be embarked. The Aeolus-2 Satellites will fly in a “dawn-dusk”, sun-synchronous orbit, with the Satellite orbiting above the day-night terminator and the Doppler Wind Lidar instrument pointing 35° off-nadir, perpendicular to the ground track, to the night side of the Earth.

The Programme will be implemented in co-operation with EUMETSAT. The ESA Aeolus-2 Programme will fund the development (Phase B2/C/D/E1), including the Proto-Flight Model Satellite.
EUMETSAT will provide a fixed financial contribution to the ESA Aeolus-2 Programme for Phase C/D/E1, and will fully fund the recurrent Satellite. In addition, EUMETSAT will develop the Ground Segment, procure the Launch Services and perform the operations. The roles and responsibilities of ESA and EUMETSAT regarding cooperation on the development of Aeolus-2 will be based on the successful cooperation model previously used for the Meteosat Third Generation and MetOp Second Generation Programmes.

7.1.10 Arctic Weather Satellite (AWS)

Approved at Space19+ (ESA's Council at Ministerial Level), this small satellite (~100kg) is the prototype for a future constellation of small satellites carrying microwave sounder instruments. The AWS advanced sensors will provide information about humidity, precipitation and ice clouds in the atmosphere. This data offers meteorological institutes excellent opportunities to improve weather forecasts in Arctic and subarctic areas and helps improve the quality of global forecasts.

EUMETSAT would operate this potential future operational constellation. Thisprototype to be launch in 2024 will serve for one year as a demo for the future constellation.

- The Mission CDR was kicked-off in January 2023 and Board was held on 7 March. The main outcomes are to re-enforce the Payload structure, to finalise the DQM test campaign and fix performance issues, improve test plans and procedures, improve AOCS and OBSW maturity and increase MCS/Operations readiness.
- The test campaign for the Spacecraft Structural Model (SM), including a detailed Payload SM and elegant Solar Array SM's, was completed in January. Results confirmed improved load levels to the Platform equipments and towards the Payload. The Payload structure was identified to require some local reinforcement and a delta Payload SM campaign has been planned for April. In addition, the Solar Array deployment shows that the Hold-Down and Release Mechanism (HDRM) created large shock towards the

Platform and a local re-design of the HDRM is on-going. The Platform Structural Model campaign has further supported correlation of the Finite Element Model (FEM), allowing the start of the PFM Structure manufacture. As part of the CDR, the Satellite thermal analysis (combined Platform and Payload) has been completed and Satellite thermal design has been consolidated. A new EMC plan for both Payload and Platform has also been agreed.

- The Platform Avionics Test Bench (ATB) integration is complete. All Platform units are electrically integrated, and functional testing is on-going together with the On-Board Software and AOCS Software testing. Manufacture of the Platform Structure PFM Panels has started with the full delivery of hardware expected in May, which will allow to start the Platform PFM integration.
- The detailed design of the necessary re-enforcements of the Payload, based on the Spacecraft SM test campaign and FEM correlation is complete. Reinforced parts are under manufacture and re-test of the SM was planned in early April. The Development and Qualification Model (DQM) has been built and the TRR was held.

Future Outlook

The key activities for the next months will be the selection of Launch Service Provider for AWS; closure of the AWS Mission CDR; completion of the Payload Development and Qualification Model and delta Payload SM test campaign; completion of the RFCT; and start of the Platform and Payload PFM integration.

7.1.11 TRUTHS

Also approved at the Space19+, TRUTHS with a launch date targeted for 2030 will provide benchmark measurements that improve our ability to estimate the radiative imbalances underlying climate change. Reference datasets from TRUTHS will be used to calibrate other satellitesensors, such as those carried on the Copernicus missions and the emerging constellations of small satellites.

System and design activities of the Phase B1 Extension have been completed with a Final Check-point meeting held on 1-2 February 2022. Analyses on the payload and satellite have been performed, the operational timelines have been evaluated with higher fidelity and the End-to-End Simulator has been completed in its first version and delivered to ESA.

-The technology pre-developments initiated in Phase-A/B1 are being completed. The Cryogenic Solar Absolute Radiometer (CSAR) Vantablack© coating has been completed with the demonstration of stability and performance after cryo-cycling. The validation model of the Hyperspectral Imaging Sensor (HIS) detector has undergone environmental tests and the results will be evaluated during a Test Review Board to be held in April. Photodiodes characterization for the (backup design) of the transfer radiometer have been fully characterized confirming specified performance and are undergoing a long-term stability test.

- Additional pre-developments for Phase B1 Bridging are continuing. The HIS spectrometer prism and polarization scrambler manufactured at TOPTEC (CZ) are

completing characterization tests, the CSAR cavities and baffles have been manufactured at PMOD (CH) and have been shipped for black coating, and the procurement of the long-lead batch of ROIC (read-out integrated circuits) of the HIS detectors at Teledyne-E2V has been kicked-off.

- Proposals in response to the ITT for the Ground Segment consolidation studies have been received and the TEB convened at end March to evaluate them. The study is procured in restricted competition within the Participating Member States and is funded with the Phase A/B1 available budget.

Future Outlook

In the Q2 2023 reporting period, the following activities are planned:

• Completion of the on-going key Technology Pre-developments initiated in Phase A/B1) and continuation of the MBSE activity.

• Reception of the Industry proposal in response to the RFQ for Phase B2/Advance C of the Space Segment at end May and TEB activities in June.

• Negotiation and kick-off of the selected bidding Teams for the Ground Segment Consolidation study.

• Completion of the TMAC Science Study and initiation of a possible bridging science activity.

7.1.12 ALTIUS

ALTIUS (Atmospheric Limb Tracker for Investigation of the Upcoming Stratosphere) is a satellite mission proposed by the Belgian Institute for Space Aeronomy and currently under development by ESA. Its main objective is to monitor the distributionand evolution of stratospheric ozone in the Earth's atmosphere. The industrial consortium is led by QinetiQ Space, acting as mission prime. The satellite design is based on the PROBA small satellite bus. The payload, developed by OIP Sensor Systems, is an innovative UV, visible and NIR instrument. Launch date readiness date is maintained to December 2025.

- Heavy workload in Instrument team is again noticeable with difficulties to cope with the required high level of task parallelism, jeopardizing the schedule. However appropriate priority settings are defined allowing the team to follow a clear road towards the CDR and the critical path related flight hardware release.
- STM assembly is complete, and the vibration test was successfully performed.
- Qualification Models: Three QM assemblies are in development, the Focal Plane, the Front-End Optics and the acousto-optic tuneable filter (AOTF). The Focal Plane redesign after shock test failure was complete but detailed analyses are still showing negative margin of safety for shock. Further design iterations are required and on-going.
- The manufacturing readiness was released for the communication Syrlinks units (X-Band, S-Band) and is about to be released for the GNSS.

- Propulsion PFM assembly has been on hold for the resolution of the thruster pipes cracks and welding non compliances. After intensive iterations, a solution compatible with structural loads, fluid analysis and accommodation on the bottom board has been found.
- Mass memory QM environmental testing completed successfully. FM PCB delivered, assembly pending delivery of last EEE components.
- The ground segment elements are progressing nominally. The change request for the implementation of the secondary product was released to industry and the proposal is under preparation. Level 2 processing performances are underassessment with a performance check milestone end-April.
  Technical iterations with NRCAN took place for the use of Canadian ground stations for Altius. The main issue remains the guarantee of the availability of the stations for Altius passes which might be a blocking point for the NRCAN solution.

Future Outlook

Platform avionics FM environmental test completion.
•Platform avionics Mass Memory FM TRR
•Platform propulsion repair work complete
•Platform propulsion mechanical tank qualification TRR
•Instrument STM TVAC test complete ready for System shock test
•Instrument electronics UV channel test complete
•FEO QM re-manufacturing complete
•AOTF EM Testing complete, QM under testing.
•FPA QM manufacturing complete
•All Instrument optical and mechanical parts PFM Manufacturing Release
•Successful completion of FPI system EM life test and delivery
•Delivery of platform flight harness

7.2 Future Sentinel missions (planned and potential)

In addition to meteorological satellites, the Copernicus missions, which form part ofthe Copernicus Space Component, will collect robust, long-term climate-relevant datasets.

7.2.1 Sentinel-1 C and D

Due to the launch delay of Sentinel-1C following the VEGA-C launch failure in Dec 2022, the Sentinel-1B disposal phase will be able to start earlier than initially planned (originally foreseen after Sentinel-1C Commissioning Phase). As agreed with COM, the Sentinel-1B re-orbiting will start in Q2 2023, with the objective to reach the final disposal orbit by end of 2023.

Sentinel-1C Launch Campaign halted, the spacecraft has been transported from TAS Cannes to TAS Rome. Sentinel-1C will be put on storage in a ‘ready-to-launch’ configuration, pending new Launch Slot announcement.

Sentinel-1C QAR successfully held on 15 December 2022, Sentinel-1C activities to be

replanned once the new Launch Slot (initially set from 22 May to 21 June 2023) will be communicated. Formal announcement of new Launch Slot proposal by Arianespace is now expected in July 2023.

Sentinel-1D AIT activities will meanwhile re-start: this allows to reduce the dependence on the repatriation of Ground Support Equipment after the Sentinel-1C launch campaign, and to exploit the expertise of the current teams. Sentinel-1D spacecraft is currently still in storage. Solar Array Wings (SAW) and SAR instrument level tests completed.

On 31 March 2023, the Procurement Board approved, with conditions, version 1.5 of the Procurement Work Plan 2023, the Contract Proposal for 'Implementation of the Sentinel-1D AIT Contractual Option', and the Procurement Proposal for 'Dynamic Purchasing System (DPS) for Copernicus Contributing Missions (CCMs): Competitions with Category 3: Earth Observation Data Suppliers for miscellaneous data needs under the MFF 2021-2027'.

Authorisation has been delivered by the European Commission to assess compatibility of Sentinel-C+D with alternative launcher as a risk mitigation measure.

7.2.2 Sentinel-2 C and D

Launch Service contract kick-off for Sentinel-2C was held with Arianespace. Sentinel-2C activities to be replanned (extension of storage and Phase E1) once a new Launch Slot will be announced by Arianespace.

An anticipation of Sentinel-2D AIT and acceptance test in 2024 (instead of at the end of the storage period) is being considered (similar approach as adopted for Sentinel-1D). Both Satellites are in storage and the yearly health check is completed for Sentinel-2C and in progress for Sentinel-2D.

7.2.3 Sentinel-3 C and D

Sentinel-3C activities need to be replanned once a new Launch Slot will be announced by Arianespace. A further extension of the storage for Sentinel-3C is being prepared. Sentinel-3C satellite is in storage in TAS-F (excluding SLSTR-C) and SLSTR-C is in storage configuration in Leonardo. Sentinel-3D satellite is in storage. PF/TOPO/POD and OLCI-C in storage configurations in TAS-F.

SLSTR-D calibration activities are completed, including instrument level reviews (CRR/DRB). SLSTR-D Pre-Storage Review is completed, and SLSTR-D is in storage configuration in Leonardo.

7.2.4 Sentinels-4/-5

The Sentinel-4 and Sentinel-5 missions are dedicated to monitoring the composition of the atmosphere for GMES Atmosphere Services. Both missions will be carried on meteorological satellites operated by EUMETSAT. The Sentinel-4 and -5 missions will

provide information on atmospheric variables in support of European policies.
Services will include the monitoring of air quality, stratospheric ozone and solarradiation, and climate monitoring.

Sentinel-4

The Sentinel-4 instrument data, jointly with other data from future meteorological missions, will cover the need for continuous monitoring of atmospheric composition and air quality over Europe with a revisit time of about one hour. The main data products will be O3 (Ozone), NO2 (Nitrogen dioxide), SO2 (Sulphur dioxide), HCHO (Formaldehyde), CHOCHO (Glyoxal) and the aerosol optical depth.

Two Sentinel-4 instruments, procured within the Copernicus Space Component (CSC) Programme, will be delivered to the Meteosat Third Generation (MTG) programme to be embarked on the two sounder satellites (MTG-S1 and MTG-S2), as Customer Furnished Items, fully verified, qualified and calibrated together with the necessary ground support equipment, test models and system deliverable inputs.

The main elements of the Sentinel-4 system are:

• The Proto-Flight Model (PFM) and the Flight Model (FM2) instruments, consisting of three main components: the Optical Instrument Module (OIM), the Instrument Control Unit (ICU) and the Scan Drive Electronic (SDE) unit.

• The Level 0 to Level 1b processor (L1OP) and the Level 1b to Level 2 Processor (L2OP), both hosted by the MTG Ground Segment. They include the interfaces to the users, the mission performance functions and the performance analyses, related, for example, to the instrument monitoring and trending together with the algorithms' maintenance and validation.

- Since the arrival of the Sentinel-4 PFM Optical Instrument Module (OIM) at the MTG Prime Contractor premises in Bremen on 9 December a series of preparatory activities ahead of the OIM integration onto the MTG-S1 platform have been completed nominally.
- A series of review meetings have taken place during this reporting period with the participation of representatives of the Sentinel-4 Prime Contractor, ESA Sentinel-4 Project, ESA MTG and MTG Prime Contractor aimed at consolidating the plans and the specifications for the S/C level functional, mechanical, EMC and thermal tests, which will take place between the second half of 2023 and the beginning of 2024. No specific criticality about Sentinel-4 has been identified so far.
- Telescope-Spectrometer Assembly (TSA) structure: the in-air alignment verification of the three optical assemblies with the final set of shims was successfully completed during this reporting period.
- Optical Instrument Module (OIM): the OIM AIT plan progressed nominally during this reporting period with mechanical and electrical AIT activities of various units (Aperture Cover, Instrument Control Units, Calibration Assembly, etc). This phase will be completed in May 2023 with the scanner integration.

- S4 / MTG Interface meetings: the S4–MTG interfaces are in a very satisfactory status with no critical aspect identified

Future Outlook

• Continue the support to the MTG-S1 S/C level AIT activities and the preparation for the final PFM instrument Qualification & Acceptance Review (QAR).
• Continue the integration and testing of the FM2

Sentinel-5

The Sentinel-5 mission, jointly with data from other future meteorological missions, will cover the need for continuous global monitoring of atmospheric composition and air quality. The main data products will be O3 (Ozone), NO2 (Nitrogen dioxide), SO2 (Sulphur dioxide), HCHO (Formaldehyde), CHOCHO (Glyoxal), aerosol optical depth and layer height, CH4 (Methane), CO (Carbon monoxide), UV index and vegetation fluorescence (through the NIR channel extension).
The Sentinel-5 Best practices tables have been removed from Annex 4 as they were not updated any longer (for info, they can be consulted in previous QSRs until Q4 2022).

The Sentinel-5 project comprises the development and production of three instruments to be embarked on subsequent MetOp-SG satellites (type A):
• The Sentinel-5A Proto-Flight Model (PFM) unit development, including the Level-1b and Level-2 ground processor prototypes, covered by the GMES Space Component Programme.
• The Sentinel-5B and -5C units development up to the Pre-storage Review covered by the Copernicus programme, and including the long term storage of both instruments subject to approval by the European Commission.

- System level activities were focussed on the execution of the environmental tests of the PFM instrument and resolution and follow-up of the various technical issues, in particular on the Mechanical Ground Support Equipment at the RAL facility. The Intermediate Integration Model was delivered to MetOp-SG, as planned, in 2021 and support to PFM satellite-level tests is provided on demand as required. The unit successfully passed vibration tests at spacecraft level. With respect to the system level Proto-Flight Model (PFM), all integration activities were completed in 2022.
- With the completion of the Optical Support Programme, which consisted of end-to-end tests of the UVN spectrometers, Airbus was able to perform early verifications of multiple optical performance parameters in ambient conditions, such as: • Field-of-view, across-track coverage, line-of-sight, spatial sampling, spectral oversampling, spot size, spectrometer smile and frown, spectral and spatial co-registration, instrument spectral response function for homogeneous and in-homogeneous scenes and preliminary straylight performance.
- The latest released version of the Application Software (ASW version 2.1.6) was uploaded in the Instrument Control Subsystem (ICS) of the instrument PFM. All

integrated tests have been executed with this version. During these integrated tests at Airbus, some additional software problem reports were identified. CRISA and GMV have corrected the issues and an updated version of the software will be delivered.
- Regarding the characterization and calibration (CnC) Optical Ground Support Equipment (OGSE), the last element (the FEL lamp) has been calibrated and is ready for use. The complete CnC OGSE has now completed individual acceptance testing. An end-to-end testing of all the GSE required for the calibration campaign is currently on-going at RAL.

Future Outlook
- Complete the new detector design validations at Lynred;
- Improve ICS shielding to resolve the EMC RE non-compliance;
- Resolve the Spectral Light Source issue and repair the CAS units
- Complete the RAL STC-3 vacuum chamber and MGSE commissioning;
- Proceed with PFM environmental test campaign at RAL;

7.2.5 Sentinel Next Generation:

Sentinel-1 NG
The two-Phase A/B1 Contracts with TAS-I and ADS GmbH are currently completing the Phase B1 for their Intermediate System Requirements Reviews: one already held in February 2023 for ADS-DE and another one to be held in April 2023 for TAS-I. Predevelopment activities are running in parallel to Phase B1 for a planned completion after the ISRRs focussing on SAR Instrument Technology technological innovation.

Sentinel-2 NG and Sentinel-3 Optical NG:
The Phase 0 activities of the two projects, including the CCNs, are expected to finish in Q2/Q3 2023. During the reporting period, an Ad-Hoc Expert Group meeting was held on 25-26 January for Sentinel-2 NG, and on 22-23 February for the Sentinel-3 Optical NG mission. Also the call for MAGs was open and will be concluded on 31 March, after which the first MAG meetings for the two missions will be held (on 27-28 June for Sentinel-2 and on 22-23 May for Sentinel-3).

Sentinel-3 Topo NG
As per Phase A/B1 PCR decision in July, the Sentinel-3 NGTopo mission will be implemented as two satellites (PFM and FM2) both carrying Wide-Swath and Nadir altimeters, together with multi-channels/beam radiometer and POD instruments as baseline. The Phase A/B1 activities proceed with PRR kick-off and Board meetings took place (for the two parallel contracts with ADS and OHB) during the reporting period. The ISRRs are planned in early 2024. The Mission Gate Review (MGR) in early 2024 will confirm the above baseline considering: a) the Phase A/B1 ISRR outcome (including risk and affordability assessment) and b) the return of in-flight experience and validation of the NASA/CNES SWOT mission (launched on 16 December).

Sentinel-6 NG:
The Assessment SEa Level rise Stability Uncertainty (ASELSU) study aimed at developing a detailed uncertainty budget in support of this mission development has concluded. A final meeting was held at ESTEC on 1 February 2023 but a CCN is currently in preparation to extend the work for 2 more years.

7.3 Copernicus Expansion Missions

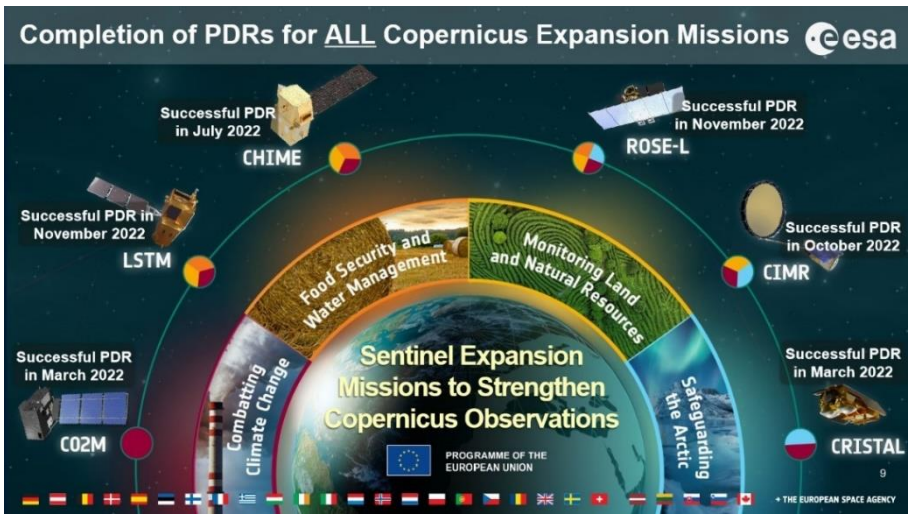
Data from the Copernicus Sentinels developed by ESA, feed into the Copernicus Services, which help address challenges such as urbanisation, food security, rising sea levels, diminishing polar ice, natural disasters and, of course, climate change.

Looking to the future, the following six Copernicus Expansion are being studied to address EU policy and gaps in Copernicus user needs, and to expand the current capabilities of the Copernicus space component.

On 20 January 2022, COM and ESA presented a joint proposal on the way forward at the occasion of the 6th Joint Informal PB-EO/Space Programme Committee in Copernicus Configuration on Copernicus. The proposal foresees: an increase of the allocated budget delegated to ESA from 3365 M€ to 3394 M€; the introduction of a new programmatic milestone called 'Funding Gate Milestone (FGM) no later than 30 June 2024; an implementation scheme based on the postponement of a series of industrial commitments. This joint proposal allows for additional budget up to FGM and to continue the implementation according to the User Requirements and the goals of EU policies while securing the missing funding.

Sentinel development activities, including Copernicus Expansion missions and Next Generation missions, continued in line with Segment 4 of the Copernicus Space Component (CSC) Programme, the FutureEO Programme and the CSC Long Term Scenario.

The System Requirements Reviews for the 6 Copernicus Expansion missions have been completed.



7.3.1 CHIME: Copernicus Hyperspectral Imaging Mission

The CHIME mission, which includes a constellation of two satellites, aims at augmenting the CSC with precise spectroscopic measurements to derive quantitative surface characteristics supporting the monitoring, implementation and improvement of a range of policies in the domain of raw materials, agriculture, soils, food security, biodiversity, environmental degradation and hazards, inland and coastal waters, snow, forestry and the urban environment.

The mission would complement Copernicus Sentinel-2 for applications such as land-cover mapping.

- Both Phase A/B1 contracts are closed.
- After the closure of the System PDR main effort concentrated on all remaining lower-level activities: The Elegant Bread-Board (EBB) of the CHIME Data Processing Unit (DPU) continued its test program and the first test results addressing the CMD/CTRL functions shared between both FPGAs are available. The DPU PDR was now postponed in order to focus on FPGA SRR and EBB test conclusion.
- Consolidation of the Structure and Thermal subsystem design is progressing as expected. Co-engineering activities between TAS-F and OHB-SE took place for the Propulsion subsystem development.
- CHIME Harness PDR was successfully held during the reporting period. The Solar Array Driving Mechanism (SADM) EQSR was closed out during the reporting period with some major actions to be fulfilled by the equipment supplier.
- After the closure of the Instrument PDR main effort concentrated on all remaining lower-level activities: With the conclusion on TRL6 for detector unit and detector package, TRL6 is achieved for all instrument related items. The instrument schedule is currently stable with a foreseen advancement of the instrument CDR by several months to autumn 2024. This advancement however might be jeopardised by hardware deliverables of focal plane system and telescope equipment for the instrument EFM and STM campaigns.

Future Outlook

- After completion of PDR, lower level PDRs are carried out.

7.3.2 CIMR: Copernicus Imaging Microwave Radiometer

The aim of the Copernicus Imaging Microwave Radiometer (CIMR) mission, which includes a constellation of two satellites, is to provide high-spatial resolution microwave imaging radiometry measurements and derived products with continuous global coverage (~95% daily, no gap at the poles) and sub-daily (6 hours average) revisit in the polar regions and adjacent seas, to address Copernicus user needs.

The primary mission requirements are to acquire global observations to address Sea Ice

Concentration (SIC) and Sea Surface Temperature (SST) with secondary requirements covering a very wide number of parameters related to COM Arctic Policy including: ice-type, sea-ice drift, thin sea-ice thickness, terrestrial snow extent, sea surface salinity, ice surface temperature, wind speed over the ocean, soil moisture, and vegetation indices. CIMR satellites will operate in synergy with MetOp-SG(B), providing collocated and contemporaneous measurements in the polar regions with MWI/ICI and SCA instruments.

- The Instrument assembly is non-compliant to the mass allocation and axial stiffness. An ESA-TAS-OHB Mechanical Peer Review has been activated, scrutinizing the driving requirements and proposed design; final decision is expected by summer. Few Instrument BBs/EMs are under manufacturing, and test results will be available by Q2 (RCA) and Q3 (RFPU) of 2023. Several reviews have been held for the Instrument equipment, such as ABSA PDR, PCU PDR, SCE EQSR, plus a number of unit-level MPCBs and Progress Meetings.
- The System Requirement Document (SRD) issue 2.0 (consistent with the SSRD 3.0 and MRD 5.0) has been released. The performances presented at the S/I-PDR are globally compliant with the SSRD, excepting few NCs that are expected to be recovered in phase C (NeDT and TSU). The re-design needed to enlarge C-band and L-band is part of the upgraded baseline and is on-going. In order to consolidate the key performances in early phase C, three ESA-Industry Working Groups have been activated, to tackle End-to-End performances, Instrument Calibration and Antenna Beam Efficiency
- Meetings with ESRIN have been held in support to the definition of the key elements of cooperation with EUMETSAT.
- The Spacecraft mass, including all maturity margins, is compliant to VEGA-C performances (with 8% system margin). As recommended at the S-/I-PDR Board, the mass evolution is kept under strict monitoring.

Future Outlook

• Sign the remaining Sub-contracts/Riders
• Complete the Antenna and LDRS PDRs
• Progress on developments (BB and EM models) at lower levels
• Progress on the GSE procurement through Best Practices process.
• 10th round of Progress Meetings with Industrial Consortium.

7.3.3 CO2M: Copernicus Anthropogenic Carbon Dioxide Monitoring

This mission, which includes a constellation of three satellites, aims to provide Copernicus with a CO2 monitoring and verification support capacity, capable of estimating anthropogenic CO2 emissions at country and megacity scales. This operational capacity shall allow evaluating the implementation and effectiveness of the CO2 emission reduction strategies proposed in the Paris Agreement. Such a system needs to provide accurate and consistent quantification of anthropogenic CO2 emissions and their trends. As part of the product portfolio and in support of themain mission

objective, there will be also CH4, NO2, aerosol and solar-induced fluorescence of vegetation operationally retrieved at similarly high spatial resolution. Although this includes air quality relevant information, these products are not necessarily retrieved in near-real time. CO2M will be operated by EUMETSAT.

- Activities from the Phase A/B1 contract are not closed.
- Over the reporting period activities are progressing with focus on preparation of the analysis towards satellite CDR and the procurement of the flight HW.

  The CO2M Payload comprises three instruments: the core instrument is the combined CO2 & NO2 Instrument (CO2I) dedicated to atmospheric CO2, CH4 and NO2 measurements led by TAS-F; the Multi Angles Polarimeter instrument (MAP) dedicated to aerosols measurement is led by TAS-UK; and the CLoud IMager instrument (CLIM) dedicated to cloud detection is led by OIP.
- The Payload engineering activities have been mainly devoted in consolidating the C phase program of work, in close collaboration with the Satellite team for system and interfaces architecture, following the PDR Board recommendation. Main activities covered were:
  - Consolidation of the Payload performance by regularly holding performance workshops
  - Progress on the Payload detailed design (architecture and analysis) required for CDR in the different engineering domains.
- The L0 Product Format Specification (PFS) common to the Operational Processor (led by EUMETSAT) and to the Prototype Processor (led by ESA) have been jointly agreed and co-signed by ESA and EUMETSAT. The actions for the System and Ground Segment PDR have been worked out in Q1 2023 with a major emphasis on the System IVV update. As part of joint approach some common processes are also in place. The first joint ESA and EUMETSAT Control Change Board is planned in April 2023. This CCB will adds up to the already existing common elements for collaboration in CO2M and is meant to manage the changes on a set of documents shared among us. Following the successful PDR, the roadmap to prepare together the System CDR, including System and Ground Segment documentation is now planned for Q2 2023. The OPSPREP forum is gradually ramping up with regular meetings between ESOC and EUMETSAT. The plan is that, after the summer, the OPSPREP collaboration will exponentially increase towards the preparation of the first Satellite Validation test (currently planned in Q2 2024).

Future Outlook

- Progress on developments programme (OM and EM tests at SAT, CO2I, MAP and CLIM level when applicable) in view of the PL and Space Segment CDR preparation
- Progress on sub-level CDRs and confirmation of PL CDR dates
- 11th round of Progress Meetings with Industrial Consortium.

7.3.4 CRISTAL: Copernicus Polar Ice and Snow Topography Altimeter

The Copernicus polaR Ice and Snow Topography ALtimeter (CRISTAL) Mission, which includes a constellation of two satellites, shall provide enhanced retrieval of land ice sheet/glacier elevation, sea ice thickness and freeboard and ocean surfaceelevation, wave-height and wind speed by measurements implementing higher spatial resolution. The primary high-level objectives are to monitor critical climate signals: ice sheet, ice cap melting and sea level, as well as to monitor variability of Arctic and Southern Ocean sea-ice and its snow loading to support Copernicus operational products and services concerning the polar regions. Other objectives are to support applications related to coastal and inland waters and contribute to the observation of ocean topography. CRISTAL will carry a multi-frequency radar altimeter and a microwave radiometer. CRISTAL will be operated by ESA and EUM will generate and deliver the globalocean L1 and L2 products. The CRISTAL QAR is currently planned for June 2027.

- In the reporting period several lower level equipment and subsystem reviews have been performed. With, in particular the execution of the structure CDR, where co-location was performed on 7-9 March. Overall, this review was very successful with only a limited number of points to be further improved and updated on the design. The finalization of the design and consequent CDR closeout was planned for begin Q2.
- On the development side both Hardware and Software activities are progressing nominally.

The Satellite configuration has been further consolidated with the confirmation that no payload of opportunity (PLO) will be embarked on CRISTAL. Globally the maturity of the Satellite design can be confirmed and proved by the fact that most of the budgets are positive and stable, namely the satellite mass budget, the power budget, the propellant and delta-V budgets. The contract change notice for the inclusion of the Active Debris Removal (ADR) hardware has been iterated with industry and the formal update of the change notice received end March, ready for implementation in Q2.

- All lower-level instrument PDR activities have now been completed and preparation of sub-system CDR's started. Central Electronics Unit procurement schedule has been stabilised during this reporting period.

- One major milestone was accomplished in this quarter: the SIRS CDR. The complete set of specification and design documents (architecture, interfaces, algorithms theoretical baseline descriptions, detailed processing models) and verification and validation plans were thoroughly reviewed.

- The first joint CRISTAL/LSTM Operations Meeting, involving ESOC, ESTEC and Industry representatives has been held in March 2023. Next meeting in planned in July 2023. A joint Copernicus Expansion ground segment co-ordination meeting (involving all 6 missions) took place with ESRIN at the beginning of February. Further iterations with ESRIN are expected to take place in Q2 2023 with respect to the CRISTAL specific Ground Segment preparation activities. The first ESOC Copernicus Expansions Flight Operations Segment (FOS) checkpoint, including the CRISTAL FOS instance is planned

in Q4 2023.

- An outline of the implementing arrangement has been presented at ESA/EUM bilateral in January 2023. A first draft of the implementing arrangement for CRISTAL has been prepared and will now be distributed for internal review and updating in Q2, planned to be finalised and implemented in Q4 2023.

- Iteration with NASA have progressed on the implementing arrangement for CRISTAL (under the framework agreement which was signed last June). Concept paper which serves as input has now been finalised and ready for submission to NASA HQ. It is planned to have formal implementation in Q4 2023.

Future Outlook

• System, IRIS and MAG PM

7.3.5 LSTM: Copernicus Land Surface Temperature Monitoring

Surface temperature is already being observed from space with thermal infrared (TIR) sensors, however at spatio-temporal resolutions insufficient for many applications and services, including agriculture. The LSTM mission, which includes aconstellation of two satellites, will increase the spatial resolution of the TIR observations currently provided by Copernicus by a factor 400, bringing them to fieldscale. This mission shall be able to complement the current visible (VIS) and near- infrared (NIR) Copernicus observations with high spatio-temporal resolution TIR observations over land and coastal regions in support of agriculture management services and possibly a range of additional services.

- ROIC HCI tests were conducted in February. No anomalies have been found. The TRB for the HCI test was held on 28.02.2023. The test is successfully concluded. Vibration, shock, thermal vacuum, and humidity storage tests on representative models have been finalised and declared successful. After initial electro optical (e/o) and spectral test, the HTS test started beginning of March. The second temperature range is scheduled to conclude beginning of April. After this, final e/o test campaign will be conducted.
- A workshop on mission analysis and another one on space debris were held. The status of both activities are in line with the expectations at this phase of the project and a clear way forward to CDR has been agreed. As a highlight, it has been confirmed the Moon entering in the FoV of the instrument twice a year. This information has been passed to the instrument team and it will be considered in the data processing.
- The control re-entry analysis was repeated as part of the actions required by S-PDR and it confirmed the consistency of the thrust performance between mission analysis and propulsion specifications, enabling a successful re-entry manoeuvre.
- LSTM / CRISTAL operational meetings with industry have been established. First one was held in March at ESOC and the next one is scheduled for July at Airbus Friedrichshafen.

- AOCS Software PDR has been conducted successfully.
- Independent software validation and verification activities have been kicked-off.
- During the last reporting period, phase C/D for all subcontractors has been released and the associated Phase C/D kick off meetings conducted with the exception of the platform thermal hardware and the test facilities, for which ample margin still exists.
- The Verification approach for the Cryo Optical Bench (COB): The activities to re-assess the representativity of the structural model (SAM) and its adequacy to secure the correct COB optical alignment, are progressing with several workshops organised between industry and ESA to converge in the most adequate model philosophy. –
- The Scan Mirror dynamic envelope interference with the CSM door dynamic envelope: Study on-going (electrical aspects completed incl. impact on harness), discussion with ICU supplier on-going to assess feasibility of the preferred option.
- Instrument application SW: Instrument SW SRR planning is being consolidated.
- TRL-6 tests for Detectors and Optics progressed as planned during this quarter. MTF tests for the TIR detector encountered delays due to the lack of adequate test bench at the subcontractor premises. Instrument prime proposes to conduct the MTF tests on-house to de-risk this activity
- The International Workshop on High-Resolution Thermal EO was held at ESRIN in May.

Future Outlook

- System, Instrument and MAG PM

7.3.6 ROSE-L: L-band Synthetic Aperture Radar

ESA has undertaken the development of the L-band Synthetic Aperture Radar (SAR) Mission, referred to as Radar Observing System for Europe (ROSE-L). This mission, which includes a constellation of two satellites, will acquire systematically and provide routinely data and information products for the Copernicus Marine, Land, Climate Change and Emergency services, as well as to the recently proposed Copernicus Land European Ground Motion service (EGMS).

Its target applications are the measurement of surface deformation of vegetated and faster moving terrain, soil moisture, land cover classification, crop type discrimination and its temporal analysis. Furthermore, the mission will monitor Polar ice sheets and ice caps, and the sea-ice conditions (i.e. type, drift, deformation, concentration, lead fraction), as well as contribute to the European maritime situational awareness. Applications will be further enhanced through the combined use of ROSE-L and Sentinel-1. The ROSE-L mission will provide repeat-pass SAR interferometry (InSAR).

Following the successful completion of the System PDR, the activities in this reporting period focused on the verification and close-out of System PDR actions. In addition, in

the frame of the Instrument PDR, end-to-end SAR performance and calibration aspects were reviewed and resulting discrepancies were discussed with industry during collocation meetings. In addition, in view of updating the end-to-end calibration budgets and in support of the SAR processer development, co-engineering activities focused on defining the requirements and achievable accuracy of the SAR instrument On-Ground Characterization (OGC).
At System level, the analysis of the impact of Radio Frequency Interferences (RFIs), with ROSE-L as source, on on-ground GNSS receivers and airport radars is progressing well. Preliminary results show that ROSE-L does not cause any risk of damaging onground GNSS receivers and the expected degradation of the performance would be well below the ITU threshold for GNSS receivers typically used for Satellite-based Augmentation Services (SBAS) such as ESA's European Geostationary Navigation Overlay Service (EGNOS).

Furthermore, following ITU regulation, the RFI analysis regarding other services operating in the L-band frequency spectrum, such as the Radio Navigation Satellite Service (RNSS) and the Aeronautical Radio Navigation Services (ARNS), is ongoing. It shall be noted that achieving compliance with the ITU requirements for these services has also been challenging for other L-band SAR missions (e.g., JAXA's ALOS-4 and NASA/ISRO's NISAR missions). The ROSE-L Project team is working in close collaboration with the ESA Frequency Management Office to define additional activities to be performed in the context of the ROSE-L application for ITU frequency assignment. Further discussions have been held with the Prime regarding the potential upgrade of the ROSE-L GNSS receiver functionality to improve the accuracy of the ROSE-L Precise Orbit Determination (POD), and as such the orbital baseline determination for repeat-pass SAR interferometry (InSAR), especially in support of achieving accurate surface deformation measurements. Such a functionality upgrade would facilitate the implementation of a Companion friendliness capability of the ROSE-L mission. Development impacts provided by the Prime are being assessed by the Project.
- The Multi Core SW (MCSW) SRR Part 3, related to common platform development, has been held with some actions to be completed before the close-out planned for June. The contract kick-off meeting for the magneto-torquer bars and magnetometers was successfully completed and supported.
- Instrument PDR was successfully concluded. The board meeting was held on 21 March with an action for Industry to define a detailed action plan to recover the current performance non-compliances; primarily to address the issue of thermoelastic deformation of the antenna, which is a main error contributor to the performance.

Following the System PDR, the activities regarding the development of the End-toEnd Simulator and Ground Prototype Processor (GPP) focused on the close-out of actions, such as the update of the Algorithm Definition Document. In addition, the further development of software modules for both the End-to-End Simulator and Ground Prototype Processor (GPP) is progressing as planned. A system-level meeting with representatives from the operational Ground Segment took place to discuss high-level

inputs to the Space-to-Ground interface and the development of the operational SAR processor.

Future Outlook

• Units/Susbystems reviews + Instrument and System PM

• Implementation of activities listed in the ROSE-L science plan

Launch manifest

The launch dates depend on technical readiness, such as the Quality Acceptance Review (QAR) and Flight Acceptance Review (FAR) and on available launch windows from the launch operators. The dates of relevant milestones are listed below. It shall be noted that future dates are indicative and will evolve over time:

Sentinel-4B AR – Q4 2024; delivery to MTG (after 10 y storage) - 2034
Sentinel-5A AR; delivery to MetOp-SG – October 2023
CHIME (PFM) - QAR – Q3 2028
CO2M (PFM) - QAR – Mid January 2026
CO2M (FM2) - FAR – End January 2026
CRISTAL (PFM) QAR – June 2027
LSTM (PFM) QAR - October 2028
ROSE-L (PFM) QAR – Q1 2028

7.4 ESA Climate Change Initiative (CCI)

7.4.1 Background

Combined satellite and *in situ* data archives can be used to produce data products for climate monitoring, modelling and prediction. To this end, the ESA Climate Change Initiative (CCI) was launched in 2009. The CCI has been created to addressthe GCOS Essential Climate Variable (ECV) requirements for satellite datasets and derived products. Its principal objective is "*to realize the full potential of the long-term global Earth Observation archives that ESA together with its Member states have established over the last thirty years, as a significant and timely contribution to the ECV databases required by the UNFCCC*". The CCI focuses on the exploitation of data records primarily, but not exclusively, from past ESA satellite missions, for the benefit of climate monitoring and climate research. It complements existing efforts inEurope (e.g. led by EUMETSAT through the CM SAF) and internationally which focus on datasets characterizing meteorological aspects of the climate system.

7.4.2 Current status

The implementation of the CCI programme continues nominally with the following highlights to be noted:

•The implementation of CCI phase 2 is on-going, with the majority of extensions to existing ECV projects, and the associated funding, being placed. The selection of the CCI research fellows is on-going. The ITT for long-lived greenhouse gases will close in April 2023.
•The new climate initiative, CLIMATE-SPACE, was presented and over-subscribed to at the Ministerial Council 2022 (CM22). The implementation approach was endorsed by PB-EO in February 2023. The procurement proposal will be presented to AC/IPC in April/May 2023.
•WCRP's Coupled Model Intercomparison Project International Project Office (CMIP-IPO) continues to establish its activities in preparation for CMIP-7workand has successfully passed its first annual review in February. Further discussions on collaboration with WCRP have taken place, in particular in view of the WCRP Open Science Conference in 2023.
•The Climate Science Advisory Board (CSAB) endorsed the CLIMATE-SPACE implementation approach in its last meeting in January 2023. The next meeting is planned for summer 2023.
•The 13th CCI and Climate Modelling User Group (CMUG) colocation meeting is planned for w/c 6 November 2023 at ECSAT.
•The River discharge_cci precursor project, led by CNRS-LEGOS, kicked off on 18 January.
•Collaboration with operational climate services and with the international climate network are on-going. A bilateral with EUMETSAT took place in January 2023.
•The CEOS/CGMS WG Climate took place 28 February-2 March at JAXA.
•In March 2023 IPCC released the AR6 Synthesis report, highlighting the main points from the WG I, II and III report and asking for climate action.

7.4.3 Scientific highlights

Water Vapour: A scientific milestone has been achieved through the publication of our total column water vapour product over land and oceans, CM SAF/CCI TCWV-global (COMBI). This dataset is a joint development with Eumetsat CM SAF, being constructed from the ESA/CCI water vapour over land product and a Eumetsat CM SAF water vapour over ocean product (HOAPS). In keeping with the CCI objective to handover CCI-developed ECVs to operational entities, this dataset is being published by the CM SAF.
Permafrost: A new paper by Bartsch, A., et al (2023) Permafrost Monitoring from Space, explains that trends from modelling results using land surface temperature agree with a multitude of proxies observable from space.https://doi.org/10.1007/s10712-023-09770-3
Lakes: A new report (Pinardi, M. et al, 2023) presents a study to investigate the effects of fire events in lake water quality, with particular focus on pristine lakes at regional and global scale. Main results indicated a response in phytoplankton biomass growth due to fire only in a limited number of oligotrophic lakes. Responses to wildfires for lakes with a higher trophic level were also found, hence suggesting the opportunity to further investigate responses in these lakes. https://doi.org/10.3389/frsen.2023.1107275

Biomass: Version 4 of the CCI Biomass dataset has been improved through the exclusive access to ALOS-2 observations through a collaboration with the Japanese Aerospace Exploration Agency (JAXA), as well as algorithm developments. Publication on ESA Open data portal, imminent)

Land Surface Temperature: A country scale assessment of the heat hazard-risk in urban areas (Cheval, 2023) has been published.
https://doi.org/10.1016/j.buildenv.2022.109892

Cloud: Stengel, M. et al (2023) could indicate potential shortcomings of a common model parametrization for cloud ice particle effective radius.
https://doi.org/10.1029/2022GL102521

GHG: The new version 1.8 of the GHG-CCI+ CH4_S5P_WFMD methane data product retrieved from TROPOMI/S5P using the WFMD algorithm has been published during the reporting period (Schneising et al., 2023 https://doi.org/10.5194/amt-16-669-2023). Former versions of the WFMD product have been used to obtain methane emission information for high northern latitudes (Tsuruta et al., 2023) and high spatial resolution methane emission information from the oil and gas industry in the Permian Basin, USA (Veefkind et al., 2023).

Sea Ice: The ESMR SIC CDR (1972-1975) provides a temporal extension to the sea ice record. This first version shows good validation results.

Sea level: A new coastal altimeter sea level dataset (v2.2) covering of Europe, Africa, Asia and America during 2002-2020. It consists in a selection of 756 coastal virtual stations, where the closest points to the coast (within 1-6 km) allow the estimate of sea level trends (https://doi.org/10.17882/74354).

SST: SST CCI v3 dataset is being used in beta-test mode by over a dozen trail blazer users.

Glaciers: A study by Kochtitzky et al. (2022) assessed marine-terminating glacier ice loss in the northern hemisphere via frontal ablation. It combined measurements or estimates of ice thickness, surface velocity using historical datasets produced in Phase 1 of Glaciers_cci+. The findings suggest that this process can have a stronger control on mass loss from glaciers than melt in some regions, and has implications for assessing sea-level. The study revealed that the most affected coastal areas are the Russian Arctic, Svalbard (both hot spots of Glaciers_cci+) and Alaska.

Land Cover: An analysis-ready 29-year time series of annual 300-metre resolution plant functional type maps has been generated for climate modellers. https://doi.org/10.5194/essd-15-1465-2023

Fire: A paper in Science reports record-high CO2 emissions from boreal forest fires in 2021 (https://doi.org/10.1126/science.ade0805), and another about the impact of wildfires on water quality (see Lakes above)

RECCAP-2: Nature publication - Heinrich et. Al. (2023), One quarter of humid tropical forest emissions offset during recovery, https://doi.org/10.1038/s41586-022-05679-w

7.4.4 New Datasets

The following new datasets are available on the CCI Open data portal (climate.esa.int/data):

•Water Vapour: A combined high resolution global TCWV product from microwave and near infrared imagers - COMBI, Satellite Application Facility on Climate Monitoring, https://doi.org/10.5676/EUM_SAF_CM/COMBI/V001
•Sea Ice: ESMR SIC CDR (1972-1975)
https://catalogue.ceda.ac.uk/uuid/34a15b96f1134d9e95b9e486d74e49cf
•Sea level: New network of virtual altimetry stations for measuring sea level along the world coastlines. https://www.seanoe.org/data/00631/74354/9
•Land cover medium resolution: Global Plant Functional Types (PFT) Dataset,v2.0.8-
https://catalogue.ceda.ac.uk/uuid/26a0f46c95ee4c29b5c650b129aab788
•Soil Moisture: SM product COMBINED product, Version 07.1-
https://catalogue.ceda.ac.uk/uuid/c7e974411cfe4cf99cb077f7cb4d75d4

CEOS/CGMS WGClimate

The last CEOS/CGMS WGClimate meeting took place on 28 February-2 March 2023 at JAXA in Japan. It was the first meeting with Jeff Privette (NOAA) being the new chairman and Wenying Su from NASA being the WGClimate vice chair. The agenda covered the ECV inventory status and gap analysis report version 4, discussing its capacity to address GCOS updated implementation needs, the evolution of the WMO use cases and their uptake, the CDR definition and the Space agencies' response to GCOS' updated implementation plan. The next meeting is planned for 16-17 October 2023.

In the Greenhouse Gas (GHG) Task Team under the CEOS WGClimate, ESA is represented by Ben Veihelmann (co-lead of the CEOS Atmospheric Composition Virtual Constellation AC-VC) and Yaska Meijer (CO2M Mission Scientist), now being the chairman of this group. Jointly with ESA's Climate Office and input from ESRIN, they have provided feedback on the GHG Roadmap implementation actions. The Task Team has completed the "Roadmap for Implementation of a Constellation Architecture for Monitoring Carbon Dioxide and Methane from Space" in cooperation with CGMS and GSICS.
ESA (SIT chair) coordinated the publication of a "CEOS Strategy to Support the Global Stocktake of the UNFCCC Paris Agreement" paper by the CEOS GST team. The GST team combines more than ten CEOS groups involved in the preparations of the CEOS' contribution to the 2023 and 2028 GST. This paper sets out a way forward by which CEOS Agencies can coordinate their efforts to support the first and subsequent Global Stocktake (GST) of the 2015 Paris Agreement among Parties to the United Nations Framework Convention on Climate Change (UNFCCC). It covers the specific modalities of the GST and proposes where and how Agencies can support its implementation. Support may be either to the overall assessment of collective progress through the GST, or to individual parties in their transparent reporting as required by the Paris Agreement. The paper includes a series of recommendations with corresponding future actions, building on the significant efforts to date.