CGMS

CGMS-40 ESA-WP-02
v1A Draft, 18 October 2012

Prepared by ESA
Agenda Item: Session III.2
Discussed in Plenary

REPORT ON THE STATUS OF ESA CURRENT AND FUTURE SATELLITE SYSTEMS AND ON ESA SUPPORT TO GCOS AND OTHER CLIMATE MONITORING ACTIVITIES

CGMS is informed of the status of the current European Space Agency Earth Observation missions. Two of them, MSG and MetOp are in co-operation with EUMETSAT. ERS-2, the second ESA EO mission, launched in 1995, was switched off in July 2011 after thirteen years of data acquisition. The Envisat mission, launched in 2002, was terminated on 8 April 2012, after over ten years of successful operation, following a sudden, unexplained, loss of communication with the satellite. The Gravity field and steady-state Ocean Circulation Explorer, GOCE, the first Explorer satellite launched on 17 March 2009, completed its nominal mission in April 2011. GOCE continues to provide top-quality gravity field data. The CryoSat-2 satellite was launched on 8 April 2010. The first CryoSat Arctic sea-ice thickness map was presented in June 2011. Release of systematic CryoSat products (Level 1b and 2) to scientific community is going on. The SMOS satellite was launched on 2 November 2009. SMOS Level 2 data products were released at the end of October 2010. All reprocessed Level 1 and 2 data are available from the ESA Cal/Val portal since mid-March 2012. About 4000 data user projects worldwide use data from the ESA EO missions and this number is increasing further. The total volume of ESA EO mission data exceeds 100 Terabytes per year.

CGMS is further informed of the status of the future European Space Agency Earth Observation missions. Two of them, MTG and Post EPS (now EPS SG) are in co-operation with EUMETSAT. The Living Planet Programme has three lines of implementation: Earth Explorer satellites, Earth Watch satellites plus services and applications demonstration. A 7th Core Explorer is under selection out of 3 pre-selected. Progress in the preparation of the forthcoming Explorer missions ADM-AEOLUS, Swarm and EarthCARE is described. GMES represents the major new initiative of European efforts in Earth Observation. The start of the GMES pre-operational services took place in 2008, with the provision of the relevant data. The first GMES dedicated satellites (the "Sentinels") will be launched in 2013. Related activities are under way at all stages within the Agency, the EC and at Member States level.

CGMS is also informed of the status of the Earthwatch Programme Element, Global Monitoring of Essential Climate Variables (also known as the 'ESA Climate Change Initiative' or CCI). The CCI Programme has continued to progress well. The eleven existing project teams have made significant progress on algorithm development and on specifying a future operational system. The Programme has been enhanced by the addition of three new ECV project teams who started work in January 2012. Overall the Programme remains on target to achieve its phase 1 objectives, with a mid-term review held on 27 September 2012.

REPORT ON THE STATUS OF ESA CURRENT AND FUTURE SATELLITE SYSTEMS AND ON ESA SUPPORT TO GCOS AND OTHER CLIMATE MONITORING ACTIVITIES

1 INTRODUCTION

ERS-2, the second ESA EO mission, launched in 1995, was switched off in July 2011 after sixteen years of data acquisition.

The Envisat mission, launched in 2002, was terminated on 8 April 2012, after over ten years of successful operation, following a sudden, unexplained, loss of communication with the satellite.

Though Envisat, ERS-1 and ERS-2 are no longer operating, users can access easily the large ESA archives to get products generated from their respective instrument complements.

The Gravity field and steady-state Ocean Circulation Explorer, GOCE, was the first Explorer satellite launched on 17 March 2009. The nominal mission, consisting of 6 uninterrupted global measurement cycles, has been completed in April 2011. GOCE continues to provide top-quality gravity field data.

The SMOS satellite was launched on 2 November 2009 and was commissioned in May 2010. SMOS Level 2 data products were released at the end of October 2010. The 1st SMOS data reprocessing campaign has been completed in February 2012. All reprocessed Level 1 and 2 data are available from the ESA Cal/Val portal since mid-March. No major anomalies have impacted the availability of SMOS science data in the recent period. The new NRT light data product is routinely generated and provided to the UK Met Office for distribution to operational agencies since February. A dedicated SMOS ocean data user meeting has taken place at EGU in April 2012. The RFI situation in particular over Europe continues to improve. However, some very strong sources are still present.

The Cryosat-2 satellite was launched on 8 April 2010 and since then, commissioning and validation activities have taken place. Commissioning activities were completed on 25 October 2010. The first CryoSat Arctic sea-ice thickness map was presented in June 2011. Release of systematic CryoSat products (Level 1b and 2) to scientific community is going on.

2 CURRENT ESA SATELLITE SYSTEMS

Satellites	Space Agency	Equator Crossing Time + Altitude	Launch date	Access to data or products(Links)	Instruments	Status, applications and other information
Envisat	ESA	10:00 (D) 800 km	1/03/2002	Earthnet on line	- ASAR, RA-2 - AATSR - MERIS - GOMOS - MIPAS - MWR - SCIAMACHY	**Operations terminated on 8 April 2012** following loss of contact with the spacecraft
PROBA	ESA	10:30 (D) 615 km	22/10/2001	Earthnet on line	CHRIS	Drifting orbit. Technology experiment. AO Science mission since 2001.
GOCE	ESA	06:00 (A) 260 km	17/03/2009	Earthnet on line	Electrostatic Gravity Gradiometer Satellite-to-Satellite Tracking Instrument	(Gravity field and Ocean steady-state Circulation Explorer)

SMOS	ESA	06:00 (A) 755 km	2/11/2009	SMOS data centres	MIRAS (Microwave Imaging Radiometer using Aperture Synthesis)	L-band radiometer for Salinity & Soil Moisture observation
CryoSat-2	ESA	717 km (92° incl.)	8/04/2010	Earthnet on line	SIRAL (SAR Interferometric Radar Altimeter) + DORIS	Polar ice monitoring

2.1 Status of current R&D satellite systems

2.1.1 Status of the Envisat mission

The Envisat mission reached 10 years of exploitation in March 2012. After the launch by Ariane-5 on 1st March 2002 and a thorough commissioning phase, the Envisat mission and its data have gradually imposed a strong presence in the Earth Observation user communities in Europe and outside Europe. The mission had doubled its planned five-year lifetime. The Envisat mission still proceeded nominally, apart from the GOMOS instrument affected by degraded harness insulation in a bundle since mid-2011.

An orbit inclination manoeuvre was performed on 1st March 2012. This was the first of a series of three manoeuvres allowing technically an additional one-year extension of the Envisat satellite operations beyond mid-2014, i.e. until mid-2015 with a view to reduce the probability of a data gap before the Sentinel missions are fully in operations. Two more manoeuvres were planned to take place in summer and autumn 2012. However communication with the satellite was suddenly lost on 8 April. Following rigorous attempts to re-establish contact and the investigation of failure scenarios, the end of the mission was being declared in May.

For a decade, Envisat had been keeping watch over our planet. The number and the diversity of its user communities is astonishing: about 2000 peer-reviewed scientific publications in many Earth science fields: oceanography, cryosphere, atmospheric composition, land use, tectonics, etc., a large operational use for public services such as oil spill monitoring, land subsidence or air quality. More than 4000 data user projects worldwide in over 70 countries have been supported with Envisat data. Now with the end of the mission, the launch of the upcoming GMES Sentinel satellites has become even more urgent to ensure the continuity of data to users, improve the management of the environment, understand and mitigate the effects of climate change and ensure civil security.

The most complete information about the Envisat mission can be found at http://envisat.esa.int/ and http://www.esa.int/esaEO/SEMWYN2VQUD_index_0_m.html.

2.1.2 Status of CHRIS-PROBA

The Earthnet/Third Party Mission (TPM) Programme enables harmonized access to non-ESA missions for the benefit of European users. Currently, ESA provides access to data from 25 Third Party Missions and more than 30 instruments, including among others MODIS on Aqua and Terra, GRACE, GOSAT, JASON, KOMPSAT-2, LANDSAT/MSS-TM-ETM, Pléiades, RapidEye, SPOT, Formosat and CHRIS/Proba.

After a long interruption Proba-1 is running nominally in its 11th year of successful operations: a software fix performed in March returned its radiation-damaged star trackers to full operations. Processing and data distribution to users were carried out nominally. Proba-1 with the CHRIS instrument is supporting a large user community (around 400 Cat-1 projects).

More information on CHRIS/Proba can be found at
https://earth.esa.int/web/guest/missions/esa-operational-eo-missions/proba

2.1.3 Status of GOCE

The aim of the Gravity field and steady-state Ocean Circulation Explorer (GOCE) mission is to provide global and regional models for the Earth's gravity field and for the geoid, its reference equipotential surface, with high spatial resolution and accuracy. Such models will be used in a wide range of research and application areas, including global ocean circulation, physics of the interior of the Earth and levelling systems based on GPS.

2.1.3.1 Initial Achievements

The mission responds to the requirements put forward by many international scientific Programmes such as the WOCE, CLIVAR and GOOS. It was designed for the determination of an accurate description of the ocean dynamic topography and, thereby, the mean ocean circulation, as an essential complement to the precise monitoring of ocean temporal variability already provided by altimetry. The gravity vector cannot be measured directly in orbit, but can be inferred from other observations. The GOCE carries a gravity gradiometer that measures gravity gradients and GNSS (Global Navigation Satellite Systems) receivers for precise satellite positioning. The satellite was launched into a 96.67 degrees sun-synchronous orbit on 17 March 2009, and reached its 254.9 km mapping altitude in early September 2009, after successfully completing the commissioning phase and the instrument calibration. Mapping of the Earth gravity field is being carried out in cycles of 61 days. Contrary to pre-mission scenarios operations are also carried out in the eclipse season. The first gravity field solutions from the mission were released in 2010, and are proving to change the understanding of the Earth gravity at medium-to high resolution.

GOCE successfully completed its nominal mission on 15 April 2011. The primary mission goal of acquiring 12 months of excellent quality data had already been achieved at the end of February 2011. Currently continuing in its extended phase the mission will – as more data is being collected – steadily deliver even further improved gravity field and geoid data products.

2.1.3.2 Current Status

GOCE continues to provide top-quality gravity field data. Measurement cycle number 11 was completed on 16 January 2012. A routine gradiometer instrument calibration was subsequently performed the day after (as is done regularly between subsequent 61-days repeat cycles).

A satellite safe-mode anomaly occurred on 5 March 2012. The platform software stopped executing and a reboot of the redundant main computer CDMU-B was triggered by the watchdog. The event that caused the anomaly left no observable trace in the telemetry and the anomaly hence remains unexplained. The subsequent satellite recovery was immediate and nominal, and all on-board systems reacted as expected. Orbit control via the ion propulsion system could be re-established within 30 hours of the anomaly. Following the anomaly, nominal science operations were resumed on 8 March. A recalibration of the gradiometer was performed on 15 March.

With the exception of a few stormy days in early March, the near-Earth space environment has – on average – been rather benign throughout the first quarter of the year. Mean drag values hover around 4 mN, a notable decrease compared to the levels seen in the previous period. An assessment of the status of the satellite's power subsystem in view of the imminent maximum of the current solar cycle has concluded that the present orbital altitude could be maintained during the forthcoming long eclipse season, i.e., from June to August 2012.

Altitude scenarios for the targeted further mission extension until 2014 are being assessed based on input from the science community and taking into account satellite resources and predictions regarding the space environment. Investigations concluded that the current orbital altitude of 254.9 km can be maintained during the critical summer months of 2012. A similar investigation into altitude scenarios for the second half of 2012 and for any further mission extension until the exhaustion of the Xenon gas (used as propellant for the ion engine) has been conducted. Contrary to the scenario described above, the justified assumption was here that all of GOCE's mission objectives will already have been fulfilled by the end of 2012 and that – if needed – certain contained and calculated risk in operating the satellite can and shall be taken in order to maximize science return in the remaining operational lifetime. Flying lower is essential to acquire data of sufficient quality and spatial resolution: hence the mission management team is strongly encouraged by the science community to explore all possible means to operate a sizable portion of the remaining lifetime at lower altitudes. The on-going investigations focus on mission scenarios with operational altitudes up to 20 km lower than the current 254.9 km. A conclusion of this investigation will be presented to DOSTAG and PB-EO at the end of September 2012.

All Payload Data Ground Segment (PDGS) components are running nominally according to procedures and the scenarios described in the PDGS operational concept documentation. Similarly, the High-Level Processing Facility is continuing its work to generate and validate the Level 2 gravity field data products fully according to plan. Data products at all levels are routinely generated and are of excellent quality. Furthermore, a detailed review of the Level 2 products (gravity field models and related functions, i.e. gravity gradient grids, precise orbits, etc.) has demonstrated the compliance of GOCE with its mission requirements.

Current Release 3 gravity field solutions expand – with a signal-to-noise ration above 1 – out to degree 250 (80 km). No other satellite mission, flying or planned, will – within the coming decade or longer – be able to map gravity at such spatial resolutions. Reprocessing of full mission history of gradiometer Level 1b products was completed by second quarter of 2012. Release 4 of GOCE gravity field model(s) will occur in October/November 2012 based on nominal and extended mission Level 1b data processed, using the updated gradiometer processing algorithms.

Xenon gas consumption figures (directly linked to the air density) predict the exhaustion of the tank by end of 2013 or early 2014, depending on the space environment predictions). Thereafter GOCE will re-enter the Earth's atmosphere within weeks. By that time, GOCE would have acquired more than four times the amount of data foreseen by the nominal mission profile.

A plan for the definition of the scientific objectives for the GOCE operations beyond 2012 until end of mission is being elaborated, taking full account of technical feasibility of the space segment.

More information on GOCE can be found at http://www.esa.int/esaLP/LPgoce.html and http://earth.esa.int/goce.

2.1.4 Status of CryoSat

The goals of CryoSat are to measure fluctuations in marine and land ice mass fluxes within the limit set by natural variability. Predicting future climate and sea level depends on knowledge of such fluctuations, while present observations are deficient in time and space. CryoSat and International Programmes will provide a decade of focused study of the roles of the cryosphere.

2.1.4.1 Initial Achievements

The technical concept consists of a single spacecraft in a high inclination orbit, carrying a Ku-band altimeter, measuring altitude with detailed precision, capable of operating in conventional pulse limited mode, synthetic aperture mode and interferometry mode.

The satellite was launched into a 92 degrees non sun-synchronous orbit on 8 April 2010 by a Dnepr vehicle from the Baikonur Cosmodrome. The main instrument – the altimeter SIRAL – was switched on a few days later and immediately showed that it was in perfect state. Commissioning and validation activities started soon after and only three months later, the first data were released to the Cal/Val community. The ground segment software and dissemination systems are in good shape. The release of CryoSat data to the scientific community started in autumn 2010, just after the end of the commissioning.

The first major post-launch validation campaign was successfully carried out in April and May 2011 in collaboration with NASA. The status of the mission and plans for the Arctic spring validation campaign were presented along with latest scientific results at the European Geophysical Union (EGU) General Assembly in April in Vienna. The first CryoSat Arctic sea-ice thickness map was presented at the Salon International de l'Aéronautique et de l'Espace at Le Bourget in June 2011.

2.1.4.2 Current Status

The overall performance of the CryoSat mission was satisfactory over last year. The space segment performed well with no major issues on the platform and payload. The overall ground segment performed nominally. The new version of the Level 1b and Level 2 processors were released into operations at the beginning of February. The first reprocessing campaign started in the 2nd quarter of 2012. A second Arctic joint validation campaign was initiated in March 2012 in cooperation with NASA.

Overall, the satellite is in very good health. The average fuel consumption is around 9.9 grams per week with more than 34kg remaining on-board. The ESOC Flight Operations Segment (FOS) experienced one major problem during the first quarter of the year, but which had no impact on the acquisition of science data. On 1st February 2012, the new version of the Level 1b and Level 2 processors were released into operations. SIRAL scientific data, now marked with a new baseline B, are being continuously released to the scientific community with the nominal average delay of 30-36 days from acquisition. The reprocessing of all CryoSat data acquired from July 2010 to January 2012 began in June. In 2011, the end-to-end mission performance, namely, the overall mission data return, taking into consideration planned (0.9%) and unplanned unavailability (2.0%), was greater than 97%.

The 2nd meeting of the CryoSat Quality Working Group took place at ESRIN on 17-19 January. The main purpose of the meeting was to certify that the new version of the processors had truly solved the issues identified. It was confirmed that the data quality of the SAR and SARIN processors are now very good. It is worth noting that the quality of the ocean data is still to be improved.

With the recent implementation of the Baseline B of the CryoSat processor and the completion of the reprocessing campaign of all CryoSat data foreseen in 2013, the first detailed assessment of the achievement of the mission objectives in terms of ice thickness variation (cm/y) will be possible.

Ocean measurements from ESA's CryoSat mission are being now exploited by CNES to provide global ocean observation products in near-real time. CryoSat ocean measurements are

being processed by CNES and distributed to the oceanography community. These products will be assimilated using models from the MyOcean project in near-real time to enhance sea surface products and to improve the quality of the forecasts.

The second major post-launch validation campaign in support of the CryoSat mission – CryoVEx 2012 – was initiated on 22 March 2012 and lasted until 10 May 2012. The main sites covered included Northern Canada, Greenland and Norway (Svalbard). Major objectives included spatially coincident under-flights of CryoSat over sea and land ice to support direct comparisons between airborne and space-borne data for L1 and L2 product calibration and validation. The campaign included extensive collaboration with parallel efforts initiated and managed by NASA. In total the campaign involved five airplanes and over 80 participants.

More information on CryoSat-2 can be found at http://www.esa.int/esaLP/LPcryosat.html and http://earth.esa.int/cryosat.

2.1.5 Status of SMOS

The Soil Moisture and Ocean Salinity (SMOS) mission is the European Space Agency's (ESA) second Earth Explorer Opportunity mission. The scientific objectives of the SMOS mission directly respond to the current lack of global observations of soil moisture and ocean salinity, two key variables used in predictive hydrological, oceanographic and atmospheric models. SMOS observations will also provide information on the characterization of ice and snow covered surfaces and the sea ice effect on ocean-atmosphere heat fluxes and dynamics, which affects large-scale processes of the Earth's climate system.

2.1.5.1 Initial Achievements

The SMOS mission was launched on 2 November 2009 from Plesetsk, Russia. The first 6 months of the mission were dedicated to commissioning the satellite and payload. The commissioning phase ended successfully in May 2009, with both space and ground segment functioning well and system requirements being fulfilled. Since then SMOS has entered its routine operations phase.

The development of the SMOS mission was conducted in cooperation between ESA, CNES and CDTI under the overall responsibility and leadership of ESA. In the operations phase ESA and CNES share the responsibility for running the mission. The platform is operated under full CNES responsibility.

2.1.5.2 Current Status

The 1st SMOS data reprocessing campaign has been completed in February 2012. All reprocessed Level 1 and 2 data are available from the ESA Cal/Val portal since mid-March. No major anomalies have impacted the availability of SMOS science data in the recent period. The new NRT light data product is routinely generated and provided to the UK Met Office for distribution to operational agencies since February. A dedicated SMOS ocean data user meeting has taken place at EGU in April 2012. The RFI situation in particular over Europe continues to improve. However, some very strong sources are still present.

The satellite platform is operated under full CNES responsibility. No major anomalies or failures have been identified since launch, and the same applies for the interfaces to the payload. The SMOS payload is operating nominally with the exception of some well-known anomalies, some of which reoccurred. With the presently implemented mitigation strategies the unavailability time has been strongly reduced and the performance in the recent period has been 99.83%.

The data acquisition is split between the XBAS acquisition system at ESAC and Svalbard (operated by KSAT), due to the near-real time requirement for SMOS data, and has successfully acquired 98.3% of the passes, with ESAC acquiring 97.0% of the passes and Svalbard 99.6%. Due to the 2.2-orbit overlap between ESAC and Svalbard acquisitions, there is no data gap due to acquisition failure, i.e. all data acquired by SMOS are ingested in the DPGS at ESAC. For example, the acquired data were successfully processed to 99.1% for Level 0, Level 1, and both Level 2 soil moisture and ocean salinity, 98.6% for NRT Level 1 for the period 13 December 2011 to 15 March 2012. The NRT product was delivered in 80.1% of the sensing time within the requirement of 165 minutes. In that period the data dissemination of the nominal data has continued from ESAC.

Since the deployment of the new NRT processor version at the beginning of March the new NRT light data product is routinely generated and provided to the UK Met Office for distribution to operational agencies. The new NRT light product is significantly reduced in size (10% of original size) whilst keeping full angular resolution on a reduced regular grid, including only land coverage. This will make the NRT data product more accessible for operational agencies.

The reprocessing of the entire mission data set since January 2010 has been completed in February and the reprocessed data are now available through the ESA Cal/Val portal operated by Brockmann. As reported previously, ESA reprocessed the Level 1 and Level 2 ocean salinity data at the DPGS at ESAC. CNES/CESBIO agreed to reprocess the Level 2 soil moisture data.

The International Soil Moisture Network (ISMN) was initiated in 2009 in conjunction with the Global Energy and Water Cycle Experiment (GEWEX), the Group on Earth Observations (GEO) and the Committee on Earth Observation Satellites (CEOS) to assemble existing global *in situ* soil moisture records in a standardized, global data base. Data hosting, maintenance and web-based distribution has been performed by the Vienna University of Technology.

SMOS NRT data are pre-processed and monitored operationally by ECMWF. These monitoring results are published semi-operationally on a daily basis on the ECMWF web site.

A number of scientific SMOS-supporting studies (e.g. ice study, data assimilation, permafrost, hydrology, etc.) as well as Cal/Val activities are being conducted. Several workshops and sessions took place at EGU in April and IGARSS in July.

Further progress has been made in identifying and reporting RFI sources and following-up the investigations of the National Spectrum Management authorities. The main changes in the overall situation concern : China, where authorities have initiated the switch off of more than 30 RFI sources ; Canada which has refurbished its L-Band radar network (during the 2nd half of 2011) to comply with ITU radio regulation – as a consequence important improvements have been observed ; Germany which is in the process to refurbish some elements of their radar transmitter network to ensure that out-of-band emissions are not interfering the passive band 1400-1427 MHz ; and, Ukraine where a wireless web-camera operating in the passive band was found as source of the single remaining RFI reported to the authorities in March 2012 – the vendor of this equipment was identified and stopped its activity within the country. Some sporadic RFIs have been detected over the ocean (in particular Hawaii).

More information on SMOS can be found at http://www.esa.int/esaLP/LPsmos.html and http://earth.esa.int/smos.

2.1.6 References

Further information about the various current ESA missions can be found on the following WWW addresses which offer the possibility to download many supporting relevant documentation:

http://www.esa.int
http://earth.esa.int

3 FUTURE SATELLITE SYSTEMS

Satellites	Space Agency	Equator Crossing Time + Altitude	Launch date	Status, applications and other information
SWARM	ESA	300/530 km (3 spacecraft)	November 2012	Geomagnetic field
ADM-Aeolus	ESA	18:00 (A) 405 km	2015	Doppler Lidar (ALADIN) wind profile by aerosol, clouds and molecular backscatter
EarthCARE	ESA-JAXA	10:30 (D) 450 km	November 2015	ATLID, BBR, CPR, MSI, Cloud, radiation and aerosol interaction processes
Sentinel-1A	ESA	18:00 (A) 693 km	October 2013	Monitoring of sea ice zones and the Arctic environment
Sentinel-1B	ESA	18:00 (A) 693 km	2015	Same as Sentinel-1A
Sentinel-2A	ESA	10:30 (D) 786km	June 2014	Land cover maps, generation of leaf coverage, leaf chlorophyll content and leaf water content.
Sentinel-2B	ESA	10:30 (D) 786km	2015	Same as Sentinel-2A
Sentinel-3A	ESA/EUMETSAT	10:00 (D) 815 km	April 2014	Ocean and global land monitoring Radar altimeter (SRAL) and MWR, OLCI, SLSTR
Sentinel-3B	ESA/EUMETSAT	10:00 (D) 815 km	2015	Ocean and global land monitoring Radar altimeter (SRAL) and MWR, OLCI, SLSTR
Sentinel-5P	ESA-NSO	13:30 (A) 824km	June 2015	Global atmospheric composition and air quality monitoring services

3.1 Status of future R&D satellite systems

3.1.1 Introduction

The Earth Observation Directorate of the European Space Agency (ESA) is currently running several Programmes. Two of these, MTG and post EPS (now called EPS Second Generation in EUMETSAT documents) are in co-operation with EUMETSAT. The Living Planet Programme has three lines of implementation: Earth Explorer satellites, Earth Watch satellites plus services & applications demonstration. GMES represents the major new initiative of European efforts in Earth Observation. The start of the GMES pre-operational services took place in 2008, with the provision of the relevant data. The first GMES dedicated satellites (the "Sentinels") will be launched in 2013. Related activities are under way at all stages within the Agency, the EC and at Member States level.

3.1.2 Status of the Earth Explorer Missions

3.1.2.1 Scope of the Earth Explorers

The Earth Explorers are research oriented space missions tackling critical Earth science issues. There are two types of such missions, subject to programmatic functions i.e.

- Core Missions, are ESA-led and dedicated to long term research objectives. They are complex and large in scope missions, which must tackle a range of fundamental problems of wide community interest whilst remaining well-focused. It must be supported by a wide (international) community of scientists.
- Opportunity Missions are smaller-scale projects, not necessarily led by ESA. They are designed to be a fast and flexible response to a single critical scientific issue and subject to strong financial and development constraints.

The financial limits only relate to the ESA contribution, but the Earth Observation Envelope Programme is designed to encourage international co-operation. In the context of international co-operation, a core mission would be expected normally to be led by ESA, but can include important contribution from partner Agencies.

In the past years, a number of missions have been selected for implementation, namely three Core missions:

- GOCE (Gravity and steady-state Ocean Circulation Explorer)
- ADM-Aeolus (Atmospheric Dynamics Mission)
- EarthCARE (clouds, aerosols and radiation)
- and three Opportunity Missions:
- CryoSat (Polar Ice Monitoring)
- SMOS (Soil Moisture and Ocean Salinity)
- Swarm (The Earth's magnetic field and environment explorers)

3.1.2.2 ADM-Aeolus

The Atmospheric Dynamics Mission Aeolus will demonstrate the possibility of providing observations of winds at altitudes between the surface and about 30 km. This will help to correct a major deficiency in the current (meteorological) operational observing network. The data will be assimilated into Numerical Weather Prediction models, and is expected to improve weather forecasts globally. It will further provide information for the study of the global circulation including general transport properties of the troposphere and lower stratosphere.

The Aeolus mission will provide data to address some of the key concerns of the World Climate Research Programme i.e. quantification of climate variability, validation and improvement of climate models and process studies relevant to climate change. The provision of global wind profiles in cloud-free air will help to accomplish several objectives of the Global Climate Observing System and improve our understanding of the Earth's global energy budget. Aeolus will also provide profiles of backscatter and extinction coefficients (so-called spin-off products), which will allow the retrieval of cloud and aerosol information.

The main space element of Aeolus is the ALADIN instrument i.e. a Doppler wind lidar intended to provide profiles of the horizontal wind in the troposphere and lower stratosphere above or in absence of thick clouds.

Aeolus data will need intensive evaluation in view of a possible operational follow-on.

3.1.2.2.1 Aeolus Project Status

The platform continues to be in storage. The regular maintenance check executed in late 2011 confirmed "good health" of the platform.

The test of the FM-A Laser transmitter under low pressure oxygen conditions and full energy is still running in SG-Firenze, ~150 million shots had been executed as of April 2012. Results

are very encouraging showing excellent performance for most of the key parameters demonstrating a laser which is optically-mechanically stable but with strong sensitivity to thermal drifts in the amplifier units. These drifts can be compensated for, but the compensable range over lifetime still needs to be demonstrated. In addition, what appears to be "a slowly developing" laser damage has been observed on one of the UV mirror assemblies. The root cause is being looked for.

The Master Oscillator alignment of the FM-B laser is completed and shows good results: low noise and low sensitivity over the operational temperature range. Extended sensitivity tests are executed (+/-1G test and cold plate exchange) prior to start of amplifier alignment activities.

The investigations associated with the amplifier connector anomalies are continuing with full intensity by the dedicated investigation team. Part procurement for the preventive repair solution is on-going and detailed *in situ* inspection procedures are being established. In parallel, the variety of observed cracks on the amplifier connectors is being classified with respect to probability of growth.

The refurbishment of the transmitting and receiving optics has experienced an unexpected anomaly in the aberration generator. Although this assembly was not in scope of the refurbishment, detailed inspection has discovered particle contamination inside the closed assembly of both the FM and the spare. The availability of a flight worthy aberration generator is now driving the schedule for the completion of the TRO refurbishment, originally planned for end of February.

The schedule for the *In situ* Cleaning System (ICS) development is continuing to slip with significant delays in delivery of the various equipments, especially the pressure transducers and the pressure regulator. The completion of the subsystem is still planned well before the need date at satellite level.

The Verta-2 launch on VEGA remains baseline, with Rockot as back-up. The earliest launch date on July 2015.

The overall mission planning projects the Satellite Acceptance Review by January 2014 excluding contingencies. The contingencies are driven by the uncertainties related to the refurbishment activities of the laser transmitter UV optics and amplifier connectors.

3.1.2.2.2 Aeolus Science

Various activities in support of Aeolus science are being performed.

The Vertical and Horizontal Aeolus Measurement Positioning (VHAMP) is on schedule with respect to the activities during the last reporting period. The complementary impact study by ECMWF, investigating the optimization of the use of continuous-mode Aeolus wind profile measurements in the ECMWF forecast assimilation system ensuring forecast impact, is also on schedule. First outputs from both of these activities have been provided for the consolidation of the Aeolus Mission Requirements for Continuous Mode operation, and in support of the update of the system requirements. The study looking into the contribution of so-called Rayleigh-Brillouin scattering on the shape of the lidar backscattered signal is on-schedule.

3.1.2.2.3 Aeolus Campaigns

The analysis of data from the last ALADIN Airborne Demonstrator (A2D) campaign in Iceland in October 2009 is being finalized. The final version of the Technical Note describing

the data analysis and main findings was delivered to ESA in February 2012 together with the final version of the report on the Rayleigh spectrometer alignment sensitivity. The report on the Mie radiometric performance was delivered before its final presentation at ESA-ESTEC on 21st of May 2012.

3.1.2.3 EarthCARE

EarthCARE addresses the interaction and impact of clouds and aerosols on the Earth's radiative budget. The difficulty of representing clouds and aerosols and their interactions with radiation constitutes a major source of uncertainty in predictions of climate change. EarthCARE will help in improving numerical models of atmospheric circulation. Accurate representation of cloud processes is also critical for the improvement of NWP.

3.1.2.3.1 EarthCARE Concept

EarthCARE will be implemented in cooperation with JAXA and consists of a single satellite in low Earth sun-synchronous orbit at about 400 km altitude. The EarthCARE mission is centred on the synergetic use of the data provided by the following active and passive sensors:

- Backscatter Lidar (ATLID) - ESA High Spectral Resolution Lidar
- Cloud Profiling Radar (CPR) - JAXA/NICT 94GHz Doppler Radar
- Multi-Spectral Imager (MSI) - ESA 7 channels, 150 km swath, 500 m pixel
- Broadband Radiometer (BBR) - ESA 2 channels, 3 views (nadir, fore and aft)

3.1.2.3.2 EarthCARE Current Status

There has been no significant evolution of satellite configuration and system. The EarthCARE phase C/D contract rider 1 between ESA and ASD has been signed and is being propagated to the full industrial consortium as the project formally enters into Phase C/D.

From a technical point of view, the Base Platform activities focused on the preparation of the sub-systems Critical Design Reviews (CDR) with particular efforts for the Reaction and Control Subsystem. The avionics sub-system is progressing well and is being prepared for the start of the Electrical and Functional test Programme.

For the Payload, good progress has been achieved in the recent months for the MSI, the CPR and ATLID, while the BBR CDR closure efforts could not yet be concluded. JAXA announced that the CPR Instrument CDR is now scheduled for December 2012.

3.1.2.3.3 EarthCARE Science

The European and Canadian members of the Joint Mission Advisory Group met in May 2012 for the first meeting with its revised membership for EarthCARE Phase C. The current instrument and system performance was presented to the Group; no significant performance non-compliances were identified. The status of Level 2 product requirements and algorithm developments was discussed. The Group recalled its recommendation on near-real time data provision for lidar and radar data assimilation and expressed concern about currently lacking commitments by both ESA and JAXA.

The CALIPSO-CloudSat-EarthCARE Joint Workshop took place in Paris in June, hosted by IPSL and jointly funded by ESA, CNES and IPSL, with contributions by INSU-CNRS. About 230 participants from various atmospheric disciplines, with particularly large delegations from France and the USA, discussed the status and further strategy of CALIPSO-CloudSat science exploitation, data products & algorithms and calibration & validation and how these experiences can be utilized for EarthCARE. The workshop reviewed the complex though synergy-driven EarthCARE science data products, and underlined the importance of much

needed global cloud/aerosol profile and radiation data sets with the expected improved performance. The need of sustaining these vitally important measurements for the understanding of key climate-shaping atmospheric processes – even beyond the lifetime of EarthCARE – was stressed.

A preparatory study for the assimilation of EarthCARE data is presently being carried out by ECMWF.

The development of scientific EarthCARE geophysical retrieval (level 2) algorithms is progressing nominally. The scope of ESA-JAXA data products with strong emphasis on algorithms exploiting the synergy of the four EarthCARE instruments was confirmed at the above-mentioned CALIPSO-CloudSat-EarthCARE Joint Workshop.

A number of ESA-funded level 2 development activities are presently ongoing, concerning the theoretical basis of retrieval algorithms of cloud and aerosol data products derived from EarthCARE instruments.

3.1.2.4 SWARM

Swarm will provide the best-ever survey of the geomagnetic field and its temporal evolution. Swarm will offer new insights into the composition and processes in the interior and surroundings of the Earth, thereby improving our knowledge of the climate. It will provide also supplementary information for studying the interaction of the magnetic field with other physical quantities present in the Earth system. Furthermore, it is also sensitive to ocean circulation. Practical applications such as space weather, radiation hazards, navigation and resource exploration could benefit from Swarm.

3.1.2.4.1 SWARM Concept

The Swarm concept consists of a constellation of three satellites in three different polar orbits between 300 and 530 km altitude. Two satellites will fly in close tandem at 480 km initial altitude and one at 530 km altitude, in orbits drifting relative to each other, thus sampling the field in varying geometries and at all local times. High-precision and high-resolution measurements of the strength and direction of the magnetic field will be provided by each satellite. In combination, they will provide the necessary observations that are required to model various sources of the geomagnetic field. GPS receivers, an accelerometer and an electric field instrument will provide supplementary information for studying the interaction of the magnetic field with other physical quantities in the Earth system, and for improving the modelling of the geomagnetic field.

3.1.2.4.2 SWARM Project Status

The three Swarm satellites have successfully completed all tests and are ready for storage.

The flight acceptance review has been successfully completed. Due to launch delay the satellites will be stored up to the date of transport to Plesetsk. The launch campaign preparation is on-going. A number of contracts for assistance during transport and the launch campaign have been put on hold due to the launch delay.

The six ASM (Absolute Scalar Magnetometer) instruments are ready for flight. All three EFI (Electric Field Instrument) instruments are installed on their respective satellite. All Langmuir probes have been successfully calibrated. The last updated software version operates satisfactorily.

The ground segment acceptance review was successfully completed with few remaining issues to be corrected and tasks to be completed. The Ground Segment Overall Validation (GSOV) is almost complete and the GS is ready for operation after launch.

Swarm should be the third Rockot launch to be completed between 10 and 13 of November according to Eurockot/Khrunichev but not confirmed by the publication of a launch manifest. The first Rockot launch planned for July 2 has been postponed to July 28.

3.1.2.4.3 SWARM Science

The study "Multi-Satellite, multi-instrument and ground based observations analysis and study of ULF wave phenomena and products" is progressing nominally and the second progress meeting was held early April in Athens. More detailed information on the contents of the study can be found at the project website: http://proteus.space.noa.gr/~ulf_wave/.

A proposal under the lead of the Finnish Meteorological Institute in response to a RFQ for exploiting synergies between Swarm and Cluster was submitted and reviewed. The proposing team contains experts from DTU Space in Denmark, IRFU in Sweden, GFZ in Germany, IRAP in France and RAL in UK.

3.1.2.5 Future Earth Explorers

A call for Earth Explorer Core ideas for Earth Explorer-7 was issued in 2005. Twenty-four proposals were received and after evaluation mission concept assessment studies of six candidate Earth Explorer missions were performed. A User Consultation Meeting was held in Lisbon in January 2009, and the subsequent evaluation by the Earth Science Advisory Committee in early 2009 led to a recommendation for the down-selection to the following three mission concepts:

- BIOMASS: aims to quantify the forest biomass, the extent of forest and deforested areas and the delimitation of flooded forests by means of P-band SAR.
- PREMIER: to provide high resolution measurements, using mm-wave and IR limb sounding, aimed to study processes in the upper troposphere and lower stratosphere.
- CoReH2O: estimates of snow water equivalent and depth on land and sea ice based on Ku- and X-band SAR observations.

The Phase A activities for the three candidate missions, BIOMASS, CoReH2O and PREMIER, have been timed to support the preparation and publication of the corresponding Reports for Selection in June 2012 and the User Consultation Meeting on Earth Explorer 7 scheduled for early 2013. The process of the selection of the candidates for the Earth Explorer Opportunity mission EE- 8 to step 2 was closed at the end of November 2010 with the approval by the ESA EO Programme Board of the selection of two candidates, namely CarbonSat and FLEX, for Phase A/B1 studies. At the end of the studies, the two candidate missions will be presented again to the user community at a User Consultation Meeting, to take place nominally in 2014. They will be evaluated by the ESA's Earth Science Advisory Committee (ESAC) with the support of the Executive for technical and programmatic aspects, in order to select the eighth Earth Explorer mission for implementation and launch around 2019.

The CarbonSat mission has the following scientific and societal-relevant objectives:

- To quantify magnitudes and spatial and temporal distributions of CO_2 and CH_4 sources and sinks from regional to sub-urban scales;
- To identify the CO_2 uptake mechanisms of the terrestrial biosphere and oceans;

- To determine the response of CO_2 and CH_4 sources and sinks to a changing climate;
- To contribute to treaty verification of UNFCCC and post-Copenhagen agreements.

The main objectives of the FLEX mission are:

- To provide, for the first time, space-based maps of vegetation fluorescence, which can be converted into a quantitative indicator of photosynthetic efficiency rates of terrestrial ecosystems;
- On the strength of evidence that canopy fluorescence is closely correlated with ecosystem carbon uptake, to provide measurements

3.1.3 Status of the Earth Watch Missions

3.1.3.1 Initial actions

These are the operational missions of ESA for partners. Three elements were approved in Edinburgh in 2001:

- TerraSAR Consolidation, phase B and pre-development of a mission deploying a SAR operating in L-band. This activity has been completed.
- Fuegosat Consolidation, born as a demonstrator of a constellation of satellites with IR sensors for (Forest) fire monitoring, it has been redirected to become an element of the EC – ESA initiative on Global Monitoring for Environment and Security (GMES).
- The GMES Service Element (GSE) is ongoing with the consolidation of a number of operational services involving more than 400 users, dozens of service providers, developers and strategic partners. They address all areas of the priorities identified by the EC: Marine monitoring, land monitoring, emergency response, atmosphere monitoring, and security. The GSE has been fundamental in identifying the requirements for the GMES Space Component.

3.1.3.2 Operational Meteorology and Climate Monitoring

ESA is co-operating with EUMETSAT on the deployment of new series of meteorological satellites: MSG (Meteosat Second Generation) and MetOp. MSG-1 was launched in August 2002; MSG-2 in December 2005. MetOp-A was launched after 5 attempts on 19 October 2006. MSG-3 was launched on 5 July 2012 and MetOp-B on 17 September 2012.

Regarding the future generations:

- Post MSG (MTG): The MTG space segment will consist of a twin configuration, MTG-I (Imaging mission) and MTG-S (Sounder mission). A major achievement in the recent period related to the approval of the revised MTG contract proposal in January, which allowed the finalization and signature of the full MTG contract by ESA and TAS-F on February 24. The target launch dates are 2018 for MTG-I and 2020 for MTG-S.
- The GMES Sentinel-4 instrument will be embarked on the MTG-S satellite. For Sentinel 4 the focus remains on the consolidation of the instrument baseline design, with the instrument PDR scheduled for Q3/2012, and progression of the Best Practice procurement process.
- Post MetOp/EPS (MetOp-SG or EPS-SG): Based on the results of the Phase 0 studies, a dual satellite configuration has been endorsed by the EUMETSAT Council in June 2010. Activities are coordinated with those of GMES Sentinel-5. The target launch date is 2019/2020 for the first satellites. ESA is preparing a Programme proposal for MetOp-SG in preparation for the ESA Ministerial Council in November 2012. Elements of this

Programme proposal have been presented to the PB-EO in late September 2011. The major recent achievements for MTG relate to the implementation of the Preliminary Design Reviews for the MTG satellites, the IRS instrument and the FCI Telescope Assembly.

3.1.3.3 The GMES Space Component

GMES represents the major new initiative of European efforts in Earth Observation. The start of the GMES pre-operational services took place in 2008, with the provision of the relevant data. The first GMES dedicated satellites (the "Sentinels") will be launched in 2012-2013. Related activities are under way at all stages within the Agency, the EC and at Member States level.

The ESA GMES Space Component (GSC) program, foresees the development of the following:

- Sentinel-1 mission: two C-band SAR satellites to provide continuity to ERS, ENVISAT, with enhanced capabilities, and to maintain the cooperation with Radarsat. The first Sentinel-1 satellite is planned to be launched in October 2013, the second one in 2015.
- Sentinel-2 mission: two multispectral optical imaging satellites to provide continuity (and enhanced capability) to the data so far obtained from SPOT and Landsat. The first Sentinel-2 satellite is planned to be launched in mid-2014, the second one in 2015.
- Sentinel-3 mission: two ocean and global land monitoring satellites providing ocean colour, sea surface topography and sea and land surface temperature. It will provide enhanced capability and continuity to data as those of MERIS, RA-1 / RA-2, and (A)ATSR. It will also provide continuity to the data so far provided by the Vegetation sensors on SPOT-4 and 5. The first Sentinel-3 satellite is planned to be launched in April 2014 at the earliest, the second one in 2015.
- Ground segment of the above three Sentinel missions. The GSC Programme funding includes the Sentinel-3 ground segment marine part and flight operations segment to be developed by EUMETSAT
- Sentinel-4 mission: two units of an instrument for monitoring of atmospheric composition from the geostationary orbit, to be embarked on the two planned MTG-S satellites (2018 and 2024)
- Sentinel-5 Precursor mission: satellite for atmospheric composition monitoring, filling the data gap between ENVISAT and Sentinel-5. The UVN instrument is provided as specific national contribution by The Netherlands. The planned launch date of the Precursor is June 2015.
- Development and pre-operational access to Earth Observation data from contributing missions required by the GMES services, up to end 2013.

The funded activities also include the studies or technology developments:

- Sentinel-5 Phase A/B1 and pre-developments activities. Sentinel-5 is a low-Earth orbit element devoted to the monitoring of atmospheric composition. The instrument is planned to be embarked on the EPS-SG satellites
- GMES Space Component evolution studies and technology developments
- In order to ensure high-accuracy altimetry data continuity for GMES, ESA is proposing the development of a follow-on mission based on the CryoSat satellite (Jason-CS) in cooperation with the US and EUMETSAT at the ESA Council at Ministerial level in November 2012. Technical meetings have taken place in the course of 2010 and 2011, involving NOAA, EUMETSAT and ESA, aiming at a more refined definition of a

potential cooperation on Jason-CS. In the same context the EC, ESA and EUMETSAT have embarked on discussions to define the long-term high-accuracy altimetry approach for GMES (Jason-3, Jason-CS(A) and -CS(B)).

3.1.3.4 Status of the Sentinels

3.1.3.4.1 Sentinel-1

The Sentinel-1A Assembly Integration and Test (AIT) final campaign is fully in place after the delivery of the Spacecraft Structure in February. Most of the flight equipment of the Platform has already been delivered. The Sentinel-1 project funded three parallel studies, carried out by universities and research institutes, for the development of SAR data-based soil moisture retrieval algorithms in preparation of the future Sentinel-1 data exploitation and potential generation of Level-2 Soil Moisture data products.

3.1.3.4.2 Sentinel-2

Concerning Sentinel-2, a large number of technological problems and of equipment development difficulties caused some schedule slippage over the last two and half years. Now technological problems of the payload instrument have been mostly resolved and relevant technologies are adequately qualified for the Sentinel-2 mission. The Sentinel-2A launch date is envisaged for end of June 2014. The Sentinel-2B Flight Acceptance Review date is March 2015, allowing a launch in May 2015 at earliest. An activity was kicked-off in April 2012 with a consortium led by INRA-F to consolidate the definition of some selected Level 2b prototype algorithms, to prepare a test data set based on airborne calibration campaigns conducted by ESA in the past few years and to make recommendations for future airborne calibration campaigns tailored for the Sentinel-2 mission.

The cooperation agreement between ESA and NASA for “OLI-MSI cross-calibration activities” was signed in the reporting period, and the characterization test activity will be performed in Astrium SaS (F) in October-November 2012. The transfer to Europe of the NASA calibration radiometers is now authorized by the US Department of State following the signature of the Sentinel-2-LANDSAT Cooperation Agreement in June 2012.

3.1.3.4.3 Sentinel-3

On the industrial side, the flight manufacturing of all Satellite elements is proceeding and several Flight units are entering their qualification Programme. The Platform PFM-AIT has entered the main phase with the integration of the first avionics units and the start of the electrical integration. At instrument level, MWR, SLSTR and OLCI EM testing is proceeding successfully and the PFM testing is planned to start shortly. As in the previous periods, the schedule control remains one of the major concerns of the project.

For most of the Sentinel-3 contractors the PFM manufacturing is on-going or almost completed, with most of the equipment deliveries in the first half of 2012. The completion of Platform integration is planned for October 2012. The instrument integration is planned to start in the first quarter of 2013, aiming to start the Satellite environmental test campaign at the end of the summer 2013. With the implementation of all recovery actions currently identified, the earliest Sentinel-3A launch date to which the Agency can commit is now by end of April 2014, with a Flight Acceptance Review for the Sentinel-3B Satellite in first quarter 2015.

3.1.3.4.4 Sentinel-5 Precursor

Sentinel-5 Precursor is a single-satellite atmospheric chemistry mission, aiming at providing a gap-filler, within the 2015-2022 timeframe, between the end-of-life of the current suite of atmospheric chemistry missions (ENVISAT, EOS Aura) and the operational availability of Sentinel-5.

Sentinel-5 Precursor is a cooperative undertaking between ESA and the Kingdom of the Netherlands for the provision of the TROPOMI payload (a UV-VIS-NIR-SWIR push-broom grating Spectrometer) to the Sentinel-5 Precursor mission as established by a cooperation agreement signed by both parties at The Hague on 2 July 2009. Dutch Space is the Prime Contractor for the TROPOMI payload.

Within the reporting period, Dutch Space began detailed design activities of TROPOMI sub-systems with the organization of a first round of Critical Design Reviews (CDRs) that will culminate in a TROPOMI CDR in January 2013. Following consolidation of the TROPOMI schedule at PDR and considering the outcome of the Satellite/System PDR just concluded, it was decided to align the TROPOMI/satellite planning by extending the satellite schedule by three months resulting in a launch date adjustment from end March 2015 to end June 2015.

4 ESA SUPPORT TO GCOS AND OTHER CLIMATE MONITORING ACTIVITIES

4.1 Introduction

In November 2008 the ESA Ministerial Council adopted a new program, the “Climate Change Initiative” (CCI) focusing on the delivery of satellite-based ECVs to support climate change modelling and prediction.

The ESA Climate Change Initiative aims to provide consistent long-term global records of the “Essential Climate Variables” that are required by the Global Climate Observing System (GCOS) to support the work of the International Panel on Climate Change and the United Nations Framework Convention on Climate Change, as described above. The Programme focuses on those climate variables for which ESA satellite data sets (past thirty years of archives, ERS-1, ERS-2, Envisat, future Earth Explorer and Sentinel missions) will make a major contribution to complement that of international partner space agencies.

The long-term preservation of data from Earth observation missions, operated and acquired by ESA, is of paramount importance for the monitoring of long-term global trends with regard to many environmental parameters. The Climate Change Initiative (CCI) builds on Europe’s substantial expertise in processing, generating, and exploiting global data sets. Its goal is to guarantee the availability of space-based information for the future, in a form readily usable by scientific communities and government bodies.

4.2 The CCI Implementation

4.2.1 Initial Implementation Steps

The implementation of the CCI has been prepared by ESA on the basis of a wide consultation with international partners and representatives of the climate research and modelling communities. A Climate Science Advisory Board (including representatives of GCOS, WCRP, JCOMM, GTOS, ECMWF and ESAC) was convened on 29 April 2009 at ESRIN and provided an independent and expert scientific advice and a series of recommendations that have helped setting up the Programme. The ESA Earth Science Advisory Committee (ESAC) was also consulted prior to, and after, the CCI Programme adoption. Wider consultation also took place in 2008-2009 through numerous opportunities, including

workshops and meetings involving international partners and user organizations active in the European framework (EC FP7, EUMETSAT, EEA, GMES), as well as in the CEOS, GEO, WCRP and GCOS context. This consultation process has led to establishing a number of prioritization criteria that have been used to define the approach and first steps for the CCI implementation.

4.2.2 Selection of the Teams

A competitive tender for proposals to perform the detailed requirements definition, algorithm development, validation and prototyping for a first set of eleven "Essential Climate Variables" was released by ESA in the last quarter of 2009. The eleven ECVs to be addressed in the first phase of the CCI were:

- Atmospheric domain: Ozone, Clouds, Aerosols, Greenhouse gases (CO_2, CH_4)
- Oceanic domain: Sea level, Sea surface temperature, Sea ice, Ocean colour
- Terrestrial domain: Land cover, Glaciers and ice caps, Fire disturbance (Burned areas and active fires).

In September 2010, contracts were signed with the following ten groups:

GCOS ECV[1]	CCI Project	Science Leader
A.6	Cloud	Deutscher Wetterdienst (*R. Hollmann*)
A.9	Ozone	BIRA-IASB (M. van Roozendael)
A.10	Aerosol	DLR / FMI (T. Holzer-Popp / G. De Leeuw)
A.8	GHG	U. Bremen IUP (*M. Buchwitz*)
O.3	Sea Level	LEGOS-CNES (*A. Cazenave*)
O.1	SST	U. Edinburgh (*C. Merchant*)
O.6	Ocean Colour	Plymouth Marine Laboratory (*S. Sathyendranath*)
T.3	Glaciers	U. Zurich (*F. Paul*)
T.6	Land cover	Université Catholique de Louvain (*P. Defourny*)
T.10	Fire	U. Alcala (*E. Chuvieco*)

Later additions were made to the Programme (starting end 2011/beginning 2012), thanks to co-funding with another ESA Programme (ESA Strategic Initiative – StrIn), namely, Soil Moisture, Ice Sheets and Sea Ice:

T. 4	Ice Sheets	DTU Space (*R. Forsberg*)
T.11	Soil Moisture	TU Wien (*W. Wagner*)
O.5	Sea Ice	NERSC (S. Sandven)

These new ECV projects significantly enhance ESA member states contribution to GCOS, and strengthen ESA's coordinated international action through CEOS WG-Climate. The projects address the same cardinal objectives and follow the same work structure as the ten already active CCI ECV projects. Although they will have started one year later, they will benefit significantly from the results already generated by the CCI teams.

4.2.3 Project Team Organization and Work Plan

Each project team typically includes experts from ten or more research organizations. Each team has a science leader who will ensure the overall scientific integrity of the project

[1] See Report GCOS-154 – Supplemental details to the satellite-based component of the "Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC (2010 Update)".

throughout the next three years. The science leader also ensures that each CCI project maintains effective working links to the appropriate international climate science Programmes, initiatives and projects and to other CCI project teams. Each science leader, who is also responsible of the contract with respect to ESA, is directly supported by a project manager who ensures communication within the project team, maintenance of schedule, tracking of actions, deliverables and reporting to ESA. Each team also has a sub-group with specialist scientific expertise in Earth observation, a sub-group specialised in climate research and modelling, and a sub-group of system engineering experts.

All thirteen projects will work in parallel on the following tasks during the three years of the projects: requirements analysis and product specification; algorithm development, inter-comparison and selection; system Prototyping and ECV production; final product validation and user assessment; system specifications; and, project management.

A Climate Modelling Users Group (CMUG) has also been set up. The CMUG aims to provide an integrated, working-level gateway from the CCI to the international climate modelling community.

The First CCI Team Collocation meeting took place in September 2010, and the Second one in October 2011, both in Frascati, Italy. The Third CCI Team Collocation meeting has taken place in Frascati on 23-26 September 2012, immediately preceding the Programme Mid-Term Review, where the progress and achievements of the CCI have been assessed by national delegations.

4.2.4 Deliverables

Each team will deliver a standard set of documents which, after internal review by the project team and after acceptance by the Agency, will be made publicly available, as a way of stimulating feedback and facilitating cooperation with other scientific teams.

Each CCI project team has set up a project web site with all information needed to ensure coordination and consistency with related projects. Each web site provides open access to project documents and data products.

It is worthwhile to note that the CCI project deliverables (data, quality, calibration/validation, documentation, review, open access) have been specified in accordance with the "Guideline for the Generation of Satellite-based Datasets and Products meeting GCOS Requirements".

4.3 Current Status

4.3.1 Overall Progress

CCI Programme activities have continued progressing well and on schedule during this reporting period. Scientific interactions with CMUG and different CCI project teams continue to develop fruitfully. International coordination is progressing constructively, both within Europe, and internationally via the recently established CEOS WGClimate.

Most projects have now passed or are approaching the midpoint in their three year plan of work. They have in most cases succeeded to follow the very tight schedule imposed on them by the Agency's statement of work. The teams have all engaged in an intensive – and for many communities unprecedented – algorithm inter-comparison ('round-robin') exercise. They are now preparing to enter a production phase, which will generate the first ECV data sets in the course of the coming year.

Recent months have seen all teams make substantial progress on System Requirements definition, and on system description. These are key steps, laying the basis for the next stage of the Program, which aims to implement operational systems. In many cases it has proven necessary to iterate the system requirements definition several times (e.g. 5) before a consensus on applicable requirements was reached. This process is challenging, because the existing proto-type chains incorporate and rely extensively upon heritage systems which are heterogeneous. For this reason the Executive has stressed the need to distinguish 'requirements' from 'implementation'. Exchanges between teams via the CCI Systems Engineering Working Group have facilitated progress.

A recurrent message emerging from all teams is that any future sustainable system(s) for ECV generation must be built around an agile development cycle, both for the algorithms at the heart of the system, and the EO data input streams. All teams, without exception, advocate a system evolution process that is based on re-use and optimization of scientific code, inside an operational production framework.

A number of options have been identified for implementations within the current projects. These, in general, are for improvements on algorithms, additional validation, or extending time series, in response to key user requirements.

4.3.2 International Cooperation

All teams have been cooperating actively with international partners both inside and outside of Europe. This includes national research projects in ESA Member States, EC FP7 research projects as well as relevant ESA exploitation projects – in particular the ESA EO Quality Working Groups.

The CCI teams are ensuring openness and transparency, specifically requested by GCOS and WCRP, by placing all deliverable documents on their project web-sites, soliciting and responding to external independent scientific review comments. On the specific issue of the User Requirements, ESA performed an analysis of the documents provided by the initial ten ECV projects and issued a Response by ESA to GCOS in time for GCOS to use these inputs for their review of their "Satellite Supplement". This ESA document will be updated to take into account the input from the 3 new projects

The CCI data standards working group, with participation from all CCI teams, has continued working actively to agree common data standards applicable for all CCI ECV data products. A document describing the product format definition as well as the naming convention is being released and will be distributed to the international community via the WGClimate as a proposal for a standard with the Climate community. A CCI systems engineering working group, with membership from each team, is in parallel looking at common system issues across all CCI projects.

Cooperation across the CC teams continues to develop, and exchanges with international science partners, as strongly emphasized by both ESAC and the CSAB, have flourished. This is well illustrated by the decision of the International Ocean Colour Coordination Group (IOCCG), at its annual meeting in March 2012, to form an international working group dedicated to evaluating water-leaving radiances for climate research. This responds directly to the joint request from directors of WCRP and of GCOS Secretariat for such action. This initiative has to a significant extent been triggered by the Ocean Colour CCI scientists.

In conjunction with the start of the Ice Sheets CCI project, an *ad hoc* scientific cooperation, the 'Ice sheet Mass Balance Inter-comparison Exercise (IMBIE)', has been initiated with NASA. The aim is to resolve the apparent disagreement between geodetic estimates of ice

sheet mass balance through a coordinated exercise within which estimates are developed from altimetry, gravimetry and mass flux techniques. Some twenty US and European research groups who are instrumental in developing independent estimates of ice sheet mass balance have met in two workshops, jointly organized by ESA and NASA (the first in New York in November 2011, and the second in Oxford, UK, in March 2012). The participants have defined a common spatial and temporal reference frame as a basis for achieving common appreciation of the contributions due to external signals (e.g. fluctuations in surface mass accumulation and post-glacial rebound). They are currently working towards a joint scientific publication within the timeframe required for the next IPCC Assessment report. The workshops and participation of the European scientists are supported via CCI. This scientific initiative was proposed to ESA by University of Leeds, who is key members of the Ice Sheets CCI team, and is ensuring technical coordination amongst the IMBIE partners, via the EOEP Support To Science Element (STSE).

4.3.3 User Assessment

It is important to note that, although the overall user assessment of the Programme results is by definition foreseen at the end of the program, user assessment is a continuous activity which is performed throughout the program: both at project-level by the climate research users within each team, and at Programme level via the Climate Modelling Users Group (CMUG).

4.3.4 Programme Schedule

The master schedule for the CCI Programme remains as planned. Following the Mid-Term Review the Executive will submit to the ESA Programme Board on Earth Observation a proposed implementation approach for the second Phase of the CCI Programme. It is intended that this should prepare the basis for a subsequent procurement action and tender(s) to be issued in early 2013, so that the resulting contracts for the second Phase of CCI can be kicked-off in the second half of 2013.

4.4 References

Further information about the ESA CCI can be found on the following WWW address which offers the possibility to download many supporting relevant documents:
http://www.esa-cci.org/