CGMS

CGMS-35, ESA-WP-02
Prepared by ESA
Agenda Item: C.2
Discussed in Plenary

STATUS OF THE FUTURE ESA EARTH OBSERVATION MISSIONS

CGMS is informed of the status of the future European Space Agency Earth Observation missions. Two of them, MSG and Metop are in co-operation with EUMETSAT. The Living Planet Program has three lines of implementation: Earth Explorer satellites, Earth Watch satellites plus services & applications demonstration.

After decision on the implementation of Swarm and EarthCARE missions, a new Core Explorer is under selection. The first Explorer launch is now foreseen in March 2008.

The Earth Watch includes since January 2002 the Global Monitoring for Environment and Security (GMES) services element.

The ESA GMES space component programme Phase 1 is well advanced. Five families of Sentinels are planned. The Sentinel-1 development phase was kicked off in April 2007. The Sentinels 2 and 3 are expected to kick off by end 2007.

STATUS OF THE FUTURE ESA EARTH OBSERVATION MISSIONS

1 INTRODUCTION

The Earth Observation Directorate of the European Space Agency (ESA) is currently running several programmes. Two of these, MSG and Metop are in co-operation with EUMETSAT. The Living Planet Program has three lines of implementation: Earth Explorer satellites, Earth Watch satellites plus services & applications demonstration. After failure of the launcher, Cryosat-2 recovery mission is planned for 2009. The Earth Watch includes since January 2002 the Global Monitoring for Environment and Security (GMES) Services Element. The GMES Space Component Programme Phase 1 has initiated, after a approval at the Ministerial Conference in December 2005. A new batch of Explorers is under assessment.

2 STATUS OF THE EARTH EXPLORER MISSIONS

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 Program 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, and are well advanced: 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)

2.2 GOCE

The aim of the 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 leveling systems based on GPS.

The mission responds to the requirements put forward by many international scientific programs such as the WOCE, CLIVAR and GOOS. It is 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 position.

2.2.1- GOCE project status

The GOCE Space Segment development is approaching the completion of the phase C/D. The integration of satellite Proto-Flight Model (PFM) has been completed. The PFM is presently in ESTEC where it will soon start the environmental test campaign and the final system functional tests. Beginning 2008 it will be transported to Plesetsk where it will be launched by Rockot. The current launch date is end March 2008.

The first part of the Ground Segment Overall Validation (GSOV) testing has been successfully completed demonstrating the compatibility of the various elements constituting the GOCE Ground Segment, namely: the Flight Operation Segment, the Payload Data Segment (i.e. data processing up to Level 1B), the High-Level Processing Facility (responsible for the generation of the Level 2 products), the Calibration and Monitoring Facility and the Reference Planning Facility. Completion of the GSOV is planned for end 2007.

2.2.2- GOCE science

Following the release of the Announcement of Opportunity for the Data Exploitation of GOCE data (L1B and L2 products) in early October 2006, 69 proposals submitted by scientist from 26 countries have been accepted. The third International GOCE User Workshop took place at ESRIN on 6-8 November 2006 and it has provided the potential users of GOCE data products with the opportunity to obtain the latest information on the satellite and the mission performance as well as details on flight operations, calibration and validation activities.

2.3 ADM-AEOLUS

The Atmospheric Dynamics Mission ADM-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. The mission will also provide data needed 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 data will help as well to accomplish some of the objectives of the Global Climate Observing System, by contributing directly to the study of the Earth's global energy budget by measuring wind fields globally in cloud free air. It will further provide information for the study of the global circulation andmore general transport properties of the troposphere and lower stratosphere. ADM-Aeolus will also deliver profiles of backscatter and extinction coefficients, which will allow to retrieve cloud and aerosol information.

The main space element of the ADM-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.

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

2.3.1 Aeolus Project Status

The Phase C/D Contract for the Satellite was signed in October 2003. The Critical Design Review was held in August and September of 2005.

Most of the flight equipments have already been delivered.

A structural model test programme at Satellite level has qualified the satellite for all mechanical environments. An optical, structural and thermal test programme for the instrument has proved the thermal control design (using flight model heat pipes) and has also demonstrated telescope stability under the thermal environment in space.

As expected the laser is proving the greatest development challenge. However, the laser diode qualification programme has been successfully completed in July 2007, although confidence tests are continuing. The optics coating qualification is mostly completed; due to the high optical power densities, the lifetime of these coatings is particularly critical. The outstanding issue is the thermal vacuum test which is planned for late 2007, and a 6 month lifetest of the laser in vacuum conditions as confirmation for the absence of laser induced layer formation.

ECMWF is implementing a level 2C processor within the ECMWF's forecast system, with the aim to contribute to ADM cal/val during the commissioning phase and to routinely generate level 2 products.

2.3.2 Aeolus Science

Various activities in support of Aeolus science are being performed.

ECMWF (European Centre for Medium-Range Weather Forecasts) carried out a study on the “expected benefits of DWL for data assimilation”. Radiosonde/profiler denial and (simulated) Aeolus observations had been used for a 6 week period. The study extended the assimilation ensemble method to assess the impact of adding simulated Aeolus data to the 2004 Observing System. The method was calibrated by assessing the impact of radiosondes and wind-profiler data in the same way (i.e. by a data-denial ensemble). The additional benefits from the Aeolus data were mainly in the Tropics and over ocean regions in both hemispheres, e.g. the North Atlantic storm track - these are widely acknowledged as priority areas for improvement. The ensemble results were consistent with independent measures of information content.

KNMI (Royal Dutch Meteorological Institute) has assessed the added value of Aeolus data in numerical weather prediction (NWP) to enhance the predictive skill of high-impact weather systems. A new system for studying impact is tested focusing on the sensitivity observing system experiment (SOSE) concept. Three scenarios, namely ‘ADM tandem’ (two ADM satellites in similar orbits), ‘ADM dual perspective’ (two ADM satellites measuring different components) and ‘ADM smart tandem’ (two ADM satellites in different orbits), have been considered for an ADM-Aeolus follow-on mission providing different coverage.

2.3.3 ADM-Aeolus Campaigns

An airborne version of the ALADIN wind-lidar has been made with equipment developed during the pre-development phase. This ALADIN Airborne Demonstrator (A2D) was functionally tested in flights in 2005, and has performed a first in ground-based campaign in Summer 2006. However, the frequency stability of the transmitter laser was insufficient for extended airborne campaigns. After modifications of the laser, airborne operation was successfully tested in proving flights in early 2007, and a second ground-based campaign has been completed in Summer. A first airborne campaign is being prepared for early 2008.

2.4 EarthCARE

2.4.1 Objectives

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.

2.4.2 Concept

EarthCARE will be implemented in cooperation with JAXA and consists of a single satellite in low Earth sun-synchronous orbit at about 450 km altitude. The EarthCARE mission is centered 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)

2.4.3 Planning

After selection in 2004, EarthCARE is being subject to bridging and risk retirement activities in ESA and JAXA. The EarthCARE Phase A extension was completed end-2006 and the preparation for Phase B-C/D-E1 industrial activities was initiated early 2007. The launch is planned for March 2013.

2.5 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 Programs will provide a decade of focused study of the roles of the cryosphere.

The technical concept consists of a single spacecraft in a high inclination (92 degree) orbit, carrying a Ku-band altimeter, measuring altitude with detailed precision, capable of operating in conventional pulse limited mode, synthetic aperture mode and interferometric mode.

Cryosat was the first Earth Explorer satellite to be launched, but the original CryoSat spacecraft was lost in a launch failure on 8 October 2005. Owing to the importance of Cryosat for the worldwide scientific community, a plan to recover the CryoSat mission, by building the CryoSat 2 satellite, including redundant SIRAL instrument) was developed.

2.5.1 Project status

The rebuild of the satellite to proceed with the mission was approved by ESA's Earth Observation Programme Board on 24 Feb 2006. The industrial activities were started a few days later and are proceeding according to the planned schedule, leading to the launch of the new satellite, again using a Rockot launch vehicle from Plesetsk, d in March 2009.
Similarly, evolutions of the ground segment are implemented to support the mission.

2.5.2 Cal/val

The CryoVEx 2006 campaign, using an airborne version of the CryoSat radar, was performed during April and May. Airborne and ground based measurements over ice-sheet sites in Svalbard, Devon Island and southern Greenland, and sea ice north of Greenland were made.

The team met in June 2006 to review early results of the CrioVex campaign and to agree on a preliminary planning for the further pre-launch campaigns.

2.5.3 Campaigns

The CryoVEx 2006 campaign, using ASIRAS, was performed during April and May. It consisted of a collection of airborne and ground based measurements. The target included ice-sheet sites in Svalbard, Devon Island and southern Greenland, and sea ice north of Greenland.

2.5.4 Studies

Recent work on the study “Combination of space, airborne and in situ gravity measurements in support of Arctic Sea Ice thickness mapping” has focused to characterize uncertainties in tidal models and ocean model simulations of the mean dynamic topography in the Arctic basin.

2.6 SMOS

In spite of the fact that both Soil Moisture (SM) and Sea Surface Salinity (SSS) are used in predictive atmospheric, oceanographic, and hydrologic models, to date, no capability exists to measure directly and globally these key variables. The main objective of SMOS is to deliver a crucial variable of the land surface: SM as well as SSS fields.

Over land, water and energy fluxes at the surface/atmosphere interface are strongly dependent upon Soil Moisture (SM). Evaporation, infiltration and runoff are driven by SM while soil moisture in the vadose zone governs the rate of water uptake by vegetation. Soil moisture is thus a key variable in the hydrologic cycle. For the oceans, Sea Surface Salinity (SSS) plays an important role in the northern Atlantic sub polar area where intrusions with a low salinity influence the deep thermohaline circulation and the meridional heat transport. Variations in salinity also influence the oceans near surface dynamics in the tropics where rainfall modifies the buoyancy of the surface layer and the tropical ocean-atmosphere heat fluxes. SSS fields and their seasonal and interannual variabilities are thus tracers and constraints on the water cycle and on the coupled ocean-atmosphere models.

2.6.1 Project status

The SMOS project is conducted in cooperation between ESA, CNES and CDTI under the overall responsibility and leadership of ESA.

The Payload Module (PLM) is developed by an industrial consortium led by EADS-CASA under direct contract from ESA. The PLM development has been completed, following the integration of the Protoflight Model at EADS-CASA and its subsequent transfer to ESTEC, where the environmental test camapign was succesfully completed by end June 2007. The PLM has been transferred to ALCATEL Cannes where it is currently undergoing satellite AIT.

The satellite platform and associated satellite operations ground segment are based on the existing PROTEUS bus developed by CNES and ALCATEL. Satellite activities entered into phase C/D in October 2005.

The Data Processing Ground Segment (DPGS) at ESAC (Villafranca, Spain), is under development, with the CDR currently in progress during the month of September 2007.

All activities are being put in place, with a launch date planned in mid- to late 2008.

2.6.2 SMOS Science

The Soil Moisture Synergy Study covering synergy of passive microwave observations and optical/SAR observations is nearing completion with a final presentation in September 2007.

The CoSMOS data analysis study is in progress with priorities for data correction being discussed.

Procurement of the SMOS Soil Moisture Data Hosting has been initiated with the Portuguese Meteorological Institute.

A study of L-band radiometry for sea ice applications is being prepared in conjunction with the University of Bremen.

2.6.3 SMOS Campaigns

An airborne SMOS demonstrator campaign over the Gulf of Bothnia has been started, using the full instrument suite planned for the SMOS cal/val program, with HUT-2D, EMIRAD, PARIS-GPS and dGPS instrumentation.

The DOMEX-2 Antarctic campaign schedule is being re-evaluated in order to maximize overlap between Concordia field radiometer measurements and the SMOS cal/val activities during commissioning.

2.7 Swarm

2.7.1 Objectives

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.

2.7.2 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 450 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 modeling of the geomagnetic field.

2.7.3 Project status

The preliminary design review has been held with EADS Astrium in February 2007.The phase B is completed and the critical design review is planned October 2008. The launch (3 satellites) is planned for 2010.

2.7.4 Science

Final results of the study ”Improved comprehensive magnetic field inversion analysis for Swarm” by DNSC (DK) in co-operation with NASA/GSFC are available.

2.8 Earth Explorer Number 7

A call for Earth Explorer *Core* ideas was issued in 2005. The twenty-four proposals received were evaluated by scientific peer review panels and by technical and programmatic panels. The strong response to the call issued by ESA as well as the scientific excellence of all the proposals showed the growing interest in and importance of Earth observation in Europe.

After evaluation by the Earth Science Advisory Committee in 2006, ESA has initiated assessment studies for six mission concepts:

BIOMASS: aims to quantify the forest biomass, the extend of forest and deforested areas and the delimitation of flooded forests. Based on P-band SAR.
TRAQ: observation of primary constituents for air quality in the troposphere.
PREMIER: to provide high resolution measurements, using mm-wave and IR limb sounding, aimed to study processes in the upper troposphere and lower stratosphere.
FLEX: to produce global scale maps of vegetation photosynthetic activity, to contribute to biosphere and global C cycle studies.

A-SCOPE: mapping the source and sink of CO2 on a scale of 500 km or better. Will use the DIAL sensor.
CoReH2O: estimates of snow water equivalent and depth on land and sea ice, with X band SAR.

When the assessment studies are completed in 2008, a down-selection of mission candidates will take place and feasibility studies at Phase A level will be initiated.

3. EARTH WATCH

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 be come 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 200 users, numerous service providers, developers and strategic partners. They address all areas of the priorities identified by the EC, in particular, ocean monitoring, land management, crisis management, and also potential new services as humanitarian aid and atmospheric composition monitoring. The GSE has been fundamental in identifying the requirements for the GMES Space Component.

3.2 Operational Meteorology and Climate Monitoring

ESA is co-operating with Eumetsat on the development 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 launch was planned for 17 July 2006; after several attempts, the launch was re-scheduled for 7 October 2007.

Regarding the future generations:

Post MSG: The two pre-phase A industrial studies for Meteosat Third Generation were concluded in March 2006. The reference system configuration for the space segment phase A studies was decided in July 2006 and the ITT should be issued in autumn 2007. Activities are coordinated with those of the Sentinel-4. MTG target launch date is 2015.

Post MetOp: User requirements have been gathered in various position papers, analyzed, discussed and harmonized by four Application experts groups (AEG), including ESA staff. The consolidated papers were presented to the user community on 29/30 March 2006. Following this, work has started both at ESA and EUMETSAT to derive the documentation to serve as a basis for the pre-Phase A activities. Activities are coordinated with those of Sentinel-5. The target launch date is 2019.

3.3 GMES services element

GMES stands for the Global Monitoring for Environment and Security. GMES is a joint initiative of the European Space Agency and the European Commission to provide Europe with an independent global information system which will support Europe's policies on environment and security. GMES will be a major European contribution to GEO.

GMES has four components: a space component, an in-situ component, a data integration component, and a service component. Work to implement GMES services started as early as 2002, via the ESA GMES Service Element which was approved by ESA member states in 2001. This was complemented by several dedicated projects carried out within the European Commission Research Framework programme. To date more that 400 user organizations from 40 countries, each of whom has a legal mandate or statutory responsibility regarding specific environmental or security policies, have been receiving and evaluating GMES services. Building on this the European Commission is implementing a suite of pan-European Fast Track Services from which customised services to meet national and local needs can be derived. These address Emergency Management, Marine monitoring, Land Cover Monitoring, Atmospheric compost ion, and Security issues. They are foreseen to enter operations in 2008.

As a result of this broad-based, early engagement of users in GMES, as well as dedicated consultations with member states organized by the European Commission, the future long-term needs for GMES observations, including those of the space component, have been established. The requirements for the GMES space component are thus directly traceable to European policies, directives laws, and will be served by a space infrastructure that includes dedicated (Sentinel) missions as well observations from other contributing European and national missions.

4. GMES SPACE COMPONENT

GMES represents the major initiative of European efforts in Earth Observation. In order to guarantee an operational start of GMES services in 2008 and the availability of the first GMES dedicated satellites (the “Sentinels”) in 2011-2012, activities are under way at all stages within the Agency, the EC and at Member States level.

The ESA programme proposal for the GMES space component encompasses the development of the Sentinels and the coordination with and access to other national and European missions, the so-called GMES “contributing missions”. The ESA

GMES Space Component programme activities have been initiated (Phase 1 of Segment 1) following a positive outcome of the ESA ministerial Conference in December 2005. Phase 2 has been approved in September 2007.

Five families of Sentinel missions are planned.

- Sentinel-1, a C-band SAR mission to provide continuity to ERS, ENVISAT and maintain the cooperation with Radarsat
- Sentinel-2, a multispectral optical imaging mission to provide continuity to the data so far obtained from SPOT and Landsat
- Sentinel-3, an ocean and global land monitoring mission providing ocean colour, sea surface topography and sea and land surface temperature. It provides continuity to data as those of MERIS, RA-1 / RA-2, (A)ATSR. It will also provide continuity to the data so far provided by the Vegetation sensors on SPOT-4 and 5.
- Sentinel-4, a geostationary element for monitoring of atmospheric composition
- Sentinel-5, a low-Earth orbit element devoted to the monitoring of atmospheric composition

Two units of each of the Sentinel-1/-2/-3 are required to fulfil the user requirements expressed by the GMES services.

The Sentinel-1 development phase (B2/C/D/E1) has been kicked-off in April 2007. The evaluation and negotiation process for Sentinel-2 and -3 should lead to a kick-off by end 2007. Phase 0 studies addressing the preliminary definition of Sentinel-4 and -5 are on-going.

The ground segment will include the flight operation segment and the payload data ground segment. The latter will provide interface to the GMES contributing missions and ensure the required level of inter-operability between the missions. Specific activities have initiated to prepare the provision of EO data for the EC's GMES "fast track services" on land, marine and emergency response, and the pilot service on atmosphere, which shall reach pre-operational status from 2008 onwards.

On the EC side, GMES related funding has been approved end 2006 as part of the Space Theme of the Seventh Framework Programme (FP7). The funding covers in particular the following activities which are delegated to ESA based on specific arrangements with the EC:

- development of GMES-dedicated satellites
- coordinated provision of observation data for GMES.

As part of FP7, additional funding has also been allocated to the GMES services and the in situ component, both under the responsibility of the EC.

5. REFERENCES

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

http://www.estec.esa.nl/explorer/
www.esa.int/metop
www.esa.int/msg
http://earth.esa.int/gmes/