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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. CRYOSAT-2 is scheduled for launch in 2009.

The Earth Watch includes since January 2002 the Global Monitoring for Environment and Security (GMES) services element. From the 10 portfolios selected, six started services in 2005.

The ESA GMES space component programme Phase 1 has started, after the Ministerial conference's aproval in December 2005.

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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 Minsiterial 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 currently in phase C/D. Following a bottom-up approach, the sequence of Critical Design Reviews (CDRs) held at equipment, Platform and Gradiometer and GPS receiver levels has culminated in the System-level CDR, which was successfully concluded in July 2005. The engineering models of the payload instruments have been delivered to the prime contractor. The manufacturing of all flight equipments has also been completed and Assembly, Integration and Testing activities are well underway in all areas. The current launch date is mid September 2007.

The Ground Segment Design Review was successfully completed in November 2004, demonstrating the suitability of the design to meet all GOCE requirements. The Payload Data Segment (i.e. data processing up to Level 1B) is proceeding nominally, and a first version of the system has been delivered to the Agency. The High-Level Processing Facility, responsible for the generation of the Level 2 products, has passed its CDR. Version 2 of the complete system is expected by last quarter of 2006. The development of the offline Calibration and Monitoring Facility is also proceeding nominally.

2.2.2- GOCE science

Following the Announcement of Opportunity for the "Scientific Pre-Processing, External Calibration and Validation of Level 1B Data products for the GOCE Mission" a Cal/Val Team has been established. A second Announcement of Opportunity for the Data Exploitation of GOCE data (L1B and L2 products) is planned for release by October 2006. The third International GOCE User Workshop will take place at ESRIN on 6-8 November 2006.

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.

Many 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. Mechanical and thermal testing of the Engineering Qualification Model laser is to start in September. 2006. The first six months of lifetime testing of the alser diodes will be completed by early 2007. As a result of delays in the laser development launch is now planned for September 2008.

The ground segment design review will begin in October 2006.

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.

IfT (Institute for Tropospheric Research, Leipzig, Germany) is focusing on the probability of building up a long term data base on atmospheric backscatter and extinction coefficients taking into account that other satellite missions (Calypso and EarthCARE) will provide similar data sets. An end-to-end simulator has been developed and the Aeolus accuracies have been estimated.

An ADM-Aeolus Workshop will he held at ESTEC on 26-28 September 2006.

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 flight in October 2005, and will be be used in ground and airborne campaigns in late 2006 and 2007 to prepare the exploitation of the ADM-Aeolus mission.

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 extention will be completed in Autumn 2006 and the Phase B industrial activities will be initiated early 2007. The launch is planned for 2012.

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 focussed 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 CryoSat was the first Earth Explorer satellite to be launched, but the launch was, unfortunately, a failure and the satellite was lost. The importance of Cryosat CryoSat for the worldwide scientific community has led to a recovery mission, Cryosat-2.

2.5.1 Project status

Following the failure, on 8 October 2005, of the launch on a Rockot launch vehicle from Plesetsk a 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 quickly. The launch of the new satellite, again using a Rockot launch vehicle from Plesetsk, is planned in March 2009.
After the failure of the Eurockot (converted SS-19) launcher in 8 October 2005, from Plesetsk, with , a recovery mission has been approved at ESA. The most time-critical industrial activities linked to the procurement of a new satellite (Cryosat-2) have been kicked off in March 2006. The launch of Cryosat-2 is scheduled for March 2009.

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 CryoVex 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 is currently in Phase C/D with its

Critical Design Review (CDR) passed end of 2005. Flight model production of subsystems should be completed by November 2006.

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. A satellite level CDR has been successfully completed.

The Data Processing Ground Segment (DPGS) at ESAC (Villafranca, Spain), is under development, with the CDR due in September 2006.

All activities are being put in place, with a launch date planned in late 2007 / early 2008.

2.6.2 SMOS Science

ESA organized jointly with the Technical University of Denmark and the SMOS lead Investigators, the 6th SMOS Workshop, attended by about 90 participants.

A study analyzing data acquired in the frame of the Australian cosmos campaign has been initiated.

2.6.3 SMOS Campaigns

The Cosmos OS campaign was successfully completed over the Norwegian sea in April/May 2006.

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 eachother, 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 first review of the satellite Phase B activities has been held with EADS Astrium in June 2006. Now a consolidation of Phase A outcome is under preparation, taking into consideration a new orbit scenario, instruments in pre-development and satellite/launcher interfaces. The launch (3 satellites) is planned for 2010.

2.7.4 Science

A special issue of the scientific journal Earth Planets and Space features a collection of 12 peer reviewed papers covering many aspects of Swarm.

The first International Science meeting related to the Swarm mission was held at the University of Nantes (F) from 3-5 May 2006. In total 119 participants from 15 European countries, USA, Canada, India and Japan participated.

First intermediate 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 new call for Earth Explorer *Core* ideas was released on 15 March 2005. Twenty-four proposals had been received by the deadline of 15 of August of 2005. They were evaluated by scientific peer review panels and by technical and programmatic panels. The strog response to the call issued by ESA as well as the scientific excellence of all the proposals are an indicator of the growing interest in and importance of Earth observation in Europe.

After evaluation by the Earth Science Advisory Committee in late April 2006, ESA has initiated assessment stuies 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.

One of the non-recommended missions was GOMAS (Geostationary Observatory for Microwave Atmospheric Sounding”., aimed at measuring precipitation amounts as well as providing frequent temperature and humidity profiles using passive microwave imagery. It was recognised that further studies be undertaken to refine the specifications including: requiremetns

on temperature and humidity retrieval accuracy versus areal coverage of precipitation measurement sand the optimisation of channel selection and horizontal resolution.. Also, there is a need to have test flights with the proposed instruments along with a more direct rainfall instrument to fully establish its capabilities. The theoretical concept proposed needing to be fully demonstrated under a variety of rainfall conditions and spatial resolutions.

When the assessment studies are completed by end 2007, 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 Edinbourgh 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 2006. Activities are co-ordinated with those of the Sentinel-4. MTG target launch date is 2015.

- **Post MetOp**: User requirements have been gathered in various position papers, analysed, 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 co-ordinated with those of Sentinel-5. The target launch date is 2019.

3.3- GMES services element

GMES stand 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 for key strategic parameters in environment and security.

In November 2001, the ESA Ministerial Council approved a new 5-year ESA programme dedicated to GMES, called the GMES Service Element (GSE for short). This is the very first ESA programme dedicated to GMES.

GSE will deliver policy-relevant services to end-users, primarily (but not exclusively) from Earth Observation sources. GSE is a key element of GMES, because it will enable end-users to become key players in the move from present generation Earth Observation satellites to future European systems that will deliver vital information on global environment and security.

The first priority list of services to be delivered by GMES is

• Land use, vegetation and soil management
• Urban and industrial zones management and security
• Coastal zone management and security
• Disaster management
• Atmospheric pollution management
• Water management

The GSE formally started in January 2002. After an ITT, 10 portfolios were selected and the studies started in 2003 for a period of 20 months. The Initial Period Final report was issued . Phase 2 started in March 2004. The GMES implementation period is up to 2008.
The scaling-up GMES on going information services are:

- Marine and Coastal Environment MARCOAST
- Polar Environment
- Flood and Fire Risk
- Geohazard risk (Land motion) TERRAFIRMA
- Food security for Africa
- Forest monitoring
- Land

The PROMOTE (Atmospheric monitoring) is expected to start in Autumn 2006. Other services are still in the consolidation phase.

4- GMES SPACE COMPONENT

The GMES (Global Monitoring for Environment and Security) initiative lead by the EuuropeanEuropean Commission EC and ESA represents the major milestone for future European efforts in Earth Observation. In order to guarantee an operational start of GMES in 2008, activities are under way at all stages within the Agency and the inter-institutional level.

The ESA proposal for the GMES space component encompasses the development of new "Sentinel" missions and coordination with and access to other national and European missions. The ESA GMES Space Component programme activities have been initiated (Phase 1) following a positive outcome of the ESA ministerial Conference in December 2005.

Five notional families of missions, the so called Sentinels, 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 monitoring mission providing ocean colour, sea surface topography and sea surface temperature, and providing continuity to data as those of MERIS, RA-1 / RA-2, (A)ATSR. It would 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

The IR element will be part of the payload of selected satellites of the Sentinel families.

The System Requirements Review SRR for Sentinel 1 was successfully completed in April 2005. ITTIndustrial proposals for phase B2/C/D/E1 are under evaluation. Definition studies for sentinels 2 and 3 are on schedule and will reach SRR by end of 2006.

The ground segment will include the flight operation segment and the payload ground segment. The latter will provide interface to cooperative missions and the in-situ component. Activities are ongoing for achievement of inter-operability. Selected activities have initiated to prepare the provision of EO data for the EC's GMES "fast track services" on land, marine and emergency response, which shall reach pre-operational status from 2009 onwards.

Service development is continuing under the GSE introduced above.

5. - REFERENCES

Further information about the various ESA missions can be found on the following WWW addresses which offers 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/