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

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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 or planning a number of 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, and services & applications demonstration. The Earth Watch includes since January 2002 the Global Monitoring for Environment and Security (GMES) services element.

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 different financial limits and programmatic functions i.e.

- *Opportunity* Missions designed to be a fast and flexible response to a single critical scientific issue and subject to strong financial (<110 MEURO) and development constraints (30 months for phase C/D).
- *Core* Missions, < 400 MEuro, more complex and larger 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.

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, four missions have been selected for implementation, namely two *Core* missions:

- GOCE (Gravity and steady-state Ocean Circulation Explorer)
- ADM-Aeolus (Atmospheric Dynamics Mission)

and two *Opportunity* Missions, out of 27 proposals:

- Cryosat (Polar Ice Monitoring)
- SMOS (Soil Moisture and Ocean Salinity)

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 in phase C/D. The sequence of the Preliminary Design Reviews (PDR's) for platform and payload elements is nearing its completion. Several equipment-level Critical Design Reviews (CDRs) have also been successfully completed and progress is steadily being made in the manufacturing and testing of equipment breadboards.

The Ground Segment Requirement Review has been successfully completed in November 2002 and the contractor responsible for the development of the GOCE Payload Data Segment (i.e. data processing up to Level 1B) has been kicked-off.

2.2.2- GOCE science

An Announcement of Opportunity for the "Scientific Pre-Processing, External Calibration and Validation of Level 1B Data products for the GOCE Mission" was issued in May this year.
The European GOCE Gravity Consortium (EGG-C), grouping 10 major European institutes, has submitted a proposal which has been already accepted, whereas other two proposals are still being evaluated. The EGG consortium has also declared its strong interest to be in charge of the Level 1 to Level 2 data processing. Given the obvious synergy with Cal/Val work and the pool of unique expertise, the ESA Executive intends to take up this opportunity and to issue a Request For Quotation to the EGG-C before the end of the year.

2.3- ADM-AEOLUS

The scope of the Atmospheric Dynamics Mission, Aeolus, is to demonstrate the possibility of providing observations of winds at altitudes between the surface and about 20 km in cloud free air. 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 and relate features such as precipitation systems, the El Niño and the Southern Oscillation phenomena and stratospheric/tropospheric exchange.

The main space element of the ADM is the ALADIN instrument i.e. a Doppler wind Lidar intended to provide profiles of the horizontal tropospheric wind above or in absence of thick cloud.

2.3.1 Aeolus Project Status

The Phase B of the Satellite contract (which includes the instrument) is complete. It has included selection of the majority of the sub-contractors who will build equipments and sub-systems. The most time critical of these have been kicked-off. Amongst the contractors who have started work is Galileo Avionica who succeeded, already, in a pre-development contract, in making a laser with adequate output power and frequency characteristics.

Another pre-development contract is in its final stages. It has produced working models of the Mie (aerosol scattering) and Rayleigh (molecular scattering) receivers, together with CCD detectors and associated electronics. The performance of these items is adequate.

Lifetime tests have been conducted on a sample of commercial pump diodes similar to those intended for flight. These tests have shown that adequate lifetime is achievable, although careful screening and burn-in are necessary.

The Satellite (and Instrument) Preliminary Design Review was held in late August. This has critically reviewed all aspects of the design. The PDR was successfully concluded in Mid September.

Member States have unanimously approved continuation of the Satellite contract into Phase C/D and E. Signature of the contract is expected in October.

2.3.2 Aeolus Science

Based on a preliminary assessment conducted by ECMWF, the impacts of Aeolus are expected to be:

- In the jet streams over the oceans, especially away from main air traffic routes, and in the African/Asian subtropical jet;
- In the lower atmosphere, e.g. western parts of the N. Pacific and N. Atlantic oceans and the Mediterranean, if cloud gaps are sufficient,
- In the tropics, where mass-wind balance is weak and hence temperature information is not effective for inferring wind.

The yield and accuracy of simulated Aeolus data has been estimated by ECMWF using backscatter data from the LITE experiment to validate model cloud cover fields. It appears that yield and accuracy estimates using cloud cover fields from an NWP model could underestimate the quality of Mie (aerosol) channel data and overestimate the penetration depth of the Aeolus Rayleigh (molecular) channel compared with estimates using real backscatter data.

Another study by KNMI will assess the added value of Aeolus data in numerical weather prediction (NWP) to enhance the predictive skill of high-impact weather systems. The work has initially focused on the collection of extreme events that were badly forecasted. A number of interesting case studies have been selected, including the Christmas 1999 storms and the Florida heavy snowfall on January 2000. Sensitivity computations are being carried out for each of the cases using the dedicated sensitivity suite at ECMWF.

2.4- 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.

2.4.1 Project status

Progress has been made in the Space Segment area. More Flight Model's equipment has been delivered to Astrium GmbH, but a few delays are being encountered with the procurement of some of the equipment. The development of the Satellite Test Bed is taking more time than anticipated.

The CryoSat Critical Design Review (Part 1) has not identified any "show stopper", but recommended a consolidation of the Assembly, Integration and Verification approach.

For the CryoSat launch services, the preliminary design of the interfaces with the launcher has been reviewed and the specific Interface Control Document agreed.

The Ground Segment development is nominal and the formal design review of the CryoSat Ground Segment has been initiated.

As a summary, the development of the CryoSat mission is progressing and no major technical problems were encountered during the last period.

However, the progress is slower than anticipated in the space segment area, and the date of the Flight Acceptance Review could not be maintained. Consequently, the launch date had to be shifted towards the end of September 2004.

2.4.2 Calibration/Validation

The first pre-launch CryoSat Validation Experiment (CryoVex) has been successfully performed mid-April 2003 in the Fram strait in spite of adverse weather conditions. This campaign was carried out in collaboration with NASA and involved the German research vessel Polarstern. Airborne electromagnetic sea ice thickness measurements and lidar measurements have also been performed.

2.4.3 Campains

Integration of the Airborne SAR/Interferometric Radar Altimeter System (ASIRAS) on board a Dornier DO228 aircraft has been performed at Bremerhaven and a first technical test flight has been conducted in June 2003.

Preliminary results are encouraging, but further tuning has to be done before the instrument could be declared operational.

2.5- 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.

Low frequency microwave measurements (around 1 GHz) offer a unique means to achieve such goals. At such wavelengths, the measured signal is directly related to the brightness temperature of the surface (negligible atmospheric contribution), which in turn, through the emissivity, is directly linked to the dielectric constants of the target (i.e., moisture or salinity). Actually, the sensitivity of brightness temperature to soil moisture and salinity is optimum in the L band (1.4 GHz). The mission should also deliver information on surface temperature, vegetation and biomass through the multi-angle dual polarisation observations.

2.5.1 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 B with it Preliminary Design Review (PDR) planned end of 2003. Activities for preparing Phase C/D (RFQ; Industrial proposal; Evaluation) are well underway in order to allow a smooth and efficient transition between design and implementation phases.

The satellite platform and associated satellite operations ground segment are based on the existing PROTEUS bus developed by CNES and ALCATEL. Satellite activities are currently in phase pre-B, to support the development of the Payload module as well as defining the interfaces between the platform and the payload module .

The Phase A of the Data Processing Ground Segment (DPGS) has been concluded mid 2003, and is being followed by the development of dedicated SMOS data processors.

Feasibility analyses have been performed with the Launcher provider, demonstrating the suitability and compatibility of the ROCKOT Launcher for the SMOS Mission.

The SMOS mission implementation phase (C/D,E) has been approved by the ESA Earth Observation Programme Board in September 2003. All activities are being put in place accordingly, with a launch date planned in February 2007.

2.5.2 SMOS Science

Various study and campaign activities were initiated to address the analysis, enhancement and validation of appropriate L-band radiative transfer models accounting for signal perturbing effects such as wind azimuthal dependence, roughness and foam, sea surface temperatures, rain, Faraday rotation for ocean salinity and forests, dew, frost, under-storey, litter, topography for soil moisture and the requirements on the timeliness of collocated observations. In addition, appropriate campaigns had to be organised and conducted to provide suitable data. Once elaborated, the enhanced retrieval schemes together with the system error budget, a vicarious calibration scheme, and a final product definition shall provide insight on the expected usefulness of SMOS data for various science communities. The following paragraphs briefly outline the activities initiated by ESA and their preliminary results. It should be noted that additional study and campaign activities were initiated within national programmes. Activities were coordinated via the SMOS Science Advisory Group and relevant workshops involving the various study and campaign teams.

The *'Soil Moisture Retrieval by a Future Space-borne Earth Observation Mission'* study was aiming at determination of the soil moisture product- and accuracy requirements for a space-borne EO Mission for scientific and semi-operational applications and included the simulation of global brightness temperature maps for subsequent studies.

The main objective of the *'Soil Moisture Retrieval for the SMOS Mission'* study to review existing and to develop and analyse new soil moisture retrieval schemes by accounting for the observation characteristics of the SMOS mission and by taking into account spatial and temporal land surface variability. For this the simulated dataset generated within the previous study was intensively used. Also a software tool based on state-of-the art retrieval techniques including a sophisticated decision tree was developed within this study activity which allows the science community to address open questions and the fine-tune the retrieval concept.

The *'Ocean Salinity Requirement Study'* study addressed the requirements of a future space-borne mission to observe sea surface salinity. The main objective of this study was to analyse the scientific observation requirements and impact assessment on ocean-atmosphere and thermohaline circulation models using different salinity accuracy. State-of-the art ocean circulation models were used to provide a first qualitative assessment of the expected salinity signal. Characteristic salinity patterns and their temporal and spatial variations have been derived.

The *'Ocean Salinity Retrieval Study'* had the objectives to advance the understanding of the physics for the SMOS characteristics (L-band, range of incidence angle, dual polarisation) for different sea state conditions and to develop retrieval algorithms for ocean salinity from SMOS observations accounting for the spatial resolution (varying footprints), mixed pixels due to wind variability, foam as well as the timeliness and accuracy of ancillary data. Modelling was based on the recently developed small slope approximation (SSA) model.

2.5.3 SMOS Campaigns

EuroSTARRS:

The main objective of the first exploitation of the Salinity Temperature and Roughness Remote Scanner (STARRS) in Europe (EuroSTARRS, 16th – 23rd November 2001) was to acquire SMOS-like observations for addressing a range of critical issues relevant to the soil moisture objectives of the SMOS mission. Additional flights were scheduled for the ocean salinity experiments.

The STARRS sensor is owned by NRL (Naval Research Laboratories, USA) and was operated during the campaign aboard a Dornier 228 by DLR (German Aerospace Center). The instrument, a push-broom scanner with six beams operating in L-band at V polarisation, was mounted perpendicular to the flight direction and tilted to one side by 12 degrees. A mount parallel to the flight direction, necessary to acquire multi-angular observations of the same footprint at almost the same time, was not possible due to technical constraints. However, by overlapping flight lines and accounting for the incidence angles of the different antenna beams, multi-angular observations of up to 50 degrees could be obtained. This required almost perfect flight navigation, which was supported by a new navigation system within the DLR aircraft.

Intensive field-work was carried out by large ground teams providing in-situ information on surface temperature, characterisation of the surface cover (vegetation type, biomass, litter mass, fractional vegetation cover, fractional soil cover, soil texture and roughness, etc.), and soil moisture (gravimetric and TDR measurements) during the overflights.

WISE:

The WInd and Salinity Experiment (WISE) was conducted in 2000 and 2001 on an oil rig (Casablanca tower) about 50 km off the coast of Barcelona. The overall objective of this campaign was to measure and analyse polarimetric L-band emission under varying incidence and azimuthal viewing angles for a wide range of sea state conditions. The LAURA L-band radiometer of the Polytechnic University of Catalonia (UPC), Spain, at the same time prime contractor and responsible for all logistics, was used as the core instrument. Systematic measurements were acquired from Nov. 16th to Dec. 18th, 2000 and continued during Jan., 9th to 15th, 2001. The experiment was repeated from October 23rd to November 22nd in order to cover stronger winds and avoid interferences (RFI problems) encountered during the first campaign which occurred in certain directions and likely are originated from airport radar systems. Data at wind speed higher than 50 knots (~100km/h) were registered during one of the most severe gale this region ever had. In addition, this experiment was coordinated with the EuroSTARRS campaign, which enabled a contemporaneous data acquisition during an overflight of the STARRS instrument.

LOSAC:

The LOSAC campaign was initiated to address azimuthal dependence of the first two Stokes parameter (Tb,v and Tb,h) with wind speed and direction which is not yet fully understood. The EMIRAD full-polarimetric L-band radiometer was exploited aboard a C130 aircraft operated by the Royal Danish Air Force over the North Sea. The large antenna horn of EMIRAD looked out through the starboard parachute door, an optimised installation for investigating azimuthal signatures by flying circles with the antenna pointing at the sea surface. Changing the roll angle of the aircraft and thus the diameter of the circle, data with different antenna beam incidence angles could be acquired. A first technical test flight was carried out January 16th, 2001, revealing technical problems due to RFI which could be solved by additional shielding. Three science flights were conducted over the North Sea on March 15 and 23, and on October 25.

2.6- SWIFT

2.6.1 Mission objectives

SWIFT (Stratospheric Interferometer for Transport Studies) mission is primarily to measure wind profiles in the stratosphere, however this mission will simultaneously provide profiles of ozone density. The mission is aimed at furthering our knowledge of atmospheric circulation and will help us to understand how pollutants are transported within the atmosphere and explain the way in which ozone is distributed in the stratosphere.

2.6.2 Mission status

SWIFT was originally proposed as an Earth Explorer Opportunity Mission in 1998, it was however, in competition with other excellent proposals and higher priority was given to the Soil Moisture Ocean Salinity (SMOS) and CryoSat missions, which are currently being developed.

Nevertheless, because of the importance of the mission, SWIFT was proposed by ESA to the National Space Development Agency of Japan (NASDA), as a third-party payload on the Japanese GCOM-A1 satellite. Out of a number of proposals received by NASDA, SWIFT was selected. In cooperation with the Canadian Space Agency (CSA), which supports the development of the SWIFT instrument, ESA performed a feasibility study (Phase A) for SWIFT on-board GCOM-A1. Phase- A has now been successfully completed.

The Greenhouse gas Observing SATellite (GOSAT) is developed and studied by NASDA for a launch in 2007. The main sensors are Greenhouse Gas and Ozone observing sensor (SOFIS) and SWIFT. SOFIS is developed by the Ministry of the Environment and NASDA.

2.7- Next Explorer Core missions

A call of ideas for the new cycle of *Core* Missions was issued in June 2000, with deadline 1st September 2000, for scientists in the ESA Member States and Canada.

The general selection procedures, including a public consultation workshop (Granada III at end of October 2001) identified the missions to go into phase A study.

- EarthCARE, to study clouds, aerosols and radiation by a combination of active (radar and lidar) and passive instruments (multi-spectral imager, broadband radiometer and infrared Fourier transform spectrometer). This is to be implemented as a joint ESA/NASDA mission.

- SPECTRA, Surface Processes and Ecosystems Changes through response analysis, based on a payload including hyperspectral sensor operating in the VNIR and SWIR and including thermal channels, to study the carbon, water and energy cycles.

- WALES, Water Vapour Lidar Experiment in Space, to provide accurate vertical profiles of water vapour concentration with high resolution by means of a differential absorption lidar.

A final selection of an ordered pair is expected within 2003, for launches in 2009 and 2011.

2.8- Next Explorer Opportunity missions

The call for ideas for the second cycle of Earth Explorer *Opportunity* Missions was released in early June 2001.These are intended to be very cost effective missions, implemented over short time scales, possibly exploiting new approaches to development and opportunities for international co-operation.

The evaluation of the twenty-five candidate proposals was completed. Feasibility studies (Phase A) for the first three have started:

- ACE+ intended to provide accurate profiles of temperature and water vapour in the atmosphere exploiting radio-occultation methods. The nominal configuration includes a pair of satellites in each of two orbit planes at 90 deg inclination.

- EGPM would be the European contribution to the Global Precipitation Mission. It would consist of a satellite in sun-Synchronous orbit carrying a passive microwave radiometer optimized for Northern latitudes and possibly a single frequency rain radar.
- SWARM devoted to the study of the fine structure of the Earth's magnetic field and its components.

Expected launches in 2008 and 2010.

3. - EARTH WATCH

A programme was proposed to the ESA Council at ministerial level in November 2001.The objectives are:

- To provide tools for operational surveillance of the Planet in the domains of environment, security and climate
- To provide operational data to support commercial services
- To provide support to long term science issues.

The main challenges are:

- Involvement of the users
- Establishment of the underlying science base
- Set-up of appropriate data policy and of business models to provide sustainability

3.1- Operational Meteorology and Climate Monitoring

ESA is c-operating with Eumetsat on the development of new series of meteorological satellites: MSG (Meteosat Second Generation) and MetOp.

Regarding the future generations:

- **Post MSG**: Following a users workshop on November 2001, a joint ESA/Eumetsat plan for the consolidation of the user requirements for the post MSG mission has been agreed. ESA is preparing an ITT for the pre-phase A studies.
- **MetOp**: Coordination with Eumetsat has also taken place regarding the payload of MetOp 3. In particular this refers to concept studies for an infrared imager (VIRI-M).

3.2- Global Monitoring Missions

On going activities refer to a visible-infrared imager applicable to ocean/land monitoring, and to innovative altimeter concepts.

3.3- Advance Imaging Missions

The plans for TerraSAR (L band) and Fuegosat consolidation are on going.

3.4- 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 should pave the way for the GMES implementation period up to 2008.

4. - 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/
http://earth.esa.int/gmes/