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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 line includes since January 2002 the Global Monitoring for Environment and Security (GMES) services element. A new batch of Explorers missions is under selection.

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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, plus services & applications demonstration. The Earth Watch line includes since January 2002 the Global Monitoring for Environment and Security (GMES) services element. A new batch of Explorers missions is under selection.

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

- GOCE (Gravity field 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 its reference equipotential surface, the geoid, 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 e.g. WOCE, CLIVAR and GOOS. It is designed for the accurate determination of the ocean dynamic topography and, thereby, the mean ocean circulation, as an essential complement to the precise monitoring of temporal ocean variability already provided by altimetry.

The gravity vector cannot be measured directly in orbit, but can be inferred from other observations. The GOCE satellite carries a gravity gradiometer that measures gravity gradients and a GNSS (Global Navigation Satellite Systems) receiver for precise satellite positioning.

2.2.1- GOCE project status

Space Segment

The GOCE space segment development activities have continued to focus on the execution of the unit level testing and the equipment-level Critical Design Reviews.
The satellite Structural Model (SM) integration activities are nearing their completion. The remaining missing elements are the body mounted solar panels and the two solar wings which will be delivered by the solar generator substrate manufacturer during the first half of April.
The satellite SM will arrive in ESTEC before the end of April. The SM mechanical test campaign will be carried out in the ESTEC test facilities and it is planned to be completed by the beginning of July.
Manufacturing of the Gradiometer Structural Thermal Model (STM) has been completed. During the coming months, this model will experience a series of mechanical and thermal tests in order to demonstrate the qualification of the overall instrument design.
It has been decided to manufacture a new ASH (Accelerometer Sensor Head) and to repeat the endurance test.
On the other hand, the electrical testing activities of the ASH Demonstration Model have been progressing nominally and the first integration tests with the ASH front-end electronics are planned to start at the end of April.
In the platform area, preparatory activities have been continued for the integration of the Engineering Model Test Bench that will be used to verify functional and electrical performance of the platform.
The EUROCKOT launch services procurement activities are proceeding according to plans. The System Requirements Meeting has been held successfully in February.
The Preliminary Design Review (PDR) of the Payload Data Segment (PDS) has been completed successfully.

2.2.2- GOCE science

Scientific topics

GOCE User Workshop

A successful second International GOCE User Workshop, entitled 'GOCE, the Geoid and Oceanography,' took place at ESA-ESRIN on March 8-10, 2004. More than 120 scientists from 16 different countries gathered in Frascati, Italy, to take part in the workshop, almost doubling attendance from the first Workshop held at ESTEC in April 2001. Abstracts, papers and presentation material from the Workshop are available on-line at: http://earth.esa.int/goce04/. A forthcoming ESA Special Publication is planned for release on CDROM.
This workshop provided a unique forum to present the latest mission developments and to discuss how data from the GOCE mission would be best delivered for scientific research and applications. During the 3-day event around 60 presentations were made covering many aspects of the mission. A number of discussion sessions enabled in-depth exchanges on user requirements, and affirmed that the present GOCE user requirements will result in a high quality geoid that will lead to significant advances in satellite oceanography.

Calibration/Validation

A first meeting was held with the Principal Investigators of the approved Calibration and Validation proposals in Frascati, in parallel to the GOCE Workshop. Attendees discussed their plans for each of the studies, in the context of ensuring coherence amongst each of the activities. Representatives of the EGG-C were also present, such as to encourage exchange of information and connectivity amongst each of the independent efforts.

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 30 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 satellite programme continues nominally on schedule towards a launch in October 2007.

Phase B was completed with a satellite Preliminary Design Review in September 2003. The phase C/D was kicked-off and the satellite procurement contract signed in October 2003.

All significant sub-contracts are now been kicked-off and are working. The majority of sub-contracts Preliminary Design Reviews have been held. Work on testing Structural / Thermal models of instrument and satellite will take place in late 2004 and early 2005.

Following discussions with EUMETSAT it has been pointed out that the satellite is compatible with delivery of calibrated engineering data within thirty minutes of sensing. Achievement of this goal requires, however, a number of X-band ground stations equipped with a 2.4 m antenna. For the present, ground stations are planned to achieve a 3 hr delivery time.

Agreement in principle has been reached with ECMWF that they will, under contract to ESA, prepare wind products from Aeolus on the basis of calibrated data. They will also investigate and report the impact of Aeolus on forecast performance. Real time calibrated data will also be provided, in parallel, to other interested forecasting centers.

2.3.2 Aeolus Science

Expected Benefit of Wind Profiles From the Atmospheric Dynamics Mission (ADM-Aeolus) in a Data Assimilation System

To obtain beneficial analysis and forecast impact of ADM-Aeolus observations accuracy, bias and random errors have to be considered.

The study is assessing the usefulness of Aeolus data in an operational environment, i.e. in complementarity with other data.

The study has analysed the atmospheric penetration capabilities of real measurements based on LITE and ELITE campaigns in meteorologically sensitive and/or dynamic regions. The study has also investigated the treatment of simulated DWL observations in a data assimilation system.

The study is almost complete. The results substantiate previous expectations that Aeolus will have a beneficial impact for NWP in meteorologically sensitive regions such as southern hemisphere oceans and in the North Atlantic storm track.

Expectations for High Impact Weather Forecast Improvement

The impact of Aeolus wind data on the weather forecasting skill was previously shown in an OSSE. Unfortunately, the period studied did not include extreme weather events that were badly forecast. Such events are often related to small-scale atmospheric structures that evolve

rapidly in time. From the performed studies there is no evidence that the coverage requirement for Aeolus is sufficient to capture these structures. Moreover, there is no consensus in the lidar community on the information content of the line-of-sight winds to resolve such structures.

This study will assess the added value of Aeolus data in numerical weather prediction (NWP) to enhance the predictive skill of high-impact weather systems. For this purpose, the presently envisaged data properties as well as modified properties as they might result from later versions of Aeolus will be used.

Impact of Line Shape on Wind Measurements and Correction Methods

Aeolus uses both a Mie receiver to detect Doppler backscatter from aerosols and a Rayleigh receiver to detect Doppler molecular backscatter.

The frequency measurement of the Rayleigh receiver is sensitive to Brillouin scattering. The theory of Brillouin scattering needs to be applied to the range of atmospheric conditions existing for Aeolus, and a realistic line shape model has to be derived and validated.

The objective of this study is to develop a validated correction scheme for temperature and pressure dependent influence of Brillouin scattering on laser return signals.

2.3.3 Campaigns

Work has started on the procurement of an airborne version of the ALADIN instrument. This will re-use equipment from the Pre-Development Model of the instrument. Work has also begun at the German Aerospace Research establishment (DLR) to prepare for ground and airborne campaigns using this instrument.

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

Good progress has been made in the Space Segment area and the completion of the activities on the Satellite Test Bed is considered as a major milestone. The on going testing of the SIRAL altimeter (Hybrid model) is showing good compliance with the expected performance. The difficulties encountered with the mass memory unit (MMFU) have been overcome and manufacturing has re-started nominally. Delivery of the solar array is imminent. However,

new delays have occurred due to alerts raised by other projects on commonly used parts. This could not affect the performance of the CryoSat satellite but only its reliability. Corrective actions are being investigated on a case-by-case basis.
For the CryoSat launch services, development is nominal and the Final Mission Analysis meeting has been successfully held mid February 2004 in Moscow.
The Ground Segment development is nominal. The first Satellite Validation Test (SVT0) has been successfully performed in a timely manner. The progress of the work is according to schedule.
As a summary, the development of the CryoSat mission is progressing significantly; but this development is hampered by the troubleshooting activities on the Space Segment mainly induced by quality concerns of some electronic parts. Since undue risks in the development of CryoSat can not be taken, the targeted launch date of 3 November 2004 will have to be revised. Corrective actions and consolidation of the schedule are currently on going. A delay of several weeks seems unavoidable.

Calibration/Validation

A meeting of the Calibration, Validation and Retrievals Team (CVRT) was held in ESTEC in January. This meeting was the last opportunity to consolidate the overall planning for the Spring 2004 CryoVEx pre-campaigns in the Arctic. During this activity an airborne radar system (ASIRAS) will perform measurements of the ice sheets on Austfonna and along the EGIG line in Greenland; it will also measure sea ice out of Svalbard, Station Nord and Alert. Detailed planning of both scientific activities (land-ice and sea-ice) and the related logistics were finalised. In addition the longer-term planning for 2005 campaigns was iterated.
CryoSat orbit requirements have also been reviewed extensively: a major outcome is that the 2-day repeat “Validation Orbit”, originally foreseen to ease the correlation between the satellite and in-situ measurements, will not be used. This will free up significant on-board resources, as no significant orbital change are required anymore.

2.4.3 Campaigns

ASIRAS
The Airborne SAR/Interferometric Radar Altimeter System (ASIRAS) has been re-integrated on a DO228 aircraft. After a technical flight in the area of Bremerhaven, a final qualification flight over land and sea ice has been successfully conducted end March in the vicinity of Svalbard. Preliminary analysis of the recorded data is demonstrating nominal performance of the radar altimeter and showing very good correlation with the laser installed onboard the DO228.
Therefore ASIRAS is now ready to support the CryoVex 2004 campaign planned end April 2004.

2.4.4 CryoSat scientific studies

The GSP sea-ice model data assimilation study entitled, “Synergetic Use of Remote Sensing Data in Coupled Ocean-Ice-Atmosphere Model Data Assimilation” was started by the UK Meteorological Office (UKMO) early January 2004. The first progress meeting was held at the new UKMO location in Exeter in March. The study is proceeding according to plan.

Announcement of Opportunity for Use of CryoSat data

An Announcement of Opportunity (A.O.) for the utilisation of the CryoSat data was released on 19 December 2003 with a closing date for submission of the proposals on 31 March 2004. Some 65 proposals have been received and the evaluation will be conducted during the second quarter 2004.
Taking into account the 21 proposals already accepted in the frame of the Calibration/Validation A.O., the grand total of proposals received is 86; a figure quite similar to the ENVISAT RA-2 instrument.

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 phase C/D contact has started.
Most subcontracts have been kicked off, and for most of them the Manufacturing Release Reviews have taken place to authorise the design baseline for the engineering model production. Long lead item definition and initiation of procurements are also nearly completed.

A first meeting of the calibration working group took place and came to the conclusion that the sun can be discarded as calibration target. Whilst the deep space view was confirmed as a necessity, the view to the moon (and according provisions in the data processing) is awaiting confirmation by ground based measurements which are currently being conducted (weather conditions permitting).

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. Phase B is expected to start in September.

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

Soil Moisture Retrieval Study:
The study extension was formally kicked-off in February and will run for 1 year.

Scientific inputs for the SMOS level-1 processor development *(with emphasis on calibration and image reconstruction techniques):*
The mid-term-review of the image reconstruction study took place during the reporting period.

Other OS Study Activities:
The study on “Synergetic Aspects and auxiliary Data Concepts for Sea Surface Salinity Measurements from Space" has been kicked-off successfully. In addition to synergetic data exploitation from SMOS and Aquarius the study team will provide a first overall scheme for sea surface roughness and surface temperature corrections necessary for salinity retrieval algorithms.

2.5.3 SMOS Campaigns

CoSMOS
The first experimenters meeting took place to refine the CoSMOS experiment plan to validate L-band passive radiometer retrieval algorithms over land and sea. Suitable aircraft/sensor combinations have been identified. A feasibility study will be initiated to define and implement adaptations required for operating the L-band radiometer preferably in conjunction with an L-band scatterometer onboard the selected platform.

Dome-C Campaign Experiment (DOMEX)
The DOMEX contract was successfully kicked off in February with the Institute for Applied Physics Nello Carrara (IFAC-CNR), Italy as prime contractor. IFAC have planned '04-'05 austral summer campaign activity at the Franco-Italian run Concordia Station Antarctica, with sub-contractor ARPAV taking responsibility for in-situ snow and ice measurements. IFAC will conduct tower-mounted time-series measurements with C- and L-band radiometers and a collocated IR sensor, over a 1-month continuous period during the time-window Nov '04 -- Feb '05. IFAC is currently preparing a Campaign Implementation plan, while developing the tower adaptor and modifying the radiometers to cope with the environmental conditions.

Justification and background on the importance of the SMOS-related DOMEX activities has been provided to the Italian Scientific Committee for Antarctic Research (PNRA) as part of their preparation of the '04-'05 field campaign plan.

2.6- 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 3 missions to go into feasibility 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 is expected within this year. A consultation to the User community took place in ESRIN (Frascati, Italy) last 19-20 April.

2.7- 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 been finished in early 2004:

- 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.

A final selection is expected within this year. A consultation to the User community took place in ESRIN (Frascati, Italy) last 19-20 April.

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 co-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. After some instrument studies, ESA has released an ITT for the pre-phase A system 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). The final selection of two bidders for the Phase A studies took place in March 2004.

3.2- Advanced Imaging Missions

TerraSAR: An initiative of European industry to deliver geo-information services based on synergetic observations with synthetic aperture radar (SAR) operating in L- and X- band. The

mission could be proposed for full implementation following initial consolidation under the Earth Watch programme, to start operation in 2007.

The TerraSAR consolidation Intermediate Review was successfully held in Portsmouth on 28-19 January 2004. The TerraSAR programmatics activity was initiated with Infoterra UK as prime contractor.

Fuegosat: It is proposed to deploy a demonstration satellite of a future satellite constellation Fuego devoted to forest fires detection and monitoring. The Fuego initiative has been pursued by a group of European companies in the frame of EC and ESA activities.

The Fuegosat consolidation is organised in two steps separated by a Fuegosat concept review, under preparation.

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.

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/