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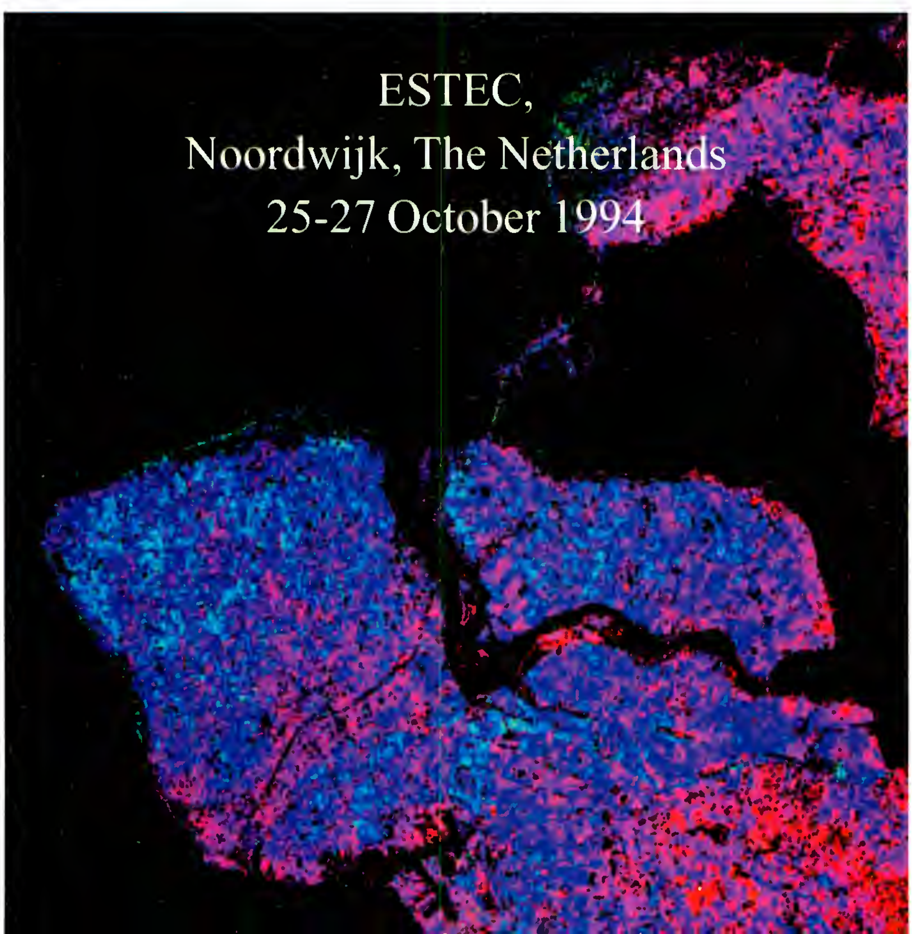
REPORT ON

THE EARTH OBSERVATION USER CONSULTATION MEETING



Cover picture: *Interferometer image of Zeeland derived from a pair of ERS-1 SAR images taken on 5 and 14 February 1994.*
Courtesy of FEL/TNO, The Hague, The Netherlands.

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THE EARTH OBSERVATION USER CONSULTATION MEETING

ESTEC
Noordwijk, The Netherlands
25-27 October 1994

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Earth Observation is assuming an increasing importance in addressing the needs and concerns of mankind and consequently it is an essential ingredient of the long term plan of the European Space Agency. Recognising this, and the need to build on the success of missions such as ERS-1 and Meteosat, the Agency is now starting to look ahead to the post 2000 era.

Basic to this is a clear appreciation of user requirements, encompassing operational and commercial users, as well as the scientific community. This requires close and continuous consultation with all sections of an ever increasing spectrum of potential users, one aspect of which is the organisation of general user consultation meetings.

This document summarises the outcome of the third of the Agency's Earth Observation User Consultation Meetings. It is intended to provide a perspective of the Agency's possible Earth Observation strategy beyond the year 2000 and to stimulate a wider debate on the form this should take.

CONTENTS

1. Introduction

This report summarises the outcome of the third Earth Observation User Consultation Meeting which was held at the Agency's European Space Research and Technology Centre (ESTEC), Noordwijk, The Netherlands, over the period 25-27 October 1994. It was attended by well over two hundred scientists and other potential Earth Observation users, including a significant number of commercial/operational users. A full list of participants will be found in Annex B1.

The aim of this meeting was to review the needs for Earth Observation in the post 2000 era building on the recommendations contained in the report of the Second Earth Observation User Consultation Meeting which was held in May 1991 (see ESA SP-1143 "Report of the Earth Observation User Consultation Meeting"). As previously, this meeting was called ahead of a meeting of the ESA Council at Ministerial level, to help clarify the Agency's long term strategy for Earth Observation.

In anticipation of the meeting the Agency drafted two discussion documents with the aid of its Earth Observation Advisory Committee (see Annex B2). One of these documents summarised the Committee's views on user requirements in the post 2000 time frame, while the other, taking account of likely evolutions in the meantime, identified a set of candidate mission profiles that together would address these needs.

These two documents were circulated in advance of the meeting and formed the basis for the Working Group discussions that formed the core of the Consultation Meeting. These discussions were organised in two phases. During the first, user requirements were discussed and during the second, candidate mission profiles were considered. Both research and operational/commercial interests were addressed during these discussions. The Working Groups (and sub-Groups), together with the names of the Chairmen and Rapporteurs, are listed in Annex B3.

In their revised form the two documents are reproduced in this document, together with the requisite inputs from the five chairmen of the Working Groups. The relevant sections of this report are Section 2 "Research Requirements", Section 3 "Operational and Commercial Requirements" and Section 4 "Candidate Earth Observation Mission Profiles".

During the final phase of the Meeting the recommendations emerging from the various Working Groups were reviewed in a plenary session. Section 5, "Recommendations from the Meeting", reproduces the statement summarising the outcome of the meeting which was endorsed during this session. This together with some subsequent evolutions are further discussed in Section 6 "Concluding Remarks".

Annex A contains summaries of the five invited presentations which were intended to help set the scene for the meeting as well as to stimulate discussion. It will be noted that, in addition to two presentations outlining the Agency's general views, there were three by external users focussing on potential commercial/operational issues for Earth Observation data.

2. Research Requirements

2. Research Requirements

2.1 Introduction

This section of the Proceedings is specifically concerned with the requirements of the research community in the post 2000 period taking account of likely evolutions in the interim.

In the past the Agency has identified four fundamental objectives underlying its Earth Observation programme, namely contributing to:

(1) *The study and monitoring of the Earth's climate and environment* on various scales, from local or regional to global.

(2) *The monitoring and management of the Earth's resources*, both renewable and non-renewable.

(3) The continuation and improvement of the *service provided to the worldwide operational meteorological community.*

(4) The contribution to the understanding of the s*tructure and dynamics of the Earth's crust and interior.*

These objectives span all four of the Earth Observation research and application areas (i.e. atmosphere, land, ocean/ice and geodesy/geophysics).

However, before moving on to consider specific requirements it is necessary to address global issues. Here specific reference must be made to the world-wide scientific and public concern:

(a) that the rates of environmental and climate change are increasingly influenced by mankind's activities;

(b) that environmental and climate changes and natural disasters will have increasingly serious social and economic impacts;

(c) that the continuous monitoring and management of Earth resources will be increasingly needed to attain a sustainable development.

These concerns impact directly on the general well being of mankind and, in particular, on the route towards sustainable development. They have led governments to agree that steps should be taken to reduce the detrimental impact of man on his environment and here special mention must be made of the Montreal Protocol which, recognising the vulnerability of the ozone layer, seeks to limit the global emission of CFCs. They also led to the endorsement of the 1990 Report of the Intergovernmental Panel on Climate Change (IPCC) by Ministers and officials from 137 countries.

This report highlighted the fact that current predictions contain many uncertainties, particularly with respect to the timing, magnitude and regional patterns of climate change, due to incomplete understanding of:

— the sources and sinks of greenhouse gases such as carbon dioxide, methane, nitrous oxide, ozone and halocarbons, and their dependence on physical processes, which will determine their future concentrations;

— clouds, aerosols and water vapour, which strongly influence radiative transfer in the atmosphere and hence the magnitude of climate change;

— oceans (circulation and transport), including sea ice, which influence the timing and patterns of climate change;

— the polar ice-sheets which affect predictions of sea-level rise;
— the land surface, which influences energy and water exchanges with the atmosphere and hence the magnitude and regional patterns of any climate change.

The IPCC also emphasised the need for an integrated international global climate monitoring and prediction programme to improve the systematic observation of key climate related parameters; to develop improved numerical models for climate simulation and prediction; and to improve understanding of the many interacting physical, chemical and biological processes that govern climate and climate change.

This present definition exercise must take into account not only the above mentioned requirements but also look beyond them and anticipate future thrusts which will mainly come from the United Nations Framework Convention on Climate Change signed at the Earth Summit in June 1992 in Rio de Janero and now enacted by the first conference of the Parties to the Convention scheduled for 28 March to 7 April 1995 in Berlin.

2.2 International Programmes Concerned with Global Environment and Climate Change

Two international programmes specifically address concerns about the environment and climate variability and change, namely the World Climate Research Programme (WCRP), and the International Geosphere/Biosphere Programme (IGBP), both of which try to advance knowledge and understanding of the Earth system (including the biosphere). They all recognise that the various components of the Earth-atmosphere system are strongly coupled and cannot be addressed in isolation.

Within the WCRP, which is concerned with furthering the understanding and ability to predict climate, specific mention must be made of GEWEX (Global Energy and Water cycle EXperiment), jointly sponsored—as all WCRP projects—by the International Council of Scientific Unions (ICSU) and UNESCO's Intergovernmental Oceanographic Commission(IOC). GEWEX tries to understand the global water cycle and the global energy fluxes, needed for their numerical modelling in order to predict and assess the impact of variations. The main climate processes to be studied by GEWEX are cloud/aerosol/radiation interactions and land surface energy and water exchange.

A new WCRP project named CLIVAR (CLImate VARiability and Predictability) addresses natural variability and predictability of the climate system in order to predict climate on seasonal, interannual and possibly multi-decadal time-scales. It complements GEWEX as it addresses the "slow response" of the climate system as opposed to the "fast response" studied in GEWEX. Ocean circulation and its variability are of fundamental importance to WOCE (World Ocean Circulation Experiment) and, after its completion in 2002, to CLIVAR. SPARC (Stratospheric Processes And their Role in Climate) is targeted at the various couplings between stratospheric processes and their relevance to climate.

The IGBP is concerned with the interactive physical, chemical and biological processes that regulate the total Earth environment system. It focuses on key interactions and significant changes on the time scale of decades to centuries. The programme will focus on interactions which are most sensitive to human activities i.e. the continental and oceanic biosphere. IGBP seeks to complement the activities falling within the compass of the WCRP through an ensemble of core projects. IGAC (International Global Atmospheric Chemistry) is addressing the various relationships between the biosphere and chemical processes in the atmosphere. BAHC (Biosphere Aspects of the Hydrological Cycle) provides focus for research activities concerned with climate and interactions involving the biosphere and hydrological cycle. LOICZ (Land-Ocean Interactions in the Coastal Zone) is focussing on the study of land-ocean interaction processes and related anthropogenic impacts. GAIM (Global Analysis, Interpretation and Modelling) is targeted to analyse current models and data and interpret the capability of current models and experimental programmes to advance and synthesize our understanding of the global biochemical cycles and their links to the hydrological cycles and, more generally, to the physical climate system as a whole. GOEZS (Global Ocean Euphotic Zone Study) is planned in order to resolve mesoscale patchiness of phytoplankton in the upper ocean, which is where small-scale motions have the greatest impact on the vertical transfer of properties from the atmosphere to the deep ocean.

The likely needs of all these programmes must be addressed when considering users requirements in the post 2000 era and reference to specific requirements will be found under the appropriate sections of this report. However, at the outset it is important to realise that these programmes pose significant challenges in the provision of data which include the need for information on:

— Radiation and clouds: involving solar irradiance, reflected solar flux at the top of the atmosphere, emitted infrared flux at the top of the atmosphere, incident solar flux at the surface, downward long-wave radiation at the surface, net radiation flux at the surface, column contents of trace gases and aerosols, cloud amount, type, heights of bases and tops, radiation flux divergences.

— Standard meteorological variables from the surface to the upper stratosphere (over land and sea) including at least temperature, water vapour and winds.

— Ozone related constituents in the troposphere and in the stratosphere - chemistry-climate coupling processes, diurnal, seasonal, annual and solar cycles of trace gases, source gases, radiative-dynamical and chemical coupling.

— Precipitation in the form of rain, snow, hail or dew—rain rate and amount, snow rate, snow water equivalent, hail events and their intensities, amounts of dew amounts over areas where dew is the main precipitation (e.g. Andes).

— Ocean variables - sea surface temperature, ocean currents (which also demands an accurate determination of the geoid), deep water formation, ocean mixed layer thickness and heat storage, fresh water fluxes, sea-ice extent, type and motion, surface biological production.

— Land surface characteristics—surface albedo, roughness, surface skin temperature, surface emissivity, vegetation parameters, evaporation, soil moisture, run-off and boundary layer variables (i.e. wind, temperature, water vapour content, temperature and humidity profiles).

In addition to the technical challenges posed by such requirements it is important to note that many of these variables cannot yet be measured directly from space and must, therefore be derived by proxy from observables using models. This in turn implies a comprehensive understanding of the processes involved.

Satellite data need validation and calibration. Calibration of sensors should be based firstly on rigorous pre-launch procedures, secondly on continuous and consistent on-board calibration methods, and thirdly, in some circumstances, on in-flight intercomparisons with other sensors.

Geophysical data products derived from satellites must be validated continuously and consistently. This requires co-ordinated experiments including ground-based and in-situ airborne measurements of atmospheric and surface parameters.

2.3 Atmosphere

In order to understand the state of the atmosphere and the distributions of atmospheric constituents as well as the different processes it is necessary to consider the interactions between radiation, chemistry and dynamics. Global atmospheric models and corresponding assimilation schemes have now reached a stage where they provide a reasonable picture of the global atmospheric systems and its interface with land, sea and ice. One way to select priority variables to be measured is to assess their impact in global simulation experiments. Models should also be used to help decide on sampling strategies.

In the subsections below the most important scientific objectives are tabled, which are often restricted to single disciplines e.g. chemistry. Structuring the report in this way is useful in order to limit complexity, but when discussing satellite missions the interdisciplinarity has to be taken into account.

Climatology and Atmospheric Dynamics

Underpinning the requirements of climatology and atmospheric dynamics also means improvements in monitoring standard meteorological quantities such as temperature, humidity and wind, the main inputs to operational NWP (Numerical Weather Prediction) models. The importance of this should not be underestimated.

The needs here are basically two-fold, namely:

— to monitor the state of the Earth's climate by observing key climate atmospheric variables on a regular basis viz. the operational observing systems.

— to advance the understanding/knowledge of the processes (i.e. radiation transfer, cloud formation, precipitation, etc.) influencing the key climate variables;

The list of variables given in the previous section provides a good starting point for considering needs and it is clear that the Agency must consider these very carefully in formulating its long term plans.

For the atmosphere, as far as the physical part of the climate system is concerned, it is necessary to focus on GEWEX and CLIVAR. Here three particular areas, of fundamental importance to the Earth's global water and energy cycles and hence to our ability to predict or understand climate change, may be highlighted:

(1) Interactions between precipitation and circulation in the tropics - on the global scale energy deficits at high latitudes are balanced by energy transport from tropical to sub-tropical latitudes. A major component of this is via convective motion, driven by water

convergence near the ground in the inner tropics. Both latent heat, sensible heat and potential energy are involved. Many physical processes are involved, spanning a wide spectrum of spatial and temporal scales, many of which are not properly understood. Prominent examples are the El Nino and the Asian monsoons. The picture is further complicated by significant inter-annual variability. Of fundamental importance is precipitation and its links to atmospheric circulation. Assignment of top priority to these items depends on availability of three dimensional wind measurements. In the absence of such wind measurements the priority for precipitation measurements drops below that for a cloud/aerosol radiation mission.

(2) Cloud/aerosol radiation interactions - this is another area of major uncertainty. Complex processes are involved whose understanding pushes our capability to measure radiative transfer and cloud physics parameters to its limits. A fundamental problem is the global observation and reliable detection of clouds and aerosol over all surfaces. Here specific mention should be made of the need to develop proper climatologies of cloud base and cloud heights as well as of thin cloud and aerosols in general and above the polar sea ice fields in particular. Further atmospheric water vapour profiles must be monitored, especially in the upper troposphere and over lower latitude regions.

(3) Water and energy exchanges through the surface—the planetary boundary layer couples energy and water fluxes from the surface to the bulk of the atmosphere. This coupling is not fully understood, particularly over irregular terrain, and consequently difficult to model. Over the ocean a further complication arises as the fluxes of energy are locally determined so the determination of ocean surface fluxes lacks the self-correcting safety feature imposed on the land surface fluxes by the quasi-perfect mean energy balance at the ground.

(4) Climatically relevant gases—a focus should be the profiling of relatively short-lived gases, which determine radiative balances and changes therein in the upper troposphere and lower stratosphere. The highest priority are ozone and water vapour, next come methane (CH_4), nitrous oxide (N_2O), some fluorochlorocarbons, halones, etc.

(5) Stratosphere-troposphere exchange—the exchanges and the variability of tropospheric height (or any changes thereof) need to be quantified, as they have consequences for the greenhouse effect of the atmosphere.

Atmospheric Chemistry and Climate Change

The composition of the atmosphere is the result of physical, chemical and biological processes occurring in the atmosphere itself and at its lower boundaries. Biochemical activity is activated/initiated by the absorption of solar radiation at the surface. The vertical and horizontal distribution of the trace gases, which largely determine climate, is therefore dependent on photochemical (photophysical), chemical and dynamical processes.

When considering the need to measure trace species in the atmosphere the dominant role of ozone, both in the stratosphere and troposphere, must be stressed. Ozone has several important functions in the atmosphere, the most significant of which are:

— absorption of biologically harmful ultraviolet radiation, thereby providing the necessary shield for the terrestrial biosphere and to a certain degree also the oceanic biosphere;

— heating of the middle atmosphere by this absorption thus grossly determines the temperature structure and hence the dynamics of the stratosphere, the height of the troposphere and radiative forcing at the tropopause;

— in the lower atmosphere its presence leads to the formation of hydroxyl radicals which to a large extent determine the oxidative power of the troposphere; thus ozone also controls the lifetimes of other radiatively active gases.

It is essential to monitor the global distribution of ozone continuously and to quantify its global budget together with those of the key species that determine its concentration (in both the troposphere and stratosphere), not forgetting aerosols and PSCs (polar stratospheric clouds). A full understanding of ozone chemistry is of fundamental importance.

Allied to this is the need to identify the processes that control the concentrations and distributions of the major climate gases which, in addition to ozone, include water vapour, carbon dioxide, methane and nitrous oxide. It is also necessary to have a clear understanding of the processes that control the other oxidants in the atmosphere (i.e. in addition to ozone).

On decadal timescales the major topics to be addressed are likely to remain:

(1) Quantification of the evolution of the stratosphere, taking into account the potential decrease in emissions of man made halocarbons (e.g. CFCs) following the implementation of regulations governing the release of CFCs and other constituents within the Montreal Protocol and nitrogen oxide emissions by subsonic (and future supersonic) aircraft.

(2) Advancing our knowledge and understanding of the processes responsible for maintaining or changing the stratospheric ozone layer:
   (a) Catalytic ozone destruction cycles involving NO_x, HaO_x, HO_x as catalysts (where Ha = Cl, Br and x=1,2)
   (b) Linkage between polar and mid-latitude ozone depletion
   (c) The role of PSCs (Polar Stratospheric Clouds), aerosols and high level cirrus clouds for the ozone budget.
   (d) Effects of dynamic variability, including stratospheric-tropospheric exchange, on the ozone distribution.

(3) Quantification of the ozone budget in the troposphere - global distribution of ozone and precursors, exchange between the planetary boundary layer and the free troposphere, stratospheric/tropospheric exchange processes, intra and inter-annual variability).

(4) Quantification of the role of water vapour and chemically/photochemically active gases, including ozone, on climate-chemistry interactions involving for example methane, carbon monoxide and hydrocarbons with emphasis on the lower stratosphere and upper troposphere.

(5) Other anthropogenic influence on the stratosphere and troposphere - quantification on a global scale of phenomena such as:
   (a) Biomass burning (primarily in the tropics).
   (b) Land cover change - deforestation, irrigation, wetland reclamation, afforestation and urbanisation.
   (c) Emissions resulting from industrial pollution, combustion of fossil fuels (primarily in the industrialised countries).

(6) Impact of natural phenomena on stratospheric and tropospheric composition and resultant behaviour - quantification on a global scale of:
   (a) Volcanic activity (e.g. Pinatubo).
   (b) Biogenic sources of gases and particles from land and ocean.
   (c) Extraterrestrial phenomena, e.g. solar radiation and particle flux changes.

To address these topics long term monitoring of stratospheric and tropospheric ozone and associated variables notably, the oxides of nitrogen, hydrogen, chlorine and bromine contents, temperature and aerosol particles is needed.

2.4 Geodesy and Geophysics

For the better understanding of the physics of the interior of the Earth, and for a better understanding of the dynamics of the oceans, it is necessary to:
— improve our knowledge of the gravity field of the Earth, both in terms of spatial resolution and accuracy;
— an improvement of the knowledge of the Earth's magnetic field and the determination of its secular variations.

A number of International Programmes recognise the urgent need for an improved geopotential field and geoid. Specific examples include, for geophysics, the International Lithosphere Programme and, for oceanography, the World Ocean Circulation Experiment (WOCE).

Geophysics

Solid Earth physics suffers intrinsically from an inability to directly observe the relevant parameters. Observations are mainly confined to the surface of the Earth. Principal sources of information about the dynamics of the Earth's interior are the magnetic and the gravity field as well as seismic wave propagation. Although seismic tomography holds a lot of promise the translation of the retrieved velocity anomaly field to density variations remains problematic.

It is known that large scale gravity anomalies are caused by motion within the Earth's interior, at the core/mantle boundary, within the mantle, by the up-welling ocean ridges and plumes and the subduction at continental margins. Associated with the latter are backarc volcanos and mass readjustment as a consequence of postglacial uplift. Therefore, any significant improvement in the knowledge of the Earth's gravity field to higher spatial resolution, in particular over the polar areas (unsurveyed so far), would be of great importance.

The "Secular Variation" of the Earth's main magnetic field yields information both on dynamic changes in the core and on the thermal state of the mantle which controls its electrical conductivity, which in turn governs the diffusion of magnetic variations through the mantle (before reaching the Earth's surface). The "Anomaly Field" reflects magnetisation variations in the crust and upper mantle. By studying remnant magnetisation in crustal rocks information on Secular Variation and plate kinematics on very long time scales can be yielded.

The combination of seismic tomography, coupled with an improved knowledge of topographic relief, the Earth's magnetic and gravity fields, are essential ingredients for a much better understanding of solid Earth dynamics.

Geoid

Satellite altimetry has proved very successful in determining the time variations of ocean surface topography, caused by meandering currents, eddies, tides, atmospheric pressure etc. Altimeters alone, however, cannot detect the quasi-stationary (steady state) sea surface topography, i.e. the mean ocean circulation itself. This would require precise knowledge of the ocean equilibrium surface (the hypothetical ocean surface at rest). This equilibrium surface, the geoid, is purely determined by the Earth's gravity field.

A precise geoid, in combination with satellite altimetry, determines absolute upper ocean circulation and at the same time provides important information about the circulation at depth. Better knowledge of ocean circulation is a key to a better understanding of the physics of the oceans and the mechanism of transport processes, including transport of heat, salt, carbon, etc.

For geodesy the precise geoid is prerequisite for the establishment of a worldwide unified height system needed for studies of crustal motion, sea level and sea level/ice mass interaction. Table 2.1 lists the agreed research requirements for each topic in terms of geoid and gravity field accuracy and spatial resolution.

Monitoring and Prediction of Geophysical Hazards

Natural geophysical hazards like earthquakes and volcanic eruptions are not only the concern of solid earth researchers, but also of institutions with responsibilities for safety and mitigation measures. Understandably, insurance companies are amongst those requiring adequate geophysical information. The objectives of this wide research and application community reach from the need to understand the physical causes of volcanic eruptions or earthquakes to the assessment of their consequences and, ultimately their predictions.

Changes in the electromagnetic environment or surface deformation, for example, are possible indicators of precursory mass variations in the Earth's interior before a geophysical event (hazard) occurs. Many other parameters are also relevant observables: the volcanic lava flows and their direction; surface temperature indicating magma rise, etc. They may be sensed timely and globally using satellites that carry suitable instrumentation for precise ranging and imaging.

Typical promising techniques are SAR interferometry, GPS positioning, visible and infrared imaging and their combination.

Table 2.1: Geophysical Parameters Benefitting from an Improved Knowledge of the Earth's Gravity Field with respect to both Accuracy and Spatial resolution

Measure Parameter	Geoid (cm)	Gravity Field [mGal=$10^{-5}ms^{-2}$]	Resolution (half wavelength) [km]
height, height variations, mean sea level monitoring	< 5		< 200
thermal structure of continental lithosphere		2	50 - 1,000
structure of oceanic lithosphere and interaction with asthenosphere		1 - 10	50 - 1,000
mantle composition, rheology and scales of convection		1	100 - 5,000
steady state ocean circulation	2-5		50 - 300
polar ice sheets and bedrock identification		1 - 5	< 200

2.5 Land Surface

Major transformations occur at the land surface. It is the prime site of human activity and is being constantly transformed and adapted in response to changes in population and economic development. In the short to medium term it is likely that changes due to human activities will be larger than any climate impact. As such land surface represents a topic of study in its own right.

Issues related to land surface span a range of scientific disciplines because they include biosphere studies, surface/atmosphere interactions, ecosystem processes, urbanisation, industrialisation, etc. The study and observation of land surface processes poses major challenges since land surfaces are generally very heterogenous and the spatial and temporal variability of the observables is much greater than is the case for either the atmosphere or the oceans. Furthermore, for a specific field of study, the requirements are quite high and relatively inflexible, in terms of scale, frequency and nature of the required measurements.

In this context scaling is of specific concern. Many land surface features and processes of global significance occur at the local scale, and must be extrapolated to regional and global scales, taking account of significant variations in both surface properties and topography.

Within the present context, the basic aim of the Earth Observation strategy, as far as the land surface is concerned, must be to advance the understanding of the various processes which are taking place at the surface of the Earth, both with respect to human activities and climate impacts (i.e. land-atmosphere interactions and transformations of the biosphere).

Land Surface Properties and Processes

Without entering into the specific requirements of all land related applications it is possible to identify a set of basic land features and characteristics which must be the focus in any space observation strategy:

— Surface characteristics and conditions (type and condition of land cover, terrain characteristics, soil, surface and subsurface water), and their changes especially if due to environmental degradation and pollution.

— Surface processes such as primary productivity, phase changes in biochemical cycles (trace gas emissions, deposition at the surface, etc.), energy and matter interactions (evapotranspiration, radiation budget, etc.)

Both sets of measurement are required for research as well as for applications; furthermore, they will have to be carried out at a range of resolutions and with a frequency of acquisition that will vary according to the particular area of concern. Of paramount importance in considering the formulation of any post 2000 strategy are the reliability of acquisition and quality of the data, also related to the sensitivity of the geophysical and biosphere models.

An improved understanding of processes, governing the continuous transformations of the geosphere, hydrosphere and biosphere, is needed to optimise the utilisation of resources, to minimise possible adverse impacts of human activities and to preserve the quality and diversity of the land surfaces. High resolution information on properties of the land surfaces, including vegetation, water and soil, as well as information on temporal changes in these properties, is needed for development and application of diversified models of land processes.

Due to the complexity of the land surfaces and of the associated processes, models need to be developed for a wide range of different ecological systems, starting from local and regional scales and proceeding to the global perspectives required for climate research. Among the key research topics are the development of models of biomass productivity, the temporal dynamics of vegetation and environmental hazards (floods, landslides, seismic activity), the hydrological cycle (including the extent and quality of surface water, the distribution of water in the soil and the land cryosphere) , soil transformation (including desertification, erosion, etc.),

Land Atmosphere Interactions and Climate Impacts

Although, in the past, greater emphasis has been given to oceanographic and atmospheric processes, it is clear that, as far as climate is concerned, the study of land surface processes is becoming increasingly important, because of their interactions with the atmosphere and the hydrosphere (e.g. energy and mass exchanges). This is reflected in global programmes such as the WCRP (World Climate Research Programme) and IGBP (International Geosphere Biosphere Programme) both of which have initiated investigations of land surface processes. These will provide the focus for research activities concerned with climate and interactions involving the land surface.

The core projects of the IGBP relevant to land applications include BAHC (Biospheric Aspects of the Hydrological Cycle), LOICZ (Land-Ocean Interactions in the Coastal Zone), IGAC (International Global Atmospheric Chemistry), GAIM (Global Analysis, Interpretation and Modelling), GCTE (Global Change Terrestrial Ecosystems). For the WCRP specific mention must be made of GEWEX (Global Energy and Water Cycle Experiment) and its project ISLSCP (International Satellite Land Surface Climatology Project) as well as BOREAS (Boreal Ecosystem-Atmosphere Study).

The land surface interacts with both the atmosphere and the oceans. Many complex processes are involved, most of which are poorly understood. They encompass bio-geo-chemical cycles as well as the more classical physical interactions. This is a two way exchange. Not only does the land influence climate processes, but also there is a major impact on man's environment from the climate.

Within this context the specific observables for a land/climate mission are:
— biospheric productivity above the surface (also as sources and sinks of greenhouse gases, aerosols);
— hydrological cycle (precipitation, evapotranspiration, soil moisture, snow cover and depth, river run-off);
— dynamics of polar ice sheets and glaciers (height, flow, ablation, accumulation);
— land transformation both by anthropogenic action and climate change;
— temporal dynamics of vegetation, including biomass burning and surface properties (viz. surface spectral reflectance);
— land surface energy fluxes.

Land/Ocean Interactions

A newly emerging scientific theme is the study of land-ocean interaction processes and related anthropogenic impacts. The coastal domain is a sink for material transferred from continent to ocean, a source of dissolved and suspended matter for the open ocean, and a source of biogenic substances for the atmosphere. It is fragile and experiences strong anthropogenic perturbations. This has led to establishment of the IGBP core project Land Ocean Interaction in Coastal Zones (LOICZ). It is recognized that, whereas the processes are local, their impact is global, and therefore satellite remote sensing is an essential tool which can enable local studies to be extrapolated globally. Fields of study include:
— coastal erosion
— flooding
— beach processes and shallow water bottom changes
— river discharge
— sedimentation
— sea level changes
— anthropogenic impacts on estuaries and coastal zones
— biological feedback and controls on environmental change

The characteristic scales of the above mentioned processes require high spectral resolution satellite observations. However, the current provision of satellite remote sensing data is not complete, in particular, due to lack of both regular coverage and ocean colour observations with high spectral and spatial resolution. The latter is to be changed within this decade. For the beginning of the next century, the following issue is likely to be considered:

— Land-ocean interaction driven by changes on land, their influence on biogeochemical and biophysical processes in marginal seas and their integrated global implications.

The major difficulty in addressing this issue is in the high frequency variability of the coastal ocean, which will ultimately require observations by different satellites. The issue falls within the primary interests and concern of coastal environment management agencies (i.e. CEO) including their responsibility for early warning or prevention of disaster and hazard. It will also provide important information to coastal industry (fisheries, pollution control, dredging, leisure and recreation,etc).

2.6 Ocean and Ice

Remote sensing plays a more and more important role in ocean science providing quasi-synoptic observations of the sea surface. It should be considered as part of a system consisting of in-situ and satellite data and numerical modelling. Today it is possible to observe the variability of ocean surface circulation, sea surface temperature, near surface wind (magnitude and direction), wave height, ocean colour and sea ice cover. Simultaneously, global ocean circulation models with adequate (eddy-resolving) resolution are reaching maturity. Provided long term continuity is guaranteed, these observations will make an important contribution to studies of the large scale dynamics of the ocean, mesoscale ocean processes, air-sea interaction and the roles of the ocean and sea ice for climate change etc. Equally important, they provide initial and boundary conditions to ocean circulation and coupled ocean/atmosphere models, required to integrate them and to predict future changes. Future development will continuously rely on mesoscale process studies, for improving the understanding of these processes and their parameterisation, and global descriptions, which in turn rely, on these parameterisations.

Dynamics of the Ocean and its Role in Climatology

There is a basic need to understand the complicated interactions at the ocean-air interface. Examples of such interactions are the ENSO (El-Niño Southern Oscillation) events and the North Atlantic oscillation affecting European climate. Key international projects within the WCRP like the successfully finished Tropical Ocean Global Atmosphere (TOGA), the ongoing World Ocean Circulation Experiment (WOCE), and the starting Climate Variability and Predictability (CLIVAR) address these topics. Establishing an ocean monitoring system will require global data acquisition over decades in order to detect climate variability and changes as well as changes of ocean heat, carbon and salt storage and ocean transport. The observing system will strongly depend on satellites, which offer the combination of global coverage, frequent observations and data consistency.

Currently, satellites are already used to retrieve some important oceanic surface parameters such as ocean wave spectra, wind stress and sea surface temperature. For application in global change studies, the spatial and temporal coverage and resolution provided by the satellite observations are acceptable. However, several parameters and processes that are associated with climate change, are currently not adequately observed. These include absolute ocean topography and thereby the mean, stationary part of ocean circulation, surface salinity, phytoplankton concentration and air-sea fluxes of heat. Observations of all these are required to advance the understanding of the role of the ocean in climate and climate change.

In the post 2000 era, specific important requirements include:

(1) *Ocean circulation and its variability* are the central elements of the observing system as this is the means by which ocean transports heat and dissolved quantities. It is best observed by satellite altimetry and in-situ data assimilated into circulation models. Long term continuity of such observations at the centimetre level is a key element of any ocean observing system. Satellite altimetry is mature enough that such a technique be made operational and part of an Earth Watch system. Observing the absolute circulation requires an independent gravity mission to better determine the geoid. The requirement for the geoid is better than 5 cm precision on space scales ranging from 50 to 300 km.

(2) *Ocean and the atmosphere exchange* of momentum, heat and moisture. The former is at present best determined by satellite scatterometry, the data of which must be assimilated into atmospheric numerical model. Such an instrument must be part of future operational meteorological satellites. Sensible and latent heat fluxes depend on many complex processes and will likely remain one of the main uncertainties of climate modelling. They can only be derived indirectly from satellite parameters like surface wind, sea surface temperature (SST) and air humidity. Accuracies of these parameters have to be high: for example, the long term accuracy of SST should be of the order of 0.2°C in order to infer climate variability and change. It seems likely that progress will rely on improved parameterisations of processes in the ocean and atmosphere mixed layers, to be implemented in global models and to be adjusted through assimilation techniques. In addition, the heat budget of the surface layer will need an extensive programme of in-situ measurements, to be transmitted via satellite techniques.
The fresh water budget is equally important as it modifies salinity and thus water density. Parameterisation of this term from microwave measurements of air humidity and precipitation seems feasible. An extensive programme of in-situ measurements of salinity in the ocean surface layer may be an equally useful approach for determining this term.

(3) Some further characteristics of the ocean surface like skin temperatures and directional wave spectra are needed to further quantify ocean-atmosphere exchange. They are potentially detectable using remote sensing techniques. The continuous development of new instruments is thus also to be supported.

The need for these particular observations has also been highlighted by the Global Climate Observing System (GCOS), decided at the Second World Climate Conference in 1990, as well as by the Global Ocean Observing System (GOOS).

Carbon Cycle and Geochemistry

An important scientific goal is to analyse the ocean's role in the global carbon cycle and a long-term objective is to understand how the biological processes, which are central to the global carbon cycle, will change in response to carbon dioxide concentration increase and to modified physical forcing. A quantitative understanding of the coupled dynamics of the ocean biology, ocean physics and atmospheric forcing on the upper ocean requires both continuous satellite observation (ocean colour, temperature, wind field, irradiation), *in- situ* observations and modelling development. There is a particular need to improve the estimation of the effect of the phytoplankton distribution and productivity on the exchange rate of carbon dioxide at the ocean-atmosphere interface as well as the carbon flux into the interior of the ocean, the goal of the planned Global Ocean Euphotic Zone Study (GOEZS).

The cycles and the fluxes of other elements (such as nitrogen, potassium, sulphur, oxygen and trace metals) are closely related to that of carbon through their simultaneous transport by ocean currents, the production (via photosynthesis) of particulate matter, followed by the transformation due to biological activity (e.g. grazing) and sedimentation. Eolian transport (aerosol, desert dust) will also influence the productivity of the oceanic algae, and, conversely, some phytoplankton species release gases (such as dimethyl sulphide) affecting, after oxidation into sulphuric acid, the cloud condensation nucleus population.

With spatial scales (from local to regional to global) and temporal scales (from seasonal to annual to decadal) as envisaged, satellites are the appropriate tools . A combined use of various remote sensing data (ocean colour, sea surface temperature, wind field, solar irradiance) is required to meet the above mentioned objectives. Improved description of specific functional groups is important to derive better estimates of production during strong episodic bloom events. This can be achieved using ocean colour instruments with improved spectral resolution as compared to present day instruments and as anticipated for the MERIS type data. This should also be part of a system including in-situ measurements of nutrients and biogenic parameters and numerical modelling coupling the physics and the biogeochemistry of the ocean.

Sea Level

The potential impact of climate change on sea-level poses a serious threat for many lowland countries, along with general socio-economic consequences for most other countries. There is not only the need to monitor global sea level rise (of the order of 1.5 to 2.5 mm/year since the beginning of the century) and its potential acceleration, but also to understand its causes and to monitor regional variations. Part of the signal is due to the thermal expansion of sea water and fresh water inputs which take decades to centuries to spread over the world ocean. The consequences of changes in sea level have been studied in a variety of international and national programmes and led to the definition of the Global Sea Level Observing System (GLOSS) initiated by the intergovermental Oceanographic Commission (IOC) of UNESCO. It consists of a global set of tide gauges which are progressively being brought into a single coordinate system by means of precise positioning techniques. Whereas tide gauges make only local measurements of sea level relative to land, regional geodetic surveys from satellite help separate tectonic motions from actual sea level signals.

Thanks to the unexpected accuracy of the most recent altimeter data, estimates of the variation of the mean sea level at a precision of about +/- 0.5 cm on a 10 day time frame, are now available. Such data, if available as a time series , would probably permit the detection of such changes in sea level within less than 10 years, their separation from other ocean signals (due to change of ocean circulation for example) and their regional mapping. However, only with ice and global ocean circulation monitoring can the change in dynamics of the ocean be determined on a global scale.

Earth rotation monitoring and the measurement of the temporal variations of the large-scale gravity field provide additional constraints on the ocean/ice/land mass readjustment.

Sea Ice

Long term monitoring of the sea ice extent and thickness is essential for climate change studies. In particular, the seasonal and annual changes in sea ice cover including melting processes significantly influence the surface albedo and fresh water cycle. Moreover, the large fluxes of heat and salt released through freezing in leads, along the marginal ice zones and in coastal polynias in winter time effect deep water formation and thermohaline circulation of importance for global ocean circulation. Observations of thin sea ice (<30 cm) formations are consequently essential. These issues are central to international programmes, e.g. the Arctic Climate System Study (ACSYS) of the WCRP.

In sea ice modelling, the dynamics and thermodynamic air-sea-ice processes are not entirely understood, primarily due to lack of surface sea ice roughness, freeboard, and ice thickness observations, which affect the air-ice and ice-water drag coefficients. Presently remote sensing methods only allow the large scale surface roughness to be observed. However, the temporal and spatial scales that characterize the thermodynamics require daily-to-weekly observations both at high resolution (100 m) and moderate-to-low resolution (10 km).

Polar Ice Sheet

The polar ice sheets in Antarctica and Greenland play a vital role within the global climate system. They exert strong influence on both atmosphere and ocean, and are, in turn, controlled by these systems. Natural or anthropogenic change in any of the components will not only have an immediate but also a very long term impact on the others. There is, however, no conclusive evidence that indicates whether the polar ice sheets are growing or shrinking. Sea level responds directly to change in ice volume of the grounded ice sheets, while global ocean circulation is driven partly by the formation of dense cold water produced beneath large Antarctic ice shelves and forming ocean bottom water. The investigation and determination of the mass balance of the Antarctic ice sheet is, e.g., emphasized as a case problem within the Filchner-Ronne Ice Shelf Programme (FRISP), an international project of the Scientific Committee on Antarctic Research (SCAR). To establish the current state of ice mass balance and its future changes requires the accurate long-term observations of the following ice sheet parameters and their changes:

- Ice sheet surface elevation relative to a precise global geoid.
- Ice sheet velocity fields.
- Ice sheet mass flux at the grounding line of ice shelves (for the Antarctic).
- Calving rate, advance and retreat of glaciers and ice shelves.
- Surface properties including snow cover, ablation, meltline and ice-free areas.

2.7 Conclusions and Recommendations

During the User Consultation Meeting it became clear from the discussions in the five subgroups Land, Atmosphere, Ocean, Ice, Geodesy and Geophysics that:

- there is above all a need for continuous observations of all parameters amenable to satellite remote sensing so far
- the combination of in-situ data and remote sensing data has to be improved to reach the necessary accuracy by both high quality in-situ data (for example a few high quality stations are preferable to many less careful run stations) and improved on-board calibration of satellite data
- operational and experimental satellite data sets contain many more research and application results if algorithm development is accelerated by more funds for this value-added research with a high benefit/cost ratio
- some research sectors are left without dedicated satellite sensors even beyond the era of the first polar platforms, e.g. a gravity mission in a low Earth orbit for a better geoid needed for many disciplines, among them oceanography
- the better understanding of the terrestrial carbon cycle, so central to all living organisms, warrants a dedicated mission on the dynamics of the biosphere, which will not be feasible with the commercial land application Earth Observation missions
- the rapidly increasing threat to the life supporting Earth system can - for the sector Earth Observation from space—best be answered by operational missions, prime candidates being the monitoring of the vertical profile of ozone and the monitoring of the coastal zones, where most of the people live.

3. Operational and Commercial Requirements

3. Operational and Commercial Requirements

3.1 Introduction

The operational/commercial users' community, including both public and private sectors, is mostly interested in the provision of data or information provided on a routine and reliable basis and in a timely fashion, irrespective of how and where they originate. Usually, this information is derived from the combination of data from various sources of spaceborne, airborne, shipborne or ground-based systems; this information is mostly used as inputs to operational models of varying complexity with the aim to predict future behaviour, in space and time, of dynamic geophysical and/or biochemical processes.

When summarising the users' requirements it is important:

- to identify the main application sectors benefitting today from space data (e.g. meteorology, sea ice monitoring, agriculture) and their socio-economic importance
- to identify their current level of maturity and their possible evolution in the coming decade.
- to identify the main existing and potential categories of customers and users paying today for services or ready to pay in the future for such services
- to review and update the list of space data used today on an operational/pre–operational basis or only on a demonstration/experimental basis
- to identify requirements not yet satisfied by today's space systems
- to identify whether an operational structure/entity already exists for handling the data; having a responsibility for a given sector of applications or whether this is still to be created
- to discuss the possible contribution of ESA, taking into account its expertise/competence and mandate.

Lastly, the operational/commercial users' community attaches an utmost importance to the services provided by the ground segment of space missions and its ability to meet their very demanding requirements in terms of continuity, quality, reliability and timeliness.

3.2 Operational Meteorology

Operational meteorology serves many sectors of the community, i.e. scientific, operational and commercial. In so doing, they already make extensive use of data from spaceborne instruments mounted on satellites flying in both geostationary and polar orbit. These data are used for forecasting in both the short and medium term as well as for the improvement and validation of forecasting models. They cover severe weather warnings, storm tide warnings, pollution emergencies, forecasts and warnings of sea conditions, etc.. Here special mention must be made of data assimilation schemes which are of fundamental importance to the exploitation of these data by the operation meteorology community.

As far as this particular community is concerned, the need for the future is to consolidate the current provision of data made available to the operational meteorological services and to extend the range and quality of these data. Here the Agency must work closely in concert with its European partner EUMETSAT, in particular in formulating user requirements and supporting the evolution of missions to take advantage of technological evolution and new sensor opportunities.

It is also clear that the current provision of data for operational meteorology falls short of requirements. Notably there is a need to improve:
— the resolution and accuracy of both temperature and humidity soundings
— the provision of global wind information in three-dimensions for both cloudy and clear conditions
— the information (i.e. resolution of images, enhanced sounding) provided by geostationary and polar imagery
— the observation of precipitation with the appropriate temporal sounding
though these are not requirements that must be satisfied regardless of cost.

The commercial applications of the meteorological forecasts are wide and rapidly expanding. Generally, they are tailored to meet the needs of specific customers. Typical examples include:
— forecasts for civil aviation including weather conditions and optimal routing
outlooks of weather conditions provided to farmers to enable them to plan future activities such as harvesting and spraying plus warnings to adverse conditions
— forecasts of temperature to public utilities enabling them to estimate demand and to plan electricity and gas generation
— forecasts and observations of precipitation provided to water authorities which are used to estimate water reserves and control discharges.
— forecasts of synoptic variables to food retailers enabling them to estimate demands for perishable foodstuffs.

Few of these depend directly on satellite data but without these data the quality of the services would be adversely affected.

3.3 Operational Activities Over Oceans, Coastal Zones and Sea-Ice Covered Areas

There is an increasing requirement to monitor and model oceanic, coastal and sea-ice processes in order to enable and improve forecasts of marine environmental conditions and parameters on a variety of scales from local, via regional, to global. The demand is driven by a wide spectrum of needs, such as:
— maritime operational applications such as shipping, offshore industry, fishing industry
— management of living resources, sea farming
— management and protection of coastal environment for tourism and recreation
— coastal surveillance and defence
— management of waste disposal and water quality monitoring.

Throughout the world, provision of satellite remote sensing data, primarily from operational meteorological satellites, is extremely important both in support of routine monitoring and operational forecasting services as well as to assist in pre-operational research activities which much underpin such services.

The scope of a marine and sea-ice environmental prediction system should include monitoring and/or forecasting of parameters such as:

- surface wind and waves
- sea surface temperature
- sea level and storm surges
- mesoscale circulation and ocean currents
- phytoplankton bloom and concentration
- water quality
- pollution
- sediment transport
- transport of heavy metals
- coastline mapping
- coastal bathymetry
- sea-ice extent, boundary and concentration
- sea-ice motion
- ice shelves extent, boundary, topography.

Current operational marine and sea-ice forecasting services (often implemented within operational meteorological services) are successfully utilising data from polar orbiting satellites to globally monitor and predict wind and wave conditions as well as sea-ice extent, concentration and motion.

However, there is obviously a need to improve satellite-based monitoring and forecasts in the following areas:

- to ensure the continuity of observations made today by pre–operational/demonstration space systems (e.g. ocean surface winds and waves provided by ERS scatterometer/altimeter)
- to better match the space-time sampling requirements of forecasting models, namely by:
    - increasing the revisit time of measurements up to 6–12 hours
    - increasing spatial resolution and coverage (e.g. of passive microwave imagery and SAR imagery for sea-ice monitoring, coastal processes and coastal environment monitoring, etc.)
- to provide essential ocean colour data on an operational basis with the appropriate resolution (100-300 m) for coastal zones in particular
- to develop all-weather measurement capabilities with the appropriate spatial resolution and coverage characteristics.

It should be stressed that a feature, common to all operational activities over open oceans, coastal zones and sea-ice covered areas, is the increasing development and use of geophysical models in which remote sensing data are assimilated (for instance for coastal shelf circulation and sediment transport). These models are becoming an indispensable tool and remote sensing data (space and non-space) are increasingly used in Geophysical Information Systems (GIS). Several examples of GIS exist today, primarily at local scale level, and there is a high user demand for GIS development.

3.4 Operational Climate Monitoring

There is increasing concern that human activities may be inadvertently changing the global climate by increasing the concentration of greenhouse gases and by other changes which can upset the complex chemical, dynamic and radiative balance of the atmosphere, ocean and land system. These concerns led to the establishment, by the World Meteorological Organisation (WMO) and the United Nations Environmental Programme (UNEP), of an Intergovernmental Panel on Climate Change (IPCC).

Subsequent activities have led to the concept of a Global Climate Observing System (GCOS), including both space and surface based systems, to measure routinely all major elements of the global climate system. GCOS is now sponsored by the Intergovernmental Oceanographic Commission (IOC) of UNESCO and International Council of Scientific Unions (ISCU) in addition to WMO and UNEP.

These long-term climate-related observational requirements from space closely match the observational requirements of the operational meteorological community and can be summarised as:

- the maintenance and improvement of the existing operational meteorological observing system
- the maintenance and enhancement of the current system for monitoring of key climate elements. Continuous, well-calibrated and accurate observations are required of the Earth's radiation budget, clouds, atmospheric constituents, winds, precipitation and information on the terrestrial ecosystem
- the establishment of a global ocean and ice monitoring system to measure such parameters as ocean surface topography (for circulation), surface stress, colour (for ocean biology), sea surface temperature, ice extent and thickness.

Table 3.1 summarises the principal observations to be made in support to GCOS together with the need to establish a long term observing and archiving system to monitor the key geophysical parameters.

Table 3.1: Summary of GCOS Principal Observations

	PRINCIPAL SYSTEM	GCOS MISSIONS	PRINCIPAL OBSERVATIONS
THE PLANET EARTH	GLOBAL	Global Radiative Properties	Cloud Amount Cloud Drop Size Distribution Surface Fluxes (heat, water) Solar Irradiance Surface Radiation Fluxes Earth Radiation Budget Multispectral Albedo Aerosols
		Ocean Characteristics	Ocean Colour Ocean Topography/Geoid Sea Ice Cover Sea Surface Temperature Ocean Salinity
	OCEANS	Ocean Atmosphere Boundary	Sea Surface Temperature Ocean Wind Vectors/Speed Sea Ice Cover (as tracer) Ocean Wave Height Spectra Atmospheric Surface Pressure
		Atmospheric Thermo-Dynamics	Temperature Profile Cloud Clearing Wind Profile Liquid Water/Ice Precipitation Humidity (profile/total)
	ATMOSPHERE	Atmospheric Composition and Chemistry	Constituents (total/profile) Atmospheric Dynamics Ozone (total/profile) Aerosols (total/profile)
		Land Atmosphere Interaction	Vegetation Characteristics Soil Moisture Snow & Ice Cover Land Surface Temperature Evaporation
	LAND	Land Biosphere Climate Response	Vegetation Change Land Use Change

3.5 Operational and Commercial Land Application Requirements

As for operational meteorological and marine applications, land applications cover a wide variety of disciplinary themes with diverse observation requirements depending on the geophysical scales of the applications (local, regional, global) and their temporal characteristics and variability (e.g. daily, seasonal, annual, etc.).

Today, primarily based on the use of multispectral optical data, at high (10-30 metres) and medium (1 km) resolution from operational satellites (such as Landsat, SPOT, TIROS), a number of land applications have developed and reached an operational (or quasi-operational) stage whilst some are still in the research of demonstration phase. The user entities are also widely spread from governmental departments/intergovernmental organisations to large private firms and small value-added service companies.

Among the classical land applications using operationally space information one may mention:

— Agriculture: crop monitoring, yield estimates, harvest control
— Land use management, land transformation
— Forestry: inventory, deforestation monitoring
— Geology/Geomorphology: mineral resource detection
— Cartography/Topographic mapping (including generation of Digital Terrain Models (DTM))
— Flood monitoring.

For agriculture and, to a lesser extent, for forestry, users have expressed the need for all-weather radar data, as a complement to optical information, to better match the phenological cycles of crops than can be performed with optical sensors alone because of the cloud cover.

For topographic mapping and DTM generation, optical stereoscopy and SAR interferometry are considered as valuable tools/techniques; though the limitations of SAR interferometry are still not fully explored.

Among the land applications still at a research/demonstration level one can mention:

— *Coastal zone processes monitoring and management*: these processes are complex and the subject of a significant research effort (e.g. within the IGBP core project LOICZ). Associated observation requirements, in terms of high repetitivity, high spatial and spectral resolution, all-weather capability are all very demanding in order to correlate the interactions between land and coastal processes and assess/predict/monitor urbanisation effects on water quality, river discharges, sediment and pollutants transport, coastal erosion, etc...
— *Environmental monitoring*: this is a major issue which, as far as land aspects are concerned, is primarily related to change detection, the objective being to understand and monitor land transformation processes such as soil erosion, desertification, deforestation. These environmental issues have many common requirements with some of the classical land applications discussed above (i.e. agriculture, forestry, land use management, topographic mapping). For instance, there is a need for up-to-date DTMs to estimate risks of flooding, landslides and soil erosion but also in support of land use management.

The European Environment Agency (EEA), within the framework of its 5th Environmental Plan, will require an increasing amount of information to establish and maintain, at the European level, an up-to-date database detailing the status of the environment. Long term series of high and medium resolution, optical as well as microwave SAR data combined with non-space data, will have to be integrated and maintained to detect and monitor land changes at local and regional scales.

— *Natural hazards and risks*: this includes, over land, mainly geological events such as earthquakes, volcanic eruptions, flooding and landslides. These phenomena are often associated with extreme or difficult environmental conditions (i.e. cover, dust, smoke, etc.). Remote sensing observations may possibly contribute. This includes the monitoring of natural phenomena (lava flow, flooding extent) to possibly determine safe areas, assessment of damage, first-aid coordination and the provision of information for decision-making. In general, information on geomorphology (drainage pattern, erosion), and geodynamic activity (tectonic analysis, surface deformations), as well as all-weather observation capability, is required. The major problem is the temporal frequency of observation required in relation to the stage of the particular event. SAR interferometry (including differential interferometry), although still at a research stage today, could prove to be a very valuable technique in view of its unique capabilities (assuming an adequate ground segment for timely data acquisition processing and interpretation).

— *Verification*: this includes treaty verification and disarmament control for which very high resolution imagery, in the visible, infra-red and microwave part of the electromagnetic spectrum, is needed. The development and launch in Europe of visible/infra-red space systems (i.e. HELIOS) having been decided, there is a need for additional SAR observation capability and, in this context, to see whether there is here a role for ESA to play (on the basis of its experience and expertise on the ERS Programme and the preparation for the forthcoming ENVISAT-1 satellite).

3.6 Requirements for Ground Segment Services

The operational and commercial users' community has very precise and stringent requirements as far as services from the ground segment (associated to space missions) are concerned, namely:

— the ground segment must be designed in terms of system delivering information and not only in terms of space data, as users often need high level products tailored to their specific applications

— users need continuity of information, not of space data; the space instrumentation technology must evolve so that it can provide users with a guaranteed supply of reliable information

— data/products should be easily accessible, well validated and inter-calibrated when applicable

— the long term provision of consistent/coherent data (coming from various instrument families) must be guaranteed through well organised databases/archives allowing easy retrieval (including calibration/processing algorithm information) by users

— the data distribution mechanisms, support media and data delivery times must match the specific user requirements to be fully exploitable for instance in models.

3.7 Conclusions and Recommendations

A number of conclusions and recommendations emerged from the discussions with the operational/commercial users, namely:

- Earth Observation missions must be designed as end-to-end systems giving the same emphasis to both the space and ground segments
- Data continuity is a prerequisite to the development of operational application
- There is a definite need to widen the user base through various possible actions such as:
  - enhancement of awareness in the user community of results/achievements of application demonstration/pilot projects implemented either by ESA or by national authorities
  - Definition and implementation of well-focussed demonstration projects between ESA, EU and National user entities.
- Further definition of institutional needs at both National and European level
- Further reinforcement of the cooperation between ESA and the EU to get access to a synthesis of requirements of institutional application users
- Involvement of the commercial/private sector which may play a growing role in the utilisation of space data
- Capability for developing Countries to have direct local access to space Earth Observation data is strongly recommended
- With the exception of the meteorological community, it appeared that the operational marine and land application community was not as strongly represented in the User Consultation Meeting as other communities; therefore, further consultation with application-oriented user groups should be organised, preferably by main application theme to further define or refine users requirements for space data and services
- With the assumption that the continuity is guaranteed for the existing operational satellite systems like SPOT, Landsat, polar and geostationary meteorological satellites (with their current and planned enhanced payload composition), the need was identified for:
  - SAR data
  - medium resolution (100 m) visible and infrared data
  - continuity of ocean colour data, possibly with high spatial resolution (100 m)
  - in general, improved resolution, coverage and revisit frequency for scatterometer and altimeter data (multiple approach).

4. Candidate Earth Observation Mission Profiles

4. Candidate Earth Observation Mission Profiles

4.1 Introduction

In considering a set of candidate mission profiles addressing user requirements beyond the year 2000, two general classes of mission addressing Earth Observation objectives were assumed, namely:

Earth Explorer Missions—these are research or demonstration missions with the emphasis on research intended to advance understanding of different Earth system processes. The demonstration of specific new observing techniques would also fall under this category. They would be funded by ESA with mission duration tailored to specific requirements. They might lead to (pre) operational services.

Earth Watch Missions—these are pre-operational missions addressing the requirements of specific emerging Earth Observation application areas. The responsibility for this type of mission would eventually be transferred to operational (European) entities. To ensure this eventual commitment by such an entity, data continuity over a period of at least ten years would be required. The emphasis would be on service.

The former would basically be ESA missions (with possible support from other bodies providing instruments, etc.); while the latter would be missions carried out in close association with a partner who would ultimately assume long term responsibility for these missions. Earth Watch would imply a series of satellites launched at regular intervals to meet operational requirements.

Many parameters of the Earth system require continuous global monitoring which can be provided from space. Other space agencies are already working on Earth Watch type missions, beyond meteorological satellites. Thus, for example, the possibility of a series of altimetric satellites for monitoring the variability of ocean circulation is being studied by CNES, NASA and NOAA. In Europe, currently two Earth Watch missions are in preparation. These are Meteosat Second Generation (MSG), the successor to the current Meteosat geostationary satellites, and METOP, a series of polar orbiting operational meteorological satellites. Both are undertaken in partnership with Eumetsat who will ultimately assume responsibility for both missions.

METOP

This is a series of operational meteorological polar orbiting satellites intended to ensure and extend the operational provision of meteorological data from the "morning" polar orbit from the year 2000 onwards. From their instigation Europe will assume overall responsibility for the provision of these data to the world-wide community. Two satellites will comprise the initial phase of the METOP series (i.e. METOP-1 and METOP-2) though the METOP-3 mission is currently being considered in more general terms.

In addition to ensuring continuity in the existing provision of operational meteorological data from the "morning" orbit, METOP is intended to address the operational specific needs for:
- improved high resolution temperature and humidity profiles;
- global ocean surface wind information (wind scatterometer);
- improved observation of precipitation and variables such as sea ice (passive microwave radiometer);
- routine monitoring of the Earth's radiation budget (broad band radiometer) and ozone (ultraviolet/visible spectrometer).

Meteosat Second Generation (MSG)

MSG is the successor to Meteosat and is intended to make observations from geostationary orbit for the operational meteorological community. It will have an enhanced imaging/sounding capability over the current Meteosat satellites, including additional channels, a high resolution broad band channel and more frequent imaging.

The current channel selection includes six imaging channels plus channels for observing water vapour (two channels) and "Pseudo-Sounding" (three channels). The current Meteosat has only three channels. In addition to this instrument it is proposed to fly a broadband radiometer to observe the Earth's radiation budget from geostationary orbit.

During the discussion, that took place in the Working Group on Earth Explorer Missions, it was assumed that, in addition to the user needs covered by METOP and MSG, there would be at least two further groups of users whose interests should be addressed by Earth Watch satellites i.e. those interested in the land surface and coastal zones. In addition the interests of the oceanographers would expand and the need for chemical monitoring would be consolidated by an additional Earth Watch mission.

The Earth Observation objectives described in this paper relate to user interests and not necessarily to specific satellite missions. Some might require a dedicated satellite mission(s); others could share a flight opportunity; others might rely on inputs from several (coordinated) satellite missions. They are grouped under Earth Watch or Earth Explorer according to whether the need is likely to be met by an Earth Watch or an Earth Explorer mission.

4.2 Earth Explorer Missions

Each of the Earth Observation objectives detailed in this paper, though focused primarily on the needs of specific disciplines, are by their very nature multi-disciplinary. This must be taken into account in considering the way the various user needs are addressed.

Radiation

This would address two specific areas of interest:
- determination of radiation budget components at the surface and throughout the depth of the atmosphere and the derivation of flux divergences;
- determination of cloud/aerosol characteristics.

Specifically it would address concerns over the lack of knowledge of radiative processes in the atmosphere and the need to make optimum use of observations made by broadband radiometers which make "top of the atmosphere" observations. This is of concern to operational meteorology as well as to environmental/climatological programmes. Lack of knowledge of the radiative properties of the atmosphere, especially with respect to the role of clouds, places serious limitations on our ability to quantify the prospects for climate changes, especially "global warming". This point has been highlighted by the IPCC.

The radiative properties of the atmosphere are also, of course, of great importance to NWP schemes.

By its very nature it would also address the interests of the ocean/sea ice research community as the information on the radiation budget and cloud/aerosol distribution would contribute to the study of air-sea and air-sea-ice interactions.

It would also be important to the land research community providing important data on the surface radiation budget, notably the long wave component. Also of relevance to this community are the observations of the bi-directional reflection distribution function (BRDF) and changes in the diurnal forcing. These data will help characterise surface features and the parameterisation of land surface processes in global circulation models (GCMs).

Precipitation

The dynamic and thermodynamic processes which generate precipitation are central to dynamic, biological and chemical processes in the atmosphere, oceans and land surface. These processes strongly influence climate and climate change. Tropical regions are of particular importance.

Reflecting lack of knowledge this is intended to address two specific research topics:

- contributing to the study of the hydrological cycle in tropical regions;
- study of interactions between precipitation and atmospheric circulation in tropical regions.

This latter should include consideration of interactions between precipitation and ocean and land surfaces viz. variations in salinity and soil moisture.

In addition to addressing the specific concerns of GEWEX for example it would provide important information for operational meteorology, both directly via the direct observation of precipitation and indirectly by providing the means to improve understanding of the processes involved and hence the ability to model them.

For the ocean community it would contribute to the study of:

- sea surface salinity variations and their impact on the evaporation-precipitation ratio and the hydrological cycle as well as thermohaline circulation.

For the land research community it should provide further insights into the way major convective systems (e.g. the monsoons) interact with the surface.

Atmospheric Dynamics

The aim would be to measure three dimensional wind fields in clear air for assimilation into numerical models/ (process models as well as general circulation models). In so doing it would provide data needed to address some of the key concerns of the WCRP:

— contribute to the study of the Earth's global energy budget by measuring 3-dimensional wind fields globally (or possibly in tropical regions only) in cloud free areas;
— contribute to the study of specific phenomena such as precipitation systems, jet streams etc. complementing information provided by the radiation and precipitation Earth Observation objectives.

These data are of crucial importance to the development of climate models, contributing to work not only on general circulation and process studies but in addition to work on air/sea interaction, land surface processes etc.

Furthermore, assuming that these data could be assimilated operationally, it would address one of the major concerns of operational meteorology, namely the lack of observations of three dimensional winds fields in clear air. Again the provision of these data should lead to significant improvements in numerical models.

Stratospheric Profiling

A potential co-passenger on all Earth Observation satellites (or stand-alone on very small missions) could be an instrument capable of observing the refraction of electromagnetic (EM) waves in the atmosphere at radio frequencies. From these data it should be possible to derive temperature, pressure and density provided humidity contents are low i.e. in the stratosphere. These data are likely to prove of increasing importance to operational meteorology.

Such methods have been used in the past to explore the atmospheres of other planets. Here it is proposed to use ultra-stable signals from global positioning system satellites to provide high resolution vertical descriptions of the stratosphere, an area which is not well covered by any other instrument with equivalent accuracy. These profiles would complement those derived from other monitoring instruments. Satisfactory global coverage with high spatial (horizontal) resolutions could be achieved if several were in orbit at any one time.

Chemistry

This would have three main objectives concerning global chemical cycles, namely to:

— Advance understanding of the processes responsible for the ozone balance including those occurring in the lower stratosphere (at global scales);
— Quantify the ozone budget in the troposphere;
— Contribute to the study of the budgets of greenhouse gases (other than carbon dioxide) and the processes controlling their distribution.

To address these issues it must observe ozone (total content and vertical distribution in the stratosphere and troposphere), tropospheric source gases (carbon monoxide, methane and other hydrocarbons), lower stratospheric aerosols, reservoir and chemically active species, temperature and wind.

It would also be important to the land surface and ocean communities as chemical processes occurring in the atmosphere, notably in the lower troposphere, directly influence the biosphere (and vice versa). Here specific reference could be made to the role of ozone in shielding the surface from ultraviolet radiation and the production of methane and carbon oxides. It will address many aspects of climate chemistry interactions including radiative forcing in the coupled stratospheric/tropospheric system.

Gravity Field and Ocean Circulation

This would be dedicated to the global and accurate measurement of the spatial variations of the Earth's gravity field, and would therefore, also result in a detailed and accurate determination of the geoid. Improved knowledge of the gravity field is essential for progress in geodesy, solid Earth physics and oceanography (ocean circulation and sea level) with important implications for climate research. It has also direct practical implications for mapping, exploration and navigation.

Its specific objectives would be:

— to measure the Earth's gravity field to an accuracy of 1-3 mGal (1 mGal = $10^{-5} m/s^2$);

— to derive the reference geoid with an accuracy between 2 and 5 cm (and in doing so derive in conjunction with satellite altimetry the stationary dynamic ocean topography globally and at any time);

— and to achieve these objectives with a spatial resolution between 50 and 300 km half-wavelength (corresponding to a spherical harmonic expansion of up to degree and order between 400 and 60), this range formulated in the spirit of satisfying the complete scope of requirements of the various areas of oceanography, solid earth physics and geodesy.

These objectives cannot be met by traditional means because (1) gravity field modelling from orbit analysis will never be able to reach a comparable spatial resolution and (2) for several reasons even decades would not suffice to attain global coverage by terrestrial measurements.

Magnetometry

Following the Oersted satellite, it will be necessary, at regular intervals (once a decade), to investigate the temporal variation in the Earth's magnetic field. This will further our understanding of the behaviour of the Main Field and support studies of importance for the physics of the Earth's interior.

Within this general context there are two specific areas to be addressed (Table 4.1):

— to monitor the secular variation of the main field "Geomagnetic Space Observations" (GSO) at regular intervals are needed. These could be accommodated on a suitable polar-orbiting spacecraft/small satellite with an altitude of less than 900 km. A GSO would be mounted at the end of a boom with a three-axis vector magnetometer (accuracy 3nT), an accurate star tracker and a scalar magnetometer (accuracy 1nT) for calibration;

— to determine the Earth's Anomaly Field a minimum of six-months of observations at 200 km altitude is needed. The scalar field should be mapped with an accuracy of 1nT and the vector field with 3nT. Using a tether up to 100 km long would enhance the resolution.

Table 4.1: Specific Objectives of a Magnetometry Mission

	Anomaly Field	Main Field and Secular Variation
Frequency	Once	Every 10 years
Altitude	100-200 km	<900 km
Orbit	Polar	Polar
Main magnetometer	Scalar (1nT) + Vector (3nT)	Scalar (1nT) + Vector (3nT)

Surface Processes and Interactions

Four issues of major concern to mankind form the basic justification for a future Earth Explorer mission dedicated to land observation, namely:
(1) Population increase
(2) Loss of bio-diversity
(3) Atmospheric composition change
(4) Loss of soils.

Drawing on this, the main objectives of the Earth Explorer Land Surface Processes and Interactions Mission should be to enhance the capability to model land surface processes, changes and interactions i.e. to advance the understanding and characterisation at process level. Concurrent with this objective it would be necessary to improve methods for observing certain geophysical parameters from space at high temporal repetitivity and high spatial resolution.

This increase in knowledge of small scale processes would need to be transferred to the global scale so in the broader context there are two coupled missions, namely:
(1) *A "Processes" (Small Scale) Mission*— a mission which would have a high potential for repeat observations coupled with the capability to obtain global access, hand-in-hand with a medium-to-low spatial resolution.
(2) *A "Global" Mission*—with a high repeat cycle and the capability to obtain global coverage at a moderate-to-low spatial resolution.

The first mission is viewed as an Earth Explorer mission while the second mission is better regarded as a candidate for an Earth Watch mission. The prime incentive underlying the Earth Explorer mission is to advance the science of geophysical parameter retrieval at the local scale and, by associated process studies, to determine the way to apply the information at global scale.

Considering the above issues of major concern and the way they are currently addressed within the frameworks of the International Geosphere Biosphere Programme (IGBP) and the World Climate Research Programme (WCRP), it is clear that there needs to be a much better understanding of biospheric processes and the interactions between renewable resources (e.g. vegetation, hydrosphere). Thus, the key objective for the Earth Explorer Land Surface

Processes and Interactions Mission would be the observation of primary productivity and dynamics.

The general mission objective would be to observe primary productivity above the surface (including hydrology, renewable resources). This means that it would be necessary to observe the surface:

— surface characteristics such as BRDF, Leaf Area Distribution, temperature, surface roughness, etc.
— and changes in surface characteristics over time.

Topography

The requirement for up-to-date global topographic data is well recognised by the cartographic community. Further support for this requirement is provided by existing applications in the fields of agricultural, hydrological, ecological and geophysical sciences. Another specific area of importance is polar ice sheet topography and turning attention from land to the ocean and ice sheets it is clear that altimetric observations are required to satisfy the data continuity requirement beyond ENVISAT-1 and the ERS satellites for retrieval of time variant (surface topography) ocean currents in combination with a high resolution and high accuracy marine geoid as to be obtained by a dedicated gravity mission. Such observations are the only available means to monitor global ocean circulation in the long term. For studies of arctic and antarctic ice sheets and ice shelves, which despite their undoubted importance to climate, are at present poorly observed, it is necessary to repeat topographic observations made on the basis of the ERS data.

Besides the need for high quality topographic maps, a requirement has arisen for geocoded image sets for use in global digital elevation models. This would enable the accurate registration of high resolution optical and microwave imaging data to cartographic requirements. For the land surface community these requirements may be summarised as map compilations and revisions (at various scales i.e. 1:50000 to > 1:10000) and change detection on a local scale.

4.3 Conclusions and Recommendations on Earth Explorer Missions

The following sections reflect the outcome of the discussions on Earth Explorer Missions, during the course of which, nine missions were, in principle, endorsed by the members of the Working Group. These are detailed in this document.

The working group stressed the necessity to fulfil several mission objectives, to ensure the long term continuity of some observations included in the on-going or planned missions. This specific requirement is fully relevant for research-type missions and does not necessarily imply that such missions fall in the Earth Watch (operational) mission category.

In reviewing these missions as an entity the Working Group, as a whole, highlighted a sub-group of three candidate missions, one of which it recommended should be selected as the first Earth Explorer mission. It does not mean that the other missions have less interest for the user community and that they are no more considered as potential candidates after the first Earth Explorer mission. The three priority candidate missions were proposed taking into account science priorities and many factors like the readiness of the mission profile concept, the availability of relevant instrumentation, the on-going programmes approved or planned by ESA and its partners.

It should be noted that a basic assumption underlying the omission of the chemistry mission from the initial short list was the provision of ozone monitoring on METOP and of an Earth Watch mission to monitor halogens in the stratosphere. The need for stratospheric monitoring in the post 2000 era, after ENVISAT, has been identified with the highest priority.

Priority Candidates

A Gravity Field and Steady State Ocean Circulation Mission—it was agreed that the determination of the Earth's interior structure and geoid was of fundamental importance not only to geophysics (and a wide span of related applications) but also to oceanography and climate. Improved knowledge of the Earth's geoid is required to define the reference surface needed to derive the mean (i.e. time invariant) component of the ocean's surface circulation.

A Radiation Mission—the need to advance understanding of the Earth's radiation balance, the distribution of sources and sinks in both the vertical and the horizontal dimensions, was accepted to be of fundamental importance to the furtherance of understanding and monitoring of the Earth's climate (cf. WCRP). In particular, much better information was needed on the distribution and characteristics of clouds and aerosols. These data will be very helpful to interpret accurately data from broadband radiometers monitoring the "top of the atmosphere" radiative fluxes.

A Surface Processes and Interactions Mission—major environmental issues arising from changes in population, loss of bio-diversity, changes in atmospheric composition, soil loss etc., are currently addressed within the framework of the International Geosphere Biosphere Programme (IGBP) and the World Climate Research Programme (WCRP). Basic to work in this area is a clear understanding of biospheric processes and their interactions with the other processes that occur in the Earth/atmosphere system. Thus, the prime objective of this mission must be the observation of biospheric productivity and dynamics. This mission would focus on the observation of biophysical processes from space at the local scale, advancing understanding of these processes, in order to further our ability to interpret and predict environmental changes on a global scale. Further studies must be initiated to better define the mission objectives in relation to the key parameters to be measured with the identification of sensors and observations.

Other Missions

An Atmospheric Dynamics Mission—this would focus on the observation of winds in clear air in both the troposphere and the stratosphere. Despite the undoubted importance of these data to both operational meteorology and climate studies technical concepts were too immature for this mission to be included in the initial short list. Further technical and system studies were essential before this could be considered a serious candidate. This mission might be a potential candidate for the Space Station.

A Chemistry Mission—there is a clear need to advance understanding of the chemistry of the atmosphere, as a gap of information on active chlorine species, as well as on the hydrogen oxides, will remain to be addressed in the post-2000 era. An optimised complementary payload, which sets the observation of these species within the context of a new atmospheric chemistry mission, needs to be defined in the very near future. It would also be necessary to review continuity requirements in depth as it is not clear that existing Earth Watch missions adequately addressed these requirements.

A Magnetometry Mission—a mission of this type is required approximately every decade, so given the imminence of the Örsted mission, it is not necessary to include this mission in the initial short list.

A Precipitation Mission—again this was an important mission to both operational meteorology and climate studies but it must be viewed in the light of TRMM and, specifically, plans for a follow-on mission i.e. TRMM-2. At this stage it would be premature to include this mission in the Agency's initial short list before better definition of the TRMM-2 mission.

A Stratospheric Profiling Mission—this is potentially an important mission. The USA is planning a "proof of concept" flight. If this is successful the requisite instrument should be flown on many satellites so there was little point in including a dedicated mission in the Agency's initial short list. An appropriate candidate will be the Gravity Field and Steady State Ocean Circulation Mission.

A Topographic Mission—the USA and France are planning a follow-on to Topex-Poseidon (the USA was also considering a laser altimeter mission) so again, although the need of continuity for these data is of paramount importance, it was not necessary to include this mission in the Agency's initial short list. However, the need for an additional mission, which provides better cover of polar regions, should be considered once plans for follow-on missions become clearer.

Fuller details of these missions will be found in the following sections of this part of the Proceedings, which also highlight the multi-disciplinary nature of these missions as well those of Earth Watch, METOP and MSG (see Tables 2 and 3). The other point worth stressing is that they are all research/pre-operational mission profiles. They are not, in themselves necessarily, self-contained satellite missions as the instruments required to realise their objectives may, in many instances, fly on several separate satellites. The decision on the grouping of instruments on actual satellite missions was not addressed by the Group.

4.4 Earth Watch Missions

While the Earth Explorer missions are dedicated primarily to scientific objectives, the Earth Watch missions must be seen in the light of their potential economic weight and/or their contribution to the public benefit.

Two Earth Watch missions are currently in preparation by ESA, namely Meteosat Second Generation (MSG) the successor to the current Meteosat geostationary satellites and METOP, a series of polar orbiting operational meteorological satellites. Both are undertaken in partnership with EUMETSAT who will ultimately assume responsibility for both missions and ensure data/services continuity until 2015-2020.

In view of the recent approval of SPOT-5a and SPOT-5b, continuity of high resolution multispectral and panchromatic optical data is ensured, particularly in Europe.

When discussing the Earth Watch missions, the participants of the Users Consultation Meeting addressed three main aspects, namely:

(1) What could be the decision process for the selection of an Earth Watch mission?
(2) What could be the possible role of the European Commission (EC) in this scheme?
(3) What are the potential Earth Watch missions which could satisfy major groups of user communities?

These three aspects are now summarised in the following sections.

Selection of Earth Watch Missions

The selection of an Earth Watch mission should be the result of an analysis which considers the two main following objectives:

(1) Economic assessment in the wide sense, i.e. direct socio-economic benefits resulting from the development/exploitation of an Earth Watch mission compared to alternative techniques/means and consequently justifying the implementation of a satellite-based system to meet these specific user requirements in a cost-effective manner
(2) Identification of potential partner(s), possibly at a very early stage of the project, so that they could already contribute to the first, if not to the second space system or to the ground segment development or exploitation.

A possible decision tree for differentiating candidates for Earth Watch and Earth Explorer missions is illustrated in Figure 4.1 and the process for the selection of an Earth Watch mission in Figure 4.2. It was strongly stressed that these two stages are a prerequisite before any decision to embark on an Earth Watch mission is made.

Role of the European Union

When looking at possible partners for the implementation of an Earth Watch mission, with the exception of the meteorological satellite programmes for which EUMETSAT is the obvious ESA partner, the European Union is often mentioned as a possible candidate being a major institutional user of space remote sensing data and services in Europe to support their sectoral and regional policies. The EU has also recently embarked on an important programme, the Centre for Earth Observation (CEO), aiming at the promotion of the use

Earth Observation data and services. Through the CEO, the EU will provide an interface between the user entities and the data providers and, more generally, will create a favourable environment and easy access conditions to users.

As regards the direct partnership of the EU in assuming some responsibility, after an initial demonstration/pre-operational phase in the implementation of the programme, this has still to be analysed further but, as a minimum, the EU could assist in identifying and/or creating the appropriate partnership.

Potential Earth Watch Candidates

Looking at the post 2000 era, five groups of potential Earth Watch missions have been identified. These include missions focussing on:

— coastal zones
— open ocean and shelves
— ice monitoring
— land surface monitoring
— atmospheric chemistry monitoring.

All are important and none can really be viewed in isolation. Thus, for example, a coastal zone mission would also be of considerable benefit to oceanographers, and those interested in land and ice applications.

There was also a unanimous opinion that there is no need for a dedicated Earth Watch mission for operational climate monitoring but rather for focussed application missions which will contribute to operational climate monitoring, provided that long time series of consistent/coherent data are guaranteed, as well as easily accessible/well calibrated data and that long term archiving (up to 20 years) is ensured.

Coastal Zones

Some 60% of the World population lives on the coastal zones which are, economically, very important sources of revenue (fishing industry, fish farming, offshore oil industry, coastal engineering and defence, recreation and tourism, etc....). However, these zones are also very fragile ecosystems subject to many environmental threats and degradations due to the various natural (e.g. river discharges, coastal erosion) and man-made industrial (e.g. coastal agriculture, biological pollution, voluntary or accidental pollution) activities.

Monitoring and management of coastal environment and resources are very demanding in terms of quality, accuracy, space-time sampling requirements for space observations (see Section 3.2). Furthermore, coastal zone applications are encompassing a wide spectrum of activities carried out at various geographical scales from local to regional and for which the responsibility is spread amongst many operational governmental and private entities. This means that a major organisational effort to structure these different users' communities and set up an appropriate partnership with an organisation or agency still to be identified. However, it should be mentioned that most of the operational observations required for a coastal zone mission exist today (e.g. with SPOT, NOAA/TIROS) or have been (or will be) demonstrated on ESA missions such as ERS, ENVISAT and METOP and, therefore, should be either continued as they are today or adjusted to the specific space-time needs of coastal applications.

Lastly, it is important to note that many coastal applications rely on the use of models tailored to the specific applications but requiring, as initial/boundary conditions, data taken over the open ocean and shelves, which therefore must be made available on a continuous basis and in a reliable manner.

Open Ocean

Monitoring of open oceans including shelves is important for oceanic circulation and sea-state forecasting and associated marine applications such as shipping, ship routing, fishing industry, cabling industry, waste disposal, hydrographic surveys, insurance companies, oil pollution, defence and surveillance. Most of the data required are available today on an operational (e.g. sea surface temperature) or pre-operational basis (e.g. surface wind and waves). Continuity and improvement of existing data systems must be ensured (e.g. with METOP satellite series) as well as the continuous provision of new types of data (e.g. ocean colour).

The operational oceanographic user community is getting organised and structured through different mechanisms such as the Global Ocean Observing System (GOOS) and has close links with the operational meteorological community.

Ice Monitoring

This is recognised as an important operational objective for many industrial activities performed in sea-ice covered areas (e.g. shipping, offshore oil industry, fishing industry) and already at a well developed stage in terms of utilisation of space data, including optical and microwave sensor data. The users' community is well organised and already pays for satellite services. However, this is an activity limited to high latitude zones and which can be combined with other objectives requiring, for instance, SAR high resolution and low resolution imagery at high temporal repetitivity (such as for coastal zone monitoring).

Land Monitoring

This is an activity which has the greatest economic importance whether at national level or at European level. It also covers a very wide variety of applications including, in particular, agriculture, forestry, land use management and transformation, for which space data are today used on a pre-operational, if not an operational, basis. These space data are mostly optical data from operational land satellite systems such as SPOT and Landsat but complemented recently with all weather SAR data from demonstration missions like the ESA ERS. One should also mention the use of medium resolution optical data from NOAA/AVHRR and from the VEGETATION instrument on SPOT-4 for global vegetation monitoring purposes.

Clearly, for land applications, the role of ESA should focus on the provision of appropriate SAR data, based on the expertise and competence found with the ERS and ENVISAT programmes, and for global vegetation monitoring to the provision of medium resolution imaging spectrometer data.

As regards potential partnership, one should look at the EC or at least work with the EC being given current sectorial (e.g. Common Agricultural Policy (CAP)), and regional (e.g. aid to developing countries) policies of the European Union.

Atmospheric Chemistry

Part of the atmospheric chemistry monitoring objectives will be covered by the operational METOP series embarking an Ozone Monitoring Instrument (OMI). However, it will also be necessary to consider regular monitoring of additional species to quantify changes in stratospheric trace gases with emphasis on halogenic budgets, i.e. chlorine and bromine (chemically active) contents. It was recommended that statements of priorities from potential users be sought and discussed with potential partners i.e. meteorological community.

4.5 Conclusions and Recommendations on Earth Watch Missions

The Earth Watch Working Group came with a number of conclusions and recommendations as follows:

- Five potential candidate profiles for an Earth Watch mission have been identified, for which space techniques can bring a useful contribution
- A consensus emerged in recommending to *study* a mission aimed at monitoring the environment and managing the resources of coastal zones
- The need for a cost-benefit assessment is required before any decision for implementation is made
- Keeping in mind that operational users are interested primarily in information and sources, it will be essential to consider the entire chain from the space segment to the ground segment including all data management activities
- It is important to also consider the utilisation in conjunction with non-space data
- When defining the detailed content and scope of an Earth Watch programme (for instance for coastal zones), the added value and synergy with existing/planned European and national missions will have to be explored and taken into account
- Earth Watch missions have focussed objectives but will be of interest to a wide community and therefore it will be important to identify the additional benefits to other users
- It was also recommended, when defining Earth Watch missions, to take into account the requirements for international cooperation and, in particular, the needs expressed by developing countries
- Need for further discussion with EC and other organisations/agencies to explore, in detail, their possible contribution and role in an Earth Watch mission
- Need for further discussion and consultation with specialised users' groups not represented or with a limited representation at the User Consultation Meeting.

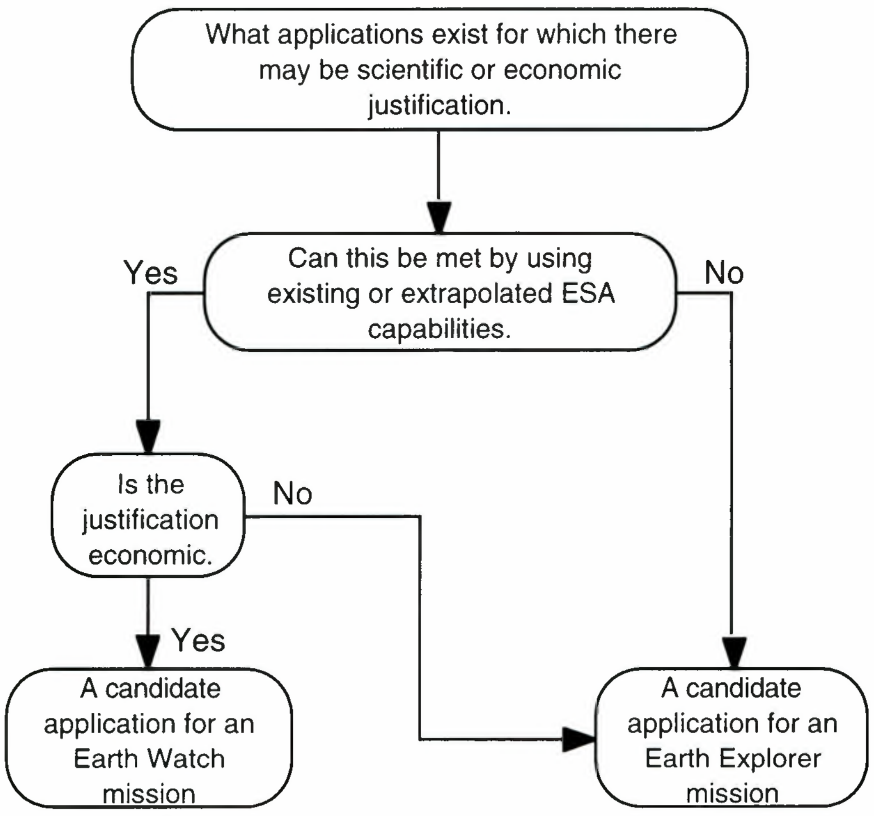

Figure 4.1: Flow Diagram for Differentiating Earth Watch and Earth Explorer Missions

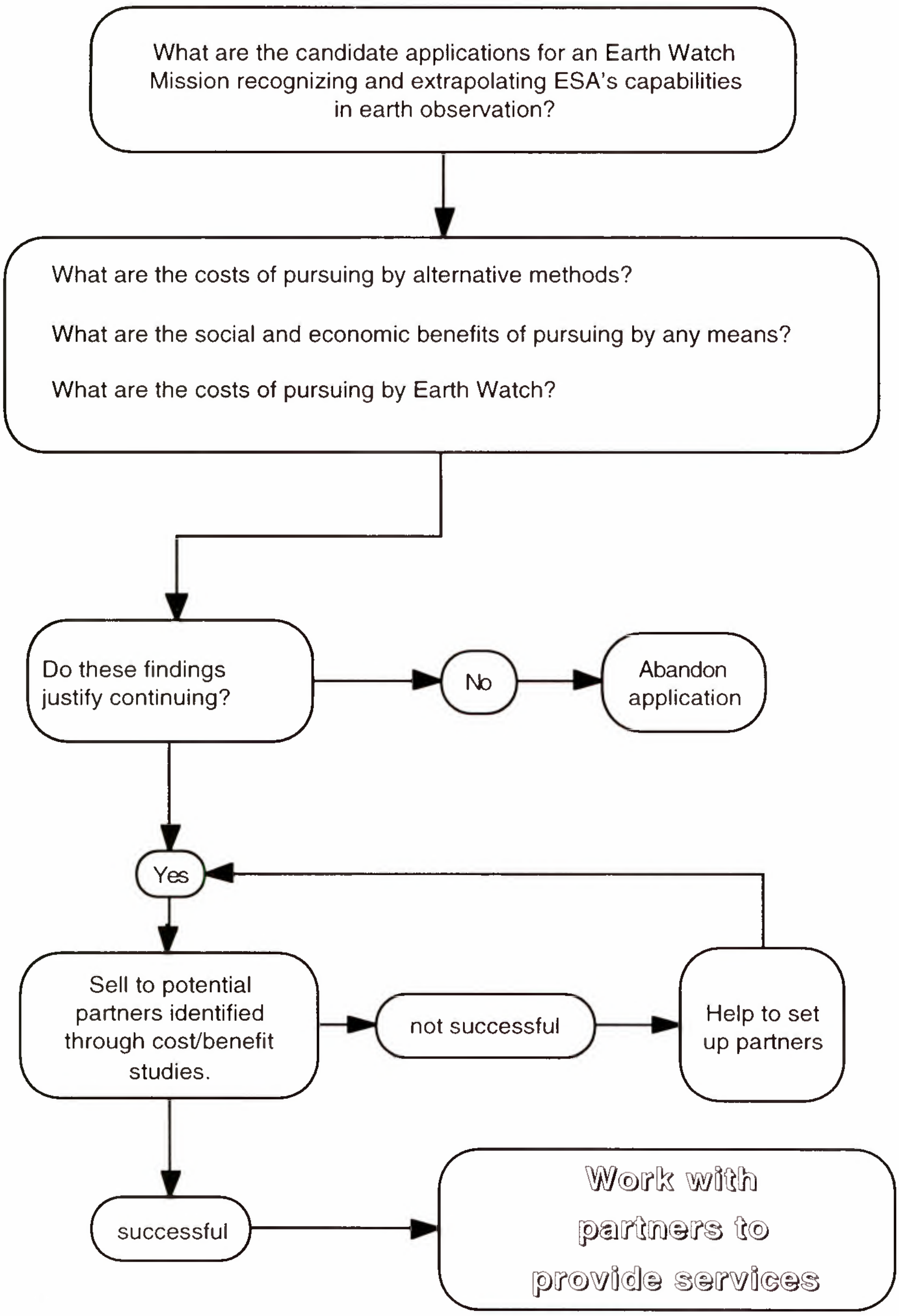

Figure 4.2: Flow Diagram for the Development of Earth Watch Missions

5. Recommendations from the Meeting

5. Recommendations from the Meeting

This User Consultation Meeting, attended by nearly 300 participants, engaged in wide ranging discussions about Earth Observation user requirements and future mission profiles. The following recommendations we made based on the conclusions and results of the different sessions.

The participants to the User Consultation Meeting:

(1) Welcome the ESA initiatives to continue the dialogue with the User Community with the view to identify the scientific and operational/commercial requirements for Earth Observation from Space;

(2) Endorse the plans of ESA, beyond ERS-1/2, ENVISAT-1, METOP and MSG, to address the post 2000 user requirements through two mission series: the Earth Explorer Missions and the Earth Watch Missions;

(3) Recommend that enhanced interactions of ESA with the full User Community be organised during the elaboration of the Earth Explorer and Earth Watch Missions.

(4) Identify for the Earth Explorer series eight missions profiles and suggest that the first of these be selected from the following missions:
— gravity field and steady-state ocean circulation
— biospheric productivity and dynamics (surface processes and interaction)
— Earth radiation;

(5) Identify a number of application areas amongst which consensus was reached on the priority to study an Earth Watch mission and associated services aimed at monitoring and managing the relevant environment and resources of the coastal zones (including land and coastal waters), including study of the costs and benefits;

(6) Request the European Space Agency to cooperate closely with the European Commission and other European entities to implement the first Earth Watch Mission and to jointly take the necessary initiatives and measures for its longer term continuity;

(7) Stress the importance that benefits from the ESA missions result for users, including users from developing countries; and welcome the initiative from ESA to enhance the exploitation of the data from its missions, in conjunction with other relevant entities.

6. Concluding Remarks

6. Concluding Remarks

The meeting confirmed the general consensus on user requirements (Sections 2 and 3) and candidate mission profiles (Section 4) in the post 2000 time frame, coupled with strong support for the Earth Watch/Earth Explorer scenario. However, in two aspects in particular its "Recommendations" were contentious:
(a) the identification of three "priority" candidate Earth Explorer Missions;
(b) the lack of an Earth Explorer "chemistry" mission.

It was also clear that further consultation would be necessary to clarify the form of the proposed Coastal Zone Earth Watch mission.

The keys to the identification of any "priority" Earth Explorer missions are firstly endorsement of the Earth Explorer concept and secondly agreement on both the selection procedure and its implementation. Both are currently being discussed with representatives of ESA Member States. In parallel the Agency is preparing assessment reports on the three "priority" Earth Explorer missions listed in the fourth bullet of Section 5. These are intended to form the basis for more detailed reviews of these three missions.

The lack of consensus on chemistry missions reflected divergence of views on priorities for user requirements coupled with recognition that a wide range of "instrument" options were available to address these requirements. The overall result was therefore an ambitious mission for which resources may not be available. Given the importance of this area it was clear that further consultation with the atmospheric chemistry community was essential. Recognising this the Agency has asked a group of experts to review the situation and to formulate a scientific rationale for a chemistry mission(s) in the post 2000 time frame. Their report will be widely circulated and is intended to serve as the basis for further (extensive) consultation with the atmospheric chemistry user community.

Further consultation on the proposed Coastal Zone Earth Watch mission has also taken place with two dedicated working meetings having been organised to which specialised groups of potential commercial/operational users, as well as some scientific experts, were invited. In addition a questionnaire has been circulated amongst these groups of potential users to try and clarify the exact nature of the requirements that should be addressed by such a mission. A report outlining the outcome of these various actions will be circulated in July 1995. This is intended to serve as a basis for further deliberations.

ANNEX A: Presentations to the Meeting

Welcome and Introduction	J-M. Luton
Perspectives for a Post-2000 Strategy for Earth Observation from Space	L. Emiliani
European Trends for Post-2000 in Earth Observation	J. Morgan
View from the European Union	M. Paillon
View from the Commercial Sector	C-G. Borg

Welcome and Introduction

J-M. Luton
Director General of ESA

Ladies and Gentlemen,

Let me start by welcoming you to this User Consultation Meeting. In particular, I would like to welcome Mr John Morgan from EUMETSAT, Mr Michel Paillon from the European Union, and Mr Claes-Göran Borg from the Swedish Space Corporation who will express the views of the Commercial Sector.

I, as I assume you are, am very encouraged by the high turnout. It confirms the high level of interest in Earth Observation in Europe. It also confirms the user community's general awareness of the importance of this meeting— a point that cannot be emphasised too strongly.

Over the next three days you will be able to make your views known directly to us and, in so doing, provide an input to the Agency's future strategy for Earth Observation. This meeting provides you with a unique opportunity to contribute to the Agency's thinking in this area.

We live on a planet recognised more and more as having both limited resources and a fragile ecosystem. The Earth's environment and climate are determined not only by complex interactions between the various components—the atmosphere, the oceans, the ice regions and the land—interactions as yet still imprecisely understood, but also by the ever increasing ability of mankind to impact them.

It follows that our well-being on Earth depends on the careful management of our resources and on an improved understanding of the complex interactions determining our ecosystem. Only in this way can we identify the true effect of anthropogenic impacts, and thereby determine the extent to which they have to be moderated.

Over the last one to two decades, Earth Observation from space has been playing an ever increasing role by providing data that contribute more and more to these ends. To a large extent this reflects the growing importance of Earth Observation:

- in terms of operational capabilities - such as meteorological satellites - which we now already take for granted;
- in the ever increasing contribution Earth Observation is making to the scientific understanding of our planet as a system;
- in terms of demonstrating the operational and possibly commercial potential of Earth Observation in many different areas - particularly those of ever increasing importance and concern to mankind.

It is therefore not surprising that, over the years, it has been increasingly recognised that many key aspects of monitoring and managing our planet can only be adequately addressed by Earth Observation from space.

In this regard, Europe has been playing an ever increasing role in Earth Observation in the world. In what way?

The success of the Meteosat programme is well known. After the development and the first years of pre-operational service conducted inside ESA, EUMETSAT was established - well represented here at this meeting - on whose behalf we have been providing, launching and operating the Meteosat operational series of satellites. We are now developing the next generation Meteosat satellites in cooperation with them.

The success of ESA's ERS-1 satellite has exceeded by far our initial objectives. Designed for a two-year lifetime, it continues to operate faultlessly after over 3 years in orbit. Its data have applications in many different areas - from furthering understanding of scientific processes to operational monitoring on a routine basis. Many of these areas—for example SAR interferometry—were never really envisaged before launch. Sea surface winds from the scatterometer are routinely ingested by the operational meteorological community—also well represented here—and make a significant contribution to weather forecasting. Sea ice and open ocean conditions are routinely monitored. New areas in the monitoring of key aspects of Europe from space (for example: resources, land use, coastal processes, to name but a few) have been developed—many by and with the European Union, also well represented here at our meeting.

ERS-2 is ready for launch next January. It will not only continue the provision of ERS data until the ENVISAT era, but will also add a new capability - global ozone monitoring.

With the recent full approval of ENVISAT-1, due for launch at the end of 1998, the Agency's contribution to Earth Observation will be greatly enlarged, particularly in the area of marine biology and atmospheric chemistry. The development of METOP, anticipated to be agreed soon, will, in cooperation with EUMETSAT, lead early next century to new capabilities for climate monitoring, as well as providing a European capability for operational meteorology from polar orbit.

No less important are the programmes of ESA Member States and Participating States, programmes that are complementary to those of the Agency. The more recent of these include:
— the SPOT satellite system led by France, of which SPOT-5 has now been approved;
— the multifrequency SAR flown recently on the Shuttle, developed by Germany, Italy and NASA;
— the Topex-Poseidon altimetry mission, developed jointly by France and the US;
— Radarsat, developed by Canada for launch next year.

Also Earth Observation by satellites is clearly global in nature. It goes beyond not only the national limits but also the continental boundaries. International cooperation in data exchange is fundamental to best serve the European users and allow their access to data from foreign satellites.

Therefore, ESA is also looking for cooperation with its international space partners NASA, NASDA and others to ensure at a time of financial and economic pressure, the complementarity of the Earth Observation space programmes such as through the exchange of instruments.

An equally important aspect of international cooperation is that of ESA, Member States and international entities working together to give support to developing countries.

With the exploitation of Meteosat and ERS ongoing, with ENVISAT and the Meteosat Second Generation now approved and under development, and with the approval of METOP anticipated in the near future, it is important to look forward.

The objective of this User Consultation Meeting is to continue the dialogue with the wide Earth Observation user community in order to identify the user requirements on which to elaborate a future Earth Observation strategy for the post 2000 era. The timely establishment of such a strategy, drawing from this user consultation, will be a key step in the preparations for the ESA Council Meeting at Ministerial level planned for the second half of 1995.

To maximise the dialogue, the majority of the time over the next three days will be spent in Working Group Sessions. Above all, we want to hear your views.

This meeting therefore provides you with an opportunity to contribute to the content of the Agency's future programme for Earth Observation. I hope you will take full advantage of the opportunity.

In so doing, you will help set the future scene, as far as Earth Observation is concerned. Many problems face mankind, and Europe has a vital role to play in solving them. If we don't meet this challenge we will have missed a unique opportunity and failed mankind as a whole—as well as Europeans. I, and I am sure you, would not want to fail to rise to the occasion.

I wish you all success over the next three days.

Perspectives for a Post-2000 Strategy for Earth Observation from Space

L. Emiliani
Director of Observation of the Earth and its Environment, ESA

Introduction

The resolution on the implementation of the European long term space plan and programmes adopted in Granada on 10 November 1992 led to the decisions to execute:

— the ENVISAT-1 mission (including the Polar Platform)
— the preparatory activities for METOP-1
— the Meteosat Second Generation programme.

The above programmes will complement the European missions which are already providing valuable data (e.g. Meteosat, SPOT, ERS), as well as the international endeavours (e.g. from NASA, NASDA, NOAA).

There is a need to define the future Earth Observation strategy beyond these missions in close collaboration with the users with a view to submitting it for approval at the next ESA Ministerial Council Meeting in 1995.

Earth Observation in Europe

A number of public European institutions are currently involved in Earth Observation from space both at European and National level with different policies, objectives, and constraints (i.e. ESA, European Union, EEA, WEU, EUMETSAT, National Space Agencies, Military Agencies). There is, therefore, a need to ensure the availability of multisource data fully processed to provide the end users with the required information.

Through the ESA National and International programmes, there is a wide supply of pre-processed (level 1.5/2) data available. However, with the exception of the meteorological data, the full use of the data within Europe is not as advanced as in the USA.

In the Granada resolution the Director General of ESA was invited:

> *"To take the initiative of consulting the European entities active in the field, in particular the Commission of the European Communities, EUMETSAT, appropriate national bodies and the user communities, with a view to acquiring a solid basis for the formulation and strengthening of a European Earth Observation policy as an element of a world-wide strategy".*

From the above, there is a need for the definition of an overall European Earth Observation policy which must address, amongst others, the following:

— roles of the European institutions/partners in the research and development, pre-operational and operational exploitation of Earth Observation space data;
— mission objectives: scientific to applications (civil and military), in line with the user requirements;
— commitment to provision of continuous long-term series of data;
— production and dissemination of data information to the users (including data policy aspects);
— synergy of Earth Observation activities and complementarity with international programmes;
— promotion of Earth Observation.

The Future ESA Earth Observation Strategy

The future ESA Earth Observation strategy should focus on the following broad objectives:

(1) Consolidation of the currently approved earth resources and environment missions (Meteosat, ERS, ENVISAT) through a continuation of essential data and deeper involvement of user entities;
(2) Implementation of missions to address separately research as well as specific fields of applications (e.g. meteorology, land use);
(3) Consolidation of the ground segment to improve the access and availability of multi-mission Earth Observation data and products and to ensure the widest distribution.

Mission Categories

In order to realise the first two of the above objectives, two main categories of missions should be envisaged:

(1) demonstration/research missions, named

Earth Explorer Missions:

aiming at improving the understanding of the different earth system processes. Each mission would focus on a particular research field (e.g. atmospheric chemistry) or regroup a limited number of research fields when this is justified by synergy or cost-effectiveness factors. Demonstration of specific new observing techniques also fall under this category.

(2) thematic pre-operational missions, named

Earth Watch Missions *:

aiming at satisfying the requirements of specific emerging Earth Observation application areas. The responsibility for these type of missions will eventually be transferred to operational entities.

In order to secure the eventual commitment by the operational users, data continuity over a first period of 10 years is necessary.

The above two main categories of missions would be implemented through the development and operation of a complete space system (satellite, instruments and ground segment). In the case of the earth watch missions, a two-satellite programme with 10 years of operations will be necessary to ensure the successful operationalisation of the new system through the guaranteed continuity of data to the end users.

Alternatively, some Earth Observation requirements could be most effectively realised through flight opportunities of instruments on other platforms (e.g. MIMR on EOS PM1 and PM2; Earth Observation instrumentation on space station, russian satellites, etc.); or as small satellite missions.

Earth Observation Ground Segment

The third objective of the ESA strategy would be addressed as follows.

The current functionality and implementation philosophy of the ESA ground segment will evolve from a *missions dedicated* ground segment (as for ERS or ENVISAT) towards *multimission* offering the user access to a wider variety of services and products. These services will include access for European users to data from IEOS partners (data exchange agreements).

ESA and the European Union (through its CEO programme) are cooperating to create a European Earth Observation System (EEOS) giving higher level products and services and taking advantage of networking (electronic highways).

The ESA Earth Observation ground segment would become one component of a European data infrastructure integrating ESA, European Union and national data services and offering reciprocal access to the rest of the world (global Earth Observation data networks).

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* the MSG and the meteorological part of the METOP missions are considered to be operational in nature even though they are *new* missions. They reflect the decision made in the 1980s to transfer an ESA pre-operational system to an operational institution (EUMETSAT).

Support to Users

The overall Earth Observation ground segment will include an element aimed at the preparation of users to new services as well as support to users to ease and speed up the transition from the research and development to the (pre)operational stage in data usage.

To ensure that the (non-specialist) end users are aware of the benefit of Earth Observation space data requires promotion activities:
— information;
— training and education;
— pilot and demonstration projects.

Particular attention should also be paid to the needs of the developing countries.

The above will be addressed through complementary cooperative actions between ESA (e.g. The Data User Programme, DUP), the Member States and the European Union.

The Earth Observation International Context

In the US, NASA and NASDA are revising their Earth Observation plans beyond 2000. *Convergence* NOAA-DOD-NASA for the future polar-orbit meteorological systems is being finalised. US government policy allowing the private sector to build and operate high resolution imaging missions is being established.

ESA is a partner of NASA, Canada and Japan in the context of the International Coordination Working Group (ICWG). ESA acquires data from the satellites of its partners to respond to European user needs and, reciprocally, the partners acquire data from ESA satellites (currently ERS-1).

International cooperation is also promoted through CEOS activities.

At a time of economic and financial pressures, the future Earth Observation strategy should place emphasis on as wide an international coordination/cooperation as possible by fostering:
— exchange of instruments
— exchange of data
— establishment of common standards.

Industrial Aspects

The future Earth Observation strategy should take due account of the current industrial competence in the space and ground systems and ensure a European presence and leadership in selected strategic areas.

It is also necessary to avoid industrial weaknesses in the ground segment development and operations: e.g. complementary actions by ESA/EU are to be envisaged for the timely availability of European industrial expertise and products aimed at serving the end users.

Programmatics

The Earth Observation long term planning along the lines of the Granada decisions leads to an ESA yearly budget of 450 MAU in 1995 rising to 550 MAU in 1997.

A working assumption of the funding level after 2000 is that it should allow:
- one *Earth Watch Mission* (2 satellites, 10 years operations) every 5-6 years on average with the first launch in 2004;
- two *Earth Explorer* satellites for launch around 2003/2005 and, thereafter, one *Earth Explorer Mission* every 3 to 4 years depending on size and complexity of mission.

Adequate complementary levels of funding by European partners and Member States are necessary for the user segment to ensure the widest use of Earth Observation space data in Europe.

Conclusions

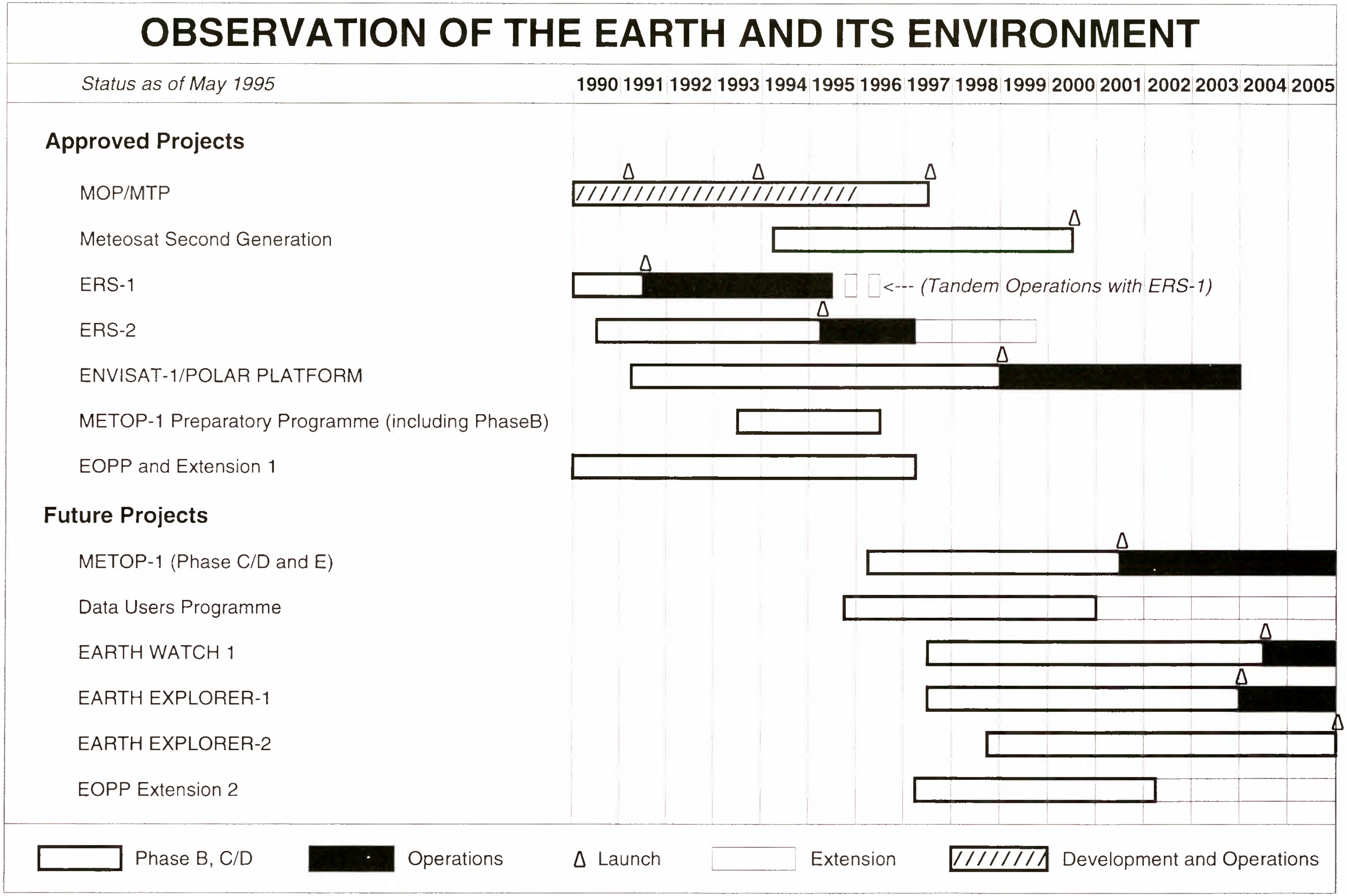
The Earth Observation strategy should be elaborated along the following lines:

1. For the definition of future ESA Earth Observation programmes, consolidate the user requirements, the first essential step being the User Consultation Meeting at ESTEC on 25-27 october 1994.

2. Enhance the efforts towards an optimal exploitation within Europe of Earth Observation space data through a partnership of European entities (e.g. ESA, EU, EUMETSAT) in cooperation with Member States.

3. Define the first Earth Explorer Missions of the Earth Observation programme.

4. In parallel with MSG and METOP define the first Earth Watch Mission.


OBSERVATION OF THE EARTH AND ITS ENVIRONMENT
Status as of May 1995
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005
Approved Projects
MOP/MTP
Meteosat Second Generation
ERS-1
<--- (Tandem Operations with ERS-1)
ERS-2
ENVISAT-1/POLAR PLATFORM
METOP-1 Preparatory Programme (including PhaseB)
EOPP and Extension 1
Future Projects
METOP-1 (Phase C/D and E)
Data Users Programme
EARTH WATCH 1
EARTH EXPLORER-1
EARTH EXPLORER-2
EOPP Extension 2
Phase B, C/D
Operations
Δ Launch
Extension
Development and Operations

European Trends for Post-2000 in Earth Observation

View from EUMETSAT

J. Morgan
Director of EUMETSAT

Introduction

During this short presentation I intend to address three topics; current EUMETSAT plans, lessons from the past, and perspectives of future requirements. In making these remarks I should point out that EUMETSAT already had firm plans extending well into the next century, hence the first two of my topics are based on established fact. However, there has so far not been a debate about EUMETSAT requirements beyond the first one or two decades of the next century; therefore my remarks concerning the third topic will be very much a personal statement and are not the official views of EUMETSAT. Nevertheless I hope that they may be of some use in opening the discussion on this important issue.

1. Current Plans

The current plans of EUMETSAT are fairly well known, so I shall not mention any details, but the overall plans are very relevant to this meeting and it is certainly appropriate to briefly bring them to your attention.

1.1 Geostationary Space Segment

1.1.1 Meteosat

As regards the geostationary space segment, there are currently four operable Meteosats in orbit. Two of these, Meteosat-3 and Meteosat-4 have already exceeded their specified lifetime in orbit and will probably be de-orbited during 1995, leaving Meteosat-5 as the operational spacecraft and Meteosat-6 as the in-orbit spare. A further satellite of the same design is being made ready for launch in 1997 and with these satellites, EUMETSAT plans to maintain operational coverage in geostationary orbit until at least the year 2000. These satellites provide an operational service based around a three-channel radiometer which has proved to have many applications beyond pure meteorology and is now regarded as an essential tool by many communities. This is certainly the first European "Earth Watch" mission and can serve as an example for further developments.

1.1.2 Meteosat Second Generation

Beyond that date, Meteosat Second Generation will provide for further data continuity. The first EUMETSAT programme has already been agreed. The prototype, MSG-1 will be developed by a parallel ESA programme which includes a substantial financial contribution from EUMETSAT. The following two satellites will be procured by EUMETSAT with the assistance of ESA. With these three satellites, geostationary data coverage will continue until at least the year 2012. These new satellites will provide data in 12 spectral channels, associated with a ten-fold increase in the data compared to the first generation. The agreed EUMETSAT programme has financial provision for the development of the ground sector under direct EUMETSAT responsibility as well as for routine operations until the year 2012.

1.2 Low Earth Orbit Space Segment

EUMETSAT and ESA are developing joint plans for an initial EUMETSAT system in low earth orbit (LEO). Each organisation has a preparatory programme in progress and a full programme proposal is under consideration. Cooperation with ESA would follow the same general pattern as in the geostationary case, with ESA developing a prototype, METOP-1, and EUMETSAT taking responsibility for the later satellites. Present plans for the EUMETSAT Polar System (EPS) call for a first launch at the end of the year 2000 and then at intervals of about 4.5 years.

These new satellites will carry a wide range of instruments addressing many observational requirements. All will be useful for both meteorology and climatology, although part of the payload will primarily address the requirements of operational meteorology, while the remaining instruments are also justified by their contribution to the monitoring of climate. Once established, EPS will provide an outstanding contribution to the long term monitoring of planet earth with an exceptional operational payload of vital significance to many user communities.

Unlike the geostationary case, EUMETSAT does not plan at present to maintain an in-orbit spare satellite. This is because back-up will normally be available from the parallel programmes of the USA. Normally there should be two satellites meeting key European requirements in orbit at any one time, one from NOAA in the USA, the other from Europe. In the event of failure of key missions on the European platform, EUMETSAT plans to make provision for a re-launch within 18 months; meanwhile the global system would degrade to global coverage by a single satellite.

1.3 Ground Segment

EUMETSAT is an operational agency with approved plans which already extend further into the future than those of any other space agency. This long term perspective makes it essential for the organisation to have close control over its ground systems as well as its space segment. Accordingly EUMETSAT is in the process of establishing a new ground segment for the present Meteosat system which shall also serve as a foundation for longer term continuity as regards the ground segments for MSG and for EPS.

1.4 Longer Term Plans

As previously mentioned, EUMETSAT already has detailed plans covering much of the coming two decades. GEO systems are now approved which will provide data until at least the year 2012. LEO systems are in the final stages of planning; approval is sought for an EPS programme providing advanced data coverage from 2001 until about 2014. A full ground segment capability is being established which will assume full responsibility for routine operations from late 1995.

EUMETSAT has not discussed its plans beyond these distant dates but the basic assumption is that as an operational agency, EUMETSAT will expect to continue to provide data coverage from both geostationary and low earth orbits over the decades beyond 2012, addressing both operational meteorology and climate change. These missions will be subject generally to evolutionary change and enhancement over the years, rather than a complete change of direction. Thus, EUMETSAT plans can be characterised as long term, operational, and an essential baseline component of a European Earth Watch.

2. LESSONS FROM THE PAST

2.1 Meteosat: From Demonstrations to Operations

Meteosat is Europe's only example of a governmental earth watch programme. It became a European programme in 1972, when ESRO took over a concept originally proposed by France. ESA subsequently launched Meteosat-1 in November 1977. Even though the satellite failed after two years, its value was so apparent that ESA was able to convene an Intergovernmental Conference in January 1981 to discuss how the continuity of this satellite system could be assured. It was agreed that the most appropriate mechanism was a new intergovernmental organisation: EUMETSAT. In a second session, held in 1983, the Intergovernmental Conference agreed on the terms of reference of EUMETSAT and in the same year ESA agreed to initiate the Meteosat Operational Programme in anticipation of EUMETSAT's creation.

EUMETSAT was established in 1986, took over formal responsibility for Meteosat in 1987 and launched the first "operational" Meteosat in March 1989. ESA continued to be technically responsible throughout this period and, indeed, will be responsible for routine operations until EUMETSAT establishes its own ground segment in December 1995.

The lesson to be learnt here is that, following the launch of the first flight model of a demonstration satellite, urgent action is needed to provide for longer term continuity where an appropriate operational agency does not already exist.

2.2 MSG: Requirements to Routine

The initial definition of MSG commenced with a series of workshops organised by ESA, starting with the Avignon workshop in 1984 and culminating in the Bath workshop of 1988. EUMETSAT did not exist when this series of workshops commenced and, in fact, rejected the conclusions presented at the Bath workshop. The consequent redefinition of requirements resulted, in due course, in the initiation of the relevant EUMETSAT and ESA programmes in 1994, when the requisite Inter-Agency Agreement was also signed. These efforts will lead to a first launch late in the year 2000, more than sixteen years after the initial discussions. This long gestation period led to the necessity of a so-called Meteosat Transition Programme to bridge a gap between the available Meteosats and the arrival of Meteosat Second Generation.

The lesson to be learnt here is that when a new long term programme is planned there is an absolute need to obtain the early concurrence of the agency which will one day take over responsibility for the routine phase.

2.3 EPS: Prototype to Operational

The EPS initiative started with a decision by the EUMETSAT Council in 1988 to study a future polar system. Several concepts were examined, leading eventually to the present joint approach of EUMETSAT and ESA for the development of a satellite series combining meteorological and climatological missions. It is noteworthy that the earlier concepts based on sequences of independently justified polar platforms (POEM) were rejected in favour of a concept which could be classed as operational from the start. What has been accepted is that METOP-1 shall be a prototype of an operational series which can be sustained over long periods of time.

The lesson here is again that a new long term programme requires the early concurrence of the agency which will one day take over responsibility for the routine phase.

2.4 Who Pays, Chooses

ESA has a vital role in the development of new instruments and systems but it must not be forgotten that until now ESA programmes have generally been restricted to the development of single flight models, with one or two additional flights added later in some cases. An operational agency such as EUMETSAT will expect to pay for follow-on satellites and for long term operations and thus may pay more than ESA for a given satellite series. This can be illustrated by the costs of EUMETSAT programmes over the thirty years since the organisation was defined in 1983; during that period development costs fully paid by ESA amount to less than 25% of overall costs.

This again points to the necessity of involving the funding user, in a formal way, at the earliest possible moment.

2.5 A European Strategy

European initiatives over the years have led to a strong Earth Observation community within Europe. This includes of course the ESA research and development activities but also includes SPOT Image, the intensive use of satellite data by the European Commission and many other users, and of course, EUMETSAT. This strong community makes it essential to establish a European strategy with the deep involvement of the major institutional players who will, in the end, have to provide financial support for long term continuity of Earth Observation from a European base.

I welcome the current initiative by ESA but it must surely be regarded as a very preliminary step in which the scientific requirements and the possible technical solutions are addressed in a wide forum. It is already apparent that there is a strong consensus in favour of long term monitoring of planet earth. It is important for Europe to play its full part in this. Appropriate institutional arrangements need to be established and as an operational agency, EUMETSAT is willing to play a full part.

If there is one major lesson to be learnt from the past it is that much time could be saved by formally agreeing common goals at an agency level before development starts.

3. PERSPECTIVE OF REQUIREMENTS

3.1 General

The growing concerns about the environment and particularly the adverse impact of the human activities which could dramatically change the climate of our planet within a few lifetimes, have provoked numerous debates on what needs to be done. An early priority is to understand the systems of planet earth and the way in which those systems inter-relate.

The earth systems are extremely complex but in certain areas such as numerical weather prediction the behaviour of the atmosphere is well understood, leading to rather precise definition of basic requirements for observations which are needed now and in the coming decades. Basic requirements for climate monitoring are also understood, so there is already a clear picture of what observations are needed over long periods of time.

These requirements lead to the definition of long term operational programmes such as MSG and EPS which are already structured to provide observations over a dozen years in the early part of the coming century and are, in principle, able to provide continuity over the longer term.

However, these operational programmes do not answer all of the questions. There must be a capability within Europe to understand more about the earth systems through so-called earth explorer missions and the capability to improve and extend the monitoring of planet earth through the so-called earth watch missions, of which Meteosat, MSG and EPS are already examples.

3.2 EUMETSAT Requirements

It has already been indicated that EUMETSAT's primary requirements over the first decades of the 21st century will be to maintain, extend and improve its present systems already operating in geostationary orbit and in the final stages of planning for Low Earth Orbit.

The experience of Meteosat has been that the original design concept (1972) will still be operable 30 years later, in 2002. This long period of operational utilisation might not be achieved in future satellite systems, but does illustrate how important operational continuity is to the meteorological user community. This long term continuity is also implicit in the requirement for climate monitoring and the detection of climate change, and will continue to be a primary goal of EUMETSAT.

To satisfy this goal EUMETSAT has to seek a careful balance between the use of reliable technology and advanced technology which will still be relevant two or even three decades after the initial design studies. This requirement for advanced technology implies a need for continued close cooperation with ESA.

The way in which EUMETSAT approaches this is to form an independent view of its detailed requirements and to determine if ESA is prepared to assist EUMETSAT through the development of a prototype. This is the successful approach employed for MSG and proposed for EPS and is likely to be followed in the future. Therefore, it would be appropriate for EUMETSAT to continue to work with ESA on the definition of future systems meeting evolving EUMETSAT requirements.

This is likely to be a continuous process; within the next few years consideration must start on the follow-on to the present MSG programme. Improvements and developments of the planned EPS programme will also be required, including the possible development of new or improved instruments for METOP-3. Therefore, the dialogue between EUMETSAT and ESA must continue and will complement meetings such as this.

3.3 Long Term Monitoring

EUMETSAT's current earth watch missions do not observe all aspects of the evolving earth system which is consistent with EUMETSAT's charter to establish systems for operational meteorology and to **contribute** to climate monitoring. This means that additional long term missions seem essential. A problem to be addressed by this Consultation Meeting is to discuss which earth watch missions are needed, technically feasible and marketable.

If we are to heed the lessons of the past, it is clear that the success and viability of any additional long term mission of this type will depend on the early involvement of any entity which is expected to take financial responsibility for long term costs. This was shown to be the case in all three of EUMETSAT's major missions. As has already been indicated, the continuity of Meteosat was assured by identifying a clear category of users, the national meteorological services, which were prepared as early as 1981 to participate in an intergovernmental conference on the future of Meteosat. MSG started to become a practical reality only after the principle funding community, EUMETSAT, had clearly stated its requirements. EPS, too, only became realistic after the convergence of views between the development agency and the end user, again represented by EUMETSAT.

This consideration points to what I see as a fundamental problem; the necessity to define and consult the entity which may take long term responsibility for long term costs.

3.4 Additional Earth Watch Missions

Participants at this meeting have been presented with two potential earth watch missions as "strawman" proposals. Taking a very personal view, I believe that it may well be possible to agree on the definition of an environmental monitoring and resource management mission. This seems to be well defined, suitable instruments are already established and, most importantly, it seems possible to determine a potential end user entity which might eventually agree to fund long term continuity.

In my view, the situation is much less clear in the case of the proposed Atmospheric Chemistry Monitoring mission, in part because there is an overlap with the proposed METOP payload, in part because the scientific requirements for particular long term measurements are not yet established and in part because a long term user entity also capable of funding a long term, highly specialised, mission of this type is not yet obvious. These considerations lead to the suggestion that chemistry for the moment might be regarded as a high priority candidate for one or more explorer type of scientific mission rather than a ripe candidate for long term earth watch.

This is not to say that I dismiss the idea of further earth watch missions, rather that a full analysis, involving the potential funding community, must be a pre-requisite for a specific proposal.

3.5 Earth Explorer Missions

A typical earth explorer mission, that is to say, a research or demonstration mission, has two attractions for EUMETSAT. First, it should serve to improve the understanding of the earth system. Second, it may serve to demonstrate a new or improved technology which could form the basis for a new pre-operational earth watch mission or serve as a replacement for a system in an existing, operational earth watch system.

With this in mind, EUMETSAT would certainly be interested in new instrumentation capable of monitoring precipitation, or the three-dimensional wind fields such as proposed in the "strawman" concepts. EUMETSAT would also eventually be interested in improved instrumentation for its currently planned satellites. Hopefully, this meeting will define a range of feasible options which will start the interactions between ESA and EUMETSAT needed for longer term plans, beyond the year 2012.

3.6 Conclusions

In conclusion, I should like to say that the concept of long term earth watch missions is already a fundamental part of EUMETSAT's operational philosophy. That is what EUMETSAT is about! It should be expected that EUMETSAT and ESA should try to work together to improve and extend these operational systems.

The proposal to add additional long term earth watch missions, to extend what EUMETSAT is already doing, should also be welcomed. It is, however, essential to develop plans to involve the funding user community at the earliest opportunity. More than this, it is essential to identify the "market", that is, the funding community, before embarking on a prototype, otherwise the prototype is not a prototype at all, but a demonstrator.

Earth Explorer missions are also an appropriate way for ESA to improve the understanding of the relevant sciences and to provide demonstration missions which may be of direct interest to EUMETSAT, but once again the paying customer must be closely involved in the mission definition.

As a last word, stressing the obvious, user entities must be identified as a matter of high priority and this conference must consider the marketability of their proposals, with the same, or even higher, priority than the scientific need and the technical feasibility.

View from the European Union

M. Paillon
Head of Space Division DG XII (Science, Research and Development) Commission of the European Communities

Before expressing the views of the European Commission, I would like to congratulate ESA on initiating this meeting. It is an opportune moment both because of the impending ESA Ministerial meeting, but also because we, in Europe, have reached a point in EO development when it is time to take stock and consider future plans. Therefore I am delighted to take part in this workshop and to have the opportunity of outlining the EC's approach in EO from Space for post 2000.

Taking advantage of the excellent job done by ESA and the Space Agencies in making data available, the Commission has been using Earth Observation satellites to provide for many years, information for the implementation of the various Community sectoral policies, most notably in the areas of agriculture, environmental monitoring, environmental research, and development aid. For example, EO plays a major operational role in the verification of subsidy claims from farmers. At the same time, the Commission's Institute of Remote Sensing Applications, part of the Joint Research Centre, provides scientific support to these applications, and conducts research on advanced techniques related to environmental change. The Commission also plays an increasingly active role in fora concerned with international coordination, for example, by ensuring regular and close liaison with the European Space Agency, and by participating in the Committee on Earth Observing Satellites.

With the space segment well on the way to being in place, the emphasis now must be on making use of the data and extracting maximum benefit from the heavy investment made or planned.

In its last Communication to the Council and the EP, the Commission stated the following broad objectives concerning a Community EO intervention :

"To encourage and support the optimal development and exploitation of EO applications, particularly by initiatives contributing to the establishment of a European operational system for the study and monitoring of the environment";

and:

"to increase and intensify the use of satellite data within the framework of various Union policies".

These objectives flowed from the knowledge that EO can deliver useful information for the management of the Earth's resources, and for the study and monitoring of its environment and climate. However, as a relatively new technology, EO has yet to reach its full potential to deliver benefits in the public interest commensurate with the massive public investment in the space segment.

A key requirement in this respect must be the provision of high quality EO services on a continuous basis over long periods of time. To sustain this it will be necessary to develop a customer base for EO-derived information which is able and willing to finance, directly or indirectly, at least a significant part of the relevant space and ground operations. The customer base will include public authorities and governments, who, in particular, must ultimately be convinced that it is cost-effective to collect information derived from EO, given their perception of the value of that information within their various policies (environmental protection, funding of research, etc.).

In addition to its concern for the optimal development of EO applications, the Commission also recognises that growth in the EO market will provide opportunities for expansion and employment in the industrial value-added sector, and will hence contribute, albeit in a small way, to the goals set out in the Commission White Paper: "Growth, competitiveness and employment".

Motivated by the above considerations, therefore, the overriding objective of the Community in this area may be reformulated as follows:

"To create the conditions necessary for the growth of a sustainable, demand-led European market for EO products and services for both research and operational purposes".

This objective implies a process of transition during which there is a need for intervention. The necessary scope of the intervention extends beyond the mandates of the space agencies. The Commission, whilst respecting the principle of subsidiarity, intends to play a key role at the European level in partnership with the space agencies, relevant organisations in the Member States, user groups, and industry.

Three approaches towards the stated objective will be followed in parallel:
— Ensure that the needs of users are adequately covered
— Increase the cost-effectiveness of EO applications
— Foster information exchange and coordination between users

The first approach will make sure that present and future user needs drive the requirements of existing or planned EO systems. The second approach will make EO a more attractive solution for potential users by reducing the effort needed to acquire information, and by raising its value. The third approach, linked to the first, will improve the ability of users to act as sophisticated customers capable of expressing coherent needs for data and services. The three approaches are primarily directed at users, but they are designed to achieve a sustainable market that is clearly in the interest of all actors in the EO sector.

The Commission will restrict the scope of its actions to applications with a European Union interest. This includes, but is not restricted to, applications that directly support the policies of the Union. Four broad themes of application have been identified :

(a) Global environment/climate change: which includes research into ozone depletion, global biodiversity, climate change prediction, climate change detection, process studies and impact research.

(b) Environmental management: which includes aspects related to land-use and habitat mapping, coastal zone management, terrestrial pollution, land degradation monitoring, ice.

(c) Resources management (Agriculture, forestry, fisheries, transport...): which includes use of EO for monitoring and inventory, both for verification purposes and in support of policy development. It could also include support to value-added industries in these sectors.

(d) Land system management: which involves the use of integrated information systems for both regional planning in Europe, and for development aid.

Other themes may also be considered if necessary.

Where appropriate, structures in support of particular themes will be established (e.g. concertation networks) to ensure that actions at the Union level are coordinated with relevant actions carried out by the Member States, and to integrate the results of national programmes into a European framework. The guiding principle will be to add value to the various efforts without introducing unnecessary bureaucracy.

Within each broad application area mentioned, the Commission intends to implement a series of measures consistent with one or other of the three strategic approaches mentioned .

The first of these strategic approaches is to ensure needs of users are adequately covered.

In order to increase the influence of users in the EO sector, there is a continuing need to raise awareness of the possibilities offered by EO, and to ensure that the requirements of users, both existing and potential, are incorporated into the specifications of EO missions. The Commission has a role to play as an intermediary in this respect, acting both as a major user itself, and as a proxy for the wider community. Two categories of action are considered:

As a pioneering customer, it is the Commission's intention to extend and intensify the cost-effective use of EO data in the implementation of the Union policies. In this respect the relevant Commission services are essentially no different from other current and potential customers, and will, it is hoped, be encouraged to adopt EO as a result of the various measures envisaged.

On the assumption that such high-profile use can encourage others to follow suit, the Commission will ensure that information on its own use of EO will be widely disseminated. As a first step, a directory of current Community projects will be compiled, regularly updated, and published in an appropriate form. The Commission will also ensure that more detailed information on particularly significant EO applications at European level, such as those of the European environmental monitoring, will be disseminated widely.

The programme of pilot projects which will be described later may be used to test the cost-effectiveness of EO methods for the Union policies. However, the research budget is intended to provide only for a transitional period before the application is proven.

When appropriate, funding of cost-effective operational EO services should be made available from the budgets corresponding to the particular Community sectoral policies (e.g. Agricultural policy, Development policy, Regional policy, Assistance to CIS) in a manner consistent with the characteristics of the programmes. As a general rule, the Commission will ensure that all relevant Union budget lines are used in a synergistic manner.

As regards the support to the development of elements of the space segment, the Commission is currently providing partial support to the development of two space instruments: VEGETATION (for biosphere monitoring) and AMAS (atmospheric soundings). These instruments have the potential to supply information of direct interest to Union policies (agriculture and environment), but are also of considerable interest to user groups in the wider community. By helping to secure space instruments that meet user needs, the Commission is acting as both customer and proxy.

Such support to the space segment is new. At present, VEGETATION and AMAS are regarded as pilot projects and "test cases". The Commission will encourage an open debate with all relevant parties in order to determine guidelines for possible future support to the space segment. The present workshop will give us an opportunity to start such a debate.

Let me go to the second strategic approach which is to increase the cost-effectiveness of EO applications.

The community of customers for EO will grow when the efficiency of the process by which useful information may be obtained is improved and when potential users are brought to understand the possibilities of this technology.

Most EO applications are currently developed by scientists who have established links with the various data suppliers, and are experienced in the necessary data processing methods (often using techniques developed in-house). Prospective users, of whatever discipline, usually have to invest considerable effort in order to become "remote sensing specialists" before they can judge the utility of EO. Many potential users are thus deterred by the real and perceived cost of becoming a user. Unless suitable remedial actions are put in place, this problem is likely to intensify as data from new sensors become available in the coming years.
There will be three components to this approach :

Firstly, in order to facilitate user access to EO data sets and products and following the results of current studies, the Commission, in partnership with ESA and the Member States, will take steps to establish elements of a decentralised ground infrastructure for the management of EO data, products and services. This will be based on the concept of a European Centre for Earth Observation which will not be a centre as such but rather a network. The CEO will form part of a wider European structure known as the European Earth Observing System which should be coordinated at global level with similar initiatives undertaken in the USA and Japan.

Funding for CEO will come from both the Community Environmental R&D specific programme and the JRC components of the Framework Programme. Relevant aspects of the CEO will be coordinated with the Telematics R&D Community programme as necessary.

The field of application of EO data also needs to be extended by provision of standard products for cost-effective inclusion in multiservice information systems.

Secondly, notwithstanding certain notable exceptions in the Member States and at the European level, R&D in data interpretation has tended to take place in a fragmented manner, often without the close involvement of end users. For many applications, there is a continuing need to develop procedures capable of delivering high quality information meeting real user requirements. In order to increase the value of derived information, it is intended to address these shortenings through both direct and cost-shared research in the Fourth Framework Programme.

Methodological research will aim at overcoming identified problems obstructing operational use of EO data in one or more applications of European interest, and at preparing for the exploitation of data from new sensors.

The JRC for its part will undertake direct research on advanced techniques for data analysis and acquisition specifically directed to support global change research, including research using the European Microwave Signature Laboratory. The JRC research will be undertaken in conjunction with relevant international bodies (including ESA), as well as with extensive networks of institutes and organisations within and beyond Europe.

In addition, a programme of cost-shared research will bring together European laboratories and industries with complementary expertise.

There will be close co-ordination between the management of the cost-shared and direct research programmes in order to ensure that they are implemented in a complementary manner.

Thirdly, a cost-shared programme of pilot projects will be designed to test, and hopefully demonstrate, the cost-effectiveness in an operational environment of applications for which the basic technical feasibility has already been proven. Such projects would have to involve a cooperating end-user, normally in consortium with a research laboratory and an industrial partner from the value-added sector.

It is expected that the value-added companies will play a key intermediary role by identifying potential applications and users, and by bringing together the necessary consortium partners.

Support from the environmental R&D specific programme would normally be at 50% of the project cost. The remaining subsidy would be found from a combination of the end user or industrial partners, in a proportion varying from project to project.

Projects will be selected according to the normal procedures of the community R&D specific programmes. Evaluation criteria will include: relevance to the policies of the European Union, and the likelihood of the application becoming fully operational on a sustainable "user pays" basis. In some cases the end user can be another service of the Commission itself, in which case the funding of the follow-up project, if any, will be found in the relevant community budget line.

The JRC will continue to be responsible for large application projects such as those concerned with tropical deforestation, ocean colour and agricultural monitoring. It may extend its programme of direct research by participating in pilot projects under the cost-shared programme.

The pilot project programme will also be used to identify limitations in the existing ground infrastructure (catalogues, archives, networks etc.) that may be overcome through the development of the CEO. It is also conceivable that successful pilot projects will lead to the definition of new space instruments to meet specific data requirements.

Furthermore, appropriate links will be made with the Telematics R&D specific programme, under which support is envisaged for "validation pilots" in line with the objectives of that programme.

We can move now to the last strategic approach which is to foster information and coordination of users.

In line with its role as a proxy for the wider user community, the Commission will take steps to assist certain groups of users to become active customers for EO products and services and will take initiatives aimed at reinforcing coherence within user groups.

This may include convening or sponsoring user meetings, commissioning of study contracts designed to analyse the requirements of particular user sectors, supporting concerted actions aimed at coordinating actions at the Member State and European levels, and improving the dialogue with the space agencies. The Commission has already taken such steps in the field of operational environmental monitoring. Other domains may be addressed in a similar way.

Further, it is expected that certain user groups will work together more closely, in order to identify common requirements, during the development and implementation of the CEO.

In the same context, the Commission will continue to participate actively in fora concerned with EO policy issues, and in particular, in the Committee on Earth Observing Satellites. In so doing, the Commission will ensure close liaison with ESA, EUMETSAT, Member State space agencies and user groups. As an example, the Commission and ESA will continue to hold regular working group meetings on EO and the environment. Other meetings will be convened as necessary.

With a concern for the internal market, and as a customer itself, the Commission has a special interest in issues of space data policy, including pricing policy. The Commission intends to promote common European positions on space data policy consistent with the overall objective stated earlier, whilst recognizing that the implementation mechanisms may differ from mission to mission (or even instrument to instrument) according to particular funding arrangements. The Commission will act in close cooperation with the competent Member State bodies, ESA, and other relevant organisations. As in the past, the Commission may support studies to investigate policy issues as necessary.

It is also possible that the Commission may propose legislative measures, within its existing competencies and following extensive consultation, that are relevant to data policy

The Commission will finally consider carefully the needs for education and training with a view to fostering institutional and corporate environments susceptible to the adoption of cost-effective EO methods. These needs may include: awareness-raising for the general public, opinion leaders and "decision makers" (including Commission officials responsible for the execution of projects), training and education of new users, and exchange of information between the experienced and active users. Whilst there will be no single Community programme dedicated to all these aspects, the Commission, in partnership with ESA and other relevant bodies, will, as far as is considered necessary, coordinate the provision of EO education and training through existing European programmes such as Human Capital and Mobility, Euro-Courses, LEONARDO and SOCRATES. The Commission will also investigate the possibilities for including appropriate components as part of its cooperative activities in developing countries, and the countries of central and eastern Europe.

In conclusion, I would like to underline that these views of the European Commission have to be put in perspective with these of ESA as well as these of all relevant actors in the field, in particular the Member states agencies and industries. There remains a need to develop a long term strategic plan to ensure the optimum development of the EO sector into the first decade of the next century and beyond. Such a plan will need to take account of the objectives, competencies and resources of all actors. It would be an important element of a more general European Space policy.

It is my hope that we will be able at the European level to develop this common approach and present in due time to our competent European bodies concrete proposals for this E.O. European strategy.

View from the Commercial Sector

Claes-Göran Borg
Swedish Space Corporation

Mr Chairman, Ladies and Gentlemen,

It is a pleasure and a challenge to speak to this huge audience alongside some of the key persons of European Research and Development in Earth Observation.

Furthermore, I found it rather pretentious to talk on behalf of the Commercial Sector. At least until I found that the title was Views from the Commercial Sector - not of. This means that what I say here is my personal view; however it is based on some 20 years of experience trying to commercialise Remote Sensing.

Having realised this, I asked myself: Why did ESA ask me? Well then one of my dear colleagues pointed out: "Don't be too flattered. It is just because you have been somewhat active and for instance asked questions about this meeting. They believe it is better having you inside the tent than outside."

Well anyhow, thank you for inviting me.

My next question confronted with this title was: What is the Commercial Sector?

It could be many things and I have listed some:

- Provider: e.g. Orbital Sciences in SeaWifs
- Mission operator: e.g. Eosat for Landsat 6 (ill fated)
- Ground Segment operator: e.g. Spot Image
- Data provider: e.g. Eurimage/Distributors
- Value Added Remote Sensing Company/ Value Added Application Company: e.g. Mapping, Forestry Consultant
- Commercial User: e.g. Forestry, Mineral Prospecting

This shows that the Commercial Sector has many faces and roles. We can talk about Scientific, Operational or Commercial Applications. I will develop just on a few of these aspects.

So let us start from the beginning in the glorious seventies (1970s).

It was like building your house in the 19th century. You had to choose the trees, cut them down, make your own drawings and do everything thereafter - not too many houses were built.

Nowadays the construction industry has matured. You can go to the building-warehouse and pick your prefabricated building blocks, doors, windows, wallsections and they are supposed to fit nicely. At least in principle.

If we take this analogy into Earth Observation, I believe we are in this transition phase to industrialisation and operationalisation.

In the present situation we have a Value Added industry helping the house owner/end user build the houses one by one - and we do not have too many End Users.

I see a trend with:
— many suppliers competing;
— the user can not choose;
— there will be a need for intermediates (lets call them Data Brokers) with very good knowledge of the data sources providing interim products;
— the user community (not always the end user) will put application intelligence into the products because they - and only they - have the necessary knowledge.

We all have to help set up these chains and here I see a role for the Remote Sensing Value Added Industry. It will never be a large community but it has a very important role in methodology development and in implementing operations.

All this is said as a general background. And against this - what could be the role of the commercial sector?

My first point:

The commercial sector is and should be a good adviser to ESA and EU on User Requirements, Methodology development and the process to Operationalisation

There is a critical need to develop means and fora for the Sector to interact with ESA, EU and CEOS.

The commercial sector needs to put its act together and present its case in a—as far as possible—coherent way. This is a responsibility we have. How else can ESA and EU work with us systematically in the long term perspective?

My second point:

There are various kinds of Missions - from scientific through public operational to various commercial ones. I have given some examples. There could be and should be a role for the Commercial Sector in all these categories especially in the exploitation phase.

True, the role will vary — from just being station operator to taking the full responsibility.

But I am convinced that by using the Commercial Partners we can create ways to:
— make the operations more efficient,
— get good feed-back from the users,

— increase the flexibility in the services provided.

This leads to my third point:

A key issue is obviously how we set up and operationalise the future systems. How, for instance, will the Earth Watch systems evolve? Here we need to work out a European Earth Observation Policy in the international perspective.

Do we not only want the users to get the right information but, at the same time, to build a competitive European industry in space and on the ground that can provide this information in international competition? And how is this best achieved?

Obviously no one can give the one and only answer. But my strong belief is that the private sector should be involved as early and as much as possible.

We must create a strong partnership between ESA, EU, National Entities and the Commercial Sector not only in space - as it already exists today - but for total operational systems including the ground segment up to the end use. This might put some more economic realism into the wish-list of the space industry as well as of the users. One example - which I like - is the SPOT/Radarsat Concept - but there might be even better ones.

By this I come to my fourth and final point:

A European Earth Observation Policy must foster a competitive Industrial and Commercial Sector. This means that we should not only now work out new experimental or preoperational ESA Missions, but at the same time outline the road to operationalisation in order for the Commercial Sector to understand the roles of the game — and to organise themselves accordingly.

I have made four points here:

- The Commercial Sector must put its act together to be able to advise and interact with the international organisations setting up the roles.
- The Commercial Sector should be allowed to play an operational role in all kinds of missions to develop the sector and to make the operations eventually more efficient.
- An European Earth Observation Policy should be worked out that fosters a competitive European industry in the whole chain from satellite to end user. This should create a good partnership between the public and private sectors.
- When defining future ESA or EU Missions we must at the same time outline the road to operationalisation. Then the Commercial Sector can organise themselves accordingly.

If these four points are adhered to, then I believe that the Commercial Sector will flourish and all of us with it.

Thank you for your attention.

ANNEX B: List of Participants & Contributors to the Meeting

B.1 List of Participants

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Name	Company	Country
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Dr R Frassetto	ISDGM/CNR	Italy
Prof. P.E. Gudmandsen	Technical University of Demark	Denmark
Prof. R. Gurney	NERC Unit for Thematic Information Syst.	United Kingdom
Prof. K.F. Hasselmann	Max Planck Institut fuer Meteorologie	Germany
Sir John Houghton,	Rutherford Appleton Laboratory	United Kingdom
Prof. Dr. G. Konecny	Institute for Photogrammetry	Germany
Dr M Lefebvre	GRGS-CNES	France
Prof. D.T. Llewellyn-Jones	University of Leicester	United Kingdom
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Prof. H. Rott	Institute of Meteorology & Geophysics	Austria
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B.3 List of Working Group Chairmen and Rapporteurs

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Scientific Research:	H. Grassl	C. Readings
Land	J-P. Malingreau	M. Rast
Atmosphere	P. Simon	P. Ingmann
Ocean	J-F. Minster	E. Attema
Ice	P. Gudmandsen	J. Johannessen
Geodesy & Geophysics	R. Rummel	S. Hieber
Operational/Commercial Applications for Meteorology, Marine and Sea Ice	A. Hollingsworth	G. Duchossois
Operational/Commercial Applications for Land Use Management and Resources	C-G. Borg	L. Marelli
Earth Explorer Missions	P. Simon	C. Readings
Earth Watch Missions	M. Paillon	G. Duchossois