ESA/ESAC(99)5
Att. : Annexes A-C
Noordwijk, 20 April 1999
(Original: English)

THE EUROPEAN SPACE AGENCY

EARTH SCIENCE ADVISORY COMMITTEE

The Call for Earth Explorer Opportunity Missions

The Evaluation of the Twenty Seven Proposals

1. Overview of the Proposals

All of the twenty-seven Full Proposals, received in response to the Call for Earth Explorer Opportunity Missions (ESA SP-1226), have been reviewed by the Earth Science Advisory Committee (ESAC). The ESAC was very impressed with the high scientific standard attained by the proposals, noting that this illustrates not only the maturity of the European Earth Observation science community but also the need for the Call. The Committee also noted the breadth of the proposals which addressed all areas of Earth Observation.

All the proposals have been evaluated scientifically and technically by the Committee in line with the procedures laid down in the Call using the seven criteria listed in ESA SP-1226 and taking due note of the two specific boundary conditions associated with this particular Call, namely:

- the total cost to the Agency for the full realisation of an Earth Explorer Opportunity Mission must not exceed an absolute financial ceiling of 80 MEuro (1998 prices);
- it must be feasible to launch any Earth Explorer Opportunity Mission selected for Phase A/B study by the year 2002 (assuming selection by the PB-EO in May 1999).

Based on the findings emerging from this exercise and in line with the instructions of the PB-EO, the ESAC has selected five proposals and listed them in order of priority. This paper outlines the procedures followed and details the results of this assessment exercise.

It should be noted that at all stages in the evaluation proposals have been assessed as submitted, neither the ESAC nor the three Joint Assessment Panels (JAPs – see next paragraph) have attempted to improve any proposal by introducing modifications. Furthermore, the proposals have been assessed in the context of the team proposed by the Lead Investigator. The ESAC recommends that, where appropriate and where specific expertise critical to the success of the project resides in this team, this must be taken into consideration in deciding membership. The ESAC also recommends that the views of the Lead Investigator be fully taken into account for this selection.

The first step in the evaluation exercise was to assess each of the twenty-seven proposals individually and for this three Joint Assessment Panels were set up, namely:

- The Ocean, Cryosphere and Solid Earth Assessment Panel
- The Land Joint Assessment Panel
- The Atmospheric Joint Assessment Panel

Each JAP was chaired by a member of the ESAC and made up of a mixture of external scientists and internal technical experts. Each JAP was asked to assess a sub-set of Full Proposals technically, financially and programmatically as well as scientifically. Proposals that spanned the sphere of competence of more than one JAP were assessed by all relevant JAPs leading to an overall assessment report. The individual assessment reports are attached as annexes to this paper grouped according to the JAP that took the lead in drafting the report in question. To help ensure uniformity of assessment the ESAC chair participated in the final meetings of the three JAPs.

Each JAP report contains a specific set of recommendations including an indication of whether, in the view of the JAP, the particular proposal should be further considered for selection or not. The ESAC has reviewed all these reports and endorsed their findings. It has also endorsed the recommendations for proposals to be retained for further consideration for implementation.

Nine proposals fall into this category, namely ACE, ACLISCOPE, CRYOSAT, REFIR, SCOPE, SIMSA, SMOS, SWARM and SWIFT. In the case of ACLISCOPE the Committee noted the close parallels between this proposal and the ACE proposal. It decided to take the latter in preference to the former as, in the opinion of the Committee, ACE presented a better scientific rationale and, in addition, recognised the crucial importance of data assimilation. In the case of REFIR, the ESAC felt that the proposal did not have the required maturity taking into account the short development time allocated for the Earth Explorer Opportunity Missions, and thus decided not to further consider this proposal but rather to propose appropriate studies to fill the identified gaps. **Therefore, only seven proposals were further considered by the ESAC, namely: ACE, CRYOSAT, SCOPE, SIMSA, SMOS, SWARM and SWIFT.**

For the purposes of the ESAC assessment, these seven proposals were considered as a short list from which to select the final list of proposals to be recommended for implementation. These seven proposals are reviewed by the ESAC in the next section of this report. All are considered to be of very high scientific merit and compliant with the boundary conditions.

In addition, among the twenty proposals which were not further considered, the ESAC identified four proposals of particular scientific merit for which additional scientific and/or technical work would be required before they could become mature enough for further consideration in a future Call. These four proposals are as follows (not in any order of priority):

a) **FLEX (COP 29)** is intended to observe the solar-induced fluorescence of the terrestrial biosphere which is linked to photosynthetic activity and vegetation physiology. This information is of basic importance for biospheric research and for studies of biosphere/atmosphere exchange processes. It is highly relevant to the Earth Explorer Program in addition to being a very innovative and exciting mission which has the capability to pave the way for significant advancements in ecosystem research. However, because of the lack of experience with area-extended measurements of fluorescence, more preparatory work is necessary before FLEX could be selected as an Earth Explorer mission.

Recognising the high potential importance of FLEX, the ESAC strongly recommends the initiation of actions needed to clarify open scientific and technical questions. Among the topics to be investigated are instrument sensitivity for observing the comparatively weak fluorescence intensities, methodological work on data analysis, in particular regarding synergy requirements for information on surface reflectance and temperature from other missions, and the development of biospheric models for the integration of area-extended fluorescence data.

b) **REFIR (COP 26)** is intended to make observations of an important long wavelength component of the Earth's radiation budget, which is not measured by any current instrument. From the spectral distribution of the long wave emission it is possible to quantify cooling effects in this spectral region and to measure the distribution of water vapour. These two measurements are essential to further understanding of the role of water vapour in the feedback mechanisms that control the Earth's radiation budget. The ESAC recognised the scientific relevance of this mission and the urgency to address the problems highlighted by it.

The technical concept includes three instruments which are to be mounted on board a small satellite, namely a Fourier transform spectrometer (FTS), which provides the primary measurement, and two imagers which provide auxiliary information about cloud coverage. Although, the project appears to be feasible, the maturity of some of the required implementations is considered to be incompatible with the short development time associated with Earth Explorer Opportunity Missions and so further studies are recommended to fill this gap. In particular, further work is necessary on the scanning mechanism to be used in the interferometer requiring either the adaptation of a device which has already flown or the development of a bread-board. Also the requirements and the feasibility of the 'add-on' imager should be better evaluated.

c) **R3-SAT (COP 20)** addresses the need to extend the information on precipitation provided by the TRMM (the NASA/NASDA tropical rainfall mission) to other parts of the globe, as well as continue to monitor precipitation from space. The ESAC was of the opinion that the proposed mission was not only very important, but that it would place Europe in the fore-front of work in this area. However, during its Granada-I deliberations on the candidate Earth Explorer Precipitation Core Mission, the ESAC took the view that the lessons of the TRMM mission must be fully assimilated before any new missions in this area should be considered.

It is clear that the instrumentation on TRMM is working well. However, at the same time, it is equally clear that it will be at least two years , before any real synthesis of scientific results emerges on which to base the planning of a new (follow-on) mission. Furthermore, R3-SAT has a very tight schedule for a 2002 launch. The interim, before the next call, should be used to investigate much more extensively the sampling and coverage requirements which must be met if the mission objectives are to be attained.

d) **VAGSAT (COP12)** is intended to provide spectral wave data which have many practical applications in the marine environment. In accepting the importance of this, the ESAC also recognised the considerable scientific interest in obtaining a detailed understanding of wave spectra and of the role of waves in oceanic processes. The Committee also noted the significance of waves in the interpretation of data from other space missions such as radar altimetry and scatterometry.

However, while endorsing the importance of this mission, the ESAC was concerned that there has not yet been a proper demonstration of the benefit of spectral wave data assimilated for operational or research purposes. It looked forward to seeing the results of demonstrations based on the analysis of synthetic aperture radar (SAR) data derived from the ERS satellite. On the basis of these results, and assuming further studies on wave spectra data assimilation in present ocean models can be undertaken, it should be possible to obtain a clearer appreciation of the benefit of the observations that would be provided by VAGSAT.

More generally, the ESAC noted the potential importance of access to the P-band as instruments exploiting this band should be in an unique position to provide data urgently needed by the Earth observation community. At present, there is no guaranteed access to this band for remote sensing, which makes difficult to select missions using P-band instruments for short-term implementation. ESAC strongly recommends that action be taken to remedy this situation.

2. Assessment of the Short List

As far as the seven proposals, which the ESAC considered were candidates for recommendation for selection, the Committee's position can be summarised as follows:

ACE (COP13) – global change modelling studies of increasing greenhouse gases show that the largest temperature changes are expected to occur in the upper troposphere (warming) and in the lower and middle stratosphere (cooling). Stratosphere cooling is further enhanced by ozone destruction. However, despite the importance of these changes, present observational data from space are inadequate to observe and monitor them either due to inadequate horizontal resolution or to insufficient vertical resolution. The lack of observational data in the upper troposphere and stratosphere is also detrimental to weather prediction as insufficient observational coverage in active weather regions leads to a rapid growth in forecast errors.

The ACE project is intended to address these concerns by providing high vertical resolution (GRAS) temperature profiles (including the identification of the tropopause) and O_3 profiles (COALA) using a set of six micro-satellites in special orbits. It should provide the requisite horizontal resolution and will have an 'all weather' capability. However, the problem of retrieving water vapour profiles (also addressed in the proposal) should not be understated as it will require the provision of advanced data assimilation capabilities in order to separate the relative roles of temperature and water vapour in the observed signals.

The involvement of meteorological and climate modelling institutes in the ACE proposal was welcomed by the ESAC as they have the requisite data assimilation and modelling capabilities. This augurs well for the delayed-mode assimilation of the ACE data though the ESAC would have welcomed a firmer commitment to the near real time assimilation of the ACE data.

However, currently ACE includes no concrete plans for the near real time delivery of precision orbits for processing the data and a sophisticated global infrastructure will be required to deliver high quality orbits for so many missions simultaneously. This delay in calculating precision orbits for ACE means that GPS occultation data on temperature and humidity cannot be used in real time data assimilation and weather forecasting activities undermining a potential application of ACE data.

Turning to the COALA component of ACE, the ESAC took the view that there was substantial redundancy between data from this instrument and that provided by instruments flying on the Envisat satellite (i.e. GOMOS, MIPAS, SCIAMACHY) which would be in orbit at the same time. The provision of COALA instruments does not significantly enhance the scientific value of ACE and, furthermore, it assumes the effectiveness of the stellar occultation technique, which has still to be demonstrated.

CRYOSAT (COP33) – this well-presented proposal is of very high scientific interest. It suggests a novel approach to addressing two major and important scientific questions, namely:

- Determining the mass balance of the ice sheets of the Earth and attempting to reduce uncertainties in estimating the contributions of the Antarctic and Greenland ice sheets to changes in global sea level.

- Providing the basic data for studies of sea ice/ocean/atmosphere interactions and for evaluating predictions of the thinning of Arctic sea ice due to global warming.

The proposal demonstrates a good knowledge of the problems encountered in previous radar altimeter missions and presents a good and detailed discussion of the uncertainties inherent in the measurements.

CRYOSAT would complement measurements made by other altimetric missions, most of which have been designed for use over the relatively level surface of the oceans and which do not provide good coverage of the polar regions. It will also complement the proposed NASA ICESAT lidar mission which will have its temporal coverage hampered by the presence of clouds.

The proposed instrument has excellent heritage, being based on well-proven technology enhanced by novel operating modes which will increase its capabilities. A conventional pulse limited mode will be used over the interior of the ice sheets, a synthetic aperture mode over sea ice (to improve the spatial resolution) and a dual channel synthetic aperture interferometric mode over the ice sheet margins (which are problematic with conventional altimetry). The latter will give access to the outer zones of the ice sheets where climate change is reflected most strongly, over-coming the problem of making observations over regions of appreciable slope (which has hampered previous missions).

Within Europe there is a very active scientific community involving not only specialists of the cryosphere but a broader community interested in climate studies and global change. Even though the interpretation of the data is not straightforward, the user community is very mature and quite capable of resolving problems arising from the complexity of reflections from different depths and the effects associated with the varying physical condition of the snow and ice cover.

A possible constraint on the timing of the mission might be the desire to overlap with ICESAT (a mission proposed by NASA) and the need to ensure the continuity of space-borne observations of ice sheets. The spatial and vertical accuracies, which should be attained by the mission, represent a significant advance on current capabilities, though CRYOSAT will only be able to provide average values, especially over sea ice. However, these data will still be very useful for monitoring trends. The 86° orbit inclination represents a reasonable compromise between the desire to cover as much of the polar region as possible and the need to provide an adequate number of calibration cross-over points. The 400 km 'blind' radius is quite reasonable.

The scientific balance and composition of the team should ensure the success of the mission. It includes scientists of world class experience and with excellent track records. The proposal is well focussed and logically structured, presenting a closely argued case and detailed justification of technological concepts. Although the project is innovative, it has very good heritage and technologically does not present much in the way of risk.

SCOPE (COP21) – for this mission it is proposed to fly a limb sounding passive sub-millimetre heterodyne radiometer in a sun-synchronous polar orbit selected to coincide with that of Envisat. The instrument would make observations in three spectral bands, which would allow the retrieval of high resolution vertical profiles in the upper troposphere/lower stratosphere of H_2O, HDO and O_3 as well as ClO and BrO in the lower stratosphere. In addition O_2 would be observed enabling the simultaneous retrieval of pressure and temperature. Microwave measurements, which are performed in emission, have the important advantage that they can be made in both day and night conditions and do not depend on the sun as a light source (which limit other techniques considered for the observation of these constituents).

The mission addresses some very important issues as accurate measurements, of high spatial and temporal resolution, of the distribution of ozone and of trace constituents associated with ozone depletion are required to further understanding of the complex processes which control ozone recovery. Many aspects of this are still not understood, restricting our ability to predict and interpret evolutions in the distribution and levels of ozone. This area of investigation directly addresses the issue of the anthropogenic modification of the atmosphere and the related obligations under the Montreal Protocol.

High precision measurements of stratospheric ClO and BrO, which are the main radicals responsible for catalytic ozone destruction, are fundamental indicators of disturbed-chemistry conditions. The isotopic ratio of H_2O and HDO can be used to trace the origin of water vapour in the stratosphere, providing a new diagnostic tool for addressing a problem which is of great relevance to climate change.

SCOPE is therefore considered to be a well focused mission which is important both for its contributions to the long term monitoring of stratospheric evolution and for the scientific information it would provide on species that are not observed by Envisat. However, if the NASA EOS-Chem mission goes ahead as planned, the ESAC noted that this would result in some overlap in mission objectives as this mission would address some of the needs motivating SCOPE .

The proposal is based on the heritage of ODIN and, if the Schottky diode option is adopted, it is not expected to pose any major technical difficulties. The improved performances that would be possible with the SIS receiver are very desirable, but appear to pose a too high risk at this stage. The ESAC noted that the implementation of this instrument would significantly reinforce the European capabilities in the technologically important field of microwave techniques.

SIMSA (COP15) – this mission is intended to provide observations of bio/geophysical, as well as chemical parameters, characterising land surfaces and coastal /inland waters in order to improve knowledge and understanding of key processes associated with terrestrial and coastal ecosystems. Among the priority topics addressed are geology, soil science, agriculture, forestry, vegetation science, land-use, quality of coastal and inland water, and biosphere/atmosphere interaction. The mission would provide data of importance to scientists working in many areas.

During the first two years of the mission it is proposed that scientific activity should focus on the development of methods for information extraction, the inversion of data to produce the physical and ecological parameters relevant to studies of the biosphere and geosphere, and the evaluation of various possible approaches to the integration of these data into ecological models. During the second phase of the mission, pre-operational demonstrations of environmental applications are planned, and, in the final phase of the proposed five years operation period, the utilisation of the sensor, as a commercial/operational tool for environmental monitoring and resource management, is envisaged.

The technical concept proposed to achieve these objectives is the implementation of a hyper-spectral imager (HSI) on a polar orbiting satellite at 675 km altitude. The imager would have 220 bands (5-10 nm spectral resolution) lying in the spectral range of 430 nm to 2400 nm, providing a spatial resolution of 25 m and a swath width of 25 km. Across swath it would be possible to point it within $\pm$ 30 degrees. However, the proposal is not without problems as the high risk development approach, which has been selected to minimise costs, could at the same time reduce performance below that required to realise the full potential of such a mission.

The ESAC concluded that SIMSA was highly relevant to the Earth Explorer research objectives, with an emphasis on Theme 3 (Geosphere/Biosphere) though it would also make important contributions to Theme 2 (Physical Climate). The science plan addresses a wide range of applications in these fields and there is an experienced scientific community in both Europe and Canada which is ready to exploit high resolution spectrometric data from space.

However, at the same time, the ESAC took the view that the science plan for SIMSA was not well focused, but only addresses potential applications of HSI data in a generic way. From the programmatic point of view, although this highlights the importance of high resolution HSI data to the scientific community and the need to view such instruments as fundamental tools capable of addressing many areas of Earth science, an Earth Explorer Opportunity Mission seems a somewhat restricted vantage from which to view such an 'observatory' type of instrument.

It is clear that the proposed mission is unique and innovative as there is presently no high-resolution HSI operating in space. It therefore has the potential to contribute significantly to the advancement of Earth observation in Europe. It would provide data complementary to a wide range of high resolution optical and microwave imaging systems, the spectral capabilities of which are nowhere near the capabilities of SIMSA. It would also complement imaging spectrometers of low resolution such as MERIS, the data analysis of which would significantly gain from scientific work with the high resolution hyper-spectral data.

SMOS (COP16) – significant progress in weather forecasting, climate monitoring and extreme event forecasting, relies on the accurate quantification of both soil moisture and sea surface salinity. The fluxes of both water and energy at the surface/atmosphere interface are very dependent on soil moisture, which is clearly an important variable for numerical weather prediction and climate models. Ocean salinity is a key variable in the determination of ocean circulation and the water cycle, as well as being an important tracer for observing the thermohaline circulation of water masses. Sea surface salinity fields and their seasonal and inter-annual variability are driving variables for the water cycle and for coupled ocean atmosphere models. In addition, the link between sea surface salinity and sea surface temperature distributions is a key element in ocean dynamics.

However, currently there is no capability for directly and globally estimating these key variables and, it is in response to these key requirements, that SMOS has been proposed as an Earth Explorer Opportunity Mission. It would have as its main objective the provision of global observations of soil moisture and sea surface salinity data exploiting the capabilities of an L-Band (1.4 GHz) two-dimensional (2D) interferometric radiometer. SMOS is viewed as a demonstrator with a broad set of ambitious scientific objectives based on an innovative approach. In addition to its scientific objectives, SMOS is intended to demonstrate the use of L-Band

2D interferometry data for possible operational use and to provide experience for future, upgraded technical implementations.

From the scientific point of view, the ESAC took the view that SMOS would provide the data required to address some major scientific issues of very high relevance to the research objectives of the Earth Explorer missions. Although the anticipated spatial resolution would be a constraint for some applications, especially over land, the data provided by SMOS would still be of great relevance to meteorological, oceanographic, climatological and hydrological studies. This would be particularly true when SMOS data are assimilated into numerical forecast and climate models.

The C-Band option had to be excluded because of cost and time boundary conditions. This means that the proposal uses a single channel approach which exploits polarisation and multi-angular information to estimate soil moisture and salinity. Studies are proposed, which would be conducted during the course of the Phase A/B activities, to implement and improve the retrieval algorithms. The availability and adequacy of ancillary data and of the assimilation techniques to achieve the required accuracy will also need further refinement before launch.
The proposed SMOS technical implementation, even with the identified limitations and uncertainties, is still very novel with high risk and no margins. Also, it is clear that the conditions for the external funding must be clarified. To safeguard the schedule and the costs to ESA, these contributions must guarantee the availability of the requisite programme elements not just financial support. If these conditions are met the project should prove feasible and, in the opinion of the ESAC, the risks are acceptable because of the great importance of the observations.

The ESAC took the view that this mission represents an outstanding scientific opportunity as well as a challenge, involving a considerable degree of innovation. It will give Europe a leading role in the provision of observations of two essential variables from space, namely salinity and moisture, which are of fundamental importance to so many areas of relevance to the objectives of the Earth Explorer missions.

SWARM (COP09) – this is a multi-satellite mission designed to observe the dynamics of the Earth's magnetic field. Six satellites would be flown in two near polar orbit planes. In principle, four satellites would be enough to collect the requisite information on the field and its dynamics, but the provision of six provides a welcome redundancy. This approach is also likely to ensure a longer lifetime for the mission and this at a lower cost than aiming for a much higher reliability for each separate satellite.

Despite its apparent complexity the mission should fall within the cost limit and does not present any technical risk of importance. The mission is in line with studies of the Earth magnetic field which have already been initiated and which will continue with, in particular, the OERSTED and CHAMP missions. Indeed, SWARM would benefit from an overlap with one of these other missions. In the opinion of the ESAC the study team has the expertise and skill needed to make optimum use of the data to address SWARM's mission objectives.

Although the mission exploits a well-established and safe technique to observe the Earth's magnetic field, it is very innovative in the way it proposes to exploit multiple point analysis at this altitude. The approach is basically unique, even when considering some similarities with the CLUSTER II mission, as the two missions address very different problems. The explanation of the approach provided in the proposal is quite clear, though more insights could have been given into the links between the chosen configuration and the quality of the data and the scientific analyses.

The altitude chosen for this mission appears well suited for disentangling the different components of the Earth's magnetic field (i.e. Earth interior, ionospheric and magnetospheric) and their variations over a large fraction of the solar cycle covering in particular the solar minimum in 2006/2007. Furthermore, the precision claimed appears to be well within reach. The mission was therefore strongly commended by the ESAC, especially as it fitted well within the research objectives associated with the Living Planet Programme. It would address a well-defined need and shows both uniqueness and complementarity with other missions.

SWIFT (COP27) – the objective of this mission is to measure stratospheric winds and vertical profiles of ozone in the height interval 20-45 km. It reflects the need to gain a better understanding of the links between dynamics and chemistry in the stratosphere, for which a full global knowledge of stratospheric profiles of wind, temperature and ozone are required. Current observations are insufficient and cannot be used even to describe stratospheric circulation in middle and high latitudes to the level required to address the problem, as, in particular, stratospheric wind observations are almost totally absent in the tropics. A topic of particular interest here is the QBO (quasi-biennial oscillation) which, despite its importance, is currently not adequately observed.

Stratospheric ozone depletion caused by CFCs and the increase of the greenhouse gases has led to a marked cooling of the stratosphere over the last 20 years. According to presently available data, the average global cooling in this region amounts to some 1°/decade, with a maximum cooling occurring at high latitudes, where the lower the temperature the more efficient the processes controlling the destruction of ozone in the stratosphere. Thus, in spite of the Montreal protocol, which by now has led to a total reduction in the emission of CFCs, ozone destruction is expected to continue much longer than previously expected because of the lower than expected stratospheric temperatures.

It is also important to note that the global ozone cycle including the exchange between high and low latitudes and between the stratosphere and the troposphere is insufficiently known due to lack of observations. In the view of the ESAC, all these reasons serve to highlight the importance of this mission and the data it should provide which are required to address some very important issues. Turning to the specific issue of the QBO the ESAC considered that the mission should be extended to last at least three years in order to cover a complete cycle of this phenomenon.

SWIFT will measure line-of-sight stratospheric winds using the Doppler shift of the ozone thermal emission line at 1133 cm^{-1} obtaining the two wind components by viewing in two different directions. The anticipated accuracy for line-of-sight stratospheric wind measurements is 5 ms^{-1}. A limiting factor would be the fact that the accuracy and precision of the instrument will be maximised above 25-30 km (i.e. above the ozone maximum). Extension to lower altitudes, where the dynamical control of ozone is largest, will require the data to be incorporated into a comprehensive data assimilation system in order to be properly combined with other available observations. This could pose some major challenges.

3. Recommendations for Selection

In considering which of these seven missions to recommend for implementation as one of the first Earth Explorer Opportunity Missions and the order of implementation, the ESA noted the philosophy underlying the approach advocated in the Living Planet Programme. This highlights the need to view the Earth as a system to be described by a hierarchy of models, each describing one facet or other of the overall system. Fundamental to the development of these models are data sets, which are required to identify processes as well as to develop, validate and exploit the hierarchy of models.

Thus, in considering the seven missions, the ESAC started by identifying, in terms of climate sensitivity, the key climate components to be observed by each mission taking into account the Committee's discussions in Granada as well as the ideas contained in ESA SP-1227 (Earth Explorers: The Science and Research Elements of ESA's Living Planet Programme). It agreed that, taking into account the current state of development of the Earth system models and the current data deficiencies, these were as follows:

- the ice sheets, sea ice and their margins
- thermohaline circulation
- soil moisture
- the dynamics and radiation balance of the upper troposphere and the lower stratosphere
- stratospheric chemistry.

It also accepted the importance of a better characterisation of land surface features and the requirement to quantitatively assess the Earth's magnetic field and its variation.

The ESAC also recognised the need to balance, on the one hand, innovative science and technology against, on the other, low risk and low cost. It appreciated that the balance was a delicate one as without innovation science could not progress though there was no point attempting the impossible. Selected missions must be feasible. Account has also been taken of existing and approved missions as well as some consideration of planned missions including the four candidate Earth Explorer Core Missions to be reviewed in Granada in October 1999.

Taking all these points into account, the ESAC decided that it could recommend five of the seven missions on the short list for implementation. In order of priority these would be as follows:

1. **CRYOSAT** – this would provide a very high science return for relatively low risk. It would provide the data required to advance understanding of the ice sheets and the marginal ice zones. These were linked strongly not only to sea level rise but also, more importantly, to the role of fresh water in the climate system and the stability of the Earth's climate to influxes of fresh water into the oceans and the impact of fresh water on ocean circulation. The CRYOSAT mission would consolidate Europe's leading position in space altimetry.

2. **SMOS** – this mission is considered of high risk, but the ESAC took the view that the risk was well justified as the lack of global observations of salinity and soil moisture were retarding progress in many important areas including oceanography (tropical thermodynamics, thermohaline circulation) and the transfer of energy between the land surface and the atmosphere. The need for these data had been highlighted for a long time in major international scientific initiatives. Implementing the SMOS mission would give Europe a clear lead in this new area.

3. **ACE** – this mission also addresses an important deficiency, namely the lack of global knowledge of temperature changes in the upper troposphere and lower stratosphere. This is not only important in the detection of climate change but also for predicting the evolution of ozone levels. It is a low risk project of high importance. However, in selecting this mission, the ESAC highlighted the need to plan for the proper assimilation of the data. It also considered that the inclusion of the COALA instrument could be reconsidered without reducing the scientific interest of the mission as it is premature in view of the lack of assessment of the stellar occultation technique and does not significantly enhance the science return of the mission. A timely implementation of the ACE mission would give Europe the lead in the meteorology of the upper troposphere and lower stratosphere.

4. **SWARM** – this mission, although not as urgent as CRYOSAT, SMOS or ACE, is nonetheless still very important as it would provide new data consolidating and complementing the observations of CHAMP and OERSTED. Indeed, the data from SWARM should enhance the quantitative understanding of the Earth's magnetic field and enable the various contributing influences to be delineated much more clearly. SWARM will thus provide further understanding of the internal dynamics of the Earth. The implementation of the SWARM mission will consolidate Europe's position in space measurements of the Earth's magnetic field.

5. **SWIFT** – the implementation of this mission will further understanding in an important area, namely the links between stratosphere dynamics and stratosphere chemistry. Furthermore, the provision of wind data in the lower stratosphere could enhance the performance of numerical

weather forecasts. The SWIFT mission is considered as a fairly low risk project but still providing a good scientific return. It will open the way for Europe to establish an expertise in direct measurements of high altitude winds from space.

ESAC decided not to recommend the implementation of either SIMSA or SCOPE.

SCOPE was not recommended because, although the data are important and would complement those provided by Envisat, they could also duplicate those obtained by the US EOS-CHEM mission. Thus, given the need to consolidate the analyses of all chemical data, which will be acquired over the coming years by Envisat and other European missions, and considering the time required to develop more sensitive microwave detectors, the ESAC decided not to recommend the implementation of SCOPE as one of the first Earth Explorer Opportunity Missions.

Although acknowledging the scientific merits of SIMSA, the ESAC decided not to propose its implementation. One reason for this decision is the lack of a well-focused science plan. Another is the lack of certain observing capabilities which have been identified as important during the scientific planning of the PRISM instrument on the Land Surface Processes and Interaction Mission, (currently being investigated in Phase A as one of the potential Earth Explorer Core Missions). SIMSA would be able to make a subset of the measurements planned for PRISM, namely spectrometric observations in the visible to mid-infrared spectral region, but would miss the thermal infrared capability and the pointing capability for instantaneous bi-directional reflectance measurements of PRISM. These features have been identified as very important by the scientific community for bio-geophysical studies of land surfaces. Another limiting factor of SIMSA for scientific applications, which might have negative impacts on the quantitative evaluation of the data, is the high risk development and testing approach, which on one hand saves costs, but on the other hand might reduce the calibration performance.

Finally, ESAC re-iterated the importance of a data policy which makes all the data from the Earth Explorer Opportunity Missions available as quickly as possible to the scientific community at large, not a privileged sub-set of the community. There must be easy access at minimum cost on a none-discriminatory basis to these data if the potential of the selected missions is to be properly realised. The design of the ground segment must reflect these requirements.