EUROPEAN SCIENCE FOUNDATION

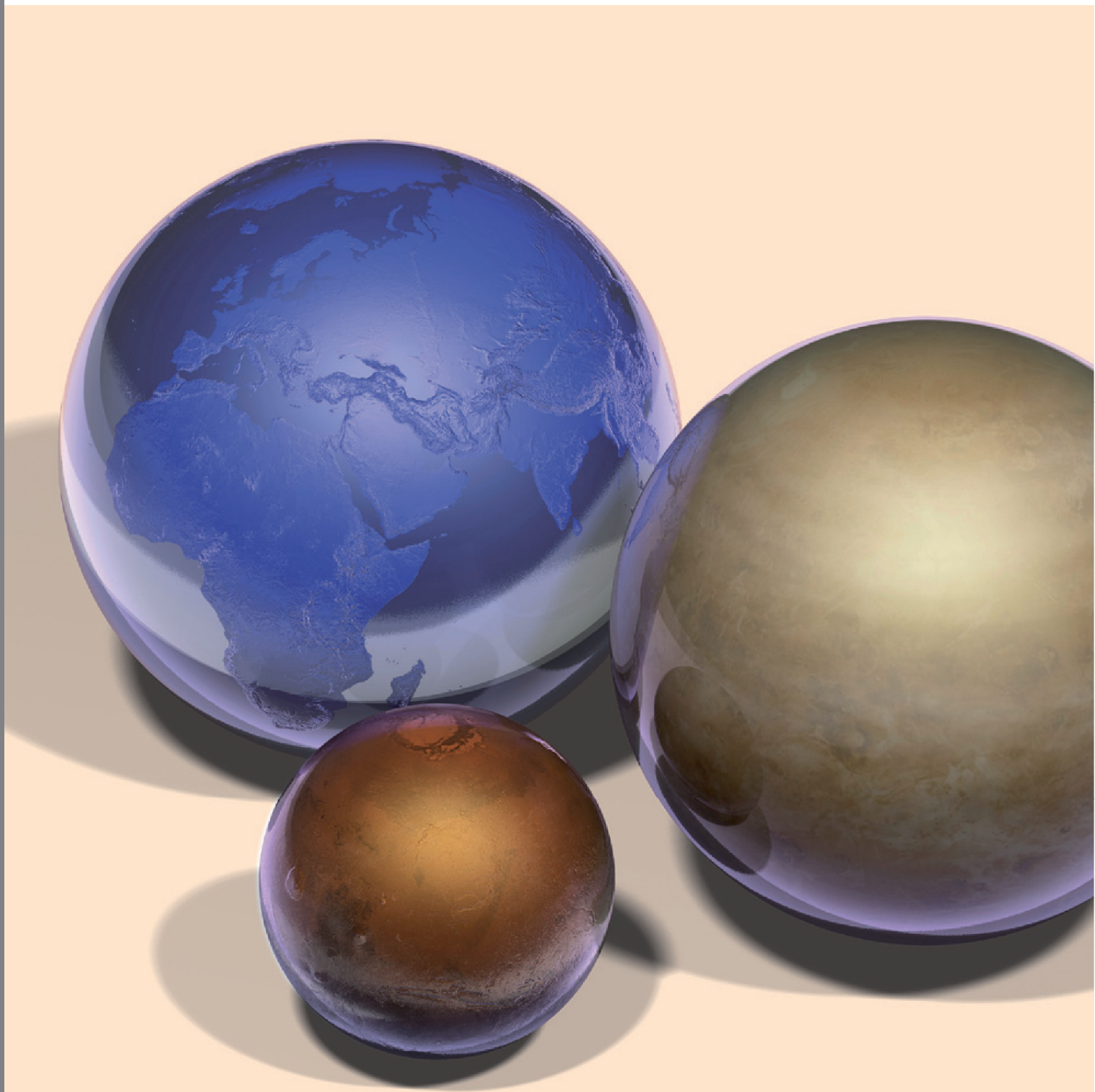
SETTING SCIENCE AGENDAS FOR EUROPE

EXPERT COMMITTEE

Recommendations to the Ministerial Conference of ESA Member States

25-26 November 2008

European Space Sciences Committee (ESSC)



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- Marine Sciences
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- Radio Astronomy Frequencies
- Space Sciences

The European Space Sciences Committee (ESSC), established in 1975, grew out of the need for a collaborative effort that would ensure European space scientists made their voices heard on the other side of the Atlantic. More than 30 years later the ESSC has become even more relevant today as it acts as an interface with the European Space Agency (ESA), the European Commission, national space agencies, and ESF Member Organisations on space-related aspects. The mission of the ESSC is to provide an independent European voice on European space research and policy.
The ESSC is non-governmental and provides an independent forum for scientists to debate space sciences issues. The ESSC is represented ex officio in ESA's scientific advisory bodies, in ESA's High-level Science Policy Advisory Committee advising its Director General, in the EC's FP7 Space Advisory Group, and it holds an observer status in ESA's Ministerial Councils. At the international level, ESSC maintains strong relationships with the NRC's Space Studies Board in the US, and corresponding bodies in Japan and China.

Front cover:
Marble planets ©iStock

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General context

1. Europe's policy makers should stress clearly, and in a prominent fashion, that the involvement in first-class (space) science is absolutely essential for the promotion of European interests and leadership, as it imparts a strong strategic drive to its technological and industrial system.
2. The ESSC-ESF strongly recommends that ways be found to support the analysis, interpretation, archiving, and distribution of space data and thus generate a high-quality return on the investments made by Europe in building satellites and outstanding instruments.
3. The ESSC-ESF recommends supporting R&D for innovative technology activities in space science and exploration in order to ensure European independence in critical areas and provide an added value to ESA's future developments.
4. It is crucial for the future prosperity of Europe that there be an adequate pool of highly-trained and motivated scientists, technologists and engineers. ESA must play a role in inspiring and training young people to become part of this next generation of scientists. ESA must enhance its education and public outreach programme, using as many communication techniques as possible. ESA must pay attention to developing its website as the portal through which it is perceived by the public at large.

ESA's space science programme

1. The highest priority in the next decade for European countries involved in the ESA Science Programme should be to give ESA the potential to implement the planned Cosmic Vision 2015-2025 programme, starting from the set of missions already being assessed, and within the timeframe foreseen in the programme (M1 in 2017, L1 in 2018).
2. To ensure the feasibility of Cosmic Vision, the goal should be to reach 500 M€ per year for the Level of Resources. We appreciate ESA's proposal for such an increase in the Level of Resources. This increase would allow a much more satisfactory balance between ESA internal costs and industrial spending that would significantly enhance the latter. We believe that this approach can have great benefits for the volume, quality and international standing of the ESA science programme, but also for European industry through stimulation of advanced technology development. This would be a clear step forward in line with the Lisbon strategy, re-enforcing many aspects of science and technology activities within Europe.
3. The ESSC-ESF recommends that a clear financial separation be maintained between the Science and the Exploration programmes. The established and highly acknowledged practice of selecting any mission activities in the Science Programme through open competition must be maintained.

ESA's Earth observation programme

1. Due to the coherence of the 'ESA Initiative in Support of Climate Change Monitoring' with documents that are recognised in the global context as a binding reference, the ESSC-ESF strongly supports the acknowledgement and implementation of this suggested programme.
2. The ESSC-ESF welcomes the data continuity and the fruitful cooperation between ESA and EUMETSAT for Meteosat Third Generation, with ESA's responsibility for the space segment technology and EUMETSAT's responsibility for the end-user requirements.
3. The ESSC-ESF supports ESA's Earth Explorer component as the important mechanism for the realisation of scientific and technological development in support of European Earth observation missions.
4. The ESSC-ESF strongly recommends funding of scientific data exploitation, which needs improved models, special data pre-processing routines or special acquisition schemes, and therefore encourages ESA and the European Commission to consider the relevant mechanisms for funding of scientific database exploitation techniques.
5. Any GMES/Kopernikus monitoring task, whether related to environmental issues or safety questions, whether on a regional or a global scale, needs historical references for comparison and judgement of severity of change. The ESSC-ESF therefore points to the importance of funding data archive maintenance and database pre-processing.
6. The ESSC-ESF welcomes the attempts to include data exploitation for policy-relevant research in the Framework Programme where possible.
7. The concert of ESA's existing and upcoming environmental satellites offers a unique set of measurements that no other space agency collects. It is hence ESA's responsibility to ensure and foster the best possible exploitation of the data and their products. This justifies ESA's role as an important partner in GEOSS and improves European recognition.

ESA's life and physical sciences in space programme

1. The era begun in February 2008 with the attachment of the Columbus orbital laboratory to the ISS, followed by the successful docking of the ATV Jules Verne to the ISS, must significantly increase the return on European investment in the International Space Station.
2. The ELIPS programme must be continued through its Phase 3 at the funding level mandated, because science utilisation and return will sharply increase as of 2008 as the Columbus laboratory is attached to the ISS and in full operation. The best usage of Columbus within the ELIPS programme is mandatory. In order to achieve a maximum output, the funding level therefore has to be raised accordingly.
3. Specific investments will therefore have to be made for a new generation of payloads (or new inserts into existing facilities) for the ISS. In parallel, preparatory steps have to be taken for the post-ISS era by looking into alternative payload carriers, ballistic flights and free-flying orbiters. Creative use of the ATV in this context is encouraged.
4. The present form of the Microgravity Application Projects (MAPs) should be continued, meaning that these projects would have application-oriented, yet not solely industry-driven, strategic long term objectives. Furthermore, Topical Teams as incubators for future research topics should be continued.
5. New programmes on solar system exploration should not be established at the expense of ISS utilisation and ELIPS.
6. The ESSC-ESF recommends that the ELIPS programme should seek to foster cross-disciplinary activities. This might be achieved by common ELIPS workshops in science and technology to look at cross-cutting science and technology problems.

ESA's exploration programme

1. The highest strategic priority for the Exploration programme is the robotic exploration of Mars.
2. Now that robotic exploration has been reorganised within ESA it is essential that the scientific aspects of this programme become embedded within the mission architecture of D-SRE, its technology aspects within D-TEC, and that a sustained and high-profile education and public outreach programme be implemented.
3. The different objectives of the Exploration programme must be recognised and must not be allowed to deplete the mandatory science programme through budget inadequacies.
4. The overarching science goal of the Exploration programme should be called "Emergence and co-evolution of life with its planetary environments", with the long-term programmatic goal of sending humans to Mars. Detailed recommendations to that effect appear in the main part of this document.

Coordination within ESA

1. The ESSC-ESF recommends that ESA should have a specific strategy for coordination between programmes and stresses the importance of assessing the consequences of the transfer of programme components from D-HSF to D-SRE.

Introduction

Since 2001, ESA and the European Commission (EC) have undertaken joint actions to define a space policy for Europe, providing a basis for the European Union's policy regarding the exploitation of space [1] and increasingly focussing on user needs in various areas, e.g., science, telecommunication, navigation systems, environmental monitoring. These needs have to be accommodated by various means, among which is the existence of a space infrastructure.

The ESSC-ESF participated in the consultation process leading to the publication of these EC policy documents by publishing a document analysing the Green and White Papers, and offering advice and recommendations concerning its science base. A more detailed view on Europe's future space policy appeared in [2]. In recent years, and following the advice of many stakeholders including the ESSC-ESF, the EC has published its 7th Framework Programme, featuring its own "Space Theme"; the EC and ESA also jointly published a Communication on Europe's space policy [3] which received a broad political support from EU and ESA Member States at the 4th Space Council (April 2007).

In December 2005, the ESSC-ESF was invited for the third time to attend the ESA Ministerial Conference and published at that time a set of recommendations to the Ministers, emphasising a number of crucial elements for Europe's future space scientific programmes and policy [4].

As the Ministers of ESA Member States meet again in Den Haag on 25-26 November 2008, the ESSC-ESF wishes to put forth a number of elements for their consideration and appraisal relating to the space sciences and exploration situation in Europe. In addition to this document, two reports are brought to the attention of the Ministers, one on the evaluation of ESA's research programme in life and physical sciences in space [5] and the other presenting the science aspects of ESA's future exploration programme [6].

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The Villafranca VIL-2 15m S-band antenna with flags of the 17 member states of ESA.

General context

The White Paper on the European Space Policy highlighted the outstanding achievements of European space sciences in the last 40 years. And indeed, the very successful and spectacular fly-by of Halley's Comet, the landing of Huygens on Saturn's moon Titan, the stunning pictures and data obtained by Mars Express or SMART-1, the surprising effect of microgravity on single cells and complex organisms, the measurements with millimetre accuracy of the sea and ground level by ERS 1-2 and ENVISAT, and numerous discoveries in the field of X-ray and infrared astronomy are a few testimonies of these achievements. However, it should be realised that these European successes were the logical outcome of the forward-looking decisions taken by the ESA Ministers in the early 1980s. What is the present situation, eight years after the courageous declarations made in Lisbon? The purchasing power of space sciences programmes decreased until the end of 2005, creating increasing major difficulties for the implementation of the programmes and resulting in continuous delays and even project cancellations.

Things improved slightly at the ESA Ministerial Conference of December 2005: for the first time since the ill-fated Toulouse Conference in 1995, the funding for the mandatory programme was increased by Member States at a level of 2.5% per annum. This put a stop to the decline in buying power of this most successful programme as recommended by the ESSC-ESF, although the recent inflation increase could reverse that trend again. However, despite these encouraging signs, the mandatory programme remains overheated in its planning, requires delaying some missions, and does not allow the long-term planning capacity required of a programme like Cosmic Vision 2015-2025 [7].

The Earth Observation Envelope programme was subscribed in Berlin at a level of 84% of the Director General's proposal; this is to be put in balance with what happened in Edinburgh in 2001, where only half of the requested amount was granted. This is also, albeit to a lesser extent, in line with our recommendations.

The Exploration programme appeared on the right track as well, whose first part, ExoMars, was over-subscribed at a level of 110%. However, the Exploration Core Programme was only subscribed at 47%. Immediately after the Berlin conference the ESSC-ESF stressed that this was a concern and should be discussed in the near future, in order to assess what the possible consequences of this under-subscription could be on the Mars Sample Return mission. Today things have not changed; the future of an ambitious European initiative in that area appears grim at best. Member States have indicated that this issue would be revisited at the 2011 ESA Ministerial Conference.

GMES/Kopernikus, which we had also addressed in our recommendations, was also highly oversubscribed (almost 130%). This was obviously in line with the EC's efforts in that area as shown in the current planning for the FP7 2009 Call.

The big "loser" of the 2005 Ministerial Conference from the science perspective was the ELIPS programme, which only gathered some 50% of the Director General's request. Although Edinburgh witnessed a similar cut to ELIPS 1 this meant a most severe blow to a number of engaged programmes, since ESA had to deal at the time with the development of the Columbus Orbital Facility. ESA then carried out a re-evaluation of the relevant programmes; several programmes were delayed or cancelled as a result, since a proportional budget reduction was not feasible.

The ESA programmes Cosmic Vision 2015-2025 for space science, the exploration programme, the European Earth Envelope Programme (EOEP) for Earth observation and the ELIPS programme for the scientific utilisation of the International Space Station are of a very high standard, while remaining financially affordable, and would offer the prospect for European space to resume its way to success and to a leadership position among space-faring nations.

An increased funding effort of European Member States in space has been advocated by various individuals and institutions. Nevertheless, despite the very ambitious objectives of the Lisbon Council, it is clear that Europe does not, at least for the present, contemplate bridging the very large gap existing with the space budgets in the United States.

Involvement in first-class science is absolutely essential for the promotion of European interests and leadership, as it imparts a strong strategic drive to its technological and industrial system. Without such involvement Europe would be left staggering behind other major space players in the world in its scientific, technological and industrial capacity. An important requisite for the construction of an efficient European space strategy is therefore to create the conditions for the development of balanced and long-term planning of the activities.

Hence Europe's policy makers should stress clearly, and in a prominent fashion, that the involvement in first-class (space) science is absolutely essential for the promotion of European interests and leadership, as it imparts a strong strategic drive to its technological and industrial system, as successfully demonstrated in the case of, for instance, the USA.

Then there is an urgent need to put in place across Europe the capabilities to exploit ESA's successes as well as we can. ESA is constitutionally unable to fund data analysis and science exploitation, and support provided by national agencies tends to be inadequate in volume, fragmented, and dictated by national concerns. This is in contrast to the situation in the USA,

where NASA takes responsibility in an integrated way for all mission-related activities, including data analysis. Indeed this policy even gives US scientists an advantage in the exploitation of European missions in which NASA is collaborating, by providing US scientists much more support than European scientists can obtain for these European built satellites.

This issue should be addressed by soliciting proposals from collaborations of European scientists, to work together on data reduction and science exploitation of ESA's missions. This would have a major and immediate impact on the volume and quality of space research in Europe, and allow the European scientific community to benefit from the very substantial investments in successful space missions made by ESA and the national European agencies. This includes:

- Mobilising the best expertise for the analysis and interpretation of space data, including support for post-doctoral researchers working on these activities;
- Developing tools to process, archive, access and distribute data obtained from different space observatories;
- Promoting the contribution of space assets to scientific and technological knowledge and foster its transfer to educational bodies.

Hence the ESSC-ESF strongly recommends that ways be found to support the analysis, interpretation, archiving, and distribution of space data and thus to generate a high-quality return on the investments made by Europe in building satellites and outstanding instruments.

Concerning upstream activities there is a major need to make Europe (ESA as well as European laboratories in charge of the development of science payloads funded by national agencies) independent of technologies presently available only in the USA, and which are of mandatory use in space science and exploration missions. Such technologies include, for instance, detectors for astronomy missions and radio-isotope based sources of energy for solar system observations. Several EU countries are equipped for dealing with these matters and could contribute to a European initiative in those directions.

Similarly, the conception and design of future European scientific space missions and instruments require the development of innovative technologies. In both of the cases detailed above, adequate support provided by ESA and the European Union's Framework Programme would be critical, and also give Europe a strong position in international collaborative missions.

These activities include:

- The development of new sensors for the different spectral windows for astronomy;
- The development of new sources of energy and reduced power consumption to enable solar system exploration;
- The development of MEMS-based sensors and actuators with improved long-term reliability and radiation hardness;
- The definition of, and feasibility studies for, new instrument concepts and the development of technology demonstrators;
- The development of technologies allowing new types of observation: formation flying, interferometer systems, measurement and relative positioning control, high-precision timing;
- The development of technologies for future Earth observation missions, i.e. specific laser sources, low-frequency radars, synthetic aperture optics for observation from geostationary orbits.

Hence the ESSC-ESF recommends supporting R&D for innovative technology activities in space science and exploration in order to ensure European independence in critical areas and provide an added value to ESA's future developments.

Overall the ESSC-ESF welcomes the attempts to ensure complementarities between ESA and the European Commission.

A larger education component and budget should be a major objective of ESA programmes. Summer schools or workshops on various research topics could be initiated or developed. ESA could reach an agreement about European Credit Transfer and Accumulation System (ECTS) in collaboration with interested universities. Thus students could become involved in space sciences early in their career. It is also recommended to substantially develop internet resources and particularly the website of ESA. A model in that domain remains NASA's numerous web sites that offer dedicated resources tuned to various audiences, from specialists to school pupils. ESA's web site should become the reference in Europe, also offering real-time coverage of Europe-specific space events through web-based ESA television.

It is crucial for the future prosperity of Europe that there be an adequate pool of highly-trained and motivated scientists, technologists and engineers. ESA must play a role in inspiring and training young people to become part of this generation. ESA must enhance its education and public outreach programme, using as many communication techniques as possible. ESA must pay attention to developing its website as the portal through which it is perceived by the public at large.

ESA's programmes

Space science

ESA's new programme for space science, Cosmic Vision 2015-2025, has been developed through a huge effort involving the whole European space science community, which identified a number of exciting scientific themes and concepts for space missions to explore the solar system up to the most distant Universe. The response to the first call for Cosmic Vision mission proposals has been excellent, showing the vision, creativity, and vigour of the community. As a result of the review process, a very attractive set of missions has been selected for a competitive assessment phase, including five missions at the "M" level (300 M€ envelope) and four missions at the "L" level (650 M€ ESA cost envelope).

We are proposing below a set of recommendations aimed at implementing the missions that are to be selected through this process while maintaining European industry and scientists at the forefront of science, exploration and technology.

The original plan was to launch the M1 mission in 2017 and the L1 mission in 2018. Unfortunately, two of the conclusions of the review process were that it will be very difficult to keep the cost of M missions within the envelope of 300 M€ and that an L mission is not compatible with a launch in 2018 within the current economic constraints. The present Level of Resources of the Science Programme only allows implementation of two to three M missions during this period. If an L class mission cannot be launched until around 2020, there will be a gap of more than six years between it and the previous planned large mission (Bepi Colombo).

A reduction in the ambition and variety of the missions being implemented in the ESA Science Programme would have a serious impact on European industry's technical competitiveness: the activity would be strongly reduced relative to the last decade, and there would be fewer opportunities to develop new technologies. In order to maintain competitiveness (both of industry and scientific laboratories) it is essential to formulate and implement a focussed, long-term plan of technological development aimed at achieving the capability to carry out the Cosmic Vision programme.

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Artist's impression of Rosetta as it flies by asteroid Steins.

The ESSC-ESF notes the creation of the new ESA Directorate of Science and Robotic Exploration. Whilst acknowledging the potential benefits – particularly the use of common technology expertise – the ESSC-ESF would like to underline the potential difficulties of managing a Directorate that will have to deal on the one hand with science-driven missions funded from the mandatory programme, and on the other hand with technology-driven missions (with some scientific outputs expected) funded optionally.

To capitalise on the creativity and vigour of the community as demonstrated by the answers to the first call for Cosmic Vision mission proposals, and to maintain Europe at the forefront of both space science and technology, we make the following recommendations:

1. The highest priority in the next decade for European countries involved in the ESA Science Programme should be to give ESA the potential to implement the planned Cosmic Vision 2015-2025 programme, starting from the set of missions already being assessed, and within the timeframe foreseen in the programme (M1 in 2017, L1 in 2018).
2. To ensure the feasibility of Cosmic Vision, the goal should be to reach 500 M€ per year for the Level of Resources. We appreciate ESA's proposal for such an increase in the Level of Resources. This increase would allow a much more satisfactory balance between ESA internal costs and industrial spending that would significantly enhance the latter. We believe that this approach can have great benefits for the volume, quality and international standing of the ESA science programme, but also for European industry through the stimulation of advanced technology development. This would be a clear step forward in line with the Lisbon strategy, re-enforcing many aspects of science and technology activities within Europe.
3. The ESSC-ESF recommends that a clear financial separation be maintained between the Science and the Exploration programmes. The established and highly acknowledged practice of selecting any mission activities in the Science Programme through open competition must be maintained.

Earth observation

ESA's Earth Observation Programme Board published the Discussion Paper "ESA Initiative in Support of Climate Change Monitoring" in February 2008. This programme suggestion is a reaction to the requirements stated by the Intergovernmental Panel on Climate Change (IPCC) in its 4th assessment report in 2007 to facilitate the United Nations Framework Convention on Climate Change (UNFCCC). The ESA Initiative is unique worldwide in its concise suggestions on how to provide a consistent set of products from Earth observation to monitor the list of Essential Climate Variables (ECV's) defined by the Global Climate Observing System (GCOS) in their 2nd adequacy report.

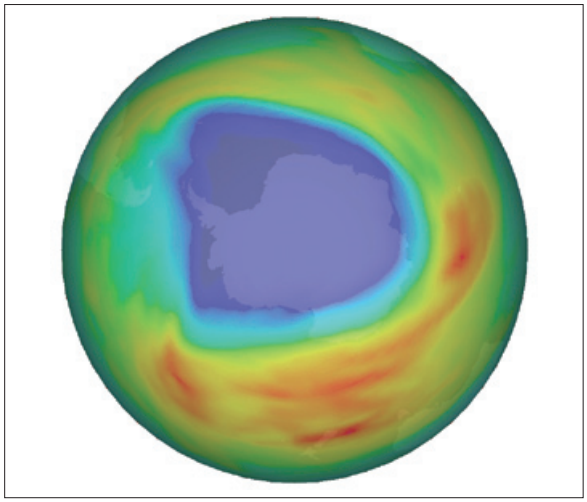
The suggested programme includes the exploration of thirty years of archived Earth observation data collected by ESA, its Member states and European partners, re-analysis of data sets in line with scientific and technical improvements, and possibilities for upcoming experimental and operational missions such as the Earth Explorers and the GMES/Kopernikus Space Component. The Initiative will unify European activities and establish a structured approach for international cooperation in the context of GEOSS, with the goal of meeting global requirements as stated by UNFCCC.

1. Due to the coherence of the "ESA Initiative in Support of Climate Change Monitoring" with documents that are recognised in the global context as a binding reference, the ESSC-ESF strongly supports the acknowledgement and implementation of this suggested programme.

The Meteosat Third Generation (MTG) is a European operational geostationary meteorological satellite system and is set to revolutionise weather forecasting and environmental monitoring. These principles identify ESA as the development agency for both the basic space segment technologies and the first twin satellites of MTG. For the satellites that follow, ESA will serve as the procurement agency on behalf of EUMETSAT. In turn, EUMETSAT will specify and consolidate end-user requirements, requirements for the overall mission, space to ground, and the ground segment itself.

2. The ESSC-ESF welcomes the data continuity and the fruitful cooperation between ESA and EUMETSAT for MTG, with ESA's responsibility for the space segment technology and EUMETSAT's responsibility for the end-user requirements.

The Earth Explorer programme is the backbone of ESA's Earth Observation Envelope Programme as it provides an efficient and cost-effective process to rapidly transfer scientific and technological advances into space missions.



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Ozone hole during 7 October 2008 as measured by the SCIAMACHY atmospheric sensor onboard ESA's Envisat satellite.

3. The ESSC-ESF therefore supports ESA's Earth Explorer component as an important mechanism for the realisation of scientific and technological development in support of European Earth observation missions.

The preservation of data and observations, including traceability of processing steps is extremely important. Their value and benefit for climate change monitoring must be fully explored. The GMES/Kopernikus Space Component will provide highly valuable long-term datasets for scientific use.

4. The ESSC-ESF strongly recommends funding of scientific data exploitation, which needs improved models, special data pre-processing routines or special acquisition schemes, and therefore encourages ESA and the European Commission to consider the relevant mechanisms for funding of scientific database exploitation techniques.
5. Any GMES/Kopernikus monitoring task, whether related to environmental issues or safety questions, whether on a regional or a global scale, needs historical references for the comparison and judgement of severity of change. The ESSC-ESF therefore points to the importance of funding data archive maintenance and database pre-processing.
6. The ESSC-ESF welcomes the attempts to include data exploitation for policy-relevant research in the Framework Programme where possible.

As stated in the ESA Initiative in Support of Climate Change Monitoring, "*… in view of the politically important negotiations currently going on about the post-Kyoto era, Europe has the opportunity to take the lead in the use of space for climate monitoring. ESA has many data in its archives which are needed to obtain essential climate information…*"

The Climate Change Initiative represents a well-coordinated contribution to a global response to the requirements for climate variables set out by GCOS and GEOSS. ESA fulfils with this initiative its appropriate role in an integrated European effort.

The GCOS ECVs (Essential Climate Variables) capitalise on a global Earth System scientific consensus that gradually emerged over nearly 20 years. The relevance of ESA missions in view of these ECVs (18 out of 37) is very significant and as such the programme proposal is scientifically sound.

7. The concert of ESA's existing and upcoming environmental satellites offers a unique set of measurements that no other space agency collects. It is therefore ESA's responsibility to ensure and foster the best possible exploitation of the data and their products. This justifies ESA's role as an important partner in GEOSS and improves European recognition.

Life and physical sciences in space

ESA's ELIPS programme was started in 2002, following plans drawn up in response to scientific developments, and after a prospective evaluation by the ESF in 2000. In 2004 the progress made with ELIPS was assessed through an ESF-driven consultation of the community; priorities for the future were also established, including the definition of research cornerstones. Four years later, another such evaluation of the achievements, opportunities, impact, and future directions of ELIPS was needed for its 3rd phase, with a view to advising the responsible bodies (ESA, Ministerial Council, national agencies) on their future course of action and investments. The recommendations appearing below are taken from the report stemming from that evaluation [5]. ESA is to be commended for its support of user-driven research in space and the opportunities that it has given to European scientists and their international partners to achieve important goals in the disciplines of life sciences and physical sciences.

Over the years Europe secured a position of excellence in these areas; in some areas Europe is the only place where certain ISS-related research can be carried out.

© NASA/JSC, 2008

Columbus is seen in the foreground as NASA astronaut Ron Garan completes the 3rd STS-124 spacewalk.

The era begun in February 2008 with the attachment of the Columbus orbital laboratory to the ISS followed by the successful docking of the ATV Jules Verne to the ISS, must significantly increase the return on European investment in the International Space Station.

The ESSC-ESF thus considers that the ELIPS programme is essential for European research in life and physical sciences in space and fully supports ESA in proposing the ELIPS 3 programme at this Ministerial Council.

The ELIPS programme must be continued through its Phase 3 at the funding level mandated, because science utilisation and return will sharply increase as of 2008 as the Columbus laboratory is attached to the ISS and in full operation. The best usage of Columbus within the ELIPS programme is mandatory. In order to achieve a maximum output the funding level therefore has to be raised accordingly.

It is believed that the full potential of ISS utilisation will not be exhausted by 2018, and the continuation of utilisation beyond that date would deliver good return on investment.

Specific investments will therefore have to be made for a new generation of payloads (or new inserts into existing facilities) for the ISS. In parallel, preparatory steps have to be taken for the post-ISS era by looking into alternative payload carriers, ballistic flights and free-flying orbiters. Creative use of the ATV in this context is encouraged.

Topical Teams are considered to be very successful incubators for emerging and interdisciplinary topics, and to prepare the ground for a network of European scientists working for the ELIPS programme. Similarly, Microgravity Application Promotion (MAP) projects are considered to be a unique platform to perform in-depth research on complex phenomena, which requires the teaming of European experts.

The present form of the MAP projects should be continued, meaning that these projects would have application-oriented, yet not solely industry-driven, strategic long term objectives. As promotion is no longer an issue, the programme should be renamed e.g. "Microgravity Assisted Research". Furthermore, Topical Teams as incubators for future research topics should be continued.

The ELIPS programme has demonstrated its high scientific value and relevance to European research ambitions; its balance must be preserved.

Hence, new programmes on solar system exploration should not be established at the expense of ISS utilisation and ELIPS.

Finally it is evident that many synergies exist between the various disciplines of the ELIPS programme. This is for instance the case for:

- Soft matter physics
- Cell bio-reactors
- Fluid flow and phase transition
- Radiation
- Bio-fluids
- Organism response to space environment

Common scientific questions can be addressed by common technical approaches.

The ESSC-ESF thus recommends that the ELIPS programme should seek to foster cross-disciplinary activities. This might be achieved by common ELIPS workshops in science and technology to look at cross-cutting science and technology problems.

Exploration programme

The international space exploration programme foresees multiple robotic and human missions in the solar system in the coming decades. A global strategy is being developed jointly by a large number of space-faring nations and organisations. Europe is now planning the launch of ExoMars in 2016 as a first step towards a robust and renewed effort for exploration. A roadmap for Aurora, the early name of Europe's Exploration Programme, started to be developed in 2001. Furthermore, a strong heritage exists in Europe within both the mandatory programme, through which several solar system missions have been launched, as well as the various ELIPS-funded research programmes. This allows Europe and ESA to face new explorative challenges, while making use of solid and successful experience.

The highest strategic priority for the Exploration programme is the robotic exploration of Mars. Now that robotic exploration has been reorganised within ESA it is essential that the scientific aspects of this programme become embedded within the mission architecture of D-SRE, its technology aspects within D-TEC, and that a sustained and high-profile education and public outreach programme be implemented.

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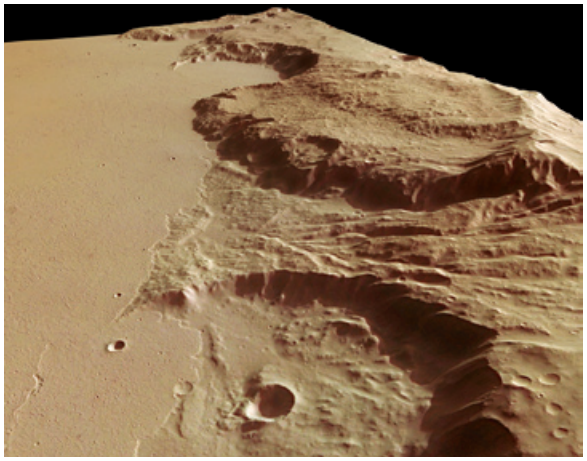

Perspective view of Mangala Fossae on Mars taken by ESA's probe Mars Express.

The different objectives of the Exploration programme must be recognised and must not be allowed to deplete the mandatory science programme through budget inadequacies.

The more detailed recommendations that follow are based upon the prospective evaluations conducted in 2006 and 2007 by the ESSC-ESF, under commission of ESA D-HME. The central message from these recommendations is that Europe's vision for this technology-driven programme should be to prepare for a long-term European participation in a global endeavour of human exploration of the solar system, with a focus on Mars and the necessary intermediate steps, initiated by robotic exploration programmes with a strong scientific content.

1. The overarching scientific goal of Europe's Exploration Programme should be called: "Emergence and co-evolution of life with its planetary environments", with two sub-themes pertaining to the emergence of life, and to the co-evolution of life with their environments.
2. Europe's Exploration Programme should focus on targets that can ultimately be reached by humans.
3. The first steps of Europe's Exploration Programme should be done robotically.
4. International cooperation among agencies engaged in planetary exploration should be a major feature of Europe's Exploration Programme, realised by concrete joint ventures such as some of the elements mentioned in the fourteen space agencies' Global Exploration Strategy document [8].
5. Mars is recognised as the current focus of Europe's Exploration Programme, with Mars Sample Return as the driving programme; Europe should position itself as a major actor in defining and leading Mars sample return missions.
6. There is unique science to be done on, of and from the Moon and of/on Near Earth Objects or Asteroids (NEOs/NEAs). Therefore, if these bodies are to be used as a component of Europe's Exploration Programme, further science should be pursued; the Moon could thus be used as a component of a robust exploration programme, including among others: geological exploration, sample return and low-frequency radio astronomy, technology and protocol test-bed.
7. The role of humans as a unique tool in conducting research on the Moon and on Mars must be assessed in further detail.
8. Since Europe's Exploration Programme's ultimate goal is to send humans to Mars in the longer term, research on humans in a space environment must be strengthened. Beyond the necessary ongoing and planned biological research and human presence on, e.g. the international space station (ISS) or in Antarctica, opportunities to this end might also arise in the context of an international lunar exploration programme. ESA needs to ensure the continuity of the necessary expertise in the longer-term by supporting the relevant groups.
9. Europe should develop a sample reception and curation facility, of joint interest to ESA's science and exploration programmes. A sample distribution policy needs to be established between international partners early in the process.
10. Understanding the processes involved in the possible emergence of life elsewhere in the solar system is important for understanding the habitability of exoplanets, and remains a high scientific priority that should be supported by ground-based laboratory studies and specific experiments in space.
11. Once Europe's Exploration Programme is funded and running it is suggested that a series of international science and technology exploration workshops be set up in the near future, which for Europe could be organised by ESF and the community and co-sponsored by ESA, in order to better define the mission concepts and technological choices relevant to the above goals as this multi-decadal programme develops.

Coordination within ESA

The ESSC-ESF expresses concern about the impact on the coordination of planetary exploration and science in ESA as a result of the movement of ExoMars (and, in all likelihood, of Mars Sample Return) from the HME/HSF Directorate to the SCI/SRE Directorate. Liaison between ELIPS and the Exploration programmes currently occurs predominantly at working level with varying levels of effectiveness, although clear scientific and technological synergies exist between ELIPS and the Exploration Core programme. The reorganisation between these two programmes, including transfer of key personnel, could alter this relationship.

The ESSC-ESF thus recommends that ESA should have a specific strategy for coordination between programmes and stresses the importance of assessing the consequences of this transfer of programme components.

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