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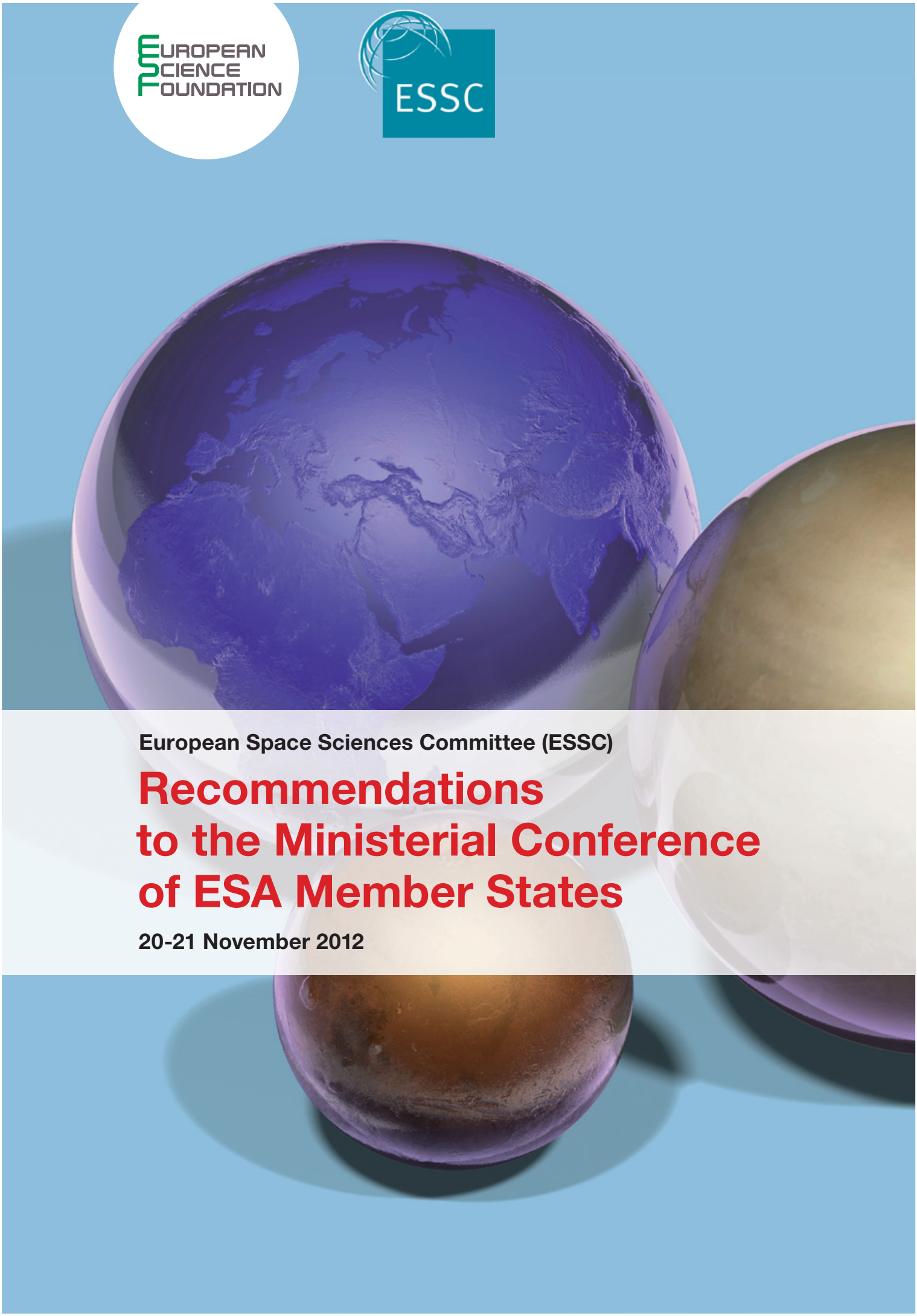

European Space Sciences Committee (ESSC)

Recommendations to the Ministerial Conference of ESA Member States

20-21 November 2012

European Science Foundation (ESF)

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European Space Sciences Committee (ESSC)

The European Space Sciences Committee (ESSC), established in 1975, grew from the need to give European space scientists a voice in the space arena at a time when successive US space science missions and NASA's Apollo missions dominated space research. More than 35 years later, the ESSC actively collaborates with the European Space Agency (ESA), the European Commission, national space agencies and the ESF Member Organisations. This has made ESSC a reference name in space sciences within Europe.
The mission of the ESSC today is to provide an independent forum for scientists to debate space sciences issues. The ESSC is represented ex officio in all ESA's scientific advisory bodies, in ESA's High-level Science Policy Advisory Committee advising its Director General, it has members in the EC's FP7 space advisory group, and it has observer status in ESA's Ministerial Council. At the international level, ESSC maintains strong relationships with the National Research Council's (NRC) Space Studies Board in the US.
The ESSC is the European Science Foundation's (ESF) Expert Committee on space sciences and the ESF's interface with the European space community.

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The European Science Foundation hosts six Expert Boards and Committees:

- The European Space Sciences Committee (ESSC)
- The Nuclear Physics European Collaboration Committee (NuPECC)
- The Marine Board-ESF (MB-ESF)
- The European Polar Board (EPB)
- The Committee on Radio Astronomy Frequencies (CRAF)
- The Materials Science and Engineering Expert Committee (MatSEEC)

In the statutory review of the Expert Boards and Committees conducted in 2011, the Review Panel concluded unanimously that all Boards and Committees provide multidisciplinary scientific services in the European and in some cases global framework that are indispensable for Europe's scientific landscape, and therefore confirmed the need for their continuation.

The largely autonomous Expert Boards and Committees are vitally important to provide in-depth and focused scientific expertise, targeted scientific and policy advice, and to initiate strategic developments in areas of research, infrastructure, environment and society in Europe.

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Recommendation Summary

General recommendations

1. Europe's policy makers should stress clearly, and in a prominent fashion, that involvement in first-class space sciences is absolutely essential for the promotion of European interests and leadership, as it imparts a strong strategic drive to Europe's technological and industrial systems, as successfully demonstrated in the case of, for instance, the USA.
2. To support sustained development and safeguard future high-level technology, ESSC supports the view that some 5% of the €120 billion stimulation package recently agreed by the EU Heads of States should be made available to the space sector. This sector is indeed regarded as a powerhouse of technology and essential for Europe's future. Use of these funds should be coordinated between the EU and ESA, e.g. through the existing framework agreement between ESA and the European Commission.
3. ESSC strongly recommends that ways be found in coordination with the EU and Member States (for instance through the EC–ESA Framework Agreement) 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.
4. For the future prosperity of Europe it is crucial that there exists 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 pool. ESA must enhance its education and public outreach programmes, using as many communication techniques as possible and engaging in partnerships with European universities and laboratories. ESA must also pay attention to developing its internet resources as the portal through which European achievements in space are perceived by the public at large.

Space Science Programme

1. ESSC recommends improving coordination in the road-mapping carried out by the different space agencies worldwide, in order to avoid out-of-phase decision processes as well as duplications. This road-mapping should also include ground-based efforts, as well as coordination with individual national agencies.
2. ESSC recommends supporting the proposal by the ESA Executive on the level of resources to maintain the purchasing power of the programme in the future, i.e. by applying a correction for inflation. This will imply investing in the future, avoiding past problems when the correction for inflation was removed at a time when inflation in Europe was relatively high.
3. ESSC wishes to reaffirm that the mechanisms by which the mandatory Science Programme is asked to support optional programmes facing budget problems should be applied only in very exceptional circumstances, and in any case be restricted to situations with a minimal impact on the long-term activities of the Science Programme, already hampered by the lack of sufficient funding to develop ambitious missions at the rate required by the community.

Earth Observation Programmes

1. ESSC urges the ministers of ESA Member States to give positive consideration in support of ESA's request for funding of EOEP-4.
2. ESSC recommends that all necessary steps be taken with all relevant EU institutions to reintegrate GMES in the MFF budget and to ensure that Europe will continue to play a leading role in global Earth science, operations and applications for the benefit of society at large.

European Life and Physical Sciences in Space Programme

1. The ELIPS programme hosts a number of exceptional experiments which are of top-level scientific quality and great importance to the scientific community as well to society, and therefore should be continued.
2. Support of ground-based facilities should be continued and even increased, and new mechanisms such as the development of small-scale multi-user instruments to be used in the various ground-based facilities should be implemented.
3. Continuous availability of long-term, man-tended in-orbit research facilities is crucial. It is therefore of utmost importance to start preparing for the post-2020 period as soon as possible.
4. Coordination between ESA and national organisations has to be significantly improved, in particular for coordinated and complementary funding of preparatory work on the ground and post-flight analyses of samples and data. It is also crucial that research grants are secured as soon as possible in the process. Reaching a stronger integration of all the experimentations' components and setting up (virtual) common pots of funds dedicated to specific Announcements of Opportunity could offer a way to streamline programme management while limiting the overall administrative load for the research teams.

Exploration Programme

1. ESSC recommends that Europe plays a major role in a developing Global Exploration Strategy for the robotic and human exploration of the Solar System (GES, 2007). Within this context ESSC strongly recommends that Europe should position itself as a global leader through:
   a. Support to the ExoMars programme as a European contribution to the Global Exploration Strategy. This would be a positive step towards a Mars sample return programme.
   b. Participation of ESA in lunar lander and lunar and asteroid sample return missions, together with the associated technology development as key intermediary steps within the Global Exploration Strategy.
   c. Search for ways in which ESA's experience in human spaceflight achieved through involvement in the ISS can be used to support future human exploration missions beyond low Earth orbit.

Space Technology

1. ESSC recommends supporting R&D for innovative technology activities in space science and exploration in order to ensure European independence in critical areas and to provide added value to ESA's future developments within the context of a global space exploration effort.
2. The infusion of the best technologies to achieve scientific breakthroughs requires an interaction between space and non-space communities and the corresponding establishment of partnerships. It is therefore necessary to combine the forward view of space sciences with the forward view of technology in non-space areas. ESSC recommends working towards a better synergy between space and non-space technology, and identifying best practices and promising technology transfer mechanisms in both sectors, through a combined effort of ESA, Member States and the EU.

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 focusing on user needs in various areas, including science, telecommunication, navigation systems and environmental monitoring.

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 by offering advice and recommendations concerning the policy's science base. A more detailed view on Europe's future space policy appeared subsequently [2]. Following the advice of many stakeholders, including ESSC–ESF, the EC then published its 7th Framework Programme, featuring its own "Space Theme", and the EC and ESA jointly published a Communication on Europe's space policy [3] which received broad political support from EU and ESA Member States at the 4th Space Council in April 2007.

In November 2008, ESSC–ESF was invited for the fourth time to attend the ESA ministerial conference. It published at that time a set of recommendations to the ministers and delivered an oral statement emphasising a number of crucial elements for Europe's future space scientific programmes and policy [4].

FP7 is now nearing its end, and its various stakeholders have started to shape the structure, content and foreseeable budget of its successor, Horizon 2020. ESSC–ESF has published its views on Horizon 2020 and the role of space therein [5].

When the ministers of ESA Member States meet again in Caserta on 20–21 November 2012, ESSC–ESF wishes to put forth a number of elements for the ministers' consideration and appraisal of the situation in Europe concerning space sciences and exploration. In addition to this document, a report is brought to the attention of the ministers on the evaluation of the fourth phase of ESA's research programme in life and physical sciences in space – ELIPS [6].

ESA Conference of Member States at ministerial level, Den Haag (NL), 25–26 November 2008.

Orion nebula in the far infrared (combined view by Herschel and Spitzer).

European Successes

Since the last ministerial council meeting in 2008 Europe can take pride in noting a very significant number of outstanding achievements in space sciences.

The Herschel and Planck missions, launched in 2009, constitute a major milestone in our understanding of the cold Universe. While Herschel has been extremely successful in studying astronomical objects in the infrared range (interstellar molecular clouds, star formation sites, external galaxies, and so forth), Planck is performing the most detailed analysis of the cosmic microwave background, the emission that originated just 400,000 years after the Big Bang.

Gaia, on the other hand, is being completed, aiming for a launch at the end of 2013. Gaia will construct a three-dimensional map of more than 1 billion stars in our Galaxy. Providing unprecedented positional and radial velocity measurements as well as astrophysical parameters, Gaia will allow us to disentangle the history of formation and evolution of our Galaxy. Gaia relies on the success of the previous ESA's Hipparcos mission and confirms the leadership of Europe in the techniques of space astrometry.

These new missions complement the continued success of other missions launched in the past but that continue to provide first-quality scientific data.

The XMM-Newton and INTEGRAL missions have provided European astronomers with access to the X-ray and gamma-ray Universe. After a decade observing the high energy Universe, more than 3500 scientific papers have been produced with data provided by both missions on collapsed objects (binary stars, galactic black holes, radioactive elements, supernova explosions).

The SOHO mission, the Solar and Heliospheric Observatory, is a project of international collaboration between ESA and NASA to study the Sun from its deep core to the outer corona and the solar wind. This mission has continued to provide excellent data since its launch in 1995, in particular relating to solar flares, space weather and the delayed start to the most recent sunspot cycle.

HINODE (sunrise) is a joint JAXA–ESA mission exploring the Sun's magnetic field, improving our understanding of the mechanisms that power the solar atmosphere and drive solar eruptions, and has a minor but extremely pertinent European contribution in the form of an additional ground station in Svalbard, which allows a doubling of the amount of data from this mission.

The MARS EXPRESS mission, launched in 2003, has had resounding success and is still producing high-level science. Mars Express has continued to provide high-quality observation of the surface of Mars from orbit, as documented by some 550 scientific publications. The results from the HRSC instrument have enormously increased our understanding of the surface of the planet. The VIMS instrument has revolutionised our view of the evolutionary history of Mars' environment, as represented by the presence of certain mineral phases in the surface materials of Mars. The Energetic Neutral Atoms Analyser mapped the distribution of hydrogen, believed to be a proxy for water at the surface of Mars. The Planetary Fourier Spectrometer made an enigmatic identification of methane in the atmosphere of Mars which sparked much interest because of its possible production by subsurface microorganisms. Recent reanalysis of the data however suggest caution in the interpretation of atmospheric methane.

VENUS EXPRESS, Europe's mission to study the Venusian atmosphere as well as the interactions between the atmosphere and the surface, gives clues about characteristics of the surface of this planet. The latest findings highlight the features that make Venus unique in the Solar System and provide fresh clues as to how the planet is – despite everything – a more Earth-like planetary neighbour than one could have imagined.

The CLUSTER mission, which studies how the solar wind affects the Earth, is making the most detailed investigation yet of how the Sun and Earth interact. It also studies the interactions between the atmosphere and the interplanetary environment (solar wind) to better understand the evolution of our planet. It has underlined the importance of the Earth's magnetic field in protecting the Earth from the solar wind.

The CASSINI–HUYGENS mission to the Saturn system, and in particular its satellite Titan, is a joint NASA–ESA mission that has had a resounding success with the publication of nearly 2400 scientific papers. The European Huygens lander provided invaluable information about the composition and structure of Titan's atmosphere as cameras filmed the landing on a surface consisting of solid methane and "rocks" of ice. Rivers and lakes of ethane were identified. The Cassini orbiter continues to provide a wealth of data, including the observation of cryovolcanism on Enceladus. This mission has importantly demonstrated excellent collaboration between NASA and ESA, particularly since the programmes of both agencies coincided.

The ROSETTA mission is on its way to comet 67P/Churyumov–Gerasimenko and has flown by a couple of asteroids, a rare E-type asteroid called Steins in 2008 and the M-type asteroid Lutetia in 2010. It also made a flyby of Mars.

LISA Pathfinder aims to prove and demonstrate for the first time the principles of the detection of gravitational waves in space and will be launched in 2014. The mission consists of placing two test-masses in a nearly perfect gravitational free-fall, and of controlling and measuring their motion with unprecedented accuracy.

BepiColombo, the mission to Mercury, will be launched in 2015. It will study the interior structure, geology and composition of the planet as well as its origin and evolution. BepiColombo will probe Mercury's magnetosphere and study the origin of its magnetic field.

The ENVISAT mission was a great success for 10 years; it unfortunately stopped functioning in June 2012, five years beyond its foreseen lifetime. Launched in 2002, ENVISAT was the largest Earth observation spacecraft ever built, and carried ten sophisticated optical and radar instruments to provide continuous observation and monitoring of the Earth's land, atmosphere, oceans and ice caps. ENVISAT data collectively provide a wealth of information on the workings of the Earth system, including insights into factors contributing to climate change.

No other space-faring nation around the world has the capabilities of current missions such as **SMOS, GOCE and CRYOSAT** in ESA's Earth Observation Envelope Programme. For instance the first results of the GOCE mission delivered the most accurate model of the Earth's 'geoid' ever.

The GOME-2 (ESA) and **IASI** (EUMETSAT) instruments on the METOP series of EUMETSAT satellites are the first instruments that perform operational monitoring of the chemical composition of the atmosphere. Both instruments brought unexpected contributions to atmospheric science, and continue to perform excellent measurements.

The ELIPS programme is a wide-ranging, comprehensive research programme providing research opportunities to scientists across Europe and beyond. It covers many scientific disciplines, spanning from human physiology to fundamental physics, and utilises a variety of facilities and platforms. Examples of ELIPS-supported success stories include: (i) in cell and molecular biology, the demonstration in vitro that osteoblast (or precursor) cellular differentiation in microgravity involves various matrix proteins, and that osteoblast differentiation is impaired in microgravity with various gene expression changes being noted; (ii) in astrobiology, where astrochemistry experiments revealed the complex chemistry that can occur in the space environment, providing insight into mechanisms for the production of molecules thought important for the origin of life; (iii) in radiation biology one of the key, pertinent findings recently obtained through ground-based accelerator facilities demonstrates the relatively low effectiveness of heavy ions to induce leukaemia; (iv) in fundamental physics the component of the ELIPS portfolio is of excellent quality. Many of these projects have also had significant impact potential for both space exploration and for humankind on Earth; for example, the atom interferometers have relevance to gravimetry and geodesy, and the atomic clocks have relevance to GPS and global time coordination and synchronisation.

General Recommendations

Despite the very high output of these missions it should be realised that most of these European successes are the logical outcome of forward-looking decisions taken by ESA and its Member States in the 1980s and 90s. When looking at the portfolio of past and current missions and comparing those with the current plans for future mission implementation, one is forced to conclude that (a) the pace, and (b) the number of missions have dramatically decreased and that a gap in mission operations is visible after 2015 should any delay affect the implementation of future missions.

What is the present situation, 12 years after the courageous declarations made in Lisbon?

The purchasing power of space sciences programmes decreased up to the end of 2005, creating major difficulties for the implementation of the programmes and resulting in continuous delays and even cancellation of projects. Things improved slightly at the ministerial conference of December 2005: for the first time since the 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 ESSC. At the next ministerial conference (Den Haag, November 2008) ESSC acknowledged the steps taken to increase the budget of this programme by 3.5% per annum at 2008 economic conditions, although the resulting annual contributions were still well below our recommendation to reach €500 million per annum, as the funding level required to enable the timely realisation of the ambitious Cosmic Vision 2015–2025 programme [7]. We had emphasised at the time that this decision risked forcing Europe to delay and/or cancel some of the missions planned in that programme. Today the planning of the mandatory programme remains overheated and overstretched, not allowing for the possibility of long-term planning, as required for such a programme.

The Earth Observation Envelope programme (EOEP) was subscribed in 2005 at a level of 84% of the Director General's proposal. This was also, albeit to a lesser extent, in line with our past recommendations. In November 2008, the Climate Change Initiative was funded, although at less than 50% of the ESA Director General's request.

The loss of ENVISAT in June 2012 has dramatic consequences for data availability for Earth observation and makes the urgent need and launch of the GMES missions (Sentinel 1, 2, 3, 4, 5p and 5) even more pressing. It is therefore very unfortunate that the GMES budget discussion (including the uncertainty regarding the inclusion of this budget in the MFF) is still ongoing. The GMES missions are needed for operational applications and climate monitoring, as the still functioning EO missions in Europe and the US can only partly compensate for the loss of ENVISAT.

In 2005 the Exploration programme appeared to move in the right direction with the funding of the first part of ExoMars over-subscribed to a level of 110%, although the Exploration core programme was only subscribed at 47%. Immediately after the Berlin conference, ESSC stressed that this was a concern and should be discussed in the near future in order to assess the possible consequences of this under-subscription for the Mars Sample Return mission. In 2008 ministers gave a high strategic priority to the robotic exploration of Mars with the Enhanced ExoMars Mission component. This clear priority was again in line with ESSC recommendations that the different objectives of the Exploration

programme must not be allowed to deplete the other scientific programmes. The full cost of this mission was still not covered by the committed contributions; however the ESA executive had the responsibility of finding ways to fully fund the mission. The situation today is still very uncertain and the future of an ambitious European initiative in the exploration of Mars is not yet solidly established.

The European Life and Physical Sciences in Space (ELIPS) programme only obtained 50% of the Director General's request in 2005. This meant a 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 engaged programmes, several of which were delayed or cancelled as a result, since a proportional budget reduction was not feasible. Moreover in 2008, ministers did not grant the €395 million requested by ESA's Director General, although in relative terms that subscription was higher than that granted in 2005, a sign that ESA Member States wanted to take stock of Europe's privileged position in these research areas after the installation of the Columbus orbital laboratory on the ISS. This was a first step in a direction that would enable Europe and its scientific community to start reaping the benefits of the important investments made on the ISS, and to sharply increase science utilisation and return with Columbus.

European leadership and stimulation of the European space economy

The ESA programmes Cosmic Vision 2015–2025, the optional Exploration programme, EOEP and the ELIPS programme are of a very high standard while remaining affordable. They represent the platforms through which Europe can obtain scientific success and, importantly, a leadership position among space-faring nations.

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

Increased funding of space activities by the European Member States 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 of other space nations, e.g. the United States. Nevertheless involvement in first-class science is absolutely essential for the promotion of European interests and leadership, as it imparts a strong strategic drive to Europe's technological and industrial systems. Without such an involvement Europe would be left staggering behind other major space players in the world in terms of scientific, technological and industrial capacity.

An important prerequisite for the construction of an efficient European space strategy is therefore to create the conditions for the development of a balanced and long-term planning of scientific activities.

Currently the economic crisis makes it very difficult for governments to invest fresh money in space activities. Stakeholders are therefore left with the painful decision of cutting the funding on one segment of a programme in order to provide support to another. One way to reap the benefits of European investments in space activities would thus be to provide it with stimulus funding that would enable it to maintain European leadership in this high return domain.

The Heads of States of the European Union have recently agreed to inject 1% of Europe's GDP, i.e. a €120 billion stimulation package, into the EU economy. The fields having a European dimension that should benefit from this package have been identified: navigation, communication, Earth resources and defence. Research and technology transfer appear to be other broad fields of prime importance for Europe that should be added to this list. Certainly space can rightfully claim that it meets the criteria for benefiting from that infusion of funds.

Requesting a share of that stimulus package at a level of some 5% therefore seems reasonable and compatible with the magnitude of the European space market.

In order to support sustained development and safeguard future high-level technology, ESSC supports the view that some 5% of the €120 billion stimulation package agreed by the EU Heads of States should be made available to the space sector. This sector is indeed regarded as a powerhouse of technology and essential for Europe's future. Use of these funds should be coordinated between the EU and ESA, e.g. through the existing Framework Agreement between ESA and the European Commission.

Data exploitation

There is an urgent need to put in place across Europe the capabilities to exploit ESA's successes. According to its constitution ESA is 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 US, 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 higher support than European scientists can obtain for European-built satellites.

This issue should be addressed by soliciting proposals for use of data from collaborations of European scientists, to work together on data analysis 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 would allow the European scientific community to benefit from the very substantial investments in successful space missions made by ESA and national space 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.

The positive role of the inclusion of this topic in the 7th Framework Programme of the EU, as well as the role of the EC's Space Advisory Group (SAG) in recommending corresponding implementation measures in FP7 Calls, is acknowledged here.

However, a critical aspect of data archiving and exploitation is the need for maintenance of the databases and of the relevant IT tools developed for and by the science community, i.e. of the stability of the databases and the associated products. This requires long-term continuity of the financial (EU) and operational (ESA) support to be provided in that domain. This could be achieved through the EC–ESA Framework Agreement.

ESSC strongly recommends that ways be found in coordination with the EU and Member States (for instance through the EC–ESA Framework Agreement) 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.

Finally it is also important that the ESA programmes provide the same level of financial support for scientific projects as the support they provide to their ITTs, and comparable to the level of funding provided by the EU. For instance the ESA Changing Earth Science Network programme is funded at a much lower level than EU and ESA ITT projects. In this programme post-doctoral students can submit a proposal to carry out scientific research with ESA satellite data.

Education and outreach

In order to close the gap with NASA on PR and education, one of ESA's major objectives should be to set aside a relevant budget for these activities. For instance summer schools or workshops on various research topics could be initiated or developed. ESA could also reach an agreement about the European Credit Transfer and Accumulation System (ECTS) in collaboration with interested universities, enabling students to become involved in space sciences early in their career.

Allocation of a pre-defined budget for education and outreach to each mission implemented by ESA is recommended, possibly as a defined fraction of its total cost.

For the future prosperity of Europe it is crucial that there exists 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 pool. ESA must enhance its education and public outreach programmes, using as many communication techniques as possible and engaging in partnerships with European universities and laboratories. ESA must also pay attention to developing its internet resources as the portal through which European achievements in space are perceived by the public at large.

Recommendations on Programmes

Space Science

Role of large observatories in the decade of 2020

Large observatories for astronomy are not planned in the future decade by any agency after JWST, presently being scheduled not earlier than 2018. This will imply reduced access to several energy ranges (far-infrared, UV, X-ray and gamma-ray) from space and the impossibility to coordinate observations simultaneously from space and from the foreseen large observatories on the ground. The crisis of the international cooperation between NASA and ESA in the last years, which blocked some proposals under evaluation by Cosmic Vision (IXO, LISA, and Laplace), has made it impossible to develop large observatories, i.e. with budgets above €2–3 billion, in the foreseeable future.

How can we proceed?

There is no agreement in the scientific community regarding the development of new large observatories at the expense of other smaller projects. Several options for the future of Cosmic Vision can be considered, namely:

- M missions only;
- Europe-led L missions, with a cost envelope to ESA of around €1 billion;
- Very large missions (larger than €3 billion) in cooperation with other agencies.

The M missions-only option is not considered an appropriate strategy. Larger missions are needed to make advances in some fields of astronomy, which cannot be achieved with medium-sized missions. Nevertheless, they are an important ingredient of the programme, providing flexibility and excellent platforms for focused studies on different areas of astronomy and fundamental physics.

Europe-led €1 billion missions seem to be the most feasible option in terms of cost and scientific return, as well as technological and programmatic risks with respect to international participation. Risk-related budgets should be kept below 20%. L-class missions would be similar in ambition to the Cornerstone missions in the Horizon 2000/ Horizon 2000+ programmes, which have put ESA at the forefront of space astronomy with missions such as XMM-Newton, Herschel, etc. Within the timeframe of the present Cosmic Vision programme (up to 2035), only two more L-class missions could be developed (L2 and L3). We consider keeping M and S missions in the programme an excellent strategy to maintain an adequate launch rate and to provide flexible options to the community. The question regarding the implementation of L2 and L3, still open at ESA's level, is whether both should be decided in the same call, or whether there should be successive calls for each one.

Finally, the possibility of implementing very large missions has to be studied in the framework of international cooperation agreements, since they cannot be developed by individual agencies. The best example presently is JWST: a very ambitious mission which will play an important role in improving our knowledge of the primordial Universe that would have been impossible without international collaboration. Another example that has not materialised is LISA. It will be very difficult to develop a complete LISA-like mission without the coordination of several agencies. Despite the recognised extremely high interest of such a mission, it might not yet be affordable within the ESA L-class envelope.

We recognise that reaching a level of confidence that would allow such missions in the future will not be an easy task, but recommend studying the different options.

We therefore recommend improving coordination in the road-mapping carried out by the different space agencies worldwide, in order to avoid out-of-phase decision processes as well as duplication. This road-mapping should also include ground-based efforts, as well as coordination with individual national agencies.

Strategy for the selection of future L-class missions

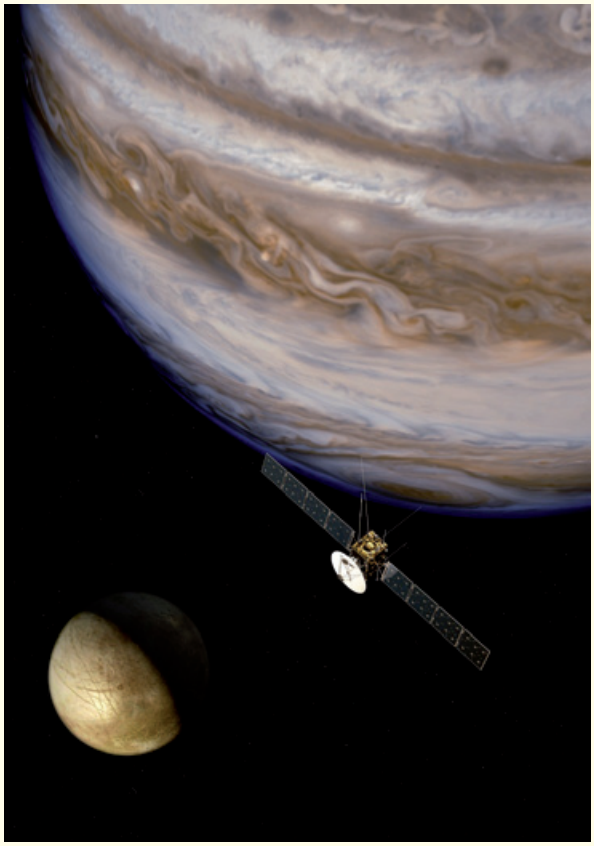
There are presently two different strategies available: following the Horizon 2000/Horizon 2000+ approach by pre-selecting the missions several years ahead, or opening each call for competition of new ideas.

The Horizon 2000/Horizon 2000+ approach was criticised because of its rigidity, since it leads to the freezing of the programme almost two decades in advance. On the other hand, the original Cosmic Vision strategy now seems to be very expensive in terms of resources, prone to generate frustration, and makes it very difficult to select between completely different missions competing at each call. The example of the L1 selection between JUICE, Athena and NGO has shown the weaknesses of this approach. Large amounts of money have been invested in the technological preparation for a large X-ray telescope and for a gravitational wave mission, but there is no guarantee that any of the two missions will ever fly. In this sense, pre-defining the missions at each L-class slot in advance would be cheaper in terms of technological development, since it will be performed for missions accepted for flight. Moreover, it gives Member States the possibility to organise their programmes by aiming to cover the gaps in different disciplines.

On the other hand, this first option would imply freezing the programme until 2035, as far as large missions are concerned. The second option would provide more flexibility for the injection of new ideas within the programme but at the cost of a large uncertainty, since the teams would have to keep working for years aiming to win a launch slot at one of the selections.

We consider that, in the first scenario, flexibility could be provided by frequent M mission calls, while the complexity of large missions implies de facto some rigidity which cannot be avoided.

Overall ESSC supports the strategy on the development of Cosmic Vision presented by the ESA Directorate for Science and Robotic Exploration, which allows for frequent launches, with a mixture of S, M and L missions.



Artist's impression of ESA's Jupiter Icy Moons Explorer (JUICE).

We recommend supporting the proposal by the ESA Executive on the level of resources to maintain the purchasing power of the programme in the future, i.e. by applying a correction for inflation. This will imply investing in the future, avoiding past problems when the correction for inflation was removed at a time when inflation in Europe was relatively high.

ESA and the concerned stakeholders should aim for better coordination between the development of ground-based and space-borne astronomical infrastructures. The lack of coordination that is observed in that domain is related to the lack of communication between the different funding agencies involved in both areas, and not to the scientific community.

Finally there is growing concern that the mandatory Science Programme will be asked to support optional programmes facing budget problems. Two recent examples (ExoMars and ISS exploitation) seem to point in that direction by proposing that the Science Programme also funds parts of their development as "Missions of Opportunity". ESSC

is concerned that these precedents could lead ESA to divert funding from the mandatory programme to support optional programmes whenever these would be facing budget problems.

ESSC wishes to reaffirm that the mechanisms by which the mandatory Science Programme is asked to support optional programmes facing budget problems should be applied only in very exceptional occasions, and in any case be restricted to situations with a minimal impact on the long-term activities of the Science Programme, already hampered by the lack of sufficient funding to develop ambitious missions at the rate required by the community.

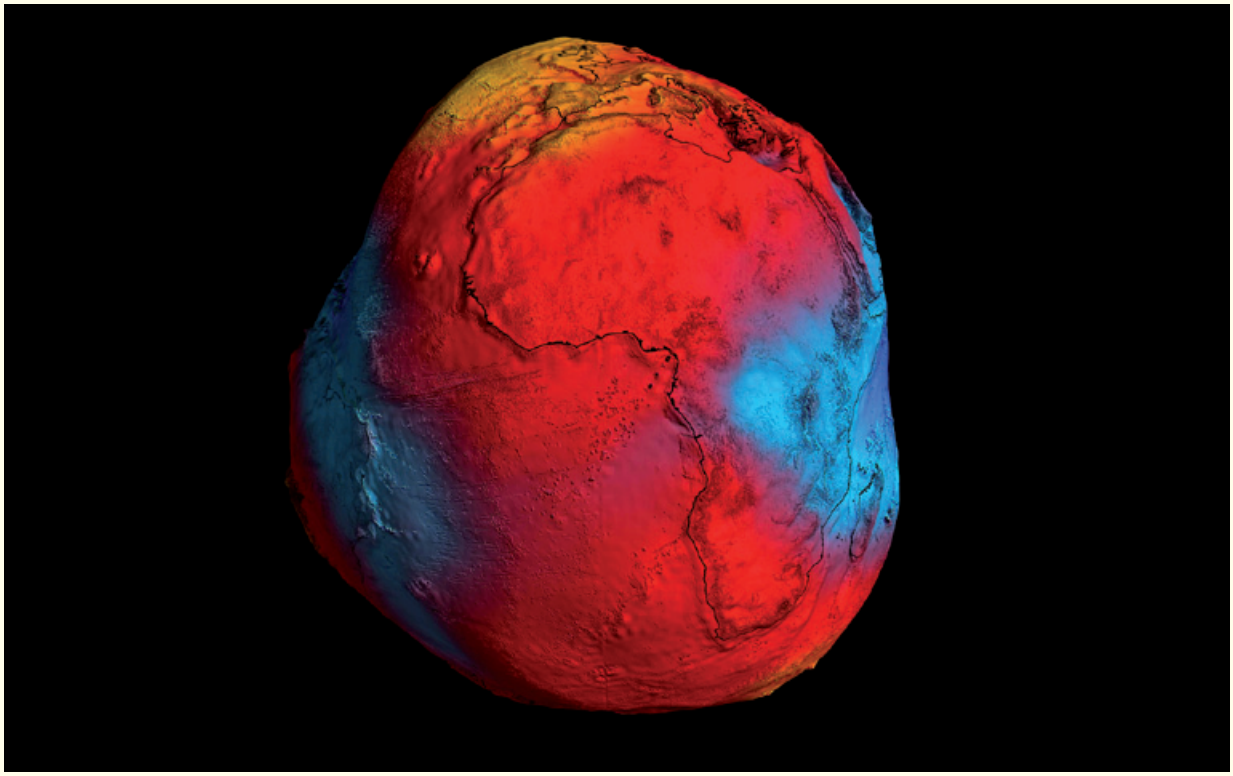
Earth Observation

The Earth Observation Envelope Programme

ESSC expresses its strong support for the fourth period of the Earth Observation Envelope Programme (EOEP-4) of ESA. This recommendation is based on seminal EOEP contributions to the field of Earth system observations and science during the past decade and highly anticipated and urgently needed capabilities in the next decade.

EOEP is implemented very effectively and is contributing to the development of a world-class European space-based Earth observation programme supported by a network of scientists to ensure its continued success. The powerful combination of technology development and use and data utilisation elements has contributed to the success of EOEP in the past and will be equally important for the future. The addition of the Climate Change Initiative (CCI) has made EOEP even stronger by enabling the provision of long-term and consistently calibrated and validated observational records for climate and other environmental research and applications. EOEP has succeeded in delivering innovative world-class observations with high exposure and impact for scientists and other users in both the public and private sectors.

Solutions to environmental challenges facing Europe and the world for the rest of this century require human ingenuity and scientific as well as technological innovations. The possibilities that EOEP has provided in the past and present towards understanding the role of oceans, polar regions, atmosphere and land that shape the Earth's environment have been crucial to progress in our scientific understanding and our ability to project potential future changes. This scientific understanding is a prerequisite for developing solutions and overcoming present and future environmental challenges. For example, no other space-faring nation around the world has the capabilities of current EOEP missions such as SMOS, GOCE and CRYOSAT. The expectation from EOEP in the future also remains



First results of ESA's GOCE mission delivered the most accurate model of the Earth's 'geoid' ever.

very high, both in Europe and world-wide, as reflected in the current slate of missions in different phases of assessment, study and development.

This already exciting, vibrant and successful ESA programme is equally important for retaining European leadership in academia and the private and public sectors in the all-important field of Earth observation. We believe EOEP-4 is also unique in bringing together bright minds and technological innovations from European nations to contribute to the development of future scientific and technical experts and business innovations in Earth observation.

We urge the ministers of ESA Member States to give positive consideration in support of the ESA request for funding of EOEP-4.

Global Monitoring for Environment and Security

At the end of 2011, ESSC expressed its very serious concerns with the way this programme seemed to be reoriented as a consequence of the preliminary decision by the European Commission not to fund the operational phase of the GMES programme from the European Union's Multi-annual Financial Framework (MFF) budget.

In the next decade ESA will launch a series of satellites for the long-term monitoring of the Earth's land, ocean and atmosphere (GMES space component, also known as the Sentinels). The Sentinels will contribute largely to the knowledge and security of the environment of European citizens. In order to monitor the Earth for environmental sustainability and climate purposes this series of operational satellites is crucial. Since climate is determined on a 30-year time scale and also needs global information, global and consistent long-term measurements are essential for monitoring and understanding climate change. Satellites are therefore essential.

Apart from the monitoring effort, there are several operational applications that are important for security (examples in the atmospheric domain are: aviation control in case of volcanic eruptions and air quality forecast). These data will also be the main source for scientific research in the context of the environment and climate change for the decades to come.

ESA took the responsibility to invest in these satellites and the EU originally took the responsibility to finance the operational phase of these satellites via the GMES programme. The recent failure of ENVISAT makes the urgent need for the GMES satellites even stronger. It is of course clear that launching satellites that are not operated after launch is useless. Such a decision by the EU would therefore lead to severe problems to exploit this set of satellites, to obtain the knowledge needed to operate in the climate policy domain, and to take the right decisions on how to manage our resources and emissions. In order to be able to operate the Sentinels successfully, the so-called ground segments have to be completed and tested about one year before launch. Taking into account the timeframe of the Sentinel programme and the status of the satellite instrumentation and ground segments, starting preparation of this operational phase in the 2012/2013 timeframe is crucial, especially as the data volume of the Sentinel missions will be of a size that has never been handled by ESA previously.

Any satellite, whether research or operational, must be operated, and, in the case of the Sentinels, the satellite operations constitute a critical function for the benefit of European citizens through the products and services that have been developed by the European research and applications industry and a large number of SMEs. The GMES programme has significant quantifiable socio-economic benefits in several areas, including climate change adaptation, global environment protection, humanitarian response to disasters, preservation and management of natural resources, and sustainable growth. The net socio-economic benefits of GMES are likely to exceed €30 billion by 2030, provided that full continuity of the commitment to provide Sentinel infrastructure and enhanced support for the continuity of data from contributing missions with full investment in services are guaranteed [8,9]. Any reduction in the continuity of commitments will substantially reduce and even annul those benefits.

From these perspectives, the decision not to fund the follow-up operational phase from the EU MFF budget would be incomprehensible. GMES is the second European flagship programme in space, after Galileo, by which the EC can demonstrate the determination of Europe to contribute fundamentally to, and even provide global leadership regarding, the solutions to worldwide problems facing mankind. By their very nature, and in accordance with the key principles of 'subsidiarity' and 'proportionality', these flagship projects require EU-level leadership in a very substantive manner. Deleting GMES from the EU MFF budget would undo the progress that has been made over the last decades towards a coherent European space policy and a leading role of Europe in space globally, and would signal a return to the pre-Galileo era where the Union was not visible as a major player in the global space arena.

The Sentinel-3 operational ocean and global land monitoring mission is developed by ESA for the GMES programme.

ESSC recommends therefore that all the necessary steps be taken with all relevant EU institutions to reintegrate GMES in the MFF budget and to ensure that Europe will continue to play a leading role in global Earth science, operations and applications for the benefit of society at large.

Eight EU Member States have recently expressed opposition to the European Commission proposal to have GMES funded outside of the MFF, and the Danish EU presidency (first half of 2012) has found it appropriate to officially propose bringing GMES back into MFF.

The continuity of ground-based and in-situ (i.e. in a specific atmospheric air parcel) measurements is a very serious concern. These measurements are needed for the validation of the satellite data, to obtain an independent check of their quality. The ground-based systems are usually funded nationally and their continuity is at risk due to the economic crisis. ESA and Member States should work towards the continuation of these ground-based systems.

ESA and the concerned stakeholders should aim for better coordination between the development of ground-based and space-borne Earth observation infrastructures. The lack of coordination that is observed in that domain is related to the lack of communication between the different funding agencies involved in both areas, and not to the scientific community.

Life and Physical Sciences in Space (ELIPS)

The ELIPS programme is a wide-ranging, comprehensive research programme providing research opportunities to scientists across Europe and beyond. It covers many scientific disciplines, spanning human physiology to fundamental physics, and utilises a variety of facilities and platforms. The programme also has a variety of research opportunities, ranging from continuous calls to large-scale dedicated international Research Announcements.

The ELIPS programme hosts a number of exceptional experiments, which are of top-level scientific quality and great importance to the scientific community as well to society, and therefore should be continued.

The programme offers a coherent wide variety of well-balanced platforms and equipment. Notably, ground-based facilities (GBF) are essential with respect to preparation, optimisation and support of investigations performed in space. They allow data from one single experiment in real microgravity to be analysed in a larger context. Therefore, support of GBFs should be continued and even increased, and new mechanisms such as the development of small-scale multi-user instruments to be used in the various GBFs should be implemented. In addition to the ISS, real microgravity conditions are cur-

rently provided by the ZARM drop tower, parabolic flights and sounding rockets through ELIPS. Given the constraints imposed by the ISS (e.g. cost, mass, power, reproducibility of experiments) the diversity of available microgravity platforms should be kept. Besides existing platforms, commercial spaceflight providers may bring new opportunities in the coming years, and the potential added-value offered by these new systems should be considered and assessed.

Support of ground-based facilities should be continued and even increased, and new mechanisms such as the development of small-scale multi-user instruments to be used in the various ground-based facilities should be implemented.

Current negotiations between international partners secure the utilisation of the ISS only until 2020, and thus far no firm assumptions can be made on the fate of the central component of the ELIPS programme beyond this date. This lack of visibility beyond 2020 is viewed as a major hurdle in making the programme reach its full potential. In the current context, with less than nine secured years ahead and considering the slow pace that has been a characteristic of the programme (mostly due to resource limitations and the inherent complexity of space experimentation), ambitions to perform new investigations on the ISS in the medium- to long term can be hampered. Continuous availability of long-term man-tended in-orbit research facilities is crucial to reap the full benefits offered by spaceflight conditions for both life and physical sciences; this continuity should be ensured even after 2020. It is therefore crucial that ESA, the scientific community and the other relevant stakeholders start considering and planning the capacity and infrastructure to be made available beyond 2020 (including potential extension of the ISS utilisation). Defining the future plans as soon as possible would also allow the maintenance of momentum and motivation among the scientific community and for new investigators to be attracted. As long as no plan is made for the post-2020 period, streamlining and shortening as much as possible upcoming ISS experiments implementation phases should be considered to optimise the use of ISS. It is also crucial to start preparing for the post-ISS period.

Continuous availability of long-term, man-tended in-orbit research facilities is crucial. It is therefore of utmost importance to start preparing for the post-2020 period as soon as possible.

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ESA astronaut André Kuipers shortly after returning to Earth on Sunday 1 July 2012.

ELIPS provides a common platform for research at the European level (and beyond) and an anchor for international cooperation. One of the characteristics of the programme is that experiments are supported by several sources: ESA provides the platforms and infrastructure while all other means to conduct investigations (including sample and data analysis) have to be provided by national research organisations and this implies a double application process. Considering the number of nationalities represented in project teams, this can be (and is) a major challenge as national agencies often do not have aligned priorities or appropriate funding systems in place. Better integration of all the components of the research performed in the programme is required. To achieve this, coordination between ESA and national organisations must be significantly improved.

An appropriate mechanism to secure funding upstream in the process and limit paperwork should be set up and agreed upon between the international partners before an Announcement of Opportunity is issued. In this context, multilateral collaborative research programmes involving the setting-up of (virtual) common pots of funding could be considered as potential benchmarks. Considering the variety of actors and partners contributing to the ELIPS programme, it seems also important that, taking into consideration national specificities (e.g. priorities, research communities), national strategies for life and physical sciences in space are developed to complement in a coherent way ESA's ELIPS programme. This would not only ease the completion of preparatory activities and exploitation of data and results but could also increase the flight options and opportunities for the community, e.g. through additional cooperative agreements.

Coordination between ESA and national organisations has to be significantly improved, in particular for coordinated and complementary funding of preparatory work on the ground and post-flight analyses of samples and data. It is also crucial that research grants are secured as soon as possible in the process. Reaching a stronger integration of all the experimentations' components and setting up (virtual) common pots of funds dedicated to specific Announcements of Opportunity could offer a way to streamline programme management while limiting the overall administrative load for the research teams.

Exploration Programme

The relevant resolutions adopted at the previous ministerial council meeting are here reiterated:

- The importance of Europe taking a leading role in space exploration, based on its domains of excellence, especially with respect to long-term vision;
- In particular, support for the enhanced ExoMars Mission component and Mars Robotic Exploration Preparation Programme (MREP) component of the European Space Exploration Programme – Aurora.

Moreover, regarding key decisions to be taken at this council meeting at ministerial level, the first and key question stated with respect to exploration was: *"Will Europe be a leading partner in a worldwide exploration initiative, encompassing robotic exploration of the Solar System and human spaceflight leading to the exploration of the Moon?"*

The answer to this question remains unresolved, and ESSC urges that decisions are taken at this Ministerial Conference that enables it to be answered in the affirmative. This could be accomplished through a number of future missions of which the prime one is ExoMars. Other missions and activities that would demonstrate Europe's leadership role include a lunar lander and/or lunar sample return, asteroid sample return, Mars sample return, and improved capabilities in space situational awareness. ESA should explore ways in which its experience in human spaceflight achieved through involvement in the ISS can be used to support future human exploration missions beyond low Earth orbit.

ExoMars

ExoMars is a mission whose main objective is the search for traces of life on Mars. Unfortunately, since the Announcement of Opportunity in 2003 scientific involvement in ExoMars has been beset with setbacks because of programmatic changes, despite the recommendation of the last Ministerial meeting that strongly supported the then "enhanced" ExoMars mission. However, the lack of appropriate financial support from ESA Member States led to a brief collaboration with NASA, which did not come to fruition. Collaboration with Russia is now being very actively explored.

The ExoMars mission is in two parts. The first part is a mission to demonstrate European capabilities in entry and descent. This technology mission is to be launched in 2016 and will also place an orbiter around Mars to serve as a data relay for the second segment, the 2018 rover mission. The science objectives of the 2016 mission are to provide information on atmospheric chemistry while those of the 2018 rover mission are to detect traces of past and present life on the surface (and subsurface, down to 2m) and to document the geological context (habitability) of the landing site.

The scientific and technological advances are of fundamental importance in preparation for a sample return from Mars, a future mission that is of the utmost importance in order to answer key science questions that cannot be answered by in situ missions, such as the detection of bio-signatures and the understanding of the evolution of the planet through subtle geochemical signatures in the rocks and the dating of those rocks.

The programmatic and technological complexity of the ExoMars mission led to a number of evaluations as to its feasibility. At the time of writing, ESA concluded that the combined mission with launches in 2016 and 2018 was feasible from both a technological and budgetary point of view.

The situation regarding ExoMars is nevertheless still worrying, not least the scenarios for funding and its appropriate programmatic place. What are the options for resolving the dilemma of ExoMars?

Future challenges

We note the urgency of ensuring that all measures are undertaken to ensure the success of the ExoMars mission, particularly as it is an important scientific and technological step towards sample return from, and ultimately human exploration of, the planet Mars. The importance of this mission to European Solar System science and to Europe's image in the global landscape of Solar System exploration cannot be overstated.

The position of ExoMars within the newly proposed European Robotic Exploration Programme (EREP) and the strategy necessary to reach a Mars sample return need to be clearly defined.

The future challenges address a number of overarching goals, already mentioned in the ESSC recommendations to the 2008 ESA Council of Ministers, including:

- A vision for a European strategy and leadership with respect to global exploration (for context see references 10 and 11);
- Understanding the evolution of the Solar System;
- The importance of a sample return from extra-terrestrial bodies in general (Moon, asteroids, and Mars) and the strategy necessary for reaching these objectives;
- Study of NEOs and their implication in security issues;
- Understanding space weather, including its relevance to robotic and human space exploration.

ESSC recommends that Europe plays a major role in the developing Global Exploration Strategy for the robotic and human exploration of the Solar System (GES 2007 [10,11]). Within this context ESSC strongly recommends that Europe should position itself as a global leader:

(a) By supporting the ExoMars programme as a European contribution to the Global Exploration Strategy. This would be a positive step towards a Mars sample return programme;

(b) By participating through ESA in a lunar lander, and lunar and asteroid sample return missions, together with the associated technology development, as key intermediary steps within the GES;

(c) By searching for ways in which ESA's experience in human spaceflight achieved through involvement in the ISS can be used to support later human exploration missions beyond low Earth orbit.

Furthermore, given the scale of the budgets necessary for these large missions in the exploration of the Solar System, they could serve as a base for excellent collaborative international effort on a broader scale (e.g. with China) within the context of the GES [10,11]. This also includes recognition of the importance of in particular space weather and more generally space situational awareness for space exploration programmes.

Space Technology

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 US and which are of mandatory use in space science and exploration missions. Such technologies include, for instance, detectors for astronomy missions and radioisotope-based sources of energy for Solar System

Three of ESA's ExoMars instrument prototypes are carried on this IARES rover model during tests, simulating the search for places to drill on Mars. ESA will provide the ExoMars rover for the 2018 mission.

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 (Horizon 2020) would be critical and would also give Europe a strong position in international collaborative missions.

These activities include, for instance:

- 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 and feasibility studies of 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, e.g. specific laser sources, low-frequency radars, synthetic aperture optics for observation from geostationary orbits.

ESSC recommends supporting R&D for innovative technology activities in space science and exploration in order to ensure European independence in critical areas and to provide added value to ESA's future developments within the context of a global space exploration effort.

Since the available funding will remain rather constant in the future, technological development activities should be focused not only on developing key enabling technologies, but also on providing cheaper hardware with existing technologies. Only in that way would it be possible to launch more ambitious missions within similar funding envelopes. Otherwise Europe might be overtaken by countries like China, India and Japan in 10–20 years.

In space sciences, as well as in "mainstream" science, the development of innovative technologies opens new fields of research and provides sophisticated new tools for scientists. However, the experience of the past decades of space research has demonstrated that too often a conservative approach to technology is followed, due for instance to the very long development times in that domain. As a result, ESA may have to deal with obsolete technologies in a fast developing field, losing competitiveness and leadership, while Europe looks to ESA for innovation in space. Whatever the reasons, the result is that evolution is gradual and breakthroughs do not happen as frequently as they could.

The domains to be covered admittedly go beyond space-related technologies and address various fields of physical, engineering and life sciences. Indeed in many domains, technology is evolving faster than in the space domain. A way of removing blocking factors and enabling scientific breakthroughs in space could be spinning-in advanced technologies that are not developed for space. Improving the situation therefore requires a development of the synergies between space and non-space technologies. For this purpose it appears important to make use of the classification of thematic disciplines outside the space sector under the broad headings of 'key enabling technologies' (KETs), as identified in 2009 by the European Commission, and in particular nanotechnology, micro- and nano-electronics, photonics, advanced materials and biotechnology. These KETs are indeed expected to be the driving forces behind future European developments. Other areas critical to space, e.g. energy, robotics, biomimetics, or advanced propulsion, should also be included.

The infusion of the best technologies to achieve scientific breakthroughs requires interaction between space and non-space communities and the establishment of partnerships. It is therefore necessary to combine the forward view of space sciences with the forward view of technology in non-space areas. ESSC recommends working towards a better synergy between space and non-space technology, identifying best practices and promising technology transfer mechanisms in both sectors, through a combined effort of ESA, Member States and the EU.

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ISBN: 978-2-918428-76-3
Printing: Ireg Strasbourg

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September 2012 – Print run: 1000