



Public consultation on a Space Strategy for Europe

**European Space Sciences Committee
Contribution**

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Summary of Recommendations

SPACE RESEARCH ON THE EUROPEAN LANDSCAPE

RECOMMENDATION: The European Space Strategy should acknowledge the transversal nature of space sciences and aim at embedding or supporting space-related investigations in all relevant research and technology development programmes. Additionally, when considering space research, the strategy should foster and catalyse a System Approach that would allow various actors and capabilities to be mobilised around a common (set of) objective. These cross-cutting approaches would allow for a better understanding of what space has to offer to a knowledge-based society, as well as what the broader industrial landscape can offer to Space.

INNOVATION FOR SPACE SCIENCES, INNOVATIONS FOR CITIZENS

RECOMMENDATION: The European Space Strategy should allow for the development and implementation of proper spin-off mechanisms that would optimise the impact of space-research related technologies on European innovation landscape and industrial capacity. Innovative supports schemes such as efficient transfer of knowledge to the SMEs should be defined. Commonalities and synergies with efforts led by the EU in other areas than space should be maximised. A challenge for the European Space Strategy would therefore be to help support such commonalities and synergies, and thereby the necessary technology pull to Europe's space programmes.

SPACE RESEARCH AT THE SERVICE OF THE EUROPEAN CITIZENS

Space Situational Awareness

RECOMMENDATION: The European Space Strategy should consider Space Situational Awareness as a structural element of the future European Space landscape. It should pave the way to an efficient (and innovative) European participation in a global monitoring and surveillance system; this should be implemented in coordination with regional, national and international institutions. Such a system should have its continuity guaranteed and should ensure that adequate scientific activities and a robust observation infrastructure are supported.

Environmental Sciences

RECOMMENDATION: The European Space Strategy should provide and secure a long-term vision for the Copernicus programme. This vision should *i)* allow for the emergence of the next generation Earth Observation missions and applications towards future EO services, and *ii)* secure the continuity in critical environmental data production and collection, as well as innovative long-term analysis, modelling and interpretation.

Health Research

RECOMMENDATION: The European Space Strategy should provide a framework to facilitate engaging space life science into translational research in order to fully reap the benefits that these disciplines have to offer to the European population in terms of health and medical research.

Material and Physical Sciences

RECOMMENDATION: The European Space Strategy should provide a framework to facilitate engaging space physical and materials science into innovation and application mechanisms in order to fully realise the benefits that these disciplines offer to European citizens.

TRANSVERSAL ISSUES

Big Data

RECOMMENDATION: The European Space Strategy should encourage and mobilise assistance to research infrastructures supporting activities that produce large amounts of data and that require high computing capacity to exploit them. As to (scientific) data, the European Commission should also support more enhanced and unified networking, pooling and sharing of data and facilities and encourage revisiting existing data with new paradigms and algorithms for data interpretation/presentation/combination.

Reaping the benefits of Cubesats

RECOMMENDATION: The European Space Strategy should address the identification of scientific opportunities made possible with CubeSats, the European Commission should provide support in order to strengthen and expand the European CubeSat community and for the development of CubeSat missions.

Strengthening European Scientific Capabilities

RECOMMENDATION: The European Space Strategy should consider the development of virtual research institutes for domains of strategic relevance and/or that would most benefit from increased European coordination. Building up critical masses, these institutes or initiatives would strengthen the European space research landscape and demonstrate flexibility and adaptability.

European Talents

RECOMMENDATION: The European Space Strategy should develop and implement mechanisms to permit – in the longer term – maintaining knowledge, competencies and know-how in areas where the European scientific community excels at the international level.

RECOMMENDATION: The European Space Strategy should acknowledge the high level of public interest stimulated by space activities (and in particular space exploration) and work towards turning this interest into improved recruitment in STEM high-school and graduate studies as well as improve general STEM literacy of the European citizens. The creation of specific coordinated programs and actions for children, pupils, and young researchers in the field of space research is highly recommended in view of the large shortage of STEM graduates.

EUROPEAN STRUCTURAL ASPECTS

RECOMMENDATION: The European Space Strategy should give strong consideration to Member States research organisations, national agencies and the European Space Agency and to the most appropriate way to optimise interactions and coordination. Although developed by the European Union's institutions, it should be developed in agreement with key European stakeholders and result

in a more efficient implementation of elements of common interest. The strategy should also consider how to allow for a more robust European position in the international cooperation context, with the aim to promote common development and partnerships at the international level, for areas of common interest and in particular for scientific programmes.

NEW STRATEGIC SPACE PROGRAMME

RECOMMENDATION: The European Space Strategy should initiate a new large scale and long term space programme. This programme should be focussed on key scientific challenges. In case the scientific purpose is secondary, the scientific community should nevertheless be involved in the programme definition as early as possible to maximise the scientific return and optimise the benefits for the EU citizens that could stem from this investment.

THE NEED FOR AN ADVISORY BODY FOR SPACE SCIENCES SERVING EUROPE'S SPACE STRATEGY

RECOMMENDATION: The European Space Strategy should equip itself with an independent advisory body, empowered to advise the EU (the European Commission and the European parliament) and other European and national institutions on space matters. This body should be tasked by EU institutions, ESA and the member states and its structure and mandate should encompass the whole scope of space science and technology, from a pan-European and international perspective.

The European Space Sciences Committee

The European Space Sciences Committee (ESSC - www.esf.org/space) of the European Science Foundation is an independent body that regularly provides expert advice to European and National research funding and research performing organisations that support space sciences in Europe. ESSC members are drawn from experts active in all fields of space research on the basis of scientific expertise and recognition within the community, they are nominated *ad-personam* and therefore do not represent any organisation or country.

The ESSC covers the whole spectrum of space-related sciences and is structured around four panels (Astronomy and Fundamental Physics, Earth Sciences, Life and Physical Sciences, Solar System and Exploration).

The mission of the ESSC is to facilitate, support and foster space sciences at the European level by providing unbiased, expert advice on European space research and policy via recommendations or reports directly to decision makers, stakeholders and all interested parties at a national and international level. Furthermore, ESSC provides a unique focal point to assist European national councils and agencies to achieve optimal science return and harmonise strategic priorities in space activities.

The following sections highlight the recommendations and input of the ESSC to the EC space policy consultation on the policy priorities, challenges and opportunities that could shape a future Space Strategy for Europe, from the perspective of the European Space sciences community.

Space Research on the European Landscape

The coming years are full of promise for the European and international space sector. The domain of space remains, and is poised to become even more, a unique opportunity for fundamental science and basic research, but increasingly also a vital component for technological innovation in numerous areas. The space sector now offers several key solutions to challenges that our modern society is facing.

Fundamental Space research delivers answers to the most important questions of mankind: In what environment do we live? Why do we live here? How did the universe and our (and other) solar system(s) develop and how will it (they) evolve. Additionally, fundamental science brings surprises. We can't plan how it will benefit society, but experience shows that it always does. For example, the need at CERN to coordinate between many, many different machines and experiments, hardware and software, support systems and beam lines, led to the development of HTML. This enabled the World Wide Web, an essential part of our modern society.

Space activities such as telecommunication and navigation, operational Earth observation services and security, space engineering and space technology are deeply rooted in European citizens' lifestyle. In return, European societies and economic welfare are increasingly dependent on these services and activities. This intertwining of space activities with our technology-driven societies and economies can also be transposed to research performed in space. Space sciences (also considering research done in space) cover an extremely wide range of sciences, they are everywhere and have relevance and impact on many scientific disciplines: health research (i.e. aging, immunity, stress related responses and cardiovascular diseases), life and environmental sciences, physical and material sciences, to name a few in addition to astronomy and planetary science.

Looking downstream, numerous space-based investigations have direct relevance for technology development (e.g. telemedicine, biomedical research, material engineering, energy production, communications, information technology, robotics, sensors and automation). Acknowledging and catalysing the role and potential of space science has for innovation in Europe would strengthen these

links between research and application and facilitate industry uptake and appropriation of investigations performed in and from space.

As science progresses and tackles more and more difficult and increasingly complex problems, it is vital to follow a 'System Approach' to answer scientific questions, i.e. to study interactions (as for example the sun-planetary interactions) as a coupled system with all available data, not just from one instrument on one satellite. This is particularly true in areas where there are multiple, complimentary assets available to the communities, both in space and on ground (free flying and Earth-based observatories). An integrated approach between ground and space research on selected topics across the full space sciences arena has high potential for progress.

Another aspect of this issue of coordination between ground and space concerns tackling the same problem from different sides (conventional and microgravity/space environments). For example, serious interaction between life scientists and physicists is advisable, since in several cases claims about microgravity effects on biological systems were not supported by a sound physical background (for example: cell mobility studies).

RECOMMENDATION: The European Space Strategy should acknowledge the transversal nature of space sciences and aim at embedding or supporting space-related investigations in all relevant research and technology development programmes. Additionally, when considering space research, the strategy should foster and catalyse a System Approach that would allow various actors and capabilities to be mobilised around a common (set of) objective. These cross-cutting approaches would allow for a better understanding of what space has to offer to a knowledge-based society, as well as what the broader industrial landscape can offer to Space.

Innovation for Space Sciences, Innovations for Citizens

Space is fast becoming a dynamic field where private companies, different in nature from the traditional space companies of old, compete to offer new services in the fields of research, Earth observation, transportation and even exploration. It is thus paramount that Europe remains at the forefront of space development and maintains and strengthens its position as a major space power and a key international partner in all space matters.

The scientific and technical challenges posed by space sciences represent a great opportunity for European industry and citizens. Technologies related to reduction of mass, resilience of space infrastructures, deployment and operation of large scale orbital infrastructure, robotics and autonomous systems (including human-robotic partnership), life support systems, telemedicine, telecommunication, human-machine interfaces, in-orbit servicing, space debris reduction as well as power generation are key enablers of future world class scientific achievements. More specifically, and considering the current challenges in planetary sciences, propulsion, new material for heat shields, new energy sources, and sample return technologies (to name a few) represent contemporary challenges that should be tackled by Europe in a coherent manner.

While they allow scientific progress, all the technologies listed above are fully relevant for the development of innovative products and techniques on Earth. Therefore, it is important to facilitate spin off to the consumers and B2B market. This could be performed not only through direct financial support but also 'in nature' through enabling effective transfer of knowledge from programme-managing institutions to the private sector and in particular SMEs. Alternative ways to the traditional method of direct funding can be exploited, for example access for non-space researchers to space facilities and experts. This would, promote cross-fertilisation and leverage key enabling technologies. In this context, it is also important to foster the development of critical technologies for European non-dependence in order to ensure that the European industry is capable of offering needed

(scientific) capabilities without undue influence of externalities. In particular, and these are critical element to allow future European exploration missions:

- Development of ITAR-free radiation hard components.
- Development of Americium 241 currently performed in the UK, that has the potential to replace the traditional plutonium based radioisotope power systems and the reliance on access to plutonium stocks.
- Development of the ability for high-power space power systems.

The traditional process of technology development in the space sector is known to be gradual rather than breakthrough. This is due to the fact that self-censorship is often applied by teams regarding not yet fully proven technologies for fear of losing in competitive assessment phases. One way to break this evolutionary path and remove some blocking factors would therefore be to spin-in more non-space advanced technologies. A report from an ESA-commissioned 2014 foresight exercise provided clues to flag up main developments in various non-space technological areas. The identification of the level of granularity at which the availability of these technologies could be assessed for potential spin-in led to the choice of the EC-defined “Key Enabling Technologies” (KETs) as references, in order to maximise commonalities and synergies with efforts led by the EU. The KET-related activities address the whole innovation chain and related support by the EC encompasses means to facilitate industrial uptake and commercialisation. Identifying commonalities would be a good way to circumvent the (traditionally) conservative approach to technology development of the space sector and exploit synergic funding. A challenge for the European Space Strategy would therefore be to help support such commonalities and synergies, and thereby the necessary technology pull to Europe’s space programmes.

RECOMMENDATION: The European Space Strategy should allow for the development and implementation of proper spin-off mechanisms that would optimise the impact of space-research related technologies on European innovation landscape and industrial capacity. Innovative supports schemes such as efficient transfer of knowledge to the SMEs should be defined. Commonalities and synergies with efforts led by the EU in other areas than space should be maximised. A challenge for the European Space Strategy would therefore be to help support such commonalities and synergies, and thereby the necessary technology pull to Europe’s space programmes.

Space Research at the service of the European citizens.

Space Situational Awareness

Space Situational Awareness is becoming increasingly important for the European society. Considering the critical importance space assets have on our daily life and also the potential vulnerability of humans and ground infrastructures to major solar events (solar flares and coronal mass ejections), the European Space Strategy should ensure that proper space weather capabilities are available for Europe. The understanding of the Sun-Earth interaction and the phenomena which control the Earth ionospheric and magnetospheric environment, potentially threatening man and manmade infrastructure are needs to be supported by a global network of monitoring satellites and ground based instrumentation, which is presently in the process of maintenance and further built-up. Europe through EU and ESA should take a leading role in the development of such a global system in collaboration with other nations for the benefit of global security and improved forecasting. To that end Europe should invest in suitable space missions (carefully tuned to other international plans) to augment the presently existing global monitoring system, which is becoming of age.

Apart from the obvious importance of being able to monitor the space environment to safeguard space and ground assets, monitoring near-Earth-objects (NEOs) pertains to national and European

security and requires increased consideration at European political and programmatic level. Similarly to space weather, the European Space Strategy needs to provide the grounds for an efficient, continuous and improved NEO surveillance and tracking system. In this context, the use of existing and planned 'non-NEO-dedicated' space platforms and data for NEO detection should also be considered, e.g. using GAIA or BepiColombo observations.

Properly addressing SSA would require coordinated and efficient interaction among national and European research institutions and operational agencies but European efforts alone can neither address the problems of NEO (and Debris threats) nor space weather in a complete and satisfactory manner. Global coordination and collaboration will be essential to create a truly global monitoring and nowcasting system, catering for both on-going and future prediction efforts.

RECOMMENDATION: The European Space Strategy should consider Space Situational Awareness as a structural element of the future European Space landscape. It should pave the way to an efficient (and innovative) European participation in a global monitoring and surveillance system; this should be implemented in coordination with regional, national and international institutions. Such a system should have its continuity guaranteed and should ensure that adequate scientific activities and a robust observation infrastructure are supported.

Environmental Sciences

Copernicus is one of the anchors of the European Union involvement in space and this programme has managed to build up a critical mass and a coherent capacity for environmental monitoring and related operational services. The Copernicus missions provide unprecedented access to high quality operational Earth Observation (EO) datasets. The Copernicus system could be further leveraged by low cost platforms in complementary orbits enabling new measurement concepts. Constellations of small satellites (micro- and Cubesats) have the potential to be used as a complementary follow-on of the current Sentinel series. Such small satellites need a change of the way of designing and building, from the current risk-avoiding approach, towards building in a higher – but acceptable – risk level. This would result in increased EO capabilities at relatively low cost, together with a greater uptake of Copernicus data and new EO services.

Whilst the focus on Copernicus exploitation is understandable and even laudable, the European Space Strategy should ensure that the programme does not only evolve into expensive support for established Copernicus services but rather ensures continued development of future innovative and cost-effective Earth Observation systems and applications.

Earth observations data are of great importance for the implementation of the COP 21 agreement. This agreement calls to strongly reduce the greenhouse gas emissions, which has to be verified by Earth observations data. In this context, the ESSC was active during the COP21 meeting and has issued a relevant statement (<http://www.esf.org/media-centre/ext-single-news/article/essc-statement-on-climate-change-1096.html>). Although there is not yet a European CO₂ satellite mission in-orbit, Sentinel observations of co-emitters, such as NO₂, CO and methane, can be used to verify reductions of the CO₂ emissions. This would result in global improvements of the emission inventories of greenhouse gases, and verification of the reductions agreed at COP21.

Future EO services, including those based on Copernicus datasets, will benefit from the continued development of new applications of EO data and the development of new missions and algorithms. The European Space Strategy should ensure that fundamental Earth Observation research is also promoted within the EU policy.

RECOMMENDATION: The European Space Strategy should provide and secure a long-term vision for the Copernicus programme. This vision should i) allow for the emergence of the next generation Earth Observation missions and applications towards future EO services, and ii) secure the continuity in critical environmental data production and collection, as well as innovative long-term analysis, modelling and interpretation.

Health Research and Life Sciences

Many data show analogies between spaceflight and clinical conditions, for example for patients with osteoporosis, autoimmune problems or nutritional defects. Despite restricted resources on the International Space Station in the past years, the last decades have pushed the European life science in space research to a high level of excellence. A strong ground-based analogue research (bedrest, isolation and irradiation studies) has complemented and contributed to this success.

As examples, the investigations performed in space have applications for the benefit of patients on Earth. Musculoskeletal research for spaceflight is fully relevant to the study of age-related osteoporosis and sarcopenia on Earth and therefore has direct potential for the wellbeing of an ageing population. Similarly, research performed in space on the cardiovascular or immune systems as well as on neurophysiology, nutrition, radiation biology or habitat management allow addressing health challenges, some of which being triggered by our modern lifestyle.

Furthermore, understanding why some of the crew members are affected by space flights more severely than others leads to studying the genetic susceptibility to certain physiological changes. These investigations require the analysis of the underlying molecular and cellular processes with model systems of different complexity and are a concrete example of how space research can support the development of personalised therapy strategies and individualised prevention programmes.

RECOMMENDATION: The European Space Strategy should provide a framework to facilitate engaging space life science into translational research in order to fully reap the benefits that these disciplines have to offer to the European population in terms of health and medical research.

Material and Physical Sciences

The European physical and material science in space has reached a high level of excellence in the last decades. The availability of short time microgravity environments (sounding rockets, parabolic flights, drop towers) allowed to prepare the ISS experiments in good conditions and contributed to this success. In some cases, the available time of these additional facilities was sufficient to obtain important results. Top class scientists became involved, leading to European leadership in the field. The present ESA microgravity programme includes 57 scientific projects, 715 scientists from 33 different countries and 39 dedicated instruments.

The investigations include fundamental physics (atomic clocks, quantum communication in space, quantum tests of principles, plasmas) as well as astrophysics and atmospheric physics. Other investigations deal with fluid physics, combustion and heat transfer (including boiling), which not only allowed to improve fundamental knowledge but also gave important information for the operation of spacecraft: for instance, the 'piston' effect allowing temperature equalisation in space was discovered during ISS experiments (it was believed before that temperature gradients would not disappear in microgravity environments due to the lack of convection). Because of the absence of convection, measurements of the Soret effect (coupling of temperature and concentration gradients) are highly

facilitated by microgravity. Oil industry readily took advantage of this opportunity. Considerable knowledge was obtained in material science including soft materials (foams, granular media including complex plasmas, colloidal glasses) which also benefited to industry. For instance, the ways by which unwanted foams can be destroyed in microgravity environments was clarified recently. Results of material science research in space have contributed to improved competitiveness of European industry.

Besides the direct gain of know-how from microgravity experiments, the necessity to miniaturise scientific setups from table top to small rack-based systems (like in quantum physics where large optical benches can be realised on a chip) and the need to ensure safety in manned space flight is an important technology driver for institutes and industry involved in design and manufacturing leading to new possibilities and applications on Earth.

It is therefore clear that space research not only provides fundamental knowledge increasing our understanding of the way in which our world has evolved and will evolve in the future. It contributes to a better understanding of physical phenomena on Earth and is very valuable to industry. Last but not least, it will also provide key knowledge for the operation of spacecraft and for future space exploration.

RECOMMENDATION: The European Space Strategy should provide a framework to facilitate engaging space physical and materials science into innovation and application mechanisms in order to fully realise the benefits that these disciplines offer to European citizens.

Transversal issues

Big Data

In all domains of science, current and future space assets produce or are predicted to produce a very large amounts of data. The request for the establishment of infrastructure for data analysis and archiving is a consistent appeal from the scientific community. There is a large amount of space missions and ground-based observations acquired by European scientists and agencies that would gain in productivity if they were organised in a coherent way, shared via public databases and properly archived and analysed in a more coordinated way. Also, facilities related to space sciences exist in many European countries, these facilities should be made available for scientists, students and schools in a broader scope, including didactical packages in STEM education. Virtual observatories (e.g. Europlanet VESPA - Virtual European Solar and Planetary Access) are concrete examples of the benefits that modern coordinated data facilities and software can have for the European scientific community. These infrastructures allow to network, pool and make available data, algorithms and computing power from different sources and located in different data centres.

The full spectrum of space sciences communities in Europe would largely benefit from such coherent organisation which would further increase their competitiveness at an international level and appealing for educational systems. The main aim of such an endeavour would be to improve framework conditions, workpower and infrastructure for space data preservation and exploitation, including the development of archives and tools for accessing, processing (including regular re-processing) and dissemination. It would also allow integrating the use of space data in the context of the European e-infrastructures for e-science, including big data and modelling.

Ideally, European space research would benefit from the development of robust cloud services that would go beyond simply making data available and would aim at providing tools for analysis and visualisation. Space data e-infrastructure should support R&D actions either focused in specific scientific domains, merging space data with knowledge and data developed on the ground, or aimed

at linking and associating data from different domains to pursue cross-disciplinary scientific goals as well as policy and socio-economic goals that go much beyond scientific interest.

More specifically, the Copernicus programme offers unique datasets with high temporal resolution that require a new paradigm in data processing. Bringing the process to the data offers many advantages over bringing the data to the process, particularly in efficient data exploitation. The aim of such approach would be to develop processing systems, e.g. based on cloud computing, that enable data processing that do not require the download and storage of huge amounts of data on the users' facilities. Bringing the processors to the data would allow for improved efficiency in data processing, distribution and interpretation, greater uptake of Copernicus data, standardisation in products, algorithms, validation and reliability. The ESA TEP is an example of an external initiative that has proved to be successful.

RECOMMENDATION: The European Space Strategy should encourage and mobilise assistance to research infrastructures supporting activities that produce large amounts of data and that require high computing capacity to exploit them. As to (scientific) data, the European Commission should also support more enhanced and unified networking, pooling and sharing of data and facilities and encourage revisiting existing data with new paradigms and algorithms for data interpretation/presentation/combination.

Reaping the benefits of Cubesats

With the development of 'commercial space', increased opportunities for LEO access at low cost for small, private spacecraft and launchers are appearing on the international landscape. One of the main developments on this era is the development of Cubesats.

CubeSats are small platforms composed of one or several elements (Cubes) of 10cmx10cmx10cm, they usually weigh less than 10 kg and are launched as piggyback payload. From less than 20 specimen launched per year in the period 2005-2011, the number of CubeSat launch increased dramatically to reach more than 120 in 2014 and is continuously rising. CubeSats can be used in many different ways to address scientific issues in most parts of the space sciences spectrum (Earth observation, heliophysics, planetary sciences, astronomy and astrophysics; astrobiology); they can also be used for technology development and demonstration as well as for education purpose at a relatively low cost and with relatively fast development time.

CubeSats provide a new set of mission opportunities sitting between the sub-orbital investigations and the bigger and more expensive orbital platform but they are also more than 'fast and cheap' platforms. Although they have obvious limitations (e.g. size, power, control, data link), they can complement ongoing investigations by e.g. filling coverage gaps (geographic and time) or by allowing for new measurements e.g. made possible by swarm constellations, particularly for NEO, Asteroid and comet exploration in the longer term.

RECOMMENDATION: The European Space Strategy should address the identification of scientific opportunities made possible with CubeSats, the European Commission should provide support in order to strengthen and expand the European CubeSat community and for the development of CubeSat missions.

Strengthening European Scientific Capabilities

Europe has world leading expertise in many areas of space sciences and technology. One of the task of the European Space Agency is to support and maintain this expertise and further develop it by providing access to scientific space missions. National research organisations support these missions by developing their payload and exploiting their data. Some countries support their own space missions. What is missing in the European puzzle is to optimise complementarities and synergies among these efforts. Such coordination would allow better and stronger European integration and cooperation on specific topics. To be efficiently addressed, these topics would need stable pan-European (possibly virtual) programmatic platforms. Such a platforms, enabling –and dedicated to– specific research areas (e.g. astrobiology, exploration, exoplanets) would serve and improve progress on scientific objectives agreed upon through coherent foresight and a road-mapping process. They would represent strong assets for the European space research community/ies. Such platforms should¹:

- Encourage and capitalise from multidisciplinary research, cross diverse space sciences and/or Earth sciences disciplines
- Allow a rational, possibly prioritised, access to relevant research infrastructures and equipment, possibly through development of specific networks
- Allow the implementation of (and mobilise around) a prioritised research plan, taking into consideration the strengths and expertise available in different countries, and allowing them to be further improved and shared
- Provide management, access and archiving of relevant scientific data
- Facilitate the design and development of new techniques and technologies
- Provide stable funding and support allowing to address scientific objectives in the medium to long term
- Catalyse and facilitate undergraduate and graduate education, help with the development of PhD programmes and Postdoctoral opportunities
- Facilitate exchange of scientific and technical staff
- Represent a European anchor for international relations
- Represent a focal point for coherent public outreach and engagement

In this context, the NASA Astrobiology (virtual) Institute, NASA Solar System Exploration Research Virtual Institute and NASA National Space Biomedical Research Institute can be considered as interesting model of efficient, flexible mechanisms that allow to pull together the required expertise around a common science plan. At the European level such virtual institutes would catalyse tremendous scientific achievements while streamlining and optimising the use of funding and infrastructure. These European Virtual Institutes

- should be science-driven with a strong representation of the community in their governance,
- should evolve organically, starting with pilot initiatives such as networks of institutes and laboratories, frameworks for Phd Students/Postdoc exchange, frameworks for the use of infrastructures; and eventually grow towards more institutionalised structures, using the experience gained through pilots,
- should be flexible and able to adapt to the European and international landscape as well as evolving priorities and breakthrough discoveries,
- should be decentralised as much as possible to reap the benefits of the European diversity without involving heavy administrative burden and overhead costs,
- should be, as much as possible, in a position to provide end-to-end funding with a common,

¹ Also from <http://online.liebertpub.com/toc/ast/16/3>

- (set of) scheme(s) to avoid the complication of calling to various funding procedures and principles.

RECOMMENDATION: The European Space Strategy should consider the development of virtual research institutes for domains of strategic relevance and/or that would most benefit from increased European coordination. Building up critical masses, these institutes or initiatives would strengthen the European space research landscape and demonstrate flexibility and adaptability.

European Talents

Maintaining knowledge

Space missions take a long time to be developed and realised. This is often followed by a similarly long phase of data exploitation. Together, these efforts can span decades, or the entire careers of researchers and engineers. Often missions will have phases which require less support (e.g., the cruise phases of BepiColombo or JUICE, but also postponed launches, etc.). These phases pose a substantial risk to the missions because knowledgeable personnel may be forced to leave the project. This sometimes results in a loss of competence and know-how in the teams involved, as well as in a higher level of uncertainty in the optimised operational and data exploitation phases.

Also related to the need for maintaining knowledge and know-how, programmatic planning may lead some discipline to be less engaged in active missions or investigation for time periods that can be very long. One can find such an example with the uncertainty raised by the de-commissioning of the International Space Station sometime in the second half of 2020s. Although schemes are being developed at national level to ensure some level of continuity for life and physical sciences in space, there is currently no integrated European plan to maintain the level of excellence built up in Europe.

RECOMMENDATION: The European Space Strategy should develop and implement mechanisms to permit – in the longer term – maintaining knowledge, competencies and know-how in areas where the European scientific community excels at the international level.

Inspiration for the younger generations

Space has been an inspiration for young people ever since the beginning of the space era. Although the first golden age of human space exploration is now over, the recent planetary science highlights (in particular the NASA and ESA's Cassini-Huygens mission, ESA's Rosetta mission, Lisa Pathfinder and most recently ExoMars starting with its 2016 launch) have drawn huge public attention, including from the younger generation. Space science and space exploration are one of the very few disciplines that have this specificity of being able to draw immense interest and enthusiasm.

Additionally, students and Post-Docs who worked on a space mission have learned how to manage a complex project, to cope with diverse requirements and interfaces, to work within the disciplines of science and engineering, etc. This is an excellent preparation for involvement in or interactions with industry, a sector that space graduates tend to choose to enter, not only in large space companies but increasingly in small SMEs or start-up companies.

Considering the current shortage of graduates in engineering, mathematics and physics in Europe, the European Union should use the interest raised by space activities as a tool to channel and build capacities in graduate STEM education and inspire young students to follow such a career, with specific attention to gender and minority groups.

Considering direct support to young researchers, ERC has created specific programs for young researchers in the area of microgravity research. This interesting opportunity is however allocated to a few individuals only. EC should develop and implement space-science and space technology-related

programs for young researchers, PhD students, and Post-Docs in the form of networks or institutional fellowships, which could benefit a larger scientific community.

RECOMMENDATION: The European Space Strategy should acknowledge the high level of public interest stimulated by space activities (and in particular space exploration) and work towards turning this interest into improved recruitment in STEM high-school and graduate studies as well as improve general STEM literacy of the European citizens. The creation of specific coordinated programs and actions for children, pupils, and young researchers in the field of space research is highly recommended in view of the large shortage of STEM graduates.

European Structural Aspects

Involving different Member States, national research organisation and/or space agencies, European institutions and international organisations, the European space landscape is indeed a complex one. Although very significant progress has been made in the past decade, there is a need for improved coherence between all European space players' strategies; this would allow an ambitious, efficient and optimised native European long-term strategy. Such an overarching 'trans-institutional' (and particularly trans-national) approach on issues of common (European) relevance would strengthen the European space sector and avoid redundant developments driven by individual geo-return considerations and/or parallel developments within different (sets of) bodies.

Ideally, such a coherent vision would translate to 'strategic areas' for the European Space activities and programme, with dedicated budgets and the distribution of funds would happen by the appropriate bodies within those areas. Here it is more than important to stress that fundamental and curiosity-driven research should not be overlooked and should be included in these strategic areas, to ensure optimal long-term scientific developments without immediate short-term technological applications. Such an approach has been taken to some extent with the Horizon 2020 programme Strategic Research Clusters (SRCs) and should be further developed in the wider context of the European Space Strategy (e.g. through the development of virtual institutes).

Such European improved coordination between actors (in areas of common relevance and interest) could be defined and implemented through the work of a reinforced EU/ESA mechanisms with improved tactical and operational capacity.

Beyond Europe, the international space sciences landscape is evolving at a rapid pace, new capacities are appearing and scientific and technological milestones are being completed in non-European countries. Besides USA and Russia, this is particularly the case in Japan, China and India and Europe is in a unique position to exploit partnership with all space powers. Although at the scientists' level, cooperation is a success and progresses internationally, several collaborative projects are hindered by lack of willingness or of capacity to achieve an agreement at a sufficiently high level in space agencies (and/or the overlaying governmental bodies) for political and/or export regulation reasons. An improved European coordination mechanism could also allow the emergence of a European anchor for international cooperation.

RECOMMENDATION: The European Space Strategy should give strong consideration to Member States research organisations, national agencies and the European Space Agency and to the most appropriate way to optimise interactions and coordination. Although developed by the European Union's institutions, it should be developed in agreement with key European stakeholders and result in a more efficient implementation of elements of common interest. The strategy should also consider how to allow for a more robust European position in the international cooperation context, with the aim to promote common development and partnerships at the international level, for areas of common interest and in particular for scientific programmes.

New EC Strategic Space Programme

Over the past years, Copernicus and Galileo represent the biggest and most stable space programmes the European Union has initiated (together with ESA). They are key milestones for the European space sector, both from a programmatic/technological point of view, providing real benefits to society at large, but also because of the important scientific data return to the community. A new flagship undertaking for the European Union would be an opportunity to continue the tradition of excellence established from these programmes.

Space sciences in Europe have been a fundamental factor of success, whether in observations of the Earth, exploration of the Solar system or discoveries in the Universe. Balancing the operational nature of Copernicus and Galileo, the ESSC strongly recommends that a new flagship undertaking for the European Union, if implemented, focusses on space sciences. The selection of topic(s) to be addressed should be performed with direct involvement of, and input from, the European scientific community, following the model of calls for proposals of the European Space Agency. Indeed, the current scientific themes considered by ESA in selected mission studies ranging from life and physical sciences, to Earth observations and astronomical aspects, should also be taken into account.

Any new long-term large space programme would unavoidably have some scientific relevance even as a by-product (e.g. geodesy relevance of the Galileo programme, payload of the EDM on ExoMars 2016). In order to maximise the scientific and societal potential of such a programme, it is critical that the European scientific community be considered as a stakeholder and involved in programme design and definition at the earliest stage.

RECOMMENDATION: The European Space Strategy should initiate a new large scale and long term space programme. This programme should be focussed on key scientific challenges. In case the scientific purpose is secondary, the scientific community should nevertheless be involved in the programme definition as early as possible to maximise the scientific return and optimise the benefits for the EU citizens that could stem from this investment.

The Need for an advisory Body for Space Sciences Serving Europe's Space Strategy

This section underlines a basic need for the EU in space matters in the creation of an independent advisory body in space sciences to offer direct and unbiased advice to the EU regarding space strategy and programme implementation. This is an issue that emerges naturally from the need of pan-European coordination in space matters.

The previous recommendations highlight the need to:

- Create a long term vision and strategy for space that would benefit the EU citizens.
- Coordinate regional and national efforts in European space affairs
- Foster and catalyse a System Approach that would allow for the various European actors and capabilities (know-how) to be mobilized around a common (set of) objective(s).
- Identify commonalities and synergies with efforts led by the EU in other areas than Space (KETs for example).
- Identify scientific opportunities offered by either new ways of doing business in space (i.e. nano- and cube- sats) or major European undertakings (new Flagship projects, following the successful space missions and for example in Earth Observations Galileo and Copernicus).
- Coordinate efforts with international partners and identify areas of common interest for co-development.

Given the increased importance of the EU in space affairs, a trend projected to increase in the next decades, it is essential that the EU receives authoritative independent advice on scientific and technological matters, from a body that can articulate and organise the needs of the wider space community, independently from national, EU or ESA considerations. It is also necessary to fight unnecessary fragmentation and duplication of efforts at European level, carry out regular surveys to assess the status and perspectives of European Space Activities and establish roadmaps and strategic plans that are widely accepted by the community.

The creation of a pan-European expert body, empowered by the EU and by ESA, to directly advise European (and national) institutions in matters pertaining to space, would allow the above needs to be fulfilled and contribute to the effective implementation of the European Space Strategy. Such a body could express the collective voice and vision of the larger European space community, on current and future space research matters. At international level, it could promote synergies between programmes and organisations, by identifying potential opportunities for shared development. Such a body could also offer a 'systemic view' to space research as it would draw its members from the large European pool of established researchers (and not only space scientists) that are vital, active and expert members of the scientific fields in question.

Examples of such bodies abroad are the Space Studies Board and the Aeronautics and Space Engineering Board of the U.S. National Academy of Sciences, Engineering, and Medicine. In Europe, the European Space Sciences Committee of the European Science Foundation already provide independent scientific advice and recommendations and has a recognised role in the EU scientific community. With careful planning and stakeholder engagement, this body could evolve in its mandate and constituency to serve an integrated European Space Strategy.

RECOMMENDATION: The European Space Strategy should equip itself with an independent advisory body, empowered to advise the EU (the European Commission and the European parliament) and other European and national institutions on space matters. This body should be tasked by EU institutions, ESA and the member states and its structure and mandate should encompass the whole scope of space science and technology, from a pan-European and international perspective.

European Space Sciences Committee – Membership as of 16 June 2016

| Title | Firstname | Surname | Affiliation | Town | Country |
|-----------------------|-------------------|----------------------|---|---------------|----------------|
| <u>Chair</u> | | | | | |
| Dr. | Athena | Coustenis | Observatoire de Paris-Meudon | Meudon | France |
| <u>Members</u> | | | | | |
| Prof. | Conny | Aerts | Katholieke Universiteit Leuven | Leuven | Belgium |
| Dr. | Mahesh | Anand | The Open University | Milton Keynes | United Kingdom |
| Prof. | Ester | Antonucci | Torino Observatory of Astronomy | Torino | Italy |
| Dr. | Sarah | Baatout | Belgian Nuclear Research Centre (SCK-CEN) | Mol | Belgium |
| Prof. | Pierre | Binetruy | Université Paris Diderot | Paris | France |
| Dr. | Eva | Boegh | Roskilde University | Roskilde | Denmark |
| Dr. | Ian | Brown | Stockholm University | Stockholm | Sweden |
| Prof. | Alexander | Choukèr | Hospital of the Ludwig-Maximilian University | Munich | Germany |
| Prof. | Paolo | De Bernardis | Rome "La Sapienza" University | Rome | Italy |
| Dr. | Laurence | Eymard | Université Pierre et Marie Curie | Paris | France |
| Prof. | Berndt | Feuerbacher | DLR | Köln | Germany |
| Dr. | Helen | Fraser | The Open University | Milton Keynes | United Kingdom |
| Prof. | Andreas | Kääb | University of Oslo | Oslo | Norway |
| Prof. | Maarten | Krol | University of Wageningen | Wageningen | Netherlands |
| Dr. | Dominique | Langevin | Université de Paris-Sud | Orsay | France |
| Dr. | Luisa M. | Lara Lopez | Instituto de Astrofísica de Andalucía -CSIC | Granada | Spain |
| Dr. | Franck | Montmessin | CNRS | Guyancourt | France |
| Dr. | Karri | Muinonen | University of Helsinki and National Land Survey | Helsinki | Finland |
| Prof. | Hermann J. | Opgenoorth | Swedish Institute of Space Physics | Uppsala | Sweden |
| Mr. | Gerhard | Paar | JOANNEUM RESEARCH | Graz | Austria |
| Dr. | Anne | Pavy Le Traon | University Hospital of Toulouse | Toulouse | France |

| Title | Firstname | Surname | Affiliation | Town | Country |
|--------------|------------------|-----------------------------|--|----------------|----------------|
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| Prof. | Roberto | Piazza | Milano Politecnico | Milano | Italy |
| Dr. | Peter | Preu | DLR | Rheinbreitbach | Germany |
| Dr. | Petra | Rettberg | DLR | Köln | Germany |
| Dr. | Hubertus | Thomas | DLR | Wessling | Germany |
| Dr. | Jordi | Torra | Universitat de Barcelona | Barcelona | Spain |
| Prof. | Stephane | Udry | Université de Genève | Sauverny | Switzerland |
| Dr. | Pepijn | Veefkind | Royal Netherlands Meteorological Institute | De Bilt | Netherlands |
| Prof. | Robert | Wimmer Schweingruber | University of Kiel | Kiel | Germany |