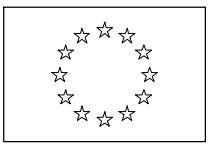

Space Exploration, a new European flagship Programme

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of the European Commission, Framework Programme 7 – Space Theme

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Disclaimer Note

The opinions expressed in this document are those of the authors.

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Executive summary

Article 189 of the Treaty of the Functioning of the European Union (TFEU) indicates the possible creation of a "European Space Programme" as a political goal of the European Union (EU). The SAG considers that there is a need to fulfil this possibility in 2014. To achieve this, the Space Programme should include activities concerning research and technology development, exploration and exploitation of space. In that context, space activities related to navigation, Earth observation, science and exploration can be defined as the main components of the Space Programme.

This SAG advice focuses on the exploration part of the European Space Programme, describing the rationale, impact and main goals to be covered in the period 2014-2020, although some of the proposed activities will continue after that date.

The need for a European Space Exploration Programme is rooted in a number of Council Resolutions in 2008 and 2009, which globally consider space exploration as one of the main priorities for the European Space Policy. It is fully justified by a combination of cultural, inspirational, scientific, political and economic reasons. The impact of space activities for innovation and competitiveness has been a driver for progress in Europe in the past and it will be even more important for the future in the framework of the Europe 2020 Strategy. Space will generate economic benefits for Europe, both direct and indirect, in the space sector and also in other industrial sectors, and will boost employment and investments in high-tech domains. The programmes of the European Space Agency and the intervention of the EU in major space programmes demonstrate the political will to act. The TFEU now provides an expanded basis for action.

The proposed Space Exploration programme introduces three main objectives related to the exploration of the solar system: 1) to support robotics missions to improve the knowledge of the solar system and more specifically of Mars; 2) to prepare the way towards future human flights to beyond Earth orbit towards Mars and other solar system bodies in a later period by building up enabling scientific and technological capabilities and 3) to exploit the ISS and more specifically the European Columbus module for scientific and technological purposes.

The SAG shares the view that "Space Exploration" focused on the aforementioned objectives can take on the role of a new "flagship" for Europe in the rest of the world by providing the impetus for accomplishing the goals of the European Space Programme.

In each of these parts of the future exploration programme, both scientific and technological goals should be covered, bearing in mind the innovation drive that will result from space activities in different economic sectors. The definition and implementation of a clear and plausible technology roadmap and the creation of capabilities constitute an essential part of the programme. Furthermore, a Space Exploration Programme will serve as a catalyser

for increasing international cooperation with other space agencies and stakeholders and for strengthening European leadership. It will also serve as an inspirational driver with regard to the general public, particularly the younger generations, and an element fostering deeper European integration. In parallel, a new comprehensive agreement with a clear distribution of responsibilities between the EU and ESA is also necessary to synergistically exploit the political strength of the EU and the technical and managerial capabilities of ESA.

The implementation of the Space Exploration programme, based on the elements described above, will require substantial financial support. Recent estimates endorsed by the SAG indicate that up to 1.8 billion euros per year coming from the EU budget are necessary in the 2014-2020 time frame to fulfil the intended goals, in addition to ESA's own resources. This will bring Europe on a par with other major world powers. A detailed estimation is not within the scope of this document; the intention is to give the order of magnitude to feed the political discussion within the Community bodies. This amount will cover both R&D and operation and it should pave the way towards a more competitive industrial and academic sector in Europe. The SAG understands that the Space Exploration programme outlined in this document should form part of a true international programme where contributions from other partners (USA, China, India, Russia, etc.) will also be necessary in a coordinated long-term effort.

Based on this analysis, the SAG puts forward five main recommendations:

1. The SAG recommends that the EU become more involved in space exploration by providing the appropriate political, societal and financial frameworks, and by taking full advantage of ESA's financial, technical and managerial capabilities.

2. Europe should build on its tradition of cooperation in space research to ensure that it is a major player in a global exploration initiative and take a leading role for a series of significant missions to Mars and other solar system bodies.

3. Europe shall prepare the operational capabilities and infrastructures enabling future robotic and in a later stage human exploration of Mars and other solar system bodies.

4. In preparation of such human exploration missions, Europe must further develop its key competencies in research and technology for human health research and habitation and environment management technologies by exploiting the unique opportunities of the European participation in the ISS.

5. The proposed Flagship programme on Space Exploration should constitute the major instrument to catalyse and coordinate the involvement of the European Union in space exploration.

Finally, the SAG understands that the involvement of the European Union in the Space Exploration Programme, as presented in this document, will give a clear political signal regarding the way forward to reaffirm the scientific and technological leadership of Europe in the space field. This is also the best way to involve other policy areas in a global strategy to capitalise on the benefits of space on behalf of European citizens.

1. Introduction

The introduction of European space policy in the Article 189 of the TFEU (Treaty of the Functioning of the European Union) in order "to support research and technological development and coordinate the efforts needed for the exploration and exploitation of space" constitutes a relevant opportunity for the European Union (EU). The same article refers to the possible creation of the European Space Programme ("establish the necessary measures, which may take the form of a European space programme") and the need to coordinate the efforts necessary for the exploration and exploitation of space, and represents a crucial step towards rethinking the goals, instruments and funding for space in Europe on a wider and ambitious scale, and to reaffirm the role of space as a catalyser for progress and innovation in many different scientific and technological areas and for wealth generation.

The support of space activities in the EU does not constitute a completely new scenario; it will reinforce the goals of the European Space Policy proposed by the European Commission (EC) and the European Space Agency (ESA) in 2007, and endorsed by Space Council resolutions and by the European Parliament (EP). From an operational perspective, space activities have been addressed in Europe for more than 30 years by ESA in many programmes, and by the EU within the Framework Programme (FP) and associated activities with the main aim of moving towards operational space applications. In this context, the development of European programmes for navigation (i.e. Galileo) and Earth observation (i.e. GMES) both constituted very important elements to strengthen Europe's global position in the field: Both programmes act as "European flagships" on the world stage. This effort is also complemented at national level in the EU through a number of national programmes and space agency activities and, in some cases, with other space agencies or governmental entities from non-European countries.

Noting that Europe has committed to play a major role in international Space Exploration initiatives, and that this global venture will strengthen international partnerships through the sharing of challenging and peaceful goals, the SAG recommends introducing "Space Exploration" as a new major element in the European Space Programme for the period 2014-2020 and develops the rationale and main elements of this recommendation as an integrated and coherent new European flagship programme.

This proposal complements the relevant efforts made by the EU on GMES and Galileo in the past and the necessary continuous EU support to these systems in the near future to ensure their operation and usefulness for European citizens and institutions. The SAG is convinced that both Galileo and GMES will enter into operation and political and economic support for them will be fully assured by Community bodies in the framework of the next financial perspectives. Future European efforts can thus now be placed on a new programme for space exploration since Europe wants and needs to strengthen its world position in the area of space and take advantage of this position for the benefit of its industry and its citizens.

The Council Resolution on "Taking forward the European Space Policy" adopted at the Fifth Space Council in September 2008 identified Space Exploration as one of four new priority areas

for the European Space Policy, underlining the importance of exploration in the context of European space activities. The Resolution highlights "the need for Europe to develop a common vision and long-term strategic planning for exploration", and affirms "that Europe, building on its successful track record in exploration over a number of decades, in which science has been the key driver, is committed to playing a significant role in the international enterprise to explore the Solar system and to develop a deep understanding of the conditions for life to function beyond our planet".

The Council Resolution from the Sixth Space Council in May 2009 reaffirmed "the need to assess the possibilities offered by European Union policies to embed space exploration in a wider political perspective and, recognising that space exploration has the potential to provide a major impact on innovation". This statement points to the important fact that space exploration should not and cannot be seen in isolation. The Council Resolution from the Sixth Space Council also stated that the Council supported the process "towards the elaboration in due time of a fully-fledged political vision on 'Europe and Exploration' encompassing a long-term strategy/roadmap".

"Space Exploration" must thus become an integral part of EU's space activities. A European long-term plan for the robotic and human exploration of the solar system should act as a "flagship" for Europe in the rest of the world. It is a decisive step in the endeavour of humanity of expanding from the planet of origin towards other places in reach in the Solar System. As mentioned in a recent Commission document[1]: "space exploration, and especially human exploration, is a source of inspiration for future generations and can make a significant contribution to strengthening the sense of European identity". Within the EU, space exploration could act as a catalyst for further integration as it would offer all EU Member States the possibility of participating on equal terms in such an inspiring human endeavour. It could also inspire young Europeans to choose a career in science and technology, which in turn would contribute further to future innovation and entrepreneurship.

Article 189 of the TFEU also emphasises the need for cooperation between the EU and ESA ("The Union shall establish any appropriate relations with the European Space Agency") formally governed today by the EC/ESA Framework Agreement signed in 2004 and extended in 2008 for another 4 year period by the Space Council. In the case of Space Exploration this synergy is crucial due to the large experience accumulated by ESA in the past on space missions and its ongoing and planned Exploration missions and the need to increase the role of the EU and the additional funds from the EU budget in the exploitation of space.

This document develops the SAG article on space exploration published in the Journal Space Policy[2]. The SAG will provide additional specific advice on GMES and on the space research

[1] Space exploration and the European Union. European Commission, 2010.

[2] Towards a European vision for space exploration: Recommendations of the Space Advisory Group of the European Commission. Gerda Horneck, Angioletta Coradini, Gerhard Haerendel, May-Britt Kallenrode, Paul Kamoun, Jean Pierre Swings, Alberto Tobias, Jean-Jacques Tortora. Space Policy 26 (2010) 109-112

priorities of the future Framework Programme FP8 in later phases and these aspects will not be addressed in this document.

2. Rationale

The relevance of space in the new TFEU should be reflected in space policies and programmes with the appropriate budgets by extending the scope and ambitions of the EU contribution. There are many reasons that justify the need to devote additional EU resources to Space exploration.

In this document, the term "space exploration" refers to "the combination of robotic and human activities for the discovery of extra-terrestrial environments that will open up new frontiers for the acquisition of knowledge and peaceful expansion of humankind"[3]. The broad scope of this definition requires that the EU prioritise the proposed activities to be addressed in line with the potential financial envelope and technological capabilities.

Over the last decades, Europe has demonstrated a capability to address space exploration challenges through a series of successful space missions. Some of these were designed from the outset as full European developments while, in other cases, they were developed in close cooperation with other non-European space agencies. As a consequence, Europe has gained key competencies, making Europe an essential partner in any global space exploration endeavour.

Europe has contributed to the exploration of the Moon (ESA Moon-orbiter SMART 1 mission and European instruments on the Chang'e, Chandrayaan and LRO lunar missions developed by China, India and the US, respectively), and has received international recognition through their essential contributions to the exploration of Mars (ESA Mars Express and European instruments on NASA's Mars Exploration Rovers) and other celestial bodies.

Starting with Spacelab 1, and continuing with the International Space Station (ISS), Europe has gained a wealth of information on the responses and adaptations of the human body to extraterrestrial conditions, i.e., lack of gravity, altered circadian rhythms and increased exposure to cosmic radiation. This knowledge is of utmost importance and the first step towards safeguarding human health, efficiency and wellbeing on exploration missions[4].

[3] Workshop on Space Exploration. European Commission, 2010

[4] Horneck, G., R. Facius, M. Reichert, P. Rettberg, W. Seboldt, D. Manzey, B. Comet, A. Maillet, H. Preiss, L. Schauer, C.G. Dussap, L. Poughon, A. Belyavin, G. Reitz, C. Baumstark-Khan, and R. Gerzer. HUMEX, a Study on the Survivability and Adaptation of Humans to Long-Duration Exploratory Missions, ESA SP 1264, ESA-ESTEC Noordwijk, 2003.

In parallel, Europe has created its own infrastructure for access to space, and manned spacecraft for the support of humans in space. Its Ariane launchers have been workhorses for the last three decades, now embodied in the Ariane-5, which is able to loft powerful telecommunications satellites, ground-breaking science missions and the Automated Transfer Vehicle (ATV). human spaceflight activities of Europe began in close association with the Space Shuttle programme (Spacelab) and have now reached maturity as demonstrated by the Columbus module now in orbit as part of the ISS, as well as by other essential ISS supplies, e.g., Multi-Purpose Logistic Modules (MPLMs), Nodes and the ATV. The utilization programmes, such as the current ELIPS programme, have produced top-level science in many disciplines. In spite of these efforts, there is currently no clear solution to cover the future European needs for a human launch capability.

Europe's space industry, supported by the programmes of the European space agencies, has developed its skills across a broad swathe of space technologies and systems capabilities. This has not only resulted in a series of successful and increasingly complex scientific and infrastructure missions, but has also made European industry a formidable competitor on the world stage for commercial launch services, telecommunications and Earth mapping missions. The pace of technological and system development in industry currently makes Europe a credible and even essential partner for NASA and the rest of the world.

Finally, Europe has a long-standing tradition of international collaboration, mainly in space science, between ESA and other space agencies (e.g., USA, Japan, Russia, China and India) in areas such as scientific instrumentation, data sharing and other mission elements. The Cassini mission to the Saturn system, with the European probe Huygens landing on Saturn's moon Titan, is a good example of a successful international cooperation programme. At present, ESA plans include a series of robotics missions to Mars thus continuing the past efforts in cooperation with NASA. In short, International cooperation has allowed Europe so far to bring humans to orbit, sustain them in space and bring them back to Earth.

These European space missions have demonstrated that Europe has the capabilities to participate in future space exploration missions. The SAG is convinced that Europe is able to undertake the exploration of the solar system, that such an undertaking is fully within reach if the EU puts all its political and financial weight behind the ongoing European effort carried out by ESA and national agencies and the international partnership, both in terms of technical challenges and economic effort.

A large portion of these activities have been carried out by ESA. The EU has devoted limited resources to space exploration until now. The activities carried out under the Seventh Framework Programme (FP7) on space exploration represent only 15% of the resources devoted to the Space theme in the FP7 Cooperation programme (itself a mere 4.4% of the Cooperation programme and a 2.8% of FP7). On the other hand, the EU position on space exploration has not been absent from the ongoing political discussion and has been instrumental at the High Level Conference held in Prague in 2009, to be followed by another similar conference in the second half of 2010, preceded by three thematic workshops jointly organised by the EC and ESA. All this reflects the political will of the EU to continue and strengthen its involvement in Space Exploration.

The set of proposed activities responds to a vision of "Space Exploration" which can be summarised as follows:

- Space Exploration has become a global undertaking with a huge proven impact on many science and technology fields in the short, medium and long term. Many public and private high-tech entities participate in Space Exploration activities both from scientific and technological perspectives. A major goal of the flagship exploration programme presented in this document is to strengthen European science and technology capabilities and competitiveness.

- Europe has gained key competencies to play a strong role in Space Exploration if a sustained effort is conducted in cooperation, as needed, with other space stakeholders. The cooperation between the EU and ESA offers a useful framework for combining the competences of both institutions in implementing the proposed European flagship programme.

- Benefits from a Space Exploration programme in the period 2014-2020 are not only linked to scientific knowledge but also to technology development, with a potentially huge economic impact. Europe and its citizens will substantially gain from the flagship programme on Space Exploration.

- The combined effects of an ambitious focused research project and its broad range of outputs will also provide a driving force to attract the interest of the younger generation in science and technology and thus will strongly contribute to Europe becoming and remaining competitive in science and technology.

- The activities to be covered in the next period 2014-2020 will pave the way towards additional goals to be addressed after 2020.

In a period of economic crisis and tight budgets when Europe needs to increase innovation and competitiveness[5], it is wise to consider if Europe should wait some years before a full recovery of the economy has been attained before making such a significant commitment. SAG considers that today is the right moment to invest in space exploration. It will be seen that Space Exploration triggers innovation, strengthens competitiveness and creates wealth, three actions required for the desired recovery. To delay the launching of a Space Exploration programme will lead to a loss of the present technical competences, difficulties to exploit European facilities[6] and the difficulty to retain the European talent in our private and public entities. Furthermore, there is a risk that European strategic partners in space will not wait for Europe and our role will be less important in the future and our research institutions and industry will not be able to reap the full benefits of the initiative.

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[5] Council of the European Union, Council Resolution on "The Contribution of Space to Innovation and Competitiveness in the Context of the European Economic Recovery Plan, and Further Steps", 10500/09, 29 May 2009.

[6] More specifically, the European participation in the International Space Station (i.e. Columbus module or AVT).

While the 20th century has initiated the development of the necessary space technology for this enterprise, it is the province of the 21st century to use it for a sustained and ultimately permanent human presence beyond the Earth, physically and culturally.

Within this context, SAG proposes to launch a Space Exploration flagship programme focused on Mars, including both robotic and human flight preparatory activities. Even if the proposed prime target is the planet Mars, NEO's (Near Earth Objects) and the Moon, with robotic missions paving the way for future human exploration, could also be important elements in a stepwise approach to acquire the necessary technological capabilities.

This goal will require a long period of time and substantial resources beyond the 2014-2020 period but the benefits outweigh the efforts as presented in the next section.

The EU should seriously consider a shift in future financial perspectives to be able to obtain benefits from sectors such as space and more specifically space exploration, which are directly linked to innovation.

3. Benefits to Europe and its citizens

3.1. Different perspectives

The proposed Space Exploration programme is a multifaceted proposal with benefits for Europe from several interconnected perspectives:

a. Science

Space exploration will help to gain a better understanding of planetary changes over long- and short-time scales. We know that such planetary changes exist (e.g., the observed climate change on Mars, or the recent changes in Jupiter's red Spot). The interpretation of global change on Earth is complicated by the co-existence of at least three different drivers for climate change: natural drivers (e.g. Sun, volcanism, thermohaline circulation), factors related to the presence of life and the impact of humans/technology. For other planets, the anthropogenic and possibly also the biological drivers are completely absent. And even the number of natural drivers is limited; so planetary changes for Venus and Mars can essentially be attributed to solar-planetary relationships. The applications stemming from the knowledge of these solar-planetary relationships are twofold: they help to gain deeper insight of the climate changes on Earth and they are prerequisites for safeguarding sustained human settlements beyond the Earth.

The scientific drive of Space Exploration is to acquire new insights into the emergence of life and the development of our solar system. The science-driven scenario of Space Exploration, as developed by the European scientific community under the auspices of the European Science

Foundation (ESF) [7], defines the acquisition of new insights into the quest to understand the "emergence of life and its co-evolution with the planetary environments" as the overarching goal of space exploration. The general goal is to understand planetary formation and evolution processes and, if possible, the origin and evolution of life.

Mars is the planet in the Solar system most similar to Earth, and the question of climatic changes, especially the loss of water and atmospheric gases, is fascinating and relevant for understanding the Earth and may contribute towards understanding the evolution of the whole solar system. With Mars Express and the ongoing and planned ESA/NASA Mars Robotic Exploration missions, Europe has recognised Mars as the focus of a science-driven space exploration programme. The ESA plan starts with a series of robotic missions, including the two ExoMars missions, devoted to in-situ inspection and the quest for habitability and the signature of life, and through intermediate missions aims at a sample return programme. In this endeavour, Europe should position itself as a major actor in defining and leading such a Mars sample return programme.

In addition, and even if Mars should represent the ultimate goal, the Moon and Near Earth Objects (NEOs) may represent complementary opportunities to perform unique scientific experiments from their surfaces and open new opportunities for cooperation with international partners particularly interested in those destinations. For NEOs there is the additional aspect of surveillance and overall planetary defence.

By investing significantly in space-based science and playing a strong role in international space exploration, Europe will embrace the spirit of the European Space Policy and essentially "contribute to the knowledge-based society".

b. Technology

Space has always been a driver for innovation to meet the challenges of the missions and to strengthen the competitiveness of industry. Robotic and especially human space exploration will pose new technological challenges not yet faced by space systems and often by any other system:

- Space Exploration implies complex system-of-systems operating with no failure and zero maintenance: ground, transportation, orbiting infrastructure, surface infrastructure, humans.
- Long travel times and operation in confined spacecraft and shelters.

[7] Worms J.-C., H. Lammer, A. Barucci, R. Beebe, J.P. Bibring, J. Blamont, M. Blanc, R. Bonnet, J.R. Brucato, E. Chassefière, A. Coradini, I. Crawford, P. Ehrenfreund, H. Falcke, R. Gerzer, M. Grady, M. Grande, G. Haerendel, G. Horneck, B. Koch, A. Lobanov, J.J. Lopez-Moreno, R. Marco, P. Norsk, D. Rothery, J.P. Swings, C. Tropea, S. Ulamec, F. Westall, and J.C. Zarnecki, 2009, ESSC-ESF Position Paper – Science-Driven Scenario for Space Exploration: Report from the European Space Sciences Committee (ESSC), Astrobiology 9, 23-41.

- New operational capabilities, access to space, rendezvous and docking (RVD), refuelling, descent, landing, ascent, re-entry, surface operations, communications and navigation beyond Earth orbit.
- The extremely hostile environment of space, radiation, temperature, long nights, dusty atmosphere.
- Far from the Earth, limited communication capabilities, very limited ground support and limited logistics.
- High "snowball effect" as 1 kg back to Earth implies many kg upload, to be constrained by the limitations of transportation systems.

Space Exploration will drive innovation in system engineering and technology in traditional space, e.g. propulsion, power, etc., and in new domains such as shelters, health, for example in the following fields:

- New methods and tools for complex systems engineering, verification and validation.
- A dramatic need to increase efficiency in terms performance/resources in all spacecraft systems, platforms, payloads, rovers, implying:
  - Reduction of mass, power energy, volume, fuel, i.e. resource needs.
  - Increase in performance, data processing, sensitivity, thrust, etc.
- Breakthroughs in remote and in-situ instrumentation for probing the atmosphere, the surface and subsurface of the visited body.
- Techniques and instruments for drilling, sampling, sample cache and retrieval, encapsulation and transfer, reception and treatment.
- A new approach to communications and navigation, remote control and monitoring, automation and robotics so as to enable mobility in space and at the surface.
- A completely new approach to operations, autonomy, intelligent systems.
- A totally new approach to human–robot interactions, habitats, resource generation, storage and management, life support systems.
- A breakthrough in health monitoring, physiology, psychology, diagnosis and medicine.

Many of these technologies, driven by the challenging requirements of Space Exploration will also be useful for traditional space systems improving the performance/cost ratio of such systems. Technology developed for Space Exploration will for instance result in more efficient telecommunication satellites. This is critical as satellite telecommunications is the main space commercial market, it drives the launcher market, generates a large service sector and thereby ensures an ample return on the investments made in satellite development.

There are many examples where technologies and products developed for space have inspired non-space industry. Space Exploration developments will also produce spin-offs for terrestrial

sectors. As space will enter new domains such as miniaturization, autonomous systems, new energy and resources generation and management, water and waste management, habitats infrastructure and life support systems, health and wellness, safety, human–robot interaction, augmented reality, etc., the potential for spin-offs will increase. Exploration requirements will make of space the lead user to be followed by other sectors and a preferred partner for joint research and development. Many of these fields have strong relevance to the broader objectives of the EC's R&D programmes and immediate benefits for the European citizens. For instance Exploration technology for water management may significantly reduce water consumption on Earth and increase recycling[8].

c. Economic impact

Space has brought innovation, competitiveness and wealth back to Earth Technologies and products developed for space have been spun-out for terrestrial applications. Space systems, telecommunications, navigation, remote sensing, used separately or in combination, are the basis for applications in key strategic and high economic value sectors, e.g. security, transport, energy, environment, etc., and in daily life. The benefits of space are mainly outside the space sector, in all countries and at all levels, from the individual citizens to companies and institutions.

Space Exploration will multiply the potential of space as a source for innovation and competitiveness in terrestrial sectors and will enhance the potential of space to create wealth and thus contribute to attaining the Europe 2020 objectives.

Space Exploration is one of the most technologically challenging undertaking humans can engage in and it requires innovative solutions to overcome these challenges. This innovation can be used to address societal challenges such as intelligent energy, resources, waste and water management, health and wellness, environment control, etc. By addressing the challenges of exploration, we will therefore invigorate innovation, competitiveness and economic growth well beyond the space sector itself. An active involvement in space exploration will contribute to attaining the Europe 2020 objectives of innovation, competitiveness, growth and employment.

In general[9], innovations from space activities arise from: the creation of novel downstream services based on the data provided by space infrastructure; the transfer, adaptation and use of space technologies in non-space applications (spin-offs); and more general knowledge spillovers to non-space actors and sectors.

In 2008, the turnover of the European Space industry reached € 5.9 bn, with a labour force of some 34,000 employees[10]. In that year, institutional sales within Europe accounted for 60% of the total, whereas commercial markets and exports represented around 40%. In the period 2009-2018, it is expected that the institutional market will represent 68% of the total and

[8] EC-ESA Workshop on Exploration and Innovation, Industrial Competitiveness and Technological Advance, Harwell 29, 30 April 2010.

[9] Space exploration and innovation, Technopolis. June 2010

[10] Eurospace, "facts & figures" 13th edition, rev. 1, July 2009

commercial markets only 32%[11]. These figures demonstrate the importance of this sector, which is also linked to high-tech activities and is a catalyser for innovation.

The economic benefits of an EU Space Exploration programme are, for the purposes of this document, grouped into two main categories, namely direct benefits and indirect benefits. The direct benefits are those directly resulting from the implementation of the programme, while the indirect benefits are those resulting from exploitation of technologies and know-how in other contexts (spillover effects, spin-offs, technology transfers, etc.) even many years after completing the programme.

Higher investments in space will generate high-tech businesses and high quality employment, and will accelerate the change of economic models. Here, the consequences will not only bring benefits for large consortia but also for many high-tech SMEs.

It is likely that the vast majority of the direct public funding will be transferred to the space industry but since Space exploration addresses new technology domains, other high-tech sectors will also benefit. Space Exploration will require between € 1 and 1.8 bn/year which can be compared with the current commercial value of all European civil institutional programmes, estimated at some € 2.2 bn per annum. These resources will also generate economic benefits.

The added value of the European space industry is well above the average of the EU's economy as a whole, as is the case with all high-tech industries. While precise information concerning the added value of the European space industry is not available, figures from the UK indicate that the value added of the upstream space sector is approximately 60 percent of gross sales.[12] This means that if € 1 bn of public funds is spent on space exploration, it will lead to up to € 600 million in direct value added within the space industry itself. This figure is considerably higher than figures found in other industrial sectors.

The European space sector directly employed some 34,000 people in 2008. The increase in turnover that would result from an EU Space Exploration programme will certainly increase sector employment. If one assumes that the sector's productivity would stay the same after the turnover increase, the direct effect of an EU space exploration programme worth € 1 bn to the industry would be some 5000 new jobs in the sector. Current employment elasticity indicates a small effect on employment (in absolute terms, the direct effect on employment in the EU will be limited) but a significant improvement in productivity is expected.

It is more difficult to analyse the indirect effects of the space exploration programme on the space sector. The Danish Agency for Science, Technology and Innovation in 2008 and the Norwegian Space Centre in 2009 concluded that € 1 million in funding to ESA generated an

[11] Questionnaire and background paper. Conference on Governance of European Space Programmes. La Granja (Spain), 3-4 May 2010.

[12] "Size and health of the UK space industry 2006", British National Space Centre

additional turnover between € 4.5 and 4.6 million on average.[13] If the situation with the proposed space exploration programme were similar, € 1 bn will generate € 4.5 bn in additional turnover with a value added of up to € 3 bn. On the basis of such estimates, and assuming that the present labour productivity in the space sector would stay at present levels, the direct and indirect effect on employment in the space sector for each € 1 bn of EU funds invested would generate some 24,000 jobs, although the short term effect is likely to be lower.[14]

Benefits are not limited to the space sector, although the spill-over effects on other sectors can be very difficult to estimate with precision. A recent study on the economic benefits of UK public investment in space indicates that for every euro invested in aerospace R&D, a turnover of 70 cents is generated in other sectors. Less recent studies conducted in the US indicated that the return on investment for each dollar invested in space R&D was slightly more than seven dollars over an 18 year period[15].

An example of an area that could benefit significantly from space exploration is that of manufacturing. For instance, the development of robots having the potential to cut costs in everyday life, such as personal and service robots, or in the area of safety, such as in the decommissioning and clean-up of nuclear power plants. The knowledge developed will lead to technology transfer into the terrestrial economy and this is of paramount importance for the Member States of the European Union. The size of the world-wide market in only these indicated areas is of the order of several billions of euros per year.

Furthermore, there is an indirect effect which should be specifically emphasised: the creation of new high-tech companies in different sectors based on technology or knowledge derived from space activities. The creation of spin-offs is becoming a significant factor in restructuring the European industrial fabric.

d. Inspiration and Education

Space Exploration has the potential to inspire people, particularly the younger generations. The search for life and its evolution beyond our own planet has the potential to arouse mankind's curiosity. Human space exploration has the potential to become an ambitious adventure for mankind, opening opportunities for great science and outstanding technological achievements. Education efforts, from kindergarten to graduate students, publicising space

[13] Evaluation of the Danish Industrial Activities in the European Space Agency (ESA), Danish Agency for Science, Technology and Innovation (2008), and Norwegian Space Centre Annual Report 2008.

[14] Present labour productivity in the space sector is some 190 000 Euros per employee, based on Eurospace data. However, the Danish study referred to in footnote 13 suggests that the effect on employment from 1 million Euros of direct turnover increase is some 1.9 full time jobs, and some 0.8 full time jobs per 1 million of indirect turnover increase. These figures suggest that the impact on employment would be lower, at least in the short to medium term, due to relatively low employment elasticity and improved labour productivity.

[15] This includes ALL impacts, i.e. the direct and indirect impact in the space sector and outside. Midwest Research Institute. "Economic Impact of Stimulated Technological Activity." Kansas City, Missouri, November 1971

exploration activities and fostering hands-on experience on space data exploitation and space hardware development will raise the next generation of space researchers and engineers, which are so urgently needed for fulfilling the ambitious goal of Europe's involvement not only in space, but in general for excellence in science and technology so as to become the most advanced society in the world.

The conclusions of a recent EU-ESA workshop on science and education[16] specifically supports space exploration as an integral part of schools curricula in order to motivate the young generation to study and engage in S&T careers and therefore contribute to the development of the knowledge society.

A human mission to Mars constitutes the next and most challenging real exploratory adventure of humankind after practically all areas of our planet have been accessed by human beings and the Moon has been visited as well. There is no doubt in our minds that it is certain that humans will eventually go to Mars and perhaps other bodies in the solar system. This is a crucial factor to "inspire" future generations of European citizens.

In these activities the EU should take the lead thereby combining the already existing different national activities. The combined effects of this ambitious focused research programme on space exploration and its broad range of output will provide a driving force for the interest of the younger generations in science and technology and thus will strongly contribute for Europe to become and stay competitive in science and technology.

e. International cooperation

Europe should build on its key competences and its tradition of cooperation in space research to become a major player in the global exploration initiative and take the lead for some key elements of a global space exploration programme.

Space exploration has become a global challenge for the 21st century. Wide public and political acceptance can only be achieved if Space Exploration is truly the undertaking of all humankind in a unifying global cooperation strategy. Fourteen space-faring nations through their space agencies – including ESA plus four European member states – have already agreed on a loosely coordinated technical approach, the "Global Exploration Strategy"[17].

Europe traditionally seeks cooperation in space research. It is not only intra-European cooperation, as embodied by ESA, but also with foreign powers. Significant achievements of the European space programmes were made possible through international cooperation. ESA's Mars Robotic Exploration is currently being developed in collaboration with NASA, by jointly preparing 3 missions to Mars, ExoMars including an orbiter and a small lander to test

[16] Conclusions and recommendations by the Chairs, Moderators and Rapporteurs EC-ESA Workshop Workshop in Science and Education within Space Exploration. Strasbourg, 29-30 April, 2010

[17] http://www.esa.int/SPECIALS/Columbus/ESAAYI0VMOC_0.htm14. The Global Exploration Strategy, The Framework for Coordination, May 2007, developed by ASI (Italy), BNSC (UK), CNES (France), CNSA (China), CSA (Canada), CSIRO (Australia), DLR (Germany), ESA (European Space Agency), ISRO (India), JAXA (Japan), KARI (Republic of Korea), NASA (USA), NSAU (Ukraine), Roskosmos (Russia). http://esamultimedia.esa.int/docs/isecg/Global_Exploration_Strategy_Framework.pdf

technology to be launched in 2016 and a twin rover mission, an ESA rover together with NASA Max-C, in 2018, and a further mission foreseen in 2020. Furthermore, a Mars Robotic Exploration Preparation programme is establishing the architecture and developing technologies for the future Mars Sample Return mission. Moreover, the experience with the International Space Station (ISS) shows that cooperative space programmes build links between countries, and between industries and laboratories from around the world, which then further develop in non space related activities, with positive impact on the economy and on scientific research.

Many technical platforms have been created to exchange information on space exploration, on the Moon (International Lunar Exploration Working Group - ILEWG) and Mars (International Mars Exploration Working Group - IMEWG). Most recently fourteen space agencies – including ESA plus four European national agencies – have laid out the basis of a coordinated technical approach, the "Global Exploration Strategy"[18]. As a consequence, the International Space Exploration Coordination Group (ISECG) was formed in 2008 with the aim of providing a platform for early information exchange between these Agencies for coordinating plans and identifying opportunities for international cooperation.

So far, the major cooperation efforts have taken a bottom-up approach, addressing technical efforts. With the expected involvement of the EU in international space exploration ventures this will change, as will international cooperation between Europe and other countries. The EU will bring to exploration the political dimension that is currently lacking in Europe. This will complement the technical expertise of ESA and national space agencies. The EU is in close consultation with ESA and should be able to better coordinate European space exploration activities to have a greater impact on the international scene. The EU could facilitate the creation of a global political forum to discuss space exploration coordination among major world powers (e.g. G8 or G20) to develop a robust multilateral architecture politically supported that will then help to define global governance and missions implementation through an adequate technical platform.

European leadership in a global Space Exploration programme will be an effective tool for implementing European international policy. It will first strengthen the European position regarding the utilisation of space and will extend beyond space to other domains.

f. European identity

After the approval of the new EU Treaty, it is essential that the EU play a central role to ensure the success of future European space exploration, not only to give a clear political signal for the way forward but also to ensure an appropriate financial framework. The EU will thus embrace the spirit of the European Space Policy and "contribute to the knowledge-based society by investing significantly in space-based science and playing a strong role in

[18] http://www.esa.int/SPECIALS/Columbus/ESAAYI0VMOC_0.htm14. The Global Exploration Strategy, The Framework for Coordination, May 2007, developed by ASI (Italy), BNSC (UK), CNES (France), CNSA (China), CSA (Canada), CSIRO (Australia), DLR (Germany), ESA (European Space Agency), ISRO (India), JAXA (Japan), KARI (Republic of Korea), NASA (USA), NSAU (Ukraine), Roskosmos (Russia). http://esamultimedia.esa.int/docs/isecg/Global_Exploration_Strategy_Framework.pdf

international space exploration." This generic goal should be shared by all European citizens, which in the near future would recognise the EU efforts in the field of Space and specifically in Space Exploration as an integral part of the EU. The role played by the European astronauts to reinforce the European identity of all citizens is a relevant example in this direction.

As a European flagship programme, Space Exploration will contribute to strengthening European identity as a set of objectives that we achieve together. Achieving this within the frame of international partnership is a must, and cooperating as Europe as opposed to single nations will strengthen European identity.

g. Space Exploration contribution to Europe 2020 Strategy

To reap the scientific, technological, economic, inspirational and political benefits and strengthen international cooperation and European identity, Europe must devote substantial effort to Space Exploration. Such a substantial EU support to space exploration would contribute to reaching the general EU target for R&D intensity, and it would contribute to reducing the gap between EU and the US public sector expenditure on space. Furthermore, it would most certainly contribute to the concept of an innovative union where "ideas can be turned into products and services that create growth and jobs", as the Europe 2020 strategy puts it.

The European Commission's Communication on the Europe 2020 Strategy[19] sets out the main objectives and goals for the EU in the coming ten years. The strategy puts forward three priorities, all relating to growth: These priorities are met by the Space Exploration Flagship Programme.

- Smart growth: developing an economy based on knowledge and innovation. Smart growth as space R&D effort is significantly above the average R&D of the economy and creates wealth and knowledge intensive jobs.

- Sustainable growth: promoting a more resource efficient, greener and more competitive economy. Sustainable growth as it addresses key enabling technologies of the future and provokes breakthroughs needed also for terrestrial applications, e.g. energy, water and resources, health and wellness, etc.

- Inclusive growth: fostering a high-employment economy delivering social and territorial cohesion. Inclusive growth as it implies space and non-space industry, research institutions, traditional and new domains all across Europe and in international cooperation.

3.2. What if Europe did not opt for an ambitious space exploration programme?

[19] Europe 2020 Strategy. European Commission. March 2010 (endorsed by the European Council on June 17).

Continuing space exploration activities at the present level and failing to initiate an ambitious European flagship Exploration project in the near future will have a number of undesirable consequences for Europe:

a. Loss of leadership in future space activities; weaker role in cooperation with other agencies outside Europe.

b. Innovation will not happen in space and terrestrial areas to the extent it would have been fostered by the challenges of Space Exploration.

c. Loss of competitiveness of European space industry as it would not have access to the advanced efficient technologies developed for Exploration. This will result in loss of markets and lower performance and higher-cost internal European institutional systems.

d. Weaker role of space as an international policy tool. The positive impacts on other sectors will be lower than expected.

e. Lack of exploitation of past efforts (i.e. ISS) where the existence of a long-term programme of activities during the life of the facility should represent an opportunity.

f. Difficulties keeping skilled scientists and engineers in Europe, which would be tempted to join other more ambitious space programmes.

g. Difficulties and critical delays to react on time when new opportunities arise due to the lack of knowledge or available human resources.

It is thus necessary to develop an ambitious Space Exploration programme as a new European Flagship as described in the following sections.

4. A European flagship for solar system exploration

4.1. Space flagship in brief

The SAG recommends "Space Exploration" as the next European Space flagship programme of the EU.

Existing examples of flagship programmes are Galileo and GMES. Like them, Space Exploration has the potential to:

a. Bring benefits to a large number of users in society.

b. Drive advances in science, technology, engineering and management.

c. Contribute to making the European research and engineering communities more productive and efficient, and establish new networks.

c. Give Europe a leading role in the domain.

d. Build a long-term programme with a first development period of at least 10 years.

e. Mobilise a substantial European budget of the order of several billion euros.

f. Be performed autonomously by Europe or in close cooperation with other partners with a clear European leadership.

Space Exploration has all the ingredients (goal, impact, novelty, ambition, inter-disciplinary research, resources, curiosity, plausibility and sustainability) necessary to constitute a European flagship. Setting up such a European flagship concept is instrumental for Europe to realise its ambitions.

4.2. Implementation

To implement the Space Exploration Programme proposed in this document, both the intended destinations, the implementation approach, technical capabilities, European coordination and international coordination in the period 2014-2020 should be outlined.

Destinations

The Space Exploration flagship should focus on targets that can ultimately be reached and inhabited by humans.

The SAG endorses the progressive approach of ESA based on building blocks and taking into account the "flexible path" of the Augustine report[20], that identifies Mars, the Moon and NEOs as destinations for Exploration and proposes the development of capabilities to reach such destinations.

The SAG recommends Mars as the ultimate destination. However, without losing sight of this principal destination, the SAG recommends that the Space Exploration Flagship address also the other destinations mentioned above when they represent instrumental intermediate steps towards the final goal, benefiting from ESA actions and seizing opportunities of cooperation with partners. The SAG believes that such a "flexible path" makes the roadmap more robust with respect to programmatic constraints and international cooperation.

The Space Exploration Flagship must bring a change in paradigm in planetary exploration. Instead of the single Mars rover or sample return mission approach, the community must engage in the setting-up of very capable robotic missions leading to a stable infrastructure followed by manned missions which should be prepared in parallel by developing the necessary knowledge and enabling technologies.

Stepwise and modular approach

Space Exploration promises benefits but entails risks. It has to be conducted in a stepwise and modular manner whereby capabilities are progressively acquired and deployed in steps. Each

[20] Seeking a Human Spaceflight Program Worthy of a Great Nation, Review of U.S. Human Spaceflight Plans Committee ["The Augustine Report"], Washington D.C., October 2009.

step must be valuable in itself, providing tangible results, and as part of the roadmap to the ultimate destination of Mars.

The first steps should be performed robotically due to scientific, technical, cost and efficiency reasons. Such steps are under preparation by ESA with partners and include the Exomars missions with NASA and preparation for intermediate missions towards a Mars Sample Return mission. These steps should be strengthened so as to allow permanent infrastructure at the destination, both in orbit and at the surface, for robotic exploration and sustaining human presence.

Europe will then possess a permanent robotic infrastructure on Mars, a network of bases whose efficiency will increase as the various missions of the flagship programme proceed, and taking full advantage of latest technological developments. It is only with this kind of investment that Europe will be able to play a leading role in integrated exploration architecture worldwide.

Manned missions to Mars will only become feasible in the next decades if they have been preceded by a well-planned series of robotic missions and by appropriate research and technology developments enabling safe human presence and operational efficiency on the Moon or Mars. Safeguarding the health and wellbeing of humans and ensuring reliability in their performance will drive technological developments, which will be beneficial for terrestrial applications, especially in medicine, information technology, automation, communication, biodiagnostics and biosensorics, as well in solving environmental problems, such as waste and water management. The ISS will serve as ideal platform for these research and technology developments.

Key to Solar System Exploration and especially to human exploration is access to space. Issues such as what transportation system, launcher, cargo transport, upload, return, and crew transport shall be addressed and a decision taken as of which capabilities need be developed.

Development of Enabling Technical Capabilities

In Fig. 1 (from ESA) the different technologies underlying a space exploration programme are exemplified for a Mars exploration programme. Each of the circles in the Figure 1 represents a huge technological challenge which should be overcome to make the Space Exploration goals a reality.

- Access to space: launcher, including man-rated launchers, cargo (upload and download) and crew vehicles.
- Transportation capabilities: propulsion, rendezvous and docking and berthing, propellant storage, refuelling, descent and landing, ascent and re-entry.
- Mobility enabling capabilities: communications, navigation, remote control.
- Scientific and support instrumentation: remote and in-situ sensing of the atmosphere, surface and subsurface.

- Surface operations, mobility, rovers, sensors, actuators, algorithms, communications, sampling, drilling, sample cache, retrieval.
- Automation and robotics.
- Dependable and resilient systems.
- Power generation, storage and management.
- Sustainable habitats: safe shelters, thermal control, resources and water management, waste management, etc.
- Health and wellness: bio-hazard containment, sample handling, remote disgnosis and medicine, physiology and psychology, etc.

The ISS offers unique capabilities to develop and demonstrate in-orbit technologies related to sustainable habitats and health and wellness, and other. Such capabilities shall be exploited and the exploitation shall be facilitated. Europe has to balance its ambitions and capabilities, its interests and the potential of international cooperation.

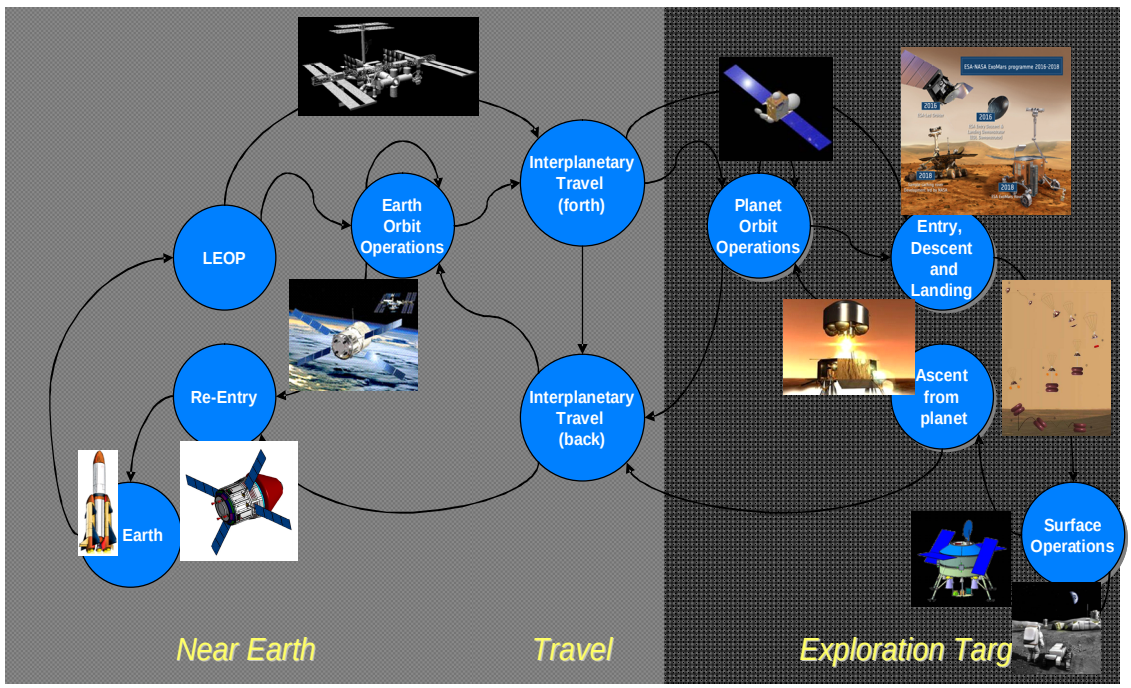

Figure 1. Technology developments required for different scenarios of space exploration

The modular concept of the Space Exploration program could serve as a basis for addressing some of the technological challenges through parallel missions conducted by Europe or by other international partners in a global strategy. Moreover, the stepwise approach advocated for Space Exploration allows the achievement of results from the beginning in science and technology through the robotic missions and the delivery of capabilities that bring breakthrough innovation in key technology domains such as those associated to the preparation for human space flights.

SAG recommends that roadmaps be drafted, capabilities identified, scenarios set-up with the partners and capabilities developed in support of the agreed stepwise deployment.

European coordination

A European vision for space exploration requires commitment and cooperation of all stakeholders, the science community, industry, the public, and the policy makers.

European Space Exploration must be based on cooperation between EU and ESA as stated in article 189 of the TFEU. ESA's demonstrated technical and managerial capabilities in large complex space programmes will be augmented by the EU's political weight.

From the SAG's perspective, it is also necessary to reinforce the long-term cooperation between ESA and EU with Space agencies of their Member States for defining joint contributions to the roadmap of the Space Exploration Programme. The public-private and EU-Member States partnerships embedded into the European Strategy 2020 should be fully exploited in this case.

International cooperation

The global character of Space Exploration as an undertaking of humankind has already been stressed. The magnitude of the challenge means that international cooperation is not only desirable but is a necessity. The proposed stepwise and modular approach should allow the definition of robust scenarios for international cooperation.

In this international initiative, Europe must strive for its independence and continue to develop its own critical technologies for non-dependence. It should be noted that ESA has a long-standing tradition and experience in cooperating with other agencies and this will be particularly valuable for the future Space Programme. This aspect deserves a specific analysis and it will be addressed in section 5.

The 2014 –2020 period

The activities for the first period 2014 – 2020 shall be conceived within the concept of a stepwise and modular approach, coordinated with ongoing and planned ESA and Member State activities, and as part of the international effort. It is also recommended that emphasis be given to activities likely to generate immediate spin-offs in other space domains and in terrestrial sectors. The following list includes Space Exploration activities to be covered by the EU and ESA. A strong coordination is needed to ensure their success.

- Robotic Exploration

  In this period, the two Exomars missions and a further mission are planned by ESA in addition to the preparation for the Mars Sample Return mission to be carried out in cooperation with the US in the next decade. Although the majority of the new effort would be required after the 2014 – 2020 period, it is recommended that the preparation of basic technology and capabilities, as well as facilities, be started in the aforementioned period.

Robotic missions to other parts of the Solar System could be initiated, as well to test new technologies, demonstrate new concepts, and act as precursor missions for future human ventures. ESA is planning a lunar lander mission for 2017 as a precursor for human missions beyond low Earth orbit. It is recommended that the EU support robotic missions to NEO's for scientific objectives, to demonstrate technologies, support space surveillance, planetary defence, and to scout potential targets for subsequent human exploration.

- Support to ISS

The ISS has been identified as an excellent facility to conduct research and development in preparation of human space flight. Current discussions on the use of ISS within the Framework Programme explore synergies between Cooperation (Space priority) and Capacities (access to research infrastructures) specific programmes. Within the coming discussions on the future FP8 structure and budget, this issue will take on full relevance.

The operation and utilisation of the ISS beyond 2015, to 2020 and possibly to 2028, is currently being discussed by the international partners. Such extended operation entails the evolution of the ISS, the provision of better logistic capabilities, heavy-lift launch capabilities, cargo upload and download capacity and crew transport. Utilisation requires a robust research and development programme, including demonstration of capabilities.

It is recommended that the EU support ISS operation, evolution, logistics, and utilisation. Concerning utilisation, the EU's efforts could be focused on the development/demonstration of capabilities for sustainable human space flight. The preparation for the post-ISS infrastructure also needs to be considered.

- Development of capabilities

A set of enabling capabilities has been identified.

It is recommended that ESA and EU agree on the capabilities to be developed in the period considered, including when applicable deployment of precursor demonstration missions. Furthermore the EU should provide support for R&D on new technologies enabling space exploration related to human survivability in space, generating major societal benefits.

- Access to space

ESA is developing the evolution of Ariane 5 and Vega and preparing a new launcher generation. Furthermore, ESA is considering the development of an automated re-entry vehicle. Eventually, Space Exploration will also require a man-rated heavy-lift launch vehicle, cargo vehicles and a crew transportation system together with associated facilities and it is recommended that the EU Space Exploration Flagship address these aspects.

5. Europe's role within the Global Exploration Initiative

International cooperation has been historically embedded in space activities. ESA has a long tradition of cooperation with other agencies (i.e. with the US, Russia, Japan) and some of the main programmes running today are true international endeavours. The example of the ISS is of paramount importance in this field. In these cases, the knowledge, experience and facilities provided by other partners outside Europe complements the European capacities and will allow the proposed goals to be reached.

The SAG considers that European leadership is not contradictory to the promotion of stronger international participation. Europe should strive to remain the so-called "partner of choice" in future activities and thus be in a position to attract other partners by engaging in ambitious ventures and seek cooperation with both established and emerging space powers. Through its emphasis on international cooperation, a space exploration flagship programme would help to reinforce Europe's position on the international scene.

ESA and the space agencies of its member states Italy, France, Germany, and UK are participants in the ISECG. This technical platform presents a global vision for robotic and human space exploration, focussing on destinations within the solar system where humans may one day live and work. Its aim is to define an action plan for sharing the strategies and efforts of individual nations so that all can achieve their exploration goals more effectively and safely. Prime targets for space exploration are the Moon, Mars and finally places beyond, with the ISS serving as a necessary stepping stone towards enabling space exploration (see Figure 2).

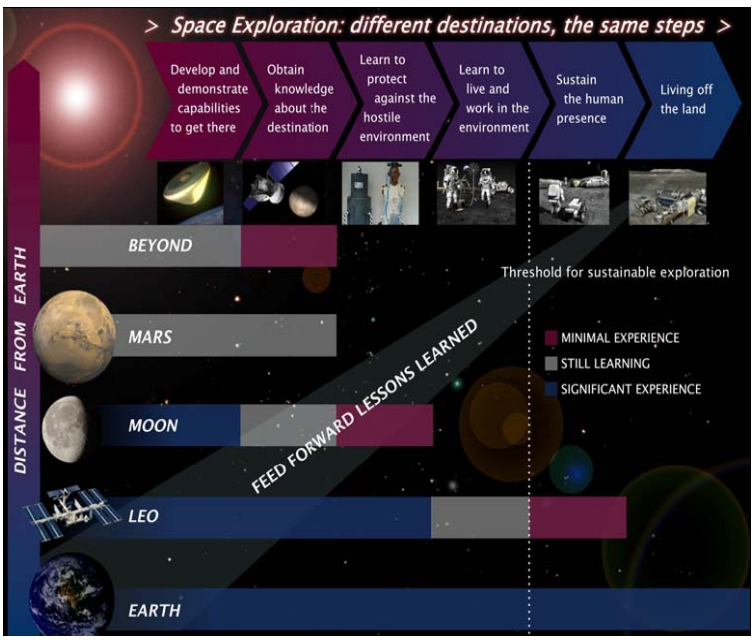

Figure 2. The different steps of space exploration as shown within the Global Space Exploration Strategy in 2007[21].

[21]http://www.esa.int/SPECIALS/Columbus/ESAAYI0VMOC_0.htm14. The Global Exploration Strategy, The Framework for Coordination, May 2007, developed by ASI (Italy), BNSC (UK), CNES (France), CNSA (China), CSA (Canada), CSIRO (Australia), DLR (Germany), ESA (European Space Agency), ISRO (India),

With the ISS, the first major international space endeavour for peaceful cooperation on a global scale has been achieved. If Europe plans to continue this international cooperation in space and become a more active player in future international human-exploration endeavours, the necessary preparations need to start now. Lessons learned from previous undertakings indicate the need for more political support.

The involvement of the EU will provide a clear added value for Europe's commitment in the international context. The EU (in synergy with ESA) would be able to provide a clear political dimension to space exploration, transcending current technical platforms (e.g. ISECG) and strengthening and protecting European interests.

6. Funding needs

The ambitions of the Space Exploration Flagship Programme require a substantial increase in the financial resources currently available in Europe, over and above those already available through ESA and their Member States. The EU is best placed to gather consensus across all Member States and mobilise the significant additional financial resources required. It is therefore considered essential that the EU have a dedicated budget for the implementation of a Space Exploration programme and the associated research and development activities, so as to ensure that the goals set are given the appropriate resources to ensure they can be achieved.

The EU could thus take a central role in defining space exploration objectives and coordinating European exploration programmes, both robotic and human, in agreement with ESA and their respective Members States. ESA should continue to act as the European implementing agency for space exploration endeavours due to its long and extensive expertise in running challenging and complex space programmes, e.g. Galileo and GMES for the EU. Europe, through the EU-ESA partnership, would thus acquire a significantly increased weight on the international space exploration scene.

A budgetary balance between robotic and human exploration activities should be respected taking into account the different time scales, with a clear value-added of the EU intervention with respect to ESA activities. In particular, while the EU involvement should focus on new space elements providing benefits to European citizens, it needs also to demonstrate tangible results in the next financial perspectives to enable future long-term developments.

For Europe, the continuity of ESA's on-going robotic activities should be ensured, and particularly the robotic Mars missions (ExoMars, MREP). Specific preparatory activities for a Mars Sample Return (MSR) mission, to be performed in cooperation with the US around 2026, should be supported. Though most of the project activities would only start at the beginning of next decade, preparation should start now.

JAXA (Japan), KARI (Republic of Korea), NASA (USA), NSAU (Ukraine), Roskosmos (Russia). http://esamultimedia.esa.int/docs/isecg/Global_Exploration_Strategy_Framework.pdf.

The detailed definition of the contents of the future European space exploration programme is beyond the scope of this document and only the main components have been outlined in section 4.2. and Table 1 below reflects the contents by allocating annual resources to the main components. It shows two options, mandatory and enhanced, the latter corresponding to independent human access to space.

Figures included in the table summarise the current discussions between ESA and the Commission. The SAG considers that this budget breakdown (up to € 1.8 bn) would be a good basis for detailed discussions between all relevant stakeholders in order to define the final budget for the Flagship Exploration Programme.

As the resources and time needed for the "Independent human access space" component are significant, a political decision on this issue after detailed technical analysis is crucial. The SAG recommends the launching of a dedicated discussion on this specific issue, involving ESA, Community bodies and relevant national policy makers.

Building block	Estimated annual cost (million €)	Option
ISS operation and exploitation for Exploration	250	Mandatory
Robotic missions (MSR and NEO missions)	350	Mandatory
Development of capabilities for a sustainable human presence in space	200	Mandatory
Education, training and dissemination	100	Mandatory
Independent human access to space	900	Enhanced
TOTAL	1,800	

Table 1. Proposed yearly EU financial contribution to the European flagship space exploration programme

The "independent human access to space" item included in table 1 will require the completion of all the previous items and it will provide a clear added value over the current Space Exploration programmes.

For comparison, it is convenient to recall the planned investments in the US for the next five years. Excluding ISS utilisation and robotic missions already planned, NASA will devote roughly $ 10 bn per year to Space Exploration[22], i.e., an order of magnitude more than European investments over the same period. Furthermore, other countries with large space programmes, such as Russia, China and India, are considering space exploration activities with substantial resources.

In order to assess the relative importance of the budget presented above, it is highly relevant to consider the public expenditure on space per capita compared to other countries. Figure 3 (data from the European Commission) summarises the situation.

[22] Laurie Leshin. A new Space Enterprise: overview of the President's FY 2011 Budget Request. March 30, 2010.

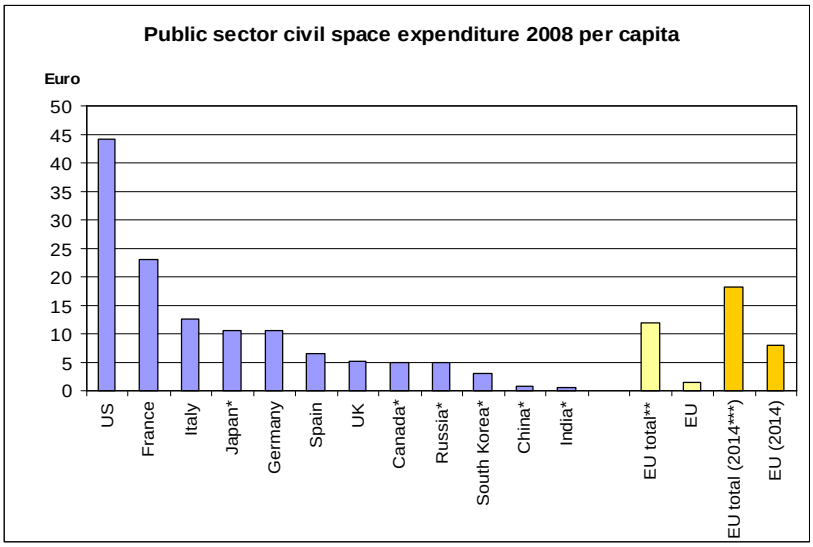

Figure 3. Public expenditure for public-sector civil space (Source: EC[23])

A rough analysis of the main budgetary chapters indicates the relatively small amounts devoted to space until now. Figure 4 shows the EU budget 2010 (€ 130 bn) per area. Space represents a mere 0.7% of the total. SAG considers that there is clearly room for improvement during the discussions of the next financial perspectives 2014-2020 in the frame of the Europe 2020 Strategy.

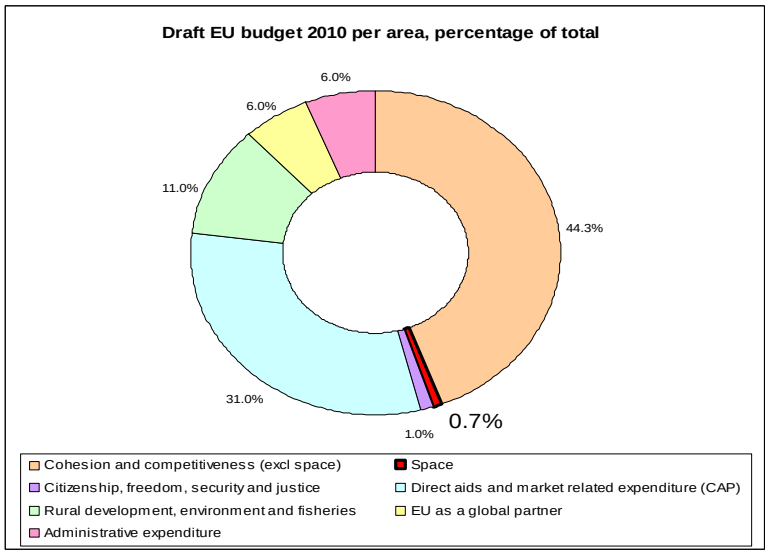

Figure 4. The relative weight of space budget in the EU 2010 budget (source: EC[24])

[23] The figures are indicative and based on a study by Ecorys N.V. and OECD data. *The public civil space budgets for Japan, Canada, Russia, South Korea, China and India are assumed to be two thirds of the total public space budget. **"EU total" includes EU, ESA, EUMETSAT and EU Member State national space budgets. ***The estimate for "EU total 2014" represents the scenario that the EU space budget would increase to € 4 billion, and that all other budgets stay the same.

[24] The total EU budget in 2010 is approximately € 142 billion. The fraction devoted to space is composed by the FP7 Space Theme (approx 1/5) and Galileo (approx. 4/5).

In the context of EU support to R&D, the € 1.4 billion allocated to the FP7 Space theme represent less than 3 percent of the financial allocation to FP7 as such, which in comparison seems highly insufficient. In the EU, public sector civil space expenditure per capita was some € 12 per capita in 2008 – almost four times less than in the US. The advantage the EU currently holds over some relatively populous non-EU space nations is likely to decrease over time if the EU expenditure does not increase substantially.

7. Recommendations

Based on the previous discussion, this SAG advisory paper has identified five main recommendations:

1. The SAG recommends that the EU become more involved in space exploration by providing the appropriate political, societal and financial frameworks, and by taking full advantage of ESA's financial, technical and managerial capabilities.

   The role of the EU is of paramount importance for future European space exploration, not only to give a clear political signal for the way forward but also to ensure that the necessary resources are made available, leading to a substantial increase in the European budget for solar system exploration. To cover all the proposed objectives, an annual contribution of € 1.8 bn would be needed over the 2014-2020 timeframe. An EU annual contribution of about € 900 million is deemed the absolute minimum necessary. An additional equivalent sum of € 900 million per year would be also needed to develop an autonomous European capability to send its astronauts into space.

   Such an exploration programme has several facets, including the scientific drive to acquire new insights into the emergence of life and the evolution of our solar system. These will drive the need for innovative technological and system developments. Space exploration has the potential to inspire people, particularly the younger generations, and foster a greater European integration by harnessing an ambitious forward-looking challenge that will help provide solutions to many societal challenges.

2. Europe should build on its tradition and experience of cooperation in space research and exploration to become a major player in the global exploration initiative and take a leading role for a series of significant exploration missions to Mars and other solar system bodies.

   Europe has gained key competencies in several scientific and technological areas from its past space activities, making Europe an essential partner in any global space exploration endeavour. Europe should acquire the key strategic competencies essential for Europe to maintain this position, while reinforcing its independence within a global cooperation initiative on space exploration, and strengthen Europe's space identity.

   It is essential that the EU play a central role to ensure the success of future European space exploration. It will bring a new political dimension to European exploration activities. Europe will thus embrace the spirit of the European Space Policy and "contribute to the

knowledge-based society by investing significantly in space-based science and playing a strong role in international space exploration."

3. Europe shall prepare the operational capabilities and infrastructures enabling future robotic and human exploration of Mars and other solar system bodies.

   Even if human missions to Mars will not be possible for several decades, it is necessary to develop the necessary knowledge and technologies to make this feasible. It may be necessary to use other intermediate targets.

4. To prepare for such human exploration missions, Europe must further develop its key competences in research and technology for human health and habitation and environment management technologies by exploiting the unique opportunities provided by the European Columbus laboratory of the ISS.

   The efforts carried out until now in the development of ISS and, more specifically, in the construction of the Columbus module and its exploitation, represent a necessary step to prepare future human exploration. These activities should be complemented through other programmes for assessing the challenges faced by humans on very long-duration missions.

5. The proposed Flagship programme should be the principal instrument to further the involvement of the European Union in space exploration.

   This will ensure that space exploration is given the budget it requires, not only to ensure success, but also to give credibility to a European leadership position in such a challenging scientific and technological field, as well as in its numerous spin-offs.

Annex: List of acronyms

ATV: Automated Transfer Vehicle

ESA: European Space Agency

EC: European Commission

EU: European Union

FP: Framework Programme

GMES: Global Monitoring for Environment and Security

ILEWG: International Lunar Exploration Working Group

IMEWG: International Mars Exploration Working Group

ISECG: International Space Exploration Coordination Group

ISS: International Space Station

MPLM: Multi-Purpose Logistic Modules

MREP: Mars Robotic Exploration Preparation

MSR: Mars Sample Return

NEO: Near Earth Object

NASA: National Aeronautics and Space Administration

R&D: Research and Development

SAG: Space Advisory Group

S&T: Science and Technology

TFEU: Treaty of the Functioning of the European Union

UK: United Kingdom

US: United States of America