Space research in Horizon 2020

Recommendations of the FP7 Space Advisory Group (SAG)

Approved at SAG plenary meeting of 16 June 2011

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Disclaimer Note

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

Acknowledgments

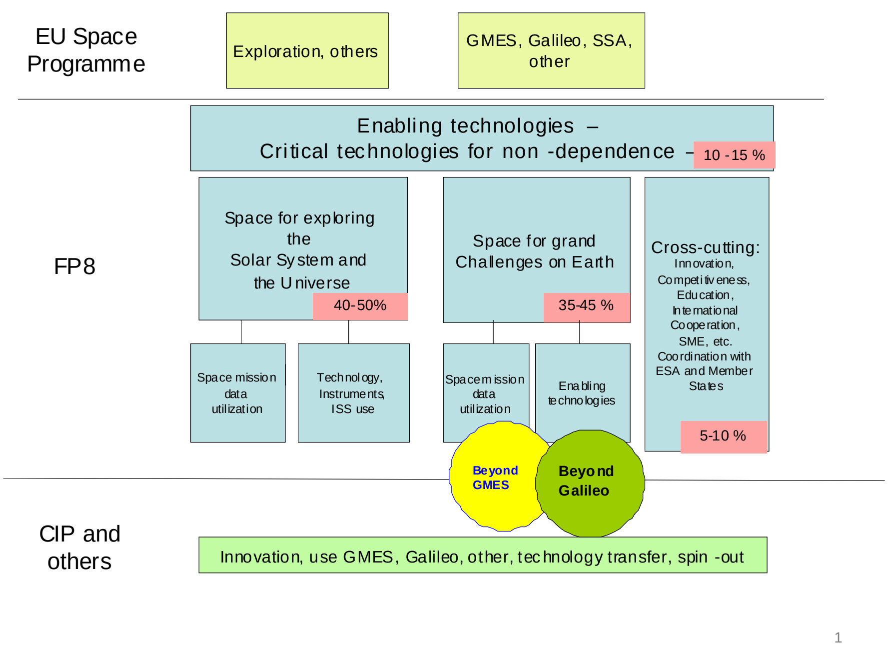
The SAG would like to thank the officials of DG Enterprise, who contributed to the preparation of this document through their participation in discussions, and the provision of relevant data and documents.

I. EXECUTIVE SUMMARY

The conclusions of the Space Advisory Group's deliberations, and thus the leitmotiv of this document's conclusions, is that Space must be a major and well-funded[1] theme of the Horizon 2020[2], commensurate with the strategic importance of this major industry sector, scientific discipline and human endeavour, and in line with the European Union's newly-established mandate to specifically address the space domain (TFEU[3], Article 189). In contrast to space infrastructure, which has been managed by ESA for several decades, space research, technology development and innovation is fragmented in national programmes. To harvest the societal benefits of space and to ensure a leading role for Europe in future space programmes, a substantial and coherent EU level space research and innovation programme is required.

Major space initiatives are becoming increasingly global endeavours as the costs involved go beyond the available resources of any single nation, and because space is by its very nature a global issue. This includes space science and exploration and also the global response to the challenges on Earth such as climate change, management of environment and resources, security on Earth, etc. If Europe intends to remain a serious global player, it must invest to ensure that its current space know-how remains at world-class level; otherwise it will simply become a minor partner in any future global space initiative.

Beyond GMES and Galileo, and in addition to Exploration, as stressed in the 2010 SAG advice towards a Flagship programme, the Horizon 2020 programmatic actions in space recommended here are to be implemented through three main pillars based partly on enabling technologies, as described in the schematic below:



[1] This is further supported by the conclusion of a Hearing organized by the EC on Dec. 8, 2010, attended by 160 participants: "Main conclusion from the event is that stakeholders see Horizon 2020 as an indispensable instrument for supporting European space research and for ensuring that Europe remains a leading player in space science, technology and innovation".

[2] Horizon 2020 is the current working title of the successor to FP7, also referred to as FP8 or the Common Strategic Framework (CSF).

[3] Treaty of the Functioning of the European Union, Lisbon version of 2007, in force since 1 December 2009

The principle recommendations and key areas for support put forward by the Space Advisory Group may be summarised as follows:

1. Space has a very strong technology development dimension, but it should be highlighted that space goes far beyond technology: it is an industry sector in its own right with very major contributions to both societal challenges and science, whilst being heavily dependent on research to continuously foster its technological development. As such, space should find a position within the overall Horizon 2020 scheme that is commensurate with its significant and growing importance.
2. Horizon 2020 must aim to support the competitiveness of European industry and promote innovation, in particular by supporting:
   - The internal market in Europe for space and the aggregation of service markets
   - Measures that strengthen the industrial chain
   - The adoption of instruments suited to these types of actions and the promotion of innovation and SME participation
   - Technology development, supporting industry- or consortia-defined roadmaps
3. Horizon 2020 must take into account the potential for cooperation and the stronger competition in the new world context.
4. Horizon 2020 shall complement the overall European effort with clear objectives and mechanisms and provide additional resources, in coordination with the existing programmes.
5. Horizon 2020 shall support research for:
   - Bridging the current gap in the exploitation of data from both scientific and operational space missions
   - Preparing future missions, including Earth-based preparatory research programmes as stepping stone for space exploration
   - The scientific exploitation of the ISS
6. Horizon 2020 shall support the education and training of the next generation of space scientists and engineers
7. Horizon 2020 shall support space technology by:
   - Devoting greater resources to the development of basic technologies for space with emphasis on critical technologies for strategic non-dependence
   - Supporting upstream technology development (low TRL level), breakthrough technologies and open innovation on enabling technologies
8. Horizon 2020's support to space must take into account the long lead times for preparing and executing space missions (e.g., international exploration missions) and should adopt a long-term programmatic approach, which should also foster collaboration between academia/research institutes and industry.

II. *SETTING THE SCENE*

II.1. Scope

Following the presentation to the European Commission by the 7th Framework Programme Space Advisory Group of an advice paper on space exploration[4] it became clear that the recommendations that paper should be integrated in the more general framework of future space R&D endeavours. For this purpose, the Space Advisory Group constituted a restricted sub-committee with the objective of presenting the European Commission with recommendations on the role the space theme should to play in Horizon 2020, expected to run from 2014 to 2024.

It immediately became evident that space ought to be an important and adequately funded theme within Horizon 2020. Undoubtedly, in the wake of the political evolution leading to the end of the Cold War, space became of an increasingly global nature as the telecommunications industry and further on such projects as satellite navigation systems, Earth observation and meteorology so well proved in the most recent years. In fact, the space sector has shown an exceptional dynamism, growing in real terms at around 9% a year since 1999, showing also, at national level, spin-offs at almost 5% and spill-over effects generating a social return of around 70%. Also for these reasons major space initiatives are increasingly becoming global endeavours as the costs involved go beyond the resources available to any single nation. Projects of that sort indeed include also space science and exploration, together with the global response to major challenges on Earth such as climate change, the management of the environment and dwindling natural resources, as well as security on Earth. All these projects and their follow-up, with strong repercussions for the global economy, are also heavily and continually dependent on research and technological development. Europe, willing to remain a serious and uncontested global player in this domain, must invest accordingly, thus ensuring that its current space know-how remains at world-class level, whilst endeavouring to lead in specific areas. If this is not achieved, Europe will be relegated to playing the role of a minor partner in any future global space initiatives, the plans for which are now advancing very quickly.

Beyond the European flagship projects, which will soon become entirely operational (principally Galileo and GMES), and in addition to space exploration, the programmatic actions in the space theme recommended in the present advice are proposed to be implemented[5] through three pillars located under the general umbrella of "critical technologies for European non-dependence/enabling technologies", themselves already acknowledged as a main driving force behind the development of future technologies and services needed by European society from a complementary perspective: enabling technologies with regard to the horizontal issue of competitiveness and critical technologies to ensure the future role of the European space industry.

This advice develops and presents the relevant arguments, descriptions and suggested remedies for the above issues.

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[4] Space Advisory Group of the European Commission Framework Programme 7 – Space Theme, *Space Exploration, a new European flagship Programme,* Brussels, 10 October 2010.
[5] See schematic presented in executive summary.

II.2. <u>The development of the space sector</u>

In the past fifty years, immense progress in our understanding of the universe, the knowledge of our solar system and our planet, including its environment, has been improving through relentless breakthroughs in the space sector. Also, more recently, our ability to predict with increasing accuracy, reliability, integrity and availability some critical components of the Earth complex systems have brought important benefits to humankind.

Because of their implicit nature, space activities have long time scales as even the commercial satellite telecommunications market with relatively short delivery times needs continuous technology development. The long lead-times needed, the massive initial capital investments required and the heavy reliance on initial research, technological development and continuous innovation, do not make this sector one of the most immediate and easiest to invest in; suitable support mechanisms have therefore to be established. On the other hand, it seems that the general public is still unaware of the diversity, span and significance space activities play in everyday life: in fact, space activities assist navigation, provide data and services about the Earth and its changing environment, forecast the weather, deliver global communications and broadcasting all over the world. With the implementation of the most recent environment monitoring systems, vital information on disaster forecasting, prevention and relief are already leading to timely humanitarian aid. All these depend increasingly on the use of space technologies, which also address other applications such as distance education, telemedicine, precision farming, land use management and monitoring of various international treaties and is extending to new domains such as air traffic management support, maritime surveillance, energy, monitoring of vulnerable zones (e.g. the Arctic) and others, to the extent of becoming a ubiquitous socio-economic reality.

Paradoxically, despite the critical role that space activities play and will play in modern society, the space sector is one of the least developed in terms of robust, internationally comparable statistics. It is therefore hard to find and quote a coherent and all-inclusive series of indicators, which allow the characterisation of this sector worldwide.

Despite these considerations, the added value of space is a fact of daily life, supported by uncontested figures. Space generates wealth, as shown in Fig. 1, illustrating the added value of space from satellite manufacturing to applications, telecommunications, navigation, Earth Observation and the high potential for integrated applications. The ratio of end-value to investment for satellite manufacturing can vary significantly from year-to-year (i.e., it is a lumpy market dependent on the deployment of fleets or constellations), but can be considered to be on average several tens of Euro for every Euro invested. Moreover, the overall impact can be much wider, for example in the case of operational meteorology, which contributes to a large fraction of economic activity and personal safety in Europe and worldwide. Furthermore, technologies initially developed for use in space have been applied in other strategic sectors of human activity, particularly in the transport, energy, security, healthcare and defence sectors. Fig. 1 also shows the high relative importance of telecommunication satellite market itself with respect to other satellite markets. This stresses the importance of industrial competitiveness as telecommunication satellites are sold in the world commercial market.

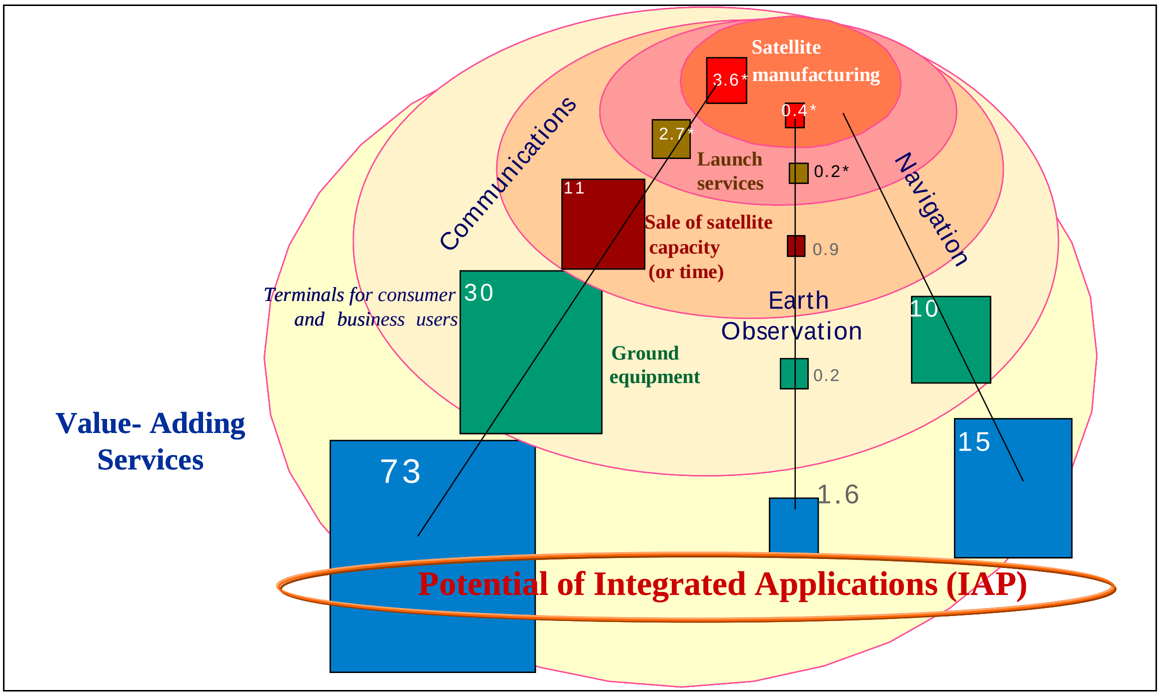

Fig. 1. *From satellite to applications 2009, in B€ (Euroconsult and ESA Telecommunications and Integrated Applications))*

There are also similar indications at national level. For instance in Norway the space sector spin-off has been constantly increasing, as reported by the Norsk Romsenter, from 4.3 in 2004, reaching a maximum of 4.7 in 2009[6] and by the Forskning- og Innovationsstyleren[7] quoting a spin-off of 3.7 to 6.7, according to the different programmes and averaging 5.4 without tax distortion.

On the other hand the space industry is growing in real terms at around 9% a year since 1999, more than three times faster than the economy as a whole[8], its productivity being more than four times the average; with "a turnover comparable in size with the web design industry and larger than market research, software publishing and call centre activities".

Technological advances resulting from research and technological development investment in the space industry can be transferred to other actors in other sectors in the form of spill-over effects: research by the Oxford Economics, using data from 25 European economies and the United States and Canada suggest that such spill-over effects amount to research and technological investment by the aerospace industry generating a social return of around 70%[9]. The space industry also helps to improve the performance of the wider industry partly through non-space sectors and between space industry and leading research organizations and universities.

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[6] This means that, for instance, in 2009 for every million Norwegian kroner of government support, space sector companies have attained an additional turnover of 4.7 million Norwegian kroner. See Norsk Romsenter's Annual Reports of 2004 through 2009, with the exception of 2006, which was not available.
[7] Forskning- og Innovationsstyleren, *Evaluation of the Danish Industrial Activities in the European Space Agency (ESA)*, Copenhagen, March 2008; and Forskning- og Innovationsstyleren, *Evaluation of Danish Contributions to Space Research*, Copenhagen, August 2008.
[8] Oxford Economics: *The Case for Space: The Impact of Space Derived Services and Data*, Final Report – July 2009, commissioned by the South East England Development Agency.
[9] This means that every 100€ invested in R&TD leads to an increase in the GDP of 70€.

Europe has been performing very well. European science missions have enabled major discoveries and today Europe is a leader and a desirable partner. Europe has a large part of the commercial launcher market and European industry competes successfully in the commercial markets such as telecommunication satellites, remote sensing systems, etc., to an extent larger than the European share of institutional funding in the world context. The success of European industry on commercial markets is fundamental for its viability and therefore for the affordability of European indigenous space systems such as GMES, Galileo. Fig. 2 shows the turnover of European industry per market.

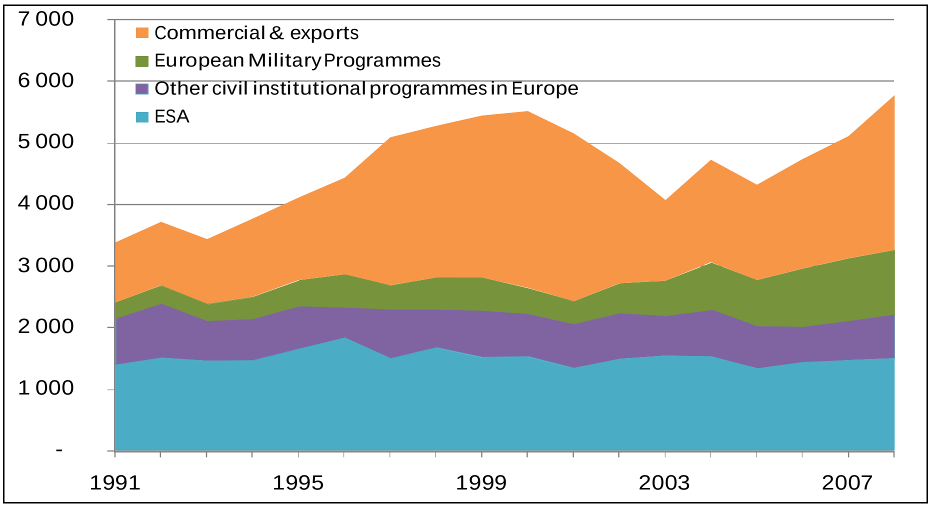

Fig. 2 *Markets of European industry (Eurospace)*

This position cannot be taken for granted. Traditional competitors benefit from economies of scale in internal markets and massive investments in technology. New competitors emerge with institutional investments increasing at a much higher rate than in Europe. Fig.3 shows the variation in institutional investment for major space players.

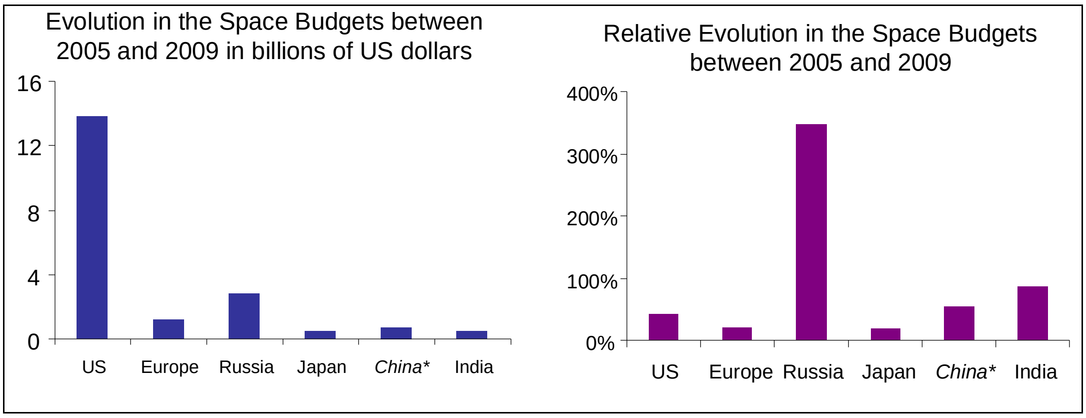

Fig. 3 *Evolution space budget of major players (ESA TSLTP derived from various sources)*

If Europe intends to remain a leader and an essential partner and if European industry is to continue to be competitive, institutional investments in space must be strengthened.

Note: The overall European stability has nevertheless remained remarkable, although the relative decrease in the numbers of European launches and instruments is quite alarming (see OECD data in annex 1).

II.3. The political and institutional framework

II.3.1. The European Economic Recovery Plan

In May 2009, the European Council considered "that, in view of the acknowledged contribution of space to the overall competitiveness and innovation potential of the European economy, space activities and their applications should receive full consideration in the use of funds allocated to economic recovery", thus anticipating the essential role of the highly productive and dynamic space sector in the European Economic Recovery Plan[10]. A strong Horizon 2020 would contribute to the European Economy Recovery Plan (see II.3.7.).

II.3.2. The Treaty of Lisbon

More recently, the Treaty on the Functioning of the European Union[11] (TFEU) gave a new and improved relevance to space activities: in order "to promote scientific and technical progress, industrial competitiveness and the implementation of its policies, the Union shall draw up a European space policy"; furthermore, its article 189 also foresees that under the auspices of the EC "the Union shall establish any appropriate relations with the European Space Agency", thus institutionalizing a long and excellent symbiotic relationship between both organizations.

II.3.3. The Seventh Framework Programme and the lessons learned from FP7

Apart from the continuously maintained, and substantial strategic research and technological development activities comprehensively carried out over the years by the European Space Agency with its Member States, the European Commission's Seventh Framework Programme has also fostered efficiently this innovative process: for the first time space was taken as an independent theme in its own right, promoting further important projects, particularly, but not exclusively, in the domain of GMES.

FP7 devotes 85% of the available resources to push forward the development of the GMES system and applications. The rest of the resources are being used for strengthening space foundations and a limited set of cross-cutting issues.

With GMES now entering its operational phase, the FP can focus on R&D, and has the possibility to address other space priorities, including not only areas not funded or only slightly covered in FP7 but also entirely new areas.

From the present situation, several lessons from FP7 can be extracted where Horizon 2020 can help:

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[10] European Council: *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, Brussels, 29 May 2009.
[11] The Lisbon version of 2007, in force since the 1st December 2009.

1. Priorities should be commensurate with the available resources. Some FP7-space calls included a long list of possible topics in areas where only one or two projects could be funded. This produces a waste of effort and a lack of focus in participants.

2. Several topics are also related to other FP7 priorities or specific programmes and a joint effort through some mechanisms like joint calls could be considered. One example is PEOPLE or CAPACITIES.

3. Horizon 2020 should reflect better than in FP7 the strengthened cooperation with ESA in areas where activities will require a clear combination of efforts from both institutions. Clear cases are technologies where efforts have to be aligned along clear roadmaps and the ISS experiments. In FP7 the exploitation of ISS was lower than expected. Another case is the development of integrated applications.

4. The development of mission enabling technology(ies) is a definite priority and it should have a specific funding scheme in order to combine the effort of individual (and somehow disconnected) R&D activities in a "mission-oriented envelope". This type of experimental missions should be defined with the space agencies, be consistent with the 2010 SAG advise for Exploration, and have a clear role towards technology maturing in space.

5. Due to financial limitations, FP7 has not been able to support sufficiently scientific research. This is unfortunate as the number of missions in operation delivering top class data is higher than ever before and a unique infrastructure such as the ISS is ready for scientific use. Furthermore the number of missions in preparation and the number of new scientific issues to be addressed is also larger than the means. Horizon 2020 should provide substantial contributions to the associated scientific research.

6. As of today, international cooperation has had no clear roadmap. Different work programmes or calls address some target countries without a clear relationship with the call or with previous calls. This element should be clarified in cooperation with other national agencies outside the EU.

A key action line in FP7 has been the support to the development of critical technologies for European strategic non-dependence. This responds to the European Space Policy and the Space Council Resolutions and in terms of contents follows the recommendations of the EC-ESA-EDA Joint Task Force so as to address issues identified in an agreed process. Experience shows that:

§ There is significant interest by all European actors in having the EU strongly supporting critical technologies
§ The present mechanisms are not the best suited to implement technology developments, e.g. co-funding, no guarantee for development in a system of calls, no customer specifications, in terms of performance and quality, no reference development plans, no commitment to deliver, etc

II.3.4. <u>The International Conferences on Space Exploration</u>

In 2009 and 2010 two international conferences on space exploration took place among the established and emerging space-faring states, which acknowledged that "space exploration satisfies the desire of humankind to discover new horizons". The conferences also highlighted the need to establish an international high level exploration platform and, after a consultation within the European Union and the ESA member states[12], invited these[13] to:

- Examine the feasibility of a European space exploration strategy building on existing competences, strengths and priorities.
- Support the extension of ISS at least until 2020 and strive for its exploitation at the general level.
- Initiate further reflection on an international common space exploration transportation policy.
- Establish in 2011 long-term roadmaps and associated programmes for technology , in particular in critical areas such as life support, automation and robotics, novel energy sources and storage and advanced propulsion.

II.3.5. <u>Space as a means to face present and future "grand challenges"</u>

Europe, as the rest of the world, is facing major challenges, some of them identified, as an example, in the Lund Declaration of 2009: global warming and its severe effects, tightening supplies of energy, water and food, ageing societies, public health, pandemics and security. Space can and must provide a substantial contribution to address these challenges. In many ways, such challenges will be addressed by remote sensing and operational meteorological systems, allowing to understand climate and environment and their process and the definition of proper management measures, telecommunications and navigation for the creation of wealth and the improvement of life, in-space research for progress in health and wellbeing, and many other areas that would result of research being carried out in relevant programmes during Horizon 2020.

Space science and space exploration are challenges in themselves, and stand out alongside humankind's greatest achievements. And the next steps will be even more challenging in space science and space exploration, both robotic and human. Overcoming such challenges will not only deliver the best science but will also result in major advances in technology in many domains with significant benefits outside the space sector.

Spin-offs from space exploration technologies will be of direct benefit for such societal challenges such as climate change (energy generation and storage), healthcare (increased understanding of cardiovascular and ageing-related disease through the exposure of astronauts to microgravity), natural resource management (water recycling technologies) and energy supply (new robotic technologies for the extraction of oil and gas resources), to name but a few.

[12] EC-ESA Workshop on Science and Education within Space Exploration, Strasbourg, 29-30 March 2010; EC-ESA Workshop on Exploration and Innovation, Industrial Competitiveness and Technological Advance, Harwell, 29-30 April 2010; EC-ESA Workshop on Space Exploration Scenarios, Capua, 21 May 2010.
[13] Conclusions of the Second International Conference on Space Exploration, Brussels, 21 October 2010.

II.3.5.1 The special case of climate change

Climate Change is potentially the single most serious long-term threat to our present way of life and the security and welfare of the world's population. Dealing with this threat constitutes one of the major grand challenges of our time. A major goal of Horizon 2020 must be to support the establishment of a European Climate Service or relevant national climate services in Europe to enable better management of the risks of climate variability and change and to assist with adaptation to climate change at all levels. This will be achieved through the monitoring on a global basis of factors influencing climate and through the development and preparation of science-based climate information and prediction services to inform policy, planning and practice.

The data underpinning the required science base, which is essential for our understanding of climate and climate change, comes nowadays in significant measure from space-based observations, without which monitoring and management of the threat which climate change poses would be an almost impossible task.

Identification of the key observables is contained in the second Global Climate Observing System (GCOS) report from 2003, updated in 2010. It defines some 50+ Essential Climate Variables (ECVs). The GMES services in the land, marine and atmosphere domains include within their product portfolios a wide range of parameters some of which correspond to these ECVs or contribute to their derivation. However, there are gaps in the ability to measure these ECVs which can only be closed by observations from space, and if the necessary new instrumentation is developed and then flown.

ESA has initiated a dedicated Climate Change Initiative (CCI) to contribute to the ECV databases required by the UN Framework Convention on Climate Change (UNFCCC) and to help to realise the potential of the long-term global Earth Observation archives. The current CCI projects closely coordinate their analyses with the GMES thematic services in the land, marine and atmospheric domains and involve the major climate modelling centres in Europe.

EUMETSAT, in following its second objective to contribute to the operational monitoring of the climate as well as the detection of global climatic changes, is contributing to this effort through the availability of some of its instruments on its Meteosat, Metop and Jason spacecraft. In addition, it has joined the SCOPE-CM (Sustained, Coordinated Processing of Environmental Satellite Data for Climate Monitoring) initiative of the Coordination Group of Meteorological Satellites (CGMS), which is delivering some of the required ECVs using the data from the operational meteorological satellites.

Also, the 3rd FP7 Space call has resulted in a set of projects performing long-term time series generation and validation, regional reanalysis and downscaling on currently available observations. These projects are also examining forcing and feedback mechanisms associated with changes in terrestrial carbon together with water fluxes, sea levels and ocean circulation over high latitude and Arctic regions.

In the implementation of the UNFCCC, representative ECVs for the ocean, terrestrial and atmospheric domains are addressed, covering elements of the carbon and the water cycle, the factors of uncertainty in climate radiative forcing and feedback, and the rapidly changing elements of the climate system. However, it should be noted that the Global Framework for

Climate Services, established by the 3rd World Climate Conference in 2009 will require a set of ECVs which will go beyond those needed by the UNFCCC.

A conference is therefore planned for summer 2011 to identify in greater detail the current and future gaps in the provision of ECVs and other underpinning data required for European climate services. This is complimented by a Coordination and Support Action foreseen for 2012 under the 4th FP7 Space call to coordinate the existing research within the GMES community. These actions will be designed to lead to a structured framework and approach for delivering cohesive, quality controlled and validated climate data records in support of climate science and services.

To ensure that space can complete its essential contribution to the challenge of monitoring, managing and adapting to climate change, it is essential that a space climate change component is carried through into Horizon 2020 and that the realisation of a 6th core service within GMES dealing with climate change is ensured..

II.3.5.2. Security of space and improved security on Earth

Since space weather events can affect critical ground and space infrastructures, such as power distribution grids and telecommunication satellites, in severe cases resulting in complete system shutdown, a space situational awareness system will definitely contribute to the security of the citizens all over the world. It is therefore essential that Europe be in a position to forecast when such severe space weather conditions will occur and to develop an integrated risk-management approach to ensure that effective preventive measures can be taken. Space weather effects on the atmosphere also provide a link to the grand challenge climate change; with the increased height range in climate models space weather effects affect the accuracy of the models and also can be used for testing parts of global climate models. A major challenge will be the support of models by observations in this so-called "ignorosphere" (upper stratosphere to lower thermosphere), for instance by sub-orbital space flight.

On the other hand, the increasing presence of space debris in critical orbits has now become a major threat to satellite infrastructures: it is thus critical that Europe acquire its own capability for identifying and tracking space debris and develop technologies for their removal/ mitigation.

Near Earth Objects (NEOs) are known to represent a significant threat, and a major impact could potentially be catastrophic for the life on Earth, raising the need for Europe to be part of a global endeavour to identify, as early as possible, potential threatening near Earth objects and develop mitigation strategies.

Whereas “Security of Space” started to be systematically addressed under FP7 and while SSA is expected to be addressed under the future Space Programme, the potential of space for security remains to be realised. Space can efficiently support crisis response management in all its phases from prevention to recovery. This requires synergetic exploitation of existing and new space and non-space systems, and within a multiplicity of assets, e.g. remote sensing, telecommunications, navigation, etc., in an integrated architecture.

II.3.6. Support to European competitiveness and non-dependence

The orientations of Horizon 2020 must also be seen in the light of the communication of the European Commission on Industrial Policy. This communication has set support to the competitiveness of the European space industry as a clear necessity. The Framework Programme, which is a key instrument to shape the future on the sector, must contribute to this objective.

With the support of ESA and its member states, the European space industry managed to secure a significant share of the global commercial markets, in both the fields of launch services and satellite manufacturing. Although the open market is just a fraction of the total world market, for European industry it peaked at almost one half of its overall turnover in 2009.

Continued support to competitiveness is thus essential to ensure that European industry will continue to keep up with its international "rivals", strongly backed by massive domestic markets. Commercial markets help European industry to maintain the critical mass of activity to provide technologies and skills at affordable conditions to meet the requirements of future European public space systems and services.

Competitiveness needs innovation in technology and products to face both the high-tech and the low-cost competitors. Innovation means mastering the technology and developing the products to the stage they can be commercially used. Innovation for competitiveness requires research of the underlying sciences, as well as development along the maturity levels until qualification for use in space. There is a gap between the initial research and the innovative technology and product.

In this respect, some lessons should be learnt from FP7 which was not successful in including actions for closing this technological gap.

European non-dependence for critical space technologies is an objective of the European Space Policy reiterated in the resolutions of several Space Councils.

In many respects, supporting European space industry competitiveness as well as addressing the issue of technological dependence of Europe converge on common objectives as both issues deal with access to leading edge technologies which condition the ability of industry to be present on all markets potentially accessible to Europe.

From a historical perspective, it is interesting to note that unlike any other space faring nations, Europe did not place much emphasis on non-dependence. As a matter of fact, United States, Russia, China, India, or Japan have all clearly set the objective of full independence in space as a high priority. This might be a sign of a European culture that is more focused on international cooperation rather than on international competition. What about "coopetition"!? Eventually, as long as other space powers do not object, the global market can provide most of the technologies needed. This is in particular the case as far as space science and open commercial business are concerned.

Technological dependence hampers industrial competitiveness and, in a tougher competitive international framework, it might also prevent Europe from gaining access to the top performance systems and services it needs for the implementation of its domestic and international policies, be it in the field of knowledge-based society, resource management or security in space and on Earth.

Ultimately, non-dependence is a matter of sovereignty. It raises the issue of the role that Europe intends to play on the international scene. Indeed, it conditions its capability to undertake autonomous activities or collaborations with other space faring nations in space without first having to seek approval for the utilization of technologies from non-European suppliers.

Europe is aware of the problem. EC, EDA and ESA recently held a major event with industry and institutions in which it was decided to set up a joint task force that would identify the issues and propose the way to address them. A list of critical technologies requiring urgent action is systematically identified and addressed by the three organisations to the best of their capabilities. Though FP7 efforts have to be recognised, they were not fully successful in systematically addressing the issues since many items were not suitable for co-funding, and closing the aforementioned technology gaps. A pre-requisite for Horizon 2020 to properly address this issue is to define the mechanisms that allow the EU to fulfil its commitment to non-dependence, thus avoiding the problems of FP7.

Horizon 2020 should thus be focused on EC-ESA-EDA agreed critical-technology targets and provide for adapted rules to adequately address the specificity of activities to be supported.

III. A STRATEGY

III.1. Objectives

Why research and development in space should be redefined in the context of Horizon 2020: an opportunity after the Lisbon Treaty.

The “space” world and its context have evolved considerably since the objectives, contents and mechanisms of FP7 were established some years ago. Furthermore, experience has been gained with the implementation of FP7 and with the Galileo and GMES flagship programmes. It is now necessary that Space R&D under Horizon 2020 efficiently responds to the objectives within this evolving context while learning from past experience.

The Framework Programme is an important tool available to the European Commission to promote scientific research and development in all areas. The Commission must make full use of Horizon 2020 as an instrument to maximise the benefits of space for European citizens and society for both the short- and long-term. One of the main targets of the Europe 2020 Strategy is to reach R&D investment of 3% of GDP: Horizon 2020 must therefore be the ideal instrument, if the contents and mechanisms are well defined. Furthermore, given that space has become an EU policy in its own right, after the entry into force of the Lisbon treaty, the Commission must ensure that it has at its disposal all the necessary tools to take on its new role, and, in this context, Horizon 2020 is obviously one of these.

III.1.1. EU Objectives for Space

III.1.1.a. General

The EU objectives for space have been established in the European Space Policy and in the Space Council Resolutions, and they have to be considered in the context of an evolving European Union that has made innovation a priority within the EU agenda 2020, as well as via smart, sustainable and inclusive growth drivers. Furthermore, with the Lisbon Treaty, space has become a specific competence of the EU, in parallel with that of its Member States. Space is furthermore an essential tool for EU policies including the security of its own citizens.

Space is a subject of research, through space science (understanding the Universe), and a tool for research, through science in space (research in microgravity e.g. life sciences, materials, etc) and science from space (Earth sciences, climate change monitoring). A major new scientific challenge is the exploration of space, both robotic and human.

Space has to help in responding to the grand challenges on Earth, such as climate change and natural resources monitoring, environment, security, innovation and competitiveness, ageing population in Europe and growing population worldwide

Space, in this context, has to demonstrate its immediate, or, at least, short-term benefits for citizens.

III.1.2. Context

a) World context

The interest for space is increasing worldwide and many new space powers have emerged in the last decade. The number of countries with space agencies or entities specifically devoted to space has increased in recent years. Investment in space is growing faster in nearly all countries other than Europe.

Horizon 2020 must take into account the potential for cooperation and the stronger competition in the new world context.

b) European context

Europe (ESA, EC and Member States) is a major space power. Europe has indeed developed top class scientific and service oriented missions, launchers and infrastructures. Space is a tool in European policies and European citizens benefit from investments in space. However, European space budgets have stagnated, affecting new initiatives such as robotic and human exploration, new space transportation systems, security and technology non-dependence. The entry into force of the TFEU gives the EU a specific competence in space. The TFEU can thus give space a stronger and more visible political profile, relate space more intimately to EU policies and bring additional financial resources to space, in addition to those of ESA Member States, which will be a necessity for new initiatives such as space exploration.

Horizon 2020 shall complement the overall European effort with clear objectives and mechanisms and provide additional resources, in coordination with the existing programmes.

c) Markets

European industry is very successful in the commercial markets. However competition is very difficult, both with major space powers that benefit from huge captive markets and thus economies of scale, such as the USA, and within new actors/partners that benefit from lower costs, e.g. Russia, China, India, and emerging space countries such as Korea. Innovation is the response: if Europe wants to remain competitive, it must innovate, within a European context of an unfortunately fragmented European institutional market leading to insufficiently exploited synergies between the civil and defence sectors.

Horizon 2020 must aim at supporting the competitiveness of European industry and at promoting innovation. Horizon 2020 shall aim at supporting the synergies between civil and defence requirements under the common frame of security.

d) Science

Space has contributed very significantly to scientific discoveries and this has to continue, as shown by the agendas of scientific communities such as “Cosmic Vision 2015 – 2025” for Space Science, the “Changing Earth” for Earth Science, the massive response to calls for mission ideas for space sciences, space exploration, and ISS utilisation, etc. Resources to exploit missions are however not commensurate with the ambitions and potential. Concerning the preparation of scientific missions, the SAG notes the need to support the next generation of scientists capable of developing new observation techniques and scientific instruments;

Horizon 2020 should support

- *Mission data exploitation*
- *Research for preparation of future missions, including Earth-based preparatory research programmes as stepping stone for space exploration*
- *Scientific exploitation of the ISS*
- *Identification and training of the next generation of scientists and instrumentalists capable of developing new scientific instruments for Space Science / Exploration or laboratory instruments for Earth science campaigns.*

e) Technology

Space systems rely on basic technologies which are sometimes not primarily driven by the needs of space but mostly by the evolution of terrestrial sectors (e.g. micro-electronics, photonics, etc.). Space, however, has specific needs that require significant investments for which the small market volumes do not guarantee sufficient returns. In Europe, investments from the space sector in such basic technologies are unfortunately low. This means that European space programmes depend on non-European suppliers for some basic technologies, which may translate into cost, delays and especially on lack of design and operation information that prevents exploiting the capabilities. These situations of dependency on non-European technologies are not acceptable and Europe can not be dependent on foreign non-guaranteed basic technology to develop, deploy and exploit space systems.

The EC has taken steps in FP7 to address the issue of critical technologies for non-dependence as part of joint actions with ESA and EDA. The EU is undertaking efforts on Key Enabling Technologies (KET[14], see also later), and is promoting the underlying scientific research and technology development: the space sector must definitely also contribute to these efforts and participate to the benefits.

Horizon 2020 shall:

- *Devote more effort to the development of basic technologies for space with emphasis on critical technologies for strategic non-dependence*
- *Open innovation on KETs with related sectors (see later)*

f) Industry

European industry, primes and suppliers, have been successful in the world markets and have provided Europe with top class science and service driven missions and strong commercial positioning in exploiting space infrastructure and assets. However, space remains a low volume market with very demanding requirements. In Europe, institutional markets are fragmented, not offering industry a strong home base. The risk for industry is extremely high where investment in basic space specific technologies is concerned. Efforts are thus required to consolidate both the demand side and the industrial supply chain.

Horizon 2020 shall:

- *support actions leading to the completion of the internal market in Europe for space*
- *support aggregation of European markets for services using space and encourage and facilitate a critical mass of demand, thereby enabling suppliers to invest and finance development of products and services*
- *support measures that may reduce fragmentation and lead to the joining of elements of the value chain, through development of consortia which reflect vertical integration of capabilities*
- *support measures that strengthen the industrial chain*
- *adopt mechanisms suited to the types of actions*
- *assist technology development efforts (supporting industry or consortia defined roadmaps) leading to new products and services and to availability of key components on competitive terms.*

[14] European Commission, *Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: Developing a common strategy for key enabling technologies*, COM(2009) 512, Brussels, 30 September 2009, and the accompanying Commission Staff Working Document SEC(2009) 1257.

III.2. <u>Proposed pillar structure of the Space component</u>

Preliminary remark: the assumption is made here that there will be a European Space Programme with GMES, GNSS, SSA being substantially covered.
Furthermore the SAG has recommended Exploration as a new flagship in the Space Programme, starting during the remainder of FP7 (see 2010 document).
What comes below is thus to be considered as significant additions and opportunities to appear in Horizon 2020: it constitutes the back-bone of a series of Horizon 2020 objectives for space, such as:

- Support the exploitation of mission data so as to address the issues raised by the scientific and user communities
- Support the exploitation of the ISS
- Support space exploration-oriented Earth based programs as stepping stone to those space missions
- Prepare for the research and service driven missions of the future by conducting pre-requisite research and developing technology
- Prepare the next generation of European scientists/users of space
- Strengthen the competitiveness of space (with respect to non-space tools) and of space industry
- Support innovation for space and from space, with emphasis on open innovation
- Contribute to ensuring European non-dependence on critical technologies
- Contribute to the design and development of the space systems of the future platforms and payloads, both in space and on the ground

III.2.1. The basic outline of the space components

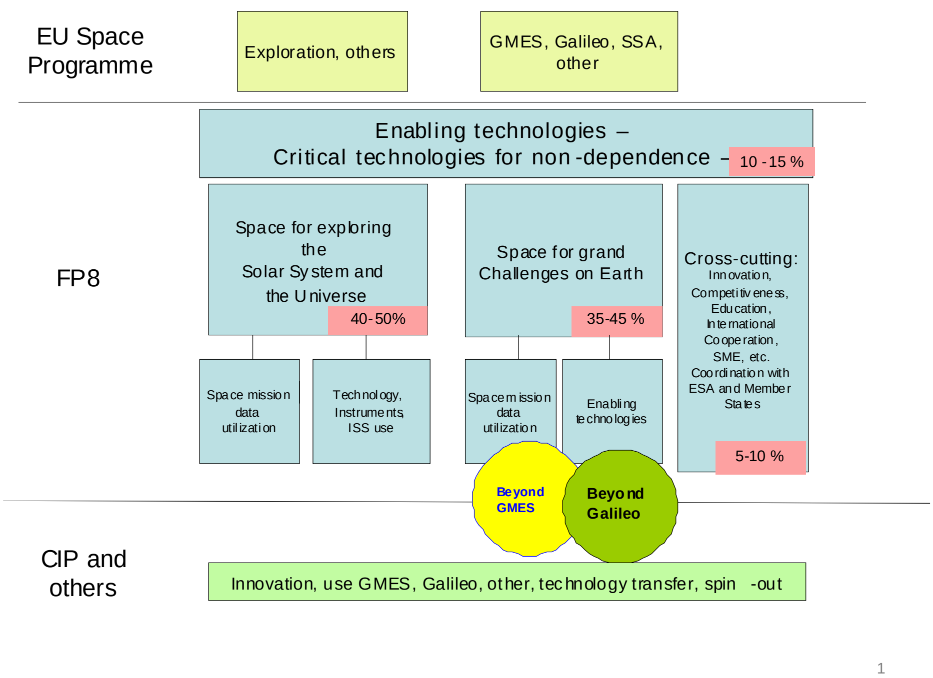


***Fig. 4 Horizon 2020** programmatic actions on space*

In the time frame of Horizon 2020 the EU space program is to be composed of (see Fig. 4):

§ A Programme, devoted to:
  - EU flagship programmes in space: service-driven activities for European citizens and responding to global challenges on Earth: GNSS/Galileo, GMES and SSA.
  - Science-driven activities addressing the challenges of space for the exploration of the solar system and the universe. It is expected that this includes a programme with ESA for small recurrent missions in the context of preparing for exploration. It is also expected that this or another part of the space programme allocates resources to cover for the operations / utilization cost of the ISS, e.g. integration of experiments, transportation, operations, crew time, etc., so as to include in Horizon 2020 a line for research on ISS (as a continuation of FP7 Earth-based research projects designed to provide scientific and technical indicators to space exploration issues are invaluable and low-cost stepping stones toward those missions, but they are not funded by ESA. It is expected that those activities are included in the programme as complementary element to ESA's programmes.
  - Both segments are to be coordinated with ESA and to be consistent with the elements presented in its Long Term Plan

§ A portfolio of efforts devoted to research and development for space / from space (see below)

§ The Competitiveness and Innovation Programme CIP-II, which could have a space component.

III.2.2. *<u>Contents of "Space in Horizon 2020"</u>*

The purpose of this section is to describe the main proposed components of Horizon 2020-Space and interactions within the proposed scheme (see Fig. 4).

The three pillars of Fig. 4 are briefly described below:

III. 2.2.1. *<u>Pillar No. 1: Space for exploring the solar system and the universe</u>*

According to the 2010 SAG advice on exploration and also as recommended by ESF European Space Sciences Committee (seen Annex 2), this should include:

- *The exploitation of data from scientific missions:*
  There are on-line (recent) as well as archives of data of scientific missions, European and non-European, maintained and made accessible by ESA as recently presented to the SAG. Horizon 2020 shall support research based on the use of those complete sets of data.

- *The scientific preparation of future space exploration of the solar system and the universe*
  Horizon 2020 must also support studies for the preparation of scientific utilisation of space science and exploration missions. This should be consistent with the strategy established by the scientific community, e.g. Cosmic Vision for Space Science, and contribute to establish such roadmaps, e.g. as recommended by the EU conferences on space exploration. It should also include Earth-based projects designed to provide indicators for space exploration.

- *The development of technologies for space exploration missions of the solar system and the universe*
  A significant part of the effort should be devoted in particular the 4 items defined in 2010 in the EC+ESA workshops and conferences:
  - Life support
  - Automation and robotics
  - Novel energy sources and storage
  - Advanced propulsion

  albeit not necessarily be limited to these 4 themes. This should also include Earth-based test campaigns.

- *The provision of challenging opportunities for the development of instruments for space exploration (small frequent preparatory missions)*

  The SAG notes the ageing of the scientific population and the bias of new scientists towards data exploitation only. If the trend is not reversed, Europe may suffer form the lack of experimental scientists capable of devising research techniques and developing instruments. This would result in Europe losing its leading position in space science. Horizon 2020 should foster the hands-on preparation of the next generation of scientists with the support of the development of flight models of instruments for space science and exploration.

  This implies the existence of carrier missions and the SAG expects EU and ESA to set up a programme of recurrent (one per year) precursor missions for exploration of the solar system and the universe.

- *The utilization of the ISS for scientific purposes, including data exploitation and the preparation for exploration*

  The utilization of the ISS has started with experiments in a multitude of science domains. Utilization shall be strengthened: this effort shall also include the preparation for exploration, according to the 2010 SAG advice on exploration.

  The SAG has discussed the conditions of utilization of the ISS for FP7 experiments. In order to facilitate the use of the ISS, SAG proposes that the Space Programme devote sufficient resources to cover the operations / utilization cost of the ISS for FP experiments, i.e. costs such as integration, transportation, crew time, etc., considering that not all EU member states are participating in the ISS programmes.

III.2.2.2. Pillar No. 2: Challenges on Earth

The objectives of this pillar are:

- The establishment of concepts (incl. archives, models,…) that allow the provision of support to EU policies, addressing challenges such as security, implementing the CFSP CSDP, etc, not forgetting climate change issues
- The preparation for the sixth GMES service, devoted to climate change monitoring and subsequent mitigation in line with II.3.5

- The exploitation of data from remote-sensing and other missions, e.g. exploitation of GNSS signals, for scientific purposes, new services, etc.
- The development of observation techniques and the development of enabling technologies
- The development of ground based instruments (incl. aircraft) for campaigns in support of new missions
- The development of instruments for suborbital flights
- The search for ways to characterise the upper atmosphere

A few other examples are:

- Research into techniques and technologies in support for crisis management response
- The exploitation of data from remote sensing and other missions, e.g. exploitation of GNSS signals, etc., for scientific purposes, new services, etc
  This should include the "operationalisation" of observations obtained by the recent scientific missions, e.g. soil moisture, ocean salinity, ice thickness variations, etc for services and conversely the use of data from service missions for scientific purposes exploiting the perspective of long time series
- The development of observation techniques and the development of enabling technologies
  This should respond to challenges identified by the community, i.e. Earth observations for the changing Earth, etc
- The development of ground based instruments for campaigns in support of new observations
- Research and technology development to address issues related to EU policies on vulnerable areas, e.g. space and the Arctic, space and energy
- The development of integrated risk management strategies in space situational awareness
- The utilization of space weather effects and measurements from sub-orbital spaceflight to understand the coupling between the lower and upper atmosphere
- Integration of certain SSA aspects into models of global change to improve our understanding of the system and the reliability of predictions

III.2.2.3. <u>Pillar No. 3 : Cross-cutting issues</u>

This pillar addresses cross-cutting issues such as

- Education, in the context of the knowledge triangle
- International aspects, which are very important in the changing world context, even more than during FP7
- Training, essential in the frame of life-long learning (scientists, engineers, instrumentalists,…)
- Market aggregation, so as to integrate civil and defence markets in the spirit of TFEU
- Innovation, one of the ingredients for competitiveness
- Competitiveness, vital for the existence of European industry
- Actions with other lines of Horizon 2020
- Opportunities to increase the cooperation between academia and industry (see synergies, III.3.5.)

Open innovation being the normal approach to development, Horizon 2020 shall therefore establish mechanisms that allow joint calls by different lines of its programme.

As the ultimate objective of space is its usefulness to the citizens in the widest sense, it is also recommended that Horizon 2020 identify in non-space lines the use of space assets for conducting research, e.g. on environment monitoring, on competitiveness, etc.

III.2.2.4 Enabling technologies / critical technologies

It is to be stressed that the three pillars described above appear under an overarching box relevant to technologies in support of European non-dependence, enabling innovation and contributing to European competitiveness: Horizon 2020 shall therefore permanently address the development of Enabling Technologies, as shown below.

Underlying advances in space research and applications in technology: at its lowest level technology is shared between space and non-space and its evolution is often driven by terrestrial sectors with shorter cycles and larger market volumes. Lack of full commercial sustainability at every layer of the chain may lead to situations of disruption, loss of capabilities and undesired technology dependence. Horizon 2020 must play a vital role in addressing this issue.

The EU has recognised the importance of key enabling technologies (KET) that are the driving forces behind future developments (EC communication 2009, 44) The objective of the European Commission in COM (2009) 512 and SEC(2009) 1257 is to show how these technologies can better be brought to industrial deployment. According to COM (2009) and SEC (2009) the following technologies have been identified as key enabling technologies:

- Micro-electronics, semi-conductor technology, advanced high-performance components
- Materials
- Nanotechnology
- Photonics[15]
- Bio-technology

Clearly the first four are of traditional interest for space, at the basis of innovation and prerequisite for competitiveness and the fifth one has increasing interest in view of exploration. In this context there is a long- and a nearer-term view. The longer-term view is suitable for open research.

The nearer-term view is more related to non-dependence. The EU has recognised the need to have unrestricted access to technology to be able to develop, deploy and exploit space systems. From the approval to the ESP and in the Space Councils, non-dependence has been a strategic objective. Steps have been taken in FP7 to implement actions agreed in a joint EC-ESA-EDA process. The EU must thus maintain its strong commitment to non-dependence, learning from the recent lessons.

The EC shall continue coordination with EDA and ESA, maintaining a non-dependence watch and identifying the issues of concern and transforming them into work plans. The established process with EDA and ESA, adapted with lessons learned and strengthened by other process

[15] Since one is dealing here with "Space", European detectors in the wavelength domains not penetrating the Earth's atmosphere are to be further developed, in the X-ray and γ-ray domains, and, especially in the IR.

such as the European Space Components Coordination initiative and the European Space Technology Harmonization process, should form the basis for this. To remedy the issues encountered in FP7, it is proposed that the EC invest in a suitable and relevant programme, whose full partnership is yet to be defined.

Critical technologies for non-dependence are explicitly shown to raise the emphasis on the issue and reflect the EC commitment to the ESP and the recommendations of the Joint EC-ESA-EDA Task Force.
This should include:

- Contribution to relevant European programmes so as to progress according to established dossiers and along roadmaps leading to permanent availability of capabilities and products
- Collaborative interaction with other Horizon 2020 programmes

III.2.3. <u>Potential allocation of resources</u>

In the absence of budget figures, the SAG has assumed that the Horizon 2020 resources would be in line with the progressive increase in the FP7-Space budget and thus proposes a balanced allocation as follows, where the allocations would of course have to be tuned to a total of 100%.

- For critical technologies – enabling technologies, 10-15%
- For actions addressing the challenges of space science and exploration, between 40 – 50 %, consistent with the emphasis of the 2010 SAG advice on Space Exploration
- For actions addressing the challenges on Earth, 35 – 45 %
- For cross-cutting issues, 5-10 %

IV. REMARKS ON IMPLEMENTATION

IV.1. Synergy of actors in the space sector

Space missions are for the benefits of users, scientists or operational users. Users express their needs in terms of data and products. Obtaining the latter requires techniques and their implementation needs technology. Satisfying user needs thus relies on the cooperation between users, i.e. scientists for scientific missions, research institutions and industry. It is essential to facilitate the **synergy between universities/labs and industry.** Today there are too few synergies and too many barriers to the development of the R&D part of space activities in Europe.

At present, Agencies act to a large extent as the bridge between scientists and industry. This is advantageous to guarantee an unbiased system in mission evaluation, selection and implementation so that this is not driven by the technical preferences of industry but by the real needs of science. The approach however may be extended too far upstream resulting in a considerable limitation of the benefits of interaction between science and industry.

Today, industry often supports the laboratories in the elaboration of responses to calls for ideas and announcements of opportunities when scientists need to propose new missions and when they need some industrial support for a preliminary system concept and a rough order of magnitude of cost. Agencies also sponsor prospective studies in which scientists and industry work together. But the resources are limited and the potential of the interaction is not fully realised.

More interactions between scientific laboratories and industry would be advantageous in the early parts of the programmes. There should indeed be a continuous upstream exchange between scientific laboratories and industry, discussing scientific questions, sharing information on technological trends and prospects, identifying needs for new measurements and technological advances. The cooperation between scientists and industry would provide mutual awareness. It would also allow faster progression towards scientific breakthroughs and technology maturing. Fostering such exchanges on a wide European scale would bring more innovations in quantity and quality with a better focus on preparing technological developments to fill the needs of the observers.

EU-funded R&D projects could for instance bring together laboratories specialized in the measurement or/and modelling of specific geophysical parameters with technologists specialised in the relevant technologies and instruments associated to these measurements. Such initiatives would considerably increase the research upstream of space missions and would provide a faster road towards appropriate technology readiness. This would support the realisation of the objectives for the preparation of future mission as in III.1.2.

IV.2. Synergy of techniques

Secondly, and regardless of whether the targeted are is that of Earth Sciences or Astronomy from space, there should probably be a more structured way of preparing the space observations of the future by developing a **deeper synergy between ground-based, airborne and space techniques**, taking into account anticipated theoretical and technological developments on all sides. This requires some specific research and reporting which is currently not adequately addressed.

IV.3. <u>Synergy between non-space and space sectors</u>

Space and non-space domains share the same technology base. In certain areas, technology advances faster in terrestrial domains than it does for space. On the other hand, space has extreme requirements that for certain technologies make space the lead user. There is ample room for common R&D between space and non-space sectors. This has been already proven in FP projects, though outside the Space theme, such as for example the IMPRESS project for materials, the LAPCAT project for propulsion, or the ASSERT project for avionics.

This has to be strengthened in particular for enabling technologies and for space exploration.

Robotic exploration and especially human exploration pose new challenges not yet faced by space systems, often by no other system:

- Complex system-of-systems: ground, transportation, orbiting infrastructure, surface infrastructure, humans operating with no failure and zero maintenance
- Long travel time and operation in confined spacecraft and shelters
- New operational capabilities RVD-refuelling-descent-landing- ascent- re-entry
- Extremely hostile environment of space, long nights, dusty atmosphere
- Far from Earth, very limited ground support capabilities and limited logistics
- High "snowball effect": 1 kg back to Earth requires many kgs upload, with many limitations on the transportation systems

Exploration will drive innovation in system engineering and technology in traditional space and new domains:

- New methods and tools for complex systems engineering, verification and validation
- An acute need to increase efficiency in terms of performance/resources in all spacecraft systems, platforms, payloads, rovers, etc. For example:
  - Reduction of mass, power/energy, volume, fuel, etc.
  - Increase in performance, data processing, sensitivity, thrust, etc.
- A completely new approach to operations and autonomy
- A totally new approach to human–robot interactions, habitats, life support systems
- A breakthrough in health monitoring, physiology, psychology, diagnosis and medicine

There is a huge potential for common space-non space R&D[16]. Though the case of space exploration has been stressed, opportunities exist in all domains.

Horizon 2020 shall support common R&D so as to realise the benefits of open innovation.

[16] Space Exploration and Innovation, Technopolis, Study commissioned by the Space Policy and Coordination Unit.

IV.4. <u>Support to new ideas on space research/technology</u>

The SAG notes that FP7 had to devote about 85% of the budget to GMES. This implied that the budget for new R&D was drastically limited.

In such conditions, the FP7 approach to support bottom–up research proposals through grants in a co-funding scheme was probably adequate. It allowed challenging goals to be addressed while leveraging additional research funding.

As of 2014, GMES will be supported under operational programmes and Horizon 2020 will be in a position to devote its resources mostly to R&D. This will make it possible to address the ambitious objectives established here by SAG using suitable funding mechanisms. Indeed, the FP7 mechanisms would not be entirely appropriate for actions that need:

- A top–down framework and the performance of R&D according to specifications and roadmaps, as for example mandated in the 2010 Conferences on Exploration
- To go beyond the initial R&D stage and leading to innovative products in a broad sense, e.g. mastered critical technologies, scientific instruments, ISS experiments, etc.
- The synergies advocated in III.2.4, users, scientists and industry; space and ground
- Common R&D with ground sectors in the very promising domains of technologies relevant to exploration

There is a definite need for balanced bottom–up and goal-driven, top–down research. While the FP7 mechanisms may have been, and are still suitable for the bottom-up approach, for top-down and goal-driven research, new mechanisms undoubtedly need to be proposed.

This delicate balance is a well known problem, which is also found in other parts of the Framework Programme. To resolve this, the Ideas programme was explicitly defined to support an ambitious goal: to fund frontier research projects proposed by individual teams. Its implementation as near-individually executed projects remains adequate for many scientific areas but its usefulness in space research and specifically for space technology, where competences and facilities surpass the possibilities of small teams, needs to be examined further. Other approaches were tested in the Cooperation programme, more specifically in the ICT priority domain, through the implementation of a new specific instrument: Future and Emerging Technologies (FET) (see cordis.europa.eu/fp7/ict/programme/fet_en.html). Under two possible implementation schemes of FET projects, open (for bottom-up proposals) and proactive (for targeted proposals on predefined topics), the Commission intended to fund consortium-based proposals which combine very innovative ideas within the widely used cooperative approach of broad consortia.

An additional step forward in this path is under way with the recent call on the so-called "FET Flagships" where even more ambitious and long-term research is being proposed under the proactive scheme. The mentioned call will support the preparation of large and ambitious frontier research projects where a limited set of them may get funded by the Commission and some Member States: obviously to be scrutinized in preparations for Horizon 2020.

Space challenges present some similarities with the above mentioned ideas as they cannot be addressed through a purely bottom-up approach. The adaptation of the reactive-based FET instrument oriented to "space missions" seems to be a possible way that could be implemented in Horizon 2020.

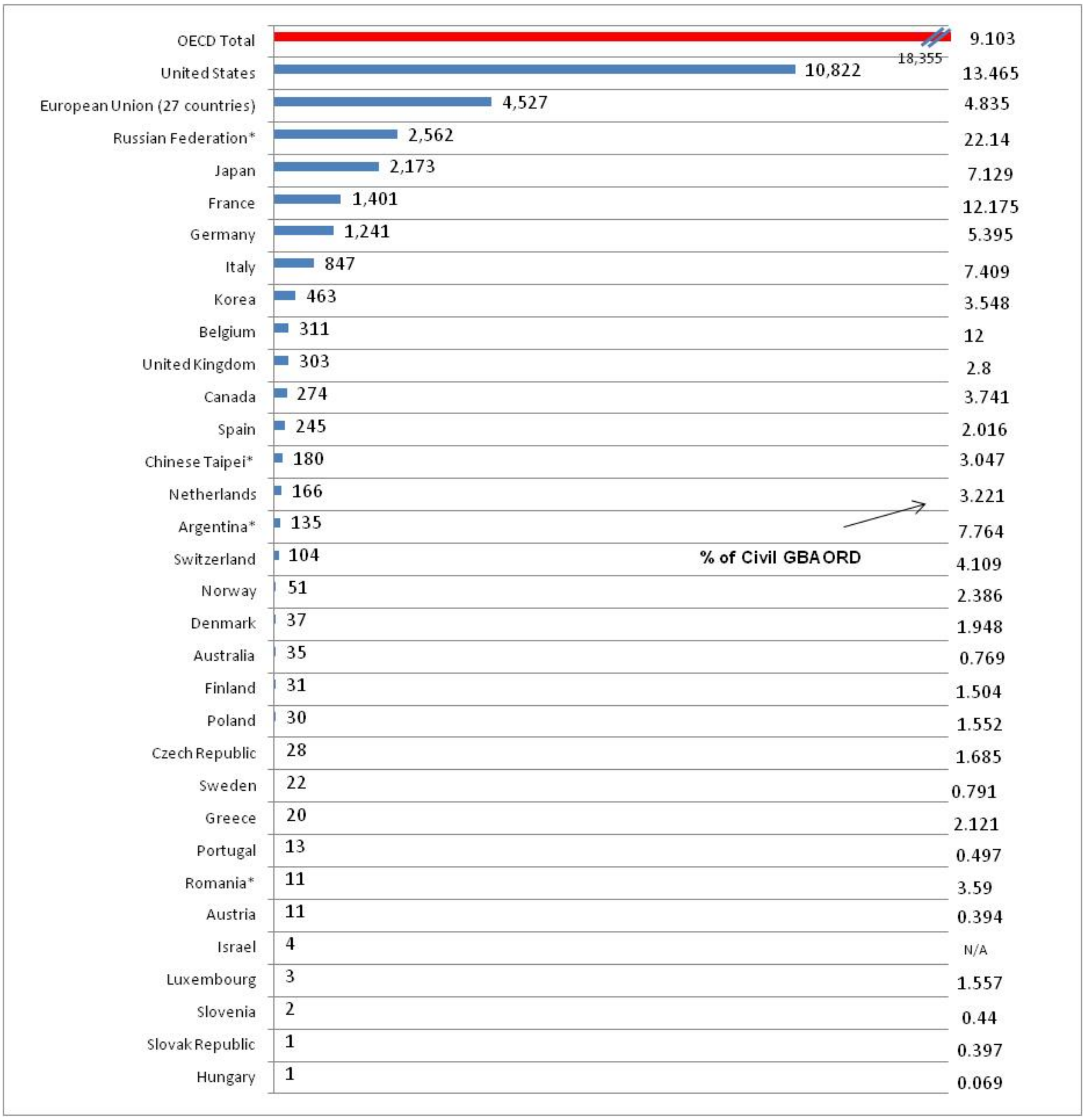
In short, the proposal would consist in a balance between bottom-up “blue sky” research and goal driven R&D. The latter shall lead to innovative products in a general sense. Such “products” could include basic technology and products, scientific instruments, experiments or science products and prototype services. The identification of issues to be addressed shall be carried out with the community through agendas established by science communities, needs defined by operational users or requirements established with industry. Existing European mechanisms shall be used, e.g. with the scientific communities by ESA, the European Technology Coordination and Harmonization Process, etc where industry and academia define the new ideas necessary to break through current limitations. After a selection according to clear mechanisms and criteria, the R&D phase could start.

ANNEX 1: OECD data*

EXCERPTS FROM OECD (2011), THE SPACE ECONOMY AT A GLANCE

Reference: OECD (2011), The space economy at a glance, OECD, Paris.

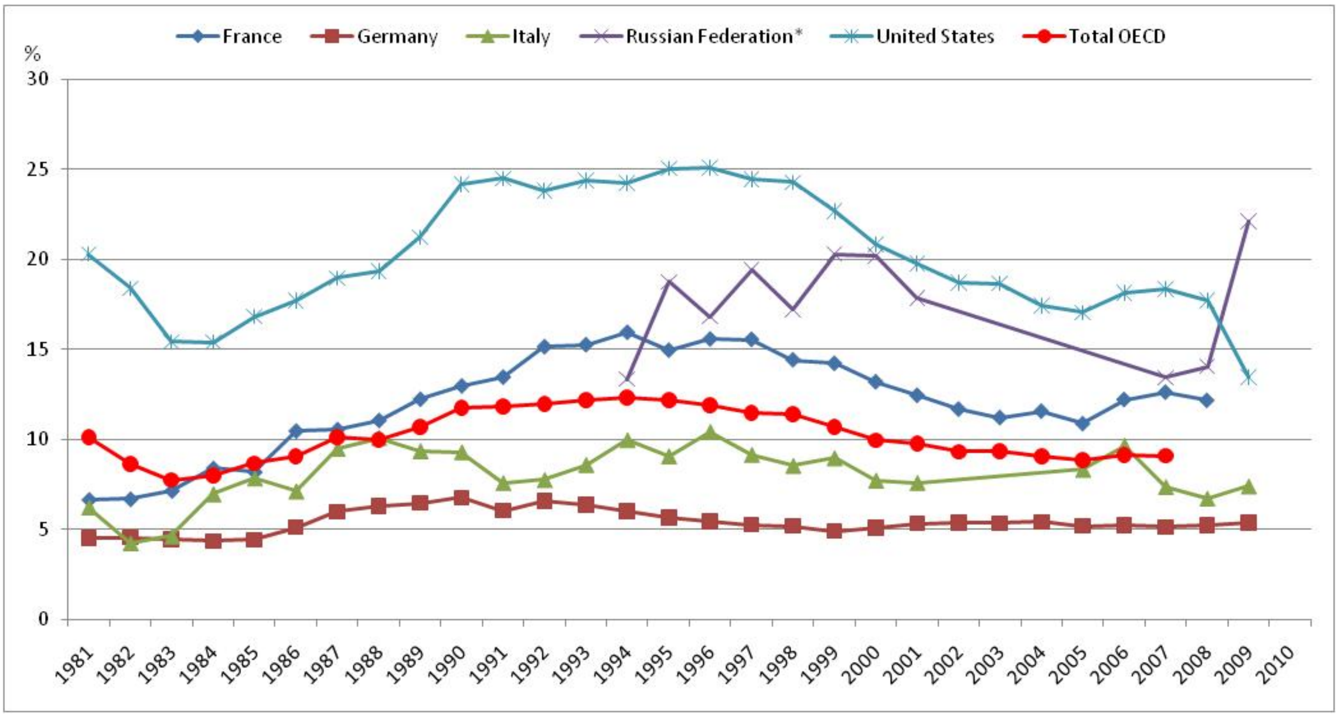
Figure 2.1a– Civil space budget in Government Budget Appropriations or Outlays for R&D (GBAORD)
Millions of current PPP USD and as % of civil GBAORD, 2010 or latest year available
Source: OECD, Main Science and Technology Indicators database, August 2010

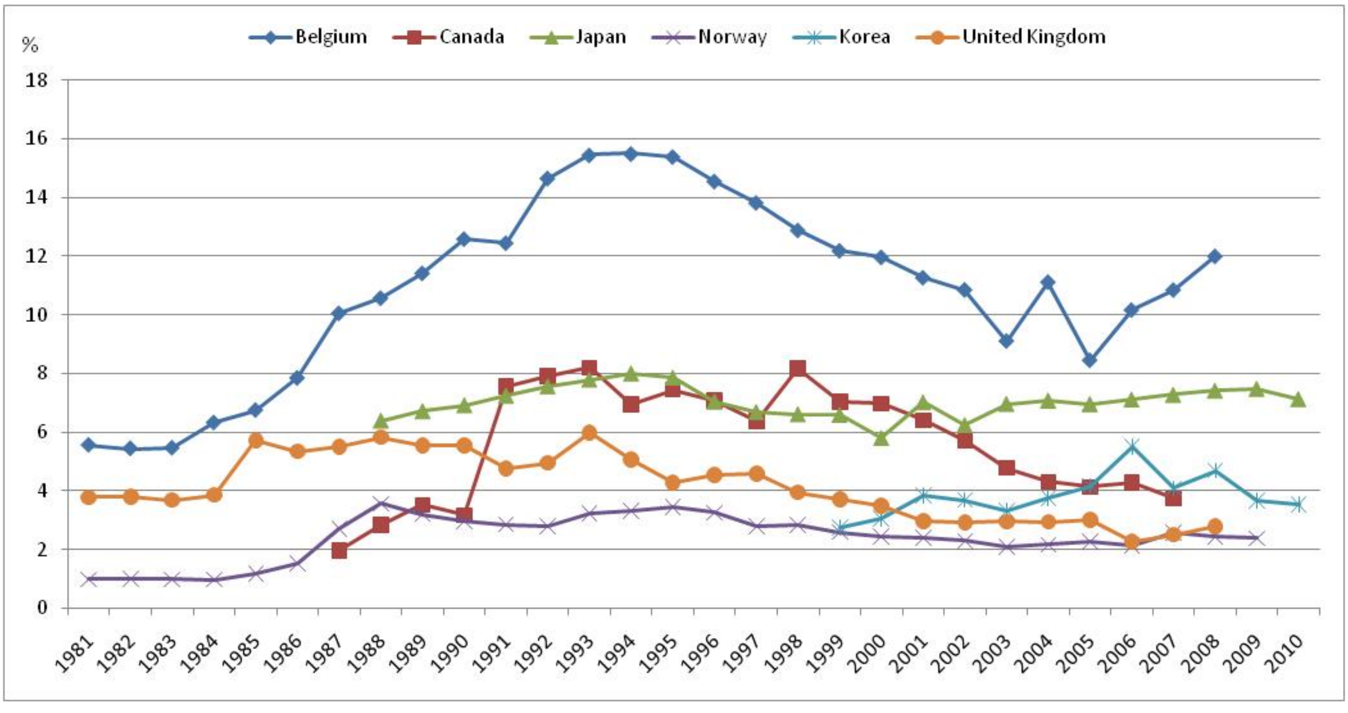


* Non OECD country

* OECD, The Space Economy at a Glance, International Futures Programme, Paris, 2011, private communication, in advance of publication (Thanks to Claire Jolly)

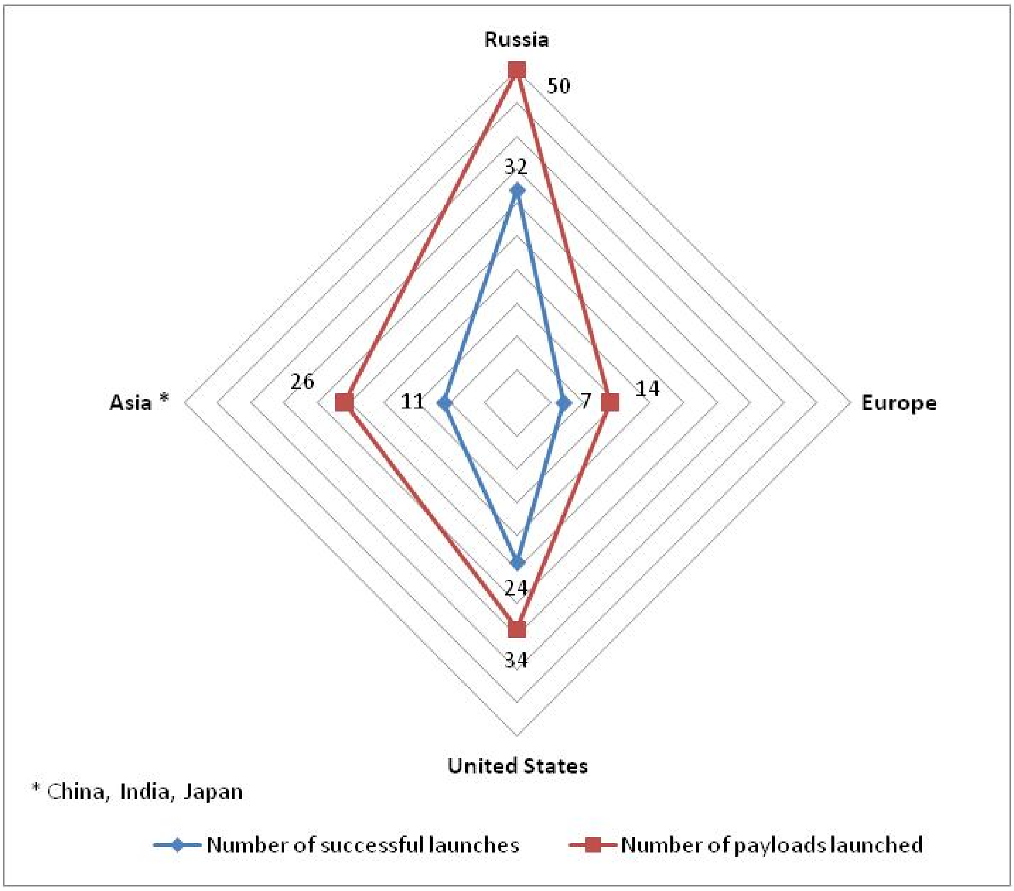
Figure 2.1 b – Civil space programmes as a percentage of civil GBAORD for selected countries
1981 to 2010 (or latest available year)
Source: OECD, Main Science and Technology Indicators database, August 2010



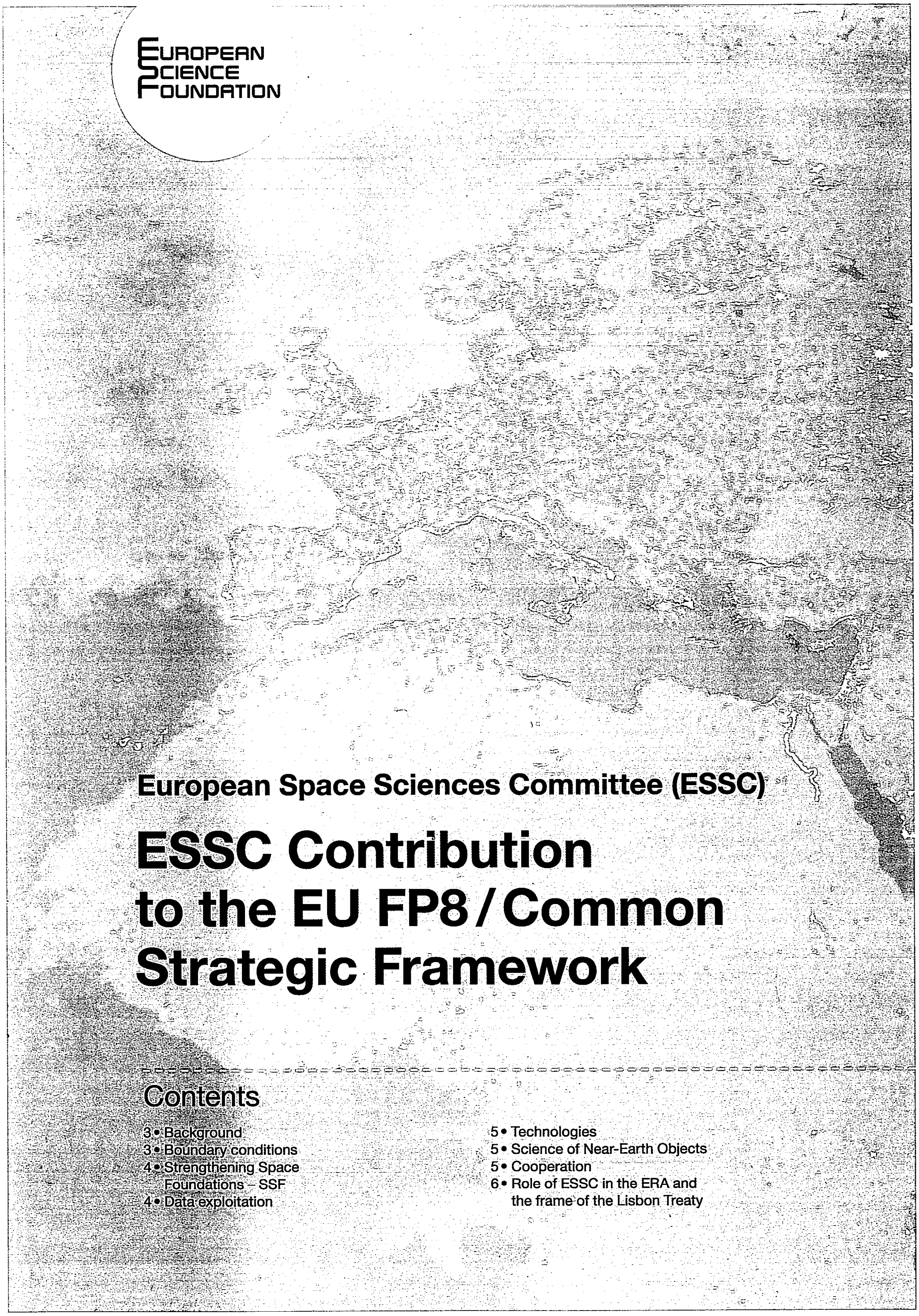


* Non OECD country

Figure 2.1 c – International distribution of successful space launches and payloads in 2009
Source: Adapted from Lardier, 2010



ANNEX 2 – ESF/ESSC contribution paper to Horizon 2020



EUROPEAN SCIENCE FOUNDATION

European Space Sciences Committee (ESSC)

ESSC Contribution to the EU FP8 / Common Strategic Framework

Contents

Foreword

On 9 February 2011 the European Commission initiated a consultation for the preparation of the next (8th) Framework Programme by issuing a Green Paper entitled "From challenges to opportunities: towards a common strategic framework for EU research and innovation funding". The EU budget review indeed proposed that the full range of EU instruments for research and innovation work together in a Common Strategic Framework (CSF).

The European Science Foundation (ESF), together with the European Heads of Research Councils (EUROHORCs), is preparing an overarching White Paper on the CSF. It will be complementary to the inputs from its scientific committees such as this document. It will constitute an important step in creating a unified voice for science and will influence future policy.

In specific areas covered by the European Commission such as the Space Theme, this consultation started even earlier. On 8 December 2010, the EC's Directorate General for Industry and Entrepreneurship organised a hearing that gathered over a hundred participants to discuss the topic of Space in the next Framework Programme. The ESF delivered an invited talk on space research needs for Europe, based on the discussion initiated within the ESF's European Space Sciences Committee (ESSC).

The present document details this discussion and provides a first series of the ESSC recommendations to the EC regarding the space component of the future Common Strategic Framework.

Professor Jean-Pierre Swings
ESSC-ESF Chair

Cover
The Night Lights of Europe

Background

The European Space Sciences Committee of the European Science Foundation (ESSC-ESF) has regularly been providing expert advice to the European Commission (EC) and European space stakeholders since 1992. Specific recommendations were provided concerning the space sciences content of the EC's Framework Programmes 5, 6 and 7. Furthermore the ESSC-ESF was a prominent actor and contributor to the White Paper on Space, published by the EC in 2003.

This document compiles draft recommendations discussed and agreed by members of the ESSC-ESF on the occasion of its 40^{th} plenary meeting held in Frascati, Italy, on 7-8 July 2010 and updated since. It was circulated to committee members and updated with their comments, and further discussed and agreed by the Committee on 29 March 2011.

This document is a first draft input to the current discussion that has started on the EC 8^{th} Framework Programme and the Common Strategic Framework. As such it does not yet represent a peer-reviewed and formally approved ESF-ESSC report. The discussion process will continue in the following months in order to come up with an approved official document that will be forwarded to the EC in due course.

These recommendations were discussed with an understanding of the financial boundary conditions under which FP8 should operate, *i.e.* an overall funding envelope similar to that for FP7, but with a decreasing share for GMES (Global Monitoring for Environment and Security) over the years. The annually available envelope for activities under the heading "Strengthening Space Foundations" (SSF) is not formally established at present although estimates around 60 ± 10 million Euros per Call (per year) in the period 2014-2020 were indicated. Other funding opportunities can be derived from the innovative approach of the CSF.

Boundary conditions

There is a strong need to ensure continuity of long-term space projects. It is in particular mandatory to assess in detail the achievements of FP6 and FP7 to ensure that FP8 can build on progress made. The interim evaluation of FP7 which has just ended should also be used for this purpose. A second pre-requisite stemming from this need for continuity is the fact that Framework Programmes of the European Union are currently not tailored to enable the implementation of long-term scientific roadmaps. This is a major weakness of the current system that prevents Europe from adequately supporting the development of visionary "grand challenges" in space sciences and exploration and, in particular, from supporting the long-term planning architecture developed through the European Space Agency (ESA) and its Member States. Improving this situation would help to give the EU the "world-beating science base" that is being advocated in the European Commission's Green Paper.

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Since there is a need to support pan-European teams working on the preparation and/or the exploitation of space missions, secured funding over 5-7 years and programme continuity would be required. Framework Programmes are not presently tailored to these needs, unless a way can be found to "bridge" support to such activities from one Framework Programme to the next. The Common Strategic Framework proposed by the European Commission, through the bridging of various funding opportunities, should be used to identify ways to improve on the current, unsatisfactory situation.

Strengthening Space Foundations – SSF

It is agreed that the involvement of the EC in space exploration is desirable because of the additional financial and political capital that only the EC can bring to a European exploration programme. The Space Advisory Group of FP7-SPACE has recently recommended basing the implementation of the 8th Framework Programme on three pillars. Two of these pillars are the use of space for (i) exploring the solar system and the universe, and (ii) grand challenges on Earth.

Beyond the funding aspect, one of the main advantages of the involvement of the EC through a Common Strategic Framework would be to enable the creation of pan-European networks or consortia of researchers involved in ESA science missions. In the present situation, Member States fund the development of ESA missions, under the global umbrella of ESA. However the development of the instruments is undertaken by individual institutes, sometimes in collaboration with others, but without any institutional organisation. The Principal Investigator of an instrument does not have any idea, for example, whether a partner will or will not be funded by its national agency. This situation can remain uncertain for a long time. The situation is even worse for the exploitation phase of the missions where it is impossible to constitute networks or consortia with a minimum degree of organisational efficiency.

For Earth Observation missions, funds for such pan-European networks would also be needed, *e.g.* for Earth Explorer missions and for the scientific exploitation of the Sentinel data. In addition, for several of these missions, instruments are in some cases provided by national contributions, which makes pan-European cooperation difficult to fund (this is for instance the case for the Sentinel 5 precursor mission). For these missions pan-European funds would therefore be very important to support space sciences and exploration in Europe.

Coordinating these national approaches and contributions, and mobilising and pooling together funding from the Member States, are thus key issues that the Common Strategic Framework should address.

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The role of the European Commission and of the Framework Programmes would especially be to constitute and adequately support pan-European consortia in all domains of space sciences, and not only to provide the additional funds that are also needed, for instance to support post-doctoral students.

This would enable Europe to play its full role at an international level, for instance in the emerging Global Exploration Strategy, provided the roles and contributions of the EC, ESA, and national agencies within such a programme are clarified.

Data exploitation

Clearly, the objectives of the FP7 3rd Call were not fully achieved in this regard; the EC and concerned stakeholders (including the ESSC) should therefore make a special effort to better inform potential proposers of the existence of this option already in FP7.

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Adequate mechanisms and funding should be identified within the CSF for supporting the scientific exploitation of European space missions. There is a clear consensus that this part of FP7 should be retained and strengthened in the future.

From this standpoint, and in order to properly prepare the grounds for FP8/CSF, future FP7 calls should already be oriented towards several specific areas, which have been insufficiently addressed in previous calls and will demand pan-European funding for scientific exploitation in the second half of the decade, including associated ground-based observations when needed:

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- **Planetary science, exploration, and ground-based preparations related to the ExoMars missions.**
- **Space science in support of the ESA Cosmic Vision programme. In particular, Solar Orbiter, EUCLID and PLATO will require a strong multinational effort, as well as GAIA for data exploitation; here FP8 could play a major role.**

- **ISS activities (life and physical sciences in space and preparation of exploration missions) already involve a large number of European laboratories. The FP8/CSF should identify means to support close collaborations between small groups of laboratories selected on the basis of scientific excellence.**
- **EC support should include funding of Earth-based preparatory research, *e.g.* in the area of terrestrial analogues and field studies for exploration.**
- **Scientific exploitation of GMES Sentinel mission data to integrate and strengthen the European Research Area, in addition to the operational data exploitation carried out under GMES already.**

GMES supports product development for services in relationship with environment and security but does not support scientific exploitation of the Sentinel missions. For example in the case of Sentinel 4 and 5 data, detailed climate research, such as chemistry-climate interaction and specifically the relationship between climate and anthropogenic emissions as estimated from space observations, are not covered by GMES. Apart from the assessment of the emissions of greenhouse gases and aerosols, assessment of emissions of air pollutants (NO_2, SO_2, HCHO and CO) are also essential to understand climate change and the relationship between climate change and air pollution. Relevant sub-topics are air quality and long range transport, which are best studied in cooperation with international partners from emerging economies.

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ESSC-ESF recommends that scientific activities in Earth Observation are also included within an SSF funding line, where they are not already covered by GMES.

Technologies

The funding for technological developments related to future missions should be maintained in FP8. Missions should include Earth and space sciences in general, *i.e.* planetary exploration and solar system science, astronomy and astrophysics, Earth observation, and fundamental physics.

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The development of critical technologies for European non-dependence should be adequately supported (*i.e.* the development of those elements that are available in other countries but not yet in Europe, or affected by ITAR and similar regulations).

ESSC felt however that the funding of technologies for launchers was not really relevant for FP8 within this topic, because it would require very significant funding to be really useful, which is not coherent with the objectives of this topic.

Science of Near-Earth Objects

The panel supported funding the scientific study of NEOs. It looks however somewhat premature for the EC to engage in the topic of prevention against NEOs. These activities should be coordinated with other countries (for instance within the context of the United Nations COPUOS), since they obviously represent a global threat and it would be nonsensical to duplicate the studies.

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Coordination with the new ESA Space Situational Awareness programme would be very much needed from the early stages.

Cooperation

ESSC-ESF agrees that this topic should be maintained within FP8.

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The Committee suggests increasing the budget for proposals dealing with Space Policy Studies, since the present envelope is considered to be too low to be useful.

Role of ESSC in the ERA and the frame of the Lisbon Treaty

While recognising that science is only one thread of the overall case for European involvement in space exploration (the others being industrial and technical innovation; stimulus for science and engineering education; and geopolitical benefits both within and outside Europe), science is the particular concern of the ESSC-ESF. Thus, as EC involvement in space develops the ESSC should aspire to providing independent scientific advice on those elements which affect science.

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The EU and its institutions need to rely on an independent scientific advisory body and the ESSC is ready to play this role. This will require adequate support from the relevant European institutions.

There seems to be a clear consensus that the ESSC-ESF can help improve coordination at a scientific level between the different agents funding space activities in Europe: ESA, EC and national programmes. This role could be strengthened in various areas, such as:

- providing advice to mission/instrumentation calls in national programmes;
- advising national institutions of the situation in other European centres concerning specific areas, for example when they start planning on future national missions;
- providing a bridge between ESA and EC on scientific issues.

In addition to this science thread, the involved stakeholders should also strive to keep space technology development as one basic pillar of the European space venture. Establishing the right connections between science and technology in space is indeed a major goal and tool, space being a main technology driver. Support for the development of key critical technologies has been advocated as a vital element of Europe's space policy.

The space sciences advisory body to the EU should therefore also be able to integrate the technology element into the picture (within the space domain and between space and non-space technologies), in addition to integrating views across the various space-related scientific disciplines. This is mandatory in order to be able to deliver strategic recommendations on a European space policy.

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The independent space science advisory body to the EU should incorporate a space technology subcommittee composed of independent technology specialists, to inform European decision-makers on space technology-related matters.

ESSC Members (as of February 2011)

- **Professor Jean-Pierre Swings** (Chair), Institut d'Astrophysique et de Géophysique, Liège, Belgium
- **Professor Heiko Balzter,** University of Leicester, United Kingdom
- **Professor Doris Breuer,** DLR-IPR, Berlin, Germany
- **Professor Jørgen Christensen-Dalsgaard,** DPA, Aarhus University, Aarhus, Denmark
- **Dr Gilles Clément,** CERCOS, Toulouse, and ISU, Illkirch, France
- **Dr Ian Crawford,** School of Earth Sciences, University of London, United Kingdom
- **Professor Hans Jörg Fecht,** Universität Ulm, Germany
- **Professor Olivier Francis,** Faculty of Science, Technology and Communication, University of Luxembourg
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