Space research in Horizon 2020

Recommendations of the

FP7 Space Advisory Group (SAG)

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DISCLAIMER NOTE

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

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1. GENERAL INTRODUCTION

1.1 Prospects for a Future of Space Research in Europe

The political evolution that lead to the end of the Cold War has resulted in space becoming an increasingly global and, in many cases, a collaborative and innovative enterprise, bringing together established and emerging space-faring nations.

In the last fifty years, through a series of tremendous scientific and technical achievements, the space sector has enabled enormous progress to be made in understanding our universe, our solar system, our planet and its environment; and there are many similarly challenging endeavours still to be tackled in such uses of space to extend our present knowledge.

The civil telecommunications industry has taken the lead in the peaceful, commercial uses of space, and, more recently, the world has seen the advent of ubiquitous satellite navigation systems and Earth observation and meteorology services which have become progressively more reliant on data acquired by satellites.

As a result, the space sector has shown unprecedented vitality, exceptional dynamism and impressive resilience, growing consistently since 1999 at an average rate of 9% per annum. Its productivity has been measured at more than four times the average.[1] This is supported by analysis at national level. In Norway, for instance, the space sector has made a constantly increasing return on government support, as reported by the Norsk Romsenter, from a multiplier of 3.5 in 1997 towards 4.8 in 2010[2]; and the Danish Forskning- og Innovationsstyleren[3] quotes an average multiplier of 5.4.

Technological advances from research and technological development investment in the space sector, which are subsequently transferred to other industrial sectors in the form of spill-over effects, have been researched by Oxford Economics[4], using data from 25 European economies, the United States and Canada. This suggests that such spill-over into other sectors contributes a further social return to GDP from investment in space sector research and development of around 70%.[5]

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[1] *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.*

[2] *This means that, for instance, in 2010 for every million Norwegian kroner of government support, space sector companies attained an additional turnover of 4.8 million Norwegian kroner.* Vide *Norsk Romsenter's Annual Reports.*

[3] *Forskning- og Innovationsstyleren,* Evaluation of Danish Industrial Activities in the European Space Agency (ESA)*, Copenhagen, March 2008.*

[4] Opus citatum.

[5] *This means that every 100€ invested in research and technological development leads to an increase in the gross domestic product in other sectors of 70€.*

Major space initiatives are increasingly becoming global endeavours as the costs involved go beyond the resources available to any single nation. Such initiatives are exemplified by space science, exploration missions and global responses to major challenges on Earth. These challenges include dealing with the threat of climate change, managing the environment and the Earth's dwindling natural resources, improving or facilitating telecommunications services in remote areas and multiple aspects of civil security. At the same time, advances in technology (e.g. for smaller satellites) have also enabled an increasing number of nations and entities to participate in satellite missions and develop space capability.

All these initiatives and their subsequent exploitation benefit the global economy and human societies; they are also heavily dependent on continued research and technological development. To retain its serious and uncontested standing as a global player in this domain, Europe must continue to invest accordingly. It must ensure that its space know-how remains world-class whilst endeavouring at the same time to lead the world in selected areas. If this is not achieved, Europe will be unable to set and achieve its own objectives and will be relegated to playing the role of a minor partner, helping others to achieve their objectives, in forthcoming global space initiatives, plans for which are now advancing rapidly. It will lose the considerable economic and societal advantages that stem from being a major supplier of technology, products and services to expanding commercial space and space-enabled markets, as well as losing the influence in global affairs that has already resulted from its position as a leading space-faring community.

For the first time including in its Seventh Framework Programme (**FP7**), in one separate space theme, such topics as those dedicated to Global Monitoring for the Environment and Security (**GMES**) and "Strengthening Space Foundations", the European Commission (**EC**) has marked the start of its highly appreciated support for space research in Europe. However, due to financial limitations, the role of the European Union (**EU**) in space research in Europe has nevertheless remained quite marginal. Also, coordination and communication between the European Commission and the other European stakeholders in space has not yet completely matured. As a result, the European Commission hitherto had to focus on 'gap filling' and addressing areas not previously dealt with by the other space organisations. It also had to take a lead, with the European Space Agency (ESA) and the Member States, in the transition to the operational phase of Europe's flagship satellite navigation project (Galileo).

The Seventh Framework Programme terminates at the end of 2013; the space theme will continue within the Horizon 2020 framework for the period 2014-2020, with a currently proposed annual budget of about 240M€ being foreseen for the whole Theme, a further increase over the amount allocated in FP7.

1.2 Process Leading to this Advice and Resulting Recommendations

The FP7 Space Advisory Group (**SAG**) has, amongst its other tasks for the Commission, been requested to provide advice concerning the positioning and content of space-related research within Horizon 2020 (also occasionally referred to as H2020 in this document). The 23-strong Advisory Group comprises members with experience in all types of space programmes (institutional, academic, research and commercial). The Advisory Group has previously presented the Commission with a series of papers taking account of both the needs and priorities of the space community in Europe and the developing policies of the Commission for the European Union. A paper published on 10 October 2010[6] was followed by a second on 16 June 2011[7], putting forward evidence and a series of recommendations aimed at securing acceptance of the argument that "space must be a major and well-funded theme of Horizon 2020"[8].

As originally envisaged, with the intended transfer of GMES to operational status, it was thought that a new Flagship Programme for space exploration would become a major part of the space theme for Horizon 2020. The membership of the Advisory Group was revised and extended by the Commission to reflect this expectation and, although it is no longer considered possible to establish such a Flagship Programme due to financial constraints, space exploration and space research remain strongly represented in the SAG's advice for Horizon 2020.

As the Galileo programme is being supported outside FP7 and this situation will continue in the Horizon 2020 period, the SAG has not addressed this aspect of European space activity with specific advice. However, some of the proposed research lines on technology will help the future development of the Galileo programme.

Following publication of various European Commission Communications on Horizon 2020[9] the Space Advisory Group was requested to produce detailed advice on the substance and content of a dedicated space theme within Horizon 2020 to meet the objectives of the Commission for the Horizon 2020 Programme overall. For this purpose the Space Advisory Group constituted a sub-committee from its membership to draft its advice.

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[6] *Space Advisory Group of the European Union Framework 7 – Space Theme,* Space Exploration, a new European Flagship Programme*, Brussels, 10 October 2010.*

[7] *Space Advisory Group of the European Union Framework 7 – Space Theme,* Space Research in Horizon 2020*, Brussels, 16 June 2011.*

[8] *Horizon 2020 is the name adopted for the Framework Programme for Research and Innovation (2014-2020), also* passim *referred to as FP8 or the Common Strategic Framework (CSF).*

[9] *In particular, European Commission,* Proposal for a Regulation of the European Parliament and of the Council establishing Horizon 2020 – The Framework Programme for Research and Innovation (2014-2020)*, COM(2011) 809 final, Brussels, 30 November 2011.*

The Sub-committee was asked to take into account input from the “Space Hearing” organised by the European Commission on 8 December 2010.[10] The aim of this hearing was to give Europe’s space research community an opportunity to provide the Commission with ideas for topics which could drive the preparation of the Horizon 2020 space theme. Participants were requested to provide concrete suggestions for particular research areas to be tackled, with the aim of identifying the space research challenges to be addressed over the next decade, with a particular focus on new areas and areas that may not have been adequately covered by FP7. The full set of submissions provided an excellent basis for discussion, being related to all types of space missions, as well as cross-cutting technologies and data exploitation. The Hearing, attended by 160 participants, concluded that “stakeholders see FP8 [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”.

The Space Advisory Group Subcommittee therefore analysed the submissions and assessed their relevance to the Commission’s overall objectives for Horizon 2020. The results of this analysis have been considered in formulating the recommendations contained in this document.

It is recognised that there is currently a significant emphasis on growth and jobs at a high level in terms of policies for Europe. At the same time it is important to maintain a level of support for inspirational space research endeavours, such as space science, aimed at obtaining greater knowledge of the Solar System and the Universe, and planetary exploration. Such activities make significant contributions to Europe’s ability to attract talent into science and technology, to demonstrate leadership on the global research stage and to participate on an equal basis with other major global players in international partnerships aiming to tackle major global challenges. The recommended activities that follow are aimed in all cases at deriving maximum value and returns from Europe’s investment in space.

In this context, two main recommendations on the balance of the programme, shown in Figure 1-1[11], have emerged thus far:

[10] *A summary of the hearing, how it was structured and the initial conclusions is contained in a report produced by the European Commission:* vide *European Commission,* Hearing on Space Research in FP-8*, ENTR H2/hb, Brussels, 8 December 2010.*

[11] *Figure 1-1 was updated, mainly in what concerns the terminology, from a previous SAG advice:* Vide *Space Advisory Group of the European Union Framework 7 – Space Theme,* Space Research in Horizon 2020*, Brussels, 16 June 2011, pp.20-22.*

Recommendation 1-1. We recommend that Horizon 2020 contain "Space for exploring the Solar System and the Universe" and "Space for Grand Challenges on Earth" as the two main pillars of the space theme, to be complemented by two further elements: "Enabling technologies" and "Crosscutting activities".

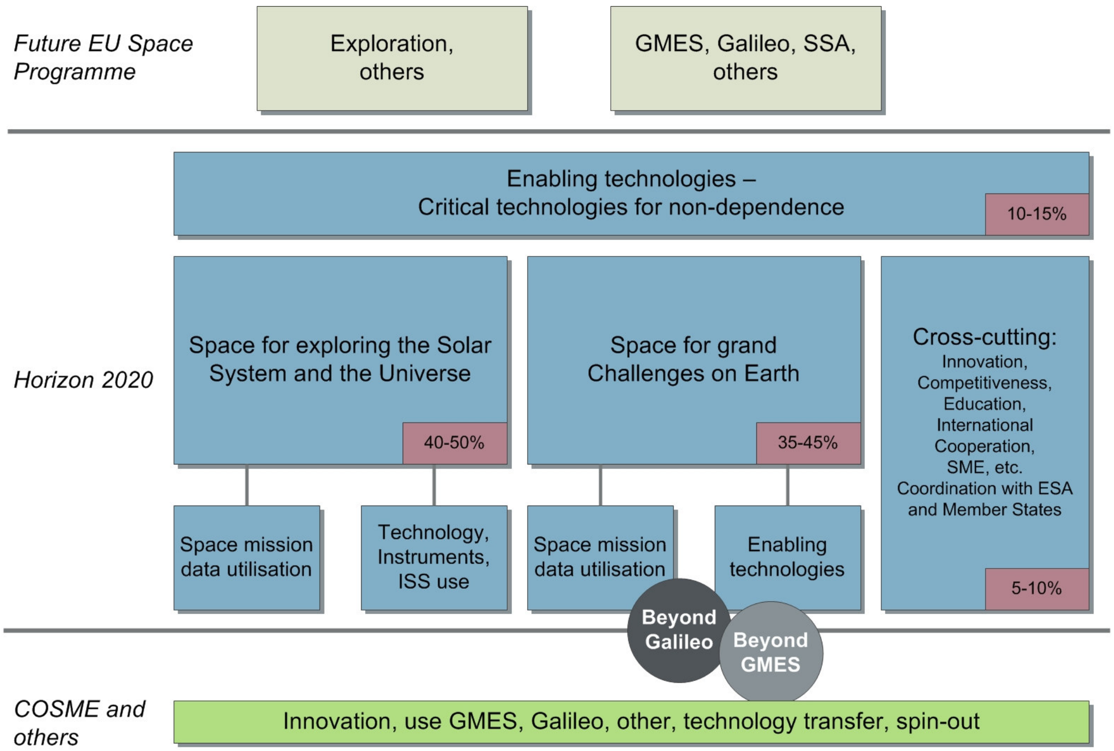

Figure 1-1: Research Topics in Context

Recommendation 1.2: We recommend that 40-50% of the annual budget should be devoted to space research activities as part of "Space for exploring the Solar System and the Universe" and 35-45% to "Space for Grand Challenges on Earth". This recommendation must be viewed by the EC against the wider objectives of the Horizon 2020 programme. It is aimed at achieving a balance between supporting the longer term health of the scientific research community and securing nearer term benefits from Europe's use of space.

The recommended composition for the space theme will allow the European Commission both to become a major player in European space initiatives and global collaborations and to strengthen European competitiveness within the global space research and satellite applications landscapes.

1.3 Structure of the Space Advisory Group's Advice

The remit given to the Advisory Group required the advice to be constructed in a way that links the recommended content and activities to four specific objectives derived from the Commission's aims for the overall Horizon 2020 Programme. These objectives for the space theme are[12]:

1. enabling European competitiveness, non-dependence and innovation of the European space sector;
2. enabling advances in space technologies;
3. enabling exploitation of space data;
4. enabling European research in support of international space partnerships.

The Space Advisory Group has therefore compiled separate chapters detailing how the recommendations for the space theme programme contribute to each of these four objectives as set by the European Commission[13].

These four chapters (chapters 3 to 6) were compiled by separate groups within the SAG, each with profound expertise in the subject area. Since there are clearly links between the four objectives, this has inevitably led to some repetition between chapters, which were kept *passim* in this advice text to allow the coherence of each chapter.

Before starting with these objectives however, Chapter 2 lays out the context in terms of the current landscape in Europe for the funding and delivery of space and satellite missions, the ground segment and operations infrastructure, 'downstream' value-added services enabled by satellite (e.g. broadcasting and satellite communications) and services using observations and data from satellites (e.g. satellite navigation and meteorology). This is a comparatively high level overview that seeks to elucidate the main features of this landscape and the current weaknesses in the provision of support for innovation in space, in the exploitation of its assets and in the exploitation of relevant capabilities by European players in both the public and private sectors.

[12] *European Commission,* Proposal for a Regulation of the European Parliament and of the Council establishing Horizon 2020 – The Framework Programme for Research and Innovation (2014-2020)*, COM(2011) 809 final, Brussels, 30 November 2011, p.53.*

[13] Idem.

2. CONTEXT – THE SPACE SECTOR IN EUROPE

2.1 Overview

The recommendations for space research have to be seen in the context of Horizon 2020 (**H2020**), the European Union (**EU**) framework programme for research and innovation. Horizon 2020 has three priorities: excellent science; industrial leadership; societal challenges.

Space research in Horizon 2020 will be funded from the budget line: "Creating Industrial Leadership and Competitive Frameworks", as one of the "enabling and industrial technologies".

Generally speaking, the term "space research" can be interpreted in a number of ways:

- Research to help us **to do space better** and more cost-effectively and provide spin-offs into other domains.
- Research to help us to **use space better** – space-based telecommunications, navigation, earth observation are attributes of our daily lives.
- **Research into space itself** – the study of our solar system and our universe is part of our human culture.

As described in section 1.1, FP7 has two main components within the space theme: GMES which was research to **use space better** and Space Foundations which was to **do space better**. For Horizon 2020, the Space Advisory Group, as stated in section 1.2, has recommended the addition of a component to address **research into space itself ("space research")**.

Being evident to the SAG members that space is not a single disciplinary domain but a multifaceted complex combination of integrated technologies and concepts being used in a specific context and requiring very complex developments, the proposed inclusion of "space research" in the Horizon 2020 deserves a particular reference. In fact, the space domain does not have national boundaries and the recommendations given in this document take into account that **space research is in many respects a global endeavour**.

Finally, the organisation and funding of space research in Europe is complicated with many European and national organisations involved. Coordination and the avoidance of duplication of effort is a major consideration and should be a significant focus of attention.

2.2 Space is an Indispensable Attribute of our Daily Life

Space provides us with invaluable data about the Earth, its resources and the impact of human and natural activity on our environment and quality of life. This includes information that is vital to the production of our weather forecasts, the efficient management of our food production and supplies, our energy production and supply, and the construction and operation of our transportation and logistics systems. It provides essential communication channels worldwide for many aspects of daily life, both behind the scenes as in the financial sector and directly into our homes through broadcast news and entertainment. The infrastructure supporting these services is based on numerous orbiting satellites with varying capabilities delivering highly efficient communication channels, global positioning signals and Earth observation data.

Earth observation provides an immediate snapshot of conditions across the Earth on local, regional and global scales, as well as contributing historical data archives that facilitate our understanding of how our environment is changing over time. It permits us to:

- monitor and forecast the weather
- manage crops and fertilisers to maximise productivity
- monitor and manage water resources
- prospect for increasingly scarce natural resources, including sources of energy, and to monitor the systems that distribute energy across the world.
- plan our cities and transport systems
- strengthen security and defence
- assist with mitigating the effects of emergencies and natural disasters
- monitorhumanitarian and political situations, peacekeeping and border protection
- monitor the incidence and spread of disease
- monitor the effects of climate change and man’s impact on the natural environment.

2.3 Space Research is an Indispensable Attribute of Human Culture

Space research encompasses the study of the Universe, the galaxies, the stars and the solar system including the search for life, embedded within the context of cosmic evolution. Research in space also includes many other domains, such as materials, fluids and life sciences. It reflects the inherent human desire to understand the origin, evolution and development of the world around us, enabling us to learn how to improve our quality of life. In other words, space is an aspect of human culture. To explore this domain, space research makes use of space missions in Earth orbit and beyond, coupled with ground-based observations, field and laboratory analogue studies and modelling of the dynamic processes taking place in the Universe. Doing this, space research essentially benefits from the cooperation and mutual interaction of space and Earth based activities.

2.4 Space Research is Multidisciplinary

An example of a multidisciplinary approach to space research can be found in the relatively new area of astrobiological research that addresses questions that have intrigued humans for a long time: "How did life originate?", "Are we alone in the Universe?", and "What is the future of life on Earth and in the Universe?" These questions are jointly addressed by scientists converging from widely different fields, ranging from astrophysics to molecular biology and from planetology to ecology, among others. Space scientists and engineers work together to develop the advanced technologies required to reach other planets and celestial bodies in order to obtain the data and information needed to answer such questions.

2.5 Space Research is Multinational

Most ambitious programmes of space research cannot be managed anymore by a sole national space programme. Over 40 years ago, European nations established ESA which in turn cooperated with other partners worldwide. In order to bundle the resources, the scientific and technical expertise as well as the financial support needed, pan-European as well as international programmes have evolved. Prominent successful examples include the International Space Station, the Cassini-Huygens Mission, the Hubble Space Telescope, XMM-Newton, Herschel, EarthCARE and operational meteorology. Cooperation with other national space agencies at the international level is a major feature of modern endeavours in space.

2.6 Space Research interconnects Space and Earth-based Activities

There are many useful synergies between ground-based observations and space missions in several areas of space research, including astrophysics, solar system exploration, astrobiology and Earth science. Furthermore, research in space enhances research for terrestrial applications, for example through experimentation into the behaviour of materials and fluids and into biology and medicine conducted under conditions of microgravity. Examples of useful synergies include (i) the use of ground-based observatories as complementary facilities and/or test beds for specific technologies of interest for space missions, (ii) use of space and planetary simulation facilities as test beds for investigating the effects of gravity, radiation and other extreme planetary and space characteristics, (iii) field studies in planetary analogue sites as stepping stones to solar system exploration missions, (iv) studies on the ISS to understand gravitational effects in biology, human physiology, physics and materials. All four topics were repeatedly stressed during the Hearing arranged by the European Commission on 8 December 2010 – see section 1.2.

2.7 The Current Situation of Space Research in Europe

There are several organisations involved in funding and initiating European space science, research and technology development and space missions. These include the European Space Agency, national space agencies, national research organisations, universities, industry and the EU (see Annex A). The richness and diversity of space activities and national competences, whilst being a challenge to coordinate, is also a strength with positive effects on competitivity.

Processes do exist in Europe for the consultation with the relevant communities and for coordination of space Research and Technology (R&**T**) development efforts. One good example is the European Technology Harmonization process. Nevertheless, as the context evolves and new actors emerge, there is a continuous need for coordination of space research, technology development and research infrastructures. This is particularly needed when the major underfunding of space in Europe in comparison with other leading spacefaring nations is considered. Improved coordination will enhance the already excellent science which is performed in Europe. It will enable Europe's current industrial leadership to be maintained, strengthened and also expanded into additional areas. It will also make it possible to establish a position for Europe as a valuable partner for exploration as well as contributing more effectively to solving societal challenges.

2.8 Comments on European Space Policy

Europe needs a coherent and forward-looking inspirational space strategy. This should take into account longer term aspects, addressing the utilisation of space as a strategic resource, as well as taking into account the shorter term needs of commercial space missions, which require lower levels of risk and need to reach operational status as quickly and as cost-effectively as possible. The strategy should encourage and facilitate the integration of new actors and programmes, such as Horizon 2020, into the space landscape.

Further, the space community has to ensure that end users do not need to be concerned with the complexity of space missions and operations, and that they can benefit from highly reliable services (such as satellite communications, global positioning, timing and environmental information), at least as easily and cost effectively as using terrestrially based equivalents.

There is a need for strengthening and pursuing clarity and coordination in such a strategy concerning the responsibilities of the different main stakeholders in the European space landscape, particularly the European Members States, the European Space Agency and the European Commission. For example, it must be possible to align decisions taken on the Horizon 2020 programme with decisions taken by future ESA Ministerial Council meetings, the next of which is due to be held in November 2012.

2.9 A European Agenda for Space within Horizon 2020

The recommendations of the Space Advisory Group in this and previous advisory documents are very ambitious. Learning from past experience, it is necessary that Horizon 2020 efforts are utilised where they are likely to be most useful in the overall European context. It is recommended that the EC undertakes with ESA and other actors the establishment of an Horizon 2020 research agenda addressing the pillars recommended by SAG and elaborated in this document.

Recommendation 2-1: Pursuant article 189 of the Treaty on the Functioning of the European Union[14], the EC should establish with ESA and other European Stakeholders a research agenda for Horizon 2020 Space identifying objectives, means and priorities.

In order to maximise the efficiency of Horizon 2020 actions through well-informed assessment of the needs and strong coordination with other European efforts, it is recommended that the EC builds on established processes such as European Technology Harmonization and similar endeavours and strongly involves ESA and industry.

The programmes of the main European actors in space, ESA, the national Agencies and the European Commission, are summarised in Annex A.

2.10 A Goal-Driven European Space Programme

In order to foster and extend Europe's leading role in space, a comprehensive, coherent and coordinated space strategy is required. For this, the different main European players in space (see Annex A) should coordinate their efforts in order to make best use of capabilities. This includes the two main pillars of the space programme of Horizon 2020 as further outlined in the following.

The following key elements within the pillar "Space for exploring the Solar System and the Universe" should form a joint European goal-driven space programme involving:

- Synergies between space observatories and ground-based telescopes, development of novel instrumentation for space missions and astrophysics, data analysis and data exploitation using data from European space missions.
- Robotic exploration of the Solar System with emphasis on Mars.

[14] The Lisbon version of 2007, in force since the 1st December 2009: its article 189 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.

- Intense utilization of the ISS for science, technology development/proving and in preparation of human exploration.

For Earth Science, within the pillar “space as a means to face present and future grand challenges on Earth”, Horizon 2020 can make a significant impact by supporting the scientific community in establishing concept development; for example, through offering assistance with campaign preparation, ground observations (in-situ and airborne) and data exploitation. It can also ensure that the resulting data is presented in a form suitable for the development of operational services and then assist with the creation of such services, particularly in the area of the envisaged climate services. In addition to working with the scientific results, data exploitation activities should have the objective of defining future operational service requirements in order to assure continuity of relevant observations.

Recommendation 2-2: There should be close interaction with ESA with the aim of setting up a goal-driven programme for exploitation of missions and experimental data. This should be an essential part of mission planning.

2.10.1 Space for Exploring the Solar System and the Universe

The multidisciplinary nature of space research and technology development requires setting up a programme of space and ground-based activities in order to achieve maximum output from each space mission. The value obtained from space missions can be increased by tight and planned ‘interactive’ coordination between space and ground elements. Activities embedded in such an interactive programme should include:

- Research and the proving of technologies to underpin the preparation of future space missions, including Earth-based preparatory research activities (for example: modelling, the use of ground based telescopes, experiments in laboratory simulations of space and planetary conditions, field studies in planetary analogue sites, human bed rest and countermeasures studies, standardisation of methods and analysis procedures, development of enabling technologies),
- Planning and the realisation and operation of space missions, such as linking to the use of space telescopes, undertaking missions within the Solar System and utilisation of the ISS.
- Extensive analysis of missions and data from experiments, communication of results and making them available to the scientific community, for example through scientific publications in refereed journals.
- Identification and training of the next generation of space research scientists, technology developers and instrumentation specialists - capable of developing new scientific instruments for space research or laboratory instruments for terrestrial science campaigns.

The desire to establish such interactive programmes, combining space and ground-based activities has also been expressed by a large number of participants at the Hearing on Space Research for Horizon 2020, organized by the EC on December 8, 2010 in Brussels. Having given due consideration to the suggestions made at the hearing, the SAG considers that the following three activities should be key elements within the pillar "Space for exploring the Solar System and the Universe":

1. Development of synergies between space observatories and ground-based telescopes, development of novel instrumentation for space missions and astrophysics, data analysis and exploitation of European space missions.
2. Robotic exploration of the Solar System with emphasis on planet Mars. Mars has been endorsed by the SAG as the ultimate destination[15]. A healthy robotic Mars exploration programme requires the interaction of terrestrial analogue studies, in extreme environments as well as in simulation chambers, with the ExoMars mission in order to test the instruments and to interpret and validate the information provided from the space mission (e.g. Mars Express and ExoMars).
3. Intense utilization of the ISS for science, technology development/proving and in preparation of human exploration. Europe has provided essential elements to the ISS, such as the Columbus laboratory with a number of research facilities, the EuTEF research platform, the MATROSHKA radiodosimetry human phantom, and other facilities to come. The ISS is an essential element for human health research, gravity research, radiation dosimetry and biology, astrobiology and solar physics. These studies need to be complemented by ground-based studies in space simulation facilities. Since the lifetime of the ISS is limited, with foreseen retirement in 2020, ISS utilization, including the development of novel instruments, data exploitation and supporting ground-based studies, should be given priority.

Recommendation 2-3: The following three key elements should be included in the pillar "Space for exploring the Solar System and the Universe":

- **An interactive astrophysical element exploiting synergies between space missions and ground-based telescopes.**
- **An interactive robotic element aimed at exploration of the Solar System with emphasis on planet Mars.**
- **An intense ISS utilisation element, including life sciences, preparation for human exploration, material sciences, solar physics, fundamental physics, and astrobiology, supported by Earth-based simulation studies.**

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[15] *Space Advisory Group of the European Union Framework 7 – Space Theme,* Space Exploration, a new European Flagship Programme*, Brussels, 10 October 2010.*

2.10.2 Space and the "Grand Challenges" on Earth

Earth observation, satellite navigation and satellite communications directly and substantially contribute to all of the six identified societal challenges at the heart of the Horizon 2020 programme, namely:

- Health, demographic change and wellbeing
- Food security and the bio-based economy
- Secure, clean and efficient energy
- Smart, green and integrated transport
- Climate action and resource efficiency, and
- Inclusive, innovative and secure societies

2.10.2.1 Data Exploitation

There are already many clear examples of the benefits of exploiting space data and the facilities afforded by satellites:

- Earth observation data has already demonstrated its ability to contribute to studies on the spread of disease for example and we should not forget the ability of satellite communication to reach remote locations with services that support the delivery of vital healthcare.
- Earth observation, with satellite navigation, is routinely used in precision farming to manage crops and fertilisers and maximise productivity whilst minimising wastage and run-off from fertilisers. There is more to be done here, particularly in advancing the use of hyperspectral data for example to monitor crop health and disease. Satellite data also helps with monitoring land use and planning.
- Earth observation data is used to prospect for natural resources, including sources of energy, and to monitor the systems that distribute energy across the world.
- Earth observation data is used for the planning of transport systems and satellite navigation data and communications are critical to their operation.
- Earth observation, along with satellite communications and navigation, has long been used to enhance security and defence. It is also being used for monitoring borders, movements and changes that could threaten national civil security. Factors that could precipitate conflict are being monitored, such as depletion of water resources for example. Satellite observations can also help to enhance security by supporting rapid response to the victims of earthquakes and other natural disasters.

But perhaps the most vitally important and challenging role for Earth Observation data going forward is connected with climate change, monitoring the factors that affect climate change and the effects of climate change on the planet and the environment, on local, regional and global scales. This includes forecasting weather and other longer term climatic changes that could in future affect all aspects of daily life; in particular, climate change will impact our ability to deal with all of the other societal challenges listed above.

To facilitate climate related research we need long term data sets which cover the defined Essential Climate Variables (**ECV**). Assuring continuity of satellite coverage and custodianship of data is not yet sufficiently well catered for by national funding agencies and is beyond the remit of ESA. Efforts must be made to ensure that sufficient quality information is available for the data gathered.

Recommendation 2-4: Horizon 2020 should support the quality assurance, archiving and analysis of Earth Observation data and the development of tools for its efficient application.

Furthermore, assured continuity of satellite coverage and data streams are necessary pre-conditions for investment in commercial services and applications that contribute to economic growth and which can help to address all six of the societal challenge areas listed above.

Europe, as the rest of the world, is facing major challenges, some of them identified in the Lund Declaration of 2009, for example: 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 us to understand climate and environment and their processes.

2.10.2.2 Enabling Technology

The acquisition of such space data and the present and future data sets necessary to meet all of these societal needs will only be completed when developments in sensor technology enable all the necessary measurements to be made from orbit with the required resolution, coverage and reliability. Research and technology development of such enabling technology is thus a fundamental prerequisite to meeting the 'Grand Challenges' on Earth.

Recommendation 2-5: In order to address the six societal challenges at the heart of Horizon 2020, the proposed pillar "Space for Grand Challenges on Earth" should include:

- **Establishing concepts that facilitate provision of support to EU policies, including protection of vulnerable areas and resources.**
- **Operationalisation of observations from science missions for service applications and use of data from service missions for scientific research purposes.**

- **Integration of remote sensing data with GNSS information for scientific and service applications and of SSA information into models of global change to improve understanding of earth systems and reliability of predictions.**
- **Support for efforts to fill gaps in data sets.**
- **Research into techniques and technologies to support Earth Observation applications including crisis response management.**

2.10.3. 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 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 atmospheric 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 the 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 (SCOPE-**CM**) 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.

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 was therefore held in 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 being complemented by a Coordination and Support Action in 2012 under the last FP7 Space Call to coordinate the existing research within the GMES community. These actions are 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.

Recommendation 2-6: Steps should be taken to prepare for an additional core service, devoted to climate change monitoring and subsequent mitigation. It is essential that a space climate change component is carried through into Horizon 2020 and that the realisation of core services dealing with climate change is ensured.

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3. EU COMPETITIVENESS IN SPACE

3.1 Main Messages

Growth in the sector will be driven by the expanding development and uptake of downstream services (see Section Annex C) and this should be the driving force for Horizon 2020 in Space. To support this objective, Horizon 2020 should be adopted as a tool for the European Union to implement the responsibilities attributed to it in the European Space Policy. It should be the means of developing the use of satellite services to deliver European policy objectives. Schemes are recommended where ESA is made responsible for the upstream space segment and its development while the EU supports preparation and exploitation, exploiting synergies with ESA to the full.

Development and maturing of technology to the point of acceptable application risk, plus ensuring, on the one hand, access to state of the art technologies in all key areas and, on the other hand, a level playing field with non-European competitors, are key factors underpinning competitiveness which need support. The current process for identifying critical technology issues and prioritizing development activities needs revision.

Analysis of user requirements should be used to identify needs for both enabling technology development in the upstream sector and other technological enhancements to improve the competitiveness of space-based solutions. Some processes for identification of technology needs from user requirements and prioritisation and harmonization of European efforts already exist. The EC should build on such efforts with the European Space Agency (**ESA**), other European space organisations and industry and Horizon 2020 should contribute to the implementation of developments required by agreed roadmaps. It is clear that current mechanisms in FP7 using open calls and co-funding are not appropriate.

Open calls, which are adapted to give a chance to new ideas and sustain potential breakthroughs, should be continued, but this is not an appropriate tool for subsequent stages of developments needed to turn technologies into products,

The principle of co-funding is acceptable by industry as long as it can identify commercial perspectives for recurrent exploitation of the considered technologies. This reality should be a driver for Horizon 2020 and the level of support that it will bring to industry should account for the nature and the intensity of the investments to be carried out for actual development and testing of high-tech products.

Recommendation 3-1: Horizon 2020 should build on an assessment of needs of European Space public and commercial programmes in a coordinated manner with industry, agencies and users. The use of open calls should be limited to the

investigation of innovative concepts, and co-funding rules should be adapted to the phase of developments to be addressed.

3.2 Introduction

Space impacts on Europe's overall competitiveness on the global stage, as it does for other space-faring nations. This impact is not limited only to the global space market itself, but it reaches into many other strategic and commercial sectors. Space systems, combined with other technologies, provide services and solutions for users in many different applications and markets.

Space is often the only way of obtaining new knowledge, as is the case for in situ planetary exploration or with observations from satellites that cover the entire planet, making otherwise impossibly difficult monitoring and research tasks practicable and feasible. Prominent examples also include science undertaken from space (astronomy, astrobiology, etc.) and in space (exploration of the solar system, experiments undertaken in conditions of microgravity, etc.). In this respect, space is an indispensable tool for the development of knowledge-based society.

Space has contributed to Nobel Prize winning science (Professor Crutzen's research on ozone photo-chemistry for example is largely based on satellite data). This in turn gave rise to new sensors and missions (GOME, OMI and SCIAMACHY for example) leading not only to new science, but also to new services which make a positive impact on daily life (providing ozone-UV indices and routine measures of air quality for example).

Also worthy of note is ESA's Planck mission, currently in operation and devoted to the exploration of the cosmic microwave background. This was the subject of the 2006 Nobel Prize for Physics. Also EUCLID, recently selected as the M2 mission in ESA's Cosmic Vision, designed to search for dark energy, is the subject of the latest Nobel Prize for Physics.

Furthermore, space is a key enabler of potential solutions to the societal challenges of the next century, thanks to its unique capabilities for worldwide telecommunications, meteorology, disaster management, navigation, positioning and remote sensing. It is indispensable for the implementation of many public policies at global, regional and local level, including climate change and environmental monitoring, security, safety and so on.

From an economic standpoint (see section 1.1), many examples can be found where space directly contributes to the growth of Europe:

- European space telecommunications operators are global and provide services worldwide,

- Major European logistic companies owe their capabilities to the use of space navigation and positioning products,
- European companies operate worldwide in the oil and gas sector supported by met-ocean data that only space-based systems can provide economically,
- Precision farming uses remote sensing and satellite navigation,
- Europe's weather forecasting is up with the best in the world and relies on satellite data,
- The financial sector increasingly relies on satellite data for synchronizing transactions and for research that underpins risk assessment by insurers,
- Space is used extensively for assessment of natural assets.

Europe's space sector is thus a net contributor to the wealth of Europe. The upstream sector alone sustains 35,000 highly skilled, high technology jobs and is not likely to out-source them from Europe. Furthermore, space develops top class scientific and engineering human resources, advanced engineering and development processes and tools, novel materials and many benefits that spin-off into other sectors.

Spin-offs from space research find application in a broad spectrum of different areas. A capable space sector is therefore a fundamental tool for Horizon 2020 to achieve its overall objectives, not only in the context of developing industrial leadership but more generally. As noted earlier, it contributes specifically to excellence in the science base and provides an invaluable tool for extending knowledge of the universe and planet Earth. It is also instrumental in addressing societal challenges, such as dealing with climate change, management of the environment and natural resources and improving healthcare in remote areas.

With adequate funding and appropriate implementation, Horizon 2020 will be a vector for fostering the competitiveness of Europe in space. Through strong support to the exploitation of space missions, for the use of space systems in existing and new markets, and for measures to develop the space industry's competitiveness, Horizon 2020 will help to achieve:

- an increased share of the global market for European space (and space using) industry,
- stronger development of commercial space companies in Europe, in particular Small and Medium-sized Enterprises (**SME**),
- better positioning of Europe in science and research,
- a contribution to more efficient and effective public services for European citizens.

Recommendation 3-2: Horizon 2020 should support the exploitation of space missions, the use of space systems in existing and new markets, and measures to develop the space industry's competitiveness (see also section 3.3).

Space therefore clearly contributes to European industrial leadership and competitive capability in the broad context of Horizon 2020 as a whole.

3.3 The Need for Competitiveness

On the global stage, Europe has to position itself to win a worthwhile share of the future international collaborations being prepared to address scientific and societal challenges. Participation in such collaborations is increasingly determined by competition between participating states. Europe's success will depend on its ability to propose and deliver effective solutions compared to those proposed by other international partners. This, and therefore Europe's leadership in space on the international stage, is directly linked to the competitiveness of Europe's industry.

Europe is highly regarded as a first-tier space-faring community delivering world-class scientific data. Many recent technological achievements have been unanimously applauded including the Huygens mission and the ATV autonomous docking system.

In the field of services, Europe has some of the major global operators, for example in satellite telecommunications, satellite based remote sensing and meteorological applications of satellite observations. These applications are strategically important and have high economic value, as well as being essential to the smooth running of our daily lives.

However, Europe is losing ground to its competitors as the other spacefaring nations begin to invest more heavily. It is essential therefore that Europe should take up the challenge of increased worldwide competition. This in turn requires:

- Europe's scientific communities to conduct top class research based on space missions and to propose new ground breaking concepts,
- Europe's space users to develop better systems, technologies, products and processes.

In order to mitigate the risks inherent in taking on such challenges, academia, and to an even greater extent, industry, require as much certainty as possible in order to underpin planning, ideally based upon assured medium and long term demand for the research they undertake and the products and services they develop. They also need access to technologies that have been taken to a level of maturity where the risks associated with on-going availability and in-service performance have been reduced to an acceptable level.

Horizon 2020, by providing adequate support to user communities and industry, can contribute to bringing about the required levels of confidence in the future by:

- aggregating user needs and facilitating the development and adoption of new services using space based assets and space related capabilities,
- helping industry to develop and demonstrate new technologies, in particular critical technologies, and to assess the risks it can afford to take while implementing innovative solutions.

Recommendation 3-3: Horizon 2020 should facilitate aggregation of user needs and the development, demonstration and adoption of new services and technologies in order to bring confidence up to the levels needed for private investment to develop commercial markets.

3.3.1 The Factors of Competitiveness

The commercial competitiveness of space related products and services relies to a significant extent on their cost-effectiveness. Continual efforts to improve cost/performance relationships are essential in order to make such products and services as attractive as possible to users and clients and, in particular, more attractive than terrestrial alternatives for downstream services and scientific research. This requires ongoing investment, coupled with flexibility and adaptability, to meet changing needs and match the advances made by competitors.

Achieving specified levels of technical performance and capability at lower cost is a key driver of innovation, which can in turn secure investment and an expanded community of users for new technology. In the context of space, efforts to increase cost effectiveness, from launch capability to satellite services, will increase Europe's productivity in the use of space for research, boost exports for space technology, deliver improved satellite services to global markets and underpin the provision of societal benefits to European citizens.

Also important to competitiveness are:

- ownership and management of critical Intellectual Property Rights (**IPR**),
- achieving better levels of customer service, and
- creating better business models, including those based on innovative financing.

3.3.2 Competitiveness: from Early Research to Full Maturity

It is clear that Research and Technology Development (**RTD**) is a key contributor to the competitiveness of industry in a technology-intensive domain like space. Support is needed:

- in the long term to identify breakthrough techniques and technologies and prepare next generation systems and components,

- in the short term to transform new technologies into products delivering the right level of performance, at affordable cost, with the required level of maturity and the desired level of non-dependence for use at minimal risk in space programmes.

With the exception of ESA's Advanced Research in Telecommunications Systems (**ARTES**) and, to some extent, General Support Technology Programmes (**GSTP**) programmes, which explicitly address the needs of industry on various time scales, publicly supported RTD programmes in the space domain usually have to focus on the needs of specific missions and can address only early stages of development, leaving the funding of subsequent phases of technology development to the missions concerned. This means that comparatively little effort is being devoted to basic generic technologies in the space domain and that individual missions bear most of the risk of the actual development and technical qualification of the technologies they need.

This is inefficient and Horizon 2020 can improve efficiency by supporting development of the basic technologies in the space domain (new materials and components for example) and user segment technologies that are needed to exploit the results and data produced by space missions and satellite systems.

Recommendation 3-4: Horizon 2020 should help to identify breakthrough technologies, research new basic space technologies, for instance novel materials and components, develop new user segment technologies needed to exploit results and data from space missions, and help to transform such technologies into new products.

3.4 Industry Performance

Europe is currently doing well on the open markets thanks to investments made years or decades ago. But the quest for competitiveness must be relentless and continuously supported in order to keep ahead of the competition.

Competitiveness can only be assessed through an unbiased comparison with the levels of price, performance and commercial success demonstrated by international rivals. This is not an easy task as space worldwide is a business to a significant extent held captive by national agencies, except on the open commercial market, which nevertheless still forms the smaller part of the global space scene and which encompasses only a limited set of space-related disciplines.

The European space industry is, however, very successful in this commercial marketplace, particularly in relation to the upstream space segment, as illustrated in Figure 3-1. The industry derives nearly half its turnover from the worldwide open market. This is an essential component of Europe's activity in space, not least because it maintains a critical mass of activity and resource otherwise not assured on the basis of European institutional demand alone. It also provides a return on the investment in space and contributes to economic growth.

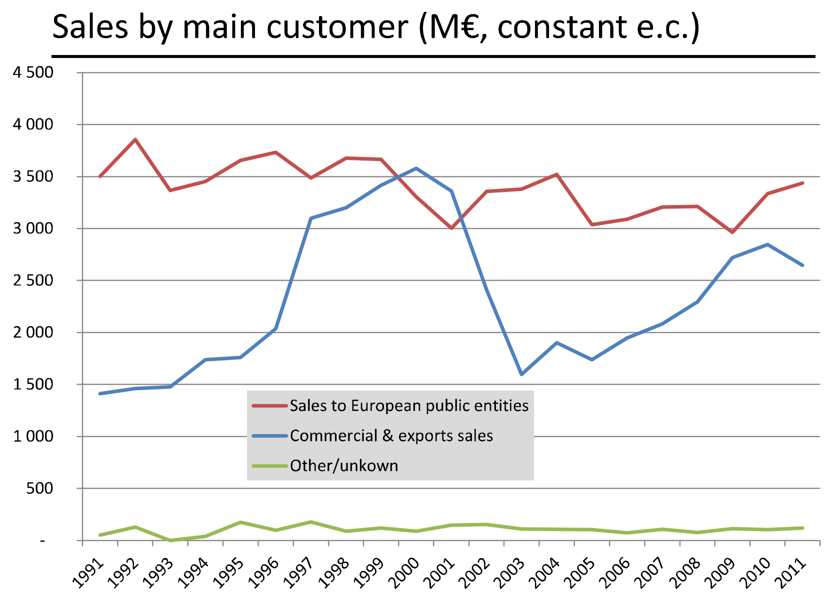

Figure 3-1: Turn-over of European space industry by customer[16]

Large European primes are highly successful in their respective segments as are smaller, more specialised prime contractors. Equipment manufacturers and suppliers are also successful in export markets, where they generate significant business directly with foreign customers.

No other space-faring nation or space industry matches this return on investment in space or relies to such an extent on the commercial market for its viability in the space domain.

[16] Eurospace Facts and Figures 2012

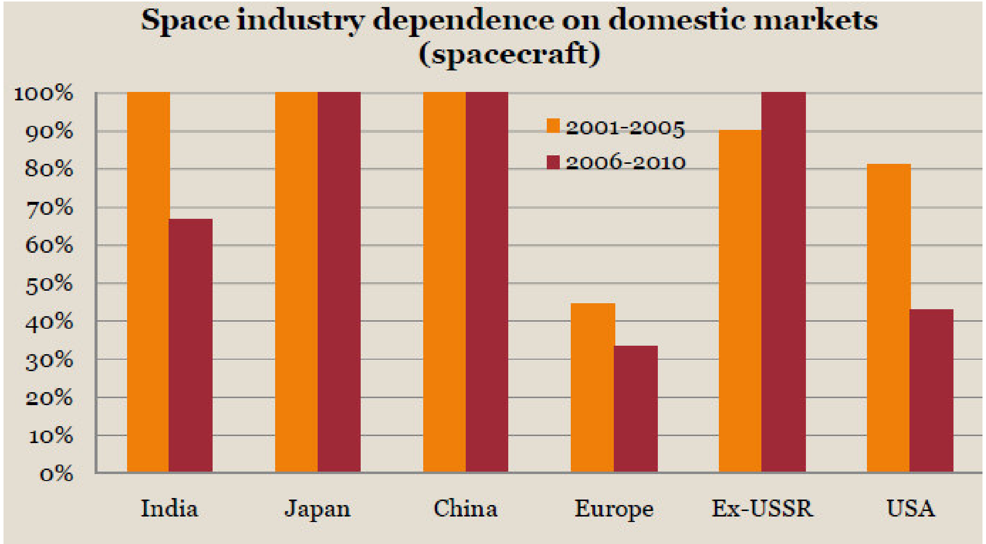

Figure 3-2: Dependence on domestic markets in % of number of spacecraft produced [17]

The dependence of Europe on the commercial market is particularly marked in the launch service sector as shown in Figure 3-3.

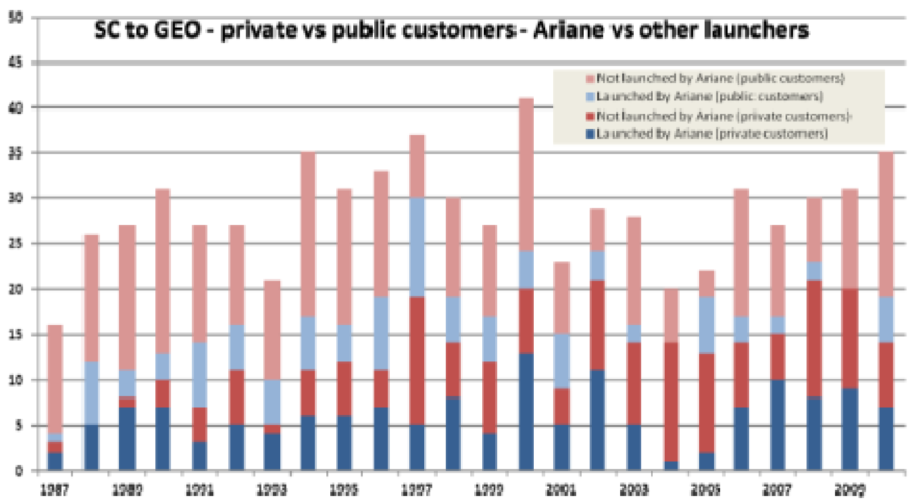

Figure 3-3: Share public – institutional market for Ariane and other launchers[18]

The existence of a competitive European industry is also vital for the affordability of European institutional systems and infrastructure, such as operational meteorology, Galileo, GMES, secure telecommunications, etc. Loss of competitiveness would weaken the space industry and Europe would become an importer in a sector where it is currently a successful exporter.

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[17] Eurospace, the place of Europe in space - Belgirate Workshop March 2012

[18] ESA, Launcher Strategy

3.5 Market Segmentation and Development

The most important market segment is satellite telecommunications, which is highly competitive and enjoys strong demand from private customers. Earth Observation (**EO**) is a significant contributor to industry's turnover and, although it is still a largely institutional activity in Europe, there is an emerging private market. Europe's presence in navigation is developing and, although the segment is institutionally dominated at present, it is already creating a market for equipment suppliers.

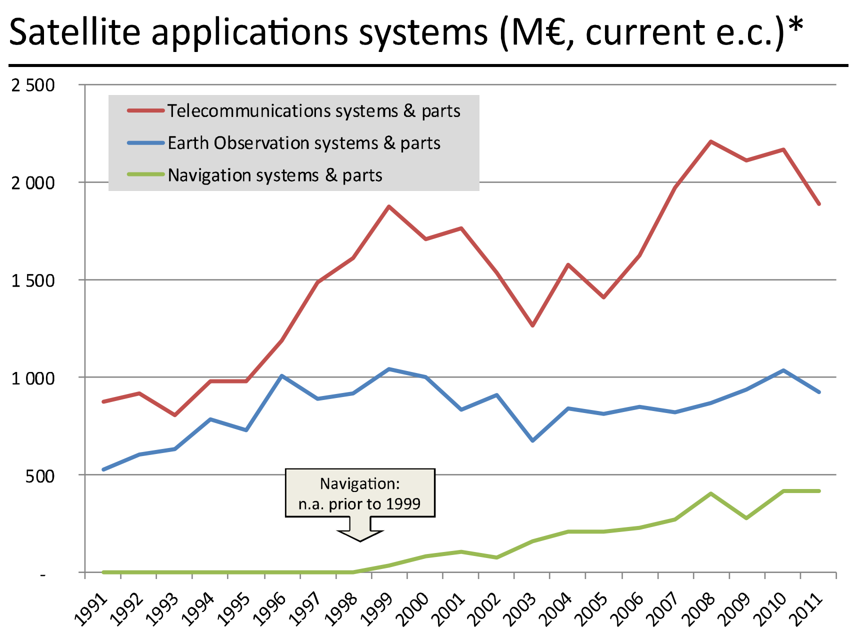

Figure 3-4: Turnover European industry by applications[19]

The satellite telecommunications market is cyclic with demand being strongly determined by the upgrading and replacement of fleets. A positive trend is evident in the increasing number of countries wanting to acquire their own space assets, in particular in the fields of telecommunications and remote sensing. Recent examples are the orders from Turkmenistan and Vietnam, new players on the space scene, to European satellite manufacturers.

3.6 Traditional Competitors and New Entrants

In the satellite telecommunication market, traditional competitors of the European space industry at all levels have been US companies. Japanese companies are competitors at equipment and supplier level, though in 2011 the Mitsubishi Electronics Corporation (Melco)

[19] Eurospace Facts and Figures 2012

has also booked successes at prime level. Recently, competitors are emerging from Russia, China, India and other nations. Figure 3-5 shows the evolution of the geostationary satellite market and the various market shares. Worth noting is the strong resurgence of US competitors in 2010, obtaining orders traditionally won by European industry.

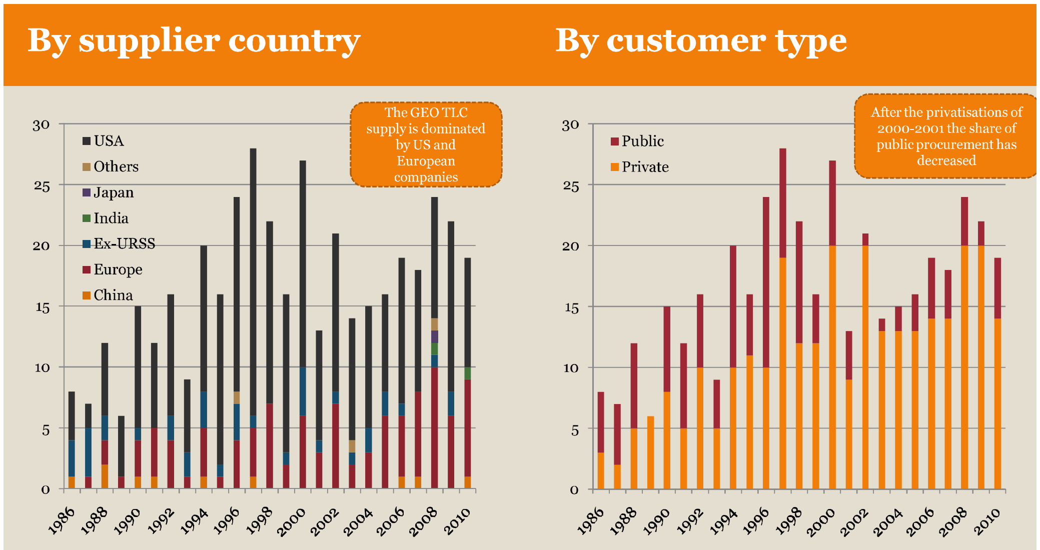

Figure 3-5: Geostationary satellites launched by spacecraft operators[20]

New launch providers like Space-X are basing their expectations, among other things, on an order book underpinned by institutional commitments. This is not the case for launch providers in Europe and highlights another critical issue, which is access to funding for basic space capabilities and institutional support for the involvement of the private sector.

Europe has managed to build up an efficient and competitive space industry but makes comparatively little use of it as a means of delivering against its public policies when compared with other spacefaring nations. The European domestic space market therefore remains very limited in size. As a consequence, despite its tremendous success in the commercial marketplace, the European space sector is 5 to 9 times smaller in terms of workforce compared to the United States, China or Russia. Its situation is therefore fragile and maintaining its competitiveness is definitely crucial as it conditions the ability of the industry to maintain its share of the commercial market and to sustain its viability and critical mass in many key areas.

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[20] *Eurospace, the place of Europe in space, Belgirate Workshop March 2012*

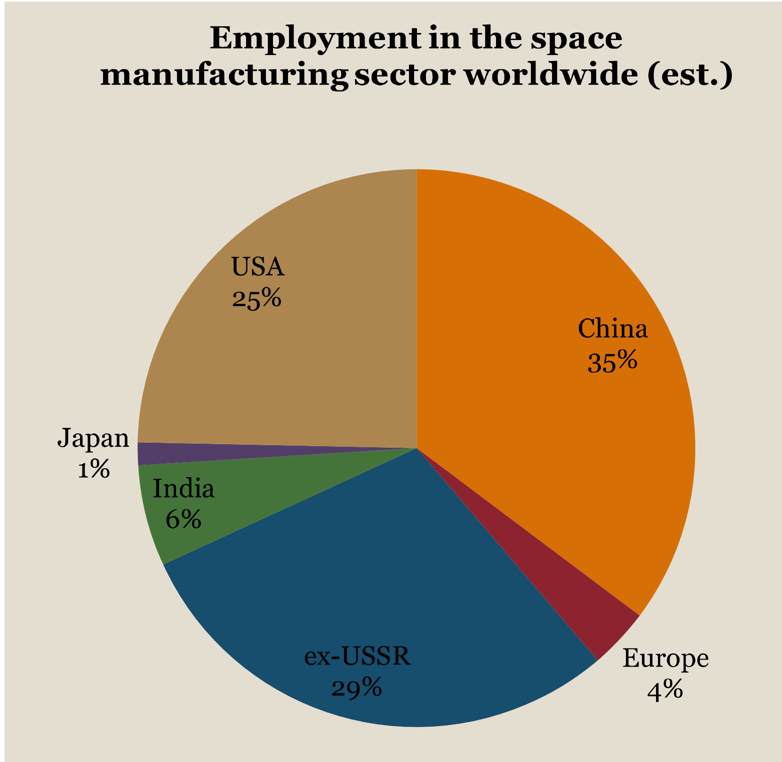

Figure 3-6: Employment in Space Manufacturing Sector[21]

Worldwide, recent data on the evolution of institutional space budgets in the main competitors nations (USA, Russia, China, India), shows them increasing faster than in Europe, as shown in Figure 3-7. Furthermore, some of these budgets are already significantly larger than Europe's. At the same time, US and Japanese companies are beginning to capture traditional European customers in the open commercial markets and exports from Russia and China are starting to rise. Europe could consider consolidating its place between the US on the upper end of the segment and newcomers on the lower end, being able to compete with the US on price and newcomers on quality.

[21] Eurospace, the place of Europe in space, Belgirate Workshop March 2012

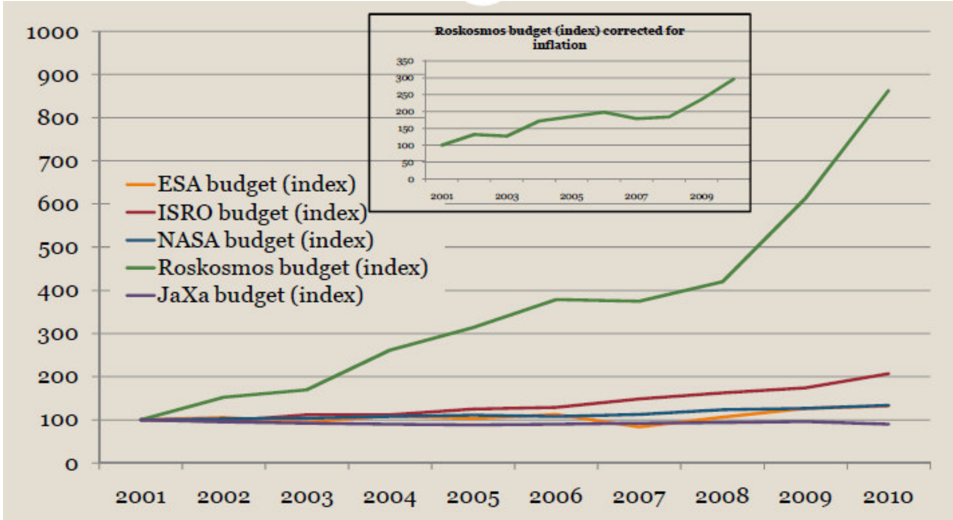

Figure 3-7: Evolution of civilian space budgets[22]

3.7 Downstream Sector Development, Markets Strengthening

Given the situation outlined in the preceding sections, it is imperative that Horizon 2020 should have a strong focus on supporting the competitiveness of Europe's space industry, aimed at creating:

- robust supply chains, including supporting capabilities and skills in the work force,
- a stronger domestic market, where Europe's institutions make greater use of space systems to deliver against policies and for the benefit of European citizens.

A significant factor driving the industry in future will be the growth of downstream services utilizing the capabilities of the satellite network. Because space offers competitive, sometimes unique advantages, it is often the ingredient that confers a competitive advantage on terrestrial products and services. As a result, space is now embedded in daily life at all levels, from institutional activity, through to commercial business and the consumer. There is a consequential demand for products and services derived from space, and therefore a commercial market for such products and services, as illustrated by Figure 3-8. This market encompasses all segments of the space industry, including upstream suppliers, ground segment and operations and downstream service providers to final customers. This constitutes a significant value-adding supply chain.

[22] *Eurospace, the place of Europe in space, Belgirate Workshop March 2012*

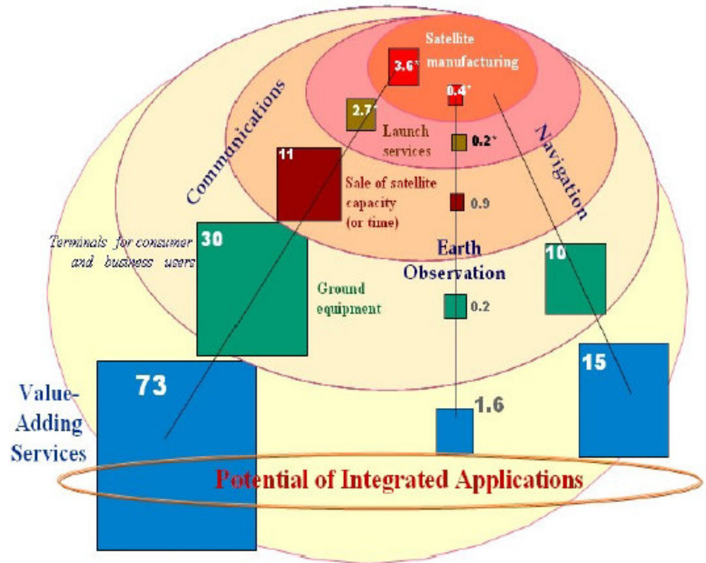

Figure 3-8: The value added chain (from Euroconsult, 2009)[23]

Horizon 2020 should focus to a significant extent on supporting Europe's position in these markets, covering all elements of the supply chain including downstream service providers and the stimulation of domestic demand for these services.

Recommendation 3-5: Horizon 2020 should help to foster a stronger domestic market, where Europe's institutions make greater use of space systems. This effort should cover the full spectrum of downstream services and all elements of the capabilities and skill sets needed to ensure robust supply chains in these areas.

As noted earlier, it is necessary to maintain and strengthen Europe's position in the satellite telecommunications market as well as developing the emerging Earth Observation and navigation markets and developing also new markets, such as in security of maritime services and air transport and in Space Situational Awareness (**SSA**).

There are, however, some space markets that may shrink or disappear or not even become established against terrestrial solutions, an example being consumer broadband provision in developed countries. It is necessary therefore to make space solutions more attractive and to develop them in advance of the emergence of non-space solutions.

To position Europe to succeed across the spectrum of high value-adding downstream service provision, where significant growth is already evident and forecast to continue, Horizon 2020 should become the tool for the European Union to implement the responsibilities attributed to

[23] *Euroconsult Government Space Markets 2009 report*

it in the European Space Policy and the means of developing its use of satellite services to deliver European Policy objectives. This can be achieved by:

- aggregating the demand for space-based services, which might also involve supporting appropriate data standardization;
- stimulating the use of such services, in particular within the framework of delivering European public policies, including security, environment, natural resource monitoring, crisis management, etc…
- supporting the development and demonstration of new service products;
- identifying potential users and supporting user uptake, including appropriate regulation;
- exploiting Galileo and GMES, together with future research missions, in order to create new services opportunities employing space assets as well as identifying needs for new assets;
- exploring partnership schemes with space systems operators which could fulfill current and future public needs;
- supporting the development of equipment and facilities for user segments; for example, terminals for broadband access and IT technologies for EO services;
- procuring launch services in Europe for European needs, including for in-orbit demonstration missions.

Recommendation 3-6: Horizon 2020 should become the tool for the European Union to implement the responsibilities attributed to it in the European Space Policy and the means of developing its use of satellite services to deliver European Policy objectives.

Such actions should leverage the use of space based resources to help effect the delivery of the above-mentioned European public policies, and should help to:

- foster and structure the demand of communities for existing or new space services and systems;
- promote and anchor new space-based services;
- extend the benefits of space on regional and local scales.

Supported activities should include:

- feasibility studies to explore new and radical ideas (including market studies, user requirement studies and other non-technological aspects of application viability);
- research into user segment technological advances, particularly supporting the above;

- support for ‘quick fire missions’ to demonstrate new advances and also to serve as a basis for timely skills and capacity development;
- addressing barriers to data exploitation (tackling the complexity of exploitation rights);
- supporting SMEs, for example through ‘Small Business Innovation Research (**SBIR**) type’ projects;
- collaborative projects leading to new products/services.

Recommendation 3-7: Horizon 2020 activities should include feasibility studies, research into user segment technologies, support for ‘quick fire missions’, tackling barriers to data exploitation, support for SMEs (including SBIR type projects) and product/service collaborative developments.

This should be a very high priority for Horizon 2020 in order to stimulate and grow further the contribution already made to European space endeavours from commercial activities. This will both emphasise the relevance of space to the European public and policy makers and help to compensate for the limited institutional resources available to European industry in comparison to other spacefaring nations.

In relation to the deployment of Galileo and GMES, which are EU-owned critical infrastructures, services are also urgently needed in the realm of Space Situational Awareness (SSA) to ensure the safety and operational integrity of these assets. This requires multifaceted efforts (legal, regulatory, technical and programmatic) which are not affordable by the private sector but which are fully within the remit of the institutional organisations and bodies. Horizon 2020 should initiate the definition and development of a service-oriented European SSA policy.

Recommendation 3-8: Horizon 2020 should initiate the definition and development of a service-orientated European SSA policy.

Development of the downstream sector should therefore be a major driving force for Horizon 2020 in space. This will then lead to the identification of actions to be undertaken in the upstream sector to improve the competitiveness of space-based solutions. As far as Horizon 2020 is concerned, this is likely to relate to basic or enabling technologies such as materials, micro-electronics, components etc…

Recommendation 3-9: Development of the downstream sector should be a major driving force for Horizon 2020 in space (also seen in connection with Recommendation 3-5).

3.8 Non-dependence and the Supply Chain

The supply chain encompasses all the companies involved in the design, development, testing and manufacturing of components, systems and facilities for access to and operation in space.

Horizon 2020 should target the full space industry supply chain, across the entire manufacturing sector. A healthy and robust supply chain, from basic technology through to the end product, whether that be in space, in the ground/operations segment or in the downstream service/end-user segment, is a condition for successful competitiveness and innovation; noting that disruption of supply chains frequently impacts other parties, reaching way beyond the components and systems directly affected. Europe needs to ensure that it can rely on end-to-end supply chains that work effectively and that connect wherever possible all the way through to end users.

Assuring a robust supply chain is not just a research and technology matter but also concerns the assurance at all levels of a set of interlinked capabilities as set out above, including design, manufacturing, packaging, quality and commercialisation etc. Horizon 2020 should enable supply chain issues to be addressed in a holistic manner.

To date, European space industry has a good mastery of most of the supply chain, except at the lowest levels concerned with basic supplies, such as specialist Electrical, Electronic and Electromechanical (**EEE**) components and specialist materials; in this respect the supply chain in Europe has particular weaknesses and in some instances cannot guarantee access to critical technologies; this situation needs to be corrected.

Horizon 2020 should tackle this issue of technology non-dependence with the reasonable objective of solving the most critical situations over the next few years in a stepped and prioritized approach based on the various assessments already made of the current situation; note that non-restricted access to critical technology, i.e. Technology non-Dependence (**TnD**) is as fundamental as access to space (i.e. launch capability).

Recommendation 3-10: Horizon 2020 should target the full space industry supply chain in a holistic manner, including the issue of technology non-dependence.

The EU, EC and the European Defence Agency (**EDA**) have reviewed ESA actions on TnD and critical items requiring urgent action are periodically identified with Member States of the these three organisations. Although some success has been achieved in rectifying the situation via this route, it is clear that the current mechanisms in FP7 involving open calls and co-funding are not appropriate and are unsuited to tackling the problem in an efficient and effective manner. Urgent remedy is needed.

The current process for identification of critical issues should be revised and made compatible with existing European initiatives such as the European Technology Harmonization (**ETH**) process and the European Space Components Coordination (ESCC) which is recognised worldwide and at the root of European exports in this domain.

The EU should therefore assure, through Horizon 2020, strong support for technology non-dependence actions, noting the following:

- The selection mechanisms which identify critical technologies need to be reviewed so as to benefit from existing Europe-wide initiatives: ETH, ESCC, CTB, and MTB;
- Funding mechanisms should be made more appropriate: 100% support for research and technology development, up to qualification and validation in the user environment, should be available in appropriate cases;
- Procurements should be based on clear specifications;
- There should be a policy of European preference for procurement of critical space technologies.

Recommendation 3-11: The current process for identification of critical technology non-dependence issues should be reviewed. Also, open calls and co-funding are poorly suited to tackling these issues and an urgent remedy should be sought. There should be a policy of European preference for procurement of critical space technologies.

As some of these technology developments are not just driven by space per se, e.g. micro-electronics, the problems being experienced may sometimes be the result of a higher level issue, e.g. a problem with micro-electronics in Europe generally, not just micro-electronics for space. By placing space in the structure of Horizon 2020 alongside Key Enabling Technologies (**KET**), actions to remedy the situation should be able to take advantage of common interests and synergies between the areas, through joint calls for example. In supporting KET, Horizon 2020 should therefore support sectors, such as those, including space, with challenging requirements for important technologies with low market volume but high strategic value and/or high export potential.

Horizon 2020 should meet the expectations of the whole supply chain, from system integrators to SMEs, providing adequate and practical support to industry by taking action to:

- reduce the bureaucracy involved in the submission of applications and offers;
- adopt timeframes more compatible with the pace of industrial development and the evolution of markets;
- provide support within a scheme that enables industry to address development risks for both research and innovation in a commercially viable manner;

- reduce the administrative burden during the execution and post-execution phases of projects.

Recommendation 3-12: Horizon 2020 should encourage broader participation from the whole space industry supply chain and should help by reducing bureaucracy and administrative burdens, adopting commercially compatible project timescales, and enabling industry to tackle development risks in a commercially viable manner.

3.9 Barriers to Overcome

Barriers to making rapid progress which threaten achievement of the desired outcomes and which could be the target of actions under Horizon 2020 include:

- Reluctance to commit to investment in radical new ideas, particularly where the technology has not yet been extensively researched;
- Shortage of skills and shortage of suitable opportunities to support rapid on-the-job skills development for students and young professionals;
- Protracted timescales, particularly so for space science and exploration missions, threatening ‘time-to-market’ competitiveness as well as restricting the capacity to build practical skills in a timely manner;
- Risk aversion, deterring exploratory and early development work, which could lead in due course to commercial products/services;
- Complex data policy issues governing the use of observations;
- Limited access to appropriate risk finance (equity and loans) to support corporate development and growth in risky, early stage SMEs.

Recommendation 3-13: Horizon 2020 should help to counter barriers to innovation in exploiting the opportunities afforded by space, particularly reluctance to adopt radical new ideas, risk aversion, skills shortages, protracted timescales for space projects, complex data policy issues and access to risk finance for SMEs.

3.10 Horizon 2020 has a Role to Play

No commercial market can sustain the level of investment required to keep up with the evolution of technical requirements in a domain like space.

Horizon 2020 should therefore assist by addressing, first and foremost, in tight coordination with ESA, basic technologies and downstream support for services and data exploitation.

Recommendation 3-14: Horizon 2020 should assist industry by addressing, first and foremost, in tight coordination with ESA, basic technologies and downstream support for services and data exploitation.

Such support is essential to enable industry to build businesses based on new solutions for both its institutional space projects and to exploit commercial markets for downstream services. A key element of this support is the work that needs to be put in to enable industry to realistically assess the risks remaining for its own subsequent investment in completing the commercialization of the technologies, products or services concerned.

Another domain of action supporting competitiveness is standardization. The European efforts so far have focused on the upstream sector and less effort has been devoted to the downstream sector. Horizon 2020 should support standardization, upstream and downstream, with initial emphasis on downstream and progressively encompassing space standardization efforts.

3.11 Summary of Main Recommendations

This chapter has contained thirteen detailed recommendations, which are here distilled into the following main recommendations.

1. Horizon 2020 should provide support within a scheme that enables industry to address development risks for both Research and Innovation in a commercially viable manner.
2. The scope of Horizon 2020 should encompass the full spectrum of space activities and in particular address downstream added-value services, including aggregation and development of European domestic demand for space-based services.
3. Horizon 2020 should offer a framework for the development of technologies and products through to a level of maturity sufficient to underpin the competitiveness of the European industry in commercial markets. Emphasis should be on user segment technologies and basic technologies such as components and materials. It should also provide support for in-orbit demonstration and validation schemes for both new technologies and user services. A dedicated effort should be made for critical technologies that have been identified.
4. The Horizon 2020 work plan should be based on an assessment of needs between ESA, industry and other European space organisations, building on existing processes for identification, prioritization and harmonization of activities and contributing to the implementation of agreed roadmaps, so as to ensure proper coordination Europe-wide.

4. ADVANCES IN SPACE TECHNOLOGIES

4.1 Main Messages

The foundation for advanced technology research in Horizon 2020 should be a unified, harmonised Horizon 2020 Space Research and Innovation Agenda (**SRIA**) for space technology, owned by the EU with content generated by ESA, Eurospace, SME's and the major stakeholders. SRIA should be fully integrated into the wider agendas of the research and user communities, in the European Technology Harmonization process and in other processes such as the European Space Components Coordination.

The strategy should address the short, medium and long term, bringing technologies from initial concept to flight proven status as appropriate.

Research must address the Grand Challenges, support existing road maps and be prioritised and focused in line with the budget available.

4.2 Introduction

As stated in section 2.7, the European Space Agency, national space agencies, national research organisations, universities, industry and the EU are among the organisations involved in funding and initiating European space science, research and technology development and space missions. This is seen as both a challenge to manage and a strength with positive effects on competitiveness.

Horizon 2020 needs a unified, harmonised Space Research and Innovation Agenda for space technologies to provide the basis upon which to plan for the most effective use of Horizon 2020 resources. ESA and industry through Eurospace[24], the Association of European Space Industry, jointly prepare space technology roadmaps in the framework of the technology harmonization process that result in agreed roadmaps and harmonized work plans. This work must be the foundation and context in which the EU should build the technology chapter of the Horizon 2020 Space Strategic Research Agenda. While the EU should be the owner of such a Horizon 2020 Agenda, the content must most suitably be prepared by a team including ESA and Eurospace and involving representatives of all the actors mentioned above with relevant stake holders, so as to integrate Horizon 2020 in the overall European effort. Only in this situation will Horizon 2020 be able to capitalize on decades of strategic thinking and development for space technologies, avoid duplication and be in a position to quickly and efficiently contribute to Europe's overall space internal market and confront international competition.

[24] *EUROSPACE Technology Road Map activity references……………….*

In so doing, the essential role of the EU in funding research and technology development for the benefit of its citizens, should enable creativity, encourage innovation and be inspirational, stimulate the use of space for research and for providing applications, enhance competivity, increase the EU share of commercial markets as well as stimulating space exploration.

Recommendation 4-1: The EU-EC shall establish, with stakeholders, the Space Research and Innovation Agenda (SRIA) for Space Technologies. The SRIA should identify Europe's objectives, future space missions, operational capabilities and technology needs as well as technology roadmaps.

4.3 The Need for Advanced Technology Development

Technology is a means to an end. It enables the development of capabilities, the implementation of operational concepts and the achievement of space missions. Technology development is essential for:

- enabling effective space missions and infrastructures: including remote sensing, exploration missions, science, launchers, navigation, telecommunications, service driven missions;
- establishing know-how and capabilities that encourage global partnerships;
- maintaining and improving the competitiveness of the European space industry in the commercial world market, where Europe already has a significant fraction of the market;
- ensuring the quality and productivity of Europe's scientific and academic community involved in space research, who are users of space technology;
- building the capability to be creative, to innovate in products, processes, systems and services;
- assuring European non dependence to develop, deploy and exploit space systems;
- providing services to Europe and its citizens that improve security, quality of life, well being and productivity.

For space, advanced technology development encompasses "blue sky", fundamental, applied and industrial research performed on-ground and in space.

Effective technology development is enabled by education, knowledge and research activities, with clear challenges, motivational career paths for the scientific and engineering capabilities of the community and society as well as by an environment which stimulates creativity and innovation. Without such a supporting, short, medium and long term strategy tailored to Europe's objectives R&T will be much less effective.

Recommendation 4-2: Horizon 2020 should include an envelope devoted to activities that encourage researchers to enter the space business.

4.3.1 The Context for Technology Development

Technology development is expensive, the demands are high and the resources short. Stakeholders have processes in place to identify needs and coordinate efforts. Horizon 2020 will allocate part of its resources to research and technology development.

There is a need for agreed dossiers and roadmaps that take into account the needs of the scientific communities, operational users, programmes and industry, and the evolution of technology. Scientific communities establish their research agendas such as Cosmic Vision 2015 – 2025[25] for Space Science or the Challenges of a Changing Earth for Earth Science. Operational users establish their requirements in terms of service requirements in various domains, examples being telecommunications, operational meteorology and navigation. The EU is sometimes such an operational user and should become even more so, as described in Chapter 3. These needs describe space missions and are translated into space system concepts, operational capabilities and specific technologies. Roadmaps are established that identify the steps to developing the necessary capabilities.

There are processes to establish such roadmaps and periodically update them. They are the result of well-established European wide practices. ESA and the Member States interact with the scientific communities and with operational users and derives with such partners the system concepts that implement the user defined missions and the needs for technology development. Processes include initiatives cutting across domains to identify overarching scientific issues and technologies enabling progress in several domains. Cold atom devices are an example of such technology recommended by the HIgh level Space Policy Advisory Committee (**HISPAC**) and its Future Technology Advisory Panel (**FTAP**). In addition to mission specific technology, generic technology is also addressed. With the European Technology Harmonization process ESA, National Space Agencies, Member States, including EU Member States, and industry, individually and through industry organisations such as Eurospace or SME4Space, establish technical dossiers and agree on roadmaps that consider user needs, markets, competitors and technology evolution. Such dossiers and roadmaps are

[25] *Please refer to Annex A for details of ESA programmes.*

agreed by the stakeholders and they are unbiased as they are not produced by a limited group of actors.

Other European wide initiatives address specific matters, e.g. EEE components. The European Space Components Coordination involves all actors and identifies critical areas, urgent actions on the fast technology evolving domain of EEE components.

These processes are at the basis of the EC-EDA-ESA action on critical technologies for European non-dependence.

Another example is Exploration. ESA with European partners, aware of the International context in which Exploration would have to be implemented, has developed roadmaps for Exploration, Robotic and Human, for the three main target destinations, Low Earth Orbit (**LEO**); Moon and Mars. Such roadmaps encompass all technology domains.

Europe is a major partner in the International Space Station, contributing the Columbus Laboratory permanently attached to the International Space Station (**ISS**) which includes a comprehensive set of research facilities. Europe's contribution also includes the Automated Transfer Vehicle (**ATV**) for transporting cargo to the ISS. Exploitation of the ISS has been agreed by the partners until 2020. Europe's contribution to the common costs comprises provision of the ATV and its first five launches. A follow on to the ATV and to the Earth orbit infrastructure for exploration is under study.

The partners track the degree of implementation of the agreed roadmaps in ESA and national programmes and by industry. The Harmonization Tracking System allows to identify systematic lack of resources i.e. gaps and / or delays in implementing the roadmaps. Such gaps and delays translate into issues when the enabling technology and the resulting products are needed in users' missions. Lack of technical maturity / technology readiness is the single most important cause of cost overruns and delays.

Technology research and development efforts shall be selective, not everything, not anything; there must be a balance between agenda driven technology and blue sky R&T. Within the agenda driven technology R&T there is a balance between mission specific and generic technology development including also realizing the potential of technology evolution. The EU shall join the European processes and the H2020 agenda shall support the European user agendas and technology roadmaps.

Recommendation 4-3: The overall roadmap preparation process should be reviewed ensuring adequate involvement of actors and stakeholders. The EU-EC should become an active partner in European technology harmonization efforts and Horizon 2020 should contribute to the implementation of the roadmaps.

4.3.2 The Challenges of Technology Development

There is a lifecycle, often iterative, for successful technology development. ESA's Technology Readiness Level (**TRL**) [26] definitions, illustrated below, indicate increasing maturity of technology on a scale of 1-9.

Figure 4-1: ESA's Technology Readiness Level Scale (now an ISO standard)

Levels 1 to 4 relate to creative, innovative technologies before or during the mission assessment phase. Levels 5 to 9 relate to developing technologies maturing to be suitable for operational use with a TRL of 9.

In space technology development, there are recognized challenges in creativity, innovation and maturing technology to make it suitable for a specific mission or for a particular market, including:

- Investigating in detail, enough promising creative and innovative concepts;
- Overcoming the so called "valley of death" in the mid TRL range where promising concepts are not further developed;
- Qualifying new technologies and providing potential customers with confidence in the technology by, for example proving it on-orbit.

Recommendation 4-4: The approach to selection and funding of space technology development must take into account the longer timescales certain space research and technology development activities require, ensuring that funding of initial phases of activities are continued, where appropriate, into subsequent phases allowing to realize the promise of advanced technology.

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[26] *NASA uses a similar scale.*

4.4 The Main Actions

4.4.1 Grand Themes/Objectives for Europe

In section 1 the grand themes and research topics have been placed in context, as illustrated in figure 1-1. In Table 4-1, below, the grand themes, objectives and challenges facing Europe, as described elsewhere in this document are related to elements and reference missions.

Table 4-1: Grand Themes and Reference Missions

Grand Theme/Objective	Element and Reference Missions
A Space for exploring the Solar System and the Universe	i. An interactive astrophysical element with synergies between space missions and ground-based telescopes. ii. An interactive robotic exploration element of the Solar System with emphasis on planet Mars, especially the realisation of the ExoMars mission and terrestrial analogue studies. iii. An intense ISS utilisation element, including life sciences, material sciences, solar physics, fundamental physics, and astrobiology, supported by Earth-based simulation studies as well as human exploration preparation, making use of the ISS, that establishes a valuable leadership profile in specific aspects of robotic and human exploration as an enabler of future international exploration partnerships.
B Space for grand challenges on Earth	i. Enabling the safety and well being of the citizens; ii. Earth Science iii. Space Situation Awareness a. Space debris b. Space weather c. Near Earth Objects (NEO) iv. Competitiveness and services a. Beyond GMES: GMES next generation b. Beyond Galileo: GNSS next generation c. Disaster prediction and crisis support
C	i. Launch

Space transportation and infrastructure: assuring manned and unmanned European access to space	ii.	Entry
	iii.	Return
	iv.	Re-entry
	v.	Space infrastructure

Each Grand Theme or Objective comprises a number of elements which are planned to be implemented as space missions, currently referred to as Reference Missions[27]. The detailed description of a reference mission establishes an understanding of the capabilities required to achieve the mission and accordingly the technology that is necessary.

4.4.2 Prioritisation and Selection

It is anticipated that the budget available in Horizon 2020 will not be adequate to achieve all objectives mentioned above. Rather than dissipate funding on a wide range of space activities which, within the funding constraints, will not have a discernible impact or result in being implemented in space missions, it is recommended to prioritise and select the focus of space technology research, considering the following:

Prioritise by:

- Relevance to EU 2020 agenda;
- Relevance to EU role, needs and systems;
- Magnitude of positive impact in contributing to the Horizon 2020 agenda;
- Reference missions with the largest impact enabled by Horizon 2020 support.

Select by:

- Technology applicable to prioritized Reference missions or generically applicable;
- Enabling capability and technology identified in an agreed roadmap;
- No other adequate source of funding for research in this technology domain, i.e. avoiding duplication of funding;
- Potential to significantly improve the cost effectiveness of space activities;
- Achievable within the resources available.

[27] *One of the tasks of the SRIA will be to identify Reference Missions. Reference missions will include those missions planned by ESA and others where a European participation is planned.*

It is expected that the Horizon 2020 Space Research and Innovation Agenda for space technologies will recommend priorities and selection of the technology.

Recommendation 4-5: In Horizon 2020 it is recommended to prioritise the research and technology development to support the Grand Themes/Objectives A and B, shown in table 4.1.

Recommendation 4-6: In Horizon 2020 it is recommended to identify a set of reference missions commensurate with the budget available, which will provide clear objectives to be achieved in Horizon 2020.

4.4.3 Concept

Limited space budgets, operational demands and the financial crisis are imposing severe constraints on the availability of R&T funds for space technology development.

Recommendation 4-7: In Horizon 2020 it is recommended that 7 actions are used as underlying pillars for space technology advancement, as listed below.

1. **Breakthrough technologies and blue sky research**
2. **Critical space technologies**
3. **Stepping stones along European roadmaps**
4. **Strengthening the downstream sector and mission exploitation**
5. **Proving/validating new key technologies and concepts**
6. **Education and workforce**
7. **Coordination and Support**

4.4.4 Strategy

The concept recommended is a mix of the best aspects of the bottom-up and agenda driven approaches. The agenda driven approach focuses on researching, developing and qualifying breakthrough technologies, capabilities and operational concepts to achieve the grand themes. The inclusion of “blue sky” research and integration projects allows novel technology to be tested and demonstrated in a mission context proving the capabilities developed.

Together the two approaches provide a concerted, focused development path enhanced when needed by proving technology in orbit that enables exploitation of the results, supported throughout by initiatives to involve researchers in space.

The coordination and support action similarly supports research at all levels by improving European coordination processes and building international partnerships.

This approach is an integrated approach which will support the incremental achievement of the H2020 objectives and will provide a firm foundation for post H2020 activities.

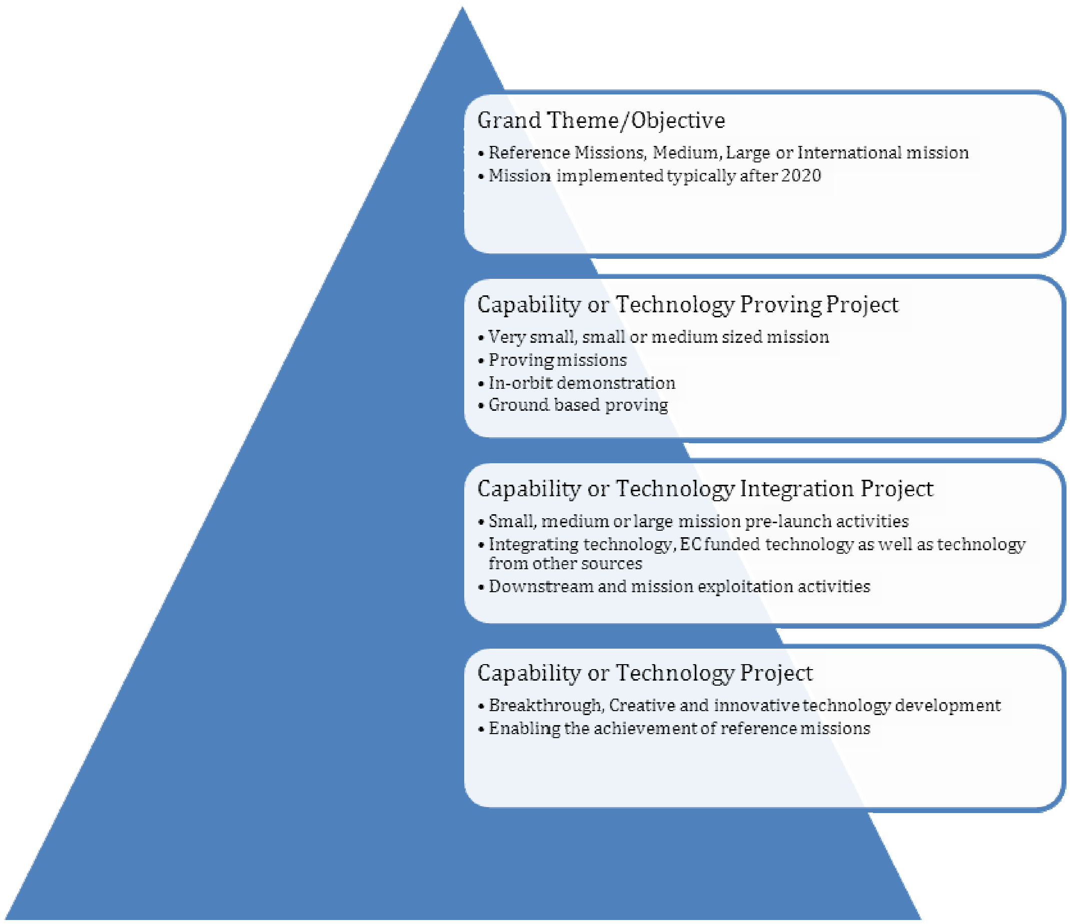

Figure 4-2: Agenda focussed R&T with bottom-up creativity and innovation

4.4.4.1 Approach

The approach recommended, illustrated below, is flexible and focused on achieving objectives:

- encouraging novel technologies and capabilities to be researched and established;
- enabling their development, integration, test and further development in systems representative of the reference missions;

- offering opportunities to prove individual or integrated technology and capabilities on ground or in orbit.

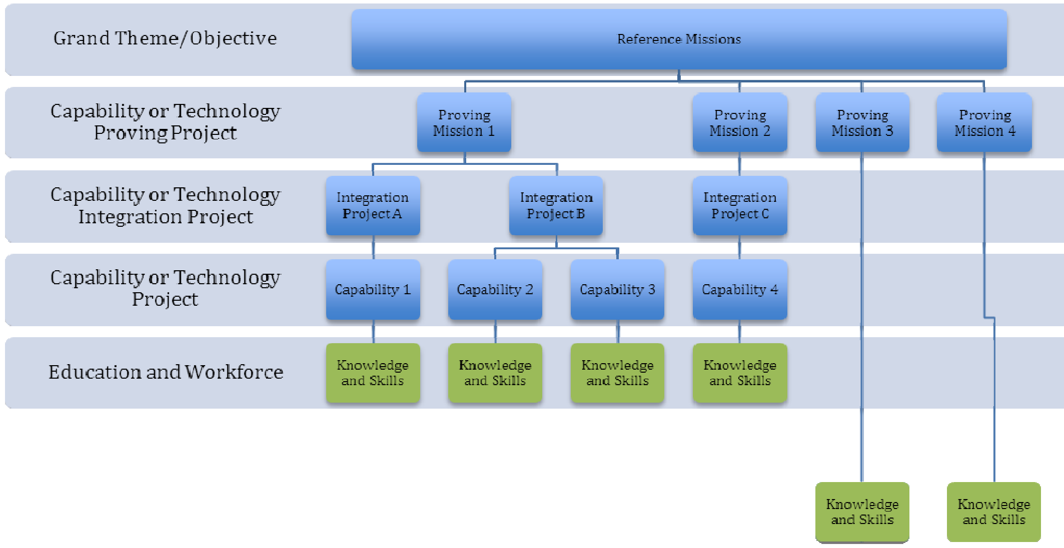

Figure 4-3: Establishing technologies, capabilities and achieving the reference missions

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Recommendation 4-8: Capability and technology projects will be used to encourage innovation and creativity to develop advanced technology and operational concepts that contribute to the achievement of the grand challenges/objectives.

Recommendation 4-9: Integrating projects will be used to integrate and enhance capabilities, technology and operational concepts resulting from capability and technology projects, and non Horizon 2020 activities, where available. These integration projects will also prove the feasibility for particular missions.

Recommendation 4-10: Proving projects will provide on ground or in-orbit testing and validation of capabilities, technology, products and services and operational concepts as a precursor to implementing the reference missions.

4.4.4.2 Advanced Technology Areas Supported

Establishing all the capabilities and technology to ensure the achievement of Europe's grand themes/objectives and the implementation of the reference missions within the financial and programmatic constraints will not be possible but the process can be started, significant progress can be made and this can be continued after 2020.

The Horizon 2020 Space Research and Innovation Agenda for space technologies is expected to provide guidelines to prioritise and select technology needs for the missions and the required operational capabilities. Within ESA and Europsace's technology roadmaps priorities have been identified and the SRIA will take these into account.

A preliminary indication of prioritized technology areas to meet Grand Theme/Objectives A and B is provided below. This table takes into account ESA and Eurospace technology roadmaps, the EC Horizon 2020 Hearings and also reflects the assumed availability of non Horizon 2020 funds for certain technology areas.

This table should be complemented by the technologies which Europe identifies as critical for non-dependence.

Table 4-2: Technology Areas and Priorities

Priority	Technology Area
1	Autonomy, Automation and Robotics Communications, Optics and Optoelectronics High Reliability Avionics Life Support Materials, Structures and Mechanisms MEMS and Nano technologies Satellite Propulsion Software Engineering and Processes
2	Energy Production, Storage and Distribution Guidance, Navigation and Control System Engineering, Design, Assembly, Integration and Test Processes Thermal Protection
3	Flexible manufacturing processes Launchers and Propulsion

4.4.5 Action 1: Breakthrough Technologies and Blue Sky Research

In this activity, research should be focused on solving key challenges of the reference missions. It is recommended that ground breaking/'blue sky' research is included. The objective should be to reach TRL 4-5 and actions should be implemented exploiting synergies in terms of industry, scientists and users.

In order to improve innovation and competitiveness it is fundamentally important that Europe spends effort and resources for space technology research and development with a horizon towards 2020.

This should include R&T leading to new services so as to contribute to strengthen the demand for space systems, the leadership of European industry in the commercial market and the contribution of space systems to the implementation of EU policies.

Recommendation 4-11: Horizon 2020 shall include exploring promising visionary ideas and non conventional targeted research as well as research targeted to solving specific problems.

It is expected that research in this area will focus on proof of concept studies based on a combination of theoretical and/or experimental work.

In addition R&T can also be achieved through spin-in and joint R&T with key enabling technologies fully benefiting from belonging to same area of Horizon 2020 as the Key Enabling Technology.

Recommendation 4-12: Horizon 2020 should liaise with the KET for two purposes: 1) spin-in of terrestrial technologies for use in space with joint R&T between space and terrestrial sectors - feasibility studies should be followed by development and experimentation; 2) use of space to develop new materials and components, thus promoting research in space, mainly ISS, and availability of new basic technology also for space.

4.4.6 Action 2: Critical Space Technologies Research

Horizon 2020 should support European Technology non-Dependence. This should build on the experience with the EC-EDA-ESA actions on critical technologies and be strengthened. FP7 has already devoted significant resources comparable to other partners and with adapted mechanisms as recommended by industry, it can become the right frame for this action.

Initiatives such as the European Space Technology Harmonization, the European Space Components Coordination with its Component Technology Board (**CTB**), possibly set up equivalent Material Technologies Board (**MTB**) should be used to identify critical technologies.

For example:

- Clear objectives to be established, e.g. by 2020,
  - European Application Specific Integrated Circuit (**ASIC**) technology in 65 – 32 nm
  - European FPGA +2 M gates
  - RF components SiGe, power components GaN
  - High impact Registration, Evaluation, Authorisation and Restriction of Chemical Substances (**REACH**) directives implemented in space, i.e. replacements developed for e.g. propellants, etc.
- Horizon 2020 should support full R&T of critical technologies to qualification TRL6-7 or validating them in orbit when required (TRL8-9);
- Mechanisms should be tuned to allow establishment of permanent capability, e.g. 100 % funding of R&D to qualification / validation; tight coordination with ESA ECI-TnD, including consideration of contribution to an ESA programme, delegation of implementation, etc.
- The results should be widely disseminated for utilization by European projects and export;
- Horizon 2020 should become the main programme for these technology actions as prioritised by SRIA.

4.4.7 Action 3: Stepping Stones along European Roadmaps

As mentioned above, Horizon 2020 should contribute to implement the technology roadmaps as agreed in the Horizon 2020 Strategic Research Agenda for Space Technology consistent with the European Technology Harmonization process in which the EU-EC should be an active participant.

The roadmaps to be supported will be identified and capability technology projects should be undertaken.

4.4.8 Action 4: Strengthening the Downstream Sector and Mission Exploitation

As discussed in objective 1, Horizon 2020 should play a role in promoting the demand for space sourced services and facilitating its adoption by user communities. As per objective 3, Horizon 2020 should promote the exploitation of space data. With GMES and Galileo, the EU owns space systems with the largest number of users. It is logic and mandatory that Horizon 2020 devotes resources to facilitate exploitation.

Horizon 2020 should therefore devote resources to develop the downstream user segment. It should contribute to the availability to space users of the best technology and products. This should include:

- for users of navigation systems, Galileo receivers for various types of users, augmentation systems for indoors navigation, etc.
- for users of satellite communications, it should include broadband terminals for satellite internet, airborne terminals for satellite communications or satellite control, etc.
- technologies for data exploitation, data calibration, including ground instrumentation (in-situ, airborne, etc.);
- technologies for data archiving and data mining, long-term data preservation, etc.

The development of new products and services based on space missions is fundamental for their exploitation and sustainability. Horizon 2020 should establish technology platforms to encourage the development of such products.

Security is fundamental when space systems are open for utilisation for an as wide as possible community. Horizon 2020 should conduct research and develop technology, products and services that guarantee the security of the space systems and the integrity of the space data, cyber security, etc.

This should also include the downstream sector for space situation awareness.

4.4.9 Action 5: Proving/validating New Key Technologies and Concepts

In this research and research integration activity, development, integration and verification of technology and capabilities will be performed. As space is a challenging and risky environment it is important that space technology is designed for its operational environment and tested in representative conditions. space qualification / in orbit testing should be included when and where necessary to verify technology which cannot be adequately verified on the ground or that explicitly needs flight heritage to be accepted by users. In this activity it is envisaged that key space technologies will be developed and integrated by industry, institutions and academia with a view to verification and validation on ground or in orbit (cubesats, small satellites, passengers on medium sized satellites, ISS payloads, analogue environments, airborne instruments etc) in coordination with existing European initiatives for the demonstration and validation of technologies.

Horizon 2020 should add to such efforts intervening where the impact can be the biggest as presently they are not well supported, e.g. financing the launch opportunities with total preference to European launchers, the establishment of analogues, experiments on the ISS, etc.

Some activities can involve proving technology for new elements of future space systems and services. Other activities can involve end to end space technology development, in orbit testing, flight results analysis or include funds from other national and international programmes.

The scope could include elements of future missions, for research and services satellite systems, both platform and payload, including planetary/lunar surface vehicles.

Activities can include:

- Integration of on-board experiments and the supporting ground segment to provide pre-operational services;
- The development of novel scientific instrumentation for future space missions;
- Elements of small science missions that have not been funded by ESA;
- Elements of single or multi spacecraft missions that replicate exploration scenarios;
- Elements of rendezvous, capture and disposal of non-cooperative objects, e.g. space debris;
- Development of terrestrial analogues;
- Provision of launch opportunities on European launchers.

Recommendation 4-13: Certain of these activities may require larger funding than the other activities and a two-step proposal and evaluation approach is recommended to reduce the effort associated with producing non-funded proposals.

4.4.10 Action 6: Education and Workforce

Key to competitiveness, innovation and sustainable growth is the ability to educate, train and grow skills of the next generation of space engineers, scientists and entrepreneurs. Specific actions are thus recommended to support universities, institutions and industry to foster collaborative research, training and educational efforts. Specifically by:

- Offering researchers the opportunity to participate in or join space research teams (e.g. Industrial Training Network (**ITN**));
- Encouraging researchers to work with space industry and boost the exchange of knowledge and skills between academia and industry (e.g. Industry Academia Partnerships (**IAPP**) and Intra-European Fellowships (**IEF**));
- Encouraging research and engineering exchanges as the basis for establishing long term collaboration (e.g. International Research Staff Exchange Scheme (**IRSES**));

- Experience placement schemes where students, researchers can spend from 3 months to one year with industry obtaining hands on experience.

Such activities can include:

- Participation to the development of spacecraft payloads and instrumentation;
- Participation in early studies such as performed by ESA's Concurrent Design Facility (**CDF**), in spacecraft design and in real time operations and training;
- Small scale in orbit space missions using space tools such as cubesats/small satellites in order to enhance space education and growth;
- Participation in analogue environments and simulations;
- Activities are suggested to be supported in which students can gain exposure to real space projects which involve space qualification, launch and in orbit operations of spacecraft; collaborative missions/research with industry (primes, SME's) such as in the development of propulsion techniques, instrumentation, cubesats, planetary micro rovers.

4.4.11 Action 7: Coordination and Support

European space activities are performed by ESA, national agencies, the EU and others. In many of these activities there is collaboration with other countries, notably, USA, Russia, Canada, Japan, India, China, etc. In order to ensure the space technology activities of Horizon 2020 are coherent and to establish the long term partnerships necessary to cost effectively perform exploration of the solar system which will be a global endeavour and the study of the Universe, cross fertilisation and coordination actions are suggested:

- Technology watch and dissemination;
- Coordination and networking activities, dissemination and use of knowledge;
- Support for transnational access to major research infrastructures;
- Actions to stimulate the participation of SMEs, civil society and their networks with other European research schemes (e.g. ICT, NMP, Biotechnology, Environment, Security).
- This must also be seen within the context of international cooperation, described in Chapter 6.

4.5 Summary of Main Recommendations

Throughout this chapter, individual recommendations have been made. Pulling these together and highlighting the main points, the following three main recommendations are made:

1. The EU-EC should establish, with stakeholders, a Horizon 2020 Space Research Agenda and will identify Horizon 2020 objectives, reference future space missions, operational capabilities and technology needs as well as technology roadmaps.
2. The selection and funding approach must take into account the longer timescales certain space research and technology development activities require, ensuring that funding of initial phases of activities are continued, where appropriate, into subsequent phases allowing to realize the promise of advanced technology.
3. In Horizon 2020 it is recommended to identify a set of reference missions commensurate with the budget available, to focus on high-priority objectives.

5. THE EXPLOITATION OF SPACE DATA

5.1 Main Messages

Greater value can be derived from the exploitation of space data both commercially and for tackling scientific, technical and societal challenges if a concerted effort is made to ensure the coordination, quality assurance and standardisation of research data sets. This is best achieved at a European level under the umbrella of the EU/EC with a dedicated budget within Horizon 2020 set aside to support this work. This approach must be coordinated with ESA and other European stakeholders to accommodate planning and operation of new missions and optimal utilisation of current mission facilities and assets; in the space research area there is particular interest in astrophysics, robotic exploration of Mars and utilisation of the ISS.

In Earth observation, continuity of data sets and satellite coverage is critically important, as is establishing the metrological accuracy of the data. Attention to these issues is necessary to ensure that investment in future public and privately supported service development can be made with an appropriate level of confidence.

Regimes for obtaining data from missions, both scientific and operational, should be reviewed to ensure that barriers to exploitation are minimised and that Europe is internationally competitive in deriving value from space data, particularly in comparison to the US.

5.2 The Need for the Exploitation of Space Data

The success of space activities is generally measured by their final results and their impact on science and the society. They are based on a concerted action of the planning, design, and operation of a space mission, as well as – equally important – on a comprehensive analysis of the data provided by the mission. There is currently in Europe a severe lack of institutional support for the exploitation of space data from all areas, from space science and robotic exploration missions as well as from experiments performed on the ISS. The reason is that exploitation of data from space missions and the operational infrastructure of orbiting satellites is largely outside the remit of ESA and beyond the ability of individual nations to support adequately.

It is also clear that on-going support is required for very similar reasons in the field of Earth Science data and its conditioning and provision to developers of the operational services which are needed to underpin efforts to tackle the Grand Challenges on Earth. This is particularly important in the case of the data required for work on the challenges of climate change.

Recommendation 5-1: A comprehensive approach to data exploitation should be implemented under the umbrella of the EU/EC. A budgetary envelope within Horizon

2020 should be dedicated specifically to this goal. This approach should be coordinated with ESA in order to adjust the envelope for data exploitation in response to the planning of new missions to be launched and to the extension of missions still in operation.

There appears to be a further problem of fragmentation of effort and communication between stakeholders across Europe in this area, leading to pockets of confusion and inefficient use of resources. The roles and activities of the three main organisations supporting space programmes in Europe (ESA, the national Space Agencies and the European Commission) are described in outline in Annex A.

Consequently Europe is missing out on opportunities to deliver as much leading science as would otherwise be possible from its investment in space and, at the same time, it is at risk of failing to maximise the commercial returns and opportunities for economic growth and job creation.

Recommendation 5-2: Horizon 2020 should support activities that are complementary to ESA's space programmes where this is necessary to maximise value from the research and where the funding needed is beyond the capabilities of individual nations to sustain, and in particular this should include:

- **support to the next generation of scientists developing new scientific instruments**
- **acquisition, processing, calibration, storage, exploitation and preservation of space (including space science) data**
- **scientific research using the science data obtained from the missions**
- **in appropriate cases, on-going costs of operation beyond the period initially foreseen in the ESA programme**
- **Development of operational services to meet Grand Challenges on Earth**

5.2.1 Space Data Exploitation within FP7

FP7 has already provided limited funds to fill some of the gap in support for the exploitation of data, but the large oversubscription of this part of the programme has demonstrated the real need of the scientific community for more of this type of support. The projects listed under space data exploitation in FP7 are essentially concerned with space science (including experiments from the ISS). A list of those currently funded is given in Annex B.

Only a few of those projects deal with the exploitation of data from real space science missions or experiments (e.g., HAMLET and ECLAT to a certain extent). The majority of the projects deal with the development of new tools for data analysis and sharing, the setting up of data bases or data base networks, which then are intended to be made available to the scientific community. It is not clear whether there exists any communication or coordination between different projects dealing with related issues (e.g., between ECLAT, HESPE, SEPServer, and SOTERIA, or between ULISSE and HAMLET). Because the funding of these projects is time-limited (they mostly run over 3 years), there is concern about the continuity and utility of the many data bases established in FP7 under the space theme. It is also suspected that the scientific space community in Europe has barely been informed about the outcome of the projects within FP7. As a measure of success, it would be interesting to know how many scientific publications in refereed journals were produced by these projects.

As is evident from those projects and as already stated in “space research in Horizon 2020, Recommendations of the FP7 SAG”, FP7 has not been able to support much actual scientific research in this area. This is unfortunate since the number of missions in operation delivering top class data is higher than ever before and the unique environment provided by the ISS is ready for scientific use. Furthermore, the number of missions in preparation and the number of new scientific issues to be addressed outweighs the resources available. The main reason for this inadequate level of support is financial. A further problem is the lack of coordination and exchange of information between different projects. This can lead to duplication of effort and facilities (such as data bases), some of which may have uncertain future.

In the following sections, the need for exploitation of space data is dealt with in the context of space observatories, solar system robotic missions, the ISS, and then Earth observation.

5.2.2 Exploitation of Data from Space Observatories

What has been proposed and funded in FP7 in the field of space science appears to focus only on the effective exploitation of existing data from space missions. This covers scientific data that has entered the public domain and is freely accessible to researchers. However it is necessary to address the exploitation of scientific data obtained by space observatories during the observing time that is awarded competitively, based on proposals submitted in response to an Announcement of Opportunity (AO) process. This data is for exclusive use during the proprietary period (usually 6 months to 1 year from the date of the observation) awarded to the research groups selected on the basis of the scientific value of their proposals. After the proprietary period has expired, the data becomes freely accessible. Presently, there is no coherent approach to the support required for the exploitation of this proprietary data. In this respect it is worthwhile to compare the situation in Europe, and more specifically the case of ESA science missions, with the approach to data exploitation implemented by NASA.

As already emphasized elsewhere, in Europe the funding of space science missions is shared between ESA and its member states. Through their national agencies, the ESA Member States provide funding for the procurement of the scientific instruments that have been selected to fly on ESA missions. ESA is responsible for mission development, launch services and mission operation, of which the Science Operation Centre (**SOC**) is one element. The SOC is in charge of science operation, comprising scheduling of observations and the acquisition, reduction and accessing of the scientific data. The SOC is also responsible for the preparation and release of Announcements of Opportunity (**AO**) for observation proposals and for their evaluation and selection. However, the ESA SOC has no funding available to support scientific groups in the exploitation of the scientific data resulting from the selected proposals. It is interesting to note that in numerous ESA Member States, national agencies that support the procurement of scientific instruments do not provide any funding for data exploitation. In fact scientific groups have to seek support through various alternative funding schemes for the preparation of proposals and data exploitation.

Contrary to the situation in Europe, in the US the approach to data exploitation is well established under the single responsibility of NASA. NASA provides the overall funding for every approved mission. This overall funding includes a specific budget allocation for grants dedicated to data exploitation. The grants cover all the personnel and equipment needed to prepare observation proposals and the subsequent exploitation of scientific data. The budget for data exploitation and the release of the grants is managed by the mission's Science Operation Centre (SOC) which, in addition, has the same responsibilities as the ESA SOC. This comprehensive US approach in support of data exploitation ensures maximum scientific return from every space mission. It should be noted that this support is not restricted to NASA missions only; the same mechanism applies successfully to US scientists competing for observation time on other agency's (ESA, JAXA, etc.) missions.

In Europe, the absence of a similarly comprehensive funding approach makes it more difficult for European groups to win observation time not only on ESA and European missions but also on non-European missions. As a consequence there is a trend towards under-exploitation of ESA and European missions by European scientists. The situation can be illustrated by reference to the ESA flagship space observatories XMM-Newton (X-ray astronomy) and Herschel (far-IR astronomy). Table 5-1 illustrates this using statistics for the proposals submitted and observing time awarded for the two most recent AO rounds for each mission. The first two columns refer respectively to the number of EU proposals for observing time submitted and accepted, compared to the corresponding total number of proposals. The third column is the total fraction of observing time awarded to EU proposals.

Table 5-1: Statistics for submitted and accepted European observation proposals

Mission	**AO**	**European/total submitted**	**European/total accepted**	**European fraction of observing time**
XMM-Newton	AO-10	290/491	100/281	0.63
	AO-11	296/501	116/295	0.57
Herschel	AO-1	299/576	103/199	0.50
	AO-2	233/531	94/200	0.57

Table 5-1 shows that between 40 to 50% of the awarded observing time goes to non-European proposals (most of which, 90%, goes to US scientists) and this is for the two major ESA space observatories. For comparison, more than 70% of the observing time goes to US scientists in the case of the NASA Chandra (X ray astronomy) and Spitzer (IR astronomy) missions. Considering that observing time is awarded competitively on the basis of the scientific value of the proposals, it appears that US groups are relatively more efficient in the preparation of proposals. This can be explained to a large extent by the fact that proposal submission and data exploitation is efficiently supported by the established NASA process. As noted above, there is no equivalent efficient mechanism in Europe. This makes it more difficult for European scientific groups to respond successfully to AOs and obtain adequate funding in support of data exploitation.

Recommendation 5-3: The Horizon 2020 programme should support scientific groups with the preparation of proposals and with data exploitation of space missions in general and particularly with exploitation of data obtained from space observatories during proprietary observation periods. In this respect the situation in Europe, and particularly the case regarding ESA's science missions, should be compared with the approach to data exploitation implemented by NASA.

5.2.3 Exploitation of Data from robotic missions in the Solar System

A comparable situation exists for robotic missions within our solar system, although the ESA mission Mars Express resulted in a relatively high output of publications with Europeans as first authors: From the 600 publications issued since orbit insertion of Mars Express, 70 % had European first authors, 25 % came from the US and 5 % from the rest of the world. .

The exploitation of data from robotic missions exploring planets, moons and small bodies of our Solar System is not funded by ESA, neither is funding secured by national space agencies. Similar to the situation with space observatories, the instrument teams and interested science community have to search for alternative funding sources. The problem is exacerbated by the fact that revolutionary and complex data will arrive in the Horizon 2020 time frame from European robotic flagship missions such as Rosetta, Bepi Columbo, Solar Orbiter. ESA's Rosetta mission is currently on its way to comet 67/P Churyumov-Gerasimenko and will rendezvous with the comet in 2014, performing a comprehensive set of measurements from orbit. It will then for the first time deploy a lander to study the physico-chemical details of the cometary nucleus. Transforming the incoming data into meaningful information will require not only instrument data analysis but also rapid, interactive, informed verification by ground truth laboratory experiments. ESA's first Mars surface mission ExoMars currently planned with Russian cooperation for the Horizon 2020 timeframe will require an interdisciplinary preparation phase (as described in chapter 2, recommendation 2.3). Building on the success of previous ESA missions (Mars Express, SMART-1, Venus Express) the science community needs funding to exploit historic data in combination with new data from international Mars missions (MRO, MSL, MAVEN), from the Moon missions (LRO orbiter and upcoming lunar landers planned by Russia, India, China and Japan), and NEO missions (such as Hayabusa-2 and Osiris-Rex). NASA's Mars Science Laboratory MSL has landed on August 6, 2012 in the Gale Crater with the scientific goal of exploring and quantitatively assessing on Mars' surface as a potential habitat for life, past or present. European scientists' participation to international robotic Solar System missions needs sustainable funding and is required to prepare for future missions of ESA in cooperation with other agencies.

Recommendation 5-4: The Horizon 2020 programme should support the preparation phase and exploitation of data from robotic missions within the Solar System and provide funding for European scientists to participate to international robotic Solar System missions. The programme should particularly support the scientific exploitation of Mars missions with the preparation of scientific payloads and science campaigns, and related field studies in Earth analogue environments. Likewise, Horizon 2020 should include support for Lunar and NEO exploration by supporting development of scientific payloads and exploitation of data obtained.

5.2.4 The Case of the ISS

Comprehensive experimentation on the ISS became only possible after 2009 when a 6 member crew was available allowing sufficient time for experimentation besides the house keeping activities on the station. This resulted in a tailback of accepted proposals. Several projects were already ready for flight and their preparation was supported by national authorities. However, because of the unforeseen long waiting list, in many cases national support was not anymore available for the data analysis, This was especially the case for scientists from countries without established space agencies. In view of the limited time still available until the retirement of the ISS (the current date is 2020) it is of utmost importance to make maximum use of this unique facility in Earth orbit and to provide sufficient support for the data exploitation of experiments on the ISS.

Experiments on the ISS are pathfinders for future human exploration missions. The wealth of data acquired so far needs to be collected and weighted in order to achieve a complete understanding of the integrated response and adaptation to space and planetary surface environments as well as of interactions with the spacecraft and between crew members. To implement this essential integrated research approach, a stable, cross-disciplinary programme needs to be established at the European level. In preparation of human exploration missions, an integrated risk assessment is required combining the risks from exposures to multiple-stressor environments, the interactive adaptations to these stressors, and from personalised responses. This should be the base for quantifying acceptable risks for astronauts during exploration missions

Recommendation 5-5: The Horizon 2020 programme should support the scientific exploitation of the ISS, which is an essential prerequisite in preparation of a successful human space exploration programme. The programme should also include preparation of new experiments and facilitate utilization of the ISS for other scientific research purposes and for all members of the EU.

5.2.5 The Case of Earth Observation Satellites

As far as Earth observation is concerned, FP7 space calls have 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. This addresses an important aspect of the modelling work aimed at understanding the Earth's climate system and improving the ability to model and predict changes to the Earth's climate and to forecast its effects.

Earth observation data is also used to monitor ground based activity having an impact on climate (e.g. deforestation).

For both purposes it is important to be able to:

- access long time series data sequences that permit changes over time to be determined with a high degree of confidence. Continuity of data is critical.
- relate such measurements to ground truth in a systematic and traceable manner
- assign levels of confidence (i.e. measurement uncertainties) to such data
- combine space data with data from other sources (airborne, marine and land in-situ)
- process and interpret the data to meet the needs of ultimate end users; this includes modelling for predictive forecasting purposes over a range of future timescales.
- move on from studies of user need to experimental demonstrations of capability.

Recommendation 5-6: Horizon 2020 should support the exploitation of data from operational missions for scientific research purposes.

Recommendation 5-7: Horizon 2020 should support the scientific community to establish concepts, particularly regarding science campaigns, related ground observations (in-situ and, airborne) and data exploitation. In addition to obtaining the targeted scientific results, these activities should, where relevant, define the

operational infrastructure and services needed to provide continuity of observations into the future.

In all cases there are several barriers to more widespread the exploitation of data:

- Uncertainty over future continuity of satellite coverage
- An incomplete infrastructure for calibration and validation, integrity checking, establishing traceability to physical standards and ground truth, calculating measurement uncertainties and metadata tagging.
- The absence of some key sensor data and the complexity of extracting indirectly measured variables and data sets (including ECVs)
- Europe's lack of an efficient and effective infrastructure for users to gain ready access to the data and associated metadata.
- Complexity and complications associated with data policy and the rights and terms and conditions pertaining to the use of the data.
- Difficulty of effective integration with non-space data and of processing and interpretation to match end use information needs.

Recommendation 5-8: The Horizon 2020 programme should seek to address and reduce the barriers to more widespread data exploitation through collaborative actions and the other instruments available within the programme.

Recommendation 5-9 Improving the handling, management and provision of climate change related Earth Observation data to users should be a priority for Horizon 2020; and since the effective application of satellite data also relies in many instances on integration with data from other sources, this aspect too should be supported.

As noted elsewhere, funding to address these issues is generally beyond the scope of ESA's activities and requires significant collaboration between nations. Without attention to all of the above, Europe will not be able to derive the real value in terms of scientific progress and economic growth from Earth Observation. Commercial investment will not be forthcoming unless there is confidence over the continuity of satellite coverage, data availability, data quality and the infrastructure for access and supply. Hence a holistic approach to supporting innovation processes and the adoption of new developments throughout the supply chain should be addressed by the Horizon 2020 programme.

5.3 Summary of Main Recommendations

1. A comprehensive European approach to data exploitation (both scientific and commercial) should be implemented under the umbrella of the EU/EC (noting that ESA does not provide support for data exploitation). Budgetary envelopes within Horizon 2020 should be dedicated specifically to data exploitation and long-term data preservation (storage, calibration, development of tools and algorithms, etc). This approach should be coordinated with ESA.
2. The European Commission, in close co-ordination with ESA and other European stakeholders, should take an active part in planning and preparing for the exploitation of European space programmes, aiming to combine space and ground-based activities in 'interactive' programmes in order to maximise outcomes from space missions.
3. Continuity of data sets and satellite coverage is critically important, as is establishing the metrological accuracy of the data. Horizon 2020 should attend to these issues to ensure that investment in future public and privately operated service development can be made with an appropriate level of confidence.
4. Regimes for obtaining data from missions (both scientific and operational) should be reviewed to ensure that barriers to exploitation are minimised and that Europe is internationally competitive in deriving value from space data, particularly in comparison to the US.
5. Improving the handling, management and provision of climate change related Earth Observation data to users should be a priority for Horizon 2020; integration of satellite data with data from other sources should be supported.

6. PARTICIPATION IN GLOBAL SPACE ENDEAVOURS

6.1 Main Messages

There is a need for a consolidated shared vision for robotic and human exploration of Mars, Moon and NEOs consistent with an international vision. A dialogue and gap analysis should help build a European consensus;

Europe, under the umbrella of concerted action of the European Commission and ESA, should initiate the formulation of coordinated international space research programmes in cooperation with major non-European space-faring nations, while retaining the European leadership in essential elements of those programmes;

Cooperation should be continued or built with established partners, with China and India as well as developing space nations;

Strategies must be developed to mitigate increasing risks incurred by climate change, in particular through the development of long term forecast of life-threatening phenomena affecting international stability and security;

Space should be a tool of EU for international cooperation in particular with emerging countries.

6.2 Europe and an Assurance of International Cooperation in Space

The promotion of international cooperation in the exploration of and use of space is understood in the framework of the principle that space activities contribute to the goals of and fully respect the principles set out by the United Nations Outer Space Treaty[28]; the exploration and use of space is thus to be regarded as carried out for the benefit and in the interests of all countries, in recognition that the outer space is a province of all humankind.

Hitherto dominated by two competitive superpowers, space science, technology and exploration has evolved, since the end of the Cold War, towards a new paradigm in international cooperation; this has also allowed other countries and regions to develop very interesting active space programmes: activities relative to space have thus developed quickly into a global venture[29]. Aware of this new paradigm, more recently other gatherings seeking for a global framework for international cooperation in space activities have proven fruitful; among these relevance should be given to a workshop meeting under the auspices of the

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[28] *United Nations,* Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies*, United States Resolution 2222 (XXI), 1967.*

[29] Vide*, for example,* The Global Exploration Strategy: The Framework for Exploration*, May 2007, developed together by fourteen world leading space agencies.*

United States National Research Council of the National Academies, exploring the advantages and disadvantages of various approaches and aiming at stimulating further deliberation on the most effective ways of structuring future cooperation coordination in space and Earth science research and space exploration.[30] The International Academy of Astronautics (IAA), celebrated its 50th anniversary with a "Space Agency Summit" in November 2010 that addressed four key areas; among them "Planetary Robotic Exploration", "Human Space Flight", "Space-applications in Climate Change and Green systems" and "Space-based Disaster management". The attempt was to reach broad consensus on international cooperation in order to consider new concrete initiatives in the future.[31]

Europe, in this context, has been assuming its position in the lead, having the Council of the European Union, in its resolution on the European Space Policy[32], invited the European Commission, the ESA Director General and the Member States (**MS**) to develop and pursue a joint strategy and establish a coordination mechanism on international relations in a strategy that should be consistent with Member States activities: it aims at strengthening Europe's role in the global space field and at benefitting from international cooperation. It naturally stems that in international cooperation particularly, but also in other fields, this strategy must also aim at strengthening the existing European leadership at least in those domains where it proves to be chiefly strong. In this context, any examination of the potential avenues for future international cooperation in space research ought to take heed of the principles, objectives and methodology[33] proposed by the European Commission in order to bring about a European

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[30] Vide *James V. Zimmerman, rapporteur,* Approaches to Future Space Cooperation and Competition in a Globalizing World, Summary of a Workshop*, 2009, National Research Council of the National Academies, available at* www.nap.edu/catalog/12694.html *.*

[31] http://iaaweb.org/content/view/393/591/ *:*

IAA, 2010a. International Academy of Astronautics Study: Future planetary robotic exploration: the need for international cooperation:

http://iaaweb.org/iaa/Summit/IAA_Study-Planetary_Robotic_Exploration.pdf

IAA, 2010b. International Academy of Astronautics Study: Future human spaceflight: the need for international cooperation:

http://iaaweb.org/iaa/Summit/IAA_Study-Human_Spaceflight.pdf

IAA, 2010c. International Academy of Astronautics Study: Space-applications in Climate Change and Green systems: the need for international cooperation:

http://iaaweb.org/iaa/Summit/IAA_Study-Climate_Change.pdf

IAA, 2010d, International Academy of Astronautics Study: *Space based disaster management: The need for international cooperation*:

http://iaaweb.org/iaa/Summit/IAA_Study-Disaster_Management.pdf

[32] Vide *Council of the European Union,* Resolution on the European Space Policy*, 10037/07, 15 May 2007, in particular § H, page 10 and Annex 3, page 13;* vide *Annex I.*

[33] *Which are not reproduced here for reasons of economy of text.*

strategy for international relations in space[34], the progress of which was welcomed by the Council[35].

As a consequence of these policies, from 2009 on, international conferences on space exploration[36] have clearly recognised the importance of these global endeavours and its direct benefits: representatives around the world committed to begin the open structured high-level policy dialogue on space exploration at government level for the benefit of humankind.[37]

Further on, in acknowledging the conclusions of the FP7 interim evaluation[38], which recommended a "coherent strategic development" of the European Union policy for international cooperation in research and innovation, the European Commission produced a strategic approach in this domain[39], closely followed both this advice and in its concomitant recommendations.

There seems to rest no doubt that space research has definitely a global nature, demanding the setting up of the adequate forms of cooperating with representative entities in other regions of the world, being relevant of the need for gathering synergies or producing European made equipment and/or European designed services available to those who otherwise will not be able to implement them[40]. Also, to the large measure that increasingly ambitious space programmes are being adopted, the cost of which is too great for any of the space-faring nations to bear alone, the need arises to find agreeable forms of cooperation that would fulfil these desiderata, whilst the requirements to optimise resources and save time could be met.

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[34] *Commission of the European Communities,* Commission Working Document: European Space Policy Progress Report*, COM(2008) 561, 11 September 2008.*

[35] *Council of the European Union,* Council Resolution – Taking Forward the European Space Policy – adoption*, 13569/08, 29 September 2008.*

[36] Europe and Space Exploration*, Conclusions of the 23 October 2009 Prague Conference; Conclusions of the Second International Conference on Space Exploration, Brussels, 21 October 2010.*

[37] *Third International Conference on Exploration, First meeting if the High-Level International Space Exploration Platform – Declaration, Lucca, 10 November 2011.*

[38] http://ec.europa.eu/research/evaluations/index_en.cfm?pg=fp7

[39] *European Commission,* Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, Enhancing and focusing EU international cooperation in research and innovation: A strategic approach*, COM(2012) 497, Brussels, 14 September 2012.*

[40] *Council of the European Union,* Council Resolution: Taking forward the European Space Policy – adoption*, 13569/08, 29 September 2008; and Commission of the European Communities,* Communication from the Commission to the Council and the European Parliament: "European Space Policy"*, COM(2007) 212, 26 April 2007.*

Europe traditionally relies on cooperation in space research.[41] The success of the European space programmes lie in their cooperative nature, combining the efforts and scientific and technical expertise of different ESA Member States. The International Space Station (ISS) experience shows that cooperative space programmes build links between industries and laboratories from around the world, which then further develop in non-space related activities, with positive impact on the economy and scientific research. There is a long-standing tradition of international collaboration in space science between ESA and other space agencies[42] on scientific instrumentation and data sharing. 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. On the other hand, there are several instances, where international cooperation has failed, due to the countermand of non-European partners. The last prominent example is the failure to materialize at this time a joint ESA/NASA Robotic Mars Exploration mission though cooperative scenarios are at present being further discussed.

Space exploration is a field where Europe can assert itself globally and where the European Union institutions can bolster their image towards citizens[43]: space exploration is a political driver for the European Union on the international scene. A major European space exploration programme will contribute to reinforcing the European identity[44].

However, it is not only in the domains of space science and space exploration that opportunities and need for participation in global endeavours arise. The particular case of risks incurred by increasing effects of climate change gives Europe the instance to lead in the overall task of tackling them adequately, whilst providing instruments to prove the excellence of its science, research and development infrastructure and its industrial leadership and strength: it is quite clear that the space domain cannot be absent from this endeavour.

6.3 Robotic and Human Exploration of the Earth-Moon-Mars Space

Several nations are currently engaging in, or planning for, space exploration programmes that target the Moon, Mars and near-Earth asteroids, and propose voyages of exploration for robots and humans alike. Building a new space infrastructure, transport systems, and space

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[41] Vide *Space Advisory Group of the European Union Framework 7 – Space Theme,* Space Exploration, a new European Flagship Programme*, Brussels, 10 October 2010, and, more recently,* Vide *Space Advisory Group of the European Union Framework 7 – Space Theme,* Space Research in Horizon 2020: Recommendations of the FP7 Space Advisory Group (SAG)*, Brussels, 16 June 2011.*

[42] *E.g., US, Japan, Russia, China, and India.*

[43] *On this topic* vide *for instance Jean-Pierre Swings and Jean-Claude Worms, "The Case for Coopetition",* Public Service Review: Science and Technology (UK) *issue 04, 2009, page 31.*

[44] *Gerda Horneck, Angioletta Coradini, Gerhard Haerendel, May-Britt Kallenrode, Paul Kamoun, Jean-Pierre Swings, Alberto Tobias, Jean-Jacques Tortora (2010), 'Towards a European vision for space exploration: Recommendations of the Space Advisory Group of the European Commission',* Space Policy*, 26, 109-112. doi: 10.1016/j.spacepol.2010.*

probes and creating a sustainable long-term space exploration programme will require international cooperation.

The primary objective of Europe's Aurora programme set up in 2001 was to create, and then implement, a European long-term plan for the robotic and human exploration of the solar system, with Mars, the Moon and the asteroids as the most likely targets. The **European Space Sciences Committee** (**ESSC**) released in 2009 the "Science-Driven Scenario for Space Exploration" which defined overarching scientific goals for Europe's exploration program, dubbed "Emergence and co-evolution of life with its planetary environments", focusing on those targets that can ultimately be reached by humans, i.e., Mars, the Moon, and Near-Earth Objects (**NEO**).[45] In order to remain a strong partner in future space international exploration endeavours of this kind it is crucial that Europe develops key technologies (such as Entry Descent and Landing and Sample Return Systems), infrastructure for sample curation as well as specific instrumentation (e.g. for life detection) that enables fruitful and balanced partnerships in the international context. Numerous activities in preparation for robotic and human exploration of Moon, Mars and NEOs such as Earth analogue programmes (recently introduced into the EU FP7), ISS experiments and instrument development etc. will empower Europe to shape and contribute to a worldwide sustainable space exploration programme.

In order for Europe to play a significant role within a global space exploration programme, supported by the EU, a common vision for a European space programme exploring Moon, Mars and NEOs is vital. Recommendations of the Space Advisory Group of the European Commission supporting a European vision for space exploration have been recently formulated.[46] The very ambitious vision assumed the allocation of significant resources through ESA and the European Commission[47], as well as international cooperation. Such resources, in the present conditions, will hardly materialise in Europe. Activities for Moon, Mars and NEO missions are distributed among various ESA programmes supported by cross R&T roadmaps (see Annex A). Currently no consensus for a European strategy has been reached.

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[45] *J. C. Worms, H. Lammer, A. Barucci, R. Beebe, JP. Bibring, J. Blamont, M. Blanc, R. Bonnet, J. Brucato, E. Chassefière, A. Coradini, I. Crawford, P. Ehrenfreund et al, including J.P.Swings. ESSC-ESF Position Paper-Science-Driven Scenario for Space Exploration: Report from the European Space Sciences Committee (ESSC).* Astrobiology*, (2009) volume 9, pages 23–41.*

[46] *Gerda Horneck, Angioletta Coradini, Gerhard Haerendel, May-Britt Kallenrode, Paul Kamoun, Jean-Pierre Swings, Alberto Tobias, Jean-Jacques Tortora (2010), 'Towards a European vision for space exploration: Recommendations of the Space Advisory Group of the European Commission',* Space Policy*, 26, 109-112. doi: 10.1016/j.spacepol.2010.*

[47] *Exploration would become a third European Union flagship programme in the space domain, after Galileo and GMES.*

An evaluation of the national environment, identifying synergies and common pathways among European countries and stakeholders how to contribute to space endeavours and preparatory ground-based activities (simulations, analogue research, curation, ISS experiments etc.) should culminate in a new roadmap to explore the Earth Moon Mars space. Existing plans and roadmaps from science-driven national and international space exploration working groups (COSPAR, ILEWG, MEPAG, LEAG), space agency groups such as ISECG and IMEWG that assist in the analysis and implementation of possible architectures as well as studies undertaken by ESF, IAA and IAF, etc. should support the evaluation of the space research potential in individual European countries.[48] The key for making a space exploration programme in Europe sustainable is by identifying a satisfying role for each country to contribute most efficiently (on scientific, technological and political/financial level) leading to a long-term binding agreement. With a consensus for a European space programme the European Commission should get together with ESA and the respective Member States in order to formulate a stepping stone approach for exploration that considers as well the long-term aspirations and international cooperation potential as well as the current situation with limited resources and international partnerships. Developing significant resources to exploration in Horizon 2020 would facilitate faster implementation of missions to the three destinations within an agreed European strategy suitable for international cooperation in the long term.

In the wake of the needed update of a joint European space policy as recommended in the general introduction to this advice (see Chapter 1), a dialogue among space exploration stakeholders elucidating the gaps, identifying the strengths and weaknesses of European stakeholders, showing the space research potential in Europe and how synergies and space expertise could be better used at European level will foster the establishment of an effective European stance to explore robotically and with humans Moon, Mars and NEOs.

Recommendation 6-1: We recommend that a dialogue aiming at identifying the strengths and weaknesses, as well as the gaps and synergies of space stakeholders in Europe be carried out[49], providing a comprehensive overview of the effective space research potential for the exploration of Moon, Mars and NEOs and proposing a roadmap how synergies and space expertise could be put at an optimum use at the European level.

[48] *Pascale Ehrenfreund (lead editor) et al. 2012, Toward a global space exploration program: A stepping stone approach, COSPAR PEX Report, Advances in Space Research 49 (2012) 2–48.*

[49] *E.g. via ESSC*

6.4 Cooperation with Major non-European Space-faring Nations

The envisaged future space research programmes, whether in the field of Earth observation, space exploration, solar system research or astrophysics, will become more and more technically complicated and thus so expensive that a single nation cannot afford to realize them. As major non-European space-faring nations, China and India will progressively play an important role besides US, Russia and Japan. Europe strengthened through a joint European space policy should make every effort to be a highly desired partner in the international space research scenario. Europe must define its role within those global space programmes and prepare to contribute its key competences and systems. Examples of European key competences are given below, which qualify Europe for leadership:

- With Spacelab, the Columbus Module and ATV Europe has gained key competences for developing habitats and research laboratories in space;
- With Mars Express, Venus Express and Rosetta, Europe has demonstrated capabilities of performing autonomous planetary missions;
- With Planck and Herschel, Europe has taken a strong role towards exploration of our Galaxy and the Universe;
- With GMES, Europe has asserted its leadership both in monitoring the environment and security and in the cooperation, in this field, with other regions of the world[50];
- There are several fields in life sciences, in which Europe has gained a competitive role, such as human physiology and countermeasures, gravitation biology, and radiation health issues – as well as in advanced life support technologies. These elements are key requirements for safeguarding human presence in space, on the Moon and ultimately on Mars.

These are examples of key competences which could make Europe a desired partner or leader in future global space endeavours: the working arrangement the European Commission has recently signed with NASA, allowing the latter's field centres and research bodies to contribute to European Union research projects[51] might be a first but positive step in this right direction.

Recommendation 6-2: While recognising that the US, Russia and Japan have been and will remain our main partners, we recommend that Europe supports international space research programmes in cooperation with major non-European space-faring nations, while retaining the European leadership in essential elements of those programmes.

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[50] V.g. *the GMES and Africa initiative.*

[51] *Principles regarding the cooperation of NASA personnel with projects funded by the European Union's framework programs in the area of space research, Brussels, 17 January 2012.*

An essential element of a coordinated international space research programme is the exploration of Mars, as emphasized by the SAG in 2010[52]. A comprehensive Robotic Mars-Exploration Programme, performed in cooperation with major non-European space-faring nations would include robotic surface missions related to the habitability of Mars, ground-based analogue studies, as well as return missions with Martian samples.

Recommendation 6-3: We recommend that a comprehensive Robotic Mars-Exploration Programme should become an essential element of a coordinated international space research programme in cooperation with major non-European space-faring nations, in which Europe must keep a leading role in its predominant components.

The Moon is a valuable and crucial target for planetary science; it represents a window through which to explore the origin of our solar system and the Earth-Moon system. The interest of several nations[53] to undertake lunar missions continues for the foreseeable future. Therefore Europe should advance concepts to participate in international efforts of Moon exploration. Near-Earth asteroids can closely approach the Earth and therefore present a threat to humans and life on Earth. However, these objects also hold clues to the understanding of the early solar system and the impact history of early Earth. Their close proximity makes them interesting targets for the exploration of raw materials and supporting interplanetary journeys. Europe should engage in international research programmes in the area of impact hazard and mitigation of NEOs and develop exploration and technological concepts for NEO probes and sample return missions.

The ISS is considered as another essential element of a coordinated international space research programme, where Europe participates with 8 % utilization rights. Every support should be given to the existing cooperative programmes on ISS utilization. However, the ISS may retire in 2020 and firm commitments for a future human space programme in Low Earth Orbit do not exist in the Western world. In this context, among others, the approved programme of China is also worth considering: with Tian Gong 1, launched in 2011, a space laboratory has been put into orbit, which will be followed by two further more advanced space laboratories in 2013 and 2015. The construction of the Chinese Space Station will start in 2018 with the launch of the core cabinet, followed in 2020 and 2022 with the launch and docking of two advanced space laboratories. Its lifetime is given with 8-10 years. Europe does not have own capabilities for human transportation to space. If Europe wants to continue a human space research programme, it must rely on cooperation with established and emergent space-faring nations.

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[52] *Space Advisory Group of the European Union Framework 7 – Space Theme,* Space Exploration, a new European Flagship Programme*, Brussels, 10 October 2010.*

[53] *Russia, China, Japan, India.*

Recommendation 6-4: We recommend that the European Commission supports in Horizon 2020 the exploitation of the ISS and the evolution of the European LEO infrastructure; in parallel, negotiations should be supported with established and emergent space-faring nations, such as China, to open fair opportunities for the continuation of human space research in Low Earth Orbit beyond 2020.

6.5 Involvement of Emerging and Developing Space Nations

Engaging developing countries and emerging space-faring nations in cooperative space programmes can create a critical step for capacity building for those countries. Building up basic space technology capacity with a wider range of countries, ensuring that new actors in space act responsibly, and increasing public awareness and engagement, provides a broader interest in space research and programme sustainability. This might also lower the entry barrier for those nations to engage in space.[54]

Potential space activities/missions for collaborative work can take place in various research areas such as:

- Space education: Engaging, training and providing industrial experience to international groups of students from space fairing and space developing/emerging countries can be a catalyst in fostering niche collaboration efforts in joint space instruments or space missions/research projects. Matching funds provided by Horizon 2020 to national funds assist in materialising education and research projects globally specifically in areas where there is a lack of inter-regional funding for space (e.g. EU-Africa, EU-South/Central America);
- Space debris/situational awareness: The ever increasing problem of space debris and the need to define an internationally accepted code of conduct in space requires an international approach. Integration of national, institutional or inter-regional situational awareness assets can solve the current fragmented approach. It is recommended that preparatory work on the formation of an international coordination body/institution is studied, focused on developing space situational information available to interested parties;
- Near Earth Object Deflection/Mitigation: Similar to space debris/space situational awareness, NEO mitigation/deflection research needs to be tackled in an international and interdisciplinary approach including emerging space countries. It is recommended that detailed research work is funded to develop practical/near term mitigation options

[54] *COSPAR Workshop,* International Earth-based research programme as a stepping stone for global space exploration – Earth-X*, Space Policy Institute (SPI), Washington DC, USA, 2-4 March 2011*.

(demonstration missions) for potential NEO threats, thus extending present on-going projects up to an international environment;

- Earth Observation/Remote Sensing Applications: The last decade has seen the development of earth observation constellations of satellites such as the Disaster Monitoring Constellation. It is recommended that follow up actions for the integration of new instruments and missions with emerging space countries in key geographical areas prone to environmental disasters. Furthermore, activities on developing integrated and more responsive of services for rapidly evolving events such as volcanic ash eruptions or tsunami/earthquake events;
- Space Exploration: Many international space efforts focused on space exploration are now being considered due to high costs or mission overlap. Space exploration concepts (e.g. solar probes, Mars sample return) are recommended to be studied in order to create the necessary technical base, teaming arrangements, mission role definition in preparation for joint future exploration missions.

Recommendation 6-5: We recommend that the European Commission takes steps to include emerging and developing space nations in cooperative space programmes in order to lower their entry barrier to engage in space as well as to enable them to participate in upfront science.

6.6 The Particular Case of Risks Incurred by Climate Change

There is a vast wealth of evidence, increasingly robust albeit diverse, suggesting that the global climatic changes are predominantly caused by anthropogenic rising in concentrations of greenhouse gases[55], summing up to already paramount but innate natural variability in the Earth climate system, the variations in solar irradiance and the volcanic activity. In effect, assessments of these natural phenomena relative influences showed the way to conclude that natural factors alone cannot account for the observed warming, particularly in the latter half of the century[56].

Additionally to current projects and initiatives on space situational awareness and space weather, sentient of these changes already observed, the Global Monitoring for Environment and Security (GMES), an Earth monitoring initiative lead by the European Union and carried out in partnership with Members States and the European Space Agency, was set up in order

[55] *Water vapour, carbon dioxide, methane and nitrous oxide.*

[56] *IPCC, 2007,* Summary for Policymakers. *In:* Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change *[Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.*

to provide information services giving access to accurate data and information in the field of environment and security, bespoke to the needs of its users. In doing so, GMES is fostering better the exploitation of the European industrial potential, of policies of innovation, research and technological development in the field of Earth observation, thus becoming a key tool *inter alia* in the support of biodiversity, ecosystems management and climate change mitigation and adaptation[57]. As a flagship of the European Union space policy[58], it will be delivered under the Europe 2020 Strategy[59] and will be included in its industrial policy initiative[60]. Based on GMES basic services[61] a plethora of other value-added services tailored to specific and commercial needs is being developed, stimulating the downstream sector. Whatever these monitoring activities are, they are carried out by these European entities, whilst in other parts of the world similar activities are also providing equivalent services.[62]

Quite recently, climate change has been seen as a risk multiplier interacting significantly with other tendencies[63]: clearly some particular societal challenges as poverty, disease and food and water scarcity and insecurity seem at present even more difficult to address in these unhelpful circumstances; these will necessarily be potentiated, in specific regions of the world, by the observed rising temperatures, changing patterns of precipitation all affecting the availability of food and water and leading to increased levels of famines and volatility of food prices. Consequently, regional tensions affecting the international stability and security are occurring: the inherent uncertainty of these increasing frequencies of extreme weather events would adversely affect human health as well as disrupting the flow and prompt availability of national resources and commodities; consequently, diverse impacts are likely to increase significantly the risks associated to these changes. As a corollary, the consequences of

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[57] *Regulation (EU) No. 911/2010 of the European Parliament and of the Council of 22 September 2010 on the European Earth monitoring programme (GMES) and its initial operations (2011 to 2013).*

[58] *European Commission,* Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions, Towards a space strategy for the European Union that benefits its citizens*, COM(2011) 152, Brussels, 4 April 2011.*

[59] *European Commission,* Communication from the Commission, Europe 2020, A strategy for smart, sustainable an inclusive growth*, COM(2010) 2020, Brussels, 3 March 2010.*

[60] Vide *also European Commission,* Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions on the European Earth Monitoring Programme (GMES) and its operations (from 2014 onwards)*, COM(2011) 831, Brussels, 30 November 2011, at present under debate*.

[61] *Land monitoring, marine environment monitoring, emergency management, atmosphere monitoring, security and climate change: no services in GMES address, therefore, the forecast of phenomena, meteorological or other, potentiating the known risks that had been so far quite patent with dire consequences on the overall society.*

[62] Vide*, for instance, Space Advisory Group of the European Commission Framework Programme 7 – Space Theme,* Space Research in Horizon 2020, Recommendations of the FP7 Space Advisory Group (SAG)*, Brussels, 16 June 2011, pp. 12 and 13 (§ II.3.5.1) and p. 21 (§ III.2.2.2).*

[63] Vide*, for instance, Foresight,* International Dimensions of Climate Change*, Final Project Report, The [UK] Government Office for Science. London, July 2011.*

climate changes elsewhere will have important implications in Europe and those countries sharing the same social and ethical values[64].

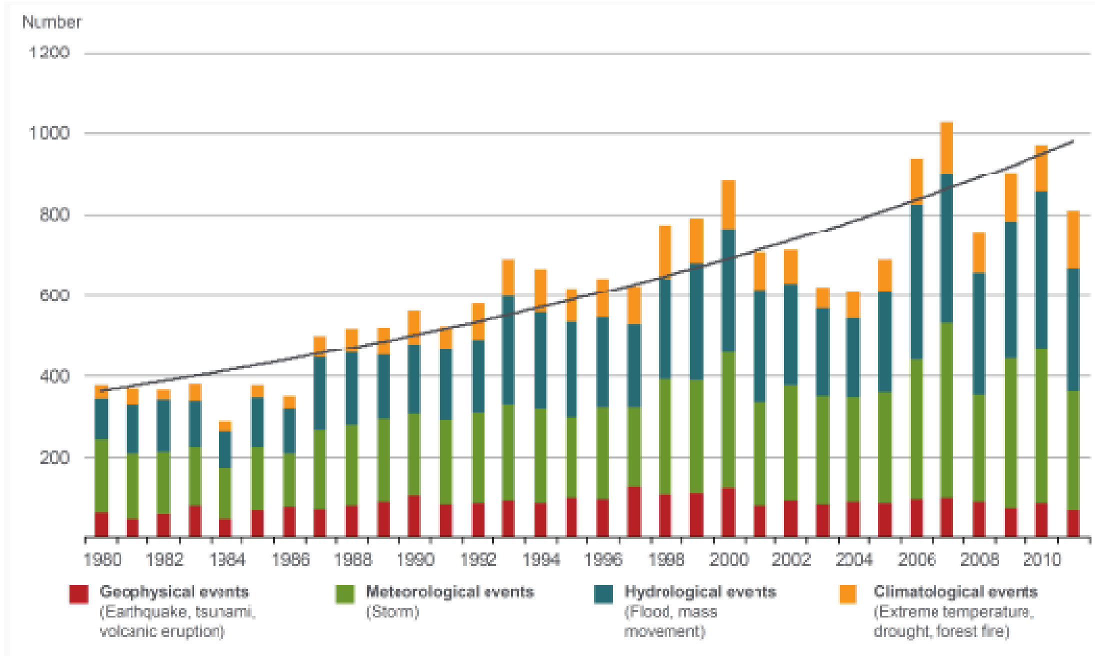

Figure 6-1: Annual number of catastrophe events globally 1980–2011[65]

These risks are particularly severe in failed states and ungovernable regions, naturally leading, in particular under the most adverse circumstances, to insurgent and terrorist activities, most of the instances with global consequences, requiring additional vast efforts to overcome them and calls for international interventions in these zones of the globe, as recent examples demonstrate. Additionally, linking climate change and the potential security implications it can pose constitutes a demonstration of seriousness in the will and resolve in dealing with the most important societal challenges: it should not be a surprise to consider, thus, that climate change is a threat vastly eclipsing that of terrorism[66].

Recommendation 6-6: We recommend that strategies are developed to mitigate the gradual increasing risks incurred by climate change, in order to better understand the mechanisms leading to avoidable dire consequences, thus acquiring an advance

[64] *The famines in Darfur and Eritreia/Somalia were events leading to diplomatic and security interventions aiming at preserving either human health and security in these regions or abate illegal actions to pressure the global infrastructure of transport and energy severely threaten.*

[65] *Source: Münchener Rücksversicherungs-Geselschaft, Geo Risks Research, NatCatSERVICE, 2012, quoted in Christophe Courbage and Walter R. Stahel, editors,* Extreme events and insurance: 2011 annus horribilis, *The Geneva Reports No. 5, Geneva, March 2012.*

[66] *Among others,* vide *A. Zinni* et alii, National Security and the Threat of Climate Change*, The CNA Corporation, Washington, D.C., 2007.*

comprehension of how such effects may threaten, through particular pressures, the security of Europe and, at large, the international stability.

For all these reasons, adding up adversely to these likely expected effects, it is certainly worthy to foster research and unearth innovation aiming at finding ways of forecasting unfavourable meteorological phenomena leading to such considerable disruption of life, thus avoiding building up conditions towards bouts of insurgency and possible terrorist activity. If forecasts of that sort are prepared sufficiently in advance, pre-emptive humanitarian action can be carried out so to avoid any physically powerful interventions, the extremely onerous calls for which will not be required or, at least, decrease their rate of recurrence. A course of action of this nature being followed, there will be plenty of opportunities then for Europe to lead in the overall task of tackling adequately the global climate change effects whilst providing instruments to prove the excellence of its science, research and development infrastructure and its industrial leadership and strength.

A service of this nature will not be brought about without the essential use of space research, particularly in the domain of Earth observation; it will certainly imply not just the European institutions: it is clearly a matter of involvement of the global international organisations aiming at facilitating international security together with their Member States with a clear proclivity and resolve towards solving the main societal challenges at present threatening the security of Europe and, at large, the international stability.[67]

Recommendation 6-7: We recommend that the research and innovation on reliable long term forecast of weather phenomena leading to adverse life threatening conditions must be concomitant with diplomatic accomplishments at the appropriate level amidst the broadest set of the eventual contributing states, it being understood that humanitarian interventions, particularly those to be initiated by those forecasts, have a definitive political connotation.

[67] *This is not the first time Europe embarks in such intercontinental ventures involving both its research and innovation structure: the initiative* GMES and Africa *set up in 2007 is a plain example that international cooperation at this level can be achieved with relative easiness, provided all the intervenient parties are aware of the aims of such undertakings and willing to work together towards overcoming definitive and threatening societal challenges.*

6.7 Summary of Main Recommendations

The chapter contains seven detailed recommendations, the main points of which can be summarised as follows:

1. There is a need for a consolidated shared European vision for robotic and human exploration of Mars, Moon and NEOs consistent with an international vision; a dialogue and gap analysis should help build a European consensus;
2. A comprehensive Robotic Mars-Exploration Programme should become an essential element of a coordinated international space research programme in cooperation with major non-European space-faring nations, in which Europe must keep a leading role in its predominant components;
3. Utilisation of the International Space Station should be fostered. The European Commission should start negotiations with established and emergent space-faring nations, such as China, to open the opportunity for continuing human space research in Low Earth Orbit beyond 2020;
4. Steps should be taken to include emerging and developing space nations in cooperative space programmes;
5. Strategies should be developed to mitigate the increasing risks attributable to climate change, which ultimately threaten the security of Europe and international stability.

Annex A The Main European Organisations Supporting Space

A.1 ESA programmes

ESA has 3 major sets of programmes dealing with space research.

- Space science
- Robotic and human exploration
- Earth science

These are supported by other programmes dealing, for example, with technology and telecommunications development.

ESA's science research is driven by the scientific community, which provides the research agenda and proposes space missions. Proposals are evaluated and selected for implementation through peer review. The science advisory committees also play an important role in identifying breakthrough technologies important for new equipment and facilities needed for the research.

A.1.1 Space Science

Space science is a mandatory programme within ESA with a yearly budget of 465 M€ (2011). Astrophysical and solar system space missions are selected and approved based on scientific excellence and then developed for flight. Missions developed within the programme that are still operational are XMM-Newton, INTEGRAL, Herschel, Planck, Cluster, Mars Express, Venus Express and Rosetta. The launch of BepiColombo, ESA's Cornerstone mission to Mercury is scheduled for 2017. Other future missions are Gaia (2013), LPF (2014), Solar Orbiter (2017), JWST (2018 - in collaboration with NASA), Euclid (2019) and, in the longer term, the 3rd medium mission (M3) and the first large Cosmic Vision mission (L1) JUICE. The programme also contributes to other ESA missions, such as Proba-2, and to national missions such as the French COROT and Microscope projects, as well to other international missions.

The ESA space science mandatory programme funds the development and construction of the space vehicles and the launch and operation of the missions, but not the development and construction of the scientific instrumentation nor the exploitation of scientific data obtained.

A.1.2 Robotic and human exploration

ESA's optional space research programme includes work on robotic and human exploration in the context of three potential destinations: low Earth orbit (LEO), the Moon and Mars.

Destination Earth orbit

Scientific utilisation of ISS is part of the optional European Life and Physical Science Programme (**ELIPS**). ELIPS is intended to undertake research on the ISS as well as on other vehicles such as sounding rockets and unmanned orbital platforms. ELIPS has a budget of 100 M€/year (2011) at its disposal. Within ELIPS, experimental hardware and utilization of the ISS and other Earth orbiting vehicles and platforms are funded by ESA, but not the preparation of the scientific experiments or analysis of the data obtained.

Utilization of the facilities afforded by the ISS is fundamental to preparations for human exploration of the Solar System.

Destination Moon

The Moon is our closest destination in the solar system and the only one which can be quickly reached by human explorers. As such, reaching it (again) is a natural extension of human space flight activities. It holds significant scientific and other interest worldwide. ESA has been preparing a Lunar Cargo Lander mission which is being proposed for implementation. Studies have also been started for cooperation on a Lunar Polar Sampler Mission which would be proposed for implementation as a follow on.

Destination Mars

Mars is the ultimate destination for robotic and eventually human exploration. Robotic exploration of Mars is carried out under an optional part of ESA's science programme. It disposes of a yearly budget of 130 M€ (2011). The ExoMars mission approved in 2005 as a technology demonstrator has evolved to a full blown programme driven as much by science as by technology and needing a concerted effort by ESA and international partners for the implementation of the more ambitious programme objectives.

This led to a joint ESA-NASA Mars programme consisting of 2 missions: the ExoMars Trace Gas Orbiter mission, including an entry, descent, and landing demonstrator module (EDM) to be launched in 2016, and two rovers to be launched in 2018, The ESA ExoMars rover dedicated to searching for habitability and signatures of indigenous life, and a NASA MAX-C rover for sampling and caching samples for later return to Earth. In February, 2012, NASA terminated its participation in ExoMars due to budgetary cuts. In order to continue the ExoMars programme, ESA has established cooperation with the Russian Federal Space Agency (Roscosmos).

Studies and technology developments have been initiated under the Mars Robotic Exploration Programme (**MREP**) and continued by the European Robotic Exploration Programme (**EREP**). Mission/system studies supported by science studies and technology development should now lead to intermediate missions exploiting flight opportunities from 2022, culminating in a sample return mission.

A.1.3 Earth science

ESA has been dedicated to observing the Earth from space since the launch of its first meteorological mission in 1977. ESA pursues a dual strategy involving scientific research driven Earth Explorer missions and service driven Earth Watch missions, the latter in conjunction with satellite operators as partners

Earth Explorers

The Earth Explorer missions are implemented within a rolling Earth Observation Envelope Programme (**EOEP**) in a series of five year implementation cycles. Earth Explorer missions include GOCE (2009), SMOS (2009), CryoSat (2010) and soon Swarm (2012), Aeolus (2013) and EarthCARE which is already under development. New Earth Explorers are being studied for launch in due course as Earth Explorers 7 and 8.

Earth science missions are proposed, evaluated, scientifically defined and exploited by the scientific community to meet the priorities of the research agenda established by that community. ESA covers the Earth Explorer missions from end-to-end, i.e. from concept development through spacecraft development, launch and operation (for a defined period) but it also supports science studies and campaigns and, to a certain level, exploitation of the data obtained.

Earth Watch

ESA's Earth Watch series targets operational missions. Operational meteorological systems are developed with Eumetsat and include geostationary satellites in the Meteosat series and the LEO MetOp satellites for the Eumetsat Polar System (**EPS**). Other operational missions, in conjunction with the EC, include the Sentinels for GMES. It should be noted that operational missions, with their potentially uninterrupted supply of calibrated data, are excellent sources of data for furthering scientific research related to the Earth System.

In addition, ESA has initiated a dedicated Climate Change Initiative (CCI) to contribute to the database of Essential Climate Variables (**ECV**) required by the UN Framework Convention on Climate Change and to help to realise the potential for a long-term global Earth Observation archive (see section 5.5).

ESA also provides access to numerous third party missions for the benefit of European users. The next budgetary decision point for ESA's programmes is scheduled for November 2012.

A.2 National Space Agency (and other national) Programmes

Depending on budgets available, some national organisations and space agencies in Europe develop and construct satellites for space missions, either alone or in cooperation with ESA or other European or non-European space organizations. This is more common with Earth Science and scientific experiments in microgravity than with Space Science and Exploration.

With respect to ESA-led missions in the mandatory space science programme and in Exploration, the national agencies and organisations within the Member States are usually responsible for funding the development and construction of the ESA-selected instruments as well as for the preparation of the scientific experiments.

A.3 Space Research within European Commission Programmes

The European Commission's Seventh Framework Programme (FP7) has been largely dedicated, albeit not exclusively, to the development of the GMES system and relevant applications (85% of the available resources). This was the first occasion on which the Commission's Framework Programmes have taken "Space" as an independent theme in its own right. A modest part of the resources available, taken from the other 15% available for the space theme (amounting to 28 M€/year) has been used for "Strengthening Space Foundations". Within this allocation, seeding money has been used for cross-cutting activities including:

- Exploitation of space data,
- Key technologies enabling observations in and from space,
- Key technologies for in-space activities.

As of May 2011, the FP7 programme has supported 13 projects dealing with technology developments for space exploration, 8 related to space weather issues, 5 on space debris, 11 dealing with space data exploitation, and 7 on developing critical technologies (Source: Space Research projects under the 7th Framework Programme for Research, European Commission, Enterprise and Industry; and Let's embrace space, Space Research achievements under the 7th Framework Programme from the European Commission).

With GMES now entering its operational phase, Horizon 2020 will focus on R&D in other important areas, creating opportunities to address additional priorities, including areas not funded or only slightly covered by FP7 together with topics entirely new to the Commission's space theme.

Annex B FP7 Space Projects on Data Exploitation

This annex contains a brief description of space projects on data exploitation funded currently within FP7, status May 2012.

- European Cluster Assimilation Technology (**ECLAT**): ECLAT is related to research on space plasma and solar terrestrial physics. It provides supporting data for the ESA Cluster Active Archive and develops new software tools for facilitating data mining and data visualization.
- ESPACE, European Satellite Partnership for Computing Ephemerides: It is planned to initiate a European expertise network in planetary dynamics. Old space data will be exploited together with ground-based data to develop new technologies for spacecraft tracking.
- EUNAWE, Building on the International Year of Astronomy - Making young children aware of the Universe: EUNAWE exploits the achievements of astronomy and space sciences to inspire, excite and stimulate children. Comprising 5 European countries and South Africa, it builds on the Universe Awareness (UNAWE) programme, which comprises 40 countries and was a cornerstone of the International Year of Astronomy.
- HAMLET, Human model MATROSHKA for radiation exposure determination of astronauts: HAMLET is dedicated to the assessment of radiation risks for humans in space by exploiting the data provided by the ESA facility MATROSHKA, a human phantom accommodating a variety of radiation detectors. MATROSHKA has been located inside or outside of the ISS. Based on experimental inputs from MATROSHKA as well as radiation transport calculations, a three-dimensional model for the distribution of the radiation dose in an astronaut's body has been produced.
- High Energy Solar Physics Data in Europe (**HESPE**): The rationale for HESPE is to formulate and implement computational methods for solar high-energy data analyses and to provide algorithms and science-ready products for the solar physics community.
- Integrated Medium for Planetary Exploration (**IMPEX**): IMPEX aims to create an infrastructure which bridges the gap between spacecraft data bases and scientific modelling tools in order to simulate planetary phenomena and to interpret spacecraft measurements, to test and improve models versus experimental data, to fill gaps in measurements by appropriate modelling runs, and to perform technological tasks regarding mission operations, including the preparation of new missions.
- POPDAT, Problem-oriented Processing and Database creation for exploration of the ionosphere: POPDAT aims to create a database of ionospheric waves catalogues. This includes the development of a set of tools for problem-oriented processing and data mining of ionospheric observational data, collected and stored by past ionospheric satellite missions.

- SEPServer, Data services and analysis tools for solar energetic particle events and related electromagnetic emissions: SPServer deals with space weather research and forecasts. It aims to add value to several existing space missions and Earth based observations by integrating scattered data from a number of international sources, and to enhance data accessibility by setting up a server that provides SEP data, related electromagnetic observations and analysis methods, as well as a comprehensive catalogue of observed SEP events.
- SOTERIA, Solar-terrestrial Investigations and Archives: SOTERIA aims to improve understanding of space weather phenomena through collaboration between experts in different fields of solar, space and geophysics, by making better use of existing data and providing better databases.
- SPACE-DATA ROUTERS, Space Data Routers for exploiting space data: This project presents a novel and innovative approach for enhancing data sharing, by developing a new communication infrastructure.
- ULISSE, USOCs knowledge integration and dissemination for space science experimentation. ULISSE aims to improve preservation, valorisation and exploitation of data produced by European experimentation in space, particularly experiments performed on the International Space Station. ULISSE plans to set up a data base network connection between different data bases established by different European space entities.

Annex C Terminology

For the purposes of this document the following definitions apply:

- **Access to Space** – the ability for a State or Group of States to launch satellites (potentially also manned space vehicles).
- **Actor -** an entity (individual or organisation) active in the domain.
- **Downstream** – the “downstream market” or “downstream segment” refers to the activities associated with the development of applications, products and services to exploit space data.
- **Earth Observation** missions encompass gathering of information about the Earth's manmade and natural physical, chemical and biological systems, the behaviour of the earth and near earth environment.
- **Earth Science** - an all-embracing term for the sciences related to the planet Earth.
- **Exploration missions** encompass robotic and human space missions within our solar system including planetary and lunar surface exploration. These missions are often precursor activities to future human long term activities in space.
- **Grand Theme** - a specific space objective for Europe that may be achieved with one or more missions.
- **Ground Segment** - a term describing all parts of a space system, not located in orbit.
- **Mission** - the intended or actual use of a satellite and its ground and/or space based infrastructure to achieve particular objectives or the use of vehicle carrying a payload beyond Earth orbit for the purposes of exploration or research.
- **Operational Concept** - the way in which technology, capabilities and satellites will be used to achieve particular objectives and to realize successful missions.
- **Reference Mission** - a description of a mission that is consistent with achieving a Grand Theme.
- **Satellite** comprises a spacecraft and a payload.
- **Science missions** encompass scientific investigations of our solar system and the universe such as astrophysics, fundamental physics, planetary observation etc. There can be an overlap with exploration missions.
- **Spacecraft** - the part of a satellite which hosts a payload, providing it with resources to enable the mission or a vehicle carrying a payload beyond Earth orbit.
- **Space Science** - all of the various science fields that are concerned with the study of the Universe, generally also meaning "excluding the Earth" and "outside of the Earth's atmosphere".

- **Space Segment** - a term describing all parts of a space system located in orbit or beyond earth orbit.
- **Space Transportation** missions cover placing of cargo and humans in orbit and their return to Earth.
- **Stakeholder -** an entity (individual or organisation) with a legitimate interest in the domain.
- **Technology** provides **Capabilities** which in turn enable the achievement of **Missions**.
- **Technology Non-dependence** – the ability for a State or Group of States to manufacture fully autonomously all components needed to assemble technology-intensive equipment.
- **Upstream** – the "upstream market" or "upstream segment" refers to the activities associated with the design, development, launch and operation of spacecraft and their associated ground infrastructure (noting that operation of telecommunications satellites is often done by their commercial operators).

Annex D Acronyms

AO	Announcements of Opportunity
ARTES	Advanced Research in Telecommunications Systems
ASIC	Application Specific Integrated Circuit
ATV	Automated Transfer Vehicle
CDF	Concurrent Design Facility
CGMS	Coordination Group of Meteorological Satellites
CTB	Component Technology Board
EC	European Commission
ECLAT	European Cluster Assimilation Technology
ECV	Essential Climate Variables , Essential Climate Variables
EDA	European Defence Agency
EEE	Electrical, Electronic and Electromechanical
ELIPS	European Life and Physical Science Programme
EO	Earth Observation
EOEP	Earth Observation Envelope Programme
EPS	Eumetsat Polar System
EREP	European Robotic Exploration Programme
ESA	European Space Agency
ESCC	European Space Components Coordination
ESSC	European Space Sciences Committee
ETH	European Technology Harmonization
EU	European Union , European Union
FP7	Seventh Framework Programme
FTAP	Future Technology Advisory Panel
GCOS	Global Climate Observing System
GMES	Global Monitoring for the Environment and Security
GSTP	General Support Technology Programmes
H2020	Horizon 2020
HESPE	High Energy Solar Physics Data in Europe
HISPAC	HIgh level Space Policy Advisory Committee
IAPP	Industry Academia Partnerships
IEF	Intra-European Fellowships
IMPEX	Integrated Medium for Planetary Exploration
IPR	Intellectual Property Rights
IRSES	International Research Staff Exchange Scheme
ISS	International Space Station
ITN	Industrial Training Network
KET	Key Enabling Technologies
LEO	Low Earth Orbit
MREP	Mars Robotic Exploration Programme
MS	Member States
MTB	Material Technologies Board

NEO	Near-Earth Objects , Near Earth Objects
R&T	Research and Technology
REACH	Registration, Evaluation, Authorisation and Restriction of Chemical Substances
RTD	Research and Technology Development
SAG	Space Advisory Group
SBIR	Small Business Innovation Research
SCOPE-CM	Sustained, Coordinated Processing of Environmental Satellite Data for Climate Monitoring
SME	Small and Medium-sized Entities
SOC	Science Operation Centre
SRIA	Space Research and Innovation Agenda
SSA	Space Situational Awareness
TnD	Technology non-Dependence
TRL	Technology Readiness Level