Towards the end of the preparation of this document, the EC posed a number of questions. In this section, these questions are repeated and summary answers given.

Q1: Balance in Different Dimensions

In all of Horizon 2020 different dimensions will have to be balanced. To maximize the impact of space in Horizon 2020 we would welcome recommendations on how a balance in the following dimensions is to be struck in the following seven classifications.

SAG Answer:

Bottom-up vs. agenda driven research. Both have been indicated to be important, but what should their respective roles be in the overall Space Programme, and in its various themes?

Actually both approaches are complementary.

Traditionally, many public-funded R&T programmes are more likely to focus on blue-sky research, as this fits with the overarching political ambition to contribute to the preparation of the long-term future. This was the case with FP7.

However, it is necessary to ensure the continuity of blue-sky research through continued support to development in order to give a chance to promising ideas to turn into effective technologies, products and services. This is true across all the applications of space, and Horizon 2020 has a role to play here.

This has some strong implications:

- First, it requires the involvement of more highly qualified and specialized skills for the management of activities. The European Commission will have to acquire them wherever available in agencies, industry or academia,
- Second, early stages of developments are most often limited to “paper” studies with limited laboratory / field work, which are much cheaper than the subsequent stages involving, for instance, the realisation of representative prototypes or the use of testing facilities. Moving up the Technology Readiness Level (TRL) scale implies bigger individual budgets for activities to be supported.

As a consequence, it can roughly be assessed that as blue-sky research represents just a few per cent of the overall development cycle, and in the optimistic hypothesis where one blue-sky activity out of 10 would ultimately end up in an actual fully qualified product, the amount

devoted to bottom-up approach should not exceed some 10% of the total budget of Horizon 2020. It is to be noted that blue-sky can also be problem-oriented, e.g. a call for solutions to say, radiation protection for long space flight.

Which parts of the TRL chain should H2020 address in its different themes? Given associated risks, should there also be dedicated activities for 'blue-sky' RTD?

It is quite a challenge to reach a consensus on such issues in the framework of a multidisciplinary group such as the SAG; obviously, everyone would like his sector to be given priority!

However, it can be said that as far as hardware development is concerned, Horizon 2020 should be able to address all readiness levels up to TRL 6, which implies in-orbit validation. Beyond that would require an involvement in the user programmes, which is not the role of the European Commission. Similarly, the development of downstream services should be supported up to and including a validation phase.

This need for in-orbit validation applies to all kinds of activities targeting a dedicated application. This is in particular the case of space telecommunications, Earth observation or navigation, which all address the Grand Challenges. This can also be the case in space science for the preparation of a specific mission. Of course, this does not preclude the need to target long-term objectives and to adequately prepare next generation systems in all areas.

For the time being, and as long as no destination has been firmly set to Space exploration, it requires more long-term investments in enabling technologies to shorten the duration of extra-terrestrial missions, to consolidate the European skills in aero-capture and landing, drilling, in-situ analysis, life support, etc. The point is to ensure the continuity of European competencies and to make sure that Europe is properly prepared to get the share it deserves in the upcoming international co-operations in this matter. In this case the use of analogues could be recommended.

Earth related activities (Challenges, EO, SSA) vs. extra-terrestrial exploration?

We cannot choose one over the other, as they are the two sides of the same coin. None of the large established space faring nations has limited its focus to one or the other of these two areas. They altogether contribute to the progress of their respective space capabilities.

Horizon 2020 should obviously make a strong case for programmes or projects having received political endorsement from the EU and its Member States, which mostly address Earth-related activities. Whilst the continuation of such programmes or projects should have some priority it would be a mistake to limit Horizon 2020 to such activities exclusively.

As a matter of fact, Horizon 2020 is meant to prepare the possibility to decide new programmes and, in an ideal world, it should even target the next step immediately once a decision has been made in one given domain.

But our world is far from being perfect. Horizon 2020 has to contribute to the achievement of European on-going activities. Thus, safeguards must be put in place so that its resources are not eaten up by short-term priorities.

In exploration related activities: robotics vs. human related activities?

Globally, robotic missions will continue for sure, to Mars, to the Moon and to asteroids. Most of them will be international co-operations. The only question is the timeframe and the respective roles that nations, with Europe among them, will play.

The evolution of human related activities beyond ISS is more difficult to anticipate, as international competition still seems to be a major driver here. However, it strongly captures the imagination and it is unlikely that these activities are discontinued worldwide. In such conditions, it is even more unlikely that Europe, as a first rank global technological and scientific actor, doesn't play a role in the new ventures to come.

One thing for sure is that in both areas, Europe has developed strong skills through its various achievements in successful missions such as Huygens or Smart-1, or its highly regarded contribution to the ISS. In a context where no clear destination is likely to be set through the firm decision of new ambitious programmes, these skills could be easily dispersed and would be very costly to be redeveloped if needed in the future. Horizon 2020, by providing researchers with new challenges, must contribute to consolidate these capabilities.

Balance between technology development and exploitation of existing infrastructures?

Exploitation of existing publicly funded space infrastructures should be a top priority. Horizon 2020 should contribute to it by providing support to the preparation of new services based on Galileo or GMES, exploitation of Earth or space data delivered by on-going European missions, or conducting science on board the ISS.

However, unless you are preparing your withdrawal from a sector, exploitation of infrastructures requires the preparation of the next generation systems. Therefore, successful exploitation includes a share of technological development.

Project size and scope: in FP7 most SSF projects have a ca. 2 million euro EU contribution. Horizon 2020 allows for a more differentiated approach in size, scope and duration. What would be appropriate for the different elements of space in Horizon 2020 (bottom-up and agenda-driven elements or topics)?

As I previously said, blue-sky research, which might result from a bottom-up approach as implemented in FP7 calls, is most often limited to early stages of development, which means "paper studies" and limited experimental work. Most of the costs involved are salaries, increased by a reasonable amount of indirect costs and some laboratory costs. The 2 M€ envelope you mention is consistent with this framework in an international environment involving a multitude of players across all EU member States.

If the scope is to be enlarged to embrace concrete realisations up to TRL 6 with in situ or in orbit demonstration, the budget for individual projects will dramatically increase. The curve showing the typical evolution of expenditures along the development of a product, which, I believe, is still respectfully taught in all knowledgeable engineering schools, can confirm this assertion.

There are many reasons for this; there is a long way from theory to real life. A major one in our sector is the tremendous cost of specific machineries and in particular test benches and facilities. In this respect, it is vital that Horizon 2020 can cover such costs.

Typically, the difference in cost between an agenda-driven and a bottom-up element can be one order of magnitude while the duration might vary from 2 to 6 years in total, depending of course of the nature of the activity considered.

What should the balance be between RTD and close-to-market activities (activities which aim to develop commercial products and services within or directly following the project)?

First, this notion of proximity to the market is meaningless in the case of very specialist but strategically important basic technologies, EEE components or materials for which there may not be a viable volume market for industry to address cost effectively. In such cases assistance will be needed right through to the establishment of production facilities.

Second, such balance should be determined by what is needed to get developments to the point where the private sector can take over unaided. Putting European industry on a level playing field with its competitors implies extending the reach of public funded R&D to higher TRL or closer-to-market, however you call it. As previously said, this has strong budgetary implications, as the funding required dramatically increases with the maturity level.

Therefore, close-to-market activities would be expected to attract a larger proportion of the budget than the R&T that preceded it. Without such follow-on support to get to market, the risk exists that the initial investment in R&T will be wasted.

Q2: Agenda-Driven Elements

Depending on the overall programme size a limited number of agenda-driven elements can be accommodated. Which areas should be considered? Examples mentioned in various fora are launchers/propulsion, SSA, exploration network mission, in-orbit demonstration missions, robotics (this is by no means an exhaustive list). Can the SAG provide a list of (~10) topics that would benefit from an agenda-driven approach while contributing in a substantial way to the 4 Specific Objectives defined?

SAG Answer:

By the very nature of space endeavours, most major objectives associated with space have to be achieved with the aid of an agenda and a roadmap within which projects can be specified and planned. This is certainly true of infrastructure development (launchers and the ISS for example), major exploration and science missions and the larger Earth orbiting satellite developments. Exploitation of results and data can also benefit from an agenda driven approach, particularly where they are aimed at tackling the Grand Challenges on Earth and the main components of the other pillars within the Space Theme. Without agendas and roadmaps, projects can become isolated activities that risk wasting money, duplicating effort or failing to attract the necessary follow through.

There is nevertheless also an important role for non-agenda driven activity. Such activity should enable and encourage very early stage investigative research into radical new ideas and innovative (and possibly disruptive) ways of doing things. This might include, for example, proposals for new, commercially competitive ways of reaching orbit at much lower cost (although mainstream launcher developments should be left to ESA, which is well equipped to carry out the major development programmes needed). In general, the Space Advisory Group would favour allocating around 10% of the budget in each of the Horizon 2020 Space Theme Pillars to non-agenda driven, 'blue-skies' research to encourage such radical innovation, with the remaining 90% being allocated to agenda driven topics.

A list of the main agenda driven topics identified as particularly important by the SAG comprises:

1. Development of operational services to meet Grand Challenges on Earth.
2. Included in the above, but specifically highlighted: activities to support investigation and management of the Earth's environment, particularly in relation to development of core services for provision of climate information.

3. Activities to support the evolution and development of major next generation satellite based infrastructures ie GMES and GNSS next generations.

4. Development of Space Situational Awareness information services (in conjunction with ESA).

5. Activities to support robotic and human exploration, particularly in relation to Mars.

6. Provision of opportunities for in-orbit demonstration for use by industry and research institutions, both for agenda triggered innovation and 'blue-skies' originated developments.

7. Exploitation of missions and experimental data (including appropriate involvement in mission planning).

8. Support for quality assurance, standardisation, archiving, access to, and analysis of space derived data, for both research and commercial uses; support also for the development of tools for the efficient application of such data. The EU should lead the development and implementation of this agenda.

9. Development of critical technologies for non-dependence. The EU should lead the development and implementation of this agenda also.

10. Development of markets for space data and information services and aggregation of user needs. The EU should lead this.

Q3: Network Activities

What kind of support is needed for network activities? Parts of the space community seem to be well networked in others cases networks seem to be absent or rely on FP7 funding.

SAG Answer:

Space activities, being by nature multi-disciplinary, can benefit substantially through awareness of research and technology developments in many domains. Space science being, in some cases, already a multi-national activity can benefit from increased international networking and coordination. Furthermore, future global exploration activities are grounded on the premise of international cooperation due to the technical challenges and their significant cost.

Networking, and coordination, activities should be supported at various levels and with various objectives, as follows:

- Networks which support the collaboration of research organisations with industry in order to increase awareness of the results of low TRL research and to foster its take up in further development;

- Networks which support the spin in/out between space and the Key Enabling Technologies (KET) research;

- Networks which support the establishment of improved scientific cooperation, including international cooperation, in the performance of space science and the exploitation of data;

- Networks which enhance the links between educational institutions, such as universities, and industry with the aim to increase the suitability of the education for careers in the space industry and to establish longer term research partnerships;

- Networks which enable scientific and engineering understanding of ways to address the challenges of exploration;

- Application and agenda driven networks that focus on broadening and increasing the understanding of challenges, solutions and the research necessary to overcome the challenges, e.g. technology road maps;

- Networks that facilitate the access to space specific research infrastructures, such as solar simulation and radiation facilities.

The networks should range from those focusing on enhancing communication within a community of interest or for a particular technological challenge, through networks which fund the participation of scientists in space research career development activities, to networks which increase awareness of activities in other domains and fund cross-domain research.

Q4: Unsupported Technology Areas

Which technology areas are not well covered by ESA or national programmes and therefore would benefit most by EU funding?

SAG Answer:

ESA and national programmes address technology developments for all service domains, i.e. Earth Observation, Space Science, Robotic Exploration, Human Space Flight, Transportation, Telecommunications, Navigation and Security-SSA. The programmes cover all 25 Technology Domains, e.g. data systems, software, control systems, electric power, propulsion, RF, optics, etc. for the missions in the above service domains and under a generic domain for technology and products common to several domains and also for technology push.

The main issue is of the resources to meet the needs and Horizon 2020 should contribute to the overall effort. Some weaker areas for which Horizon 2020 could have a stronger or even leading role could be:

Basic technologies: mainly EEE components, materials and substances, difficult to implement under the ESA mission driven and geo-return constrained environment. Such technologies moreover are critical for strategic (technology) non-dependence (TnD) and drivers for innovation, performance and efficiency that underpin competitiveness. These are:

- EEE components, so far addressed by transitory measures in ESA and national programmes;
- Materials, an area where space is too much subject to the evolution of other sectors;
- New substances replacing those affected by environmental regulations, REACH.

The EC has been contributing to the effort in the context of a joint task force with the European Defence Agency (EDA) and ESA. Critical areas were jointly identified and the agreed list of concerns was an input to the programmes of the 3 organisations, i.e. also FP7. The problem in FP7 was the non-suitability of the mechanisms.

H2020 could be the lead European programme for TnD.

User segment technologies: These are fundamental to promote the use of space systems and to benefit from a large market. It is not sufficiently addressed in ESA and national programmes because of resource limitations.

Technologies for data exploitation: Data exploitation is not sufficiently covered by ESA or national programmes and therefore the SAG proposes a strong effort in Horizon 2020 for data exploitation. The data needs to be stored, calibrated, processed and exploited. This implies the use of technologies cloud, web2, google, data mining, virtualisation, emulation, etc. It is to be noted that with GMES, EU owned systems will be by far the largest source of data.

Technologies better developed by cooperation with other sectors: Horizon 2020 can benefit from the multi-theme character of the programme. This is particularly important for Key Enabling Technologies.

Other areas will depend on arrangements between ESA and the EU and within the EU. For example, satellite navigation technologies were so far developed under ESA programmes. If navigation becomes a programme funded from start to finish by the EU, we must be careful that such technologies are funded and not forgotten under Horizon 2020, under the mistaken assumption that they are being funded under other programmes.

Q5: Satellite Communications and Launchers

In Council discussions, amendments were proposed to prioritise two further areas, SatCom and Launchers, in which major ESA technology programmes exist (in particular SatCom with ARTES, and launchers with FLPP, 80 M€/year each). In these areas, what kind of activities could H2020 fund which do not overlap with the ESA programmes and will contribute in a major way to the four objectives defined?

SAG Answer:

SatCom and launchers are closely inter-related through the exploitation of Ariane. Altogether, they represent up to half of the activity of the European space manufacturing industry. At such level, it is a matter of survival to ensure their sustainability. Thus, it makes sense that the Council proposed to prioritise them. However, they are two different cases.

Let's consider first the case of satellite communications. Much has been said on the challenge posed to the European manufacturers by the absence of a global level playing field. The ESA ARTES programme has been very effective in positioning the European industry at such a prominent place, and in promoting a number of successful PPP projects. However, its budgetary envelope is faltering while the competition is getting fiercer with the emergence of newcomers and the strong return of the US providers motivated by the pressure on federal budgets. Therefore, Horizon 2020 can be a welcomed supplement, especially as it is designed to be a tool for support to competitiveness. The key issue is to make sure it will get the right inputs from industry to orientate its activities. This is precisely why we are recommending a Strategic Research Agenda.

In addition, Horizon 2020 shall develop services that promote the use of space services and the EU itself should be the anchor tenant for these services and promote the development of first units. An example would be secure telecommunications for EEAS.

The launchers issue is more delicate:

- First because it is difficult to divide the development of a new launcher between several players. The Europa launcher failure painfully taught us this reality. Therefore, if a new launcher is to be developed in Europe, this will happen under the coordination of ESA, and it is difficult to devise a scheme where Horizon 2020 would partly contribute to it. In this respect, most of the SAG members agree that it is not the right tool for this and that it should not interfere with ESA's leadership in this area.

- Second, it is true that space transportation is a sector where no breakthrough technology has ever drastically changed its fundamentals. Of course, progress has been made, but propulsion for instance, which is the key enabler, remains basically unchanged. In this respect, prospective research should be continued as major improvement are needed in the long run, in which Horizon 2020 could be active in hosting some fundamental activities preparing the long term future.

- Another way where EU support is needed is the provision for European launchers for EU needs, e.g. periodic procurement of a Vega for in-orbit demonstration, bulk advance orders for GNSS and GMES.

Q6: Space Data Exploitation

Which domains of the following would need differing approaches because of diverging community needs: ISS, astronomy, solar physics, planetary sciences, exploration, ISS, Earth observation?

SAG Answer:

We can divide the space community in Europe according to the three major ESA programmes:

1. Space science, an ESA 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. Therefore, Horizon 2020 should support scientific groups with the preparation of proposals and with data exploitation of space missions in general and particularly with the exploitation of the 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.
2. Robotic and human exploration, an ESA optional programme, funds the scientific utilisation of the International Space Station including the provision of research facilities, as well as the planning and development of robotic missions to the Moon and Mars, but not the exploitation of scientific data obtained. 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. Concerning robotic space exploration, Horizon 2020 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.

3. Earth sciences, an ESA optional programme that pursues a dual strategy involving scientific research driven Earth Explorer missions and service driven Earth Watch missions. Earth Observation data exploitation requires an approach which facilitates: a) production of long time series data sets, b) stringent quality assurance and cross referencing with data from other space and non-space providers and sources, c) assembly into a variety of different data sets for different purposes, and d) easy access by non-space users.

What is needed in each of those fields to enhance data exploitation by EU researchers? What is missing from the user/scientist perspective? Examples: Direct funding to scientists to use data for scientific publications, basic archive, processing tools, higher level archives, standardization.

SAG Answer:

The answers will be given for each of the three groups, mentioned above:

1. Space science: Presently there is no coherent approach to address the exploitation of scientific data obtained by space observatories during the observing time (proprietary period) that is awarded competitively, based on proposals submitted in response to an Announcement of Opportunity (AO) process. These data are 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. Horizon 2020 should support scientific groups with the preparation of proposals and with data exploitation of space missions (ESA; NASA and others) in general and particularly with exploitation of data obtained from space observatories during proprietary observation periods. In addition, Horizon 2020 should support long-term data preservation (storage, calibration, development of tools and algorithms, etc).
2. Robotic and human exploration: Horizon 2020 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. In the latter studies, a harmonisation of procedures, sample curation and data management should be aimed for. Likewise, Horizon 2020 should include support for Lunar and NEO exploration by supporting development of scientific payloads and exploitation of data obtained. Concerning human studies on the ISS, standardised protocols and procedures for studies on integrative human adaptation to the

conditions of space during exploration missions and the development of efficient countermeasures need to be developed. Further, a database of results from ground and space-based integrative human research based on standardised protocols and procedures including the exertion of countermeasures need to be established. A data management and distribution system should be established in coordination with major European stakeholders (especially ESA and EC) to make these data accessible to the scientific community. Finally, mathematical, physical and biological modelling should be developed to understand and anticipate various risks to astronauts associated with exploration missions and for applying means to reduce them to an acceptable level.

3. Earth sciences: Support is especially required for labour and computing resources, tools, techniques, algorithms and standardisation to permit the objective in the bullet above to be realised.

How and by whom should data exploitation be coordinated and / or organised?

SAG Answer:

A stronger cooperation and cross-information is required between the different projects on related topics, such as through the use of pre-defined data models and a single window to access data collected in several projects. To do that a pan-European entity could take the responsibility. This entity could be created ex-novo or delegated to a pre-existent one after an open tender for a limited number of years (period to be extended if necessary or useful after evaluation).

How should the activities be linked with existing ESA or national data archives?

SAG Answer:

Already existing data storage systems, data bases and data distribution systems, especially set up by ESA or in earlier EC projects (e.g. ESA's ERASMUS Experiment Archive - a comprehensive database of experiment records based on ESA-funded or co-funded experiments that have been performed on various space platforms in Low Earth orbit and microgravity ground-based facilities; FP7 project HAMLET a Human model MATROSHKA for radiation exposure determination of astronauts; FP7 project ULISSE, USOCs knowledge integration and dissemination for space science experimentation) should be used to a maximum way possible.

As a general comment, 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 – at least 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 is largely outside the remit of ESA and beyond the ability of individual nations to support adequately. Therefore, the Space Advisory Group (SAG) of the European Commission recommends that a comprehensive approach to data exploitation (both scientific and commercial) be implemented in Horizon 2020.

Q7: Entrepreneurial Activities

How could H2020 support entrepreneurial space activities?

SAG Answer:

Help and funding for researchers with commercialisation of concepts and their translation into the non-space world would be valuable to supplement what ESA already does. Also, support for entrepreneurs wishing to explore and investigate radical new approaches to space activities should be made available. Horizon 2020 should stimulate the creation of spin-offs.

… and one final comment

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 and engineers 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