HORIZON2020 Space Advisory Group

ADVICE ON POTENTIAL PRIORITIES FOR RESEARCH AND INNOVATION IN THE WORK PROGRAMME 2018-2020

1 Preface

This document presents the views of the Space Advisory Group (SAG), which provided guidance and advice on the strategic priorities for the European space sector in the spring 2016, in view of the preparation of the H2020 work programme 2018-2020. The detailed work of the SAG was divided into four themes, *Science, Technology, Mainstreaming space,* and *New Space*. The themes *Space Science* and *Space Technology* are self-explanatory and will be introduced below together. By *Mainstreaming Space* we mean the various new opportunities being introduced and offered by the existing and coming space infrastructure (e.g., Copernicus and Galileo), and the new innovative services and applications that the space sector provides through these infrastructures, such as management of natural resources, digitalization, robotics, ICT, health, and many others. By *New Space*, we mean the currently on-going paradigm shift, where new private companies are being established at an accelerated pace. Their activities are mainly driven by commercial interests. Space technological development for them does not necessarily follow the slow and highly bureaucratic procedures for technology development to which many international organisations have been used to. *New Space* companies mainly use commercial off-the-shelf components and target to shorter lifetimes, giving them a competitive advantage both in building costs and speed of development. Using smaller and more dedicated spacecraft, they are aiming for commercial revenues in innovative topics, such as the Internet of Things (IoT) and the digital economy. *Mainstreaming Space* and *New Space* are introduced below together, as both are targeted towards services, and the commercial use of space, while requiring innovative business models.

Within the selected themes, we determined three guiding principles that offer the strongest strategic advance for Europe. These principles are 1) Competitiveness, innovation and strategic independence, 2) Evolution and future of space activities, and 3) Continuity and harmonisation of space activities. We present the guiding principles below, before considering the five given questions within the themes *Space Science & Space Technology,* and *Mainstreaming Space & New Space*.

1.1 Competitiveness, innovation and strategic independence of European space activities

Because of the strategic nature of space and Europe's technology-based economy, Europe needs to continue and reinforce its present focus on maintaining competitiveness in all aspects of the space business. The European Union has in the last few years become a major space power. That position is due to several parallel advances. The Union programmes like Galileo and Copernicus entering operational phases provide a prime example. European companies have demonstrated innovative industrial approaches, making them major worldwide providers of spacecraft, launch vehicles and components. Through the European Commission's partnering with organisations and agencies like ESA and EUMETSAT, Europe has a pioneering role in both scientific discoveries and in transforming science and R&D into operational service-providing systems. Europe's international position at the leading edge of discovery is shown by the high visibility of the results obtained. For example, the historical soft landing of the probe Philae on a comet, and the Planck map of the relic radiation from the Big Bang were major news articles all over the world. Both missions are also premier examples of technical achievements in space, in particular with

Rosetta's flight dynamics as the first spacecraft to orbit around a comet. The leading position of the Ariane launch vehicles on the commercial worldwide market and the success of the small European launcher Vega highlight the European competitiveness in accessing space. Regular flights of European astronauts to the International Space Station (ISS) are also an example of a present competitiveness.

1.2 Evolution and future of space activities

Within the modern developed world, space has become a sustaining and enabling infrastructure. Space is already an integral and no longer an erasable part of our daily lives, through telecommunication, satellite navigation, weather prediction, and earth observation. This will expand in the future, as space will permeate through society with innovations in surface transport, aviation, ICT, medicine, environment monitoring, social networking, IoT, robotics, just to name a few. At the same time, space science and new discoveries are continuing to be an important inspiration for new technologies used on ground, as well as for stimulating the young to scientific and technological occupations, thus further increasing Europe's competitiveness in research and applications. Our push to understand space, the Universe, extraterrestrial objects in space, the limits of life, and the kinds of life forms that could exist in the Universe has established a huge spin-off in a number of industries, including biotechnology, health, robotics, ICT and material science.

The most prominent evolution of space activities is present in the *New Space* paradigm. Innovative, generally private enterprise-driven routes to space are being pursued. These are often seeded by private investment and sometimes underpinned by public investment. The potential of new technology needs to be understood and, wherever possible, the efficiencies of any new system must be integrated as appropriate into any public infrastructure. Hence it is essential to maintain bottom-up knowledge of evolving new technologies and products, such as sensor and system miniaturisation, constellations of spacecraft, and new launch systems compliant with a strong market-driven business development approach. These provide new competitive opportunities for scientific activities, as well as innovative products, processes, systems, and services from the acquired data in future.

Means need be found to ensure that techniques derived from space are efficiently communicated between disciplines and also used outside the space arena. For example, space has massive importance for global and regional environmental applications but these must not be seen in isolation. Indeed, similarly expansive and inclusive philosophies are needed for communications and navigation systems. It is necessary to ensure a seamless interface between local terrestrially sourced and space-derived information. The yield from data sets in disciplines that might have no obvious connection with space can be significantly enhanced with space-derived data. For example, epidemiological health data can be enhanced by the use of the regional environmental data on pollution, climate or environment in general that space can provide. In the area of health, the unique low gravity environment provided by the ISS is certain to make a special contribution to medical research. Monitoring of our planet, oceans, atmosphere, climate, water resources, etc. has become a necessity for the survival of our planet. The only means for global monitoring is space-based, while also ground-based monitoring and modelling efforts remain essential.

At the same time, it is important to consider the rapid evolution of technology in non-space industries as potential enabling factors or elements for current and future space missions. This is particularly true for the *New Space* paradigm, where private companies are applying non-space technology in new and innovative way to reduce lead-time and mission costs while improving their business performance to satisfy market demands and still being compliant with the space environment requirements.

1.3 Continuity and harmonisation of space activities

Once it is recognised that space is going to be increasingly a part of European mainstream infrastructure, continuity and harmonisation are essential. Space infrastructure, spacecraft and launch systems are inherently large expenditure items, where investment is long term and development takes a long time. *New Space* may lead to changes but in many aspects the present situation will continue to exist. It is therefore important that European-level attention is paid to maintaining non-dependence, continuity and balance in all aspects of space activities.

In Europe, space support remains a competence shared between EU, ESA, EUMETSAT, and at a national level. Resourcing at the national level may be focussed on specific aspects, leaving gaps in the large-scale picture. Harmonisation needs to be achieved for instance by identifying at the European level the multiple options for space to be used in smarter government and governance. There are efficiencies to be gained by seeking the maximum systematic use of space systems for regulatory provision, for example. The Union's position as an overarching organisation is crucial in utilising the best competence base in strategic themes.

2 Strategic priorities for space

Here we consider the given five questions within themes *Space Science, Space Technology, Mainstreaming Space,* and *New Space*. We have reformulated the questions to highlight our guiding principles.

2.1 What are the challenges that prevent us from being competitive, innovative and strategically independent?

Space Science & Space Technology

One of the most difficult problems in Europe today is that different organisations and nations have different goals for science and technology. For example, not all competent nations invest in optional ESA programmes due to declining public funding, in which case the competence of those nations is not used in developing European capabilities. This may lead to oversubscription in the Union calls, where a larger number of member states participate. Therefore, there is an inherent inefficiency in using the scattered resources, and also inadequacy to utilise the expertise and knowledge available. Long-term continuity from one programme to another and harmonisation between European goals is critical in European competitiveness and leadership. The European Union is in the best position to set mutual strategic goals fostering the best competence and assets. In this respect, it is useful to consider dedicated research, innovation and development infrastructures to better exploit best expertise and coordinate space science and technology goals in close collaboration with industry. Such structures could be, for instance a European Space Institute, a European Space Weather Institute, or, given the imminence of missions to bring extraterrestrial samples back to Earth, a European Sample Curation Facility.

To protect the present competitiveness and strategic non-dependence, it is critical to efficiently utilise and exploit the existing space infrastructure scientifically, technologically, and in terms of downstream services. This requires both safety of operations and efficient exploitation of present data. In safety of operations, there are two key aspects: 1) space debris mitigation technologies and regulation, and 2) understanding of space environmental conditions. Europe can be the forerunner in space debris mitigation technologies and global regulation, thus opening new markets also outside of Europe. In terms of space environmental conditions, investigations into changing physical conditions in space (modelling and observations) and accurate space weather predictions are critical to maintain European competitiveness and strategic non-dependence. Efficient data exploitation should take into account present European and international missions, as well as, increasingly, the *New Space* activities, where harmonisation and homogenisation of long time series data is a challenge.

In guaranteeing the future competitive and non-dependent space infrastructure, the following aspects are critical: 1) Better and cheaper access to space, 2) better opportunities for demonstration including in-orbit demonstration and validation (IOD/IOV), 3) support for strategic mission concept studies to improve accessibility and exploitation of space data, and 4) development of qualified technologies and devoted products for non-dependence, including key enabling technologies. As computer-aided design is often more cost-effective than actual space infrastructure, it is critical to utilise and invest in present European modelling assets (e.g., Earth-analogue simulations, space environment simulations). In the same way, support of ground-based studies is an essential, cost-effective method of improving future technological and scientific return of investment in the more expensive space infrastructure.

To support European key policies and international collaboration, development and qualification of clean and green space technologies is essential. To make the European assets more attractive in the global markets, reducing the cost of space technology (e.g. propulsion) is critical. At the same time, Europe should create an environment supportive of the development and fast implementation of new and disruptive bottom up technologies, which for example can be key in future exploitation of space (mining, settlement etc). The effects of changing political and environmental conditions between space faring countries and the level at which the nation takes part in space activities should also be taken into account.

Mainstreaming Space & New Space

A central challenge in *Mainstreaming Space* is to maximise the integration of space information to demand in different sectors, and thereby strengthen European competitiveness. Moreover, this needs to be done to maximise the potential for entrepreneurial use, for SME seeding, while recognising that one important and vital market is in the public sector and institutional use. Finding direct links to public regulatory responsibilities is critical, as well as encouraging use of data and tools for economic and strategic decision-making. The sheer complexity of potential downstream use of space data has hampered the creation of a straightforward market-driven response. As Copernicus and Galileo start delivery, the resource created must be exploited and exploitable. Often this will need innovative approaches to linking public and private finance. Further, it is crucial to make sure that the data utilised in regulatory actions is certifiable and standardised, requiring improved seamless techniques in data fusion, calibration and validation.

A primary challenge raised by the emerging *New Space* economic activity is to understand and decide when the 'traditional' space approaches are superseded, and *New Space* infrastructures resilient enough to be mainstreamed, i.e., used for public infrastructure. Because of the size and cost of traditional payloads, emphasis has been placed on reliability and high-quality of manufacture, which has led to high cost and long design life. It is not always easy to determine whether and when the use of smaller and cheaper space hardware designed with shorter operating life and with less reliability brings an efficiency gain (e.g. by fast replacement) sufficient to offset the advantages of the tried and trusted approach. The ultimate goal is to achieve agility in design and technology evolution comparable to what we are familiar with in software/IT development. For this to happen, cheap mechanisms for small satellite launches need to become available and the environmental impact (debris control, i.e. platforms end-of-mission reliability) needs to be controlled.

2.2 What is the impact within 5-7 years that will make us competitive, innovative and independent?

Space Science & Space Technology

There are a number of upcoming missions and related ground-based observations within the next five to seven years that will increase the European visibility as a competitive, non-dependent space power (ESO, Bepi Colombo, ExoMars, Juice, Electra, Euclid, Neosat, Earthcare, JWST, Solar Orbiter, Cheops, and a number of *New Space* constellations). It is essential that these missions are fully exploited scientifically and technologically, as well as in light of downstream services. It is critical to maintain a steady flow of competitive missions and strategically investigate European assets to support future mission selection. In this respect, some of the most effective demonstrations of European capabilities in Solar System science are Rosetta (the first orbiting and soft landing on a comet in history), and Cluster (the first multipoint constellation magnetospheric spacecraft, revolutionising understanding of space physics), while in studying the far away universe, e.g. Planck and Herschel have brought astounding information on the origins of stars and planets, of galaxies and of the universe itself. It is important that Europe continues to pursue "first ever" missions rather than following others in scientific specifications.

While exploiting the upcoming missions scientifically, it is also vital to investigate and support industrial spin-offs (e.g., in the field of astrobiology, biotechnological advances due to research into extremophiles), and spin-ins (e.g., use of off-the-shelf-components, ICT, robotics) to ensure both return of investment and future technological competitiveness. Innovations in relevant technical fields (e.g., modular system architecture, miniaturisation, new materials, new production processes, robotics and automation, propulsion and de- and re-orbiting systems, system life-time and energy supply, space medicine including telemedicine) should be seamlessly infused in mission concept studies. When new technological breakthroughs have been demonstrated, it is vital to standardise the innovations in international collaboration.

Mainstreaming Space & New Space

Mainstreaming Space by properly distributing and managing large-scale data-intensive information from space will build a more efficient society, better able to communicate, and to manage and monitor the health of our planet. New markets that can be addressed by applications that use satellite data and technologies combined with ground infrastructure and modelling efforts include maritime, air and land transport applications, disaster management, environmental monitoring, urban development, media, telecoms, secure satellite communication, and space weather. New needs and requests from our rapidly changing society may lead to new applications that could be easily developed using the existing or *New Space* infrastructure. Innovation means also a new way to test reliable solutions and new business models to guarantee the transfer to market in a short term. In orbit demonstration and validation (IOD/IOV) is crucial to ensure technological capability, market response and fast go-to-market approach. Space will become a major sustaining feature of the "Internet of Things" and an integral part of the solution for the exploitation of "*Big Data*" supporting societal challenges in areas such as health and climate.

Disruptive innovations, innovative products and services derived from space in combination with parallel development in IT and, particularly, *Big Data* should be used to accelerate processes for market uptake and demand-driven solutions and improve exploitation of R&D results for the creation of new high-margin markets.

2.3 Which gaps and potential game changers are there, which make us non-competitive, non-innovative, and dependent?

Space Science & Space Technology

One of the most critical aspects in *Space Science* and *Space Technology* is to gain the acceptance and interest of the European taxpayers and private/commercial user sectors. Therefore it is imperative to engage with citizens proactively at all levels, seeking to build not just understanding of and support for European space activities, but creating pride in European achievements in space. The public should be involved from the conception of a mission to final data exploitation and future. In light of the latest developments, it is also vital that the private sector and, in particular the private investment, is more involved in space science and space technology. While the task of many new commercial companies is to provide opportunities for space exploitation, it is the mandate of space scientists and engineers to make sure the new investments use the most up-to-date knowledge. Moreover, ground-based facilities and infrastructure should be strategically coordinated to support space-based activities, e.g. through a coordinating research infrastructure. Furthermore, both space infrastructure and supporting infrastructure should efficiently and sustainably utilise resources, and the utilisation of space nuclear power should be allowed. The existing gap in European and international private funding opportunities may be reduced with the involvement of public infrastructures' smart exploitation (as it is, for example, with free use of Copernicus data).

Mainstreaming Space & New Space

There is a central role for the public sector, nationally, intergovernmentally, and through the Union. *Mainstreaming Space* to enable this central role for the public sector requires data that are easily accessible and interpretable by users. The data path from observation to the desk of the decision-maker should be transparent, indicating that the techniques in data homogenisation, calibration, validation and visualisation are based on quality science. Moreover, attention must be paid to how to move research undertaken in Earth science space programmes (such as ESA's EOEP) smoothly into application use, even possibly creating opportunities for an early link with the potential commercial customers.

Potentially game changing is to find mechanisms and protocols that would make large scale space data the preferred and realistic answer. This could require mandating use in a policy context, for example as a basis for meeting regulatory requirements. Game changing could also come from *New Space* developments, which are almost by definition commercially driven. Institutional users need to increase awareness and readiness to exploit both European mission data as well as *New Space* missions. One critical aspect is to make sure that clear requirements are set for publicly funded missions in order to stimulate competitiveness among space and *New Space* industries. These include clear definition of minimum reliability for a satellite platform or precise requirement for de/re-orbiting systems independent of the main satellite platform, resulting in a higher technical and service quality, and eventually showing as market competitive advantages.

2.4 How will the competitiveness, innovativeness, and independence improve, if we include horizontal issues?

Competitiveness, innovativeness, and strategic non-dependence of European space scientific, technological, and systems activities are strongly dependent on public interest and acceptance. Therefore fostering outreach in all senses of the term – from stakeholders including the public, social scientists and decision-makers – is key in the future success of the European space power.

Our competitiveness depends on making sure that all views (e.g., gender, minorities, age groups) are present in all levels of space activities, from conceptualising missions to making decisions and carrying out space activities. Europe needs to render space more gender neutral. Mixed teams usually provide broader perspective, thus improving return and, as space moves into the mainstream of society, both gender association and aversion needs to be tackled. It is vital to guarantee that gender is also taken into account in areas, such as solving environmental issues, public health background information, and frontier research in medical science. Taking the gender into account can lead to a competitive advantage in space industry research. Specific actions to facilitate the involvement of females in the space sector (for example, through the facilitation of organizations like Women in Aerospace, or specific executive programmes) should be taken.

Europe should address and reasonably implement ethical and regulatory aspects, e.g., in technological standardisation, and making sure that key enabling components are always available for European actors. Europe should take the global lead in regulating space debris for sustainable and environmentally friendly use of space, opening markets to debris studies and technologies.

Synergies between space and non-space sectors, including H2020 societal challenges, should be fully exploited and applied. Space is a major horizontal contributor to progress in delivering large-scale information for climate and sustainable development. There is no possibility to better manage the planet than with the global and regional data that only space can provide as a primary source or as a background. Further, exploration of our Solar System and the Universe help stimulate the interest of young people, help them chose careers in science and technology, and thus improve the competitiveness and internationally high standing of Europe.

2.5 Specific questions related to the field concerned

Last but not least, space activities are deeply inspiring, and while major international powers can disagree on many issues, on our planet Earth we belong to the same family. Therefore the unifying/pacifying aspect of space is essential, and investments into deep-space human and robotic exploration are worthwhile not only for scientific purposes, but also from this perspective. Eventually we only have this one planet. We are currently exposed to a number of uncontrollable variables that may severely impact humans on Earth. Investing on human and robotic space exploration and colonization-related activities may reduce the risk for our civilization on Earth and create a solid base for the human evolution in space.

New Space raises issues of principle about past practice. If *Mainstreaming Space* leads into a mainstream infrastructure, how much can the efficiencies offered by *New Space* allow for reductions in reliability, verification and testing? How can more flexibility and innovation be brought more speedily to the delivery of mainstream services?