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European space research in support of international partnership

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ABSTRACT

The envisaged future space research programmes, whether in the field of space exploration or Earth observation are becoming more and more technically complicated and so costly that a single nation can hardly afford to realize them. Major non-European space-faring nations, China and India will progressively play an important role besides US, Russia and Japan. The Space Advisory Group of the European Commission recommended that the European Commission supports within Horizon 2020 a comprehensive Robotic Mars-Exploration Programme under European leadership that should become an essential element of a coordinated international space research programme. 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. Strategies need to be developed to mitigate the gradual increasing risks incurred by climate change. In order to lower their entry barrier to engage in space emerging and developing space nations need to be included in cooperative space programmes. We present the recommendations of the Space Advisory Group of the European Commission concerning Europe's participation to global space endeavours.

1. Introduction

The European Union's future funding programme for research and innovation, Horizon 2020, will run from 2014 to 2020 with a proposed €80 billion budget [1]. It includes among other topics the theme "Space" within the Directorate Enterprise and Industry of the European Commission. An average annual budget of 240 M€ is foreseen in the European Commission proposal for the space theme to cover the next 6 years period. A separate Space theme was first included in the preceding Seventh Framework Programme (FP7) with two main topics dedicated to "Global Monitoring for the Environment and Security" (GMES, recently renamed to Copernicus) [2] and "Strengthening Space Foundations". This has marked the start of support for space research by the European Commission.

In the search for strategic advice regarding the Space theme the European Commission established the Space Advisory Group (SAG) since the start of FP7. The SAG is composed of individual members from science and industry with expertise from the different areas of space. One example of a previous SAG advice to the European Commission is the recommendation to develop a European vision for space exploration, which was prepared in view of the emerging international interest in this research field [3].

With regard to the future Horizon 2020 programme, the SAG produced detailed advice on the substance and context of the dedicated Space theme to meet its overall objectives:

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.

In this context, the Space theme within Horizon 2020 should be balanced with two main pillars, namely "Space for exploring the Solar System and the Universe" and "Space for Grand Challenges on Earth", with 40–50% of the annual budget dedicated to the first pillar, and 35–45% to the second one. These main topics should be complemented with the ancillary elements "Enabling technologies" and "Crosscutting activities" [4].

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In this paper SAG's views concerning objective four "Enabling European research in support of international space partnerships" are discussed. Essentially benefitting from the cooperation and interaction of space and Earth based activities, multidisciplinary and multinational efforts in space have shown to be eminent. In order to achieve the highest possible results in this domain Europe needs a coherent and forward looking inspirational space strategy encouraging and facilitating the integration of new actors and programmes including Horizon 2020 in the international space landscape.

2. Scope for an intensified cooperation in space

Europe has developed over the last decades a well-established recognition as a soft power rather than a hard or military power. Its own development as well as the cooperation with other countries in a multitude of areas has repeatedly demonstrated the importance of international cooperation rather than confrontation to achieve its goals. Space exploration and space research are definitely of global nature, demanding the establishment of worldwide cooperation [3,5,6] and are therefore perfect fields of interest, where Europe can show and further its capabilities as a space power in the world.

Significant statements supporting international cooperation in space and Earth science and space exploration have been expressed during the 50th anniversary commemorations of the International Academy of Astronautics [7–10]. European main stakeholders for space activities (e.g. European Union, ESA, national space organizations and industry) – are becoming increasingly aware of the need to pursue a credible, joint strategy that must result in a coordination mechanism on international relations. It naturally stems that this strategy must also aim at strengthening the existing European leadership in the respective fields. In the context of the fourth objective, "enabling European research in support of international space partnerships", major initiatives are increasingly becoming global endeavours as the cost involved goes much beyond the resources available to any single space-faring nation. Prominent examples are robotic and human exploration of the solar system, as well as facing the challenges of climate change, as given below in further detail.

2.1. Exploration of the Earth–Moon–Mars space

Advancing robotic and human space exploration endeavours require challenging multifaceted missions and often multinational cooperation. All major space-faring nations are currently engaging in space missions that target the Moon, Mars and/or Near-Earth objects (NEOs), the environment "where humans can go".

The Moon represents a window through which we are able to explore the origin of our solar system as well as the dynamic of the Earth–Moon system. The Moon has been visited recently by orbiters from the US, Europe, Japan, India and China that obtained data with unprecedented resolution leading to important new discoveries, e.g. the presence of water on the Moon [5]. The search for extinct or extant life on Mars or organic material is one of the main goals of future surface missions developed during this decade, paving the way for returned samples and human exploration. NASA's successful multi-decadal Mars Programme of orbiters and rovers and Europe's MarsExpress spacecraft have given Mars a new face. With NASA's strategy to "follow the water" as well as detailed mapping of the surface mineralogy, excellent data on the evolutionary history and habitability of Mars have been revealed [11]. The current NASA rover "Curiosity" operating on the surface is sending back spectacular pictures. Near-Earth asteroids closely passing the Earth represent a potential threat to humankind and life on Earth, as recently witnessed by the Chelyabinsk meteor. However, apart from that, 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. The Japanese asteroid sample return mission Hayabusa has achieved an absolute first by bringing back a sample from the asteroid Itokawa in 2010 [12].

Despite the reduction in funding for space research the coming decade still promises to deliver interesting science data from missions that are currently in operation or development [6]. New Moon exploration orbiters and landers that will launch in this decade are developed by China (Chang'E programme), Japan (SELENE programme) and Russia/India (Luna Resource programme). NASA's "Mars Atmosphere and Volatile EvolutioN" (MAVEN) spacecraft scheduled for launch in late 2013 will investigate the Mars exosphere, and NASA's mission "Interior Exploration using Seismic Investigations, Geodesy and Heat Transport" (InSight) with a scheduled launch in 2016, will probe the early geological evolution of Mars.

A long-term ESA–Roscosmos cooperation plan for the exploration of Mars, ExoMars with two missions in 2016 and 2018, has been recently developed; these missions will investigate the atmosphere and the surface of Mars for signs of habitability and life and prepare for the Mars Sample Return mission. A second Japanese NEO sample return mission Hayabusa-2 is planned for launch in 2014. NASA's New Frontiers programme will launch the "Origins Spectral Interpretation Resource Identification Security Regolith Explorer" spacecraft (OSIRIS-Rex) mission to an asteroid in 2016.

Many of the past, current and future missions are/will be conducted in international cooperation through the provision of instruments, bilateral agreements and international science data exploitation. However, none of them are truly multi-national. And none of the space exploration missions described above is truly led by Europe. For the joint European/Russian ExoMars programme the essential elements such as launcher and Entry Descent and Landing (EDL) technology is provided by Russia. Europe's involvement in Mars sample return architectures on international level has not yet materialized.

As emphasized by the SAG in 2010 an essential element of a coordinated international space research programme should be the exploration of Mars [13]. A comprehensive Robotic Mars-Exploration Programme, performed in cooperation with major non-European space-faring nations should include robotic surface missions related to the habitability of Mars, ground-based analogue studies [14], as well as return missions with Martian samples. The SAG 2012 recommendations [4] propose that Europe should also engage in international research programmes in the area of impact hazard and mitigation of NEOs. Furthermore the development of exploration and technological concepts for NEO probes and sample return missions and technology enabling participation in international efforts of Moon exploration were recommended.

The SAG 2012 recommendations state specifically that Europe must define its role within those global space programmes and prepare to contribute its key competences and systems. Among them are the Columbus Module and the Automated Transfer Vehicle (ATV). Europe has gained key competences for developing habitats and research laboratories in space. Autonomous planetary missions such as MarsExpress, VenusExpress and Rosetta have demonstrated Europe's excellence. In order to remain a strong partner in future international space 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 the curation of returned samples 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), experiments on the International Space Station (ISS) and instrument development will empower Europe to shape and contribute to a worldwide space exploration programme.

The ISS is exemplary of a successful international undertaking, where its elements are provided and operated in an international partnership of space agencies. The principals are the space agencies of the United States, Russia, Europe, Japan, and Canada. With 8% utilization rights ESA is one of the small partners of the ISS. ESA has provided essential elements to the ISS, such as the ATV with the most advanced approach and docking capabilities, and the Columbus laboratory module.

Starting with Spacelab 1, and continuing with the ISS, European scientists – in cooperation with international partners – have gained a wealth of information on the responses and adaptations of the human body to extraterrestrial conditions, i.e., lack of gravity, altered circadian rhythms, and increased exposure to cosmic radiation. This knowledge is of utmost importance and the first step towards safeguarding human health, efficiency and well-being on exploratory missions [15–17]. Likewise, the ISS has served as a large research facility for astrobiology research, i.e., for studies on the responses of organics and microorganisms to the conditions of outer space and simulated planetary conditions [18]. The results have provided basic information in our quest for the conditions of life beyond Earth.

For the upcoming years, 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 physiology and astrobiology space programme in Low Earth Orbit do not exist in the Western world. In this context, among others, the approved programme of China is worth considering: with Tian Gong 1, launched in 2011, a space laboratory has been put on orbit, which will be followed by two further more advanced space laboratories. This opportunity opens for Europe new perspectives of global cooperation with other countries in order to be able to carry out our ambitious human-flight and long-term astrobiology research programmes in Low Earth Orbit.

2.2. *The case of climate change*

There is a vast wealth of evidence proving that the global climatic changes are predominantly caused by anthropogenic rising in concentrations of greenhouse gases: for its dire consequences a societal challenge in itself, it sums up to the natural variability in the Earth climate system, the dissimilarities in solar irradiance and the volcanic activity; recent assessments of these natural phenomena relative influences allowed conclusions on the observed warming, particularly in those more recently observed [19].

In addition to current projects and initiatives on space situational awareness and space weather, Copernicus was set up in order to provide information services giving access to accurate data and information in the field of environment and security, tailored to the needs of its users, thus better fostering the exploitation of the European industrial potential, of policies of innovation, research and technological development in the field of Earth observation: it became a key tool inter alia in the support of biodiversity, ecosystems management and climate change mitigation and adaptation [20]. Standing on the Copernicus basic services a plethora of other value-added services bespoke to specific and commercial needs is being developed, stimulating the downstream sector all over the world.

Yet climate change has been seen as a risk multiplier interacting significantly with societal challenges such as poverty, disease and food and water scarcity. In specific regions of the world these are potentiated by 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 are affecting the international stability and security: the inherent uncertainty of these increasing frequencies of extreme weather events adversely affects human health, disrupting the flow and prompt availability of national resources and commodities and increasing significantly the risks associated to these changes: consequences of climate changes elsewhere will have important implications in Europe and those countries sharing the same social and ethical values.

For all these reasons, it is certainly important to foster research and innovation aiming at finding ways of forecasting unfavourable meteorological phenomena. If forecasts of that sort are prepared sufficiently in advance, pre-emptive humanitarian action can be carried out. This will be another opportunity for Europe to lead in the overall task of tackling adequately the global climate change effects whilst providing instruments and expertise in science, development of infrastructure and industrial leadership and strength.

3. Involvement of emerging and developing space nations

In the coming decade the well-established space-faring nations the United States, Russia and Japan, together with Europe, will be joined by China and India. Therefore it will clearly be in the benefit of Europe to design a common space policy and partnerships in diverse space research programmes with those nations and prepare well in advance to contribute with its key competences.

As has been already mentioned in chapter 2, Europe has a globally respected reputation as a soft power. The global challenges of the 21st century will force Europe to further enhance this role if its voice is being heard on these issues in the coming decades. Europe has a decade-long tradition of cooperating with emerging and developing nations, fostering the capacity building in areas like industry, agriculture and health with the goal that such countries master the critical steps towards self-sufficiency. Space should be no exception, since increasing basic space technology know-how will ensure that potential new actors will eventually be able to participate directly from the benefits of space activities, as well as enabling them to join the responsibilities, which come with being a space faring nation. Cooperative space programmes with emerging and developing space nations will not only lower their entry barrier to engage in space activities but as well enable them to participate in upfront science.

Amongst the main domains for such cooperative efforts the following areas seem to be the most promising: (1) Space education should be fostered by engaging, training and providing industrial experience to joint groups of students from space faring and space developing/emerging countries. Thus space education should be regarded as an important catalyst for future collaboration efforts in joint space instruments or even joint research projects in larger space missions. (2) Developing their own Earth Observation/Remote Sensing capabilities and applications will enable emerging space countries to monitor their own territory with the goal to assess the consequences of natural disasters (volcanic eruptions, earthquakes, large scale forest fires, floods or even tsunamis, etc.) and mitigate the associated damages and losses. This is in particular true for countries, which are especially prone to be affected by the increasing risks incurred by climate change. The associated and probably not completely avoidable dire consequences may even result in political instabilities, which in the end might threaten not only the security of Europe, but also the international stability at large. (3) Emerging space countries should be included early on in the ever increasing problem of space debris and the importance of space situational awareness. Today's fragmented approach can only be overcome by integrating currently existing institutional, national and inter-regional situational awareness assets, while at the same time imbed future actors in the related activities. Related to this is (4) the mitigation of the potential threat through NEOs. Developing mitigation options requires an international and interdisciplinary approach including the participation of emerging space countries. Finally, emerging space countries should be invited (5) to participate in the development of space exploration concepts to mature the necessary technical foundation and mission role definition, which may lead to active participation in space exploratory scenarios.

4. Conclusion

With Horizon 2020 (2014–2020) the European Commission will substantially augment its support to the Space theme. This will include, among other objectives, to foster Europe's involvement in international space partnerships. As recommended by the SAG of the EC, prominent candidates of Europe's involvement in international cooperation in the field of robotic and human exploration are as follows:

- 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.
- Europe should participate to international research programmes in the area of Moon and NEO exploration and develop exploration and technological concepts for sample return missions.
- The European Commission should support 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 and extension of human, life sciences, material sciences and astrobiology research in Low Earth Orbit beyond 2020.

The existing infrastructures of international cooperation in the field of Earth observation should be expanded and manifested, as well as supported by research activities for climate change. On the particular risks of climate change affecting the people in developing countries, the SAG recommended that:

- Strategies need to be 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 advanced comprehension of how such effects may threaten, through particular pressures, the security of Europe and, at large, the international stability.
- 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.

Finally, the SAG recommended 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.

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