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ANNEX 1

COMMISSION STAFF WORKING DOCUMENT

IMPACT ASSESSMENT

Accompanying document to the

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

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ANNEX 1

1. LIST OF STAKEHOLDERS CONSULTATIONS

1. Bilateral meetings held in 2009 by DG ENTR with MS actively involved in the space sector: Germany, France, UK, Spain, Italy; industry association.

2. Interviews of relevant stakeholders, conducted by Ecorys in the context of the "Study on the EU Space Programme 2014-2020" (December 2009-January 2010)

3. Eurobarometer survey on the space activities of the European Union conducted by Gallup in July 2009

4. EU-ESA workshops in spring 2010

   Workshop on Science and education within Space exploration, 29-30 March 2010, International Space University, Strasbourg, France

   Workshops on Space exploration and innovation, industrial competitiveness and technological advance, 29-30 April 2010, Harwell, United Kingdom

   Workshop on Space exploration scenarios, 20-21 May, Cira, Capua, Italy

5. Events under Spanish Presidency

   Workshop on Space and Security, 10-11 March 2010, Madrid, Spain;

   Conference on governance of European Space programmes, 3-4 May 2010 Segovia, Spain.

6. Contributions and speeches of the conference "Space policy: a powerful ambition for the EU", Brussels, 15-16 October 2009

7. Contribution and conclusions to the conference "1st EU-ESA International conference on Human Space exploration", Prague, 23 October 2009 (add conclusions)

8. Space Advisory Group contribution on an EU vision for space exploration.

9. ESA contribution to the definition of future EU space activities.

2. EC-ESA Workshop: Science and Education withn Space Exploration, Strasbourg, 29-30 March, 2010

2.1. General Recommendations

Europe being ready and willing to show strong ambitions in space exploration, it must now prepare a coherent long-term programme consisting of a mix of robotic and human-related activities and strive for optimal coordination between all relevant players, in particular the European Union, the European Space Agency, their Member States and international partners. To this end, a greater synergy between scientific, technological and industrial activities is needed, as well as more efficient coordination of national, ESA and other initiatives. The EU is in an ideal situation to take up such a coordination effort in close collaboration with ESA and Member States. Whether it is science enabling exploration, or science enabled by exploration both aspects need to be adequately supported and accompanied by a significant education and outreach programme.

2.2. Main findings and recommendations (from the questions in the background document)

Overall, how can space exploration best contribute to the EU and Member State research and education policies and in particular to make the European trans-disciplinary research more competitive?

An ambitious and resilient long-term European space exploration programme is needed, with clear and visible milestones. It should in particular support **trans-disciplinary** initiatives, including the linkage of science with technology to support European research priorities and overall competitiveness. A coordinated EU-ESA exploration programme is also needed to make space exploration an integral part of **schools** curricula that will motivate the young generation to study and engage in S&T careers and therefore contribute to the development of the knowledge society.

How can space exploration engage the interest of the citizens, stimulate scientific careers and be linked to societal benefits?

Europe must have a coherent space exploration programme relying on balanced **robotic and human** activities. Space exploration can contribute to build a European **identity**, as well as to **inspire** European youth to engage in scientific and technical studies. **Benefits** for citizens should be highlighted in every mission to attract the interest of both the decision-makers and the general public alike.

What could be the European view and role in the international exploration context?

Europe should strive for a role in future space exploration ventures on par with its aspirations. European activities while fulfilling short-term European goals should be embedded in a wider international context. On scientific activities linked to space exploration, Europe must push for a leadership role in **instrumentation** for remote and surface/sub-surface studies of planetary bodies of interest to exploration, as well as for research fostering human presence in space (e.g. habitats, life support). Europe has been the largest scientific user of the **ISS** up to now and should continue to show excellence in science preparing for human exploration. It has strong expertise in space flight **analogues** or simulations and this advantage should also be further nurtured.

What would be a specific added value of the EU in this context?

The EU should take up a leading role in close relation with ESA and Member States for European space exploration initiatives. The EU should also have a substantial role in **education** policy and outreach activities.

2.3. Specific issues

Exploration and Science

European Martian robotic exploration should focus on life detection, drilling capabilities, network science, and sample returns. In this context safety and planetary protection issues need to be advanced and support needs to be gathered for a European sample curation facility. European missions to Mars should look for example at bio-signatures, water reservoirs and atmospheric science.

The Moon is an important target to investigate the early Solar system history and can provide a platform for space exploration. Lunar surface activities would also provide opportunities to develop new instrumentations. Other destinations such as Near Earth Objects (NEOs) and Lagrangian points provide major scientific potential as well. In particular, NEOs are repositories of solar nebula material and could therefore be an integral part of a scientific exploration programme.

ISS is acting as a Low Earth Orbit (LEO) platform for fundamental and applied research, focused on life and physical sciences, but can also contribute to other domains such as Earth observation-based science. It is a unique tool to continue to foster international cooperation for scientific research.

Space exploration provides also a unique opportunity for synergies among scientific fields such as geology, biology, planetary science and others which need to be better exploited. Furthermore, benefits for Earth and terrestrial research stemming from exploration activities exist and should be stressed, such as a better understanding and modelling of the evolution of the Earth (e.g. climate change) that require comparative planetology as a tool. In general, a European leadership role in instrumentation concerning remote and surface/sub-surface studies of planetary bodies of interest to exploration should be sought.

Space exploration can benefit from research on terrestrial environments (e.g. instrumentations and techniques). Therefore making the best use of synergies with analogue environments on Earth (e.g. for understanding the origin of life) in order to prepare the grounds for significant exploration programmes should be reinforced. Complementary elements between planetary remote sensing and in situ research should be enhanced. Ground-based research is key to prepare for human exploration. Europe has strong expertise in simulations and analogues (e.g. bed rest studies, use of Concordia Antarctic station, physical countermeasures) and this advantage should be further nurtured.

Europe has been the largest scientific user of the ISS up to now and should continue to show excellence in science preparing for human exploration. In addition, benefits for citizens on Earth (e.g. in the sectors of health, ageing, waste recycling, life support) should be emphasised in order to attract the interest of both the decision-makers and the general public.

To meet this objective, top-down calls should be issued both for ground-based and ISS research to address the most realistic short-term challenges for human exploration. Moreover, interdisciplinary teams that address new and innovative science should be promoted to fully exploit the potential of the ISS and foster user-driven research. The long-term utilisation of ISS should be optimized in cooperation with partners to sustain cutting-edge research activities and to benefit from the experience gathered by continuous human presence in LEO.

Exploration and Education

All space programmes, especially space exploration, are inspiring, but inspiration is no longer enough to justify and support those activities. Space exploration programmes must increasingly compete for the attention of the public and politicians. More public outreach must thus be done in Europe and adequate activities to promote exploration should be defined upfront. Communication must be an integral part of space exploration programmes and particularly of any related mission. Public support for space exploration needs, however, more than just increased awareness. Better and more efficient communication is as important as the science and technology (S&T) itself to sustain any long-term endeavour. The overall society has to be involved as an integral part of space exploration. There is also a necessity to engage the future generations in exploration activities (e.g. with participatory exploration) as they will enable and fund most of it.

Space exploration can help to improve Science, Technology, Engineering and Mathematics (STEM) literacy and motivate students to engage in S&T careers. It is an enabler that can be linked to many subjects and integrated with many other disciplines. School material derived from ISS utilisation and other space missions can be very useful to address diverse topics such as physics, mathematics, life sciences, international relations, humanities and social sciences. Beside governments, industry should play as well a role in education and outreach.

2.4. Conclusions

The primary goal of space exploration is to expand – for ultimate benefit of citizens – the range of human activities which requires a synergistic combination of robotic and of human exploration activities. Space exploration is driven by a combination of aspects such as science (increasing knowledge), economy (finding new opportunities), political (prestige and promoting global cooperation), education (improve the workforce and S&T literacy of society) and public engagement (raising societal support and inspiring new generations). In this context science will undoubtedly benefit as a passenger of space exploration.

There should be a common willingness for Europe and other partners to cooperate and strive toward common goals even if there might be technological and experience gaps in several areas. Moreover, stronger synergies between fundamental and applied research are needed to foster technological developments. Europe has several strengths to build on, but Europe could do more and the future European role in exploration has to be clearly identified. There is a necessity to identify the niches for European leadership.

Space exploration addresses multidisciplinary scientific questions and challenges, and to solve those, a trans-disciplinary approach must be fostered. Indeed, synergies between science and technology can allow challenges to become opportunities. Future European programmes, coordinated between ESA and the EU, should therefore encourage trans-disciplinary initiatives, including between science and technology. Future ambitious exploration missions will also require technology breakthroughs such as nuclear propulsion that will provide benefits for science.

There is a necessity to engage the general public to support space exploration, especially the younger generations. Space exploration can be a support to STEM education. The best practices throughout Europe should be shared. However, to make space exploration an integral part of schools curricula, an ambitious European space exploration programme is needed.

Space exploration can sustain the European identity. However, future major exploration ventures will be done in international cooperation as exploration is now a global project. In this global endeavour, Europe must play a key role. Indeed, Europe has the strengths and competences to become a major player in space exploration. Moreover, its experience in cooperative activities due to its very nature can be an asset for future ventures. European priorities must however be consistent and compatible with those of potential partners.

3. EC-ESA Workshop, Exploration and Innovation, Industrial Competitiveness and Technological Advance, Harwell, UK, 29-30 April 2010

3.1. General Recommendations

Europe needs a long-term vision on space exploration with clear objectives and intermediate milestones including short-term demonstration missions. Space exploration has a great potential as a technology and innovation catalyst because of its inherent complexity and the diversity of the challenges it faces. Therefore, the European Union, in close cooperation with ESA, should promote space exploration to meet the challenges of society's needs'.

Space exploration is undoubtedly a driver for innovation in the space sector but also outside, providing many tangible Earthly benefits.

Long-term goals and short-term technology missions will support the European space industry but also attract new players with value-added competences (e.g. regions, SMEs, entrepreneurs).

Europe should consider new procurement mechanisms to address specific exploration challenges and involve new players, including non-space actors.

Europe should establish new platforms and forums for ‘spin-in, spin-out and common R&D’ to reach out to non-space industry and remove existing barriers to innovation.

New financing tools need to be introduced to stimulate innovation to find answers to specific exploration goals (e.g, cash prizes to attract SMEs and commercial initiatives).

3.2. Specific issues (from the questions in the background document)

3.2.1. How can space exploration contribute to industrial competitiveness and innovation?

How can space exploration unleash the innovative potential of Europe?

This will not happen unless Europe establishes a clear long-term vision with a clear roadmap and identified targets and milestones including short-term technology demonstration missions and short-term preparatory missions. New actors including regions, SMEs, entrepreneurs, non-space actors should also be involved in exploration initiatives.

How can space exploration promote innovation for societal needs?

Earthly challenges should be used as drivers (e.g. improving citizens' life) and dedicated platforms should be funded by the European Commission, to integrate space R&D activities into larger multidisciplinary activities.

Are there new ways of financing space exploration programmes?

To enable a resilient European space exploration programme robust and continuous financial commitments will be needed. The European Commission could promote linkages among various areas of its R&D framework programmes, for example with thematic areas such as health, information and communication technology, aeronautics, environment, or materials sciences. Different procurement schemes could be investigated (e.g. cash prizes for specific goals) to foster innovation. As well as triggering innovation, common R&D could facilitate the identification of additional financing.

How to strengthen European technology and industrial base?

To optimise R&D developments Europe should better exploit synergies with other domains (space and non-space). Furthermore, administrative simplification and a faster allocation of resources are needed to attract new firms.

How to reconcile cooperation and competition or technological advance and international cooperation?

Space exploration can undoubtedly be a boost for industrial competitiveness, but Europe should avoid unnecessary duplication of activities and a fragmentation of its research programmes. The space sector has to open itself more to other ideas and other actors; space exploration could represent a perfect opportunity to do so.

3.2.2. Space exploration at 'system' level – innovation prospects for robotic and human spaceflight

How to support and engage the European space industry in exploration activities?

Europe should have a clear and long-term commitment for exploration, which in turn would allow European space industry to maintain its capacities and competitiveness. It should also concentrate its investment in specific and selected niches of excellence to enable Europe to make critical contributions to targeted challenges. Europe should support enabling technologies and capabilities by using small missions "to derisk" technologies (reduce the risk through demonstration and validation).

What areas of technical excellence need to be nurtured or acquired?

Two main domains emerged as being important for Europe, as well as being strong domains for European industry and instrumental for the success of exploration: sustainable life technologies (including power generation), and advanced propulsion for interplanetary travel. They should be considered as priority domains along with robotic systems.

How to build on European expertise and competences and engage in new areas?

Strong support to ESA technology programmes should be maintained, but the European Commission should also increase its support as advances in technology for exploration will lead to advances in other domains, crucial for innovation in Europe.

How to identify technological priorities for Europe?

Strengths of European industries should be analysed and matched with the political wish to master some key technologies, in line with the Europe 2020 strategy.

How to support technology breakthrough and high risk research?

Many innovations are serendipitous or build on incremental technologies but Europe should encourage and support technology breakthrough and high-risk research by establishing clear, specific exploration goals for industry to work towards.

3.2.3. Space exploration technology challenges at 'sub-system' level – trans-disciplinary synergies for robotic and human spaceflight

Which domains of space exploration are most promising for synergies between space and non-space actors?

Areas of most promising synergies between space and non-space sectors are life-support (e.g. health and wellbeing, food and water security, recycling, waste recycling); power management (energy production and storage); robotics and automation (to replace or assist humans in dangerous environments).

Are new mechanisms needed to (better) engage the space community?

Knowledge exchange between the space and non-space sectors should be nurtured by creating dedicated forums and encouraging co-locations between space and non-space actors (e.g. innovations centres acting as hubs). In this context, the European Union should provide means to define common needs, and to set up adequate discussion networks: enabling in particular earlier involvement of actors (e.g. SMEs, entrepreneurs) at problem definition stage, promoting adaptability/flexibility and bridging organisations. A more aggressive and targeted communication activity to raise awareness about exploration ideas, realisations and challenges is also needed.

What are the incentives to connect space exploration-related research to other sectors?

Space exploration-related research could benefit from the expertise and capabilities residing in other sectors and the stringent exploration boundary conditions will be a clear driver for innovation (e.g. severe environmental conditions that imply complex and innovative answers to respect mass, volume and power limitation, answers which could later be adapted to Earthly issues). However, the space market is very small and not

What are the barriers to cross-sector technology developments?

There is often within non-space sectors a lack of awareness of the potential cooperation opportunities offered by the space market. Moreover, substantial differences in time-scales, attitude towards risks, levels of financing, expectations of return on investment, and working cultures exist between the space and non-space sectors.

Is space exploration an engine for disruptive/breakthrough technologies?

Space exploration challenges can be an engine for innovation stimulating disruptive/breakthrough technologies but in any case, Europe needs to continuously invest in technology to enable future benefits for the European industrial base.

3.3. Conclusions

Space has always been an innovative sector and space exploration in particular has a great potential to act as a catalyst for societal and economic progress because of its inherent complexity and the diversity of the challenges that it shares with many non-space areas such as the health sector, energy (e.g. nuclear energy), waste disposal, food security and water recycling. Space exploration and innovation are thus interlinked and exploration will drive further breakthroughs in traditional space domains as well as in new areas and will bring back innovation and foster economic growth.

Europe has all the capabilities and skills to engage fully into space exploration, the building bricks for this exist, but the need is to ‘operationalise’ the technology assets and existing capabilities to, among others, maintain the necessary know how in Europe. For this, Europe must set clear and specific goals (e.g. sustained 'human survival' in space; a robotic asteroid mission) towards which the space and non-space industry can direct their innovative talents. Combined research into solving linked exploration and terrestrial challenges could also be beneficial (e.g. climate change and low-carbon energy, remote health care for aging population, secure access to energy and to safe drinking water).

Continuous public support is needed to enable the private sector to develop cost-effective and efficient products and solutions. European regions could also play an increasing role in space exploration. However to better engage the industrial sector, including SMEs and entrepreneurs, new procurement mechanisms and financing tools such as cash-prizes could be investigated. Common ground with the non-space sector should be sought as well as pooling skills and funding. Existing identified barriers should be overcome.

4. EC-ESA WORKSHOP, SPACE EXPLORATION SCENARIOS, CAPUA, IT, 21 MAY 2010

4.1. Draft conclusions and recommendations

Europe has a longstanding **history** of successful exploration of space, conducted through projects managed by the European Space Agency and its Member States. Today, with the Lisbon **Treaty**, space became an EU policy in its own right. Indeed, article 189 provides that the EU shall “*coordinate the efforts needed for the exploration and exploitation of space*”.

The first space exploration conference in Prague end 2009 launched a **consultation** process that was followed by three thematic workshops co-organised by the European Commission and ESA; the next steps in 2010 will be a Commission Communication on space including a chapter on exploration, the second conference in Brussels on 21 October 2010 as well as the 7th Space Council in November.

The added value of the EU involvement in space exploration is that it can connect space exploration with many other **policy areas** over which it has responsibility. The EU contribution to space exploration can therefore make a difference compared to past and current practices. The EU contribution must be **visible** and financial resources must be used for clear projects where the EU added value is most effective.

As emphasised in the first EC-ESA workshop, **science** will best benefit from space exploration by a trans-disciplinary approach but it has been underlined that space exploration is more than science or technology. It contributes significantly to innovation and the knowledge base and above all it has a political dimension. Space exploration will thus in turn **inspire** European youth in scientific and technical education and careers.

The second EC-ESA workshop concluded that space exploration generates **innovation**. It was acknowledged that exploration should be promoted as a challenge for societal needs to attract new players with value-added competences (e.g. non-space actors, especially SMEs) while supporting the space industry to nurture its overall competitiveness. For an optimum science and innovation return Europe must however have a coherent **long-term** space exploration programme of **robotic and human** activities with clearly identified intermediate milestones including short-term **technology** demonstration missions.

As shown in the third workshop, a large consensus emerged in support of the European exploration **scenarios** elaborated by ESA which should rest on three pillars: a solid technological programme; a use of ISS assuming its extension and including the development of a common space transportation policy; a robust complementary robotic exploration programme.

It is recognised by the participants that space exploration is a matter of **global cooperation** and must be carried out within a broad international partnership. The EU in close collaboration with ESA needs to promote this global approach and raise it to the **political level**. [*The participants of the workshop identified the need for a more political level forum to discuss space exploration as a global endeavour*].

5. CONFERENCE ON SPACE AND SECURITY, MADRID 10-11 MARCH

The Workshop emphasised the relevance of space to security users as a tool with the potential to address specific needs, in particular that of timely response. Being one tool of many, space can provide the most added value when seamlessly integrated with others. To achieve this, effective integration of space technologies such as Earth observation (and especially GMES), satellite communication and navigation (Galileo with its PRS) will be required. In parallel, the way the space systems interact and network with ground based and airborne platforms needs to be further looked into.

Services of the EU Council and the European Commission, the European Defence Agency (EDA) and the European Space Agency (ESA) have been working together on the identification of security related user requirements under the umbrella of the Structured Dialogue on Space and Security. The new Crisis Management and Planning Directorate of the Council offers the potential for genuine synergies between civilian and military effort, and will continue to contribute to the ongoing developments in space and security. The expertise of the EUSC in analyzing EO data and disseminating geospatial products for security applications should be taken in due account in the implementation of GMES security services.

Concerning the security dimension of GMES, workshop participants recognised the progress made to date. Recommendations have been made on how GMES should support EU border surveillance (in particular EUROSUR), while work on the identification of user requirements for GMES to support EU External Action has begun. GMES security services to be developed on the basis of these requirements will complement the support provided by GMES to Emergency Response.

The complexity of integrating both civil and military requirements has been illustrated by the cooperation on Space Situational Awareness (SSA), which is the first European space initiative to consider dual use dimensions from the outset. ESA, in the framework of its SSA preparatory programme, has been mandated to gather civilian SSA user requirements and design the technical architecture of what could become a European capacity. The European Defence Agency is currently drafting military requirements for SSA. The EU Council and European Commission, together with potential SSA contributors, will have to define the governance model and the related data policy for an operational European SSA system. The EUSC data model could be considered in this context.

Discussions on effective synergies and the governance of GMES and SSA highlighted the importance of national assets as essential components of any European Space system responding to security objectives. These national assets could be complemented by European capabilities when needed, while avoiding unnecessary duplication. As an example, Spain presented its National Earth Observation Satellite Programme consisting of an optical and a radar satellite (PAZ) that will be operated together and have been designed to serve the needs of security and non-security users both at national and international level in the context of GMES and other cooperation programmes.

The European Space Policy highlights the need for the European Union, ESA and their Member States to increase synergies between their security and defence space activities and programmes. The Structured Dialogue has started this process. The Workshop highlighted the need to increase and expand this coordination. It also suggested the setting up of an appropriate coordination platform with Member States owning relevant assets.

These issues should be further explored during a dedicated follow-up seminar planned for summer 2010 with a view to provide input for a discussion at ministerial level in an appropriate setting.

6. CONFERENCE ON GOVERNANCE OF EUROPEAN SPACE PROGRAMMES, SEGOVIA, SPAIN, 3-4 MAY 2010

Europe needs space. It needs strategic space capabilities and efficient space-based services to ensure the wellbeing of our citizens and as a tool to support public policies. It needs to exploit these capabilities and services to their maximum potential.

Europe needs a range of activities and organisations to meet its wide range of objectives for space. How these interact in the short- and longer-term will be the key determinant of Europe's continuing success in space.

The Conference has recognised that the entry into force of the Lisbon Treaty presents an opportunity to further develop the institutional framework for Space activities in Europe. The Treaty on the Functioning of the European Union (TFEU) provides a legal basis and an explicit competence in Space for the EU. This competence, which is shared with the Member States, calls upon the EU "to coordinate the effort needed for the exploitation and exploration of space" and to "establish any appropriate relations with the European Space Agency". It then consolidates the triangle of European space actors i.e. the EU, ESA and their respective Member States.

Governance arrangements are a tool to deliver objectives. Clarity of vision and objectives must come first.

The current institutional set-up for the European Space Policy – the EC/ESA Framework Agreement which entered into force in 2004 – has provided a solid foundation for coordinating and aligning the space activities of the EU and ESA. This arrangement works well but may have to evolve at the end of the current analysis, in view of Art. 189 TFEU and in order to expand the opportunities for Space in Europe.

The Conference recognised that the existing institutional asymmetries between the two organisations (supranational v. intergovernmental) pose a number of challenges which will have to be addressed. Along with the growing EU role in space, Member States also value intergovernmental ways of working within ESA as a research and development agency. Efficient collaboration will require adaptation, including possibly through continued institutional convergence between the EU and ESA. ESA, its Member States and the EU have to explore the different scenarios for the evolution of this collaboration.

Industrial policy and technology policy are inextricably linked. The Conference recognised the importance of a coherent framework for Space Industrial policy in Europe. The peculiarities of the space sector call for a combination of measures at EU, ESA and Member States level in order to create the right environment that will nurture a competitive industry and ensure a fair and balanced participation of all industrial actors, including in particular SMEs. These measures must and will continue to evolve.

The Conference identified procurement as the major but not the only instrument driving industrial policy. Other instruments should continue to be promoted. At the EU level, examples include instruments such as FP7, CIP and structural funds, as well as EIB loans and EIF guarantees. While taking full advantage of the existing EU, ESA and Member States industrial policy instruments, other instruments could be designed as incentives for the European space industry to maintain and improve its competitiveness and develop technologies, applications and services which are innovative, sustainable, reliable, cost-effective and efficiently respond to growing societal needs in Europe.

The Conference widely recognized the technical expertise of ESA in designing and procuring European Space Programmes. Despite difficulties, the first EU flagship projects in Space, GMES and Galileo, are moving closer to fruition. Future industrial policy should allow for the development of mechanisms to enable EU-ESA cooperation in Space. Past experiences, in these programmes and also in ESA-EUMETSAT programmes, provide valuable lessons in the governance of future endeavours.

In future programmes, governance arrangements will have to be put in place, from the beginning, that should guarantee the efficiency of public investments in Space, the long-term sustainability of the programmes and their optimum utilisation as well as ensuring motivation of Member States to continue their volunteer investments in space. Continuity between the research and development and exploitation phases will have to be ensured. While it will be impossible to find ‘one-size-fit-all’ solution for all the programmes that could be conceived in the future, a degree of coherence will be necessary.

The EU identity in security and defence matters has been reinforced. Security and defence policy is in an evolutionary period. The EU has a competence in foreign and security policy, including the progressive framing of a common defence policy, in conformity with the TEU. Space actions may serve foreign and security (including defence) policy goals.

Governance of space activities related to security and defence needs will have to reflect that evolution.

7. EUROPEAN SPACE BUDGETS

Europe, through the activities of the European Space Agency (ESA) and its Member States[1], most of which are also EU Member States, has built significant achievements in the space domain over the past 30 years. European scientists have contributed to the exploration of several planets in the Solar system: Venus (Venus Express), Mars (Mars Express) and the Moon (e.g. SMART-1, European instruments on Chandrayaan-1). The successful Huygens mission to Titan has marked the farthest landing in the solar system so far. Building on the experience gained with Spacelab in the 1980's, Europe has recently contributed to the success of the International Space Station (ISS) through the Columbus laboratory, the Automated Transfer Vehicle (ATV) – the largest ever automatic cargo space vehicle, and other essential ISS supplies, such as the Multi-Purpose Logistics Module (MPLM) flying in the Shuttle payload bay to bring supplies to ISS. Nearly 50% of all pressurised elements on board the ISS have been manufactured in Europe by European companies. Furthermore, Europe has gained leadership role in several segments of astronomy and astrophysics covering a broad spectrum of measurements of the universe with XMM-Newton, Integral, Corot, Hubble and the James Webb Space telescopes (the last two in cooperation with NASA). More recently, the launch of Herschel and Planck have marked a new step in this quest for the understanding of the origin and evolution of the Universe.

In parallel Europe has created its own infrastructure for access to space through the European Spaceport in French Guiana and the Ariane family launchers which have been the commercial workhorses for the past three decades. The Ariane 5 launcher is able to lift 20 tons into Low Earth Orbit in the form of groundbreaking science missions and the ATV, as well as putting the most powerful telecommunications satellites into geostationary orbit.

The programmes of ESA and national space agencies have given rise to a strong space industry, which has managed to transform Europe’s space ambitions into concrete successes. This industry has developed a broad spectrum of space technologies and capabilities, and is today a recognised leader in the global commercial space markets for launchers and telecommunications satellites.

But the industry is relatively small in size[2] and dependent on public sources of funding for nearly 60% of its turnover (against 80% in the US).

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1 ESA currently has 18 Member States: Austria, France, Germany, Italy, Spain, UK, Belgium, Netherlands, Luxembourg, Sweden, Finland, Denmark, Greece, Portugal, Ireland, Czech Republic, Switzerland and Norway.

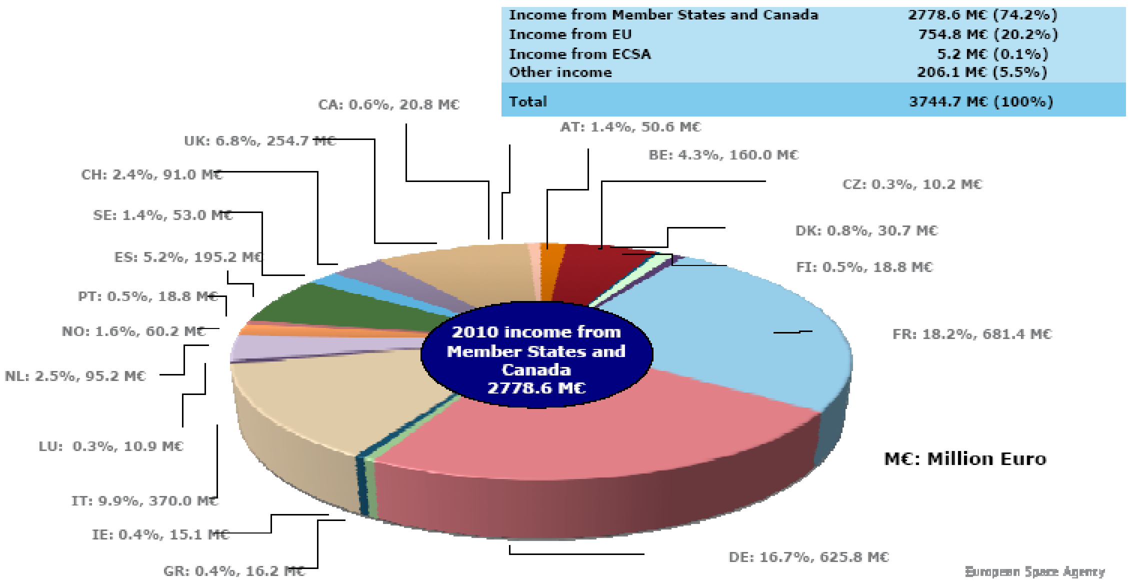
2 Around 30,000 employees and consolidated turnover of €5.9bn in 2008.

In Europe the budgets spent on space activities are divided between ESA, which accounts for nearly 2/3 of the current spending (i.e. €3.7 billion in 2010 of which €750 million are contributions from the EU) and individual Member States which together spent a total of €2.1bn in national programmes in 2009. The total European space expenditures were estimated at €6.7 billion in 2009, of which only around €1 billion in defence-related space budgets.

The US invests considerably more than Europe in space. The budget of NASA in 2009 was $17.8 billion, roughly 5 times that of ESA. The gap becomes even wider when taking into account military spending (1:20). The US has today by far the biggest space budget in the world: $48.8 billion in 2009, or 72% of the world's total government space outlays. The new US national space policy foresees a further increase in the NASA budget of $6 billion over the next five years, specifically for space exploration enabling technologies.

Other countries, including more recently emerged space nations strongly support their domestic space industries. China and India are quickly closing their technology gap and aggressively asserting their presence on the commercial space markets. Both have increased their civilian space budgets in recent years (India spent $900 million in space programmes in 2009 and China $2bn). Russia is recovering its levels of expenditure and increasing its national space outlays by 40% on average in the past five years (total of $2.8 billion in 2009). Overall, the global trend of government spending on space programmes (both civilian and defence) is rising. It amounted to $68 billion in 2009, which represented a 12% increase over the previous year, according to Euroconsult[3].

In Europe the biggest investor in space is France, followed by Germany, Italy, the UK and Spain. Countries like Belgium and the Netherlands have significant space budgets per capita as well. The following chart presents the Member States contributions to the ESA budget for 2010.



Source: European Space Agency

3 Profiles of Government Space Programs: Analysis of 60 Countries and Agencies, Euroconsult, 2010

Outside ESA, only a few Member States have any significant national space programmes: France, Germany, Italy, Spain and the UK. These represent a mixture of national or bilateral satellite missions and programmes designed to exploit ESA missions, for example through the provision of scientific instruments. France, Italy and Spain spend more on national programmes than they contribute to ESA. Germany's contribution to ESA exceeds its spending on national programmes. Smaller countries put most, if not all of their national space funding into ESA.

National space expenditures (in M€)

Year	A	B	DK	FIN	F	D	I	NL	N	P	E	SE	CH	UK	Total
2002	29.0	20	4.0	20.0	1083.0	100.0	481.0	35.0	3.8	0.5	9.0	16.1	2.1	98.7	1902.2
2003	30.0	20	3.0	26.0	1040.0	270.0	400.0	30.0	5.5	0.5	10.1	16.0	2.0	63.8	1916.9
2004	23.2	20	3.3	27.4	690.1	340.0	436.0	24.0	6.8	0.5	14.5	17.0	2.0	99.4	1704.2
2005	18.8	20	5.0	26.4	681.5	415.0	421.1	23.7	6.2	0.5	226.0	16.0	2.0	99.0	1947.2
2006	16.6	20	5.0	27.0	691.6	416.0	420.0	24.0	6.2	0.5	311.0	16.0	2.0	100.0	2054.9
2007	17.0	25	5.0	27.0	713.2	458.0	430.0	25.0	8.0	0.5	300.0	16.0	2.0	79.9	2153.6
2008	18.0	25	5.0	27.0	856.6	460.0	400.0	25.0	8.0	0.5	300.0	16.0	2.0	80.0	2221.1
2009	18.0	25	5.0	27.0	703.5	460.0	430.0	25.0	8.0	0.5	300.0	16.0	2.0	80.0	2100.0

Source: European Space Directory, 25th Edition

Among the group of EU-12 only the Czech Republic is currently a member of ESA. Several others have cooperating states agreements with ESA (i.e. Hungary, Romania, Poland, Estonia, Slovenia). Some of these countries have had traditions in certain areas of space activity but currently lack the necessary industrial base and the means for any significant involvement. Besides, the barriers to entry in this industry are very high for newcomers. Still a few countries make their modest contributions through the ESA budget.

ESA Contributions (in M€)																						
Year	**A**	**B**	**DK**	**FIN**	**F**	**D**	**H**	**EI**	**I**	**NL**	**N**	**P**	**E**	**SE**	**CH**	**UK**	**CZ**	**L**	**GR**	**CND[4]**	**Others**	**Total**
2001	29.5	113.1	24.3	10.5	614.6	534.9		6.6	287.4	58.9	20.7	2.7	92.2	48.3	61.3	141.3	0.3			12.2	792.0	2847.3
2002	27.7	140.3	27.7	14.1	680.0	680.1		7.8	444.0	70.0	26.4	6.4	117.2	59.6	57.9	127.8	0.3	2.4		17.5		2992.7
2003	29.3	148.0	22.2	12.5	680.0	603.0	1.1	11.2	370.0	75.9	29.1	5.8	120.2	58.7	64.5	149.8	0.25	3.8	1.2	17.1		2677.1
2004	32.5	181.1	28.0	20.6	680.0	653.0	1.1	12.3	280.0	70.0	26.0	11.1	131.2	57.1	86.3	229.9	1.36	3.8	7.2	16.5		2791.8
2005	31.0	190.1	29.3	21.6	685.0	631.0	1.1	11.5	363.0	72.0	39.1	11.9	136.6	68.0	88.4	241.0	1.43	3.9	7.5	17.9		2926.0
2006	33.6	149.5	24.9	16.5	685.0	555.0	1.1	11.5	344.0	64.1	28.5	12.2	128.0	51.0	89.0	202.9	1.43	5.1	10.0	22.3		3197.4
2007	33.2	145.2	26.2	17.2	753.2	578.3	1.1	12.1	369.9	74.9	43.3	12.8	141.3	51.9	92.9	243.1	1.43	9.2	11.1	22.3		2975.3
2008	32.8	138.4	23.9	16.4	556.4	533.4	2.0	13.3	343.0	98.0	43.9	16.6	152.8	54.6	87.1	264.9	1.43	11.1	11.4	22.3		3028.3
2009	43.3	161.0	27.8	20.0	716.3	648.3	2.0	13.3	369.5	99.0	44.6	15.7	184.0	56.0	94.4	269.4	6.87	12.8	14.5	22.1	777.96	3591.7
2010	50.6	160.0	30.7	18.8	618.4	625.8		15.1	370.0	95.2	60.2	18.8	195.2	53.0	91.0	254.7	10.2	10.9	16.2	20.8	968.1	3744.7

Source: European Space Directory, 25th Edition

8. OVERVIEW OF EXISTING SSA CAPABILITIES

8.1. European assets

Activities in the area of Space Situational Awareness (SSA) are being conducted both at European and national level. A number of Member States have developed SSA capabilities, many of which – in particularly tracking and satellite imaging facilities – are owned and operated by national defence agencies. In Europe, such facilities are available in France, Germany, Norway and the UK, the latter two being part of the US anti missile defence network. Some facilities are also operated by space agencies, e.g. optical telescopes for surveying the Geostationary orbit (GEO). An overview of existing space surveillance assets in Europe prepared by ONERA[5] in 2007 on behalf of ESA[6] found that more than 65 % of existing sensors for the Low-Earth orbit (LEO) area are partially or fully operated by ministries of defence-related institutions.

Existing radar capabilities such as the GRAVES system or the Armor radar in France (see description below) are owned and operated by the Air Force. Operational since December 2005, the GRAVES radar produces surveillance and tracking data used for cataloguing space objects in the framework of a dominant military interest. More specific radars such as Armor (under the responsibility of the French Navy) have direct military uses and may contribute to the surveillance, tracking and characterisation of space objects. In Germany, the main radar equipment FGAN-TIRA is run by research teams from the High Frequency Physics and radar Techniques (FHR)[7], with a special partnership with the German Ministry of Defence, a

4 Cooperating country
5 Office national d'études et recherches aérospatiales.
6 Study on capability gaps concerning Space Situational Awareness, ONERA, 2007.
7 Under the auspices of the Research Establishment for Applied Science – FGAN.

dominant user of the radar capability for space imagery. The list attached at the end provides an overview of the main European space surveillance and tracking resources.

Since January 1, 2009 ESA has been implementing a preparatory SSA Programme as an optional programme with 13 participating Member States at present (Austria, Belgium, Finland, France, Germany, Greece, Italy, Luxembourg, Norway, Portugal, Spain, Switzerland, the UK). The programme, which runs until 2011, should lay the groundwork of a future European SSA system. It focuses mainly on the definition and architectural design of the system, its governance and data policy. A small hardware component is also foreseen (i.e. a test-model of surveillance radar) and a prototype demonstrator of user-services (so-called Pre-cursor services).

8.2. The US Space Surveillance Network

The US Department of Defence established a space surveillance network as early as 1957. The system was built up progressively by networking different observation capabilities, some of which were initially developed for ballistic missile detection. Access to this database has subsequently been made available to any (registered) user. Today, the US Space Surveillance Network (SSN) represents the reference for all space surveillance information across the world. ESA, EU and ESA Member States authorities and space agencies acting as operators of space systems as well as European commercial operators today rely to a large extent on the US SSN.

However, the US system has some aging capabilities and faces new challenges with the increasing orbital population. The US recognises today the need to widen international cooperation and in the different fields covered by SSA, and looks at earmarking potential domains for increased trans-Atlantic cooperation on SSA, in support of common civil, commercial and military requirements. The new US national space policy adopted on 28.06.2010 makes specific reference to the need for international measures to promote safe and responsible operations in space through improved information collection and sharing for space object collision avoidance.

8.3. Other space surveillance activities

The Russian federation, via the Russian military space forces, operates space surveillance capabilities independent of its ballistic missile early warning (BMEW) assets. These systems have performed various military and civil roles, including the analysis of the surface impact point of the Mir Space Station and identification of space debris[8]. Russian companies are in a position to offer or sell space surveillance data to external entities.

China, since joining the Inter-Agency Debris Committee (IADC) in 1995, also maintains its own catalogue of space objects. Space surveillance is an area of growth for China, which announced new investments in optical telescopes for debris monitoring in 2003. In 2005, the Chinese Academy of Sciences established a Space Object and Debris Monitoring and Research Center at Purple Mountain Observatory that employs researchers to develop a debris warning system for China’s space assets.

[8] http://geimint.blogspot.com/2008/06/soviet-russian-space-surveillance.html

8.4. Space weather activities

The current working prototype of the European Space Weather data network, SWENET, supported by ESA can be considered as an embryo of the space-weather component of a future European SSA system. It is currently based on a distributed model, providing a centralised web-based access point to specialised space weather data and service products produced by several groups including SIDC (Solar Influences Data Centre of the Royal Observatory) in Belgium, SWACI (Space Weather Applications Centre - Inosphere, project of DLR) in Germany, CLS (Collecte Localisation Satellites) in France, BGS (Geomagentism Group, British Geological Survey) in the UK. A data exchange agreement has been established with the National Oceanic and Atmospheric Administration (NOAA) space weather data centre in the U.S.

8.5. International cooperation

For SSA international cooperation plays a very important role. Today international cooperation efforts in the area of space surveillance for debris monitoring and awareness are largely dominated by the existence of the US space surveillance network. This system makes non-sensitive information freely available over the internet (a subset of the US space surveillance catalogue of orbiting objects.) There is also bilateral cooperation between the US and some European states, between US agencies (NASA, NOAA) and ESA, as well as *ad hoc* cooperation with commercial and national satellite operators in case the US system detects a collision threat.

There is today a growing awareness of the desirability of enhanced cooperation between the US system and a future autonomous European SSA system. Both sides have expressed willingness to take the existing cooperation further during recent high-level meetings, including a recent EU-US space dialogue held in April 2010 in Washington, DC.

To facilitate such cooperation, the EU is already making funding available through the FP7 Space Theme: e.g. a number of projects have been selected in 2010 which include US partners (as well as partners from the Ukraine, South Africa and India). These projects address space weather as well as space surveillance and anti-collision issues.

At the level of space agencies, cooperation takes place in the context of the Inter-Agency Space Debris Co-ordination Committee established in 1993. IADC comprises 11 national space agencies including NASA, ESA and some of the European space agencies (CNES, BNSC, ASI, and DLR). Its primary purposes are to exchange information on space debris research activities between member space agencies, to facilitate opportunities for cooperation in space debris research, to review the progress of ongoing cooperative activities, and to identify debris mitigation options. In 2002, the IADC adopted a set of recommendations for debris mitigation, which has achieved wide international recognition (*Space Debris Mitigation Guidelines, IADC, 2002*). The UN Committee on the Peaceful Uses of Outer Space (UNCOPUOS) developed these recommendations into a set of guidelines, which were adopted by the UN in 2008. These guidelines for good conduct in space are voluntary and non-binding. At technical and commercial level, the recommendations are translated into international engineering standards, such as International Organisation for Standardisation (ISO) or European Cooperation for Space Standardisation (ESS).

In the space weather segment, international cooperation is more advanced and is currently implemented through the International Solar Energy Society (ISES), the World

Meteorological Organisation (WMO) and other organisations that support the development and use of space weather service provision standards. Other major international cooperation venues include the International Space Environment Service (ISES) – a permanent service of the Federations of Astronautical and Geophysical Data Analysis Services; the International Solar Terrestrial Physics Science Initiative; the International Astronomical Union, which has a working group dedicated to international collaboration on space weather, and the Scientific and Technical sub-committee of the UN-COPUOS which also currently considers an International Space Weather Initiative.

8.6. Examples of existing European capabilities for space surveillance and tracking

8.6.1. Optical sensors[9]:

Tenerife: ESA operates a space debris telescope on Tenerife that covers a sector of 120° of the GEO ring. From single observations, initial orbits can be derived which are generally adequate for re-acquisition of the object within the same night, and which can then be successively improved. The Optical Ground Station (OGS), installed in the Teide observatory 2400 m above the sea level, was built as part of ESA long-term efforts for research in the field of inter-satellite optical communications. The original purpose of the station, equipped with a telescope (1m aperture), is to perform the in-orbit test of laser telecommunications terminals on board of satellites in Low Earth Orbit and Geostationary Orbit. Since 2001, the ESA survey of Space Debris in the Geostationary Orbit and the Geostationary Transfer Orbit is also being carried out with a devoted wide field camera to determine the orbital parameters of debris objects. The Optical Ground Station was inaugurated in 1995. The Instituto de Astrofísica de Canarias participated in the integration of the station instruments and has since then been in charge of the station operation. This is the contribution of ESA to the worldwide common efforts on this task with NASA and NASDA (National Aerospace and Defense Agency of Japan).

TAROT: CNES uses observation time of the TAROT telescope (Télescope à Action Rapide pour les Objets Transitoires) in France to survey the GEO ring. TAROT's primary mission is to detect the optical afterglow of gamma-ray bursts. A companion telescope, TAROT-S has been deployed in Chile. Since 2004, CNES observes satellites in the geostationary orbit with this network of robotic ground based fully automated telescopes. The system makes real time processing and its wide field of view is useful for detection, systematic survey and tracking both catalogued and uncatalogued objects.

Starbrook: The British National Space Centre (BNSC) has sponsored the Starbrook wide-field telescope as an experimental survey sensor since 2006. The telescope is located at Troodos/Cyprus, It can detect GEO objects down to 1.5 m sizes (visual magnitude of +14).

ZIMLAT/ZimSMART: The Astronomical Institute of the University of Bern (AIUB) operates a ZIMLAT telescope. From its location in Zimmerwald/Switzerland, the telescope covers a sector of 100° of the GEO ring. The primary applications of ZIMLAT are astrometry and laser ranging. However, up to 40% of its night-time observations are used for follow-ups of GEO objects discovered by the ESA telescope at Tenerife. ZIMLAT was complemented in 2006 by the 20 cm ZimSMART telescope (Zimmerwald Small Aperture Robotic Telescope).

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[9] Optical telescopes suitable for observation of the Geostationary (GEO) ring at 36000 km altitude and (Medium Earth Orbit) MEO at 23000 km where Galileo satellites will be placed.

SPOC and ROSACE: SPOC (Systeme Probatoire d'Observation du Ciel) is part of the French DGA network of target tracking systems. The ROSACE and TAROT telescopes are used by CNES for observation of GEO objects > 50 cm. TAROT detects the objects, ROSACE determines their orbit.

PIMS: The PIMS telescope (Passive Imaging Metric Sensor) is owned by the UK Ministry of Defence. They monitor objects in GEO > 1m. They are stationed in Gibraltar, Cyprus and Herstmonceux (East Sussex, UK).

8.6.2. Radar sensors[10]:

Fylingdales: A most powerful space surveillance sensor located in Fylingdales (UK) and operated by the British/US armed forces. Most of the activities are geared to the US Space Surveillance Network (SSN) early warning and space surveillance mission.

Globus II: A second facility associated with the US SSN is the Norwegian Globus II radar. It is located in Vardø, at the northernmost tip of Norway. Due to special bilateral agreements between the US SSN and the operators of Fylingdales and Globus II, data from these sites have so far not been available for unclassified use within Europe.

GRAVES: The French GRAVES system (Grand Réseau Adapté à la Veille Spatiale) is presently the only European installation outside the US SSN that can perform space surveillance in the classical sense. GRAVES is owned by the French Ministry of Defence and operated by the French air force. GRAVES started operational tests in 2001. Routine operations started in 2005. The system produces a 'self-starting' catalogue which can be autonomously built up and maintained. It is limited to objects of typically 1 m size and larger in low Earth orbits (LEO) up to an altitude of 1000 km. The object catalogue contains currently about 2500 objects. Object data of GRAVES are used for target allocation of other radars.

TIRA: The German FGAN Radar belongs to the Research Establishment for Applied Science at Wachtberg (organisational arrangements are currently changed to create a legal position, to be able to use the radar operationally for SSA and not only for research). In its tracking mode, the TIRA system determines orbits from direction angles, range, and Doppler for single targets. The modes include target tracking and imaging (for identification). The detection size threshold is about 2 cm at 1000 km range, 40 cm in GEO orbit. For statistical observations this sensitivity can be enhanced to about 1 cm, when operating TIRA and the nearby Effelsberg 100 m radio telescope in a bistatic beam-park mode with TIRA as transmitter and Effelsberg as receiver.

FS Monge: DGA/DCE, the Systems Evaluation and Test Directorate of the French Ministry of Defence, is operating several radar and optical sensors throughout France. The most powerful of these systems, Armor, is located on the tracking ship Monge. The two radars are dedicated to tracking tasks, based on high resolution angular and range data.

Chilbolton: The Chilbolton radar is located in Winchester, UK, operated by the Radio Communications Research Unit (RCRU) of the Rutherford Appleton Laboratory (RAL). It is mainly used for atmospheric and ionospheric research. With a planned upgrade the radar will be able to track LEO objects down to 10 cm sizes at 600 km altitude.

10 Radar stations suited for observation of the Low Earth Orbit (LEO) region up to 2000 km.

8.6.3. *In-situ sensors*[11]

SODAD (Orbital System for the Active Detection Of. Debris) are French space debris detectors currently in orbit (1 on ISS and 3 on satellite SAC-D) measuring the flux of micrometeriods (natural) and microorbital debris (manmade).

9. EXAMPLES OF SPIN-OFFS FROM SPACE EXPLORATION

Since 1976, NASA has created new technologies with direct benefit to the private sector, supporting global competition and the economy. The resulting commercialisation has contributed to over 1800 recorded developments in products and services in the fields of health and medicine, industry, consumer goods, transportation, public safety, computer technology, and environmental resources.

The following list provides some lasting and wide spread examples from the Apollo programme:

– Freeze drying technologies for food preservation have led to innovations in the food market (e.g. production of corn flakes);

– Computation for automatic checkout of space equipment has led to improvements in retail checkout and banking transactions;

– Space suit fabrics have led to development of environment-friendly building materials and fire resistant materials.

Some more recent examples include:

– Image processing used in automatic space exploration missions has led to applications in medical imagery (tele-medicine);

– Insulation of cryogenic fuel tanks has direct applications in acoustic and thermal insulation;

– Mobile communication platforms for robotic exploration have led to development of explosives detection devices.

Although ESA has invested significantly less into space exploration compared to NASA, a technology transfer programme has been successfully put in place. Pertinent ESA examples include:

– Automatic space craft docking technology (e.g. for ATV) has led to innovations in the car assembly systems;

– Smart suits technologies are now being used for medical monitoring devices;

– Aero braking algorithms are used for crisps packaging;

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[11] Sensors that measure flow of small objects such as micrometeriods and microdebris. Such sensors are mounted on space craft (ISS, Space shuttle, satellites)

– Developing ISS information systems has led to applications in fire fighter emergency planning.

<u>References:</u>

– NASA Hits – how NASA improves our quality of life http://www.nasa.gov/externalflash/hits2_flash/hits1.pdf

– NASA SpinOff, 2009, http://www.sti.nasa.gov/tto/Spinoff2009

– Technology Transfer from Space Spin-off; ESA, NSO, NIVR, April 2010

GLOSSARY

ARV, Advanced Re-entry Vehicle

Space Transportation system for cargo, comprising two main modules: a service module, derived from the ATV spacecraft and a re-entry module. Unlike the ATV, which is destroyed during its return to Earth after supplying the International Space Station, the ARV may make a re-entry to Earth.

ATV, Automated Transfer Vehicle

Unmanned re-supply spacecraft developed by ESA and designed to supply the International Space Station with propellant, water, air, and various other payloads including experiments.

CNES, Centre Nationale d'Etudes Spatiales

The French Space Agency.

ESA, European Space Agency

Inter-governmental organisation established in 1975 to provide for and to promote, for exclusively peaceful purposes, co-operation among European States in space research and technology and their space applications. Today, 18 European Countries are ESA Member States: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxemburg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and United Kingdom.

GMES, Global Monitoring for Environment and Security

European initiative for the implementation of information services dealing with environment and security**.** GMES is based on observation data received from Earth Observation satellites and ground based information. These data are coordinated, analysed and prepared for end-users. It develops a set of services for European citizens helping to improve their quality of life regarding environment and security. GMES plays a strategic role in supporting major EU policies by its services.

GSC, Guyana Space Centre in Kourou

Launch site created in 1964 by France. Since 1977, the site has been exclusively devoted to the Ariane launchers, developed by the European Space Agency and commercially operated by Arianespace. By end 2010 – early 2011 the Soyuz and Vega launchers will also make their first flight from GSC.

ISS, International Space Station

Permanently inhabited space station orbiting the Earth at 400 km altitude for peaceful purposes. Its design, development, operation and utilisation are based on the Inter Governmental Agreement signed in 1998 between the 15 International Partners. The ISS is managed by the following space agencies: ESA (Europe), NASA (USA), Roscosmos (Russia), CSA (Canada) and JAXA (Japan).

Launchers

Rocket-based systems that deliver payloads (satellites, manned vehicles, etc.) into space. They can be heavy, medium and small, according to the relative weight of payloads that a particular launcher can carry into space.

LEO, Low Earth Orbit

Generally considered to be an orbit at an altitude of 400 to 1000 km.

Meteor

Brief streak of light seen in the night sky when a speck of dust burns up as it enters the upper atmosphere. Also known as a shooting star or falling star.

Meteorite

A fragment of rock that survives its fall to Earth from space. Usually named after the place where it fell.

Meteoroid

A piece of rock or dust in space with the potential to enter Earth's atmosphere and become a meteor or meteorite.

NEO, Near Earth Objects

Asteroids or comets whose orbit brings them into close proximity with the Earth (less than 1.3 astronomical unit a unit defined by the Earth – Sun distance).

Payload

Equipment carried by a spacecraft. A product becomes a payload once it is intended to fly on board a spacecraft.

Satellite

A man-made object (such as a spacecraft) placed in orbit around the Earth, another planet or the Sun.

Soyuz Launcher

A launcher system developed by the Soviet Union now also being adapted for use as a medium-lift launcher for Europe.

Solar flare

Sudden violent explosion on the sub-surface of the Sun which occurs above complex active regions in the photosphere. They usually last only a few minutes, but their temperatures may reach hundreds of millions of degrees. Most of their radiation is emitted as X-rays, but they can also be observed in visible light and radio waves. Charged particles ejected by flares can cause aurorae when they reach the Earth a few days later.

Solar storm

Violent outburst of explosive activity on the Sun.

Solar wind

Stream of plasma, mainly electrons and protons, which flows from the Sun's corona at up to 900 km/s. It is found throughout the Solar System as far away as the heliopause.

Spacecraft

Artificial satellite. Term often used before a satellite is placed in orbit around the Earth, when it is transporting something or when it is being sent into deep space.

Space weather

The changing conditions in interplanetary space caused by fluctuations in the solar wind.

SSA, Space Situational Awareness

Comprehensive knowledge, understanding and maintained awareness of the population of space objects (spacecraft such as satellites or space debris), of the space environment, and of the existing threats/risks to space operations. SSA systems rely on ground or space based tracking and monitoring sensors.

The Space Situational Awareness (SSA) Preparatory Programme is a new initiative of ESA, accepted at the November 2008 Ministerial Conference in The Hague. SSA includes activities in three main domains: space surveillance, space weather and Near Earth Objects (NEOs).

CALCULATION METHODOLOGY

The impact assessment provides quantitative estimates of the impact of proposed SSA activities on the basis of available data. The present note explains the methodology followed.

The parameters taken into consideration are the following:

- On 1st April 2010, 183 out of 928 satellites in orbit had EU contractors/owners (19.71%)[12]; it is assumed that the proportion is the same for Low Earth Orbit as for Geosynchronous Orbit;

- There are twice as many commercial satellites in GEO (253) as there are in LEO (130)[13];

- According to Euroconsult, the average satellite price over the next decade will be $99 million and the satellite launch price is predicted to remain flat, at $51 million[14];

- The annual revenue produced downstream by satellite-driven services[15] is estimated to exceed $60 billion US. European industry has managed to retain a market share of about 40% of the space segment[16];

- Nowadays, around half of satellites on orbit are operated commercially and half by governments and the military[17];

- The average number of catastrophic collisions during the next 40 years is one every 5 years[18] in Low Earth Orbit;

- The average number of catastrophic collisions at GEO is 1 every 155 years[19], therefore negligible for the purpose of our calculations; the risk in Medium Earth Orbits is also considered negligible;

- World direct satellite losses due to space weather[20]:

Loss type	Frequency of event	Annualised loss

12 http://www.ucsusa.org/nuclear_weapons_and_global_security/space_weapons/technical_issues/ucs-satellite-database.html

13 http://www.ucsusa.org/assets/documents/nwgs/quick-facts-and-analysis-4-13-09.pdf

14 "Satellites to be Built & Launched by 2018, World Market Survey", Euroconsult, http://www.euroconsult-ec.com/research-reports/space-industry-reports/satellites-to-be-built-launched-by-2018-38-29.html

15 Example of downstream services are telecommunications or TV broadcasting

16 http://telecom.esa.int/telecom/www/object/index.cfm?fobjectid=456

17 http://www.parliament.uk/documents/documents/upload/postpn355.pdf

18 http://www.parliament.uk/documents/documents/upload/postpn355.pdf Page 2 Chart 2

19 http://www.mcgill.ca/files/iasl/Session_5_William_Ailor.pdf

20 http://www.esa-spaceweather.net/spweather/esa_initiatives/spweatherstudies/ALC/WP1200MarketAnalysisfinalreport.pdf

Complete satellite failure	Rare (<3 per solar cycle)	~€30 to 60 million
Service outage	Frequent (up to 60 anomalies per annum)	~ €30 million
Shortened satellite lifetime	Rare (<10 per solar cycle)	~€5-10 million

- Complete satellite failure due to space weather has occurred 11 times in the 25 years[21];
- It is assumed that the average lifetime of a satellite is around10 years;
- For the purpose of calculation we assume that collision take place at satellite's mid life and its cost at this stage would be 50% of its average cost ($99 million), namely $49,5 million;
- For the purpose of this calculation $1 = € 1;
- Damages caused by debris smaller than 10 cm have not been considered.

Calculation of annual direct loss due to collision:

Number of collisions concerning the total satellite population over 40 years in LEO (at one collision every 5 years) = 8 collisions;

Number of EU satellites affected by collisions in the next 40 years [8 collisions x (19.71% of EU satellites over the total satellite population] = 1.57;

Annualised cost of satellite loss over a 40 year period in LEO 1.57 x (satellite cost at midlife, i.e. $49.5 million + cost of launch, i.e. $51 million)/40 years = ~$4 million.

Calculation of annual indirect (revenue) loss due to collision:

Annual revenue produced by EU satellite-driven services ($60 billion x 40%) = $24 billion;

Annual revenue loss per destroyed satellite in LEO [$24 billion / 3 (only 1/3 of commercial satellites are in LEO)] x (19,71% of the 130 commercial satellites in LEO are considered to be EU) = ~$0.32 billion;

Number of EU commercial satellites destroyed over a period of 40 years (1.57 x 50%) = ~0.8;

The total annual revenue losses: [($320 million x 0.8)/40] x 5 (assuming satellite is hit at midlife) = ~$32 million.

Calculation of annualised cost per EU satellite due to space weather

[21] http://www.esa-spaceweather.net/spweather/esa_initiatives/spweatherstudies/RAL/TR110v2_1.pdf-a.pdf

Direct cost due to complete satellite failure is calculated on the basis of the mean value according to table under point 6, which is €45 million x 19.71% EU share of world satellites = ~€9 million;

Annual cost due to Service outage ($30 million) and shortened satellite lifetime ($5 million) as per table under point 6: €35 million x 19.71% = ~€7 million;

Annual revenue loss due to complete failure: [(11 satellites destroyed / 25 years) x 19.71% EU satellites] x € 262 million x 50% commercial satellites x 5 (assuming satellite is lost at midlife) = ~€57 million.

Calculation of annualised cost for satellites due to geomagnetic storms

Severe geomagnetic storms occur at a 1 in 30 year to 1 in 100 year frequency[22]. Potential economic loss has been estimated at more than $70 billion, including lost revenue (~$44 billion) and satellite replacement for GEO satellites (~$24 billion)[23]. Considering a 1 in a 100 years event, world-wide annualised losses would account for $700 million. Assuming that the EU has a 40% share of annual satellite revenue and that EU owns 19,71% of all satellites, the total annualised losses would amount to $223 million.

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22 http://www.ofcm.gov/swef/2009/Booklet%20FINAL%20for%20PDF-website%2020090522.pdf

23 http://www.economics.noaa.gov/?goal=weather&file=events/space&view=benefits