ESPI

European Space Policy Institute

Europe in the Future and the Contributions of Space

Report 55

January 2016

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Short title: ESPI Report 55
ISSN: 2218-0931 (print), 2076-6688 (online)
Published in January 2016

Editor and publisher:
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Design: Panthera.cc

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Executive Summary

Humanity is at a crossroads in its development. Not only are societies and technologies changing faster than ever, there are also some potential game-changing events lurking in the near future. While some current trends and likely future developments will create or reinforce challenges on different levels, other factors are creating new opportunities for our species. In the light of these dynamics, and considering the nature of human progress, it is unlikely – improbable even – that the role of space will not become more important for society at large. The aim of this report is to look ahead and assess how space might be able to deliver benefits to society in the future and what can be done to enable this to the fullest extent possible.

First, the study sets the scene and defines the approach to this endeavour. This starts off by sketching the pitfalls and difficulties in predicting the future. Here, it seems that history has a lesson to teach us when it comes to offering future outlooks. Either because of a lack of inventiveness, or an excess thereof, there is an abundant record of instances in which predictions about societal evolutions have proved to be strikingly wrong. For useful foresights to be made, the scope and framework for identifying evolutions should always be tailored to the topic concerned. In this respect, the two elements that are crucial in assessing how space might contribute to the future are explored.

The first element relates to the position of space within overall human activities and development. It is advocated that in order to build an analysis on the right premises, space should be regarded as a part of wider scientific and technological developments and their interaction with society. It is further argued that science and technology development and societal change are characterised by a dialectic relationship in which innovation is as a dynamic connection. On the one hand, technological innovation leads to structural societal changes that translate into changing practices, relationships, values, attitudes, customs, norms and ethics. On the other hand, these (and other) structural changes within society determine what kinds of further innovations are pursued and how this is done. This continuous feedback mechanism is elaborated in more detail by looking at how attitudes towards innovation have changed over time and how they have become more subject to optimisation.

The impacts on space of these mechanisms are subsequently assessed in more detail, in an endeavour to shed light on the historical relationships between space and societal needs / social changes. This results in two main findings. First, the relationship between space and society is a very peculiar one – different from most other types of technology. This is caused by the specificities of the outer space environment and space technologies, which necessitate strong governmental involvement by means of public governance and investments. Because of this, space serves as an environment and tool for addressing what can be described as "societal needs", rather than market needs. Because of their wide scope and diversity, the fulfilment of societal needs is subject to different dynamics. Both features should be taken into account in the future outlook when assessing changing technologies, markets, societal needs, and the role of the private sector. At the same time, it is to be noted that space itself structurally affects the evolution of human society and its societal needs, illustrating that this "endogenous" variable should be taken into account when looking ahead in time.

In order to assess the major societal needs Europe might need to address in the future, the study identifies – based on a broad review of the literature – a set of unfolding mega-trends that are bound to generate profound transformations in the global environment up to 2030. The most discernible pattern of change is offered by the progressive expansion and ageing of a global population made up of increasingly empowered individuals. Among the major factors underpinning – and benefiting from – this rise of "people power" (increased urbanisation and mobility of people, growth of the global middle class, near-universal access to education, health care advances, reduced gender gap, etc.) is technological innovation, which can be expected to broaden and accelerate.

Over the next 15 to 20 years, the technological landscape is projected to become ever more dynamic, with new technologies being adopted faster, and innovation cycles becoming shorter and shorter. Besides accelerating advances in individual technological domains (e.g. ICT, robotics, manufacturing, health and resource technologies, etc.), future technology trends are expected to be marked by an increasing convergence of new technologies that could lead to paradigm-shifts in the way economies and societies function.

Greater social development will be likely accompanied and offset by increasing pressures and constraints in access to natural resources. Primarily owing to the increase of the world population and expansion of a global middle class, the demand for food, water, energy and other commodities will increase virtually exponentially over the next 15 to 20 years. This increase in demand will however take place in a more challenged environmental context, which could potentially lead to scarcities, in addition to causing large-scale disruptions and exacerbating geopolitical tensions.

The world of 2030 will in all likelihood be multipolar, with a pronounced shift in economic and political power from the West to the emerging non-Western world, but also downward to the level of individuals and non-state actors (e.g. smart megacities, transnational corporations, and civil society). Owing to this accelerating shift in national power and transformation in the nature of power, no single country will be able to play a hegemonic role comparable to that played by the U.S. over the past 25 years, and this will have far-reaching impacts on world politics. As power becomes more diffuse and spread across different types of actors, global governance may become more fragmented and less effective in managing future economic, political and societal problems, at a time, however, when increasing interdependency will make the need for collective responses more crucial than ever.

While these unfolding mega-trends do not *per se* provide a well-defined picture of how the world will look from 2030 onward, their identification is nonetheless helpful to identifying the ensuing societal challenges that Europe may face in the years to come, and they are thus a necessary element for European policy-makers to address in a timely manner. The most visible appear to be those that relate to the ageing of the European population, the likely growth of urbanisation, the increasing mobility of people, and the consolidation of the information society, and those related to the state of the environment and the use of natural resources. In tackling these multiple challenges, space appears to be able to make a strong contribution, and key examples are provided to demonstrate this great potential.

Following this, the multiple ways in which space-based solutions could play an important and at times essential role in preparing for the future are outlined. All in all, this reveals that Europe will increasingly need to design new services centred around citizen's needs, possibly integrating navigation, Earth observation and communications space systems with ground infrastructure, to ensure monitoring and forecasting of the environment of Earth and space, availability of integrated mobility solutions, and innovative ways to provide welfare solutions to the ageing European population.

Space technology will substantially contribute to new ways to move in cities and around the globe, by enabling the deployment of cars with automatic driving systems, and potentially facilitating ultrafast point-to-point transport moving through air and space. Space programmes designed around a world changing at a fast pace will, on the one hand, have to be flexible, and on the other hand, more and more resilient, thus ensuring optimum services essential for the functioning of the society of tomorrow.

As outlined in this report, climate change is one of the most significant challenges and there space will play a key role in providing data for long-range and climate forecasts, and in supporting the development and implementation of appropriate mitigation and adaptation measures. New services of Earth Observation programmes may even provide accurate measurement and control of localised carbon dioxide emissions, thus potentially providing a further effective tool in support of the activities of the United Nations Framework Convention on Climate Change (UNFCCC). Particularly in fast developing regions, governments can provide major carbon dioxide producing companies with precise information on their emissions. This enables the implementation of mitigation measures and enhances compliance with international environmental agreements in line with goals agreed in implementation of the COP21 outcome.

The report also highlights the opportunity for the European Union in creating market opportunities while addressing the major challenges ahead. The creation of a European digital single market, new platforms aggregating space data and Internet of Things information, and the full implementation of Industry 4.0, of which Space 4.0 will become an integral part, indicate the multiple ways in which space can play an important and sometimes essential role in fulfilling the vision of a new European renaissance.

In order for space to be in a good position to cope with future societal challenges and expectations, it must be ensured that the links between space technology and innovation on the one hand, and society on the other, are steered in the right fashion and the right direction.

For a long time, meeting societal needs was mostly the focus of governments, but over the last decades this has started to change as private and non-governmental actors have become involved. Nevertheless governments have a responsibility to ensure long-term sustainability for their citizens, ensure solidarity between different social groups, and set up mechanisms to ensure intergenerational solidarity. So, even if public entities are helped in the collection and addressing of societal needs, the government still has the duty to track and map the overall process in order to guarantee the democratic character of mechanisms aimed at fulfilling societal needs. This means that different governments and public organisations have to set up interaction and communication mechanisms to stay informed about developments and societal needs and potential solutions in different fields. The first thing to do, however, is to identify stakeholder groups that might have different - and often conflicting - needs and expectations. The next step is to qualify and collect their needs. In this respect, this report has identified and discussed a number of possible mechanisms, including the deployment of Virtual Observatories, Social Media and Liaison Offices. Irrespective of their specificities, what needs to be highlighted is that to be effective, these potential instruments have by necessity to address the complex interaction among societal expectations so as to integrate different needs in one model and identify scope for potential synergies when addressing them.

Once societal needs are collected, it is important that the right steps are taken to address them. In this respect, governments must not only be informed about all potential societal needs, they also must have a clear understanding of, and approach to, how societal needs can be best served. They can choose either to fulfil these needs themselves, or to let the market find solutions to certain needs. In reality, however, this often calls for complementary, mutually reinforcing approaches, since the division between public and private sector involvement is in fact an either–or fallacy.

Although all societal needs should be regarded as being important, the perennial limitation of resources may not allow addressing all of them at the same time. While the eventual decision to cope with one societal need over another will ultimately play out only in actual political discourse, establishing a ranking among needs could nonetheless provide decision makers with some guidance in the process of determining societal spending priorities. In this respect, this report argues that the deployment of the abovementioned mechanisms of dialogue can not only be used to qualify societal needs; but could also be used for ranking different needs and, equally important, for measuring the preference intensity of those needs so as to establish preference patterns and truly stimulate the "societal pull" rather than envisaging ex ante technological solutions to meet such "pull".

This report also goes into some detail on the 'push' side by, for instance, recommending the establishment, at both governmental and industrial levels, of central registers for good ideas that at the time of their formulation were perhaps not feasible to implement, but that could become relevant once the context changes. Similarly, it might also be worth considering whether large institutions, such as the EU and ESA, could benefit from establishing the function of a "Chief Innovation Officer", who would work under or parallel to the Chief Scientist and ensure that innovation is pursued much more intensely wherever it has the prospect of leading to improved outcomes in the long run.

Finally, the report identifies how European society can be made future-proof in the long run by taking certain actions now. Among the various measures, it is in particular proposed to evaluate and revise education systems in order for students in the future to be in a better position to think out-of-the-box and approach reality and its challenges and opportunities in a more creative and interdisciplinary fashion.

1. Introduction

In what has been merely a blink of an eye from an evolutionary perspective, humanity has become a spacefaring civilisation and has developed space technologies, applications and services that have become ever more important for the functioning of society.

Despite all our strides, or perhaps because of them, we live now in an age of disruption. This is exciting in the sense that our world is changing faster than ever before in our history. While the digital revolution is still in the midst of transforming society, recent breakthroughs – such as 3D printing – are already starting to shake up and radically alter things in a fashion we could not have imagined a few years ago. At the same time, other game-changing technologies – such as nano- and biotechnology – are maturing as a result of sustained innovation efforts that might create entirely new revolutions in the near future. But the situation is not all rosy. Since the challenges we are facing are both immense and ubiquitous, we cannot be complacent. In agriculture for instance, it is predicted that the global supply of food for the next fifty years will have to be as big as all harvests combined in the thousands of years since civilisation began with the invention of agriculture. Similarly, the challenges in the areas of energy, urban growth, security and sustainability are vast and will require adequate solutions, soon.

In light of opportunities and challenges like these, and considering the nature of scientific and technological progress as it has unfolded in modern history, it is more than likely that space assets will have a vital role to play in the future. But the very same dynamic of opportunities and challenges will also affect space itself. With new technologies and changing markets having the potential to alter the way we have been using space, the position of Europe will be less secure than in past decades. As more players enter the space arena and establish ambitious space programmes, innovation and competition will also become more likely to change the *status quo* that has characterised the post-Cold War era in space. So while it is clear that society in the future will be radically different in some respects, the same will be true for space.

This raises all sorts of questions. What will space look like in the future – say from 2030 onwards? How will society be different from that in anno 2016? And what will the differences be in how citizens, companies and governments approach space in the future? In turn, how will these trends affect the way governance, policies and programmes are conceived? The aim of this ESPI report is to look ahead in time and see how and why, in a future context, space might be approached and used in different or new ways for society in Europe and beyond.

If Europe wants to be well positioned to administer space in the best possible fashion in the future, it is crucial to have a good understanding of what is to come. Unfortunately, however, looking into the future is not rocket science – it is far more complicated and treacherous! In order to perform such a delicate exercise properly, the analysis has to be approached from the right perspective and it has to be based on the right premises. The structure of this report, which is centred on three main chapters, is devised to meet these requirements as much as possible.

Central in this structure is the way space activities contribute to society, which is visualised in Figure 1 below. Before this report looks into the future, it will explore and describe the mechanisms through which space contributes to society today. This is the focus of Chapter 2, which is represented on the left side of the Figure. From an abstract perspective, space contributes to society by addressing societal needs and increasingly also market needs. Space does this, however, not in an isolated fashion. On the one hand, it is strongly embedded in the larger context of science and technology (yellow upper left box). On the other hand, societal needs are strongly dependant on the structure of society (blue lower left box), which is in a constant interactive dialogue with science, technology and space. An understanding of the processes and contexts that determine how space addresses societal needs is a prerequisite for understanding how space might provide solutions to societal needs in the future.

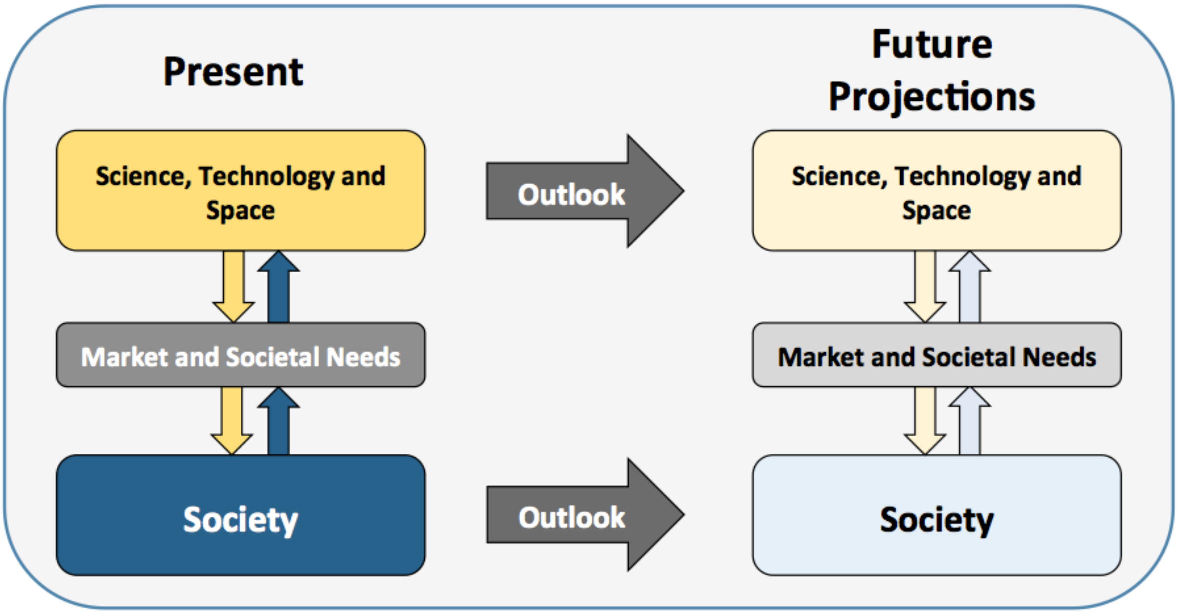

Figure 1: The Links between Space, Society and the Future through Societal Needs (Source: Authors' Visualisation).

Subsequently, Chapter 3 and Chapter 4 will focus on how space might address societal and market needs in the future. In this respect, the report identifies a fair number of new candidates of societal needs, and potential space solutions to address them.

Following this, Chapter 5 will shed light on the mechanisms that need to be in place or evolve in order for space to address societal needs in an optimal fashion. This includes the policy, governance and interaction schemes that link space to the rest of society and determine the context in which actors can use space technologies and services to the benefit of European society. In addition, this chapter will also look at how European society can be made 'future-proof', referring to the actions we can take now to facilitate and foster the transition to the future (the flow from the left to the right side of the figure).

Finally, the main findings of report are set out in the conclusions, which also contain concrete recommendations relevant for many actors in the European landscape that have a major role to play in shaping the future. This is done in Chapter 6.

2. The Future, Society and the Role of Space

» "The future depends on what you do today."
— Mahatma Gandhi

The objective of this report is to see how space activities in the future might be used by society in a different fashion and what the consequences of this will be in terms of how – and by whom – space is used. Before such an exercise can be performed it is necessary to figure out how to set it up and orientate it. In this respect Chapter 2 aims to provide a set of reflections and insights that will elucidate the link between space and society. It will do so not only by looking at the historic developments in this relationship, but also by distilling some universal trends that are dissociated from that particular relationship. The latter is necessary to see how society and space will interact to address societal needs in different circumstances and contexts. First, however, this chapter will sketch some of the common pitfalls that occur when predicting the future.

2.1 Looking Ahead: Prophetic Visions or Retrospective Illusions?

People have always been intrigued by the future. In the past, those who claimed to see what the future would bring – from Mayan priests to medieval fortune-tellers – were attributed supernatural talents that in turn often gave them status and power. Nowadays, society tends not to rely on these superstitious practices of old. Nonetheless, we are still very strongly fascinated and occupied with what is to come – perhaps even more so than in the past. Visions for the future are not only an explicit undertaking, they are also very much embedded in many more subtle ways in everyday activities. In fact, the contemporary nature of human existence is fundamentally permeated by the idea of an unfolding future that can be anticipated and actively shaped. This perception underpins the rationale of very divergent human activities such as ideology, religion, politics and international relations, scientific research, and overall societal planning and organisation.

This raises the question of how we can imagine and thus characterise the future. Humanity's farthest-reaching sense of upcoming change is probably channelled through one of its oldest cultural practices: art. The symbolic ideas and interpretations behind the works of visionary artists sometimes herald paradigm shifts in society at large. This process is also reflected in popular forms of culture such as literature and cinema, which have developed entire genres devoted to imagined futures. In some science fiction works, such as Star Trek, humanity finds itself amidst a wave of galactic colonisation, whilst others offer the unsettling prospect of a dystopian world, such as those described in Aldous Huxley's '*Brave New World*' or George Orwell's famous '*1984*'. All in all, the flights of fancy in science fiction have resulted in extremely divergent conceptualisations of possible future realities. Most of them did not, or will not, turn out to become reality. But then again, offering an accurate outlook of the future is not what science fiction is supposed to do in the first place.

In a sense, science fiction stories probably reveal more about their authors and their society than about the future itself. When the makers of the early 1900s French visual series "*en l'an 2000*" imagined the world a century later they envisaged flying fire-fighters with flapping bat-like wings attached to their backs and mechanically powered machines that would transmit printed knowledge from books directly into pupil's heads by means of wires. Instead, we got helicopters and the Internet. The ideas the makers had in mind turned out to be hypothetical solutions for genuine societal needs. The way these needs were eventually addressed, however, is fundamentally different from what they could foresee. Not only were they addressed with different solutions, but the technologies upon which these solutions are built have numerous other applications. Mismatches like these occur, even at present, because of the trade-off between freedom of imagination on the one hand and the uncertainty of predictions on the other. In hindsight, many of these so-called 'retro-futurism' examples are comical because they are based on linear extrapolations of how people perceived progress and its direction in their days. Societal change, however, does not lend itself to being predicted in this way.

To minimise the risk of this fallacy, and thus to allow more accurate predictions to be made, certain branches of society approach the future from a more scientifically substantiated perspective. All over the world, governmental agencies and institutes, international organisations, academic institutions, think tanks and other types of observatories are concerned with offering future outlooks as they try to identify trends, tipping points and potential game-changers within their fields of study. Even here though, in many of their familiar and specific research areas, many attempts to make accurate predictions have failed, in some cases even miserably so.

There is an abundant record of instances in which predictions about societal evolutions have proved to be strikingly wrong in either their lack of inventiveness or excess thereof. It is for instance well known that in an internal Memo of 1876, Western Union confidently stated that the telephone had "too many shortcomings to be seriously considered as a means of communication". On the other side, in 1955 Alex Lewyt, president of the Lewyt Corporation, was forecasting that nuclear-powered vacuum cleaners would have become a reality within the next 10 years. In the longstanding debate between future predictability and unpredictability, these type of misfires inevitably appear to validate the point that Noam Chomsky so eloquently made when stating: "The record of prediction in human affairs has not been inspiring, even short-range. The most plausible prediction is that any prediction about serious matters is likely to be off the mark, except by accident".[1] This is not only true for the potential of specific inventions but also for society at large. The Great Recession that followed in the aftermath of the global financial crisis of 2007 has severely affected European cohesion and the effectiveness of governance in ways that strongly contrast the optimism that characterised the continent in the early 2000s. A decade ago, when growth figures were still expressed in multiple percentage points and the introduction of the Euro as a currency set high hopes for European integration prospects, the outlook was very different from the reality of today.

Particularly at a time when the world seems to be experiencing change at an unprecedented speed and intensity, it is undeniable that there are inherent and perhaps insurmountable trapdoors when it comes to our capability to anticipate the future. Yet, awareness of such challenges diminishes neither the need nor the value of foresight exercises. The fact that predicting the future is not exact science, and thus often fails, does not mean we should not reflect on how the future might look or that predicting cannot yield valuable conclusions. On the contrary, it is crucial to keep our eyes open and to anticipate changes and their potential implications. Just as for an individual, a society that does so sensibly will find itself able to tackle upcoming challenges faster and better and it will be strategically well positioned to reap benefits from arising opportunities. Both result in lead-time and other competitive advantages compared to other societies that anticipate the future less, or in a less effective fashion. Therefore, future-oriented societies will be better positioned for economic growth and societal well-being, and will be in a better position to maintain, and even expand, their influence and power in the world. This principle was well understood by the renowned policy planner George F. Kennan, architect of the U.S. containment policy vis-à-vis the Soviet Union at the dawn of the Cold War, who believed that predicting the future is not about getting it right or wrong, but about ensuring that current policy settings can accommodate whatever might come. Looking into the future is thus not only interesting, but vital!

The fact that many futuristic visions of the past have so far become illusions rather than visionary forecasts should not discourage us from continuing to look into the future. Rather, it should make us reflect, as a society at large, about how we can do so in a more sensible and nuanced fashion so as to derive more useful estimations that in turn allow us to take wiser action. This implies that for every attempt to look into the future or certain aspects of it, a proper framework must be used which fits the scope of what one tries to foresee.

A variety of techniques have been deployed in the field of future(s) research to advance our foresight capacity. Trend extrapolation is perhaps the most widely used approach. In this method, future developments are predicted by assessing and projecting historical and present trends and cycles - which are known as data points - into a future time frame by *inter alia* making use of mathematical techniques. Another well-established approach is provided by the so-called Delphi method: a structured and interactive forecasting technique based upon the interactions of a panel of experts that progressively converge toward a final result. This approach is

[1] Chomsky, Noam. "Language Design". In: Sian Griffiths (ed). Predictions. Oxford University Press. 1999: 30.

intended to make better use of expert knowledge rather than relying on mathematical trend extrapolation. An additional relevant method is provided by futurology, the study of postulating possible, probable and preferable futures through the use of both quantitative and qualitative data. Futurology makes use of wild cards to highlight potential changes to key features of the global environment that can substantially affect how the world will work in the future. Scenario planning is another relevant method that has grown out of military organisations and has gained much adherence in industry. It aims to conceive and analyse several plausible future states, according to alternative conditions. It usually draws up extreme (best case, worst case) or typical scenarios. Simulation – the imitation of some real thing, state of affairs, or process to show the effects of alternative conditions and courses of action – and prediction markets – virtual market places where people trade shares of persons/events/outcomes in order to gather and aggregate relevant information – offer two additional modalities for anticipating future developments.

While each of these approaches entails specific characteristics, the common trait that unites all is that they only in part aim to draw exact predictions about future developments. Their most important objective is rather to provide the tools for understanding the present from a wider perspective in order to prepare for and pro-actively shape what may eventually come.–Similarly, this report does not seek to provide a well-defined picture of what the world will look like and how it will work in the future. Rather, it focuses on the future potential of space for European society at large. In this context two issues that could hamper a forward-looking analysis should be given regard:

- *Wider Focus:* space is part of the more embracing field of Science and Technology (S&T). By focussing on space only, the risk exists that certain mechanisms or developments in the wider fields of S&T that could impact space in the future will be overlooked. As this would be detrimental to the attempt to look at the future potential of space, the general relationship between science & technology and society has to be characterised before focussing on space specifically. A central concept in this respect is innovation, which – as will be demonstrated – serves the function of a bridge between societal progress and technological advancement. This is the focus of section 2.2.
- *Historical Perspective:* in order to avoid linear extrapolations based upon the contemporary situation, it is necessary to shed light on the generic principles that have determined the historic relationship between space and society. Although space is part of S&T at large, it has certain particular characteristics that have strongly influenced the way society has dealt with space. The economic, technological and societal specificities of space utilisation have determined which actors have become involved in space innovation and how their innovation was pursued. In turn, this has also determined how space has structurally affected society and societal changes. These elements will be explored in section 2.3.

2.2 The Link between Science & Technology and Society: Innovation

In order to characterise the relationship between science & technology and society over time, one must look at how advances in S&T and changes in society are related over very large time scales.

2.2.1 Societal Change and S&T Advancement

Over the past centuries and millennia, humanity has made incredible advances that have fundamentally changed nearly every aspect of human life. At first sight, one is inclined to ascribe the reasons for these profound changes to new inventions and technological innovation.[2] After all, it is things like the discovery of antibiotics and the mass production of consumer goods such as cars, radios, telephones and the television that have increased the quality of life; making it easier, more comfortable and radically different from the past. This is an observation that can be made for today, as well as for most times in the past when compared to the time before.

But of course societal change is neither expressed nor constituted solely by new, better and more advanced technologies. In addition to developing technologically and materially over time, human societies worldwide have, alongside, also radically changed in their

[2] Innovation is defined as a new idea, more effective device or process. Innovation can be viewed as the application of better solutions that meet new requirements, unarticulated needs, or existing market needs. This is accomplished through more effective products, processes, services, technologies, or ideas that are readily available to markets, governments and society.

social structures. Although newsreaders will always perceive that we live in dangerous times, statistical and social analyses reveal a very different general picture: in spite of occasional tempo-spatial regressions, the overall long term direction of these social changes and developments has been a progressive one – not random! By nearly all imaginable parameters, contemporary societies score much better than they did in the past. Not only has the world become much less violent, it also has become more inclusive and fair for more people. Woman's rights and the protection – and even empowerment – of minorities, have replaced witch burning and commonplace discrimination. Large scale institutionalised suppression and systemic exploitation of people (such as slavery and systems of formal social stratification) have been replaced, in most parts of the world, by human rights and increasing individual freedom. Obviously a lot of work remains to be done in many fields and in many places around the globe. The point is, however, that the overall situation is progressing and that there is no reason to assume that this progress will halt in the (near) future. On the contrary, recent modern history even hints at an increasing rate of societal progress in many areas.

The reason why societal and technological progress has developed so much in parallel has to do with the way they influence each other.

On the one hand, innovation leads to structural (economic) changes that translate into changing practices, relationships, values, attitudes, customs, norms and ethics. In this sense innovation facilitates social change, and it typically does so in such a way that society can eventually find new equilibriums that are more complex in structure than before the advent of the innovation. In turn, this increased complexity is a necessary – but not in itself adequate – condition for concepts such as stability and democracy to be established and maintained at large scales and over longer periods of time. For instance, it is hard to imagine how social achievements such as universal suffrage could have arisen without the social revolutions that emerged in the then newly urbanised cities in Europe that in turn were made possible by technical inventions such as the steam engine. Similarly, innovations in household appliances such as washing machines in the 1960s – 1970s were of great importance for the entry of women to the labour market, which in turn became a milestone in the overall process of women's position in society and more gender equality in the long run.

Conversely, the structure of and changes within society will determine what kinds of innovation are pursued and how this is done. In this sense society determines – at least to a certain extent – its own possible future development paths since its own structure or context will have ramifications for how innovation is pursued and how it will create benefits and opportunities that can in turn be used within that society. The focus of innovation efforts can be influenced by internal societal changes such as changing demographics (population growth or ageing) that necessitate and force breakthroughs in production methods or new technical applications. But they can also be determined by particular external contexts such as war or conflict – which have always been an extremely strong driving force behind the focus of technological innovation. Examples of war-related innovations include radar, computational science and rocketry. Other important changes can arise as a result of shifting values, priorities or changing trends, such as the establishment of universities in medieval Europe, the impacts of the Renaissance and the Age of the Enlightenment, or the widespread introduction of compulsory education in Europe in the 19th century.

That technological advancement and societal changes are generally characterised by a progressive development is because at a deeper level they are part of the same unfolding reality. This reality is steered by innovation, which not only has a technological dimension but also a very prominent social one.

2.2.2 Changing Attitudes Regarding Innovation

The dialectical relationship between technical and societal innovation has grown organically over time and has spread ever wider. This is the reason why innovation itself is subject to profound changes.

As a general trend, efforts related to technology optimisation and the pursuit of new inventions have become more pronounced over the last centuries. Moreover, a general understanding, even an expectation, has emerged within society that technology and societal life at large will change continuously over time, as evidenced by the examples of futurism and the more rational forward-looking activities illustrated in the previous section.

Yet, this understanding can be expressed at different intensities within the fabric of society and thus it can evolve over time. For a long time society and individuals approached innovation from a trial-and-error perspective. This type of approach with respect to innovation took place on an ad-hoc basis, was rather random and singular in the sense that its sole focus was to improve efficiency or productivity of a certain technological process or product.

Only more recently has innovation received a paradigmatic dimension as our approach towards it started to change as a function of overall changes in technology and society. In this respect, distinction should be made between how innovation paradigms have changed on the company level (micro perspective) and how innovation is dealt with on the overall economy level (macro perspective).

On the micro-level, this has happened as a result of a "snowball effect" whereby the concept of innovation itself has become subject to academic study and evidence-based science aimed at continuous optimisation. As a result, the dominant innovation model in society has shifted approximately every decade since the Second World War, changing the way companies position themselves with respect to the market and their surrounding context, thereby thoroughly affecting market and societal structures. A concise overview of the different models of innovation and their characteristics is presented in Table 1 below.

Model of Innovation	Structure	Concept	Context
1. Technology Push	Linear	More resources into R&D will result in more successful new products for the market.	· 1950 – 1960s · Strong economic growth · Capacity and R&D development in companies
2. Market Pull	Linear	Introduce new products based upon market demands, often based on existing technologies.	· Mid 1960s – mid 1970s · Relative wealth, low unemployment · Focus on needs and consumer demands
3. Coupling of R&D and Marketing	Dynamic	Combines the insights of technology push and market pull with feedback loops.	· Mid 1970s · Economic crisis · Inflation and saturation of markets · Shift towards rationalisation, consolidation, control and cost reduction
4. Systems Integration	Dynamic	Parallel use of integrated research teams, and involvement of supplier and main customers. More linkages and alliances.	· 1980s · Focus on knowledge · Shorter product lifecycles · Market both at beginning and end of innovation process
5. Networked	Dynamic	Flexible organisational structures, extensive networking, IT approaches, collaboration with external partners.	· 1990s · Changing IT landscape · Strong globalisation
6. Open Innovation	Open	Paradigm shift from closed to open innovation. Wide variety of approaches to spur innovation, both in and outside the core company.	· 2000s · Innovation solution depends on the need. · More tailored to individual sectors and cases.

Table 1: Evolution of Innovation Models (Source: Authors' Visualisation).[3]

[3] Based upon: Žižlavský, Ondřej. "Past, Present and Future of the Innovation Process" International Journal of Engineering Business Management 47.5 (2013): 1-8.

Although each type of innovation paradigm has its own specificities and 'older' versions can still be very relevant today depending on the context and activities concerned, there have been two trends within the overall evolution:

1. As a general rule, innovation approaches have become less constrained by 'traditional' barriers – elements that were often taken for granted in previous approaches (e.g. internal departments, internal company matters, national borders, sector borders, technology scope, and types of collaboration or production methods).
2. New paradigms have developed in a way that incorporates and reflects an ever better understanding of the factors that might be relevant for innovation performance (IT, efficiency, changing market structures, etc.).

On the macro-level, the implications of this understanding developed a bit later. From early times societies protected the efforts of inventors and innovators through patents and other types of intellectual property protection. After the Second World War, more and more governmentally funded organisations were set up to deal with R&D in specific areas where state involvement was advised (such as the military sector, telecommunications and space). The scope of these efforts was relatively narrow and specific and mostly related to the core activities concerned. In addition, this innovation was pursued in a stove-piped fashion – meaning that the efforts and outcomes related to R&D efforts remained distinct from one another and, that they were only slowly translated into wider technology areas that could benefit society at large.

The idea that societies should invest in general purpose R&D at large and set up programmes and policies to do so only developed a few decades later. This process gained impetus on a level of theoretical economics when in the early 1980s growth theorists developed the "*endogenous growth theory*", which holds that economic growth is primarily the result of endogenous and not external forces. This was the first theory to incorporate and reflect the understanding that investments in human capital, innovation, and knowledge are significant non-predetermined contributors to economic growth and that therefore, policies which embrace openness, competition, change and innovation have to be developed so as to ensure long term economic growth in a modern society. At the same time, the ideological rise of neoliberalism reinforced the belief that markets are a main driving force in generating wealth and economic growth and that they should be given the means to use and develop technologies for this purpose.

Because these paradigms reverberated throughout Western society at large at the time, it did not take long before these insights were put into practice. In the United States and Japan, private industries were encouraged by their governments to translate maturing technologies into consumer products for the mass market. This development spurred a strong innovation dynamic in household appliances and computing technologies. In Europe, these insights led to the Europeanization of R&D efforts. Upon the suggestion of the French President François Mitterrand, the European Community developed a large-scale research and development initiative: the so-called Framework Programme (FP). The resolution instituting "framework programmes for Community research, technological development and demonstration activities", adopted in July 1983, laid the basis for a new type of European policy activity aimed at spurring innovation that has become an increasingly important part of EU policies ever since.

Since these public R&D investments are aimed at benefiting society and the economy at large, the European Framework programmes seek to spur the development of technologies that have a wide and promising applicability and potential. At the outset of the FPs the focus was on telecommunication and computing technology. In FP7 and its successor Horizon 2020, the EC has given a central role to what it has coined "Key Enabling Technologies" (KET). More specifically, these are: nanotechnology, micro- and nanoelectronics, photonics, advanced materials and, biotechnology. Being highly multidisciplinary in nature, they are present in many technology areas and tend to bring a multitude of applications. In this sense they will enable processes, goods and service innovation throughout the economy and thus they have a systemic relevance as highlighted by the Commission.[4] In terms of shared characteristics they all have high R&D intensity, rapid innovation cycles, high capital expenditure and high-skilled employment.[5]

[4] Commission of the European Communities. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: "Preparing for our future: Developing a common strategy for key enabling technologies in the EU". COM (2009) 512 final of 30 Sep. 2009. Brussels: European Union.
[5] Ibid.

		Rivalry	
		Rivalrous	Non-rivalrous
Access	Non-excludable	**Common-Pool Goods**	**Public Goods**
		Near-Earth space environment *(e.g. commonly used Earth orbits and orbital slots, frequency spectrum)*	Space at largest scales *(e.g. for planetary and solar system exploration)*
	Excludable	**Private Goods**	**Club Goods**
		· Telecommunications · Launchers · Human Space Flight	· GNSS signals · Earth observation data · Space science

Table 2: Economic Classification of Goods and the Position of Space Uses (Source: Authors' Visualisation).

2.3 Space and Society: a Historic Perspective

The dialectic interaction between society and science & technology, as illustrated in the previous section, has also played out in the relationship between space and society, albeit in a particular fashion. This section describes how society has approached space and illustrates the main mechanisms through which space utilisation has facilitated societal change.

2.3.1 How Society Approaches Space: Societal Needs

There are some particular features related to space technologies and the use of the outer space environment that have strongly defined the way society has dealt with space, and how this relationship has changed over time.

The characteristics of space as an environment impose some boundary conditions that have repercussions on how it can and should be managed. In economic terms, outer space is a non-excludable "good", meaning that access – once having launcher capabilities – cannot be denied or excluded, just like 'access' to the atmosphere and the oceans is generally non-excludable. At the largest scales, the use of space is also non-rivalrous, meaning that the use by one does not reduce availability to others, regardless of the number of simultaneous users. In practice, however, the vastness of space and the non-rivalry that relates to it, does not apply. Since space is used mostly for specific applications and services that are constrained by the different types of orbits, their characteristics, and the exhaustibility of communication means between spacecraft and ground segments, there is significant rivalry in near-Earth space utilisation. Not only is this the case for limited duration mission-specific uses, but also in terms of long term sustainability, as evidenced by the pressing issues of space debris and traffic management. This, together with the safety and security concerns that arise from having space access, has led to the establishment of a global framework setting out the principles for the use of space. This regime of use, as embodied by the different international treaties and principles of the United Nations (UN) framework, puts a very strong emphasis on the peaceful use of outer space and the fact that it should be used to the benefit of humankind.[6] These elements call for a minimum of regulatory schemes and the related public governance and management of space, and they treat the near-Earth space environment as a "common-pool good" (see Table 2 for an overview).

On the level of individual types of space uses, applications, and services – all of which are excludable in terms of use – the situation is more diverse. Still, these areas are very much dependant on strong public sector involvement.

Services like GNSS and EO are considered club goods because their respective signals and data do not decrease in quality as a function of the number of users. Yet, their use can technically be restricted and controlled

[6] More precisely these are: the 1967 Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies, the 1968 Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space, the 1972 Convention on International Liability for Damage Caused by Space Objects, the 1975 Convention on Registration of Objects Launched into Outer Space and the 1979 Agreement Governing the Activities of States on the Moon and Other Celestial Bodies.

and is therefore excludable. The reason for strong government involvement in these areas is a market failure. Although their excludability in use makes it theoretically possible for private sector actors to provide them at a price, other mechanisms largely exclude this option. Major impeding factors in this respect are the huge investment costs and risks companies would face in commercially developing and exploiting these systems. In addition, governments also have an interest in owning EO and GNSS capabilities, as both are strategic goods with security considerations and dual use applications.

Although launchers, human space flight and space science activities are private goods in economic terms (i.e. they are both rivalrous and excludable), they are still very much under control of governments because of strategic and scientific objectives. Recently, however, thanks to the commercialisation trend in space, private sector involvement in these areas is increasing, both within governmental programmes as well as outside, such as in space tourism. A remarkable exception to the overall trend is the telecommunications sector, which was largely privatised in the 1980s because of its unique predisposition to commercialisation (critical mass in market demand, proven technology, manageable risks and complexity).

All in all, governments worldwide are responsible, in one way or another, for the provision of most space-related services and benefits. Even when the development and integration of the technical systems is often procured from or outsourced to private space industry, governments are and remain in most cases the end customers.

A crucial reason why this is so strongly the case for space compared to other sectors is that space addresses societal needs, rather than strictly defined consumer demands. Societal needs, in their most essential meaning, are immediate needs that are present within a society or considerable parts within it at a given time. While some needs may arise, vanish or change over time, others will never change because they go back to intrinsic human nature. Structurally, they can be divided into different categories according to their characteristics in terms of accumulation:

- *Aggregated Needs*: needs that are the sum of individual needs of people and actors (such as food, water, energy, natural resources etc.).
- *Collective Needs*: only arise at a critical mass and relate to functions that benefit society at large (infrastructure, security etc.).
- *Meta-societal needs*: social, economic and political needs that have a group dimension but are, in essence, independent of the number of people (democracy, liberty, social inclusion, transparency, autonomy, competitiveness etc.).

Because of their versatility, space technologies and applications – and even the sector at large – generate benefits and solutions that are much more transversal and present within society generally. In this sense the space sector and its applications help provide solutions for various societal needs of different natures: aggregated, collective and meta-societal. This is the main reason why the types of space use that are classified as "private goods" – i.e. that have the highest commercial viability – are still, even today, to a very large extent under public control, management and governance. It is also the reason why space uses in the category "club goods" are mostly provided free of cost (e.g. Copernicus and Galileo in Europe), in spite of the fact that it is technically possible to provide them at a cost. By providing them through public funding at no cost to the user (at least for basic use), the socioeconomic and strategic benefits of these systems can propagate throughout society much more freely than when a cost, even a low one, creates entry barriers for citizens, companies and governments.

Because of the features described above, space technology development and innovation have been pursued in a manner that is different from other types of technology.

As a general trend, the paradigm shifts that have affected technology innovation in society at large (as presented in Table 2) have been less prevalent in the space sector and can therefore not be literally mapped onto it. There have been, however, noticeable trends in terms of who is pursuing space innovation and in what ways these trends are linked to innovation paradigm shifts in the rest of society and the economy. Although the exact timing of these developments has played out differently in various parts of the world (e.g. United States versus Europe), the resulting general propagation has been largely similar and the overall evolution can therefore be visualised in an abstracted fashion. This is done in Figure 2 below, which shows how over time more actors have become involved in pursuing space innovation and how new approaches have been introduced.

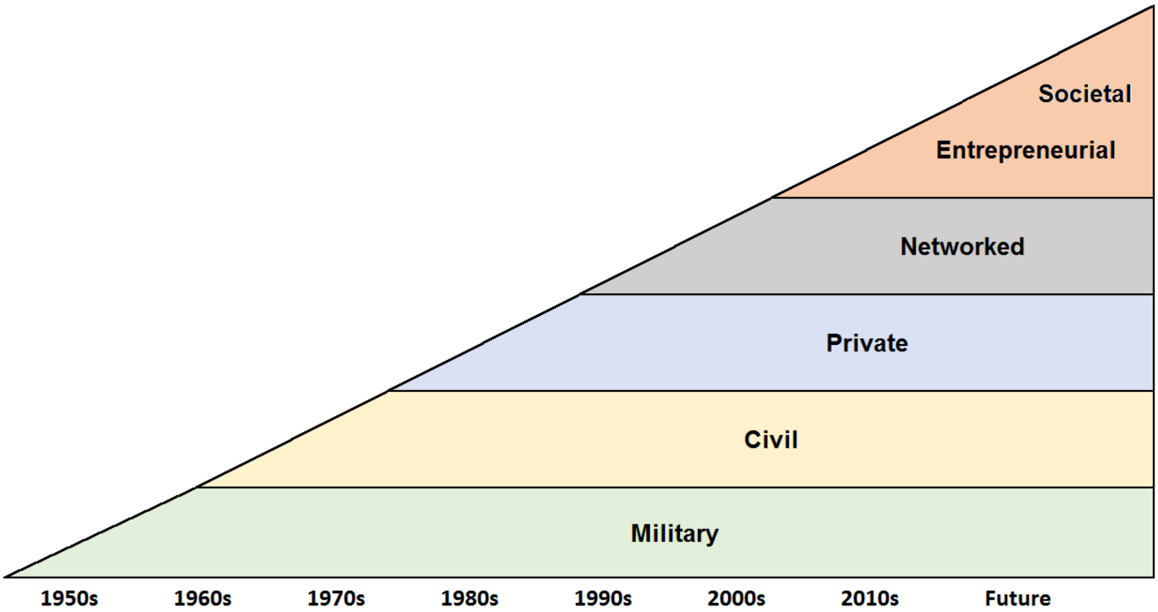

Figure 2: General Evolution of Space Technology Innovation Approaches (Source: Authors' Visualisation).

In the run up to and at the dawn of the space age, during the 1940s and 1950s, space technology development was mainly in the hands of military departments and actors and the applications were narrow in focus (first generations of launchers, telecom and some proof of concept missions in Earth Observation). This type of development was not only very much focussed on technology push – as was most innovation at the time – but it was also secluded in the sense that it was highly classified and that society at large did not have a high degree of visibility or interaction with its progress.

Once the potential of outer space utilisation was proven, both for unmanned missions and human space flight, a civil dimension to space innovation was added to the military component. It was at the outset of this phase, in the 1960s, that the major national space agencies in Europe were established, followed somewhat later by the establishment of ESA in 1975, after the first attempts to create pan-European space institutions had been made with ESRO and ELDO. Since the emphasis on civil space at the time was very much on development, space agencies worldwide initiated a strong innovation phase in space that led to a very fast increase of capabilities in nearly all basic areas: telecom, navigation, Earth observation, scientific instrumentation, human space flight etc. Not only did the innovation lead to better performance of spacecraft and their instruments, space agencies also increased overall system robustness that reduced failure rates, and their activities created a critical mass of institutional demand in society which allowed a market to emerge.

In turn, this allowed a phase of privatisation in the 1980s, whereby certain public sector activities were given to the market – in line with the general trend of neo-liberalisation that strongly characterised economic reform at the time. This trend mainly affected those space sectors that focused on "private goods": the launcher sector (Arianespace) and telecommunications (Eutelsat, Intelsat). In addition, it fostered the emergence of a significant private space sector in Europe that, over time, started to scale up by means of acquisitions and mergers into a sector with a few central large system integrators, supported by subcontractors and suppliers that were often part of their corporate structure. Since private sector is by definition more focussed on the needs of the market, innovation practices in the segments concerned shifted somewhat from technology push to demand pull, as the industry kept a closer eye on the evolving needs of the markets and adapted production and R&D efforts accordingly. Still, because of robustness requirements in space technologies and launching costs, innovation practices remained fairly conservative compared to advances made in technologies for terrestrial use.

Throughout the 1990s, the different actors in the maturing space ecosystem, especially the civil and private actors, started interacting in a more integrated and networked fashion, drawing inspiration from the system's integration and networked innovation paradigms that had gained a foothold in society at large. Space agencies set up new platforms aimed at more systemic approaches to integrating product development in a way that emphasised the response to customer expectations

– such as NASA's Project Design Center at the JPL (opened in 1994) and ESA's Concurrent Design Facility at ESTEC (opened in 1998).[7] In the industrial landscape, space innovation practices developed a more dynamic structure. Practices such as industrial partnering and reliance on various forms of external collaboration, such as knowledge brokers, increased and led to less stove-piped approaches in dealing with technology innovation and the structure of value chains. Thanks to new concepts such as incubation centres, technology parks and the creation of spin-offs, innovation was pursued by many more actors and in a decentralised fashion, away from the centralised geographical innovation models to which governments had adhered for so long. This trend was supported by the rise of IT and the use of the Internet in business environments.

More recently, in the 21st century, space innovation received another strong boost from two elements: a new entrepreneurial approach and a reinforced link to society that occurred as we entered the digital age. Space technologies in the fields of launchers and human spaceflight and their markets have matured to a point where more radical types of innovation are worth being pursued from a risk – outcome perspective. In the upstream segment, a global array of commercial companies currently covers the entire spectrum of technologies in a much more disruptive fashion than in the past, including: cube and nano satellites and swarm concepts, crew vehicles, cargo transport vehicles, space station modules, propulsion systems, launch vehicles in different sizes and types, landers, rovers and probes for planetary exploration.[8] On the one hand they are in a position to do so because of a reorientation in space policies towards favouring private capacity developments and the related mechanisms that have been set up to achieve this. On the other hand the contextual factors for these "private goods" are reaching a critical mass for market mechanisms to start kicking in and become interesting for private investors.

At the same time, things are moving in the societal field. The advancement in electronic appliance technology and increased connectivity in the digital society have made it possible for space services and applications to benefit users in terms of their individual needs, in addition to the overall societal benefits that are generated on a collective level. Governments, which were interested in spurring this development and reaping the spill over effects on economic growth, made use of this development to invest in existing and new constellations in the areas of GNSS and wide-scope operational EO. This initiated a transition away from the trend of technology-push civil innovation in space programmes towards a more societal demand-pull type of innovation. Especially in the long run, when programmes like Galileo and Copernicus evolve and user requirements will have to be taken into account more thoroughly than in their design phases, this feature will become more prominent. These remarkable developments fit into a larger trend of rapprochement between space technologies and societal needs, as evidenced by developments in downstream sectors and the stronger integration of space and non-space based data and services in daily life and applications. This is a trend that can be expected to continue in the future. The potential implications of this innovation "catching up" trend will be discussed in the following chapters.

2.3.2 How Space Affects Society: the Mechanisms

All in all, it is fair to say that, in spite of its humble size, the space sector has developed capabilities that have generated vital benefits for society. In fact, these capabilities have probably been disproportionally beneficial relative to their size within the entire realm of human activities. The aim of this section is not to quantify and map the full complexity of the diverse benefits of the use of outer space, which would fall outside the scope of this report. Rather the aim is to shed light on the different mechanisms behind it so as to see how these mechanisms might change or lead to potential new opportunities in the future.

In the first instance space refers to the entire set of technologies, capabilities, institutions, programmes, companies, applications and services that result, fully or in substantial part, from outer space access, utilisation, science, and exploration. In this sense it is a very broad field of technology, highly transversal in nature and therefore strongly connected to all other fields of scientific and technological development. In assessing the nature and structure of these benefits, distinction should be made between the different parts of the value chain.

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[7] Giannopapa, Cristina, Peter Hulsroj, Arne Lahcen, and Nunzia Paradiso. Space and the Processes of Innovation. ESPI Report 43. Vienna. 2012.

[8] The list is long and includes, among others: SpaceX, Boeing, Sierra Nevada Corporation, Lockheed Martin, Bigelow Aerospace, Blue Origin, Orbital Sciences Corporation, Airbus Defence and Space, Reaction Engines Ltd. and, Starchaser Industries. For more info, consult: Lahcen, A., "The Globalisation of Space Activities: The Implications for Europe and Possible Strategies to Pursue". In: Yearbook on Space Policy 2012-2013: Space in a Changing World. Springer. Vienna. 2015: 287-332.

At the downstream end, the use of space as an environment has resulted in the emergence of applications and services that offer direct and tangible socioeconomic benefits to individual users, companies, governments and society at large. From a high level perspective, the mechanisms through which all space based applications and services contribute to society all go back to the same principle, namely, that they all advance existing human activities by adding a new dimension to the way these activities are performed. Whether in the area of Earth observation, navigation, telecommunication or science, human activities in these fields existed before we started using space and they are still performed today, in a complementary fashion, on a terrestrial basis. Yet, the new space-based perspective on these activities has had vast implications. Not only have these activities been greatly improved and optimised thanks to space technologies but because of the global perspective, they have enabled the emerging of new types of activities, services and sectors that could not have been established by using terrestrial capabilities only. Without space, weather models would have greatly reduced accuracy and navigation and telecom services would never have global coverage. It goes without saying that the absence of such space applications and services would have had devastating consequences that would have propagated throughout the different layers of contemporary society.

The space sector as a whole also provides societies with more strategic benefits. Since most space technologies – such as launchers, remote sensing and telecom – allow and serve dual use applications, they constitute a strong element of security and defence related activities and programmes. In addition, the space sector is both overlapping and interlinked with other high technology fields (such as material science, advanced robotics, nanotechnology, artificial intelligence, 3D printing and others) and therefore space programmes create different spill-over effects in terms of innovation, competiveness, autonomy and economic growth.

At the political level, space – for the reasons described above – has become an important tool in terms of prestige, influence, soft power and diplomacy.

The three levels of benefit described are the reason why space capabilities have such a strong appeal to nations and explain why at present so many states are developing space programmes and focus on developing domestic capabilities in this field.

But on an even larger spatial-temporal scale, space affects societal progress in more subtle but nevertheless structural ways. The concept of space in the context of this report also refers to the social aspects that result from being a spacefaring species. The structural ramifications of space for humanity go beyond the specific, well-known and proven tangible, strategic and political benefits that arise from space utilisation.

From a historical perspective, space has been an important driving force behind three processes that have steered societal change over the 20th and early 21st century: (1) Universal Understanding, (2) Globalisation and, (3) Environmentalism.

The first element "Universal Understanding" relates to our evolving notion of the physical reality of the universe and our position within in. These breakthrough discoveries and changing insights started over 100 years ago, when Einstein postulated his general theory of relativity. Ever since, they have intensified immensely thanks to space science missions and discoveries in related fields such as particle physics at CERN. At the same time, human spaceflight and space exploration missions have given us a sense of orientation and perspective regarding our position in the solar system and the universe at large. Together with the theory of evolution that evolved in the 19th century, the findings resulting from scientific discoveries in the areas of astronomy, astrophysics and cosmology have fundamentally impacted the changing *Weltbild* of contemporary western society. They have done so not so much in the sense that these insights have directly applicable consequences for the more mundane human activities. Rather, they have confronted us with strong insights and paradigm shifts that have forced us to look at the world in a way that is fundamentally different from how people looked at the world in pre-modern times. In addition to contributing to further rationalisation and methodological thinking in scientific endeavours and societal structures, these insights have forced us out of our comfort zones: forcing us to approach matters in more open fashions, with fewer preconceived notions and with more humility because of the realisation that our understanding of the world and the universe is limited, in spite of all scientific progress made.

The second trend, "Globalisation" started somewhat later, at the dawn of the space age. Although the concept of globalisation is typically not associated with space and space technologies, space activities have made a significant contribution to the globalisation processes that shape the world as identified by scholars. Thanks to the courageous efforts of astronauts, and scientific progress, humanity now has a much more global, all-embracing and rational perspective of the planet, the universe and the processes that have given them shape. In addition, the emergence of spacefaring capabilities in the late 1950s posed the risk of exporting conflict into outer space, which, perhaps surprisingly, forced the international community to figure out a governance model based upon global consensus - a challenge that succeeded despite the dominance of a Cold War that profoundly divided the world along ideological lines. The consensus approach is to this day expressed by the regime for outer space governance embodied by the different international treaties and principles in the UN framework. Space can thus be seen as a pathfinder for harmonious global governance schemes.

Moreover, space technologies have become an indispensable asset in the functioning of modern society, which is characterised by time-space compression, complex interdependencies and the constant gathering and sharing of information on a global and instant basis.[9] The various services provided today by remote sensing, telecommunication and satellite navigation satellites enable the global economy and society to function according to principles of immediate cause and effect. This is expressed by the global networks that spread news, information, culture and knowledge around the globe, acting as a global-scale nervous system. Finally, space-dependent technologies anno 2016 have an enormous strategic and socioeconomic value, since they facilitate the worldwide mobility and protection of data, services, material goods, cultural goods, capital and people. In this sense space has to large extent spurred the processes that constitute the core elements of globalisation as defined in the literature.

Third, space technologies and programmes have played a role in stimulating Environmental Awareness and Consciousness on Earth. The discovery of the "greenhouse effect", for instance, was made by NASA scientists who investigated the composition and characteristics of the atmosphere of Venus. But this awareness was also raised by less science-specific events. The famous Earthrise picture (see below), for instance, is often cited as an important event in creating awareness that we all live on a small and fragile spaceship called Earth: the so-called "overview effect" which was later repeated from different perspectives, including Mars and the equally famous "Pale Blue Dot" picture sent to us by Voyager-1.

Figure 3: "Earthrise", made by astronaut William Anders during the Apollo 8 mission in 1968 (Source: NASA)

In turn, this realisation was further substantiated by the data from the series of meteorological and environmental monitoring satellites that was launched in the second half of the past century. These missions, and the scientific research performed on their data, have increased our understanding of the many complex and interlinked processes that make up our biosphere and its constituent elements: the lithosphere, the hydrosphere and the atmosphere. Moreover, they have made us aware of the impacts of our actions, as demonstrated by satellite images of large-scale deforestation and the impacts of acid rain. Together with other developments on Earth (such as the oil crises and local pollution events) space capabilities have fostered ecological awareness and thinking. As a result, recent generations put much more emphasis on the concept of sustainability and have taken actions, such as recycling of waste and water, to change human impacts on the environment.

[9] Agnew, John. "The New Global Economy: Time-Space Compression, Geopolitics, and Global Uneven Development." Journal of World-Systems Research 7.2 (2001): 133-154.

3. A Glimpse of the Future: Unfolding Global Trends

» "The Future ain't what it used to be."
— Yogi Berra

As already mentioned, only by providing forecasts of what may come there is a possibility for people living today to prepare for and actively shape the future in a more positive way, rather than merely reacting to its consequences. Chapter 2 shed light on the history of the dynamics that set the context for space to interact with society and vice versa. This chapter is forward-looking and its overarching objectives are to identify which global trends are positioned to gain momentum within the next 15-20 years, assess the possible European societal challenges revolving around these discernible patterns of change, and eventually highlight potential contributions that space might bring to the table in finding solutions that are in the interest of the future European society.

Identification of the global mega-trends is based on a wide-ranging review of the literature and statistical data provided by authoritative institutions, academia, and think tanks. The most relevant reports, studies, and data sources are listed in Appendix A of this report. While in several cases the review has revealed the existence of different and sometimes divergent forecasts in specific issue-areas, from an overall perspective a number of common mega-trends can be discerned.

The unfolding megatrends that emerged from the literary review have been grouped into four main headings, namely: an expanding and ageing population of empowered individuals, increasing pressures on key resources in a constrained environment, an ever more dynamic technological landscape, and the diffusion of power in a polycentric and less secure world. The various projections associated with the developments of mega-trends have inevitably been made on the basis of some core assumptions, which do not take into account the possible materialisation of so called wild-cards, possible occurrences that could cause large-scale disruptions on the prospected pathway. A set of potential wild cards associated with each of the defined trends is summarised in a box at the end of Section 3.5.

3.1 An Expanding and Ageing Population of Empowered Individuals

One of the most relevant themes in the literature on global trends in 2030 concerns demographic patterns and the associated societal transformation. Over the next 15 years, the global population is set to increase by about 1.2 billion, passing from 7.3 billion today to 8.5 billion in 2030.[10] Yet, compared to the population growth of the past 20 years, growth is slowing both in absolute and relative terms. Previous projections even indicated a possible plateau and subsequent decrease after 2030, but the latest UN World Population Prospects forecasts do not confirm this trend - by 2050 the world population is set to balloon to 9.7 billion people.[11]

Africa and Asia are projected to be the first and second largest contributors to future global population growth. By 2030, 76.6% of the total population is expected to live in Asia and Africa, with China and India alone representing the 34.6% of the total world population (see Figure 4). The percentage of the global population living in OECD countries will thus notably decrease, and some of these countries/regions, most notably Europe and Japan, are even projected to experience a shrinking population.

The most relevant trend associated with demographic patterns is ageing. As life expectancy continues to rise and fertility rates progressively decline,[12] the average age in almost every society around the world will rise and population ageing will accelerate. Today, there are 901 million people aged 60 or above, comprising 12% of the global population. This number is projected to reach 1.4

[10] United Nations, Department of Economic and Social Affairs, Population Division (2015). World Population Prospects: The 2015 Revision. United Nations. New York. 2015.
[11] Ibid: 3.
[12] Globally, life expectancy is expected to rise from 70 years in 2015 up to 73.7 in 2030 and 77 years in 2045-50. Ibid.

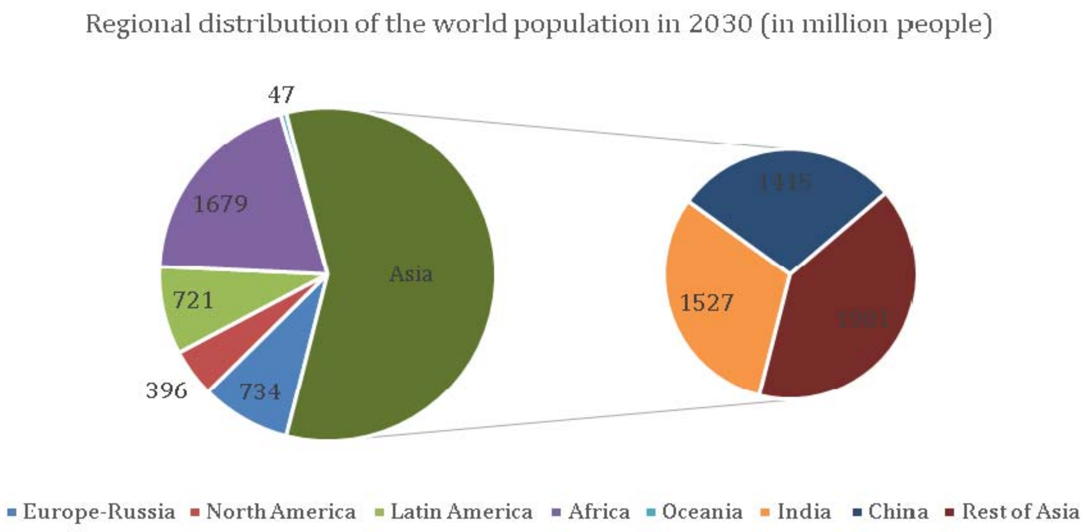


Figure 4: World Population Prospect in 2030 (Source: UNDESA)

billion in 2030, constituting more than the 16% of the world population.[13]

Ageing will likely become a global phenomenon, although it will be more pronounced in the OECD world and in certain non-Western countries, such as China and Russia. The number of countries with youthful populations (average age of 25 or below) will decrease substantially and remain concentrated only in Sub-Saharan Africa, while the age structures of the majority of European countries and some East Asian countries, including Japan and South Korea, is projected to move from the mature (35-45 years) to the post mature category (over 45 years). [14] With an average age of more than 42 years and 24% of the population already aged 60 years or more, Europe is already the oldest region in the world, and the proportion of 60+ is projected to reach 34% by 2050.

Widespread ageing will have far-reaching consequences in many post-mature societies. While most of these consequences (e.g. reduced predisposition to civil conflict)[15] remain speculative, it is fair to assume that post-mature states will be striving to maintain economic growth and living standards, and will be challenged to undertake serious and costly reforms of their pension and health-care systems. Although likely advances in health care could enable people to work longer, the working age populations of these countries will inevitably decline, with labour demand (in addition to income disparities) likely contributing to economic migration.

Overall, between 1950 and 2015, Europe, North America and Oceania have been the major receivers of international migrants, while Africa, Asia and Latin America have been net senders. The attraction of high-income countries has been strong: between 2000 and 2015 Europe, North America and Oceania received an average of 4.1 million migrants per year from lower and middle-income countries.[16] In the future, net migration to high-income countries is projected to remain high in volume and to become a major contributor to their population growth, providing a mechanism for rebalancing labour markets, stimulating economic development and also accelerating diffusion of ideas and technologies.[17] The impact of international migration vis-à-vis societal structures remains uncertain: it could be as much a positive force for furthering social development as a cause of reduced social cohesion and increasing instability.

In addition to differences in age structure and income disparities between countries of origin and countries of destination, future cross-border migration will continue to be primarily driven by factors such as globalisation, the effects of climate changes and regional instability associated with crises and conflicts.

[13] United Nations, Department of Economic and Social Affairs, Population Division (2015). World Population Prospects: The 2015 Revision. United Nations. New York. 2015.

[14] See National Intelligence Council. Global Trends 2030: Alternative Worlds. NIC 2012-001. Washington D.C. 2012: 20-22

[15] Building on the evidence that since the late 1970s, the majority of all armed civil and ethnic conflicts have originated in youthful countries, it has been projected that the so called “demographic arc of instability” – which implies a direct correlation between age structures and propensity to armed conflicts – will progressively narrow as a much larger group of countries will enter the mature category. Ibid: 22.

[16] United Nations, Department of Economic and Social Affairs, Population Division. World Population Prospects: The 2015 Revision. United Nations. New York. 2015.

[17] Ibid: 6.

While no massive international and internal migration flows have been projected in the specialised literature, it is likely that migration will "become more globalised, as demand for both skilled and unskilled labour soars in traditional and new destination countries for migrants.[18] […] Over time, governments may need to increasingly manage mobility rather than simply immigration as more short term movements occur in addition to permanent migration".[19] People and goods will be moving more often, further and faster, requiring a higher degree of inter-connectivity and inter-modality in the sectors servicing future mobility needs, particularly transport.[20]

Another key trend closely associated with future demographic patterns is the burgeoning growth in urbanisation. While by 2030 developed countries will still have a far larger share of urban population than developing countries, urbanisation will increase most rapidly where rates of population growth are higher, and in particular in Asia and Africa. The UN estimates that by 2030 there will be an additional 276 million people in China and 218 million in India living in urban areas. Also in Africa, half of the population will be living in urban areas by 2030.[21] Such a scenario will inevitably pose formidable challenges with respect to mobility and infrastructure. As interestingly estimated by the National Intelligence Council report: "owing to rapid urbanisation in the developing world, the volume of urban construction for housing, office space and transport services over the next 40 years could roughly equal the entire volume of such construction to date in world history".[22]

Cities will likely reach unprecedented size and the overall number of megacities is also expected to increase from 27 to 41 in 2030. However, urban growth patterns are likely to be very different from today's dynamics, "as megacities will become strongly limited [in their growth] by physical land constraints and burdened by vehicular congestion, costly infrastructure legacies and deteriorating sanitation and health conditions. The so-called "peri-urban" areas will grow faster than city centres creating metropolitan regions that will spill over multiple jurisdictions to create mega-regions. By 2030, there will be at least 40 large bi-national and tri-national metro-regions".[23]

While expected to increase pressures on land and water resources (see below), urbanisation prospects will also stimulate economic growth and contribute to poverty reduction and a parallel emergence of a global middle class.

The percentage of the population that will have middle-class status is projected to grow everywhere in the world, and to possibly account for 60% of the total population in 2030, corresponding to 5 billion people.[24] This growth will almost certainly go hand in hand with greater educational attainment – according to ESPAS 90% of the population will have achieved literacy in 2030 – as well as increased access to new technology, with some 50% of the world population having Internet access.[25] The rise in national wealth will also be accompanied by greater gender equality,[26] and continued progress in health care, further benefiting people's wellbeing and contributing to the consolidation of a global knowledge-based society. At the same

[18] According to some projections, the rising shortage of qualified labour in key countries and regions will cause a serious war for talent in the period up to 2030, with the globalisation of the labour market triggering migration of qualified people and causing "brain gain" and "brain drain" phenomena. See Roland Berger Strategy Consultants. Trend Compendium 2030. Munich, Germany. 2011: 110-112.

[19] Cit. National Intelligence Council. Global Trends 2030: Alternative Worlds. NIC 2012-001. Washington D.C. 2012: 32

[20] It should be highlighted that in the future, mobility may not only be seen as physical movement but also as virtual presence, a multi-modal service to which everyone can have access and which incorporates holographic reality and fast broadband connections allowing persons unfit to move to reach a desired place. See European Strategy and Policy Analysis System. Global Trends 2030: Can the EU meet the challenges ahead? Publication Office of the European Union. Luxembourg. 2015: 35.

[21] United Nations, Department of Economic and Social Affairs, Population Division (2015). World Population Prospects: The 2015 Revision. United Nations. New York. 2015: 6.

[22] National Intelligence Council. Global Trends 2030: Alternative Worlds. NIC 2012-001. Washington D.C. 2012: 32

[23] Cit. Ibid: 28.

[24] North America, Europe and the Asia-Pacific region are projected to have 322, 680 and 3,228 million people respectively joining the middle class status in 2030. While specific estimates vary according to different data sources, the progressive growth of a global middle class is recognised as a certain, unfolding trend. See, among others, Kharas, Homi and Geoffrey Gertz. A Global Middle Class: A cross over from West to the East. Brookings Institution Press. Washington, DC. 2010.

[25] European Strategy and Policy Analysis System. Global Trends 2030: Can the EU meet the challenges ahead? Publication Office of the European Union. Luxembourg. 2015: 20.

[26] The gender gaps in education and employment are projected to narrow considerably by 2030. In many OECD countries there could be almost twice as many female students at university as male. The literacy gaps between men and women will fall also in developing regions, though with some regional variations (the lowest progress is expected in Sub-Saharan African countries such as Ethiopia Eritrea and Guinea). In both developed and developing countries, more women are expected to have higher-qualified jobs, but will still lag behind men also in terms of wages. See Roland Berger Strategy Consultants. Trend Compendium 2030. Munich, Germany. 2011: 108-110.

time, increasingly affluent societies will be offset by a rise of inequalities, both real and perceived, between those who have access to knowledge and the digital world and those who do not.

All in all, the prospects of increasing urbanisation, poverty reduction and expansion of a global middle class, near universal access to education, greater gender equality, improved health care, and widespread exploitation of communication and manufacturing technologies (see Chapter 3.1.3) are considered to act as both the *cause* and the *effect* of one of the most important mega-trends shaping the world up to 2030: the progressive empowerment of the individual.

Growing individual empowerment is indeed a common theme in the literature on global trends, potentially bearing complex, far-reaching impacts on all players – states, the markets, businesses and media – and in all areas of society – the economy, politics, culture and even the social value systems. As noted by several analysts "empowerment may or may not lead to further diffusion of Western values in the world, but will anyhow generate increased expectations and demands",[27] with an increased emphasis on self-actualisation and quality of life.

From an overall perspective, the impact of the rise of "people power" is seen to potentially move in diametrical opposed directions. On the one hand, more empowered individuals can stimulate the advancement a creativity-based society and, by increasingly acting as *prosumers* of information and knowledge, contribute to new forms of social innovation. They could also take a lead in providing solutions to global problems through both greater political mobilisation and new sustainable lifestyles.[28] On the other hand, empowered individuals will likely become "more critical and demanding", almost certainly putting serious strains on governments' authority and businesses practices.[29] In addition to the growth of anti-establishment movements and greater citizens' control of institutional structures, it is also likely that individuals or small groups will have greater access to disruptive technologies as well as to Weapons of Mass Effect (WMEs) such as cyber instruments that could profoundly affect the future security outlook. In short, while the rise of the individual presents invaluable opportunities to be harvested at broader societal levels, it could also involve high risks in terms of instability and disruptive societal changes.

Similarly, the changes in the value systems of future generations associated with the progressive empowerment of the individual are surrounded by a strong dose of ambivalence. Although such changes are hard to foresee, some studies have pointed to the possible shift from materialistic to post-materialistic value systems, to changing work values putting an increased focus on self-expression and short-termism, to the maintenance of youthful lifestyles into later life, all moving the living experience from work to leisure time-centricity, as well as to novelty- and experience-seeking lifestyles characterised by both self-actualisation and impermanence in relationships, uncertainty and a sense of social vulnerability.[30]

3.2 Increasing Pressures on Key Resources in Severe Environmental Conditions

A second unfolding megatrend emerging from the literature review is the increasing pressures on and the growing nexus of food, water and energy in combination with the effects of climate change. Principally owing to the increase of the world population and the expansion of a global middle class, the demand for these resources is projected to substantially increase over the next 15 years.

Demand for food is expected to rise by almost 50%, not only because of the growing world population but also because of growing per capita food consumption.[31] Food consumption growth will be likely accompanied by changes in composition. FAO estimates that patterns of food consumption will be-

[27] Cit. European Strategy and Policy Analysis System. Global Trends 2030: Can the EU meet the challenges ahead? Publication Office of the European Union. Luxembourg. 2015:13.

[28] Increased awareness on such issues as social justice, environmental protection and human rights could inter alia stimulate significant growth in the number and work of NGOs and in global philanthropic donations and initiatives. The philosophy of giving could also change from the conventional support to major non-profit institutions to forms of venture philanthropy (supporting a social business with financial, intellectual or human capital) and catalytic philanthropy (where donors catalyse a campaign to achieve measurable impact on a social issue they are deeply concerned about) along the lines of what Bill Clinton and Bill Gates are doing. Ibid: 124-128.

[29] People's concerns about the collection and analysis of large quantities of personal data that are invasive of personal privacy could for instance generate pressure on governments to dismantle big data systems or introduce new forms of accountability.

[30] See: European Commission. Global Europe 2050. Directorate General for Research and Innovation. EUR 25252. Brussels. 2012: 72-73.

[31] Source: Food and Agriculture Organization; from: European Strategy and Policy Analysis System. Global Trends 2030: Can the EU meet the challenges ahead? Publication Office of the European Union. Luxembourg. 2015

come more similar throughout the world, shifting towards higher quality and more expensive foods such as meat and dairy products.[32] Future demand for livestock meat and dairy products can be met, but increased production will have dramatic consequences, particularly on agricultural land and water resources.[33]

The growth in annual global water requirements is projected to reach 6,900 billion cubic metres in 2030, some 40% above the current sustainable water supply.[34] Efficient water management through technological innovation will thus be key to avoiding global water scarcity and to meeting global food needs. Similarly, given the limited availability of new agricultural land – which will be further constrained by urbanisation– improving crop efficiency will be of utmost importance to ensuring long-term food security. It is, however, likely that a large part of the world's population will live in areas with severe water stress, and that several countries, mainly in Africa and the Middle East, are also likely to become more vulnerable to food insecurity, in addition to water shortage.[35] Future fish supplies are also expected to become constrained by resource limits, as will the availability of some raw materials, particularly metals and minerals. Some rare minerals, which are key for current and future technology development (e.g. indium and gallium), are even projected to run out by 2030.[36]

Owing to the rapid economic growth in the developing world, the demand for energy will also increase almost exponentially over the next 15 years, with non-OECD countries accounting for 93% of the total rise in consumption. According to the International Energy Agency, China will become by far the largest consumer of energy, followed by the U.S. – which is projected to become energy-independent in the medium term – Europe and India (see Figure 5).[37]

Even if competition for energy resource continues, the overall energy outlook is, however, brighter than those for water, food and other commodities. It is expected that enhanced oil and gas production capabilities provided by horizontal drilling and hydraulic fracturing will be largely able to satisfy future demand, although the negative environmental impact, particularly in terms of pollution of water sources, could in part hinder such developments in favour of renewable energy sources. Wind, water and solar power are expected to progressively become more cost-competitive and account for an increasing share of total energy production, though it is unlikely that they will replace conventional energy sources (see Figure 6). Finally it has been argued that by 2030 nuclear fusion could be introduced and begin to revolutionise the global energy landscape, with potentially beneficial impacts for the environment.[38]

Specific estimates apart, what needs to be underlined is the ever-stronger linkage between the demand for food, water and energy, and the problems stemming from climate change. While increasing resource demand might not *per se* automatically lead to a world of scarcities – the review of current literature pinpoints potentially different scenarios[39] - the combination of all these growing demands with the effects of climate change will almost certainly generate costly trade-offs. In other words, "tackling problems pertaining to one commodity [will not] be possible without affecting supply and demand for the others" and without impacting on the

[32] A rapid increase takes place in livestock meat, milk, eggs and vegetable oils as sources of food calories. See: Food and Agriculture Organization of the United Nations. June 2012. FAO.Org 12 Oct. 2015 <http://www.fao.org/docrep/016/ap106e/ap106e.pdf>.

[33] The amount of water required to produce meat is far more than required to produce an equivalent amount of grain or vegetables. As noted by the National Intelligence Council "given that agriculture uses 70% of global freshwater resources and livestock farming uses a disproportionate share of this, water management will become critical to long-term food security". National Intelligence Council. Global Trends 2030: Alternative Worlds. NIC 2012-001. Washington D.C. 2012: 32

[34] Currently agricultural irrigation wastes about 60% of the water withdrawn from freshwater sources. NIC 2013.

[35] "World agriculture 2030: Main findings." 1 Oct. 2002. FAO.Org 12 Oct. 2015 <http://www.fao.org/english/newsroom/news/2002/7833-en.html>.

[36] The current consumption of indium and gallium already exceed by far annual production and their reserves are expected to dry up by 2030 unless substantial new sources are found. Roland Berger Strategy Consultants. Trend Compendium 2030. Munich, Germany. 2011: 62.

[37] International Energy Agency. World Energy Outlook 2013. OECD/IEA. Paris. 2013.

[38] For an overview on the status of nuclear fusion see: Dixit, Aabha. "The Energy of the Future: The Status of Nuclear Fusion Research and the Role of the IAEA". 15 Sept. 2015. IAEA 16 Oct. 2015 <https://www.iaea.org/newscenter/news/energy-future-status-nuclear-fusion-research-and-role-iaea>.

[39] In some instances, managing widespread scarcity is considered to be one of the major challenges of the world in the next 15 years; in other cases prospects remain more optimistic.

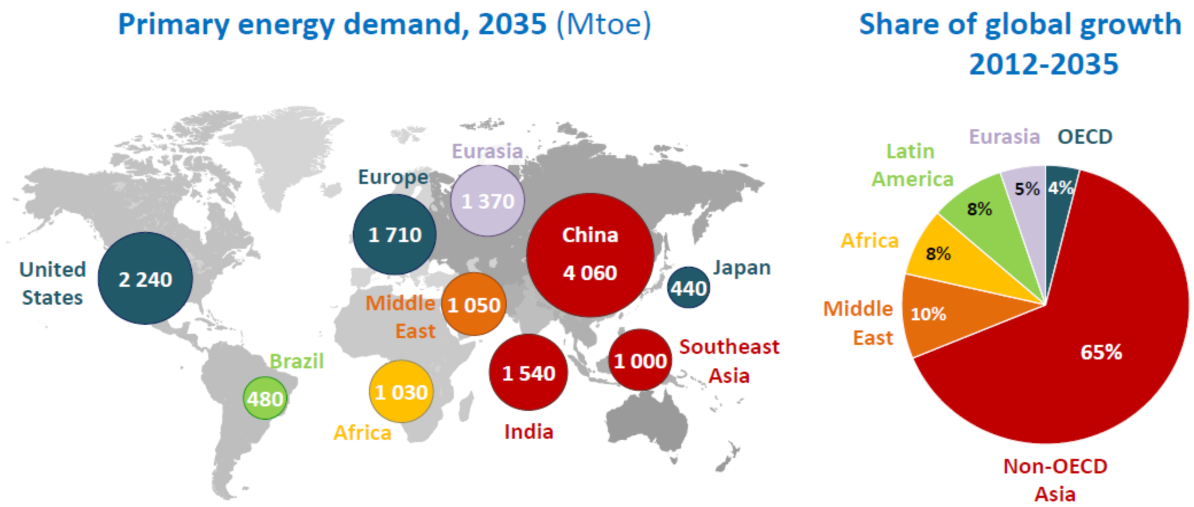


Figure 5: Future Energy Demand (Source: WEO)

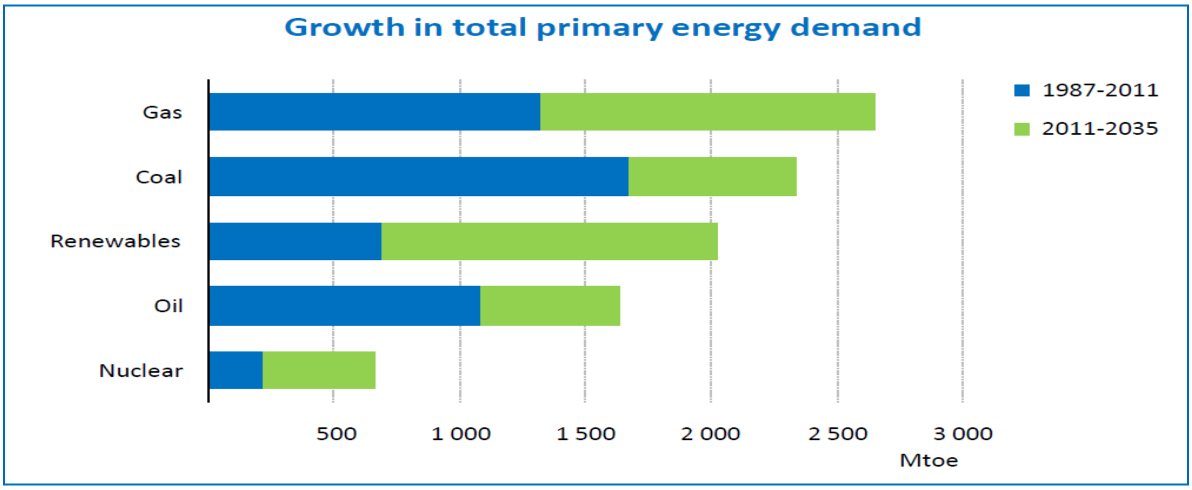


Figure 6: Growth in Total Primary Energy Demand (Source: WEO)

climate.[40] Absent positive synergies, the scope for such negative trade-offs is inevitably bound to increase. To echo the admonition of the UK scientific adviser John Beddington, the point is that we have to deal with increased demand for energy, increased demand for food, and increased demand for energy *together*, while mitigating and adapting to climate change".[41]

The overall environmental outlook remains bleak. While the increase in CO_2 emissions from fuel combustion is projected to slow down compared to the past 20 years (the projected increase by 2030 is16% compared to 44% for the period 1990-2010),[42] past and current studies confirm that even by cutting back emissions to the level of the 1990s a temperature rise remains inevitable, generating far-reaching consequences.[43] The extent of this rise remains under debate within the scientific community. However, as the 2014 report of the fifth Intergovernmental Panel on Climate Change warns: "increasing magnitudes of warming increase the likelihood of severe, pervasive and irreversible impacts".[44] The risks are considered very high in the

[40] Cit. National Intelligence Council. Global Trends 2030: Alternative Worlds. NIC 2012-001. Washington D.C. 2012: iv.

[41] See Population Institute. 2030: The "Perfect Storm" Scenario. March 2009. Web. Professor John Beddington. Chief Scientific Advisor to HM Government and Head of the Government Office for Science, March 2009

[42] Roland Berger Strategy Consultants. Trend Compendium 2030. Munich, Germany. 2011

[43] U.S. National Academy of Sciences. Climate Change. Evidences and Causes. The National Academy Press. Washington D.C. 2014.

[44] Intergovernmental Panel on Climate Change Working Group II. Climate Change 2014: Impacts, Adaptation and Vulnerability. UNEP-WMO. 2014

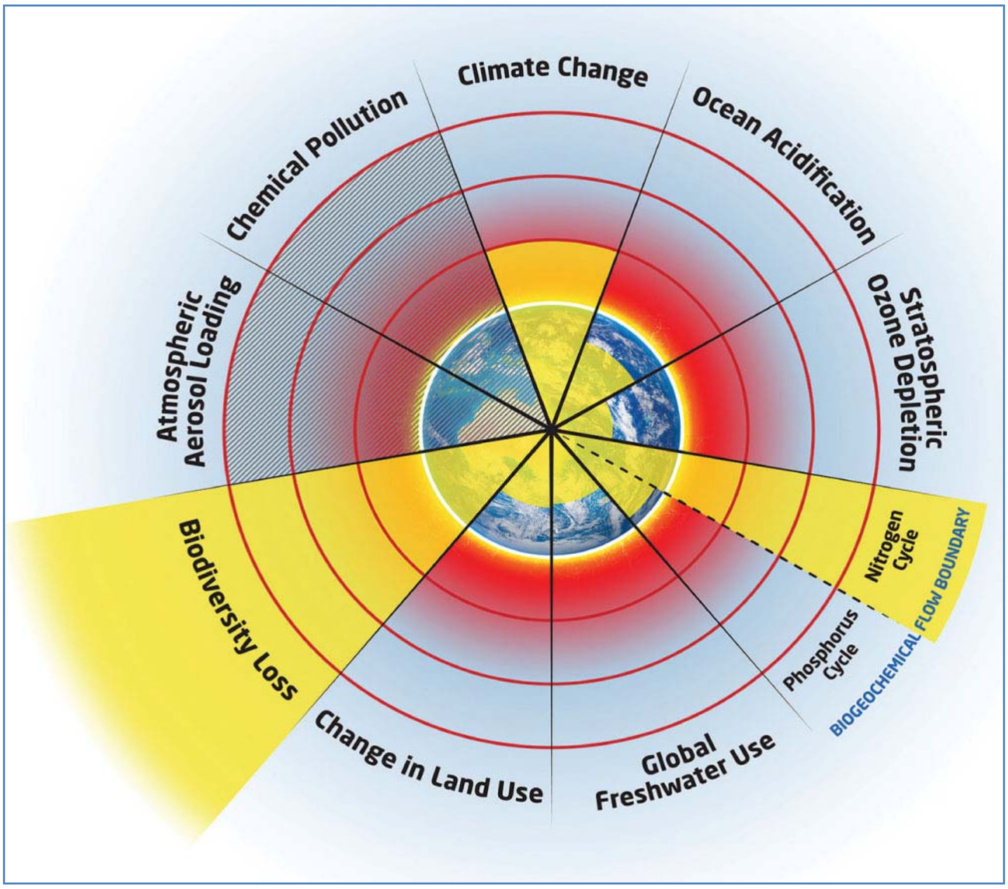


Figure 7: The Nine Planetary Boundaries (Source: SRC)

event of a temperature increase of more than 4°C, but even an increase of 2°C could generate dramatic effects on the ecosystem, possibly jeopardising food and water security.

In 2009, a group of internationally renowned scientists identified and quantified a set of nine planetary boundaries, the crossing of which could generate abrupt or irreversible environmental changes.[45] These boundaries are: ocean acidification, ozone depletion, the biogeochemical cycle (nitrogen and phosphorus), freshwater use, land use, biodiversity loss, atmospheric aerosol loading, chemical pollution, and climate change (which refers to the concentration of CO2 in the atmosphere). As Figure 7 shows, at least three of the nine planetary boundaries have been already crossed.

Absent a bold and comprehensive agreement at global level that would be capable of redirecting the activity of humans within the "planetary boundaries", the future will certainly be marked by large-scale effects.

While there are still uncertainties as to the precise nature and extent of these effects, there is a wide consensus that all of them, including natural ones, will be disruptive. The most certain effects include a more rapid melting of Arctic and Antarctic ice caps,[46] with subsequent rises in sea levels and dramatic consequences for exposed coastal areas, thermal expansion and changes to oceans' currents and flows, reduced precipitation in dry areas and excessive precipitation in wet areas with serious repercussions for agriculture, increased desertification, profound disruption of the seasonal cycles, and substantial decline of biodiversity in both the

[45] Since the planetary boundaries were first presented in 2009, researchers from around the world have been working to advance the concept. See: "Planetary Boundaries research". 19 Sept. 2012. Stockholm Resilience Centre 21 Jan. 2016 <http://www.stockholmresilience.org/21/research/research-programmes/planetary-boundaries.html>; See also: Rockström, Johan et al. "Planetary boundaries: exploring the safe operating space for humanity". Ecology and Society Vol. 14 Issue 2. 2009: 32.

[46] Artic ice could disappear completely during the summer between 2020-2040, making the region more accessible in terms of shipping routes and natural resources exploitation (the Artic region contains between 15% and 30% of undiscovered gas reserves and a large quantity of mineral resources such as zinc, nickel and graphite). At the same time, this change will also put serious strains on the natural environment with possible irreversible damage. Furthermore, it could potentially create a number of geopolitical issues. European Strategy and Policy Analysis System. Global Trends 2030: Can the EU meet the challenges ahead? Publication Office of the European Union. Luxembourg. 2015

developed and developing world [47] The frequency and intensity of extreme events – flooding, heat waves, high-water levels, tornadoes, etc. – will also continue to increase during the next 15 years, possibly generating catastrophic repercussions, including loss of lives.

All in all, future environmental changes are inevitably projected to act as a threat multiplier that will likely increase competition for critical resources, trigger large-scale migrations and exacerbate old and new geopolitical tensions.

3.3 An Ever More Dynamic Technological Landscape

As both a cause and effect of individual empowerment,[48] the speeding-up of scientific and technological innovation is another central tenet within the literature on global trends. The pace of technological change has already become more rapid, as has the absorption of new technologies. While it took almost half a century for electricity to make its way into general use, only 18 years were needed for the diffusion of colour television and 7 years for that of the World Wide Web. The absorption rate has been particularly rapid in the developed world, but also in developing countries it has been quickening, "allowing these states to leapfrog stages of development that advanced countries had to pass through". [49]

There is a wide consensus that these trends will continue over the next 15 years. Technological progress is expected to generate breakthroughs at an unprecedented rate and its diffusion will continue to speed up, with new technologies being adopted faster and innovation cycles becoming ever shorter. The overall importance of technology will thus exponentially increase, creating an even greater reliance on technology itself in almost every sphere of human activity. However, ethical and societal dilemmas associated with the invasiveness of new technologies (e.g. think big data) will likely "spark debates about the usefulness of certain innovations and whether they ultimately benefit people and societies".[50]

While there is no definite vision of what to expect in 2030, as predictions on basic innovations and their future utilisation remain largely speculative, some technology arenas promise relevant evolutionary and revolutionary breakthroughs that will possibly mature on a massive scale over the next 15 years:

- Information Communication Technologies (ICT), which have been the main driver of innovation over the past two decades, will continue to revolutionise the way we live with such developments as the "Internet of Things", cloud computing and virtual reality. Already by 2024 one trillion human-made items, ranging from clothes to cars, are expected to be connected to each other and the Internet.[51] Multiplication of Big Data and cloud computing will provide a number of novel applications revolutionising the economy, business models and perhaps even the welfare state.[52] Increased computational power and new algorithms will for instance allow corporate decisions and their consequences to be simulated before being taken. Moreover, new social networking technologies and virtual reality will generate radical changes to how people think, entertain and educate themselves. The applications associated with virtual reality (work in virtual teams, virtual learning agents, virtual holidays, etc.) will potentially create a culture of multi-layered realities, which will make it more difficult to distinguish between reality and virtual reality, in addition to changing people's perspectives of what community and family mean.[53]
- Some important breakthroughs are expected in the resource technology do-

[47] Much of the decline in precipitation is projected to occur in the Middle East, northern Africa and southern Europe, Central Asia, Southern Africa and the United States southwest.

[48] There is a mutually reinforcing circle between technology and individual empowerment, since empowered individuals in a knowledge- creativity-based society are expected to lead to further technological progress.

[49] Cit. National Intelligence Council. Global Trends 2030: Alternative Worlds. NIC 2012-001. Washington D.C. 2012: 2

[50] European Strategy and Policy Analysis System. Global Trends 2030: Can the EU meet the challenges ahead? Publication Office of the European Union. Luxembourg. 2015: 36.

[51] European Commission. Preparing the Commission for future opportunities. Foresight network fiches 2030. EC Working document. Brussels. 2015.

[52] It has been for instance argued that the continuous aggregation of data related to health, education, transport, and energy could in the long run expand so much as to become *de facto* a replacement for welfare state functions. See Morozov, Evgeny. "A dystopian welfare state funded by clicks instead of tax". Financial Times. 3 August 2015: 7-8.

[53] It is expected that virtual reality and digital technologies will contribute to creating "non-traditional families", which include avatars, social and virtual networks, digital gurus, virtual learning agents, as well as a family of communities such as communities of practices and discourse communities. See Roland Berger Strategy Consultants. Trend Compendium 2030. Munich, Germany. 2011: 136-142.

main. Increasing demand for food, water, energy and other commodities will pull technology advances to enhance water management and agricultural productivity (e.g. micro-irrigation technology, precision agriculture and genetically modified crops.) New resource technologies are also expected to increase the availability of energy for instance by enhancing the methods of gas and oil extraction, but also by achieving cost-competitiveness for solar, wind and bio-based power that could help reduce greenhouse gas emissions. By 2030, geo-engineering operations on weather modifications (e.g. clouds-seeding) might possibly have begun to be used to tackle the effects of climate changes in a variety of sectors.

- Robotics and new manufacturing technology promise to change work patterns in a wide range of civil and military applications. It is expected that by 2030 automation technologies will eliminate human labour in some domains while additive manufacturing will have begun to replace some conventional mass-produced products, providing benefits to both developing and developed countries in terms of flexibility, speed and customisation. By 2030 additive manufacturing may also be able to combine some structural components with functional capabilities such as electrical circuits or memory, and to have paved the way for bio-printing of arteries and organs. [54] In this domain much uncertainty is associated with the furthering of artificial intelligence and its interaction with humans, as there is as much scope for promising developments as there is for negative, unpredictable consequences.
- Great innovations are also expected in the area of health technology, (including biotechnology, medicine and pharmaceuticals), which could become a driver of innovation comparable to ICT today. By 2030, expected developments in molecular diagnostic and regenerative medicine will drive great advances in disease management, while a combination of bio-nano- and information-technology will revolutionise health care and enable increased life quality and life expectancy. "In addition to organ regeneration, stimulation of cognitive capacities, genetic choices, delayed ageing and even human augmentation may be possible".[55] The latter will potentially radically transform people's lives, with developments ranging from powered exoskeletons to brain-machine interfaces that could enhance innate human abilities such as strength, speed of movement and thought, memory, as well as providing functions not previously available such as, for instance, night vision.[56] It is worth noting that such a human-technology fusion may not only generate a transformative effect on human beings, but also deeply impact intra-societal relationships, especially between augmented humans and non-augmented humans.[57]

As evident from the above, in addition to advances in individual technologies, it is expected that future technology trends will be marked by a progressive convergence of technological domains. As *inter alia* stressed by a report of the European Strategy and Policy Analysis System, the convergence of digital, biological and industrial technologies and the proliferation of digital tools available and affordable to large multitudes, everywhere and for virtually any purpose, will fundamentally change the way economies and societies are functioning", and potentially lead to several societal paradigm-shifts.[58]

Such a convergence might in particular mark the beginning of a new "knowledge society" as well as of a new, true industrial revolution, with subsequent transformation of the economic order through the establishment of new value chains, new structures of competition, new forms of capital accumulation, and a reconfiguration of the locations of "knowledge centres".[59] Indeed, the future geography of technological innovation could potentially see important changes, and while the U.S. and Europe will likely remain important epicentres of science-, technology- and knowledge-production, new "knowledge centres" are expected to emerge over the next 15/20 years, particularly in highly dynamic countries such as China and India.

[54] National Intelligence Council. Global Trends 2030: Alternative Worlds. NIC 2012-001. Washington D.C. 2012: 90.

[55] Cit. European Strategy and Policy Analysis System. Global Trends 2030: Can the EU meet the challenges ahead? Publication Office of the European Union. Luxembourg. 2015: 36

[56] National Intelligence Council. Global Trends 2030: Alternative Worlds. NIC 2012-001. Washington D.C. 2012: 97.

[57] European Strategy and Policy Analysis System. Global Trends 2030: Can the EU meet the challenges ahead? Publication Office of the European Union. Luxembourg. 2015: 36.

[58] Ibid: 7.

[59] Ibid: 36.

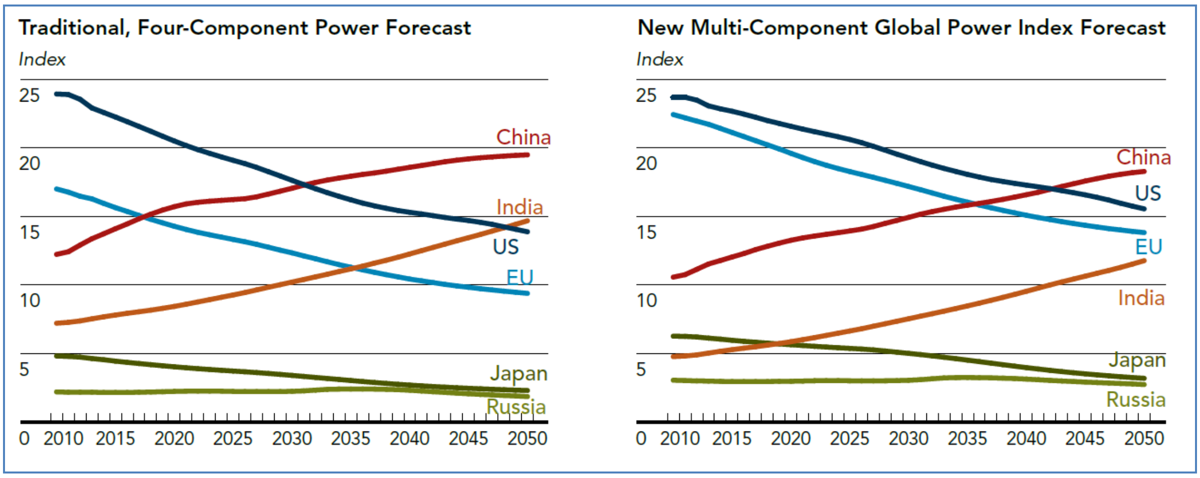


Figure 8: Global Power Shifts (Source: NIC[60])

3.4 Global Power Shifts in a Polycentric and Less Secure World

Even more than technological innovation and its social effects, political developments remain inherently unpredictable, and many projections could turn out to be highly speculative. Particularly at a point in which the international system seems at a critical juncture, carefulness is perhaps the most important tool. The basic assumption upon which current projections are built is that the Westphalian state-system will not unravel in the 2030 time frame. Despite a progressive erosion in their traditional functions, nation-states will almost certainly continue to represent the most important unit of interaction within the international system.[61] The structure of the system, however, will be profoundly transformed, primarily owing to an acceleration in the diffusion of power.

The world of 2030 will be in all likelihood multipolar, with a pronounced shift in economic and political power from the West to the emerging non-Western world.[62] There is broad consensus that by 2030 Asia will have surpassed North America and Europe combined in terms of power based upon GDP, population size, military spending and technological investment. Barring a major backlash, China alone is projected to have the world's largest economy, outstripping that of the U.S. some time before 2030,[63] while India will probably become the rising economic superpower that China is seen to be today.[64] In the meantime, the economies of Europe, Japan and Russia will likely witness a relative decline, primarily owing to their shrinking and ageing populations.

While from an overall perspective China, the U.S. and Europe will ostensibly remain the major geo-economic "hubs" of the world, accounting for slightly more than one half of global output and exercising the most influence on global issues,[65] an increasing number of states – including the so-called "Next Eleven" group (Bangladesh, Egypt, Indonesia, Iran, Mexico, Nigeria, Pakistan, the Philippines, Turkey, South Korea and Vietnam) – will possess increased economic and political weight, with potentially dramatic impacts on regional and global politics.

No single world power, however, will be able to play a hegemonic role comparable to that played by the U.S. over the past 25 years.

[60] The Four Component Power Index is based upon: GPD, population size, military spending and technological investment. The Multi-Component Power Index also includes: health, education and governance. See National Intelligence Council. Global Trends 2030: Alternative Worlds. 2012: 16.

[61] For an interesting analysis of the future transformation of the Westphalian system and international order see Kissinger, Henry. World Order. Penguin Press. New York. 2014.

[62] See European Commission. Global Europe 2050. Directorate General for Research and Innovation. EUR 25252. Brussels. 2012: 14-15.

[63] See. The World Bank. China 2030.Building a Modern, Harmonious and Creative Society. Washington D.C. 2013: 3.

[64] During the next decade, China's rate of economic growth will continue to slow down, while India's will continue to rise. These forecasts have been largely built upon the demographic patterns of the two countries, and in particular on China's progressive decline in working age population and India's continuous increase. National Intelligence Council. Global Trends 2030: Alternative Worlds. 2012: 15.

[65] Although the concentration of economic mass in the three largest poles will not change significantly, the main difference is the shift within this G-3, with China moving from being the smallest pole to becoming the biggest. Gros, Daniel and Cinzia Alcidi (eds). The Global Economy in 2030: Trends and Strategy for Europe. European Strategy and Policy Analysis System. 2013: IV.

There are several elements underpinning this projection. For one thing, a larger number of players will possess substantive national power. Even though the multi-polarisation of the international system may not be pronounced from a military capabilities perspective, as the U.S. and China will continue to widen the power gap between them and other major powers,[66] the utility of hard power is bound to decline in the future, with military means not sufficing to steer global politics. This will be in large part due to the fact that "the shift in national power will be likely accompanied – and perhaps overshadowed – by an even more fundamental shift in the nature of power",[67] which will make hard power a less determining factor of future world politics. As argued by the National Intelligence Council, "enabled by communications technologies, power almost certainly will shift toward multifaceted and amorphous networks composed of state and non-state actors that will form to influence global policies on various issues".[68] More broadly, there is broad consensus that not only will power be shifting from the West to the "Rest", but also downward to coalitions of non-state actors and individuals.[69] In this situation, it will be harder for individual states to dictate the course of events and define the structures upon which world politics and economy unfold.

Globalisation itself is seen to be moving towards a more polycentric system, characterised by a bigger cast of players such as transnational corporations, regions and megacities that will be more interconnected and interdependent economically, financially and technologically.[70] The literature on global trends also draws attention to the possibility that – despite the likely multiplication of free trade agreements such as the TTIP and the TPP – by 2030 globalisation in traded goods may have peaked among developed economies, even though the globalisation of services, finance and people will almost certainly continue and deepen, particularly among the developing economies of today.[71]

A deepened level of interdependence and increased flows of capital and people will not necessarily imply convergence around interests and basic values (such as human rights, democracy, secularism or the social market) and more robust governance structures. On the contrary, as power becomes more diffuse and spread across different types of players, the current multilateral schemes of cooperation and institutions of global governance may become weaker and less equipped to manage future economic, political and societal problems.[72] Fragmented governance is indeed a common trait within the literature on global trends for the next 15-20 years, meaning that prospects for achieving progress on global issues will vary depending on the issue and on the ad hoc coalitions that could form around them. In the absence of structural reforms, the current multilateral regimes and international organisations such as the UN, the WTO, the World Bank and the IMF, will run the risk of becoming less and less relevant and effective, at a time, however, when the need for collective responses will be more crucial than ever.[73]

With weaker instruments of global governance and a more fragmented and polarised international system, also the security outlook remains largely bedevilled with uncertainty and feverishness. The progressive erosion of U.S. capacity to serve as a systemic guardian of the global order is already affecting the post-Cold War equilibrium and is believed to act as a catalyst for greater instability, particularly in Asia and the Middle East. In these regions, the risk of open interstate

[66] It is estimated that over the next 15 years, only the U.S. and China may be able to spend more than $500 billion on defiance annually, thus reinforcing the trend towards a bipolar world structure in terms of hard power capabilities.
[67] National Intelligence Council. Global Trends 2030: Alternative Worlds. 2012: 132
[68] Ibid: 132.
[69] As demonstrated by the Covenant of Majors initiatives, alliances of committed cities, businesses and civil society, from both the developed and developing world, can play key roles in future governance schemes and also put increasing strains on typical state functions. European Commission. Preparing the Commission for future opportunities. Foresight network fiches 2030. Working document. Brussels. 2015: 127-128
[70] European Strategy and Policy Analysis System. Global Trends 2030: Can the EU meet the challenges ahead? Publication Office of the European Union. Luxembourg. 2015
[71] Gros, Daniel and Cinzia Alcidi (eds). The Global Economy in 2030: Trends and Strategy for Europe. European Strategy and Policy Analysis System. Luxemburg. 2013
[72] See European Commission. *Global Europe 2050*. Directorate General for Research and Innovation. EUR 25252. Brussels. 2012: 14-15.
[73] As noted by the ESPAS report, the current global system is increasingly under strain from opposing forces: on the one hand, the strengthening of interdependence and need for collective actions, and on the other a deterioration of the multilateral system, which is likely to worsen. Multilateral negotiations and cooperation are already witnessing serious setbacks (think Doha Development Agenda, IMF and UN reforms, climate change-related initiatives, Middle East crisis, etc.) In 2030, most organisations will still exist but will need to adapt to the new international conditions and notably to the rise of emerging countries, by redefining the weight of their stakeholders, their purposes and capacity. At the same time, they will be increasingly flanked by more restricted and functional working formats such as regional organisations, new alternative arrangements between emerging countries, and even public-private partnerships at large scale. See European Strategy and Policy Analysis System. Global Trends 2030: Can the EU meet the challenges ahead? Publication Office of the European Union. Luxembourg. 2015: 44-45.

conflict is expected to increase as a result of a number of factors, including regional power shifts, old territorial disputes and frozen conflicts, the strategic activism of such key players as Russia, China and India, and stiff competition over resources. Although the prospect of catastrophic consequences will provide strong disincentives and limit probability, the risk of conflict involving two major powerhouses cannot be discounted.[74]

The number and intensity of intra-state conflicts will not necessarily increase in the future,[75] but the risks are expected to remain particularly high in those countries that are incapable of exercising a minimum degree of domestic governance and where social cohesion is low, also due to the presence of politically adverse ethnic/religious minorities. These fragile or failed states, which will notably continue to be concentrated in Sub-Saharan Africa, the Middle East and Central America, will likely witness a growth of internal destabilising movements that will challenge state authority through armed conflicts. The literature also draws attention to the increasing proliferation of both lethal and non-lethal WMEs (e.g. biological and chemical weapons; cyber-attacks aimed at causing widespread economic/financial disruption, etc.) among a larger number of non-state groups, including criminal and terrorist networks. Such a prospect will inevitably trigger broader instability, at both internal and international level, thus contributing to a worsening of the global security outlook.

3.5 Trends, Possible Outcomes and Future Societal Challenges

Whereas all the identified mega-trends are progressively unfolding and already pointing to a number of key transformations in important features of the future global environment, there is no definite answer as to how the world will look and function in the future. Due to the interaction of the different trends and the possible materialisation of either negative or positive game changers (see Box 1), a number of completely different scenarios could eventually play out. Not only that, a plausible outcome constructed upon the interactions of the key variables could be eventually derailed by unpredictable events.

At the same time, however, the identification of these trends is of great help in supporting reflection on the ensuing societal challenges that Europe may face, and thus makes it easier for European policy-makers to address them in a timely manner.

- Massive migration flows prompting regional instability
- A severe and widespread pandemic
- Climate changes produce consequences at a faster rate
- Major natural disaster on a global scale resulting in crucial alteration of living conditions
- Wheat rust destroying crop production and endangering food supplies
- Radical breakthroughs in technology bringing paradigm shifts in management of key resources
- A major technological catastrophe resulting in technological backlash
- A radical confrontation between China and the U.S.
- A major war, potentially nuclear, involving one or more major powers
- A massive financial and economic crisis
- U.S. disengagement and the advent of a new era of international disorder
- A collapse of China's economy and regime
- A mature and conscious global society leading to a new era of harmony and prosperity
- Radical changes in the value system of future young generations

Box 1: Potential Wild Cards

In a nutshell, the major European societal challenges to be faced in the coming decade appear to be those related to the ageing of the European population, growing urbanisation prospects, the increasing mobility of people and the consolidation of the information society, and those related to the state of the environment and future use of natural resources. The following section will elaborate on these challenges, in particular by exploring the potential contributions offered by space in addressing them.

[74] Future conflicts may see important changes in the way they will be conducted. The future battlefield could see the deployment of augmented humans, ubiquitous robots, automated-decision-making and autonomous processes, cognitive modelling of the enemy, increased used of misinformation as a weapon, dynamic hacking and spoofing. See Kott, Alexander et al. Visualizing the Tactical Ground Battlefield in the Year 2050: Workshop Report. U.S. Army Research Laboratory. 2015.

[75] As a general trend, intra-state conflicts have declined during the past 20 years and while for some they could further reduce during the next decade, other see increased potential for intra-state conflict.

4. Space Contributions to European Challenges

> "Your task is not to foresee the future, but to enable it."
> — Antoine de Saint-Exupéry

"The future belongs to the ones that can handle complexity and engage with uncertainty. Anticipating the technology convergence revolution and societal expectations within a political vision is the key. A political vision is a must, not for a technology-pushed but for a technology-enabled society. If political guidance brings 'the what and the why', science and technology can bring 'the how'".[76] With this vision, the European Commission started elaborating a strategy for catching future opportunities while targeting the growing challenges that will affect Europe in the mid-term future.

In fact, it is clear that the future of Europe passes through decisions that are taken at the present moment, at political, governance, technical or scientific levels. It is important that these decisions are taken looking at the long-term implications and potential positive outcomes for society.

The level of complexity and interaction that European society will reach in the coming years will become more and more difficult to handle with the means currently available. It is in this context that it is important to reflect on what can be done today to address the potential needs of European citizens in the future. Some challenges that European nations are already facing will grow, as forecast in the previous section on global trends. Some other challenges will appear from nowhere, entering the scene as result of new and complex interactions in society that are difficult to predict. Both types of challenges will require appropriate and timely responses by political actors, who will inevitably tackle the hot issues with the resources, technologies and assets available at the time. Following from the global mega-trends in the previous chapter, a number of challenges has been identified that Europe could face in the future and where space assets and services can contribute significantly.

[76] European Commission. *Preparing the Commission for future opportunities. Foresight network fiches 2030.* Working document. Brussels. 2015: IV.

An expanding and ageing population of empowered individuals will live in increasingly large urban areas, with increasing population density and stretched services. For this reason, investing in Smart Cities is of paramount importance in maintaining and possibly improving the quality of life of the European citizens.

This development cannot take place without enhanced connectivity and harnessing the potential of big data to monitor the interconnections between cities, inhabitants, energy management, and transportation systems. New services will also have to be developed and, of these, e-health applications for an ageing population will be examined in more depth.

The dynamic technological landscape, with a rapid pace of innovation and new technology absorption will rest on the pillars of a restricted number of Key Enabling Technologies, examples of which are robotics and additive layer manufacturing, which are both being extensively studied and applied in space and whose accelerated development, for example for future exploration missions, could not only bring many benefits on Earth but also fuel the transition towards a new era of space utility, an era that has been dubbed Space 4.0.

The space industry is indeed already gearing up for the shift to the Space 4.0 paradigm where interactions with society and technology transfer in an "open innovation" setting will change the roles of industry, academia and the general public, thus enabling greater efficiency in the use of technological developments.

In a polycentric world characterised by global power shifts, Europe must also reflect on its global role and how to utilise its space assets and know-how in an effort to contribute to global challenges, providing advanced services and solutions to the rest of the world, in particular to developing countries. In particular, the space-aided contribution of Europe can be orientated towards monitoring and reducing the effects of climate change, responding to natural disasters, and earthquake prevention.

The general ambition of the current chapter is to give specific ideas and examples of how the knowledge, data and assets derived from space programs can be used to design new services and programmes for the benefit of the European citizens as they step into the future.

4.1 Smart Cities

The growing urbanisation prospects highlighted in Chapter 3.1 will have a number of far-reaching impacts for Europe. As engines of productivity, urban centres will stimulate economic growth and innovation, but at the same time they will put serious pressures on the environment and on key resources such as food, water and energy. Whereas European cities are not currently threatened by a massive urbanisation comparable to that of many Asian countries, there will be an increasing need for enhancing and optimising urban planning, governance, physical and communications infrastructure, resource-management, transportation systems and security services, among others.[77] In order to meet these needs, cities will have to become smart.

Smart cities will have the primary goal of minimising resource consumption and environmental degradation, while maximising citizens' quality of life and increasing economic productivity and competitiveness. Within the context of future smart cities, ICT will play the pivotal role in many areas of applications. From households to industry and institutions, more and more networks (electricity, gas, heat, water, transport) and systems (e.g. buildings) will make increased use of sensors, converters and actuators and progressively become integrated within a system of systems. This will support the end-users in a more sustainable fashion and ensure an optimal utilisation of different utilities and services, while providing city managers with a real-time comprehensive situational awareness of the state of their cities. So called "city dashboard solutions" will offer invaluable inputs for modelling and simulation activities that will help cities to "work" and grow more efficiently.

According to the EC, the full deployment of enabling ICT technologies (smart appliances, smart meters, and smart grids) will be the technical priority by 2030. This will necessarily be accompanied by standardisation efforts for the full interoperability of all systems and by the creation of synergies with other technologies and applications (e.g. in the area of resources technologies, automation systems, logistics and mobility).[78] In addition, given the more active role of end-users, new governance models embracing the wider participation of citizens and new policy measures will be needed to ensure the safe and smooth deployment and use of smart technologies.[79]

In the context of future smart cities, there is a strong role that space can play. Space assets can, *inter alia*, support the operations of future "city dashboard solutions", by integrating ground sensors and video data with EO, GNSS and telecommunications capabilities, enhancing the quality of the situational awareness of cities and allowing better planning. And smart cities are likely to make extensive use of drones for various monitoring and delivery purposes, which would often involve satellites for telemetry and control.

4.2 Connectivity and Big Data

Global connectivity and its related aspects of data transmission, processing and storage, are already part of the digital agendas of the main European states. But how will the "Internet of Things" and social media interactions evolve in the coming years? And what will be their impact on the communication infrastructure of Europe?

The answers to these questions are difficult to predict in the medium to long term, but it is clear that with increasing demand driven by new user needs, flexibility will be the key and multi-modal telecommunication means will be required.

Space assets are expected to remain an important instrument in filling telecommunication needs, as they allow for broadband communication over long distances without the hurdle of putting down cables. But in addition space research is tackling issues such as quantum communication and laser communication. Thanks to these new fields of research, the ground is being prepared for the implementation of new services that will go well beyond those that can be designed making use of the available or on-going new infrastructural developments. Space tele-

[77] National Intelligence Council. Global Trends 2030: Alternative Worlds. NIC 2012-001. Washington D.C. 2012: 86

[78] European Commission. Preparing the Commission for future opportunities. Foresight network fiches 2030. EC Working document. Brussels. 2015: 127-128

[79] Although a massive deployment of ICT in future smart cities can "promote the evolution of working patterns, different mobility schemes, the advent of more connected citizens bringing increased inclusion, and more benefits on healthcare", it also raises a number of policy issues with regard to cyber security, data protection and privacy. Ibid: 127-129.

communication capabilities are already starting to be combined with airborne systems such as drones and balloons to address connectivity in remote areas and to provide real-time information in natural disaster situations and other cases such as refugee and migration crises.

In a conversation between ESPI and IBM on the role played by technology in addressing future European societal needs, it emerged that, in the first place, European citizens are asking their governments for more efficient and accessible services, particularly in the welfare sector. Innovation will enable better and faster access to basic information via mobile devices and Internet platforms, more efficient platforms for social security purposes (i.e. job search, teleworking, etc.) and health care systems (i.e. faster diagnostics and remote collection of patient data). Scandinavian countries and the Netherlands are at the forefront in digitalizing these types of services, but also the European Commission has highlighted the need for the development of e-government solutions to better address citizens' needs. As a consequence it has launched a Digital Agenda initiative within the Europe 2020 strategy.

IBM expects that over the next 10 years the way humans interact with technology will be completely different from today. Data analytics play a central role in this respect, as managing big data efficiently will enable both government and technology companies to provide a wide range of services. The continuous aggregation of data related to health, education, transport, industry and energy could, in the long run, expand so much as to become a de-facto replacement for welfare state functions. In the provision of healthcare, for instance, wearable sensors could enable technology companies to constantly monitor the physical activity of people, detecting disease and even preventing them from falling ill. In doing so, they could eventually become the direct providers of services that traditionally have fallen within the remit of governments. Along these lines, Google is offering to provide free Wi-Fi access in Sri Lanka, as well as in New York City, and Facebook plans to connect the world to the Internet for free, although possibly limiting access to some selected applications initially[80].

While these solutions could certainly meet citizens' needs and expectations in a very effective way, it should be highlighted that a trading of personal data for services could also generate collateral, undesired effects in terms of privacy and Big Brother societal effects[81]. Some examples of potential misuse could include constant surveillance, ascertaining social and political preferences, or more simply, market targeting. Even more importantly, entrusting private companies with the delivery of essential services, traditionally provided by governments, poses a number of risks in terms of inequality, democracy, volatility, and possible arbitrary provision of services.[82]

The main areas of future development in this domain are the Internet of Things (IoT), e-commerce, data analytics, and cloud and cognitive computing. It is expected that the Internet of Things will reshape various sectors, such as transport (car management, tracking and data analysis of traffic), urbanisation (smarter cities and buildings) and management of resources (mapping and spatial analysis). And data analytics, cloud and cognitive computing can particularly address the needs of new citizen-driven services that rely on massive data amounts. In this respect it should be noted that space is not only a key instrument of connectivity now and in the future but also a tremendous source of data, both for scientific and monitoring purposes and can be expected to remain so in the future. One example is the provision of real-time data from Earth Observation satellites, which will require much more flexible infrastructures to promptly cover changes in the demand for services while ensuring small latencies in accessing the information. The on-going GEO-Cloud experiment is part of an FP7 project and addresses the need to provide highly demanding EO services by using future Internet technologies (e.g. a cloud environment that covers the end-to-end service, from acquisition to on-demand data distribution to end users with remote access)[83].

4.3 Mobility

Driven by a number of socio-economic and technological trends (including the increase of the world population, growing urbanisation, the shift of geo-economic balances and exponential growth of connectivity between peo-

[80] See Internet.org. 25 Jan. 2014. Internet.org. 21 Jan. 2016 <https://info.internet.org/en/>.

[81] National Intelligence Council. Global Trends 2030: Alternative Worlds. NIC 2012-001. Washington D.C. 2012: 36

[82] Morozov, Evgeny. "A dystopian welfare state funded by clicks instead of tax". Financial Times. 3 August 2015: 7-8.

[83] Becedas, J. "Global Earth Observation System computed in cloud. Evaluation of Future Internet Technologies for processing and distribution of satellite imagery". The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume XL-7/W3, 2015 36th International Symposium on Remote Sensing of Environment, 11–15 May 2015, Berlin, Germany

ple and devices), the accelerating mobility of people and goods will pose some major challenges for Europe. Meeting future mobility needs will require a transition towards more sustainable, more intelligent and well-integrated transport systems that will reduce environmental impacts while increasing safety as well as time and energy efficiency. The utilisation of ICT could support the development of fully autonomous transport solutions, although data privacy issues and security concerns may have to be overcome[84]. What is clear is the GNSS services are indispensable for autonomous transport systems-

According to the European Commission[85], the European air transport system is directly affected by new challenges, among which climate change and sustainability are prominent, with the need to reduce noise and greenhouse gas emissions. It is therefore particularly important to define at the earliest time a long-term vision for Europe's aviation system and industry, focusing on meeting the needs of citizens and the market as well as maintaining global leadership. Thus it is expected that by 2050 all travel services should be based on a more resilient air transport system thoroughly integrated with ground transport modes on a global scale (e.g. in order to accommodate the forecasted 16 billion passenger per year in 2050, nearly 8 times the passengers of 2010).

Any resilient air transport system in the future will clearly require extensive use of GNSS capabilities and may be assumed to also make more extensive use of space-based telecommunication means.

Intelligent, or automatic driving, is quickly developing and is only possible using satellite based navigation capabilities as the basis. If automatic driving becomes pervasive, it must be assumed that the demand for GNSS services will increase significantly and that new functionalities will be required. Furthermore, automatic driving will become part of the wider concept of IoT, and will integrate Earth Observation data on pollution and weather conditions with home based data, such as the contents of the fridge (message from car: you are low on milk and you are currently close to one of your favourite supermarkets).

[84] European Commission. Preparing the Commission for future opportunities. Foresight network fiches 2030. Working document. Brussels. 2015.

[85] Flightpath 2050. Europe's Vision for Aviation. Maintaining Global Leadership & Serving Society's Needs. Report of the High Level Group on Aviation Research. Directorate-General for Research and Innovation. European Commission. 2011.

But the Internet of Things universe will also affect mobility in other respects.

It can be imagined that something like an application on a smartphone, smart watch or other smart device, will allow for the real time identification of the fastest and cheapest mobility solution for the citizen willing to choose between a smart electric assisted bicycle, a motorbike, a pooled car, an hourly rented city car, a bus, a tram, a train, a plane or a boat. Such services would probably also include information on the weather as well as indicating the best means of transportation based on the traffic, rain, snow, road hazards, etc.

In addition the future mobility challenge will be addressed not only by the movement of people but also by tele-presence, either with existing web-cam technologies or augmented and virtual reality. This would enable a reduction of carbon footprint and increase of productivity by reducing physical transport, enhancing communication for people with limited mobility, and creating new job and business opportunities (e.g. teleworking). For tele-mobility the telecommunication capabilities addressed in the preceding section are critical, and space based telecommunication will be part of the enabling mix.

In the domain of radical new mobility, suborbital point-to-point travel could well be considered. This is a dream of long standing (mentioned already in 1928 by Hermann "Noordung" Potočnik), that has been revived from time to time, for instance by President Reagan in the State-of-the-Union address in 1986. Currently there is much entrepreneurial energy involved in break-through innovation in space transportation, such as the vertical landing of spent rocket stages. The ultimate prize in this respect is however the development of technologies that will enable both easy access to space and suborbital point-to-point travel. The UK-based Skylon project is possibly a pathfinder in this respect, and it would seem reasonable that Europe should timely fund this sort of high-risk technology development in order to possibly become the birth-place of a most revolutionary new mode of transport.

4.4 E-Health

Innovative e-health services will be required at an increasing pace as the European population follows the ageing trend described in chapter 3.1

Innovative services will create many businesses around the e-health domain, such as home care teleservices, telemedicine, the fully digitalized and integrated medical profile. In fact already today the first generation of 'digital patient profiles' is being developed based on patient's data provided by home carers, medical professionals and *sensors*, enabling better, safer and cheaper integrated care, treatment and diets. It should be underlined that in order to ensure proper management of medical information, the European Commission has already issued guidelines on the use of medical data[86].

In the future, according to the European Commission[87], the combination of ICT and the Omics (e.g. genomics) will open up even more possibilities, such as personalized medicine, not just for treatment but also for probabilistic prevention as a function of environmental and genetic parameters. Personalized medicine promises to deliver the right treatment or prevention strategy for a specific person at the right time, capitalizing on advances in health research and IT. People will be able to manage their health with highly customized lifestyle plans (e.g. diet, exercise and relaxation), as well as deal with acute health problems with precision. The roles of GPs, medical specialists and other professionals will change radically and their activities will require a solid background in genomics and proteomics to make the best use of new data. Here, an important question will be how to manage the integrity, trustworthiness, confidentiality and quality of personalized health data 'in the cloud' and how to deal with (new) information monopolies regarding (personalized) health data.

The new concept of personalized medicine will require a combination of factors to be in place in a fully integrated fashion, such as innovative sensors to monitor the health condition of people, mobile applications that will collect, process and distribute the data to the cloud, and artificial intelligence systems that could create a sort of personal medical avatar for each individual, based on the digital patient record. There will be an increased need to make use of satellite assets, such as telecom and Earth Observation satellites and navigation services, to support this new and dedicated personalized medical care of European citizens.

In addition, there is already considerable experience in the space sector, especially in the frame of the medical operations associated with the long duration spaceflights of astronauts[88], that includes both potential spin-offs of sensor technology[89] and know-how matured in routine checks of the crew via telemedicine links.

Several experiments conducted on board the International Space Station have looked at the rate of changes in pulmonary oxygen uptake (VO2) and heart responses during changes in workload, and at the thermoregulatory and cardiovascular adaptations during rest and exercise during spaceflights. These experiments were made possible by the development of dedicated sensors and instruments, which are non-invasive tools to assess the condition of the human body. Spin-offs of these developments are already commercially available for use by GPs, sport facilities and private individuals, helping them prevent and manage health risks, or supporting workers in mines, underwater activities, fire fighters, pilots and babies in incubators. New developments are on-going and envisage the utilisation of *Lab-on-a-chip* technologies to investigate promptly the health condition of an individual by checking blood and urine parameters in near real time and on-the-go. It can be expected that space spin-offs will continue to play a role as the digitalisation of health care progresses, given that human space flight is continuously pushing boundaries also in terms of managing and researching human health issues.

4.5 Key Enabling Technologies

As mentioned above, Key Enabling Technologies (KETs) are technologies that are cutting-edge and of multipurpose utility. Some general Key Enabling Technologies under development share specific commonality with the aerospace sector, among others: augmented reality, advanced robotics with artificial intelligence, exoskeletons, advanced manufacturing based on innovative materials, and additive layer manufacturing.

One question related to robotics is how the future European society will organise the work of its citizens. One possibility is that robots will take over some of the heavy tasks, leaving to humans the possibility of concentrating on creative and intellectual

[86] See: "Overview of the national laws on electronic health records in the EU Member States and their interaction with the provision of cross-border eHealth services" Final Report Milieu Ltd. Brussels. 2014.

[87] European Commission. Preparing the Commission for future opportunities. Foresight network fiches 2030. Working document. Brussels. 2015.

[88] European Space Agency. "Space Medicine Office". 19 December 2013. ESA 12 Oct. 2015 <http://www.esa.int/About_Us/EAC/Space_Medicine_Office>.

[89] European Space Agency. ESA's Report to the 40th COSPAR Meeting. ESA SP-1328. Moscow. August 2014: 167-168.

activities. Space may be leading the way in this respect.

NASA developed the Robonaut, a robot capable of carrying out tasks of a certain complexity (e.g. mechanical assembly) and assisting astronauts during Extra Vehicular Activities. Its second version, the Robonaut 2 or R2, was launched to the International Space Station on space shuttle Discovery as part of the STS-133 mission and was the first dexterous humanoid robot in space. Initially deployed on a fixed pedestal inside the ISS, it is already planned to upgrade it with a leg for climbing through the corridors of the Space Station, and then to send it outside into the vacuum of space, finally having future versions with legs and wheels to travel across Lunar and Martian terrain.

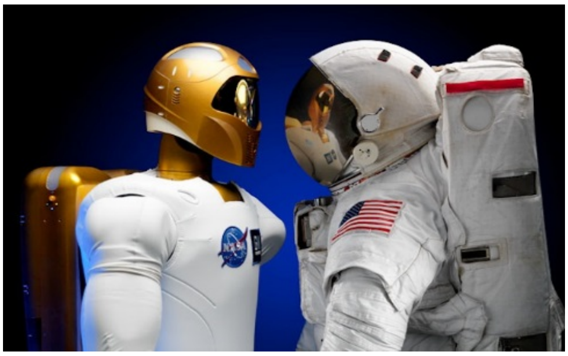


Figure 9: Robonaut and Astronaut (Source: NASA)

Robonaut 2 (R2) is a state of the art highly dexterous anthropomorphic robot. Like its predecessor Robonaut 1 (R1), R2 is capable of handling a wide range of EVA tools and interfaces, but R2 is a significant advancement over its predecessor. R2 is capable of speeds more than four times faster than R1, is more compact, is more dexterous, and includes a deeper and wider range of sensing. Advanced technology spans the entire R2 system and includes enhanced mobility and flexibility mechanisms as well as high-resolution cameras and IR systems. The dexterity of R2 enables it to use the same tools that astronauts currently use and removes the need for specialized tools just for robots.

One advantage of a humanoid design is that a Robonaut can take over simple, repetitive, or especially dangerous tasks in places such as the International Space Station. Because R2 is approaching human dexterity, tasks such as changing an air filter can be performed without modifications to the existing design.

Another way this might be beneficial is during a robotic precursor mission. R2 would bring one set of tools for the precursor mission, such as setup and geological investigation. Not only does this improve the efficiency of these types of tools, but it also removes the need for specialized robotic connectors. Future missions could use the tools currently on location.

Experience from space missions can therefore not only provide advanced technology for the creation of robots to replace humans in factories, but can especially give insights on human-robotic collaboration and how this can improve efficiency in a range of scenarios and tasks.

In the future there will be versions of the Robonauts adapted to various functions to be carried out on Earth. NASA and General Motors are already working together with Oceaneering Space Systems to accelerate the development of the next generation for use in the automotive and aerospace industries.

The possibilities opened up by *Additive Layer Manufacturing* are extremely wide and range from building small components up to entire structures, starting from a variety of base materials, such as feedstock, metals, composites, glass and concrete.

Both NASA and ESA are currently looking into the possibilities offered by this technology and are carrying out tests inside the Microgravity Science Glovebox of the International Space Station, while conducting terrestrial feasibility studies for the construction of planetary bases making use of in-situ resources, such as a Moon regolith.[90]

Figure 10: Moon Base Concept (Source: ESA)

Some advantages offered by this technology are that it enables the construction of large structures in space, freeing them from the constraints of the lift capabilities and volumes of the launch vehicles. The other key point is that robotic systems can entirely print such structures without the need for human inter-

[90] Morring, Frank. “Printing Structures. Additive-manufacturing tests under vacuum could lead to larger spacecraft at lower cost”. Aviation Week and Space Technology. 24 August 2015: 23-24.

vention, opening up entire new business and technical opportunities associated with in-space just-in-time production, such as new components, spare parts, cubesats, antennas, truss structures, and habitats. The terrestrial spin-offs include the provision of sustainable and effective solutions in various environments, some of which are already being investigated such as building houses in deserted areas of developing countries and reconstructing underwater coral reefs[91]. Thus the benefits of these developments could significantly contribute to the manufacturing revolution on Earth in various fields, such as architecture and engineering, materials processing and nanotechnology, science and robotics, offering new shapes, new materials, and new design solutions where they are needed at the time they are needed.

4.7 Europe's Global Role

When talking about spaceflight, one fundamental question is always: will humanity ever leave its cradle? Space cannot yet provide practical solutions for this purpose and only a far future can bring the spread of humanity to other planets in our and other galaxies.

It is important, however, that the dream of cosmic colonisation does not become an escapist dream. First we need to fix Earth and then we can go to Mars (and beyond) was the statement of NASA Administrator C. Bolden at IAC15 in Jerusalem.

In terms of fixing the Earth, Europe can play a role at global level and this should not be neglected. On the contrary, capabilities derived from space programs should enhance European ability in this respect, as illustrated by a few prominent examples in the below:

4.7.1 Climate Change

Since climate change already heavily affects living conditions on this planet, all available tools should be employed to face this challenge, while planning for innovative programs that can hopefully reduce its impact in the future. Space can offer solutions that are twofold:

- Monitoring how climate change evolves on a global scale and modelling this process in order to predict its effects and to limit the consequences of natural disasters.
- Optimizing the exploitation of renewable energy, thus reducing the carbon footprint of human activities on Earth.

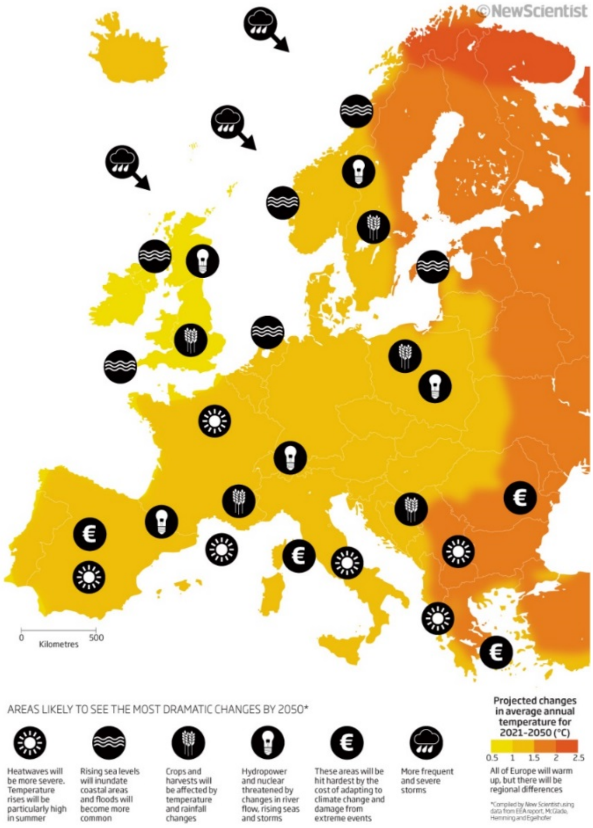


Figure 11: European areas likely to see the most dramatic changes by 2050 (Source: New Scientist)

The 21st session of the Conference of the Parties (COP21)[92] to the United Nations Framework Convention on Climate Change (UNFCCC) held in December 2015 in Paris, reached a global climate agreement to limit global average temperature increases to less than 2°C and facilitate the transition towards resilient, low-carbon societies and economies.

The Heads of Space Agencies presented a joint declaration to COP21, outlining satellites' unique role in observing climate, understanding its variations and mitigating its effects by supporting the implementation of precise actions. In fact, out of the 50 essential climate variables (ECVs) defined by the Global Climate Observing System (GCOS), 26 can only be monitored from space (e.g. Soil Moisture, Fire, Land Cover, Glacier, Antarctica, Greenland, Ocean Colour, Sea Level, Sea Surface, Temperature, Sea Ice, GHG, Ozone, Aerosol, Clouds). Satellites acquire the data needed to develop climate models and guarantee global, precise and multi-

[91] Private conversation with Mr. Dini, D-tech Company, September 2015.

[92] See "COP21". Web. Climate Action Programme. 21 Jan. 2016 <http://www.climateactionprogramme.org/cop21>.

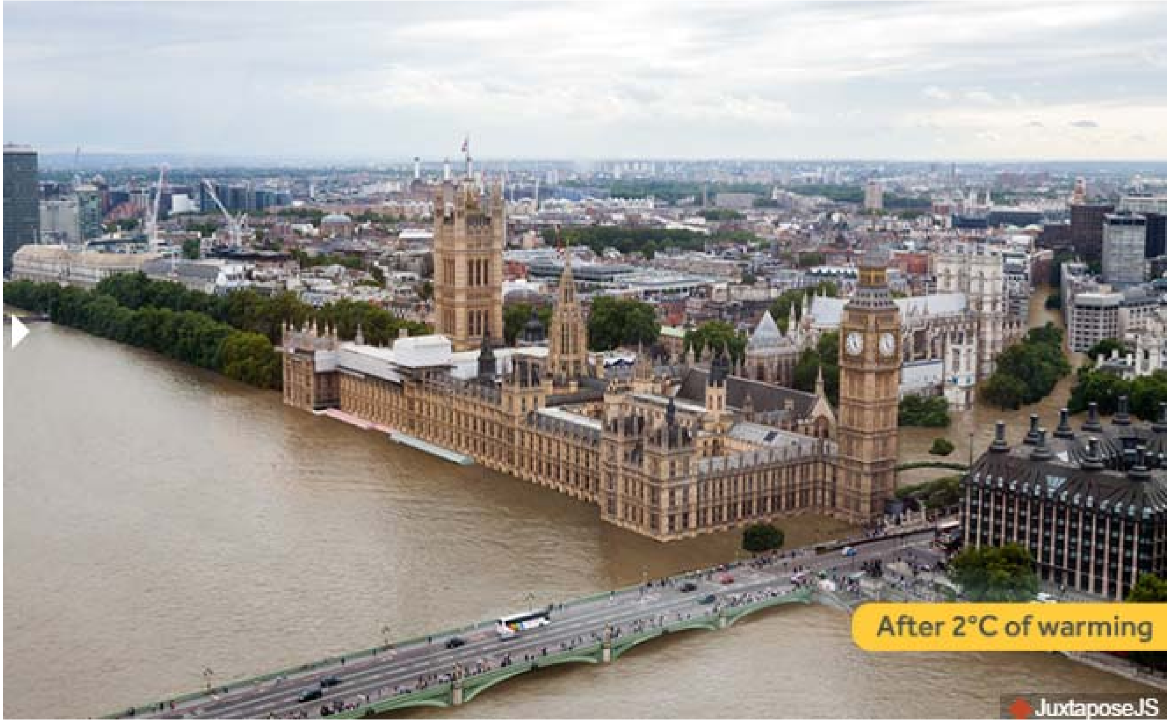


Figure 12: London in the Future? (Source: Climate Central)

parameter observations, allowing us to measure sea level rise and global warming of the atmosphere, two of the most serious consequences of climate change.

And space-based Earth Observation enables detailed measurements of greenhouse gases such as carbon dioxide and methane. Space is also a precious ally in predicting and managing natural disasters that are another major consequence of climate change.

The International Charter on Space and Major Disasters now numbers 15 member space agencies and gives countries hit by a natural disaster priority access to data from satellites all over the world. This charter has been activated more than 400 times since the year 2000. In future, satellites will also offer their aid ahead of such events through their ability to provide early warning of tsunamis and earthquakes[93].

A unique contribution to addressing the climate change challenge is provided by space programs which, through their global observation capacity and long-term coverage, already provide users with series of data requested for research, while complementing other ground based observation and measurement tools.

It is advisable that dedicated programs at European level, such as the EU's Copernicus programme and the on-going EUMETSAT-ESA cooperation for the development of next generation meteorological satellite observation systems should continue in the future, since they provide valuable modelling and forecasting capacities, which also allows for future European leadership in the global context[94].

Among its most dramatic effects, climate change is also increasingly affecting seasonal cycles, which could *inter alia* cause profound changes in animal migration paths. La Tierra Herida by Miguel Delibes and Miguel Delibes de Castro (Destino, 2005) mentions the work of a voluntary, citizen ecologist, Pere Comas, near Barcelona, who carefully noted the dates of appearance of leaves and flowers, the maturation of fruit and the arrival of migratory bird species, over a 50-year period. On average he found that spring had advanced by 16 days and lasted 13 days longer over the course of the second half of the 20th century. The full winter was almost a month longer in 2000 compared to 1952.

In this respect, acquiring relevant data about migratory habits of small animals like birds and insects can be a key tool in preserving ecosystems and even anticipating the propagation of pathogens and diseases that could

[93] "Heads of Space Agencies Summit in Mexico City. Final Declaration. Space for climate." 19 Sept. 2015. IAA.org 16 Oct. 2015 <https://iaaweb.org/iaa/Communication/pr1502.pdf>.

[94] Council of the European Union. Underpinning the European space renaissance: orientations and future challenges. Competitiveness Council meeting. 5 December 2014.

potentially evolve into pandemics (e.g. avian flu).

Today, only limited information is available to the scientific community, however, as the International Cooperation for Animal Research Using Space (ICARUS) project plans to demonstrate, there is an invaluable contribution that space can offer to put a remedy to this dearth of accurate knowledge. The goal of the ICARUS project is to track global migratory movements by making use of radio chips and satellite systems.[95] An experimental system was installed on the Russian module of the International Space Station at the end of 2015, allowing data collection to start and enhancing understanding of migration paths, the impact of climate change on the seasonal cycles, and anticipation of the eventual spread of diseases.

Space-based observation of the Earth is thus a key tool to help monitor the health of the Earth and how Earth-related patterns change, and we are probably only at the early stages in terms of applying the available data sets across the great variety of potential uses. And we will no doubt find new data sets to collect from space as the human endeavour in this domain intensifies.

4.7.2 Carbon and Energy

In order to help ensure that the targets agreed at COP21 to reduce carbon dioxide and other pollutants will be respected by the signatories, Europe could pursue the CarbonSat[96] project, which was presented by ESA recently.

The CarbonSat mission aims at determining the global distribution of two of the most important greenhouse gases in the atmosphere: carbon dioxide and methane.

Data from the mission should lead to a better understanding of the sources and sinks of these and other gases and how they are linked to climate change. Thus this mission could provide the necessary products and complement the data that will be acquired by the future Copernicus Atmosphere Monitoring Service (CAMS)[97].

Along these lines, in the future it will be possible to design space missions and services not only aimed at identifying the sources of gases and pollutants produced by human activities, but also to support the identification of new ways to ensure sustainability over the long term.

Future worldwide efforts should focus on the exploitation of the full potential offered by renewable energy, thus reducing the carbon footprint of human activities on Earth. As presented by Professor Sachs in the New York Times article "The Clean-Energy Moonshot", a group of leading scientists, innovators, and economists has identified our era's "Moonshot" to be to *replace fossil fuels with clean-energy technologies* within this generation, thus echoing President Kennedy's statement of the early 1960s "I believe that this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the moon and returning him safely to the Earth." Their engagement is built around the "Global Apollo Programme to Combat Climate Change", that consists of exploiting the idea of "directed technological change", for the production of clean energy.

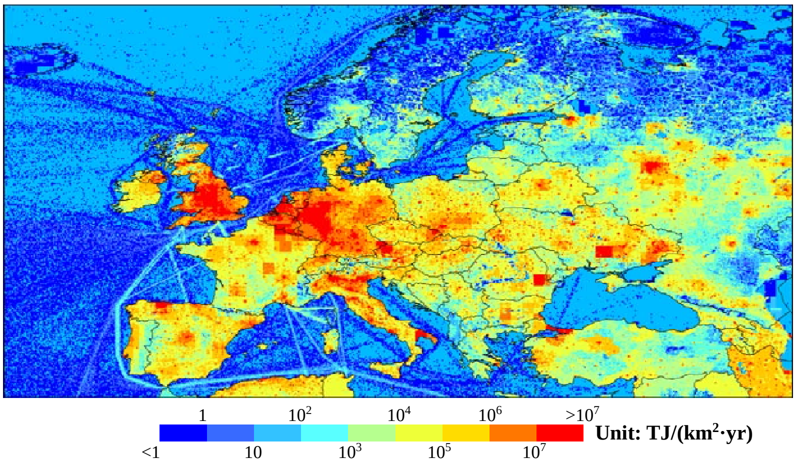
The Programme's final objective is to reduce the cost of renewable energy to below that of coal, oil, and gas, including the cost, and technical challenges, of storage. Professor Sachs argues: "As JFK showed, great progress begins with a great goal, one that is bold yet feasible. The goal today, backed by the Apollo Programme, is deep decarbonisation. It is time for world leaders to commit to the planet-saving clean-energy Moonshot"[98].

To achieve this ambitious goal space has, again, an important role to play, as illustrated below:

Geothermal energy makes use of heat-generated underground to provide electricity and warm water. While its potential worldwide remains vast, more effort is needed to develop and harness it, particularly because these energy sites are often located in remote areas and are difficult, expensive and time-consuming to explore and measure. Space researchers are currently testing a technology based on measurements of Earth's gravity made by the GOCE satellite[99],

[95] For more information on ICARUS, See: "About Icarus." 16 Nov. 2011. Icarusinitiative.org 26 Nov. 2015 <http://icarusinitiative.org/about-icarus>.
[96] European Space Agency. "Carbonsat Flex. Report for mission Selection. An earth explorer to observe greenhouse gases". ESA-SP1330/1. June2015.
[97] European Commission. "Towards a European Operational Observing System to Monitor Fossil CO2 emissions" , Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs, October 2015.

[98] Sachs, Jeffrey D. "The Clean-Energy Moonshot". 6 Oct. 2015. Project Syndicate 18 Oct. 2015 <https://www.project-syndicate.org/commentary/renewable-energy-decarbonization-by-jeffrey-d-sachs-2015-10#2EVCIEPkODPP50r1.99>.
[99] European Space Agency. "GOCE helps tap into sustainable energy resources". 16 April 2015. ESA 18 Oct. 2015 <http://www.esa.int/Our_Activities/Observing_the_Earth/GOCE/GOCE_helps_tap_into_sustainable_energy_resources>.



The temporal resolution is 0.1 degree by 0.1 degree.

Figure 13: Total fuel consumption in TJ in Europe in 2013 based on sub-national disaggregation. (Source: Wang et al., 2014)

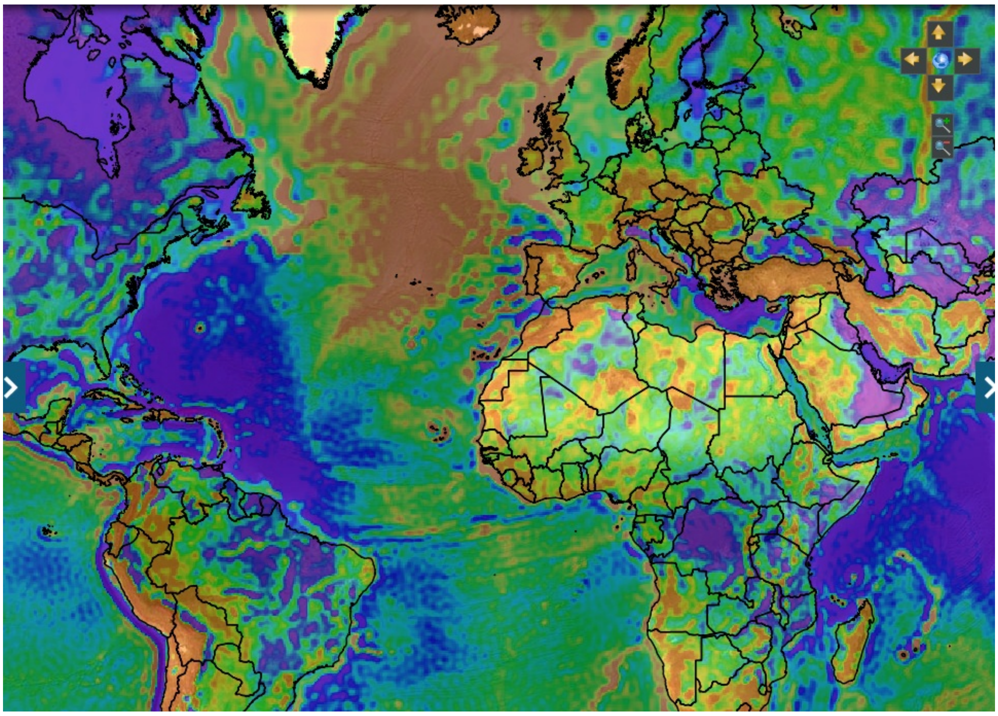


Figure 14: Free Air Gravity Anomaly (Source: ESA & IRENA)

in order to identify potential areas of interest for geothermal energy production. ESA and the International Renewable Energy Agency (IRENA) have created dedicated maps that identify potential geothermal reservoirs by analysing geological structures in combination with information of global topography (e.g. features such as thin crusts, subduction zones and young magmatic activity).

According to Henning Wuester, Director of IRENA's Knowledge, Policy and Finance Centre, "these maps can help make a strong business case for geothermal development where none existed before. In doing so, the tool provides a shortcut for lengthy and costly explorations and unlocks the potential of geothermal energy as a reliable and clean contribution to the world's energy mix."

"This is the first time that global gravity data from GOCE has been used as a tool for geothermal energy site exploration, and ESA will continue its collaboration with IRENA to further improve space-based gravity data as a resource for sustainable energy development" said Volker Liebig, Director of ESA's Earth Observation Programmes.

With respect to *solar energy*, in order to maximise efficiency and production of systems while containing costs, new installations should be concentrated in optimal locations. Here, too, space based observations can be of continuous assistance.

A future contribution of space to the energy challenge might be the construction of an orbiting solar photovoltaic plant which can benefit from about 10 times higher solar irradiance than a terrestrial plant. This concept has been proposed by JAXA to be flown in 20 years' time. European efforts in this domain are led by industry, which is currently working on smaller concepts to be eventually flown as demonstrators already in the 2020s, in order to prove the feasibility of the concept and of the energy transmission chain to the ground (e.g. radio, microwave or laser).

For optimal exploitation of the Solar Energy potential at the Earth's surface, an interesting method has been developed at the Institute for Energy and Transport of the Joint Research Centre of the European Union, the Photovoltaic Geographical Information System (PVGIS)[100] which allows performance of a Geographical Assessment of Solar Resource and Performance of Photovoltaic Technology, aimed at optimised energy production according to the geographical and territorial characteristics of the area.

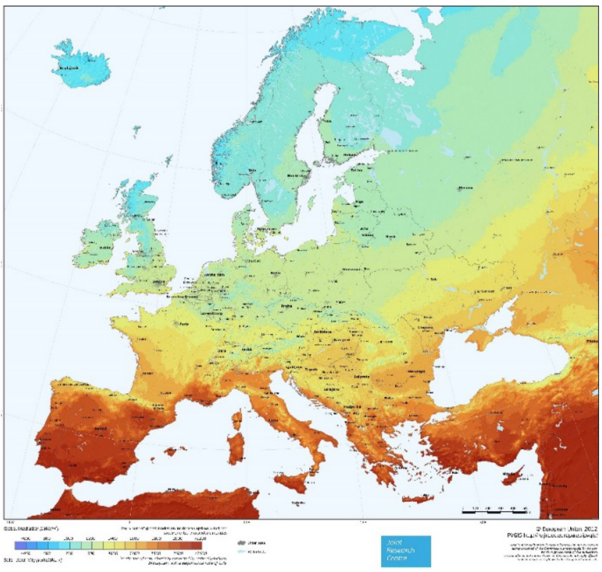


Figure 15: PV Solar Electricity Potential in European Countries (Source: EC-JRC)

100 "Photovoltaic Geographical Information System (PVGIS)." European Commission - Joint Research Centre 10 Oct. 2015 <http://re.jrc.ec.europa.eu/pvgis/>.

Taking this approach a step further, in the future it may be possible to combine the use of space assets (e.g. Synthetic Aperture Radar (SAR) imagery from Cosmo-SkyMed and Sentinel satellites) and GIS applications, to optimally manage European critical energy infrastructures[101].

Noting that the challenges posed by climate change will likely affect the European landscape, it is important to underline that the analysis of extreme environmental and hydrogeological events allows for quantitative risk assessments and the classification of the exposure value of critical infrastructure. A dedicated service could thus be implemented as a downstream product as part of the future evolution of the Copernicus program, providing real-time predictive analyses related to the natural impacts on infrastructures, and therefore supporting civil protection agencies, regional and local governments in the identification of the best actions to protect their assets, while increasing the resilience of critical infrastructures and ensuring business continuity.

4.7.3 Earthquake Prediction

One of most relevant services that is recommended for development as part of the future evolution of the Copernicus programme is the predictive and real-time monitoring of earthquakes.

Several European regions are highly susceptible to Earth crust movements, as shown by the history of countries such as Italy, Greece, Spain and the entire Balkan region.

The role of space has thus far proved to be relevant mostly for emergency response, thanks to the provision of satellite images of the affected areas to civil protection agencies.

Since 2010 Space has also provided new capabilities such as the exploitation of SAR data to analyse displacements of the Earth's crust and the movements of buildings and infrastructures. This capability also enables monitoring and mitigation of bradyseism effects.

[101] Mazza, Isabella, Fabiano Constantini, Francesco Sarti, and Stefano Ferretti. "Space data exploitation and GIS modeling as tools for infrastructure management". International Astronautical Congress - IAC-15. Jerusalem. October 2015

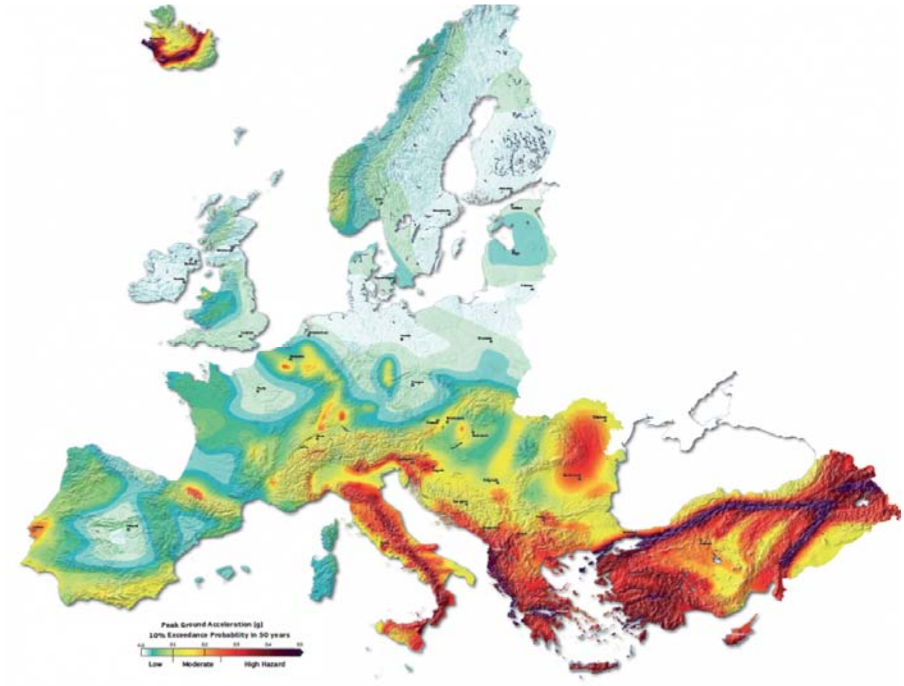


Figure 16: The European Seismic Hazard Map (Source: EC[102])

The Italian Space Agency (ASI) has already flown two payloads on board Chinese satellites and is planning a further mission in 2016 to test satellite-based monitoring of large-scale geophysical phenomena. This capability should facilitate predictive analyses of earthquakes, for example allowing early warning and timely evacuation of buildings, followed by precise and prompt deployment of civil protection aid.

Prevention via anti-seismic consolidation of buildings in accordance with the latest legislation and European directives[103], integration of network sensors and space-based capabilities is an absolute requirement for European citizens to be able to live safely.

[102] Du Brulle, C. “Mapping Europe’s earthquake risk” 3 Mar. 2014. European Commission 18 Nov. 2015 <http://horizon-magazine.eu/article/mapping-europe-s-earthquake-risk_en.html>.

[103] European Commission – Joint Research Centre. “Eurocode 8: Seismic Design of Buildings Worked Examples” JRC Scientific and Technical Reports. EUR 25204 EN – 2012. Publications Office of the European Union. 2012

5. Europe's Tools to Seize the Future

> "The beginning is the most important part of the work."
> Plato

At the beginning of this report it was demonstrated that there is a strong and dynamic link between societal needs and space assets, and that this link has changed and widened over time. Because of the nature of upcoming challenges and opportunities it is expected that this trend will continue, especially considering that it is part of a continuously ongoing optimisation process. The subsequent chapters of this report revealed that by looking at the megatrends that will affect the near future, a fair number of cases were identified in which space is in a good position to help cope with future societal challenges and expectations.

For this to happen in an optimal fashion, however, the links between space technology and innovation must be ensured, and society must be led in the right manner and direction. This raises some big questions with respect to the mechanisms and processes that ensure societal needs can be addressed properly. For instance, how can it be ensured that space industry develops the technologies and innovations that respond to the needs manifested by society? And what elements do governments and decision-makers have to take into account to organise this process?

The aim of this chapter is to shed light on the most relevant issues and aspects related to these topics. It is structured according to the different elements that determine how societal needs can be addressed in the future. As a first step, it focuses on the collection of societal needs and the mechanisms that can be set up to do so in the future. This is represented by the blue and yellow arrows labelled *A* on the right side of Figure 18 below. In the second step, this chapter looks at the framework that determines how exactly societal needs, once identified, can be best addressed by concrete policies, actions and programmes. This context is represented by the arrow *B* at the right side of the figure. As a third and final step, a section sheds light on the actions Europe can take today to ensure it will be future-proof and able to reap as many benefits as possible in the future given its particular situation and needs. All these elements, which are strategic in nature and play out over the long-term, are represented by the *C* arrow that flows between the present (left) and future projections (right).

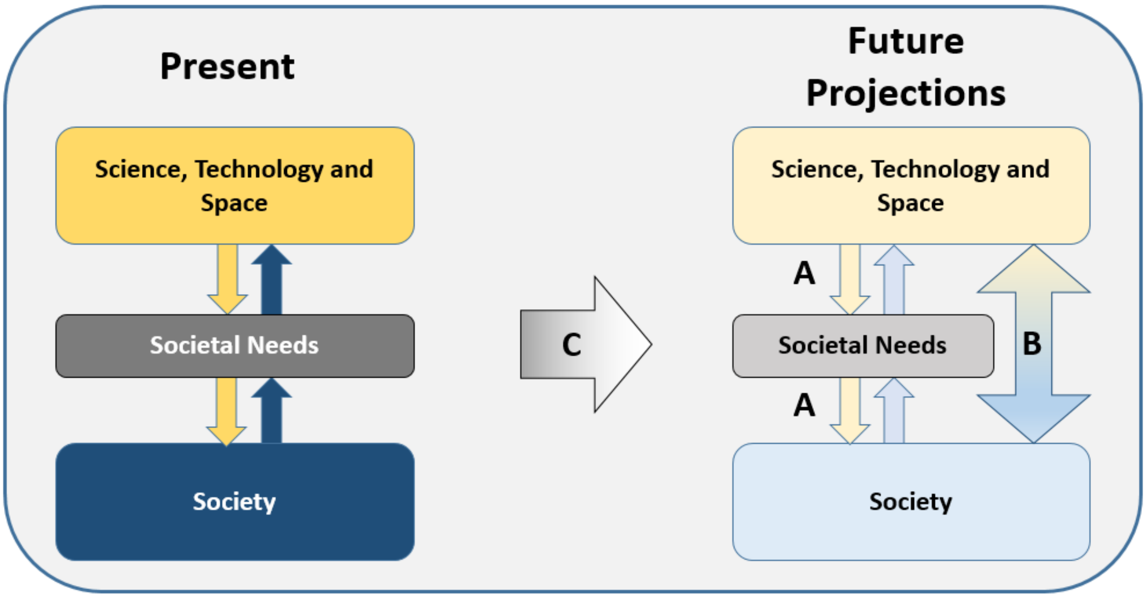


Figure 17: The Framework of Addressing Societal Needs in the Future (Source: Authors' Visualisation).

5.1 How to Capture Societal Needs?

An important element determining how society in the future will capture societal needs is the position and status of the actor that gathers them. Today, societal needs are typically collected by the public sector (national governments and public agencies such as the UN, EU and OECD), the private sector and Non-Governmental Organisations (NGOs). However, for a long time most societal needs were mainly the focus of governments but over the last decades this has changed.

As a first trend, markets have become increasingly better at identifying societal needs. This has happened because of a convergence of certain assets. Thanks to paradigm shifts in the way society approaches innovation, private companies have a much more diverse toolbox at their disposal to pursue innovation and translate technology into products and services that correspond to market and societal needs. This is in line with the continuously evolving paradigms on innovation discussed in Chapter 2 above.

Because of the transition to an information society, many dotcom companies have developed the mechanisms to gather information on general trends and desires that are present within society. In line with this, private companies are also getting access to ever better and more complex technologies that are (potentially) relevant in addressing societal needs. Moreover, there is a growing awareness among certain branches of the private sector of the importance of addressing grand challenges and opportunities, and this understanding has grown along with the willingness to invest in R&D so as to find potential solutions. The latter is illustrated, for instance, by the fact that more and more wealthy people are setting up their own philanthropic organisations and pursuing their own causes – a phenomenon that has been called "philanthrocapitalism".

At the same time, the voices of NGOs in identifying and broaching societal needs have become louder and louder. In the second half of the 20th century the limited ability of the public and private sectors to address all societal needs accurately became more pronounced, visibly, for instance, in cases of pollution and the violation of human rights. At the same time, as individuals became more empowered, they started to organise on an independent basis under the framework of NGOs to advocate for change.

In general, the diversification in the collection of societal needs is a very positive and promising trend. Not only does it allow more societal needs to be identified, it also makes it possible for people with different backgrounds and motivations to offer an outlook on how they might be fulfilled. Yet, having multiple actors collect societal needs does not diminish the role of the public sector, quite the contrary normally.

Governments, because of their unique role and scope, have a strong responsibility to make sure that they collect, map and monitor all societal needs. If governments *a priori* decided to refrain from looking into certain societal needs, issues would arise. In the event of such a failure, certain societal needs and their solutions would be addressed by the private sector; some would go unaddressed. In addition, the private sector has vested interests that could lead to suboptimal societal outcomes if it was left alone to identify certain needs. Even when private companies develop technologies that can serve societal needs, the bias towards commercial applications and profit could leave aspects of societal needs unaddressed, or could lead to disturbed distribution effects wherein only certain sections of the overall population have access to solutions that should serve all. Governments have a responsibility to ensure long-term sustainability for their citizens, ensure solidarity between different social groups and set up mechanisms to ensure intergenerational solidarity. So, even if public entities are helped in the collection of societal needs and even when private actors can address certain societal needs, the government still has the duty to track and map the overall process in order to guarantee the democratic character of mechanisms aimed at fulfilling societal needs. This means that different governments and public organisations have to set up interaction and communication mechanisms to make sure they all stay informed about developments and societal needs and potential solutions in different fields.

There are existing mechanisms for collecting societal needs, of course. As the need for collecting and addressing changing societal needs becomes bigger, it is important to expand and optimise the existing mechanisms. To this effect, this report makes several suggestions that might help in optimising the collection process. As will be illustrated, several mechanisms could be deployed in this respect.

5.1.1 Virtual Observatories

The very first system that can be effectively used in monitoring and collecting societal needs are Virtual Observatories - digital platforms whose main function is to:

- Increase citizens' participation in the societal context
- Favour intergenerational conversations
- Initiate closer interaction with decision makers, thus reinforcing democracy.

Virtual observatories could make optimised use of ground breaking survey methods as well as focus groups and control groups. On the local level, these platforms could provide a means to improve the quality of life of local residents, creating a virtuous circle between citizen, public institutions and services providers. Smart cities will become human-scaled cities, as they will encourage their citizens to express their needs, thus encouraging them to feel more responsible for their own neighbourhoods, and to be active participants in the decision-making processes.

Virtual Observatories could also become an ideal platform for further processing the needs and ideas collected, involving industrial actors and business incubators, thus opening new markets and leading to the creation of new business opportunities.

5.1.2 Social Media Content Analysis

Younger generations tend to make more intense use of social media, not only for leisure purposes, but also to actively participate in public debates and forums, creating new forms of sociality, collaboration and solidarity.

This increasing openness, availability of, and access to, information will contribute to increasing public awareness and sensitivity to injustice and social problems around the globe. Governments will have to take these emerging societal trends into account, both for internal matters and for international relations purposes.

Certainly the decision-making processes will need to become much faster and, in some cases, even predictive. It would therefore be of utmost relevance to put in place appropriate analysis mechanisms to collect, process and use this information for a more democratic, fair, just and conscious world. The data generated by social media analysis could also be used to identify new markets in order to address identified needs and opportunities.

Moreover, combining this social media information with space data, such as navigation and Earth Observation information, will provide valuable assets for businesses in the future. The added value of this method is that *the social context is added to the physical information* on location and circumstance, and can be made available to users all over the world. For example, the company Starbucks already plots where to place new store locations on the basis of current and future demographics, and environmental groups (e.g. Nature Conservancy) also use enhanced software to track wildlife patterns and map nature preserves.

5.1.3 Advocacy Groups

A noticeable trend of the last decades has been the increasing importance and influence of advocacy groups, particularly those organised as NGOs. Greenpeace, Amnesty International and WWF are testimony to how civil society can influence public discourse outside the traditional structures of political parties, unions, employer and trade organisations. In fact, the decline of political parties has been accompanied by an increase in NGO participation. Governmental structures have been slow in capitalising on this kind of active engagement of citizens, partly perhaps because early NGOs were seen in a rather antagonistic light, and positioned themselves rather antagonistically. There is little realisation in government or the traditional political system that NGOs constitute a particularly valuable asset because they engage citizens without actually vying for direct political power. NGOs thus constitute a kind of perpetual opposition, but one whose positions other actors can adopt without paying a political price to an actual opposition party. NGOs are often forgers of political ideas and alternatives for free use by governmental authorities.

It goes, perhaps, with the highly autonomous nature of NGOs that there is little organisation between them. NGOs do not have an equivalent of the United Nations, a United NGOs, and even sectorial NGOs tend to get together only when governments get together, such as for COP21. It would be societally desirable that NGOs would create superstructures within which civil society concerns could be expressed also in a more aggregated way, environmental groups having a loose environmental umbrella organisation, humanitarian organisations another, and that at the top level there would be an equivalent to the UN. This would have direct benefits and would also help to counteract the political estrangement that is such a defining feature of our current political life.

It also goes with this territory that governments and parliaments should establish dedicated mechanisms to reach out to NGOs. The prime ministers' offices should have dedicated and prominent NGO liaison officers, as should particularly relevant ministries, such as those dealing with environment, justice and foreign aid.

And paradoxical as it may sound, governments should also actively encourage the formation of NGOs, even those that might be vehemently opposed to governmental policies, because the ultimate prize is not the success of a given policy or government but the success of democracy. NGOs play a key role in expressing societal needs and that is what a well-working democracy needs.

There is also relevance for space in this in a narrower sense. NGOs in space tend to be those of space enthusiasts, the devotees of human space flight or space science – and that is fine – but there is a true need for NGOs at a more political level; NGOs expressing societal needs and opinions from a civil society perspective. It is ironic that the current focus of space agencies on providing terrestrial utility has been driven by the space agencies themselves, partly in response to budget concerns, and that few, if any, NGOs have been flanking these efforts. So, the space community should encourage policy level NGOs to be formed and should make sure that there are proper liaison functions with NGOs, not only with those dealing with space, but also with NGOs that are relevant for space and for the societal needs space may be able to fulfil!

Such functions could be complemented by broader high-level liaison functions through which the space community can engage in bidirectional dialogue with the rest of society. The potentialities of space are poorly understood by general decision makers, and the space community is sometimes oblivious to the needs of general society and general decision makers. An ambassadorial role towards particularly the Chief Scientists of governments is advisable.

5.1.4 Integrating Societal Needs Mapping

To capture "societal pull" in the best possible manner, a key aspect is that the mechanisms devoted to collecting societal needs should be enhanced in their capacity to identify interlinkages among needs. In other words, it will be important to avoid collecting specific needs in isolation from one another, meaning that a holistic approach should be put in place. To illustrate, the needs that stem from urbanisation challenges should not be considered in isolation from those resulting from climate change and the management of key resources such as water, food and energy.

To be effective, the deployment of such potential instruments as virtual observatories, social media analysis and advocacy group liaisons by necessity must address the complex interaction among societal expectations so as to integrate different needs in one model and identify scope for potential synergies when addressing them. This aspect also links with the future potential of behavioural sciences and their integration with other domains. Over the last decade there has been a stronger emphasis for social sciences to focus on, and develop, evidence-based policies. In the future it is possible that a new generation of evidence-based policies will build on larger data sets with a wider set of indicators. By using integrated data sets the social sciences will be able to generate models that could support decision makers on very divergent topics, ranging from the effectiveness of certain social policies to the planning of new urban infrastructure. For these new approaches to develop, however, the landscape of the education and academic structures also has to evolve accordingly. This will be addressed below under the topic "human capital" in section 5.3.

5.2 How to Address Societal Needs?

Once societal needs are collected, it is important that the right steps are taken to address them. In this respect, governments must not only be informed about all potential societal needs, they also must have a clear understanding of and approach to how societal needs can be best fulfilled. They can either choose to fulfil these needs themselves, or to let the market find solutions to certain needs. In reality, however, this often calls for hybrid approaches since the division between public and private sector involvement is in fact rather an either–or fallacy. This section will elucidate the foundations on which fulfilment considerations should be made and seeks to illustrate which approaches could be adopted to translate identified societal needs into concrete policy and programme actions.

5.2.1 Who Should Address Societal Needs?

Whereas all societal needs should be regarded as being important, the perennial limitation of resources may not allow addressing all of them at the same time. Hence, the establishment of societal spending priorities is needed. And when it comes to prioritization, apart from timing, the foremost question to answer is who is best positioned to address given societal needs? Inevitably, this raises questions about the role of the public and private sectors in serving the "pull" of society (and of its various stakeholders groups) in the best possible way.

At a time when the role of the private actor – in space and elsewhere – is growing in importance, one could assume that once societal needs and related expectations are identified, prioritisation in the allocation of resources would be spontaneously determined by market mechanisms, whereas the role of the government should be limited to simply supporting the economic dynamic of private initiatives and to fixing potential market failures. This, at least, would be the view proposed by the neoliberal mainstream; a view, however, that is as widespread as it is contended by many innovation scholars.

Indeed, since the seminal work of Chalmers Johnson on the Asian developmental states – a state where the visible hand of state bureaucracy acts over the invisible hand of the market in stimulating innovation and economic growth[104] – an increasing number of economists has drawn attention to the potential risks implied in such a relocation of authority and has revisited the actual role of public initiatives in driving innovation, by *inter alia* contesting the neoliberal view of an inefficient, bureaucratic state versus a dynamic and innovative private sector. Scholars such as John Kenneth Galbraith, Paul Krugman, Bruno Amable and more recently Mariana Mazzucato have in their analysis highlighted the key role governments can play when it comes to sustaining long run, innovation-led economic growth.

As poignantly argued in a recent essay published in *Foreign Affairs* by innovation economist Mariana Mazzucato, "in countries that owe their growth to innovation, the state has historically served not as a meddler in the private sector, but as a key partner of it – and often a more daring one, willing to take the risks that business won't".[105] As corroborated in a number of key examples – from the IT industry to the green-tech industry, passing through to the biotech and nanotech industry – the private sector has been willing to invest only when prior high-risk investments by the public sector have made technologies mature enough to open technical and market opportunities for businesses. Put simply, the action of the private actor is essentially guided – and perhaps inevitably so – by considerations of technological maturity and commercial viability, and, for these reasons, markets may well neglect to solve the most pressing societal and technological challenges.[106]

It is undeniable that in addressing societal needs such as those stemming from climate change or inequality, market forces on their own may be unable to set the directions with regard to investments in innovation. It is the government that needs to set these strategic directions and implement policy actions including market support. And it should ideally do so by putting the needs of society at the forefront and identifying the lacunae in the market mechanisms addressing them.

This calls for a hybrid approach in which the role of the public and the private sectors should not be seen as mutually exclusive, but rather as complementary and mutually reinforcing.[107] Indeed, the respective roles of the public and private sector do not necessarily have to be split in a very distinct manner, as there are innovation tools that could allow both to take on responsibilities and tasks in the provision of one specific societal solution in a more fluid and mutually reinforcing manner. It goes beyond the scope of this report to plot exhaustively these innovation tools, as there is considerable literature on the topic[108], however some concrete steps are described below that may be undertaken to optimise innovation outcomes.

In terms of knowledge management systems, a highly recommended approach is the establishment of central registers for good ideas that at the time of their formulation were perhaps not feasible or appropriate to implement, but could become useful once the context changes. Such registers would be regularly reviewed internally in order to establish whether the time has come for a certain idea, and the registers may even be made available to knowledge brokers.[109]

Similarly, it might also be worth considering whether large institutions, such as the EU, could benefit from establishing the function of a Chief Innovation Officer, who would work under or parallel to the Chief Scientist Officer

[104] Johnson Chalmers. MITI and the Japanese miracle. Stanford University Press. Stanford. 1982. P. 132. According to Johnson, the developmental state is a state that, beyond taking over many of the developmental functions usually driven by private initiative, directly intervenes in all economic processes to stimulate innovation and long-term growth.

[105] Mazzucato, Mariana. "The Innovative State". Foreign Affairs. January/February 2015: 61-68.

[106] Ibid: 64

[107] The role of the government should not only be limited to fixing market failures. It should be also directed to the creation of new markets by wisely complementing market mechanisms in addressing societal needs.

[108] Giannopapa, Cristina, Peter Hulsroj, Arne Lahcen, and Nunzia Paradiso. Space and the Processes of Innovation. ESPI Report 43. Vienna. 2012.

[109] For a more complete overview of the relevant mechanisms in this respect in society at large and their degree of application in space, please consult: Ibid.

and ensure that innovation is pursued much more intensively wherever it has the prospect of leading to improved outcomes in the long run. This would also enable a better cross-fertilisation between innovations from the public and private spheres. A visualisation of this idea is depicted in the figure below.

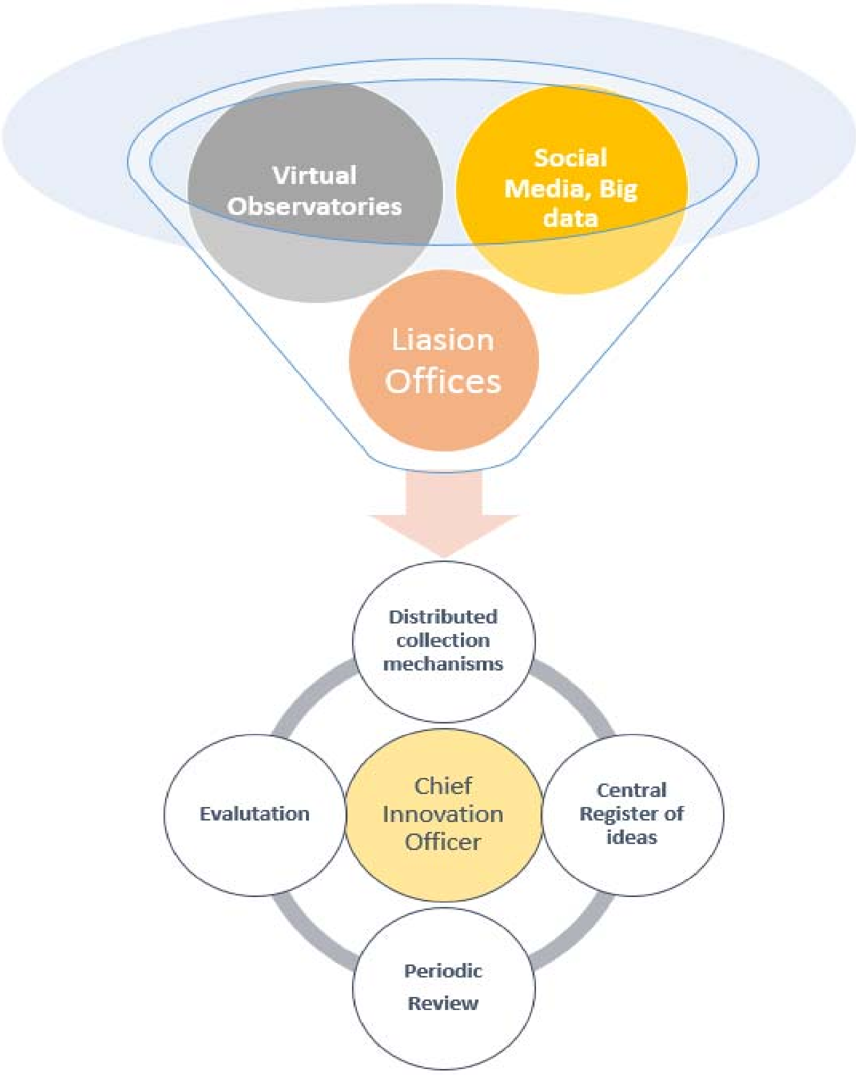


Figure 18: The Role of the Chief Innovation Officer

5.2.2 What Needs Come First?

Putting the spotlight on the complementary role to be played by public institutions in both collecting and addressing societal needs, does not, however, answer the question of *what* and *whose* needs are the most relevant or, in other words, how societal needs should be prioritized?

While it is evident that in a resource-constrained environment the eventual decision to address one societal need over another can only play out in actual political discourse, establishing a rank among needs could nonetheless provide decision makers with some guidance in the process of determining societal spending priorities. This, in turn, raises questions relative to what should be the most important criteria in this sense. Whereas a variety of criteria and approaches could be ideally identified on the basis of several sociological theories (e.g. Maslow's hierarchy of needs,[110] Manfred Max Neef's model on human scale development)[111], the ensuing prioritisation of needs would arguably remain a far too rigid schematic, as it would *inter alia* confine the various needs in categories that are artificially constructed and

[110] Maslow's hierarchy of needs is made of: psychological needs, safety needs, love needs, esteem needs, and self-actualization needs.

[111] Manfred Max Neef's scale includes: subsistence protection, affection, understanding, participation, idleness, creation, identity and freedom.

	Low Risk	High Risk
Concerns part of society	Least Important (e.g. ultrafast travel)	Important (e.g. ageing)
Concerns whole society	Important (e.g. enhanced connectivity)	Most Important (e.g. climate change)

Table 3: Addressing Societal Needs (Source: Authors' re-elaboration)[112].

inevitably overlook the complex interactions between different needs in different categories.

Such limitations could be – at least in part – resolved by introducing a multi-criteria decision-making method built on the basis of criteria interaction. To illustrate this approach, two basic criteria are introduced. The first criterion could be the extent to which a specific need concerns society (e.g. a very small segment of the population or its entirety). A second criterion could deal with the risks associated with leaving a need unaddressed (e.g. causing severe difficulties to people or endangering their lives). By combining the two criteria, it is possible to create a double-entry table for visualising and establishing basic prioritisation criteria among needs (see Table 3).

Building on the interaction between the two criteria, a utilitarian perspective would suggest that a need concerning the entirety of society with a high risk factor (e.g. climate change) should logically deserve to be addressed first, while a need that concerned only a small portion of society and had a lower risk factor (e.g. meeting future intercontinental mobility needs) should be the one to be tackled last. As for the others two cells in the table, the question would remain open and arguable.

While theoretically additional and more sophisticated criteria could be introduced to decide what specific social need should have the next priority, the key point to highlight is that ranking societal needs on an ordinal scale would inevitably continue to be a rather rigid schematic having inherent pitfalls. For one thing, it is likely that the prioritisation of needs would be performed from a narrow utilitarian, common sense perspective, rather than by methodologically assessing each need against all others. In addition, such an approach would not allow measuring and contrasting the preference intensity of one need with respect to the other needs among the various stakeholders.

Since perspectives on what the most relevant societal needs are and what constitutes their resolution differ across various societal groups, the establishment of the abovementioned dialogue tools with the public and its diverse stakeholder groups could play a crucial role also in circumventing these limitations. Indeed, the deployment of such dialogue-mechanisms as liaison offices and observatories of demand could not only be used to qualify societal needs; it could also be instrumentalised for both ranking different needs and, equally important, for measuring the preference intensity of those needs so as to establish preference patterns and truly stimulate the "societal pull" rather than envisaging *ex ante* technological solutions to meet such "pull".

Only by devising proper means of mutual dialogue with society and its stakeholder groups can concrete policies, actions and programmes be implemented in order to drive innovation to fulfil societal needs in the best fashion.

5.3 How to Make European Society Future-Proof?

Based on the findings of previous chapters, it can be assumed that future generations will be faced with a much more challenging landscape in terms of societal steering. More than ever, fulfilling societal needs will require complicated trade-offs to be made or solved through radical innovation. Addressing these issues will require more emphasis on integrative thinking and interdisciplinary approaches. The specific suggestions in the previous sections are essential in making sure that space is properly incorporated in the formulation of answers to societal needs. In addition to this, there are also more strategic actions that can be undertaken to make sure future generations approach social challenges and opportunities from a more holistic perspective.

[112] Re-elaboration from: Crone, James A. How Can We Solve Our Social Problems? SAGE Publications. London. 2011: 7.

5.3.1 European Innovation Union

According to the European Commission,[113] European innovation systems will become more efficient in the future with an increased role given to users, leading to higher returns on investment, favouring both economic and social development.

The first step to achieve this goal is to harmonize research agendas across European Member States. In this context, the European space sector has been a landmark for research and innovation integration for decades.

Lessons learned from European cooperation in space can be transferred to the wider innovation agendas, including all other sectors. In this respect, one key strength is the ability of the space sector to structure its own activities with a long-term view and strategy that ideally positions program development and implementation.

This forward looking approach enables European decision makers to plan investments that no single country would be able to make on its own, with one of the highest returns on investment seen in European R&D. Furthermore the approach means that Europe can define a stronger role for itself in the global context, and it enables the anticipation of future needs and the creation of international cooperation from a leading position.

The "EU 2020 strategy for smart, sustainable and inclusive growth", paving the way for the creation of an Innovation Union,[114] is a step in the right direction in terms of looking at innovation in a holistic fashion and in concert with other societal factors, and the 7-year time horizon of the EU's Multi-annual Financial Frameworks (MFF) does provide a degree of planning security similar to that of the institutional space sector. Yet, the difficulties of accommodating Copernicus within the MFF 2014-2020 is an example that shows that even if the toolbox is available there is still room for optimisation both within the space field and beyond. But, crucially, the individual European Member States generally operate on yearly budgets without the advantage of a financial superstructure like the MFF. This means that if innovation is to be harmonised and optimised in Europe then individual states might have to create general financial commitment mechanisms that allow for the long-term perspective that is often necessary to meet new societal needs. It can be argued that the annual budget process in the United States is one of the most costly impediments to its institutional innovation investment, and this should give rise to reflection at individual country level also in Europe.

5.3.2 Productive Innovation Ecosystems

In order to be able to translate social needs into policy and action, proprietary measures such as patents, trademarks and copyrights can be important in encouraging innovation, which is a fundamental tool for Europe to respond to the evolving needs of its citizens. This is especially the case in a sector such as space, which is technology-intensive and where large investments in infrastructure are needed up-front, therefore increasing the need for private companies to invest in protecting innovation and know-how.

ESA's Intellection Property Rights (IPR) system strikes a careful balance between allowing industry to own IPRs generated under public funding and ensuring that the ESA and its Member States have access to such data for their continuing activities. This system functions appropriately and gives industry an incentive to innovate and commercialise innovation.

On a general level Europe may, however, have to reflect more on how it stimulates productive ecosystems of innovation, particularly when publicly funded IPRs are involved. In the United States Apple and Google have shown that productive innovation ecosystems sometimes require rather free access to intellectual property originating from the central actor in the ecosystem, and how this sometimes serves the interests of the original owner of the IPRs.

Europe would be well-served by discriminating clearly between situations where IPRs should be protected and remain with the publicly funded originator, meaning that the owner becomes the only or the main actor in leveraging the innovation, and situations where free access to IPRs (possibly ring-fenced to allow only European use) would create innovation ecosystems for many actors, all bringing in their expertise to further increase the utility of the original IPR. For this to succeed it would, however, be necessary not only to open up the IPRs for more general use, but also to create effective virtual platforms where the information can be shared and ideas exchanged.

[113] European Commission. Global Europe 2050. Directorate General for Research and Innovation. EUR 25252. Brussels. 2012

[114] European Commission. Innovation Union – A pocket guide on a Europe 2020 initiative. Publications Office of the European Union. Luxembourg. 2013.

5.3.3 Human Capital

If Europe wants to ensure that future generations incorporate the complex nature of reality better in their worldview and thus in their activities, this will have to be reflected better in the education and knowledge transfer systems that inform the decision-makers and citizens of future generations.

To date, however, education systems – in spite of evolutions and renewal processes – still very much reflect the 19th century context in which they were established. That is, their purpose is to prepare citizens for economic engagement and productivity on the labour market. That is why in most countries children start their school career by learning how to read, write and count. Only at later stages, education systems start addressing what is considered as "more advanced" studies: the natural and social sciences. Yet at this stage there is already a distinct degree of specialisation present, which makes it difficult for students to establish a proper multi- or interdisciplinary perspective on the reality of nature and society.

In addition, the recent advances made in our understanding of the world and reality in general have not yet led to a revision in how we should pass on this spark to the upcoming generations. In Chapter 2 it was illustrated that space has been influencing societal change by fostering what was labelled as "universal understanding". Yet, as was also argued, it has done so in a very indirect way. The paradigm shifts that have arisen (partially) as a result of an increasing general understanding of reality have done so in an organic, fragmented and time-lagged way.

Taking space as a pathfinder for how to move to more integrative understanding and education, it can be argued that space–based knowledge should be incorporated much earlier in the societal processes that foster understanding. After all, space is the meta-environment in which all other human activities and biological, chemical and physical processes take place. Perhaps future generations would be better served by also learning very early on, in a story-telling fashion, how all came into existence, how our universe, its solar system and planets evolved, and life and humanity on it.

Not only would this foster a perspective of universal understanding, but it would also spur students to think out-of-the-box and in a more creative fashion. This is not a question of outreach, but rather a question of rethinking the consequential logic determining the way people conceive, approach and contemplate reality. A generation inspired in this fashion might develop new skill-sets and mind-sets that are able to rewardingly combine the insights of traditional STEM disciplines with humanistic ones. In addition they will be far more prone to approach new information in an open fashion and to think about challenges in a different fashion. In this sense it would foster paradigm-shifts that will propagate throughout the entire society and economy and will encourage radically different choices in many fields.

The broader question on interdisciplinarity is, however, how educational systems can embrace this approach in a more systematic fashion. It is not strange that maths is taught separately from literature or chemistry, yet how to bring the different strands together for overall understanding is the outstanding question.

What seems to be missing in most, if not all, educational systems is interdisciplinary teaching functions. Already early on, even at primary school level, there could be regular lessons devoted to interdisciplinary studies. And this could be implemented all the way though the educational experience, including at university level. The strength of the U.S. college system is that it does not pigeonhole students too early, yet even there true interdisciplinarity is seldom taught. And at law school there would be good reasons to have a course dealing with what literature can bring to legal understanding, just as scientific approaches can be highly relevant for 'the legal method', and *vice versa*.

It is obviously a significant societal investment to devote even a small part of the curriculum to interdisciplinary studies, and train the involved teachers appropriately, yet in an interconnected and interconnecting world this may be the most prospective means to break free from the 19th century education paradigm.

6. Conclusions and Recommendations

The objective of this report was to look ahead in time and see how, in the future, the relationship between space and society can become even more intimate and mutually reinforcing; and thus what actions need to be taken to enable the harvesting of future opportunities and addressing societal grand challenges.

As a first step, the disposition of space as an environment and tool to the benefit of humankind was considered in a wider framework. It was advocated that space should be regarded as part of the wider fields of science and technology and that their interaction with society and social progress is dialectic in nature – meaning that developments in one field will ultimately have repercussions on developments in the other. This has also played out for space. On the one hand, paradigm shifts regarding innovation have changed the way society approaches space. On the other hand, space itself has played a role in changing humanity, by creating universal understanding and strengthening the processes of globalisation and environmentalism. Looking at the future, it can be expected that this mutual relationship will continue to change society and space utilisation. This trend has to be taken into account when it comes to further optimising the institutional and policy context for space activities in addressing societal needs.

Subsequently, the report looked at the major events and trends that are likely to play a role in determining future social needs and challenges. Although unfolding global trends do not necessarily provide a well-defined picture of the world in 2030, their identification is helpful in shedding light on the societal challenges Europe will be facing. More precisely, the report addressed four overarching, unfolding trends. A first element is given by the progressive expansion and ageing of a global population that becomes increasingly more empowered. Second, technological advancement will continue to progress at a rapid pace thanks to the diffusion and convergence of technologies, and this could lead to changes in the functioning of the economy and society. Third, the context in which ever more societal needs will have to be addressed will be increasingly challenged from an environmental perspective, potentially enlarging the negative trade-off in the management of crucial natural resources. Fourth, the economic and political power shift toward non-Western countries and non-state actors will decrease the power of Western governments, further fragmenting global governance whilst at the same time increasing interdependencies.

Following this the report explored the potential contributions to be offered by space to address European future challenges. As a general trend, it seems that Europe will increasingly need to design new services centred on citizen’s needs and integrate space applications in the areas of EO, GNSS and communications with existing and new ground infrastructure of this nature. Since the world will be changing at an ever-faster pace, space programmes will have to become more flexible and more resilient at the same time. Further, climate change was identified as one of the main challenges and space can and will provide a key role in developing mitigation and adaptation measures and provide for monitoring. In addressing these societal challenges, there are also opportunities for Europe. The EU has the chance to create an integrated digital market, establish new platforms aggregating space and cloud data, and spur the development of industry 4.0 of which space will be a strategic element.

In order for space to be in a good position to reap the above opportunities and address the main challenges, it must be ensured that the space community is probably adapted, attuned and optimised vis-à-vis society at large. This was addressed in the final main chapter of this report. As a first step, governments must ensure that they identify and collect all existing societal needs and their likely evolution. This means that different governments and public organisations have to set up new interaction and communication mechanisms such as virtual observatories, social media channels and liaison offices, and improve existing mechanisms. It might also be worth considering whether large institutions and organisations, such as the EU, could benefit from establishing the function of a “Chief Innovation Officer”.

Once societal needs are identified and collected, the second question is how they can and should be addressed. In this respect governments should establish proper prioritisation mechanisms and initiate an open and transparent dialogue process with various stakeholders. Finally, it must be ensured that European society becomes future-proof. Here, the report looked at the importance of an EU innovation union, the role of intellectual property rights, and the importance of evaluating education and learning systems and mechanisms.

Recommendations

In light of the findings of this report and the current economic, political and societal challenges in the European context, it is important that societal grand challenges of the future will not be studied in a fragmented and isolated fashion. It is high time to initiate a thorough dialogue and reflection, and eventually take actions so as to make sure Europe remains a strong, prosperous, attractive and *just* society in the world. In this respect the following recommendations are made regarding the role of space and its responsible institutions:

- The identification, collection, registration and monitoring of societal needs should be pursued in an integrated and centralised fashion by dedicated public actors. In this process, it should be possible for different parts of society (e.g. NGOs, private industry, other public actors, citizens, etc.) to interact and get more and more involved. To this effect, the creation of well-coordinated mechanisms at European level should be incentivised in the very near future.
- The main relevant players and stakeholders in the European space community (and beyond) should establish dialogue mechanisms to reflect on the potential of space for humanity in the future. This way, the fragmented space community in Europe could eventually converge its perspectives and speak more strongly and with one voice in non-space contexts. More specifically, it is recommended to tackle the following:
    - How current space applications and technologies can be further used to address existing societal needs should be mapped.
    - Continuous assessments should be made of how space in the future might address current or new societal needs.
    - Space actors should reflect on their respective roles in identifying and addressing societal needs, taking into account the complementarity of their focuses and functions.
- The development of new space programmes should take into account the future European challenges and societal needs. The ensuing services will have to be, by necessity, centred on citizens, possibly integrating navigation, Earth observation and communications space systems with ground infrastructure. They will also have to be flexible on the one hand and more and more resilient on the other, thus ensuring business continuity.
- The establishment of governance frameworks for the management of innovation, should be considered, together with new mechanisms to spur the development of solutions to societal needs. In this respect, there is a strong need to enhance the link between space actors and public institutions and, to make sure that innovation is sought in a more explicit fashion. Innovation in the space sector should be pursued in a manner less isolated from innovation in other technological fields and domains.
- In order to foster more productive innovation ecosystems, industrial policy in the space domain should be enhanced *inter alia*, by elaborating a strategic plan capitalising on a free, open a full data access policy, where appropriate. This is a crucial element in maximising new business and service creation in Europe. To this end, it is recommendable to identify areas where European space-based assets can support a competitive advantage in the global marketplace and encourage appropriate protection mechanisms to defend this strategic position.
- Europe should promote international cooperation schemes and make use of its technological prowess as a tool for internal economic growth and global leadership. Specifically, Europe could position new space programmes and their long-term evolution as world landmarks in the areas of environment, energy and smart infrastructures.

The nature of upcoming challenges and opportunities is vast. Therefore, it is important that problem solving itself becomes subject to intense study. In this respect, European education systems and social sciences should become more subject to evidence-based policies and should embrace interdisciplinarity to a much higher degree.

List of Acronyms

Acronym	Explanation
A	
ASI	Agenzia Spaziale Italiana (Italian Space Agency)
C	
CAMS	Copernicus Atmosphere Monitoring Service
CERN	Conseil Européen pour la Recherche Nucléaire (European Organisation for Nuclear Research)
COP21	Conference of the Parties - 21st Session
E	
EC	European Commission
ECVs	Essential Climate Variables
ELDO	European Launcher Development Organisation
EO	Earth Observation
ESA	European Space Agency
ESPAS	European Strategy and Policy Analysis System
ESPI	European Space Policy Institute
ESRO	European Space Research Organisation
ESTEC	European Space Research and Technology Centre
F	
FAO	Food Agricultural Organisation
FP	Framework Programme
G	
GCOS	Global Climate Observing System
GDP	Gross Domestic Product
GHG	Green House Gas
GNSS	Global Navigation Satellite System
H	
H2020	Horizon 2020
I	
ICARUS	International Cooperation for Animal Research Using Space
ICT	Information Communication Technology
IEA	International Energy Agency
IMF	International Monetary Found
IoT	Internet of Things
IPR	Intellection Property Rights

Acronym	Explanation
IRENA	International Renewable Energy Agency
J	
JAXA	Japan Aerospace Exploration Agency
JPL	Jet Propulsion Laboratory
K	
KET	Key Enabling Technologies
M	
MFF	Multi-annual Financial Framework
N	
NASA	National Aeronautics and Space Administration
NGO	Non-Governmental Organisation
NIC	National Intelligence Council
O	
OECD	Organisation for Economic Co-operation and Development
P	
PVGIS	Photovoltaic Geographical Information System
R	
R&D	Research and Development
S	
S&T	Science and Technology
SAR	Synthetic Aperture Radar
STEM	Science, Technology, Engineering and Mathematics
T	
TRL	Technology Readiness Level
U	
U.S.	United States
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
W	
WME	Weapons of Mass Effect
WTO	World Trade Organisation

Annex

A.1 Relevant Sources

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Acknowledgements

The authors have greatly benefitted from discussions with many knowledgeable authorities and colleagues during the preparation of this report, each of which cannot be thanked individually. A special thanks, however, goes to Dr. Didier Schmitt who has been helpful in connecting the dots in so many ways.

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