Key Enabling Technologies & Open Innovation

New impulse for the space sector

Final Report

Prepared for European Science Foundation - ESF

by

EUROPEAN SPACE POLICY INSTITUTE

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ESF Officer:	Jean-Claude Worms
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Technological Breakthroughs for Scientific Progress

Final Report

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European Science Foundation

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European Space Policy Institute

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Executive Summary

Analysis and Findings

Science, Technology and Innovation. Terminological and conceptual foundations with respect to science, technology and innovation, and their relationship, were given. The words science and technology were defined. Science and technology are mostly used side by side. There is an overlap and common territory between the two, and when boundaries are drawn they are often arbitrary. Scientific and technological advancements are often pursued simultaneously by the same person, group, or institution, and through the use of the same means. In the ESA terminology "Science and technology" are clearly differentiated and are used in a different way than by others. The term science refers to what is widely known as pure or fundamental science, for space and earth observation. On the other hand, when the word technology is used, it also covers the pure or applied science that leads to knowledge which can be translated into technological developments. Regarding innovation, various definitions of Innovation were presented as described by OECD and DG Enterprise and Industry of the European Commission. Different models for innovation and science and technology were described. The two models were 'closed innovation' and 'open innovation'. In order to describe the science and technology relationship, the push-pull model was used. General examples of science pull and technology push in various fields were presented. Certain technologies can be used as a core for different scientific and industrial developments, but it is only recently that these have been identified as 'Key Enabling Technologies' (KET), which are: Nanotechnologies, Micro and nanoelectronics, advanced materials and biotechnology. Definitions and descriptions of the different key enabling technologies were given.

Innovation in different sectors. Different sectors perceive innovation in different ways and implement it at different levels around two main components: 1) incremental by improving existing products, services etc. or, 2) breakthrough by making a complete change from existing practices. Based on this, they are classified into two categories: "conservative" or "fast moving" sectors. Examples of conservative sectors that were studied are space, aeronautics, transport, energy, pharmaceutical, while examples of fast sectors are ICT and biotechnology. The construction sector is one of the most conservative sectors when it comes to innovation. The main problem in innovation is that new technologies are developed outside the ones that can implement them and thus, they are not aware of them. A Technology Watch company is suggested as a solution. The energy sector and transport sector analysis concentrated on policies as facilitators for innovation. The aeronautics sector analysis concentrated on the fact that, during the initial emergence of the sector breakthrough innovations were experienced, whereas in recent years, an incremental approach to innovation has been taking place. Innovation in this sector is expected to occur through technology advancements in other areas like ICT. The pharmaceutical sector stagnation in innovation is mainly attributed to strict regulations. The biomedical engineering sector experiences acceleration of innovation mainly thorugh advancements in automation. Innovation in the ICT sector is very much dominated by technology push. When new innovative technologies do not make it up to their full potential, the reason can be attributed to the inability to properly capture the user needs, and the inability to properly explain the potential of the new technology to the user. At the same time, the user needs are constantly changing in this sector, thus, traditional marketing tools fail. Bad marketing decisions fail to capture the user needs and deliver the wrong message, to the user, about the technology at hand.

Partnerships and Institutions at European Level. An overview of the European perspective was given for EU 27 showing, in particular, the areas of specialisation in Europe with respect to the key enabling technologies. The steps of Europe with regard to the 2020 vision were highlighted and the new initiatives which have recently emerged, like joint programming and international Science and Technology cooperation, were listed. There is a multitude of institutions in Europe from which the following were identified, due to their European perspective and creation to bridge gaps: European Research Council (created to bridge the gap between national funding bodies for fundamental research and provide a European perspective), European Institute of Technology (created to bring together the knowledge triangle of research, innovation and education and to bring R&D to the market), European Technology Platforms (aiming developing a coordinated scientific research agendas of key stakeholders in various areas).

Innovation Technology Projects in Europe. Projects in Europe were listed and categorised under the relevant Key Enabling Technologies. These projects were financed under the European Commissions Framework Programme and were conducted by European consortia with academic and industrial partners. The projects listed were selected in order to indicate the European activities in the KET fields and were not, at this stage, examined for their suitability in the space sector.

Recommendations

The recommendations from this study are categorised into concepts, partnerships and mechanisms below:

Concepts

- A clear distinction should be made when the terms “Science” and “Technology” are used since, in the ESA context, there is a clear distinction between the two terms, in contrast to others who mostly use “Science and Technology” side by side. In ESA the term “Science” refers to what is widely known as pure or fundamental science, for space and earth observation. On the other hand, when the word technology is used, it covers the pure or applied science (space and non-space) that leads to knowledge which can be translated into technological developments for space.

- The following definition for “space innovation” should be used in the space sector and by ESA: *"Innovation is the use of new, or existing, ideas, discoveries and inventions in the space sector, stemming from other sectors (spin in), and vice versa, the use of new, or existing, ideas, discoveries and inventions in other sectors, stemming from the space sector (spin out), to create economic and social benefits. Innovation also consists of scientific, technological, organisational, financial and commercial steps, which are intended to, or actually, lead to the implementation of innovations by space-non-space partnerships (spin together).”* Innovation is characterised by three stages: a) incremental, b) breakthrough and c) utilisation.
- The basic mechanisms in the ESA science and technology relationship can be described by the “technology push” and “need (science) pull” model. In this model, science (in the ESA terminology) asks scientific questions, which drive the technology to develop, whereas in technology push technological advancements allow science to use them as means for its advancement. Nevertheless, it is recognised that in practice this model is simplistic and more complicated models might be need to fully describe the relationship.
- The time scale from the moment the ”need pull” is identified (a mission is approved) which “pushes” the technology to develop, to the time all technologies need to be integrated, is very short. Therefore, it is essential that technologies are also developed independently before the “need” is identified. This independent development (“technology push”) should be based on “potential future user needs”.
- The Key Enabling Technologies (KET) identified, by the EC, as nanotechnologies, Micro- and nanoelectronics, advanced materials and biotechnology should be considered comprehensively by ESA’s research and development programmes. Concerning this, the Information and Communication Technologies (ICT) should also be considered, creating the “ESA Enabling Technologies” concept. These categories are essentially very broad and specific subcategories should be identified in consultation with space and non-space experts in these fields in order to identify the ones mostly relevant for the space sectors to develop coherent roadmaps.
- At low Technology Readiness Levels (TRL), such new technologies do not need to be developed exclusively by space funding schemes. This may allow the utilisation of funding from the non-space sector by jointly investing in KET’s building blocks.

Cooperation

- Public and private partnerships should be set up for co-financing research and development in Key Enabling Technologies, since they require large investments that ESA alone would not be able to afford.
- ESA already works together with the European Commission in the Framework Programme in particular under the Space component. This cooperation should be expanded to other components of the Framework Programme in particular related to investments in KETs. This can be done either by co-financing together with the Commission or simply coordinating programmatically.
- ESA should consider creating new, or strengthening existing, partnerships with the European Commission and in particular with DG Research, DG Enterprise and Industry, Joint Research Centre (JRC), as well as the European Research Council (ERC). The basis for this cooperation should be to bring together and align funding means, time scales as well as programmatic content, by jointly defining roadmaps.
- ESA is currently actively involved in two space European Technology Platforms (ETP) and should continue and expand this coordination with other platforms, especially those involved within the thematic areas of KET's.
- ESA should consider partnering with other sectors for the development of KETs. Examples of these sectors are Energy, Automotive, Aerospace, Healthcare, and Telecommunications. The European Technology Platforms can be a good platform to find common ground in the various scientific research agendas.
- Space science research, in the ESA terminology, is still mostly handled at a national level, with some coordination at the European level. National space research programmes for science and technology should open up and coordinate with each other. Programmatic partnerships should be created between ERC, ESA and national programs. This would allow *frontier research* at a pan-European level in space research.
- The knowledge triangle (education, research, innovation) has become an essential component for modernisation to reflect today's demands. ESA should partner with Knowledge Innovation Communities (KICs) of the European Institute of Innovation and Technology (EIT).

Mechanisms

- The space sector and ESA invest in research that leads to technological developments needed for future missions but they also need to continue and strengthen investing more on basic and applied research underlying generic and disruptive technologies that are not directly related today to future missions. New mechanisms should be developed that allow "technology push" development, of enabling technologies, based on "potential future user needs". Adequate mechanisms involving the ESA science community should be developed to capture these "potential future user needs".

  - Effective mechanisms should be developed for: a) monitoring "potential future user needs" and b) informing the user of potential benefits of new technologies under development. In this process the ESA science community should be involved, as well as the non-space science community. Technology push fails when the potential of a technology is not understood by the user and when his needs are not properly captured at all times. Therefore, it is necessary to develop adequate 'marketing' strategies to be able to assess these needs in a double mirror push-pull innovation model, so that the push technologies capture the needed features, functionalities and the potential of the new technologies is properly communicated to the user at an early stage.
  - Workshop organisation with potential users during the course of the development of technology push under e.g TRP and GSTP could be a way of capturing various user needs at an early stage and informing them about the potential of new technologies.
- ESA should proceed to apply for participation in research and technology development under the non-space components of the Frameworks Programme. This participation, by performing research and development in ESA laboratories, should be enhanced.
- Two scenarios are foreseen for co-financing under the Framework Programme non-space component. One option is to use ESA existing funding tools and make a funding co-alignment. The other option is to crate new specific funding programmes for this specific purpose.
  - The first scenario would be to use existing programmes like TRP, GSTP funding in combination with FP funding for key enabling technologies at low TRL levels in order to balance the high expenditures needed for these technologies and can be used for technology push. This scenario already partially exists, firstly, by the Agency's participation in FP programmes (non-space), and secondly, by contractors of TRP, GSTP etc in their individual strategies, but in an uncoordinated manner. Thus there is the need to develop a coherent coordination mechanism.
  - The second scenario, would be to develop new funding programmes in order to be able to co-finance frontier research where basic and applied science lead to technological breakthroughs that are not necessarily related to an ESA mission at present. A new Science and Technology Research Programme can be envisaged where roadmaps are created together with other funding bodies, like DG Research for the key enabling technologies ,where industrial, research institutes and universities partnerships are fostered. In such a programme, non-terrestrial partnerships should be another essential component.
- An effective technology watch 'Technowatch' construction is necessary in order to be able to identify new and disruptive technologies early enough; a 'Technowatch' that can facilitate spin-in, spin-out and spin-together. ESA

does currently have mechanisms which are used as observatories for following science that is likely to produce technology. This could be institutionalised with clear targets and responsibilities in a more integrated model. The possibility of having a Technowatch, independent from ESA or joint with other technology watch institutions, should also be considered. It is suggested that a Technowatch should be an independent body as they are seen as more credible when they are not governmental agencies or those that conduct the research.

- The use of the open innovation model that the space sector inevitably needs to utilise efficiently to achieve technological breakthroughs and scientific innovations needs flexible and modern models of dealing with IPRs. Current IPR mechanisms of ESA and other funding and developing bodies need to be examined closely as IPR treatment is one of the most essential components of the success or failure of an open innovations system. The current ESA IPR system where the IPR stays with the agency for space use does provide the basis for open innovation in technology development with non-space sectors as they can essentially use the IPR in other markets.

1 Introduction

The space sector has recently received significant attention and commitment by political decision-makers as space science, technology, applications and services are recognised to be a significant contributor in crating jobs. Innovation in all sectors is becoming a central focus of governments, companies, universities, research institutes and society as a whole. On 5 March 2010, the Commissioner for Research, Innovation and Science, Máire Geoghegan-Quinn created the term 'era of i-conomy' at the Innovation Summit of the Lisbon Council. Europe's 2020 vision is: to be a union of innovation. The relationship between science, technology and innovation and the bringing of new products on the market is considered an important factor, in the western world and in developing countries, for creating competitive advantage and improving quality of life.

The European Space Agency has a long history in pushing the borders of knowledge further through, scientific missions that are backboned by technological excellence. In order to remain at the forefront of scientific progress, technological breakthroughs are necessary. The space sector is experiencing a slow down in breakthrough innovations and a more incremental innovation, but it is not the only sector. Breakthrough technology innovations may occur in areas other than the space sector and can have tremendous impact on the space sector. Adaptation requires time, and the lag between the invention and full-scale adaptation in the space sector is one of them most frustrating unknowns. Cooperation, using approaches like multidisciplinary, cross- and inter-sectorial, and inter-governmental, enable innovation. In order to stimulate innovation it is important to identify the basic reasons behind stagnation and to identify the types of cooperation that are needed. It is also important to identify technologies that are important to build in partnerships, the institutions to cooperate with, and the mechanisms to put in place for achieving it.

The present ESPI report is based on work performed for the European Science Foundation (ESF) in the framework of a Forward Look. These will address the following on the basis of breakthrough scientific objectives: (i) identifying the associated technology development; (ii) considering forecast for technologies that would enable the achievement of these scientific objectives; (iii) identifying partnership schemes (space and non-space); and (iv) facilitating the spin-in of top non-space technologies.

The present study was adopted from the work conducted for ESF. The ESPI study was performed by using a stepwise approach where, initially, the terms science, technology, and innovation, and their accompanying interrelationship were described, defined and analysed. Different sectors were studied and exhibited different approaches to these concepts. These sectors were divided into: a) conservative sectors and b) dynamic sectors. Partnerships and institutions at national and European level for science, technology and innovation were further studied. European projects in key technology domains were listed.

In this study, Section 2 provided the terminological and conceptual foundations for the study. The terms science, technology and innovation were examined and the relationship between them was analysed. The multidimensional façade of science and technology and how they are perceived by different actors, how they are perceived in the space sector and, particularly, in ESA terminology. Furthermore, innovation was defined, by different entities, and its development over the years was analysed. A definition of innovation in the space sector was derived. The technology push-need pull model was chosen to exemplify the basic characteristics in the science and technology relationship. Key enabling technologies were identified and described. In Section 3 innovation in different sectors was analysed. The sectors studied were: construction, energy, transportation, aeronautics, pharmaceutical, biotechnology and ICT. In Section 4, partnerships and institutions, at European level, were studied. Some European institutes involved in innovation were identified and described, as well as some European Technology Platforms. In Section 5 the findings, conclusions and recommendations of the study were given.

2 Science, Technology and Innovation

2.1 Terminological and Conceptual Foundations

In present times the terms science, technology, research, development and innovation are used as essential drivers in the western world and developing countries. Public and private sectors associate them with growth, prosperity and quality of life and develop policies, regulations and strategies for effective facilitation. The system has become so complex that the questions arise of whether one is talking about the same things and how these words are perceived or use in a high level abstract way and how one is able to translate meaning to ones own specific problem or sector. Therefore, as a first step the complexity of these words will try to shown and will be broken down into some meanings that will be useful for this study.

2.1.1 Science and Technology

Science and technology are nowadays mostly used side by side. Historically, a number of groups have been interested in their definitions and in their relationship ranging from philosophers to sociologists and historians whose primary interests are theoretical; to engineers and scientists who have a direct personal interest in this relationship; to policy makers whose views are based upon specific theories and who are interested in determining policies and practices at an international, national, regional, or local level, which can help facilitate science and technology to create competitive advantage; and the general public that is generally affected by this relationship.

The exact distinction between science and technology and their relationship is a matter of debate {Mayr, 1976 #193;Barnes, 1982 #59;Narin, 1992 #51;Gardner, 1995 #54}. Therefore, nowadays the terms “Science” and “Technology” are often used side by side. Nevertheless, for the purpose of this study the Oxford dictionary {, 2008 #206} definitions are applied.

science[1] (• noun) 1) the intellectual and practical activity encompassing the systematic study of the structure and behaviour of the physical and natural world through observation and experiment. 2) a systematically organized body of knowledge on any subject. — ORIGIN Latin scientia, from scire ‘know’.

At this point we should make a distinction between fundamental or pure science and applied science. Fundamental or pure science is the part of science which describes the most basic knowledge that it develops and which is typically

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[1] {, 2008 #206}.

studied without regard to the practical applications of this knowledge. On the other hand applied science is dealing with applying scientific knowledge to practical problems.

technology[2] (• noun, pl. technologies) 1) the application of scientific knowledge for practical purposes. 2) the branch of knowledge concerned with applied sciences. — DERIVATIVES technological adjective technologically adverb technologist noun. — ORIGIN Greek tekhnologia' –'τεχνολογία' — 'techne', 'τέχνη' ('craft') and 'logia', 'λογία' ('saying').

It should further be added that technology is a consequence of applied science and engineering, although several technological advances predate the two concepts. Technology is a broader concept dealing with the usage and knowledge of tools and crafts used to adapt and control an environment.

In this battle of defining Science and Technology, the terms are treated as two distinct entities that can be clearly separated and their relationship is typically hierarchical. In one side of the spectrum is science and on the other technology. Traditionally, physics is regarded as science whereas the manufacturing of engines is regarded as technology. Other models recognise the overlap and common territory between the two. In any case when boundaries are made, between science and technology, they are often arbitrary.

One can argue that one distinction that can be used to define the boundaries is that of aim, purpose and motivation. In this case, for science, it can be seen as trying to understand the world that surrounds us, whereas technology can be seen to solve problems that occur around us. Often scientific and technological advancements are pursued simultaneously and in many cases by the same person, group, or institution, using the same means. This is another reason why "science" and "technology" are mostly used side by side.

The relationship between science and technology is very complex and it varies considerably in the particular field concerned {Mayr, 1976 #193;Narin, 1992 #51;Brooks, 1994 #56;Breschi, 2010 #63}. According to {Brooks, 1994 #56} science contributes to technology in at least six ways:

(1) new knowledge which serves as a direct source of ideas for new technological possibilities;
(2) source of tools and techniques for more efficient engineering design and a knowledge base for evaluation of feasibility of designs;
(3) research instrumentation, laboratory techniques and analytical methods used in research that eventually find their way into design or industrial practices, often through intermediate disciplines;
(4) practice of research as a source for development and assimilation of new human skills and capabilities eventually useful for technology;

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[2] Compact Oxford English Dictionary of Current English, Oxford University Press, Third edition revised, 2008.

(5) creation of a knowledge base that becomes increasingly important in the assessment of technology in terms of its wider social and environmental impacts;
(6) knowledge base that enables more efficient strategies of applied research, development, and refinement of new technologies.

The contributions of science to technology are widely understood and acknowledged by scientists and engineers. Equivalently technology contributes to science:

(1) through providing a fertile source of novel scientific questions and thereby also helping to justify the allocation of resources needed to address these questions in an efficient and timely manner, extending the agenda of science;
(2) as a source of otherwise unavailable instrumentation and techniques needed to address novel and more difficult scientific questions more efficiently.

The terms “science” and “technology” have a multidimensional relationship and refer to phenomena on various levels. They refer to bodies and activities of knowledge that form educational, industrial and governmental institutions.

Science and technology advancements result in numerous journal publications and patents. The numbers of these publications and patents are often used as indicators for measuring the effectiveness of public policies in S&T. The time between journal publication and patent citation or other scientific article citation is closely looked at as an indicator of science and technology drive.

In the classical classification of research there is a clear distinction between ‘basic’ and ‘applied’. Basic research is focused on answering fundamental questions of sciences, whereas applied research can use the acquired knowledge to transfer it back to technology, as a necessary step for the creation of innovation. However, nowadays the distinction often loses relevance as emerging science and technology frequently embrace an element of both. Therefore, the term *‘frontier research’* rather than ‘basic’ is used to reflect this reality.

At this point we should also differentiate how the terms science and technology are used in the space sector and in particular in ESA. In the ESA terminology there is a clear distinction when the terms science and technology are used. The term science mostly refers to pure or fundamental science related to space and earth observation. This type of pure or fundamental scientific question becomes the main driver for scientific missions. On the other hand, in ESA wording, technology is defined as “*the practical application of knowledge so that something entirely new can be done or so that something can be done in a new way*”. The underlying science needed to develop technologies that can be used for space is not addressed when the word ‘science’ is used. Nevertheless, applied scientific research and development is needed for developing technologies for space and is persued by ESA mainly under the Technical and Quality Management Directorate of ESA, where about 8% of the ESA budget is spent on direct research and development. The technology development research activities of ESA are mainly related to science missions of space (e.g. space science, astronomy), from space (e.g. earth science) and in space (e.g. life and physical science); and utilisation (e.g. Meteorology, GMES, telecommunications, navigation, integrated applications promotion). Thus, in ESA terminology ‘science’ refers to pure or fundamental science related to space, and ‘technology’ encompasses the classical definition of space technology and space-non-space applied sciences for creating space technology.

2.1.2 Innovation

In the last couple of decades it has been well understood that R&D is an important strategic asset in all sectors around the word. In the last 10 years the word ‘innovation’ has become an essential component in strategic discussions and it does not appear without mentioning the work of Chesbrough {Chesbrough, 2006 #58;Chesbrough, 2003 #205} who made a distinction between open and closed innovation. The first step would be to look at the definition of innovation as a whole and then make the distinciton between open and closed innovation.

There are various definitions of innovation that can be found and that are used. The most accepted and most complete one is the one of OECD. According to OECD *“Innovation activities are all scientific, technological, organisational, financial and commercial steps which actually, or are intended to, lead to the implementation of innovations. Some innovation activities are themselves innovative, others are not novel activities but are necessary for the implementation of innovations. Innovation activities also include R&D that is not directly related to the development of a specific innovation.”*

The shortest definition of Innovation is “*a new way of doing something or new stuff that is made useful”* {McKeown, 2008 #203}

DG Enterprise of the European Commission is using the following definition of innovation:
“An innovation is the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organisational method in business practices, workplace organisation or external relation. The minimum requirement for an innovation is that the product, process, marketing method or organisational method must be new (or significantly improved) to the firm.”

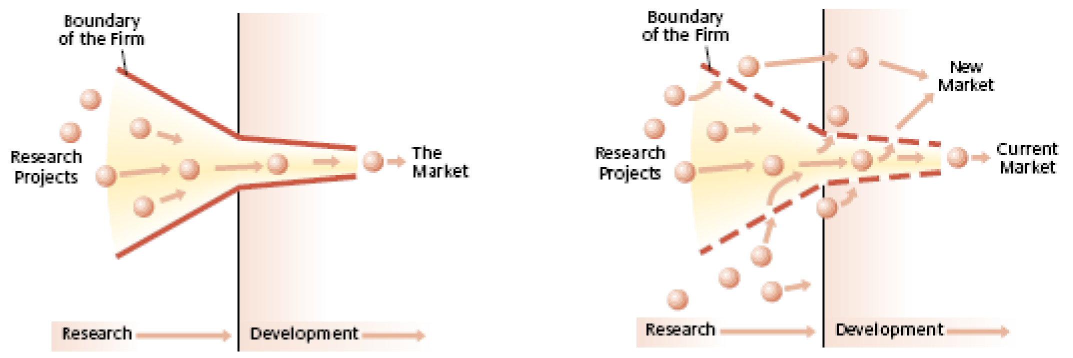
The European Union’s official journal in the regulation EC No.294/2008 [294/2008] published for establishing the new European Institute of Innovation and Technology (EIT) gave the following definition of innovation “Innovation means the process, including its outcome, by which new ideas respond to societal or economic demand and generate new products, services or business and organisational models that are successful introduced into and existing market or that are able to create new markets”

Communities focusing on products and services capture these components in the OECD definition by defining innovation as *“Innovation refers to new or better products and (intangible) services as well as new or better ways of producing these products or services*”[3] {Fagerberg, 2005 #204}.

Below there is an attempt to define the term **'space innovation'**, where innovation to and from space are essential components.

"Innovation is the use of new, or existing, ideas, discoveries and inventions in the space sector, stemming from other sectors (spin-in), and vice versa, the use of new, or existing, ideas, discoveries and inventions in other sectors, stemming from the space sector (spin-out), to create economic and social benefits. Innovation also consists of scientific, technological, organisational, financial and commercial steps, which are intended to, or actually, lead to the implementation of innovations by space-non-space partnerships (spin-together).”

As a next step the concepts of open and closed innovation as defined by Chesbrough will be described, the concepts of clusters of innovation and furthermore an attempt will be made to describe how open innovation could be represented in the space sector.
The classification Chesbrough makes about innovation as ‘closed’ and ‘open’ were initially developed by looking at various commercial companies and the way they performed R&D to approach the market. Figure 1 shows the closed and open innovation models in R&D of firms.



Closed Innovation Model Open Innovation Model

Figure 1: Chesbroughs’ open and closed innovation model of companies R&D {Chesbrough, 2003 #205}

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[3] {Fagerberg, 2005 #204}p. 182”

According to Chesbrough “a company generates, develops and commercialises its own ideas.” In leading industrial corporations of the 20th Century the R&D departments were based on the philosophy of “self reliance” and the mind frame that “if you want to do something right you better do it your self”. This model is known as “Close innovation”.

This model worked well until the end of the 20th Century. After that many factors changed that lead to the need for new models. An important factor was related to the increase of mobility of workers which meant that knowledge could no longer be necessarily kept within the company. Another factor was related to the increase of private venture capital that allowed the creation of new companies based on novel ideas outside the corporate R&D labs. These meant that the boundaries between companies own laboratories and the surrounding environment became porous enabling innovation to and from the boundaries of a firm.

Thus a company can commercialise both its own ideas as well as ideas coming from outside as well as trying to bring ideas developed inside to other markets by exploiting pathways outside its own business. This model of Chesbrough became known as “Open Innovation”. Open innovation has required a different way of thinking and dealing with Intellectual Properties Rights. This is very essential and needs more attention but is outside the scope of this study.

In a contesting way the basic principles of open and closed innovation as conceived by Chesbrough {Chesbrough, 2003 #205} were:

Closed Innovation	**Open Innovation**
The smart people in our field work for us.	Not all of the smart people work for us so we must find a tap into the knowledge and expertise of bright individuals outside our company.
To profit from R&D, we must discover, develop and ship it ourselves.	External R&D can crate significant value; internal R&D is needed to claim some portion of the value.
If we discover it ourselves, we will get it to market first.	We don’t have to originate the research in order to profit from it.
If we are the first to commercialise the innovation , we will win.	Building a better business model is better than getting to market first.
If we crate the most of the best ideas in the industry, we will win.	If we make the best use of internal and external ideas, we will win.
We should control our intellectual property (IP) so that our competitors don’t profit from our ideas.	We should profit from others’ use of our IP, and we should by others IP whenever it advances our own business model.

Table 1: Contrasting Principles of Closed and Open Innovation {Chesbrough, 2003 #205}.

The last decade one has witnessed the agglomeration forces bringing together knowledge centres creating clusters and networks of innovation. These clusters consist of small-medium size enterprises in technology based or high technology industries working together with large industries, research institutes and universities. These work together under the open innovation model setting up science parks and technopoles in various regions and further establishing links between regions.

It is important to describe what innovation is in ESA terminology. ESA missions require innovation drivers. In ESA innovation is described by three components: *“a) incremental: improving a product, customising adding functionality, utilising in a new environment; b) breakthrough: a step change and c) utilisation: e.g. integrated applications”*. The concept of Open innovation is also endorsed by ESA and the space sector in general where it is recognised that in many domains technology advances faster in terrestrial than in space applications requiring the notion of ‘spin-in’. On the other hand space technology has attractive features for demands in terrestrial applications requiring ‘spin-out’ to other sectors. At the same time there are various common quests with other sectors like aeronautics, automotive, ICT which enable spin-in, spin-out and even proceeding in joint actions. NASA also endorses the ‘spin-in’ and ‘spin-out’ terminology in communication about innovative research.

In particular for pure and applied research for science and technology development based on Chesbroughs’ school of thought the model for open innovation for the space sector can be described by Figure 2.

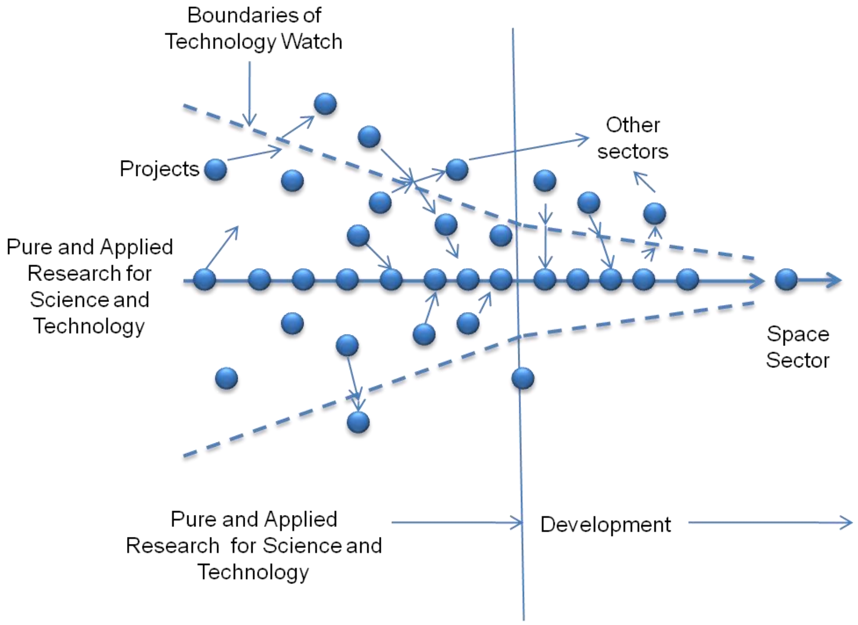

Figure 2: Science and Technology Open Innovation Model for the Space Sector

In the science and technology open innovation model for the space sector, as shown in Figure 2, the conventional definition for science and technology is used. Research and development projects can exit or enter the space sector domain at any time. A technology watch mechanism acts as a filter of ideas going to and from the space sector area. If a project has potential interests for space, it can enter at any stage of research and development (spin in), and vice versa it can exit the research and development space sector domain to enter other sectors (spin-out). At the same time, if these R&D projects result in enabling technologies, they can be developed together with other sectors (spin-together). Intellectual Property Rights (IPR) is an important issue that needs to be considered in such a model. In the case of ESA, when technology is developed ESA has the right to use the IPR for space but is not restricted from the using these IPRs in other sectors. This is a good enabler for cooperation in spinning together projects with other sectors.

2.2 Technology Push and Need Pull Model

In early literature innovation behaviour often occurs when it is recognised that there is a demand or a new technology {Utterback, 1975 #147}. The ‘technology-push’ and ‘need-pull’ model is often used to describe the driving forces behind innovation. The ‘push’ concept regards technology as being the driving force that acts as a facilitator behind scientific innovation whereas the ‘pull’ concept regards the scientific needs to be the driver for technological advancement.

In order to tailor the need pull and technology push model to the ESA terminology, the assumption made is that the scientist is not the technology developer. According to this, it is the availability of new inventions and discoveries that facilitates scientific progress. Therefore, when the ESA terminology for science and technology is used then the push and pull model can be described as follows:

Need Pull Scientific requirements –the need- translated to technical requirements ‘pull’ the technology to develope.

- What do scientists want?
    - What is required to perform certain science and how technology can be developed for it?

Technology Push Technological developments ‘push’ science to realise certain scientific experiments and answer scientific questions that were not possible before.

- What do technology developers have?
    - What technology is available and how to use it for science?

Considering the assumption that the scientist is not the technology developer but the user of the technology, a parallelism can be made between the scientist (of fundamental science biologist, geologist, space, etc) and the consumer of different markets (energy, construction, etc.) as shown in Figure 3. It is assumed that both scientist and consumer are not involved in the technology development. In this way, theories about capturing user needs and developing effective technology pushes may be seen in a generic way. This will be useful when different sectors will be analysed via the push-pull model, and conclusions will be drawn that will have relevance to the technology pull-science push according to the ESA terminology.

Nevertheless, one should keep in mind that when the conventional definitions of science and technology are used, in most cases, the push-pull model is very difficult to apply as the scientist is part of the technology deployment cycle (as a developer himself).

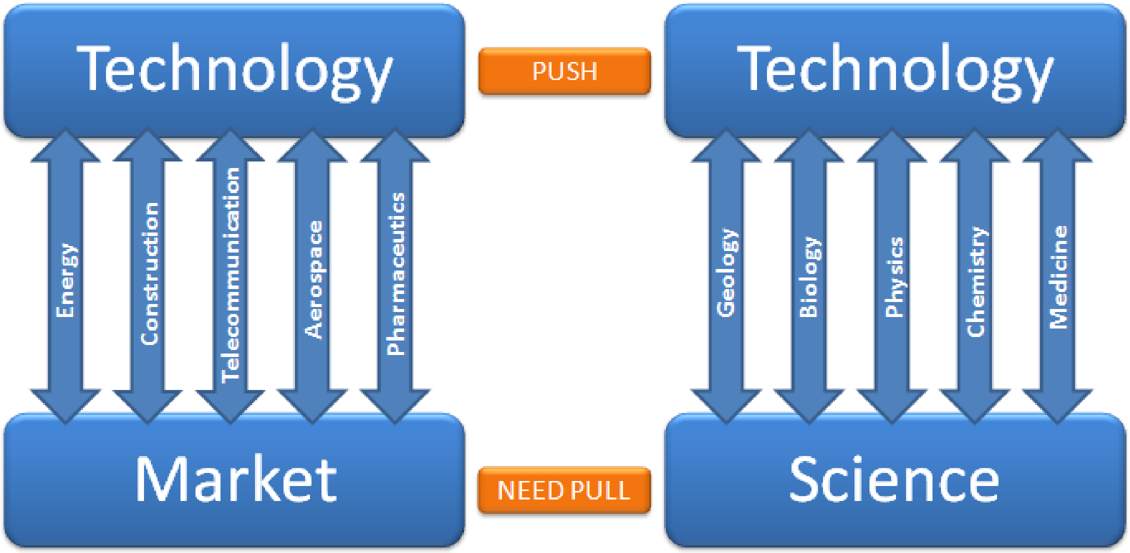

Figure 3: Technology push-need pull model.

2.3 Science Pull

Scientific questions cannot always immediately be answered if technology means are lacking behind. Thus, the need to answer some questions triggered the need for technological developments to facilitate answering these questions. There are various examples of this process and here only few are mentioned.

In the fundamental process of understanding the structure of matter, physicists needed a tool enabling them to address the problem of identifying increasingly smaller objects. The limit of optical measures was quickly reached and as the atomic model advanced further, the need to be able to fission atoms safely, in order to investigate their internal structure, became a very important topic for the advancement of knowledge on the structure of matter. Particle accelerators (including the complicated electromagnetic lens systems, vacuum chambers and vacuum pump), electronic and computational methods were designed to meet the scientists' demands. CERN, for example, was initiated as a response to particle and theoretical physics reaching a new level, predicting the existence of certain particles (e.g. Higgs Boson,..), which can only be created in collision processes at very high energies, to be able to verify or falsify important concepts and theories in modern theoretical physics.

As knowledge about the universe is advancing, our models of stellar evolution have reached a stage where simple earth based observations cannot deliver any more answers. At an early stage of the birth of a star, thick clouds of dust (interstellar material) obscure the view to one of the most spectacular and complicated processes scientists are interested in. Entire galaxies are hidden from view, as their light is blotted out by thick clouds of dust making observation very difficult. To see through interstellar dust clouds, or to peer far into our own stellar system to understand more about the origins of our own solar system, observations in the infrared light spectrum are necessary. Very cold bodies, such as planetoids or comets, or stars hidden in dust clouds are visible in infrared light. Observations from the surface of earth are impossible, as our atmosphere blocks most of infrared radiation from space. Thus the Herschel observatory was designed, orbiting millions of kilometers away from earth around a Langrangian Point of the Earth-Sun system to be protected from our own infrared radiation, using its specially designed instruments to observe stellar evolution and the bodies within our own solar system.

2.4 Technology Push

Technology advancements have played a very important role in scientific breakthrough, in particular, through the development of new instruments, sensors and measurement techniques.

Technological development has fuelled scientific research by the development of radical inventions such as the transistor, the laser, the computer, nuclear fusion power, and the World Wide Web, where most of the breakthrough science in various fields has followed subsequently rather than preceded the technological advancement. Such inventions have opened up new horizons in various basic research fields and produced unforeseen by-products beneficial to society.

The ‘push’ of the World Wide Web came about as the particle physics community at the European Laboratory for Particle Physics (CERN) was constructing the Large Electron-Positron Collider (LEP) and related experiments in the late 1980s. As the structure and tools for sharing their common information left much to be desired, the researcher Tim Berners-Lee developed the fundamentals and initial prototypes of the World Wide Web. The system was immediately adopted by a number of universities and research laboratories inducing its release to the public domain in 1992, marking the beginning of its subsequent explosive growth.

The invention of laser technology in 1958 revolutionised various aspects of science in life and physical sciences, leading to applications in a very wide array of fields such as medicine, electronics, information technology, military applications and industry. Laser technology revolutionised data storage in the advent of optical storage devices, such as CD and DVD drives, where a semiconductor laser is used to scan the surface of the discs. Barcode scanners, laser printers and laser pointers became an essential part of every day life and essential components of scientific instruments. Industrial and military demands pushed the boundaries of laser technology even further, giving rise to highly advanced technologies such as laser cutting of materials, 3D scanning and modelling, high precision distance measurements and many more, using modern, very high energy laser systems.

In the area of nanoelectronics the technology push initiated in 1959 with Jack Kibly’s patent submission of ‘Miniaturised Electronic Circuits’ for the making of resistors and capacitors together with transistors in one and the same silicon substrate, which today is known as an integrated circuit or silicon chip. The number of devices that useit today for scientific research in all fields is vast.

Another example of technology ‘push’ was the development of fissionable materials for the atomic bomb. In order to develop this technology the United States used the push method to fund five different ways to achieve the objective, and succeeded.

Scientific breakthrough has also occurred by technological push in the area of post-genomic biology. At the European Molecular Biology Laboratory (EMBL) technological advancements through the combination of two techniques made EMBL a leading centre for proteomics. A set of novel mass spectrometry techniques combined with a biochemical technique using specific tags for rapid, non-invasive purification of macromolecular enabled to overcome major challenges of post-genomic biology. This helps to understand how genetic information results in the concentrated action of gene products in the time and space to generate biological function.

In the space sector the role of space technology has played a very important role and revolutionized astrophysics and cosmology by making available to scientists a much wider range of the electromagnetic spectrum accessible to measurements than was possible when the observation was limited by the lack of transparency of the atmosphere to X-rays, g rays and the far ultraviolet and some parts of the infra-red. Recently, availability of a new generation of atomic clock technology in space will allow scientists to accurately test Einstein's theory of general relativity4.

Nevertheless, the relationship between science and technology described by the 'push-pull' model only outlines the basic principles. The idea that science and technology co-evolve and interact in a more complex way is well accepted and is affecting the design of public policies. Many governments around the world are looking for ways to stimulate technology transfer from one sector to another and from academia to industry. Breschi {Breschi, 2010 #63} is tracing the links between science and technology and is providing an explanatory analysis of scientists and inventor networks.

2.5 Key Enabling Technologies

For many years it has been realised that certain technologies can be used as a core for different scientific and industrial developments without a clear identification of these technologies and, therefore, not a coherent strategy on how these technologies can be brought in for development on the European level.

In 2009, the European Commission published a communication {, 2009 #44} where it was identified that certain technologies named as 'Key Enabling Technologies (KETs)' are expected to be the driving forces behind future developments, and it was pointed out that these technologies are of great strategic importance to the EU. The objective of the European Commission in COM (2009) 512 and SEC(2009) 1257 is to show how these technologies can better be brought to industrial deployment. Nevertheless, these technologies can also be brought back in for scientific progress.

According to the description in COM (2009) 512 and SEC (2009) 1257, "***Key Enabling Technologies (KETs) are technologies that are multidisciplinary, cutting cross many technology areas with a trend towards convergence and integration"***. They enable process, goods and service innovation and are typically associated with high R&D intensity, rapid innovation cycles, high capital expenditure and highly-skilled employment. According to COM (2009) and SEC (2009) the following technologies have been identified as key enabling technologies:

Nanotechnology originates from the Greek word 'nano' meaning 'dwarf' and in science and technology the prefix 'nano' signifies 10^{-9}. It refers to science and

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[4] http://www.esa.int/esaCP/SEMRDI9K73G_index_0.html
http://einstein.stanford.edu/content/faqs/gpa_vessot.html

technology at the nanoscale of atoms and molecules as well as to the scientific principles and new properties that can be understood and used when operating in this scale. It holds the promise of leading to the development of smart nano and micro devices and systems and to radical breakthroughs in vital fields such as healthcare, energy, environment and manufacturing;

Micro- and nanoelectronics, including semiconductors, are essential for all goods and services which need intelligent control in sectors as diverse as automotive and transportation, aeronautics and space. Smart industrial control systems permit more efficient management of electricity generation, storage, transport and consumption through intelligent electrical grids and devices;

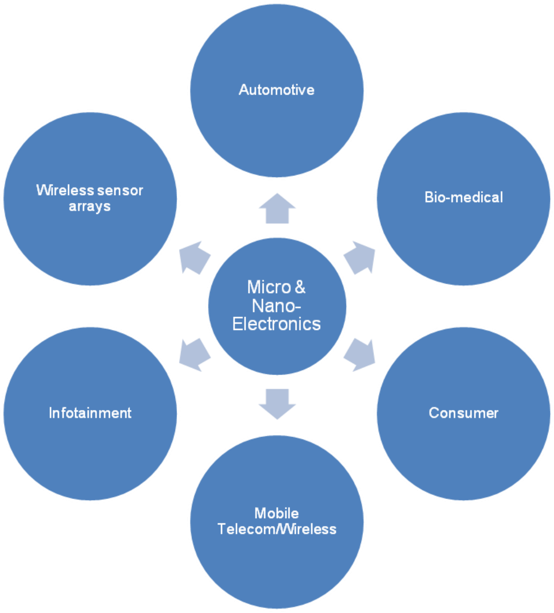

Figure 4: Micro & Nano-Electronics application sectors.

Photonics as defined by 1967 by Pierre Aigrain, "*is the science of the harnessing of light. Photonics encompasses the generation of light, the detection of light, the management of light through guidance, manipulation, and amplification, and most importantly, its utilisation for the benefit of mankind.*". It is a multidisciplinary domain dealing with light, encompassing its generation, detection and management. Photonics encompasses multiple applications including information, communication, imaging, lighting, displays, manufacturing, energy, life sciences and health care, and safety and security.

Figure 5: Photonics application sectors.

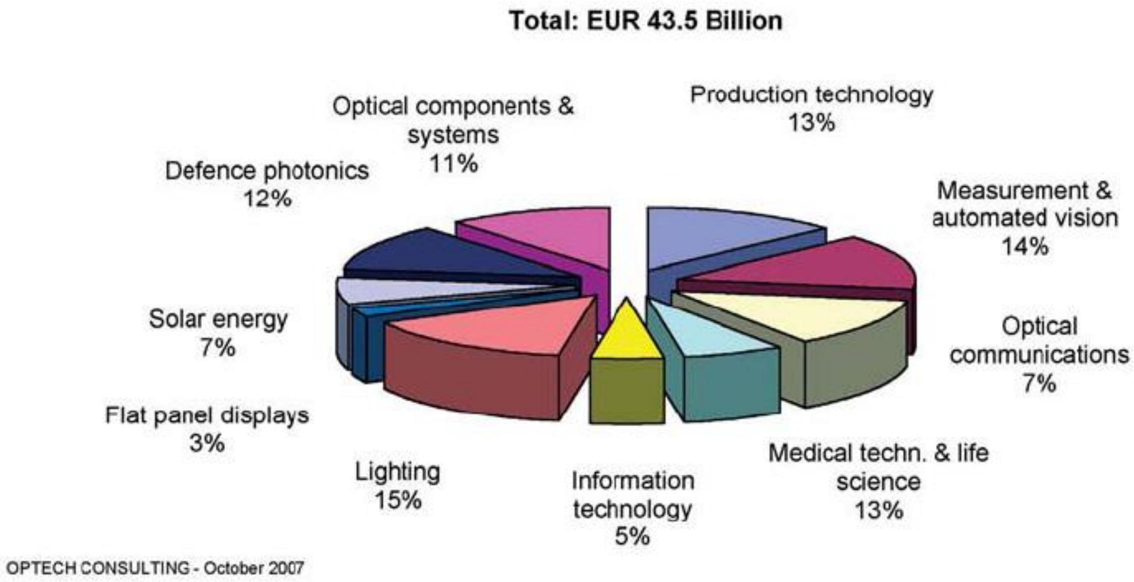

Figure 6: European Photonics Production by Sector, 2005[5].

Among other things it provides the technological basis for the economical conversion of sunlight to electricity which is important for the production of renewable energy, as well as a variety of electronic components and equipment such as photodiodes, LEDs and lasers.

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[5] Photonics in Europe, Economic Impact, Photonics, Opteck Consulting, European Technology Platform Photocincs 21, December 2007, p.10.

Advanced materials Advanced materials can be categorised in hybrid and multi-materials, materials for extreme conditions and multi-functional materials .They offer major improvements in a wide variety of different fields, e.g. in aerospace, transport, building and health care. They facilitate recycling, lowering the carbon footprint and energy demand as well as limiting the need for raw materials that are scarce in Europe.

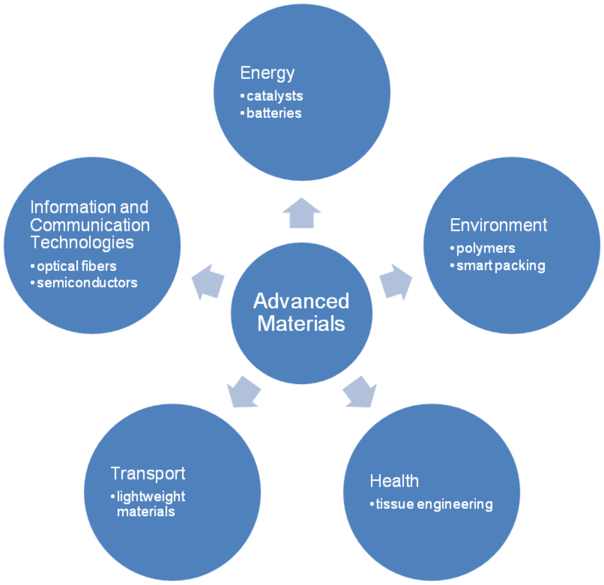

Figure 7: Advanced materials application sectors.

Biotechnology is defined by OECD as “*the application of science and technology to living organisms as well as parts, products and models thereof, to alter living or non-living materials for the production of knowledge, goods and services*”. It is a fast growing area and plays an increasing role into a large number of industries including pharmaceuticals, agri-food, industrial processing, materials, chemical, paper and pulp, textiles, energy, fuels. Biotechnology is expected to allow replacement of non-renewable materials, which are used in various industries with renewable resources, in the future. Nevertheless, the use of Biotechnology and its broad spectrum of applications is still largely unexploited.

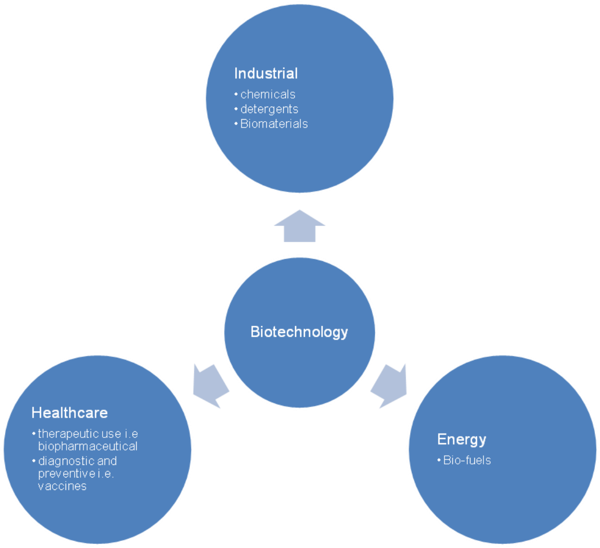

Figure 8: Biotechnology materials application sectors.

Although in the Key Enabling Technologies the Information and Communication Technologies (ICT) are explicitly part of the group, the authors believe that ICT should be considered as part of ESA's KETs.

According to Science and technology reports, countries like China, Japan and US are also focusing on enabling technologies, and in particular on biotechnology, ICT and nanotechnology.

It is understood that these categories are very broad and that sub technologies within the KET's should be further studied in order to identify the ones that are relevant for the space sector and ESA. This is, however, beyond the scope of this study and should be considered further in the future.

3 Innovation in Different Sectors

The way innovation is perceived and the level at which it is implemented in different sectors varies significantly. It is related to various factors that are assimilated to the characteristics of the sector. Even though different sectors have different characteristics one can group them into those that have a more conservative approach to innovation, in this study called the ‘conservative sectors’, and into those that are promptly adapting to innovation, which here are call the ‘fast moving sectors’. The conservative sectors typically use a more incremental approach to innovation, whereas the fast moving sectors are more prone to employ a more breakthrough approach. The space sector can be described as a conservative sector together with sectors like energy, transport, aeronautics, pharmaceutical, with the construction sector probably being the most conservative one. On the other hand, sectors like ICT and biotechnology are fast growing and are rapid in putting out innovative products on the market. In the following sections these sectors and their relationship with innovation is analyzed.

3.1 Space Sector and ESA

In the course of the past year, the space sector has received increased attention and commitment on the part of policy- and decision-makers. For the large part, the space sector is ‘user driven’ and many space programmes materialise when the user - scientific community, governments, and public -produces a demand or displays a political will to advance certain required developments. Space technology is recognised in Europe as a significant contributor to economic growth and to the creation of jobs. The space sector planning process can be seen in Figure 10.

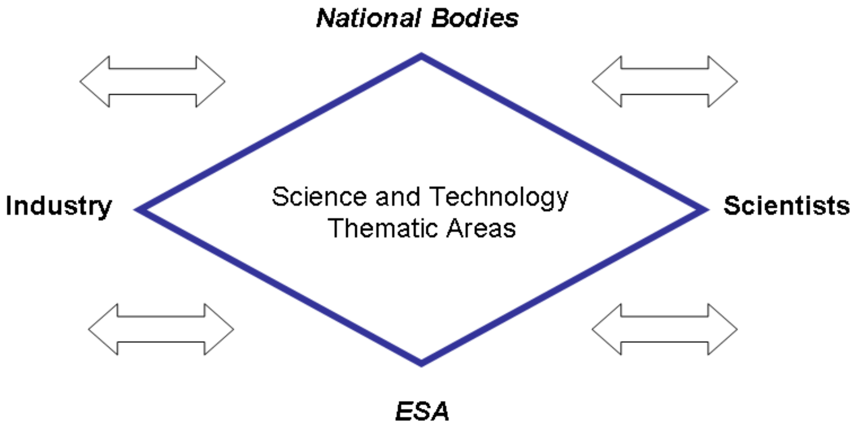

Figure 9: Science mission actors in Europe.

Science and operational missions are driven by the need of the user categorised as operational users (e.g. telecommunication, navigation) or science users which are the smaller portion of the community. Figure 9 shows the main actors in Europe related to scientific mission. On one side are the scientists who define the objectives of the scientific mission and on the other side is the European industry that eventually develops the hardware platform for the mission. The national bodies and ESA are involved in the realisation of a mission and oversee the development of the mission platform and scientific payload.

Figure 10: Space sector planning process.

The term scientist here is used in the ESA terminology related to science missions of space (e.g. space science), from space (e.g. earth science) and in space (e.g. life science). It does not include the scientist involved in technology development for example of the material scientist needed to develop material technology.

The scientific community proposes concepts for scientific missions. They describe the objectives of the mission and establish the scientific strategy. Scientists backed by industry and in interaction with ESA respond to the challenges of the mission concepts. Their proposals are peer review evaluated and are chosen or rejected. Once a mission is selected the objectives and scientific challenges are translated to scientific requirements and these in term are translated to technical requirements. Scientists and engineers are involved in this process.

Technological excellence and maturity are essential components for mission success and essential in risk reduction in the space sector. The maturity of technologies and correlated risks are measured with the Technology Readiness Level (TRL). In the space sector the TRL does not refer to the maturity of a technology in the terrestrial sectors but is used, in particular, to describe how mature a technology is in its use for space. In addition the TRL level of technology maturity in one mission might not be the same in another mission. This can be seen in Figure 11 and is described for different levels as[6]:

TRL1 Basic principles observed and reported
TRL2 Technology concept and/or application formulated
TRL3 Analytical and experimental critical function and/or characteristic proof-of-concept
TRL4 Component and/or breadboard validation in laboratory environment
TRL5 Component and/or breadboard validation in relevant environment
TRL6 System/subsystem model or prototype demonstration in a relevant environment (ground or space)
TRL7 System prototype demonstration in a space environment
TRL8 Actual system completed and "flight qualified" through test and demonstration (ground or space)
TRL9 Actual system "flight proven" through successful mission operations

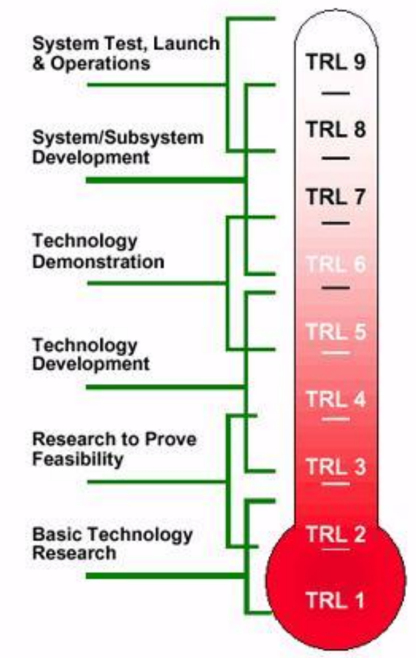

Figure 11: Technology Readiness Level (TRL) and risk associated with it [ref].

The relationship between the science (user) community, technology developers and space hardware developers for different S&T thematic areas can be

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[6] NASA description

demonstrated by a triangular relationship (Figure 13). Three distinct interfaces can be assumed between a funding body like a space agency and the outside scientific community, space industry and technology developers like universities, research institutes, industries and SMEs with strong R&D. In the 'user driven' context the 'scientific coordinator' interfaces to the scientists and is responsible for the coordination of the scientific communities which is proposing the scientific activities it wishes to endeavour. The "flight hardware coordinator" interfaces with the space industries for flight hardware development. The technology development coordinators interface with universities, research institutes, industries and SMEs with strong R&D to develop the necessary technologies 'pulled' by the scientists' needs.

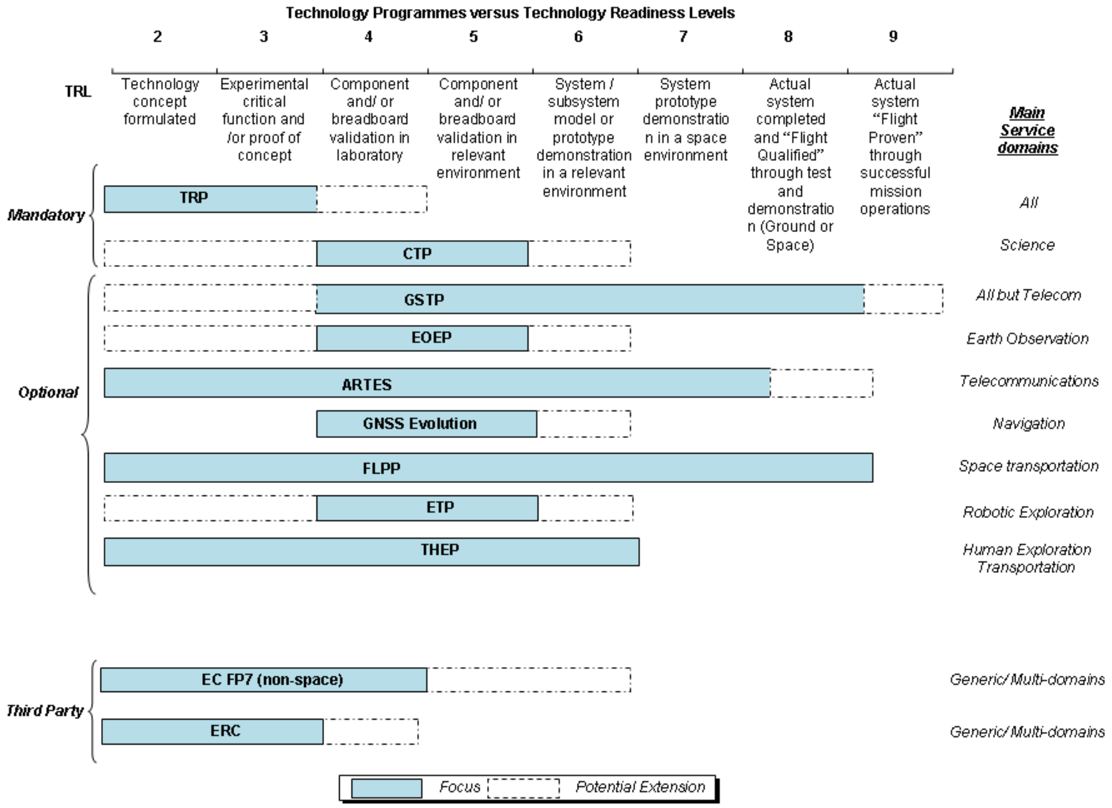

Figure 12: ESA technology programmes and EC community programmes and TRL levels[7].

The Technology Programmes of ESA in relation to the TRL level can be seen in Figure 12. The applied scientific research and development needed for developing technologies for space and is perused by ESA mainly under the Technical and Quality Management Directorate of ESA, where about 8% of the ESA budget is spend on direct research and development. The technology development research activities of ESA are mainly related to science missions of

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[7] European Space Technology Master Plan, European Space Agency, 2007, Issue 4, p.34 modified for the purpose of this study.

space (e.g. space science, astronomy), from space (e.g. earth science) and in space (e.g life and physical science); and utilisation (e.g. Meteorology, GMES, telecommunications, navigation, integrated applications promotion.

Technical requirements are used as a guideline to develop flight hardware and are used as guidelines for pulling technologies to develop new instruments, sensors, materials, techniques, etc. at higher maturity levels so that they can be picked up by the projects at a later stage. Technical constrains and specific demands related to the projects are providing the technical constraints for possible future integration in the flight hardware. At lower TRL level the necessity of in-depth space sector knowledge is not a prerequisite as most of the novel technologies are developed outside the space sector. Nevertheless, currently the participation of space associated institutions is dominating such developments with the idea to 'spin-in' terrestrial technologies in space.

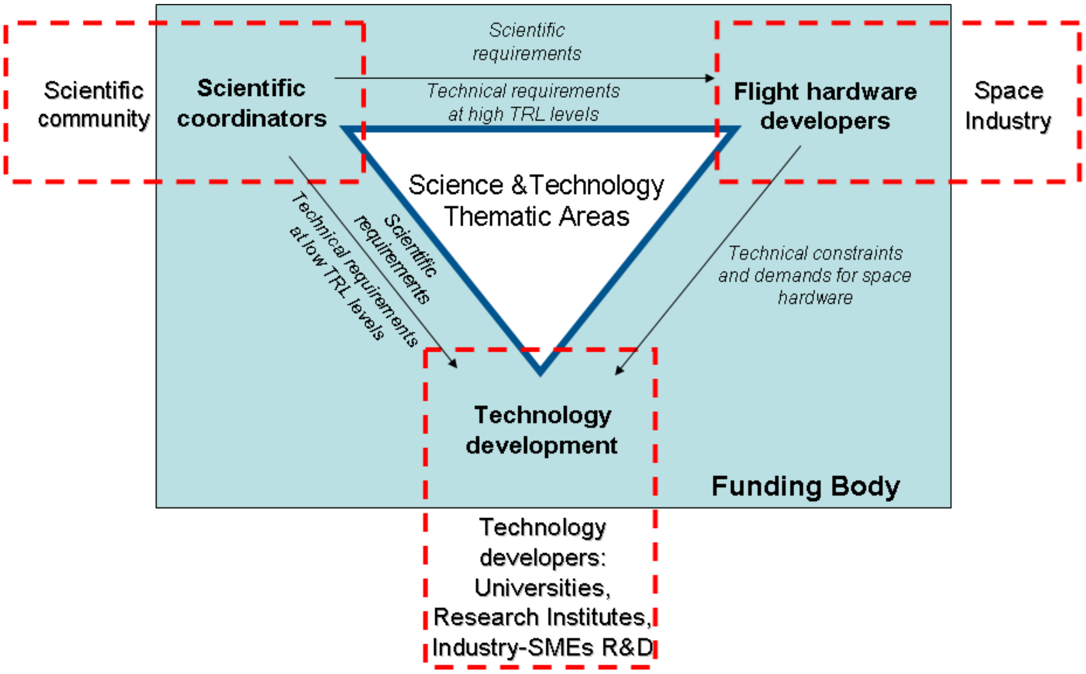

Figure 13: Scientific Programmes, Technology and Hardware development in the space sector.

In practice the 'need pull'-'technology push' relationship, in this triangle relationship, exhibits difficulties in the effectiveness of implementation related to the inherent nature of space. Space is a sector like many other sectors that cannot afford to use technologies that are not mature enough when needed due to the high risk s associated.

Therefore, scientific progress is restricted by the lack of maturity of related technologies needed to make a significant impact on science. Some of the reasons for this could be:

- Development times from the time of the identification of the ‘need pull’ to the time the technologies need to be integrated in the missions is too short for new technologies to reach maturity and technologies are not developed enough outside the mission development path.
- Even though the space sector invests significantly in the technology development directly related to a mission, it does not invest enough in basic research underlying technology and on science likely to produce technology that will be needed for future missions, before the need has been identified.
- Insufficient mechanisms of developing ‘push technologies’ based on ‘projected user needs’ (before they are identified).
- Lack of sufficient correlation of push-technologies that can be available to the scientists for future mission.
- Insufficient or not appropriate enough mechanisms for pushing or pulling technologies within the timeframe they are needed.
- Technological breakthroughs in the “push” context are often developed by other sectors and often the space sector conducts developments in isolation without being aware of these other technologies.
- Even when these technologies are identified and efforts are made for ‘spin-in’ in the space sector the time needed to bring them to the safety standards required for space is too long. These technologies in many cases require complete adaptation and/or full qualification for space which significantly prolongs the start-to-finish development time.
- Implementing push-technologies like the key enabling technologies requires high levels of investment to achieve the technological threshold needed to make an impact.
- The space sector has many ‘one-off-projects’ which differ significantly from one another. This implies that lessons learned are difficult to follow and might not facilitate future improvements.
- Possibly embarking into missions that are too ambitious even scientifically.

Outlook

In order to create technological breakthroughs for scientific progress, there are some simple conclusions that can be directly drawn, on how to better facilitate their development. At low TRL new technologies do not need to be developed exclusively via space funding schemes. Partnerships can be created with other terrestrial sectors for the development of key enabling technologies that are associated with high investments. These partnerships can utilise various national funding schemes, as well as EC framework programmes for non-space applications. Figure 14 shows the funding possibilities in a relationship between the space sector and other terrestrial sectors in relations to space TRL. Figure 12 shows how EC Framework programme and ERC could be used on a speculative TRL. In this way the space constraints can be implemented at an early stage in the design of new technologies, which will help shorten the space qualification time at later stages. A technology watch is essential to systematically identify the new emerging technologies and possible associated partnerships for the space sector. In Table 2 a first attempt is made to put together the push-pull model envisaged based on this outlook. The scientist who is producing knowledge leading to technology is also included.

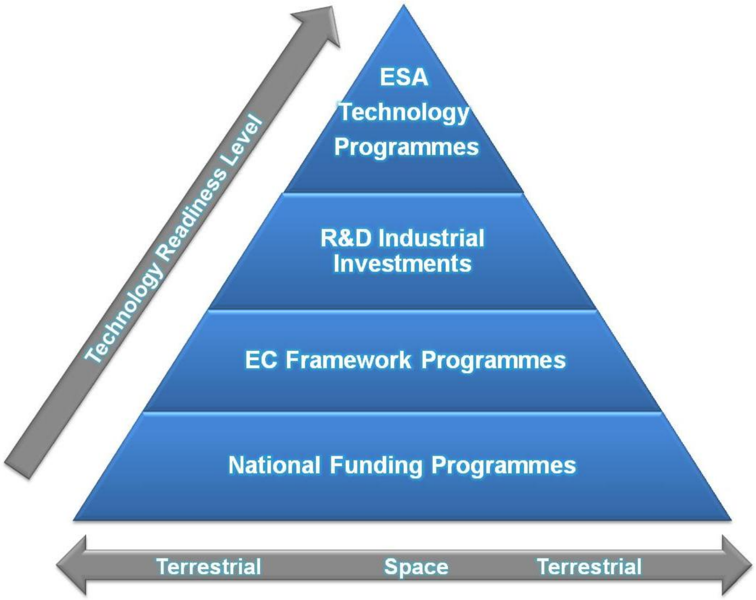

Figure 14: Funding schemes for space and terrestrial application in relation to TRL.

concept	lead time	involvement	application	cooperation	budget	programme	laboratory utilisation	developer	target
Pull	short – medium	Space programs scientific community (technology user)	targeted to science (user) teams needs	Specific space technology and flight hardware development programmes with science teams (user) at national, European and international level	Small-Medium	ESA Space programs and technology programmes	Support to Missions	Mainly European space industry	Mission Application Incremental Innovation
push	medium-long	space and non-space programmes at national, EC. Scientific community (technology developer)	- generic technologies; - key enabling technologies (KET);	- Space and non space technology development programs (ESA, national) - EC Framework Programme (space, non-space), JRC, ERC, EIT - large industries (space, non-space) with R&D orientation	Large	ESA Technology programmes + ESA on sight R&D, EC FP, ERC, National Funding (space, non-space)	Technology development Third Party R&D	European space industry + Examples: - universities - research institutes -industries &SMEs with strong R&D	Technology development Breakthrough Innovation

Table 2: Push-pull projected overview utilising ESA programmes and other programmes and mechanisms.

3.2 Construction sector

The construction sector is the biggest sectoral employer and a major contributor to Gross Capital Formation in Europe. It typically consists of the following areas: infrastructure, repair and maintenance; public and private housing; non-residential public property; industrial and commercial construction. When it comes to innovation this sector can be described as a sector:

- with a very low investment in innovation;
- where research is usually performed, if ever, by entities who are not actively involved in construction, such as universities or research groups;
- which is rarely high-tech
- where innovation is usually constrained by prescriptive contracts. The way of operation is moving from project to project, working on tight schedules and thus due to prescriptive contracts and strong competition, there is barely any time for companies to consider topics like R&D or refine existing procedures.
- where the company sizes are usually restricted (such as SMEs), with the exception of a few civil engineering contractors and materials manufacturers.

It is thus easy to understand, what difficulties have to be faced in terms of R&D for the construction sector. The key problem is the processing of information and transforming it into knowledge which is applicable to SMEs {Kahaner, 1997 #102;Davidson, 2001 #100} .

The innovation process and its problems are deeply rooted in the social environment of the industrial sector and thus do not always follow the usual, logically predictable path from invention to production. This is manifest in e.g. the denial of information scarcity, provided by research institutions, as this research is frequently incomprehensible to those people, e.g. the workers, and needs translation {King, 1984 #103}. The use of published results is as low as 2% and the knowledge of existing research is only about 10 % {Davidson, 2001 #100}.

The question that arises is: how can the gap between research and application be bridged? A research in Canada {Rostenne, 1989 #104} suggests that role models or “innovation gatekeepers”, namely companies that have successfully adopted an innovation, are more credible examples than governmental agencies or those who in fact conducted the research. Using this concept as its foundation, the concept of technology watch by Davidson, 2001 #100}, implies a better, more profound understanding of the section, to serve as a complement to the current and intuitive approach to innovation and decision-making {Jakobiak, 1990 #101;Davidson, 2001 #100} .

In order to introduce R&D innovation in the development of new ideas and concepts in the construction sector, the term *“technology watch”* was conceived. This is a process term, very much like innovation itself, describing the process of introducing innovative procedures into construction companies.

Technology watch

The process which the term technology watch stands for is considered to be natural for large companies. However, the question arises whether there can be something like a watch function for SMEs? Generally, even if the concept of innovation and the importance of R&D is understood by decision makers of SMEs, they cannot be applied if the risks and the stakes are high, or their R&D can only be considered in response to specific projects (e.g. Mega Constructions like The Palm Jumeirah, Dubai, or very tall buildings) or recurring problems in construction.

The notion of “relay stations” was proposed {Davidson, 2001 #100}, in forms of networks or local and shared platforms, which provide (confidential) answers to specific questions on demand (pull situation), or promote new applicable concepts (push situation).

In case of the pull-situation, the relay station has to

1. understand the methods and the structure of the local domain it is operating in;
2. be able to provide information as precise and as specifical as possible;
3. express research based information in a language that can be understood by SMEs.

The push situation requires other capabilities, but usually the demand for additional, new information is just vaguely perceived. Thus, as proposed in Davidson, 2001 #100}, these relay stations have to generate a demand for its offerings, creating a push-pull situation. In this case, the priorities of the relay stations are similar to those mentioned above, with the following additions:

4. The relay station has to identify procedures that inhibits innovation in their clients’ companies;
5. Appreciation and thorough understanding of what constitutes R&D for various categories of companies which they are interacting with.

Technology watch companies

Suitable operational modes for such relay stations can have many forms, such as a professional or a trade association {Davidson, 2001 #100}, which should mainly depend on the factors of proximity to the clients’ requirements and on the attitude of the members towards the competition.

A neutral organisation might also carry out the same tasks, as long as it does not appear as a governmental tool. It should not be associated with university institutions unless they are given visible autonomy.

In construction, there are two competing tendencies in the area of innovation:

- Improving current practice at all stages, ranging form design to construction, by means of modifying procedures.

- Breaking away from those traditional methods in favor of newly conceived technologies.

It is therefore the duty of these relay stations to carefully select the information to be transmitted, to identify the key participants affected by innovation and to carefully translate the appropriate information to those key participants.

As an example, the Government of Quebec set up CeVeC – Centre de Veille de la Construction (Construction watch centre), being conscious of the importance of SMEs to the construction business. This company adopted a policy for addressing opportunities with its clients, including a technology watch as a follow up activity. By the time of initial contact with a client, their needs and problems are already identified, making it possible to add follow-up information specifically tailored to their needs. (for more information please refer to {Davidson, 2001 #100}). Figure 15 visualizes the duties of technology watch companies.

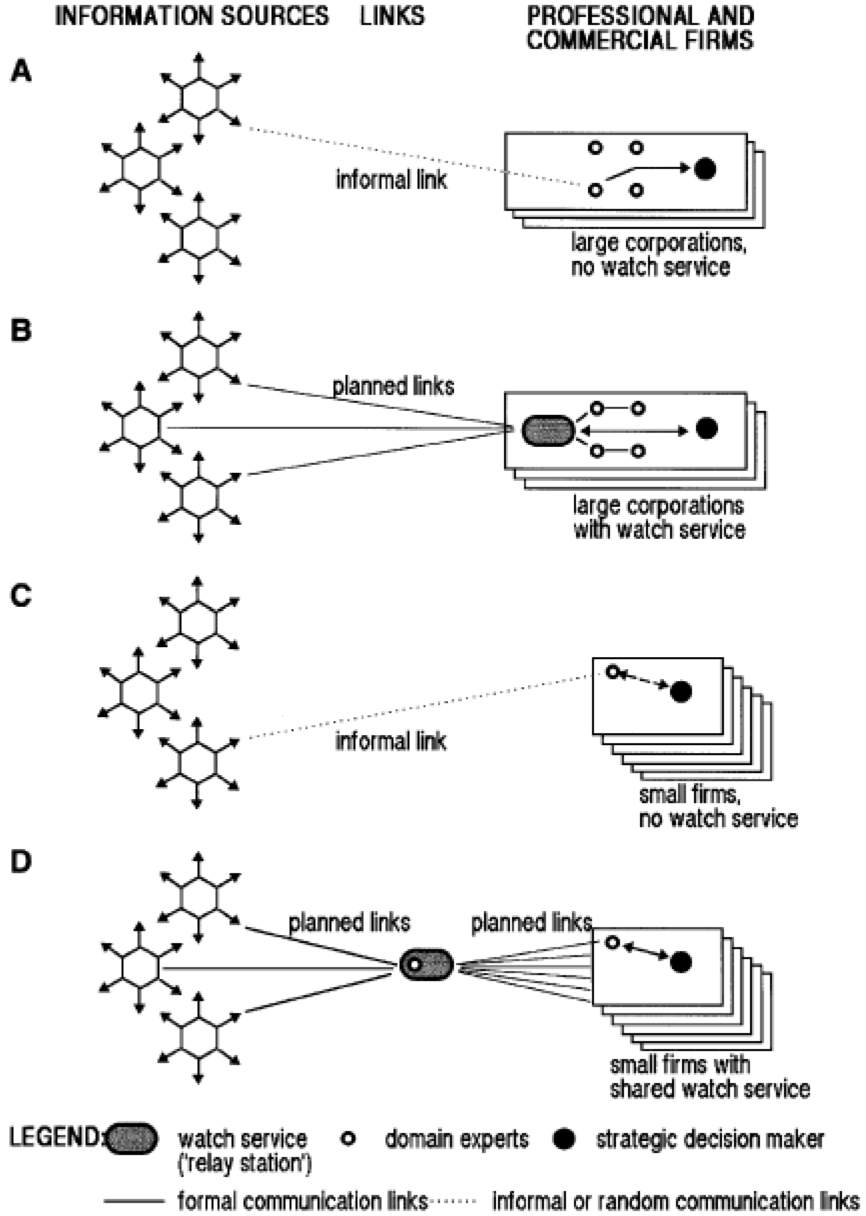

Figure 15: Construction Sector: Communication links in the technology transfer process. A, B represent large corporations; C, D represent small firms; A and C show no technology watch; B and D are with technology watch {Davidson, 2001 #100}

3.3 Energy sector

Current situation of Innovation: new, sustainable energy technologies in the innovation trap

The book by Steger {Steger, 2002 #105} defines the energy sector as energy production and energy distribution infrastructure. They further claim that albeit the fact that this sector has seen much investment lately, the legal and social standards imposed by policies (CO_2 reduction,…) are pushing innovation towards the development of sustainable energy solutions. This change in direction is only emphasised by the fact that conventional resources are limited and long time energy policy can not fail to include developing sustainable energy generation and distribution systems.

The terms “sustainable development” and “sustainability” are also differentiated: while sustainability is described as the initiator of a learning process leading to concrete results, sustainable development can be understood as a guide for action.

In the energy sector, specific technologies are frequently found in a situation described as an “innovation trap” by {Steger, 2002 #105} which slows new, innovative and sustainable technologies from quickly advancing in the market. This “trap” situation can arise from a number of points, which are comprehensively discussed in {Steger, 2002 #105}, summarised below.

Thus it seems valid to use the arguments brought forward to promote sustainable development in the energy sector, as the “sustainable development” term can also include the adaption (and thus the innovation in) conventional methods and procedures and does not exclude the conventional parts of the energy sector.

First of all, the interest to reduce costs, by promoting new and more efficient technological changes in the energy sector, is not very high. There are only a few heavy industry sectors that spend up to 10% of their production cost on energy, while the vast majority of industrial sectors only spend around 1% of their production costs on energy. This ratio also applies to other sectors, such as the service sector and agricultural sector. Even for households, energy expenditures, typically only amount to a small percentage of the total costs, and have been stable in terms of adjusted wages, due to inflation, over the past decades. Thus, decisions in the energy sector are not usually driven by the will to reduce costs by investing in R&D, and the value of these investments is not really perceived as an important factor in decision-making.

Secondly, the positive potential of innovation in the energy sector, when it is considered at all, is rarely fully taken into account and generally underestimated, usually depending on respective company standards. These positive external effects may be, e.g. lower CO_2 emissions, monetary cost savings through more efficient technologies, sustainable production methods and many more. These benefits are difficult to perceive as such, if energy is subsidized (e.g. agriculture, air transport,..) or if emission limits can also be kept using conventional technologies The advantages of innovation are thus distorted in favour of conventional technologies and innovation is only advancing slowly.

Thirdly, new technologies have not undergone the decades of continuous improvement processes that conventional technologies have. The lack of technological maturity causes initial high costs for small production quantities in comparison to older methods. A good example for this would be the relatively inefficient engine in cars, which albeit having large disadvantages in terms of emission and consumption, has undergone decades of development and no other alternative could yet replace it. An alternative, such as the hydrogen engine, was a large investment in R&D and has already reached market readiness. Yet, due to the lack of hydrogen fuel processes and no distribution infrastructure for hydrogen as fuel, this new technology did not succeed in being a viable alternative to the conventional engine. New, immature technologies can be considered to be at the summit of a learning curve with a steep curve towards cost efficiency, with high costs, technological improvements and external effects (e.g. infrastructure for using hydrogen as fuel), that have to be faced at the beginning of a newly developed system, while conventional technologies are approaching a stable minimum on that same curve, being efficient, well understood and cost effective at the same time. This learning curve is especially fatal for the energy sectors since R&D, albeit large investments, has not yet taken new technologies to the same cost efficiency level as conventional systems.

The fourth point is that innovations in this sector are usually technologies that have to be integrated in conventional systems or production chains, such as power grids or power lines. A high level of capability to conventional systems is required and high industrial standards present very narrowly defined margins for operational parameters of new technologies. Further, support structures, which are present for conventional systems, are largely absent for modern and innovative technologies.

Finally, there is a problem referred to as “sunk” costs, a particularly important factor in the capital intensive energy sector. Once a facility, e.g. a nuclear power plant, has been built and taken into service, the capital raised in the process is “sunk”, or bound, presenting strong competition to the new R&D of new technologies. In the case of a nuclear power plant, e.g. built 17 years ago with a remaining service life of typically 35 years, it is very difficult for decision makers to invest in R&D.
The same phenomenon can also explain why unprofitable facilities are maintained over long periods of time in capital intensive industries.

Outlooks

Strategies to meet the problems above include many ideas and are the topic of large parts in {Steger, 2002 #105}. The most relevant ones are summarised in the following.

- Creating custom made support measures for different stages of development can help to accelerate innovation. As a new technology becomes ready for the market, it is expensive and difficult to handle at first. This is due to many factors, such as the need to educate staff, create awareness for new technologies in the public and the slow process of maturing technologies, creating knowledge and new procedures. Technologies in their early phase of introduction need a different policy approach than well established ones like start up financing and other similar subsidies. These policy measures need to be specific enough to take into account the current realities of innovations, e.g. windpower being far closer to profitability than voltaic energy generation methods, and yet flexible enough to meet the requirements of a dynamic market.

- It has been shown that new, sustainable or otherwise innovative technologies do not exceed the costs of old technologies in the long run. This kind of awareness has to be created.
- Policies, such as national procurement programmes, can be used as a means to create demand for new technologies.
- Governments should extend and focus more clearly on basic research (such as nuclear or fusion,…) and include the topic of energy in their educational agendas.
- Introducing “greenpricing” and informational campaigns to trigger more public awareness for the ever rising power consumption and the problems associated with it. The poor success of former attempts of labelling “green” technologies, according to {Steger, 2002 #105}, can be found in too extensive labelling efforts flooding the customers with information and thus undermining all efforts to educate and form the public opinion.
- In the process of social and organisational innovations the creation of supply structures, partnered by public institutions and enterprises, enabling them cut free from the pressure of selling more and thus spending more time on developing and offering profitable services for the efficient use of energy.
- It is not enough to look into innovating certain components of the entire energy sector while neglecting other parts of it, which are essential to the success of an innovation. E.g. it does not make sense to create huge wind farms in rural areas while neglecting the local electrical distribution network and conventional electricity generation, because wind farms may cover the entire demand of a region on windy days, while on average days they can only cover a few percent of the electricity use. The wind farm needs to be included into the local supply chain in an intelligent and flexible way, such that it can cover the peaks of power demand on windy days or simply add power to the general demand on other days. Conventional energy supply chains can not act so flexibly and need to be improved together with the new innovation. By doing so, the surplus energy generated by new technologies (including photovoltaic elements, wind farms,..) can be effectively redistributed and innovation benefits the entire region, making it more competitive and making them more mature.

3.4 Transportation sector

Transportation is a very important part of our lives and is present everywhere: from the massive transport of goods to urban transportation and personal transportation. Society strongly depends on transportation, although it has many negative effects such as pollution, noise, waste, unsustainability and not always safe traffic. The paper of Zuylen and Weber {van Zuylen, 2002 #162} provides a comprehensive overview on this field.

Innovation in transportation can be used to:

- Overcome problems such as pollution and thus facilitate transport with as little negative impact as possible. The catalytic conversion of exhaust gases is a good example of technology being used to realize policy goals (lower emissions) and for a technology having an impact on a sector; dynamic traffic control management is another example of how technological advances can improve an entire sector.
- Technology can also be a tool to implement policies, as the catalytic conversion mentioned above. Another example could be the support of law enforcement bodies provided by new technologies in speed limitation enforcement, such as improved radar systems or intelligent speed adapters capable of automatically reducing the speed of cars entering a certain area.
- Technology from other sectors can have direct or indirect impact on the transportation systems, such as the emerging eCommerce currently starting to show secondary effects, both good and bad, on traffic patterns and transport procedures.

Although subsidized R&D is the tool of choice to push innovation in this sector, there are a number of reasons that make their success difficult to estimate and make innovation proceed very slowly. According to {van Zuylen, 2002 #162} this might lie in the nature of the sector: as many actors are involved and thus require cumbersome coordination of innovative processes. Further, the “spontaneous” nature of innovations is often difficult to unite with fulfilling goals set by policy. Regional or national problems can additionally stall the innovation process. Thus a normative policy approach can help to find the best mix of policy measures to ensure to fully benefit from innovations.

The problems that have to be overcome are rooted in the strong mutual link of different layers of the public sector; e.g. cities often lack the power to stimulate innovation involving industry while national governments have only little power to impose new applications onto local authorities {van Zuylen, 2002 #162}. National governments are limited by regulations imposed by the European Union, since the Union would not allow national regulations to restrict the open market and free competition.

Policies for technological innovations in the transport sector are confronted with a very complex situation: it has to deal with:

1. many actors and competing technologies,

2. multilevel and multi-domain decision making,
3. the problem that transport is embedded in our social and economic environment and with
4. the distribution of “labour” among the Union member states.

Aside from these factors, organizational changes might be necessary if technologies are being integrated into present services or transport concepts. It is also difficult to assess if a new technology is indeed a suitable replacement for an existing system which implies that policies have to be conceived to deal with possible failure and prevent the gains of an innovation to leak away by an increased transport demand or changes in customer behaviour.

Project FANTASIE

The Fourth Framework Project FANTASIE described in {van Zuylen, 2002 #162} analyzed innovation in transportation and came up with a series of conclusions concerning the current issues in the sector and policy decisions to stimulate innovation. First, the barriers of innovation identified in this report will be described.

- Slow innovation: Due to the strong link of transportation already mentioned above, innovations usually are not limited to single aspects but rather to many components of the sector, slowing down innovation significantly. The long lifetime of infrastructure and transportation means is another reason for the low inertia of the sector.
- Many actors involved: Each actor involved has his / her own agenda and cooperation or at least co-ordination has to be realised – which takes a long time, additionally slowing down the entire process.
- Further barriers to innovation identified by an investigation conducted by the European Commission in 1999:
    - Lack of awareness of available information
    - Legal and regulatory barriers in the form of institutional barriers, liability issues, administrative and organisational issues and protection of intellectual property.
    - Technical problems in the form of a lack in standardisation, certification and problems with interoperability and interconnectivity.
    - Financial and commercial issues due to insufficient innovative financial mechanisms, lack of incentive to innovate, market related issues and the lack of competition within a certain market.
    - Social issues related to the lack of qualified manpower in certain fields of transport and insufficient acceptance of certain innovations.
    - Decision making barriers because of the fragmented levels of decisions and the lack of comprehensive and co-ordinated action towards the resolution of the mobility problem.

The report on Project FANTASIE also suggests a number of policy action items which will be shortly described in the following.

- Facilitating the innovation process: The project showed that promising technologies would benefit from a combination of measures, but these have to be implemented either at national or European level, depending on the technology itself. A fine balance has to be found to successfully provide incentives for innovation.
- Legal and regulatory measures: These are usually implemented at European level and need to be harmonized to some extent, taking care to avoid heavy administrative and financial burdens that slow innovation.
- Technological measures involving Research and Development: While some technologies can benefit from being implemented a regional or national level first, several technologies need a bigger scope where international research activities have to be considered to successfully develop a new product (as it is the case with propulsion technologies or in the aeronautics sector). Furthermore, in the innovation process during the experimental stages of development, pilot projects funded by the European Union have been shown to be useful in identifying application conditions. However a balance between protection of experimental technologies and fostering competition is essential to keep the innovation process running effectively.
- Compatibility measures: The standardization of transport solutions is not only important to ensure compatibility within the European Union but also in creating essential weight for global market introduction. Standardisation at a too early stage however might prevent future options from being established.
- Cultural measures: Creating awareness among the public is important and has already been partially initiated by the Green and White papers of the past years.
- Institutional measures: Facilitating the emergence of new systems, lessons learned from the past show that it is sometimes important to create networks and new organizations to make the cooperation of many carriers easier. This process can be aided or initiated be the Union itself.
- Role of the European Union: An important point elaborated by {van Zuylen, 2002 #162} is considering whether new technologies require particular policy attention. The issue whether policies are better implemented on the European or national level is important, since it has to be considered whether policies can actually really aid innovation. The effectiveness of policies seems to be connected to the development stage of a new technology, as well as to the kind of innovation, the speed of the innovation process and the competence of governments or national entities, in the special field of that technology. The role of a government has to be reconsidered as the innovation process advances as well; industries are often dissatisfied by changes in funding when they reach a more mature stage of technology or are about to enter the market. This policy change might change the level of funding or be shifted from subsidies to regulations, with the Union adapting the role of either a neutral agent, innovation agent, regulator or in specific cases even the

role of a developer. Roles have to be chosen with the objective to be as effective as possible within the frame and limitations of the European Union. It seems that in the case of a common transportation policy are the ones as regulator and research agent.

For an in depth view and a more detailed analyses of the FANTASIE project the fifth chapter of the FANTASIE report is suggested.

3.5 Aeronautics sector

The aeronautics sector started with human aviation and is a little over a century old now. In 1890, Otto von Lilienthal created the first successful glider and was followed by the Wright brothers a mere 10 years later with the first powered flight. The first fifty years of aeronautics experienced tremendous and frequent innovations that changed our everyday life. In this period a better understanding behind the underlying physics phenomena was achieved and daring new concepts and creative solutions emerged, which for example finally led to the first Boeing 367-80 707 prototype {Kroo, 2004 #115}. After that, in the next fifty years of aeronautics it appears that no dramatic revolutions took place but rather the focus was in fine tuning existing technologies. An aircraft essentially havs not changed much in shape or design. The work of {Kroo, 2004 #115} gives an overview of developments and challenges in the aeronautics sector.

Overall there are various opinions on the reasons for this apparent stagnation. Many consider that the apparent luck on innovation in aeronautics is a sign of a mature sector. While some state that all necessary innovation in the sector occurred the first 50 years for example the aircraft design have reached an almost perfect level in 1954, others argue that the tremendous costs and risks involved with a new technology in this sector make it difficult case for innovation. Thus, only until new ideas are well-proven, they can be taken up and in a low risk incremental innovation approach.

The case study of Elco van Burg {Burg, 2008 #1} looks at knowledge networks for introducing the new technology of Clare material in aeronautics which took more than 30 years of development and testing before it was used in the Airbus A380 and attributes the long development path as other authors to a) extensive material qualifications are necessary before a new material can be applied to any aircraft structure; b) aerospace manufacturers will generally only make an investment in a new material when they design a completely new type of aircraft. In this study the path of knowledge management in the entire development was followed and innovation networks were studied. The formal informal links between information, knowledge and people were analysed. The Glair network changed in the course of the 30 years but always included a university, research institute, government funding body and industrial partners. It could be characterised as decentralized, international, and continuously focusing on a single innovation. The study showed the importance of informal mechanisms and showed the problems related to personnel change and personal disputes. Another important point was the value distribution which can also limit the knowledge sharing because industrial partners wanted to protect the knowledge. According to van Burg {Burg, 2008 #1} the solutions proposed in the study were in a) interpersonal relationships because they are important in partner motivation; b) rules and agreements as important for the commitment to engage in development; and c) meetings, which are important in establishing interpersonal relationships and which served as opportunities to share knowledge.

In the long run conservatism in innovation may prove to be detrimental for a sector. Thus, insufficient or absence of future developments can ultimately lead to the destruction of the aeronautics industry. According to {Kroo, 2004 #115}, the solution to this lies on two factors:

- the need for significant changes in air transportation will create an incentive for innovation; environmental requirements and new regulations will create the need to innovate.
- the introduction of new technologies in other fields, related or unrelated to aeronautics, may create a push for technologies that revolutionize this sector.

Technology areas that may drive innovation

The work of Kroo {Kroo, 2004 #115} looks at the history of aeronautical innovation and identifies three areas that may drive the future of aeronautics innovation. These areas are:

- Exploiting computational advances for high-fidelity simulation and improved design;
- A paradigm shift from having to create an aircraft around pilots and passengers to more advanced solutions;
- Designing the system rather than the vehicle, thus creating collectives and systems of systems.

Aside from these points, a survey by eBusiness watch {Watch, 2005 #119} suggests an additional important point:

- ICT innovation as innovation push.

Simulation and Design

Modern computational capabilities have advanced considerably in the past decades, allowing academia and NASA to create powerful algorithms for solving nonlinear equations of fluid flow and structural mechanics in the 70’s and 80’s already. This led to a more profound understanding of complicated airflow that provides the lift for an aircraft and allowed constructors to save time by using computers to simulate wind channels instead of building expensive, time consuming down-scaled models of concept crafts. As mentioned in {Kroo, 2004 #115}, many areas of aeronautics are just beginning to fully exploit the potential that computational methods have and this still holds.

DARPA´s Shaped-Supersonic Boom Demonstration {Pawlowski, 2005 #117;Graham, 2003 #118} is a good example for extensive use of simulations providing substantial cost savings, since the testing and modification of an existent supersonic design is generally very expensive.

Another interesting example is provided in a case study in {Watch, 2005 #119}, describing the importance of ICT innovation in aeronautics: the Dassault Aviation Group used a “virtual office” to construct its newest business jet. In 2002 the Group linked all collaborating companies in a single, virtual workspace in which they shared a common, configured, constantly updated digital mock-up of their new product, the Falcon 7X. This solution allowed the cooperation between all companies beginning at the conceptual design level, the sharing of knowledge and of tools and databases. All 40.000 parts of the aircraft were predesigned in 3D precision, accelerating the assembly of the first jet substantially – it took only 7 month to assemble the new aircraft, instead of 16 months as usually. 3D CAD designs enabled the constructors to learn assembling the aircraft on the screen prior to doing it for the first time.

Continued advances in computation and electronics are enabling automatic systems to slowly replace pilots in an increasing number of platforms. While this might bring a reduction of operating costs in the future, the potential for redefining the role of an aircraft has to be considered. The extensive use of Unmanned Aerial Vehicles (UAVs) in the past years for surveillance and reconnaissance missions, such as the RQ-4 Global Hawk {, #121} and the Rheinmetall KZO {, #122}, have made more extreme applications of UAV seem more probable, such as Aerial Regional-scale Environmental Survey (ARES) aircraft for Martian exploration {Guynn, 2003 #120}.

New, very small aircraft or micro-air vehicles designed by aerospace companies, governments and universities are another inexpensive approach to test new concepts and are exemplary for the possible design changes that might change aircraft concepts in the future.

Swarm Systems

Another incentive for innovation in this sector is the fact that until now, aircrafts were usually built as individual vehicles as aircrafts always needed human pilots. Since UAVs do not need humans on board, it is possible to move away from single individual aircrafts and to assemble many of them into a fleet. As the number of aircrafts increases a collective of aircrafts can be managed to perform certain tasks as e.g. transportation or air freight. As the numbers increase, the complexity of managing these collectives increases as well. But due to recent theories of collective behaviour and new, powerful computing options, new approaches to these multi agent system designs can be taken.

Over the last couple of years significant competence has been built through development of swarm management software tools for robots from which aeronautics may benefit. These technologies are still in a very early stage of development but the potential for future applications is already being recognised and the first promising results are available {Wolpert, 2000 #123}.

ICT innovation

A key issue in many of the approaches mentioned above lies in ICT standards. The use of internal networks (LAN) and remote access capabilities can be essential to successful innovation for large companies. However, SMEs usually

slowly develop their ICT infrastructures and thus have increasing difficulties to meet customer demands or to cooperate with other SMEs {Watch, 2005 #119}. In fact, there is no smooth data exchange possible between these companies. Sending data to another company using different applications requires translation, which in practise usually means that an employee has to manually insert datasets (and thus increases the factor of human error and means a significant increase in costs). This means that knowledge gained anywhere within the production chain remains isolated and difficult to access. This problem would be met if certain common industrial standards in terms of software use, data exchange and interfaces / compatibility were introduced. At the same time, forcing these standards would also create immense problems for SMEs as innovating internal ICT standards requires long time planning, allocation of resources and usually result in very complex and massive changes of internal procedures {Watch, 2005 #119}.
A prominent example for this standardisation process was the initiative to develop and introduce electronic data interchange (EDI), a uniform framework for data exchange. EDI-based applications were extensively adopted by companies in the past two decades, especially by manufacturing industries with complex and broad value chains such as the automotive industry.

Outlook

The sector still has to see the global challenges that may trigger transformation. These most profound challenges are environment protection regulations; safety and other regulations; comfort to passengers; air transport system capacity; affordability and competitive of the sector; and technology advancements in other sectors. The technology push and transfer from other sectors will be essential. In particular openness and efficient knowledge management and innovation networks will play an important role in the next era of i-economy that we are entering.

3.6 Pharmaceutical sector

Research and development in this sector is a long and strongly regulated process. New products can be designed by isolating the active ingredients in plants or traditional remedies, or by understanding metabolic pathways of diseases and pathogens and thus designing a drug with the tools of Biotechnology and molecular Biology. The development stage can generally be split into early stages, involving in vitro studies, and trial stages with in vivo and clinical trials.

Once these pre-approval stages are passed, a new product in the European Union (EU) developed by a company may submit a single application to the European Medicines Agency for a 'marketing authorisation', or a licence, that is valid simultaneously in all EU Member States, plus Iceland, Liechtenstein and

Norway. This is called the 'centralised (or 'Community') authorisation procedure', and is mandatory for certain types of medicines and optional for others, according to Regulation EC No 726/2004 {, 2004 #200}.

According to the European Commissions Study on the Pharmaceutical Sector {Associates, 2004 #114} this sector has seen a recession in innovation. This has been measured by comparing the number applications to marketing licenses applied to those that have effectively been granted in the decade before 2004. The reasons for this recession are not well understood and are probably not simple to understand. The following analysis will largely follow the EC study {Associates, 2004 #114}.

Even though in 2004 a number of new technologies such as gene therapy were already in the process of being developed, their potential to contribute significantly to market applications or authorisations were considered fairly low. New technologies have to pass through clinical development and testing prior to reaching a mature state where it can reach the market. In 2004, R&D slowly increased in the US while showing first signs of regression in Europe as mentioned above.

Factors stalling innovation

According to {Associates, 2004 #114}, there are three major processes that slow R&D in the pharmaceutical sector:

- *Cost of developing new drugs*: evidence supports that the general costs for R&D have risen in the past decade, even though large companies stopped investing in drugs which were unlikely to make it to the market. These costs vary significantly from one product to the other. Furthermore, the mean costs of undertaking clinical trials rise with the complexity of the researched product. The number of trials needed to get approval for a new product has risen in past decade as well, thus raising costs further. Interestingly there is no clear evidence that regulatory requirements associated to the approval of new products have contributed to the increase of development costs.
- *Expected returns from Innovation:*
    - Price regulation and parallel trade: In the first years of the decade all major European countries have introduced cost containment measures which led to tougher price regulations and lowered profits, hence are likely to have reduced incentives for innovation.
    - Generics: With the increasing importance of generic drugs and a recent shift of governmental policies towards encouraging generic competition expected revenues are quickly dropping after a patent expired. This has a long term effect by increasing the importance of the branded period, thus providing an incentive to channel R&D resources into products likely to be approved quickly to the market.

    Another effect of that might be a shift to incremental innovations in order to extend market exclusivity.
    - Research Location: Given that cost containment measures are increasing in Europe, companies in countries where expected returns of innovation are higher have a marketing advantage for research.
    - Cost effectiveness measures: Studies on cost effectiveness increase the cost of development and thus reduce the incentive to invest in innovations. However, cost-effective products which are truly beneficial for society need incentives in order to increase the investment in R&D. If these incentives are provided, this process can lead to increased efficiency in innovation processes.
    - Therapeutic reference pricing: This recently introduced policy in a number of European countries regulates the premium pricing of first products of a new category used to enjoy, thus leading to lower incentive to invest in new technologies. At the same time it is expected to improve general R&D processes and ultimate lead to truly innovative products on the long run.
    - Data protection and market exclusivity: In order to increase incentives for companies to innovate, extended data protection and market exclusivity have to be provided.
- Industry Restructuring: Mergers and acquisitions within the pharmaceutical sector seem to negatively stimulate innovation on a short time. However it is difficult to estimate the long-run effects of these processes on innovation: while merging or acquiring other companies can improve the productivity of innovative activities and increase the probability of patenting a new product by reducing competition, the loss of the same by gaining a significant headway relative to remaining rivals can lead to a lower incentive of those rival companies to invest in innovation. The reduction of independent lines of research by eliminating or taking over competitive companies will also result in higher costs for R&D. Observations of large mergers in the sector showed that these processes always went along with divestitures or other remedies to address the potentially negative effect on customers.

Improving innovation

What are stimulating factors for innovation in this sector? The low level of market licences in 2002/04 described in {Associates, 2004 #114} were understood as indicators which did not imply a real crisis in pharmaceutic companies but rather taken as motivation to devise long-term remedies and strategies to help R&D.

The following issues have to be addressed:

- Faster market access for products offering a significant therapeutic benefit in order to stimulate the development of new products and increase the revenue from marketing these.
- Streamlining and simplifying the regulation process and to shift the focus of EMAE to the provision of scientific advice and support to the industry. Thus the danger of fragmenting the European regulatory system is lowered.
- Raise the level of clarity of the market exclusivity of a product by introducing a harmonised ten-year data exclusivity period, while allowing generic products to be developed before a product loose exclusivity. This represents a call for consistency and transparency and may increase the incentive to innovate.

Aside from these key issues which are already partially addressed by other, more general EC policy proposals on innovation, the attractiveness of Europe as location for R&D needs to be increased:

- A first step would be to identify industrial capacity in Europe, with a special emphasis on understanding the specific problems of innovation in this sector. It has to be determined whether current investment policy is appropriate to help European pharmaceutical industry.
- The returns of innovation have to be increased by changing the current structure of pricing. Encouraging the development of generics while at the same time the prices of prime products are regulated or even forced to be lowered will reduce the readiness to invest in new developments. This measure might also be used to make pricing more flexible: the possibility of achieving a price increase for a particularly valuable product on the market could be used to stimulate further research. This is also strongly correlated to the policy of extending the period of protection for new products.
- Stimulating a better cooperation between public and private research organisations has already be recognised a potentially beneficial, but a careful follow up is of great influence on increasing Europe´s attractiveness to companies.

Finally, the work Charles River Associates {Associates, 2004 #114} suggests the following key steps to encourage innovation in the pharmaceutical sector. First of all, gaining a more profound understanding on how technical innovation can improve later stages of development processes is deemed of great importance. This process involves an improved communication between regulators and the industry during the key phases of developing a new product, thus addressing fundamental problems of the production process to prevent future bottlenecks in the long development phases and thus increase industrial capacity. On the topic of pricing, {Associates, 2004 #114} suggest that using branded prices may increase incentives to innovate while stimulating greater generic competition. Also, greater pricing flexibility and improved public-private communications can provide incentives for innovation.

3.7 Biotechnology sector

Biotechnology has been recognized as a fast growing area with high potential for businesses and policy makers {Commission, 2007 #78;, 2007 #88} {European Commission, 2007 #89} It has also been recognized as one of the key enabling technologies as described in Section 2.5.

This field encompasses a very wide variety of topics, ranging from biology, medicine to electrochemistry and nanotechnology and is thus difficult to define precisely. According to the United Nations Convention on Biological Diversity {United Nations, 1992 #208} it can be defined as *"Any technological application that uses biological systems, living organisms, or derivatives thereof, to make or modify products or processes for specific use".* In Europe biotechnology often uses colour coded classification with the most known the red (pharmaceutical and medical), blue (marine), green (agriculture and environmental) and white (industrial).

Discussing the procedures in biotechnology is a difficult task since all emerging branches of biotechnological applications will naturally face slightly different problems. For example a device identifying genetic markers in biological samples will have to meet other requirements than detectors for biological weapons or systems that directly interact with humans. For the sake of providing a general overview, we will try to describe innovation in biotechnology using two interesting and promising technologies: biosensors and microarrays.

Specific Technologies

A. Biosensors

The paper {Luong, 2008 #157} provides a very comprehensive overview on biosensor technology and this section is outlining the main findings of this paper.

A biosensor is by definition a device that incorporates a living organism or a product derived from living systems (like enzymes, proteins or other biological agents, etc.) and a transducer to provide an indication or signal in the presence of a specific substance in the environment. This transducer can operate on electrochemical, piezoelectrical or optical modes to detect the reaction of the bio-component to an analyte. Ideally, these sensors must be designed to be able to detect a few molecules of significance and thus be able to provide quick and reliable information on pathogens, toxic compounds and other potentially dangerous or otherwise interesting substances.

An example of such a sensor is the glucose pen by Medisense: using the enzyme glucose oxidase to break blood glucose down that oxidizes the glucose in the blood sample. The reaction triggers a change in the electrochemical environment of the substances involved, thus resulting in a current which can be used as a measure of the concentration of glucose. In this case, an electrode is the transducer and the enzyme is the biologically active component. This device also illustrates the importance of small, handheld and quick biosensors: the simple and reliable design significantly improved the life standard of insulin-deficient patients and replaced lengthy manual work in a lab.

In the wake of recent incidents of contaminated food and the fear of biological hazards since Sept. 11th 2001, creating accurate environmental sensor has become an important issue and thus has been reflected in a significant increase in funding of biosensor research. In the years from 1984 to 1990, about 3000 scientific publications dealt with biosensors and about 200 patents on biosensors were issued; in the years from 1998 to 2004 the number of publications doubled to 6000 and 1100 patents were issued or were pending.

Albeit this impressive and indicative increase in scientific output, commercialisation significantly lags behind. The reasons for this, according to {Luong, 2008 #157} might be related to some technical barriers that have to met, like stability, sensor sensitivity and reliability. These issues are also related to cost considerations.

Specific innovation issues

Innovation in this field is increasingly associated with automation and system integration with high throughput. These are very challenging requirements as biosensors are usually designed to detect a single or few target analytes. The reason for this lies in the biological component that is tailored to detect traces of certain analytes and is usually highly selective. A further problem addressed above as “stability” is also connected to the detection mechanism – some reactants and bio agents used for triggering the detector are spent in the process of measuring, which results in a drop in efficiency over time and often renders the sensor not usable after a given amount of measurements.

Another key issue that has to be met in the case of biosensors is the validation of the sensor by established procedures. This technology is usually highly sensitive to matrix effects or subtle changes in the environment and thus a prone to fail measuring “real-world” samples. Biosensors have to prove to be an inevitable choice as cost-effective analytical tools.

In particular market viability of a biosensor depends on the following points:

- A sensor must function continuously over a long time, at least a month long. This is a very important requirement and is currently barely met by any sensor.
- A short analysis time is essential, and has to be around a few minutes. Nowadays many sensors need only 4-5 min to a few hours to deliver an accurate measurement.
- Establishing comparability of sensor performance with already established methods and protocols in order to get approval from regulatory agencies (like in the case of medical applications) and to deliver proofs that a new product can indeed work in real world conditions. The financial and technological risks of this process can be very high and are very difficult to predict.

The environmental and food industries are potentially emerging markets for biosensors, since recent events triggered a reasonable investment in these sectors (e.g. recent problems with food poisoning, pandemic outbreaks of H1N1, H5N1 and SARS,..) and biosensors can satisfy the high demands of these markets.

Defence/military industry has invested considerably in biosensors to rapidly detect biowarfare agents and potentially dangerous substances. However, the near future of biosensors in this sector is unclear, since absolute reliability is an extremely important issue for homeland security and defence applications.

For an overview on current investment in this sector the reader is further referred to {Luong, 2008 #157}.

Outlooks

The development to meet market needs significant upfront investment for R&D. Currently the sector is slowly increasing with low success rates. This can be understood since huge volume markets are generally missing and the push of these new technologies have yet to create a market. Future trends need to further include miniaturisatisation, integration of leading edge integrated circuits and wireless technology.

Feasibility studies and a careful analysis of the user demand are essential to decision makers prior to investment and have to be understood as very essential task to be performed in this sector.

B. Microarrays

A microarray is a revolutionary technology and could shortly be described part of “lab on a chip” technology. It was initially developed in laboratories in order to research on gene expression of model organisms and has nowadays evolved to allow diagnosis of disease disposition in humans, identification of specific viruses, protein analysis {Blagoev, 2001 #194;Brewster, 2004 #196;D'Ambrosio, 2005 #195}.

A microarray works on the principle that on a solid substrate, such as glass or a silicate wafer, a 2D array of cells is arranged. Each cell contains a certain reactant, checking/testing for a specific analyte respectively. A large number of tests can be performed at the same time, checking for several thousand of analytes simultaneously. If the analyte is detected by the according cell, it is indicated by a change of the cell properties e.g. a change of transparency, colour or other easily observable parameters. Additional information about the concentration can be typically obtained by illumination.

This allows weeks of manual laboratory work performed in the past to be replaced by a short test, measured in minutes (up to one hour) instead of days. This system has revolutionised analytical procedures, enabling quick, reliable and simple investigations. Although these microarrays are difficult to produce, their advantage lies in being very cost effective (using only the smallest amount of chemicals, saving equipment and specialists working in a fully equipped laboratory) and saving considerable amounts of time. For an overview on the first microarrays developed ten years ago, see {Brewster, 2004 #196}..

According to {Brewster, 2004 #196}, it is clear that the development of array-based technologies represent a fundamental shift in the way scientists study living organisms. An array is more than just a new experimental technique, microarrays change the way scientists can deal with the massive amount of data involved in any kind of genetic research. This technology provides a first glimpse into how researchers will utilize genome data in coming years.

Prospects of Microarray Technology

Having realized the importance of this technology, educators globally are beginning to teach genomics, proteomics, and bioinformatics in undergraduate biology and computer science courses to ensure the basic principles are understood. Microarrays has also created a link to ICT innovation, since many arrays are now being analysed automatically and the future scientist has to be able to understand ICT processes to an extent which is new. Thus Brewster et al. {Brewster, 2004 #196} refer to this technology as a new age of biology to the next generation of scientists.

A key issue to the future applications is data processing and networking of genome projects. According to Ambrosio et al. {D'Ambrosio, 2005 #195} the following points still have to be overcome:

- Accessibility to microarrays at the beginning was limited due to still high costs of instrumentation and consumables. The prices have dropped dramatically already in the last couple of years, but can still be improved. New and cheaper development methods have to be created to resolve this cost issue.
- Data management: to fully exploit the results of an array “essay” a large number of scientists needs to be able to access recent results and coordinate with other groups globally. Companies have to be able to protect their products and results at the same time – which clearly contradicts the proper and correct data management that would push R&D further.
- Further problems lie in unresolved legal and ethical questions regarding patient’s confidentiality, communication of important information to patients and their families, health insurance issues, missing or incomplete regulatory national or international frameworks and intellectual property rights.

3.8 ICT sector

Innovation in the Information and Communication Technology (ICT) sector has been analyzed by a number of entities in the past 15 years innovation and innovation strategies have been thoroughly investigated. The paper by De Marez Lieven and Verleye Gino {De Marez Lieven, 2004 #178} presents a very good overview on the lessons learned from the first decade of following innovation in ICT.

The current trend of innovation in ICT according to {De Marez Lieven, 2004 #178} started about a decade ago and has been associated with many terms by a number of authors:

- Evolution from "Industrialism" to "Post-industrialism" by Lyon, 1995 {Lyon, 1995 #180} and Burgelman, 1993 {Burgelman, 1993 #179}.
- "Technological Revolution" by Sheth in 1994 {Sheth, 1994 #181};
- "Information Revolution" by Jankowski and Van Selm in 2001 {Jankowski, 2001 #182};
- "Information Society" by Toffler in 1980 {Toffler, 1980 #199}, Servaes in 2000 {Servaes, 2000 #197} and Servaes and Heindercykx in 2002 {Servaes, 2002 #198}

These terms usually associate a wider field than ICT alone, nevertheless we still live in a society that has changed rapidly in the past years which makes it necessary to re-evaluate traditional assumptions as both demand and supply side of the sector have changed.

From the suppliers side, a strong technology push has resulted in the confrontation with many new products (WAP, digital TV, X-Box, GPRS, UMTS,...) and confronted us with a number of new innovations. However not all new technologies lived up to their potential. The digital television which experienced slow acceptance and WAP which mostly failed are such examples.

Barriers for innovative products

The authors in {De Marez Lieven, 2004 #178} have tried to figure out possible reasons for failing market introductions of certain products and came up with a number of points which will be summarized in the following section.

- The most important of those is that many suppliers seem to lack insight into the customers adoption potential, the needs of customers and how they perceive a product beforehand. The main argument of suppliers when confronted with unsuccessful innovations implies that introduction and marketing strategies have failed and that the strategies lacked vital knowledge to work effectively.

  These "badly judged marketing decisions" are also quoted by many other authors and seem to be the cause of innovation failure in the ICT factor. A possible explanation to this are changes on the demands side {De Marez Lieven, 2004 #178}. In contrast to the former perception of the customer the socio-demographic, - economic, and lifestyle profiles have changed considerable to such an extent, that the typical user is not necessarily male, higher educated, young, self employed, … any longer and the classic marketing approach is not effective enough. The rapidly growing market might also contribute to the failure of previous marketing strategies, which understood owning many technologies in the ICT segment as asset to successfully innovate any product, since competition has reached levels that users are overwhelmed with new technologies. The bottom line is that companies rely too heavily on these traditional strategies and thus fail in targeting the right people or deliver the wrong message to their costumers.

- Another tendency seems to be associated with an overly strong technology push by the suppliers: being overly confident with a new product can lead to mismanagement and failure. Although this approach seemed to be very effective in former times, the current environment has changed and customers became more exacting and are confronted with a really broad market. Thus it is naïve to stick to the “field-of-dreams-approach” {Baldwin, 1996 #192} or the supply-side concept reasoning {Jankowski, 1996 #190}.

Traditional and recent models of ICT innovation

The study of innovation processes sooner or later brings up the theory of “diffusion of innovations” by Everett M. Rogers, formulated in 1962. This theory has been debated, criticised and cited, yet, albeit being over 50 years old, certain concepts are still being considered to be valid. However, the paper Lieven {De Marez Lieven, 2004 #178} leaves no doubt the basic idea of this theory can still be seen in practise today. The full scope of discussing the “diffusion theories” and their many critics is beyond the possibilities of this paper and the interested reader is referred to chapter 2 and 3 of the paper being followed here {De Marez Lieven, 2004 #178}.

A short description of the “diffusion” theory is given in the following graph: the market is split up in 5 different sections under a bell shaped curve, with the x-axes depicting the risk aversion of companies/suppliers (in effect proceeding to the far right means the readiness to risk investing decreasing significantly while those to the left are ready to risk investment) and the y-axes indicating the degree of “innovativeness” (where higher values of y, approaching the maximum of the curve, mean an increase in complexity, scale and maturity of the innovation). At this point it is again emphasized that this is just a rough sketch of a widely discussed, quite complex topic, and it is thus not easy to simply define all terms involved. The graph below illustrates the mentioned curve (innovativeness vs. risk aversion) and an adoption of the same with some examples of innovations placed on the graph.

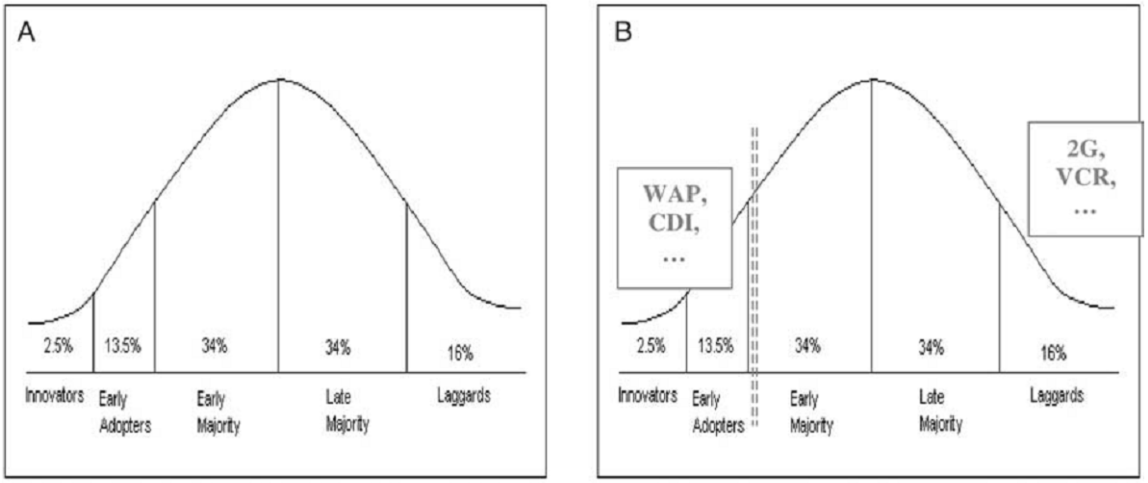

Figure 16: Adoption-curve in theory by {De Marez Lieven, 2004 #178} describing the process of how innovations are slowly adopted by the market

This model suggests the diffusion of innovation to the market to be a linear process involving the entire market and reading the graph in Figure 16 from left to right almost seems like the temporal evolution of that process – however this has been widely discussed and criticised, as mentioned above, and is not fully accounting for why some technologies fail and other succeed.

The authors in {De Marez Lieven, 2004 #178} take a new approach, adapting the curve to modern insights on the ICT market, the changed situation as already described above and they adapt it to their own observations. To explain the sometimes surprising failure of innovative technologies they use the concept of “The Chasm” {Moore, 1999 #201}, which describes a critical stage somewhere between early adopters and early majority that can be understood as a consequence of the first hype of a technology passing. This is part of the so-called “Hype Cycle” model by {Fenn, 2000 #202} that tries to model the sometimes very rapid adoption of new technologies by the customers (hype), reaching a maximum and saturation, followed by a rapid decent, or ravine (chasm) triggered by the heightened customer expectations that exceed the maturity of the product. This “chasm” has to be overcome in order to reach the large bulk of the market or the technology fails in diffusing into the market. A good example for that behaviour is WAP, which never made it out of that stage.

This behaviour is understood by {De Marez Lieven, 2004 #178} as a second peak in the tradition bell shaped model, resulting in the slightly modified graph seen in Figure 17. The local minimum between the two peaks depicts the barrier posed to innovations, while the new group “ID”, Innovation Dislikers, indicate those who refuse to innovate. This makes it possible that the graph covers only a certain aspect of the entire market, not necessarily the entire market as before, and thus enables to rescale the 5 traditional segments and the minimum to reflect the market more precisely. A technology might pass from hype to full market/market segment penetration the traditional smooth and direct way (indicated by the dotted lines; this was the case for 2 and 3G) or recede into the ravine (which can be very deep, as in the case of WAP), as the minima between the two peaks is variable. The x-axis can now be understood as a rough timeline, with arbitrary time units.

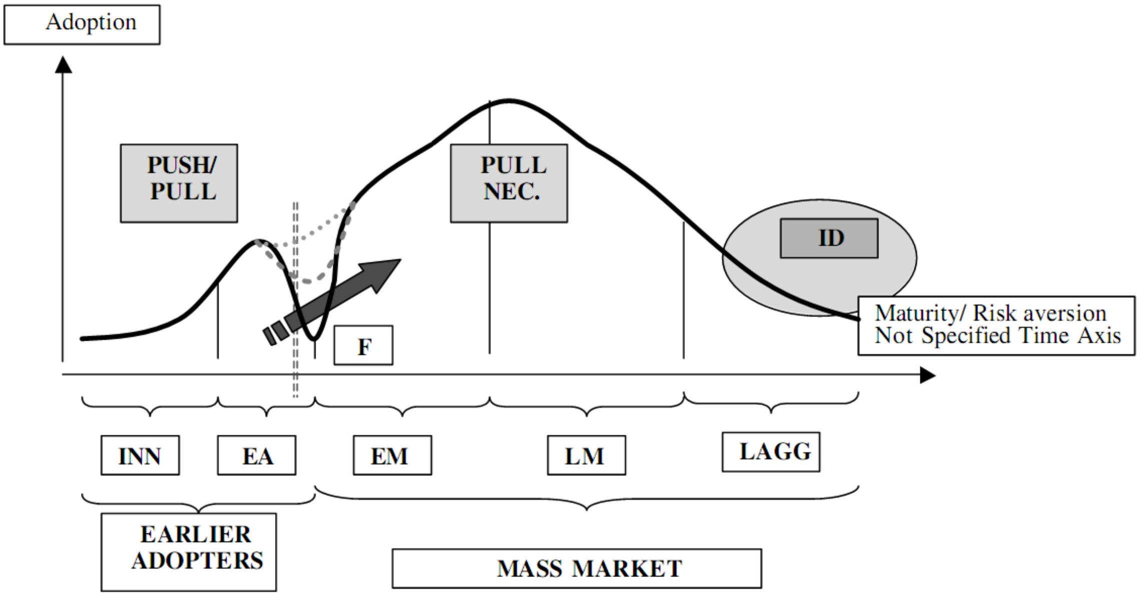

Figure 17: Effective adoption curve by {De Marez Lieven, 2004 #178}; the five segments of the original theory remain (INN= Innovators, EA= Early Adapters, EM= Early Majority, LM= Late Majority and LAGG= Laggards) and are completed with Innovation Dislikers.

The first hype leading to a quick adoption of innovation is spurred by the strong push of innovators and developers, as innovators and early adapters do not really care much about how a product is introduced since they will adapt anyway (push), while the diffusion through the barrier, or “funnel” (label F in Figure 17), can only partially be achieved by technology push. Here it is more important to understand the pull of the market, implying that understanding the needs of the majority of customers grows in significance in the later stages of the market introduction. Marketing strategies have to take this into account and have to react flexibly and quickly to more customers and a wider market. As an example, strategy forecasts for the introduction of a new product predict that changes in communication strategy can be made in five months; the right marketing strategy should continuously verify if that timeframe is valid since changes in innovation strategy or marketing strategy at a wrong time could stall the diffusion process to the market. If the “hype” has reached its climax after 3 months, strategy changes 2 months later are far too late and would not result in the desired effects; on the other hand starting to change strategy before that climax would lead to a situation where innovation is presented to customers who are not ready for it yet. This bottom line of needing to communicate with customers effectively for ensuring increasing product adoption rates is shared by a number of authors.

For applying this theory and create an effective marketing strategy, research tools are needed that are capable of being used before the launch of a new product, deliver accurate and reliable forecasts for specific products and specific market segments. These are further discussed in the paper by Lieven {De Marez Lieven, 2004 #178} and are beyond the scope of this survey.

4 Partnerships and Institutions at European level

4.1 European Perspective

Since March 2000 Lisbon European Council endorsed the objective for creating a European Research Area (ERA). According to the Commission’s Green Paper “The European Research Area: New Perspectives” {, 2007 #38} the ERA concept combines: a European “internal market” for research, where researchers technology and knowledge circulate freely; an effective European-level coordination of national and regional research activities, programmes and policies; and initiatives implemented and funded at the European level. The ERA has become the key reference for research policy in Europe. The six axes, as described in the Green Paper, that ERA should have are:

– An adequate flow of competent researchers with high levels of mobility between institutions, disciplines, sectors and countries;
– World-class research infrastructures, integrated, networked and accessible to research teams from across Europe and the world, notably thanks to new generations of electronic communication infrastructures;
– Excellent research institutions engaged in effective public-private cooperation and partnerships, forming the core of research and innovation 'clusters' including 'virtual research communities', mostly specialised in interdisciplinary areas and attracting a critical mass of human and financial resources;
– Effective knowledge-sharing notably between public research and industry, as well as with the public at large;
– Well-coordinated research programmes and priorities, including a significant volume of jointly-programmed public research investment at European level involving common priorities, coordinated implementation and joint evaluation; and
– A wide opening of the European Research Area to the world with special emphasis on neighbouring countries and a strong commitment to addressing global challenges with Europe's partners.

Progress on the various axes has been made over the last decade, with focus on reducing fragmentation on programmes and policies at a European and at a National level.

The European Commission’s document “A more research-intensive and integrated European Research Area: Science, Technology and Competiveness key features report 2009/2009” {, 2008 #41} examines the progress on the ERA in the six areas. It initially looks at research institutions, research programme funding and research infrastructures, and subsequently looks at the mobility of researchers, transnational knowledge flows and internationalisation of R&D.

In the need for an effective ERA, the role of funding instruments, as well as policies and institutional reforms, are important in the global world of science and technology. In Figure 18 the European Unions system of knowledge and innovation can be seen.

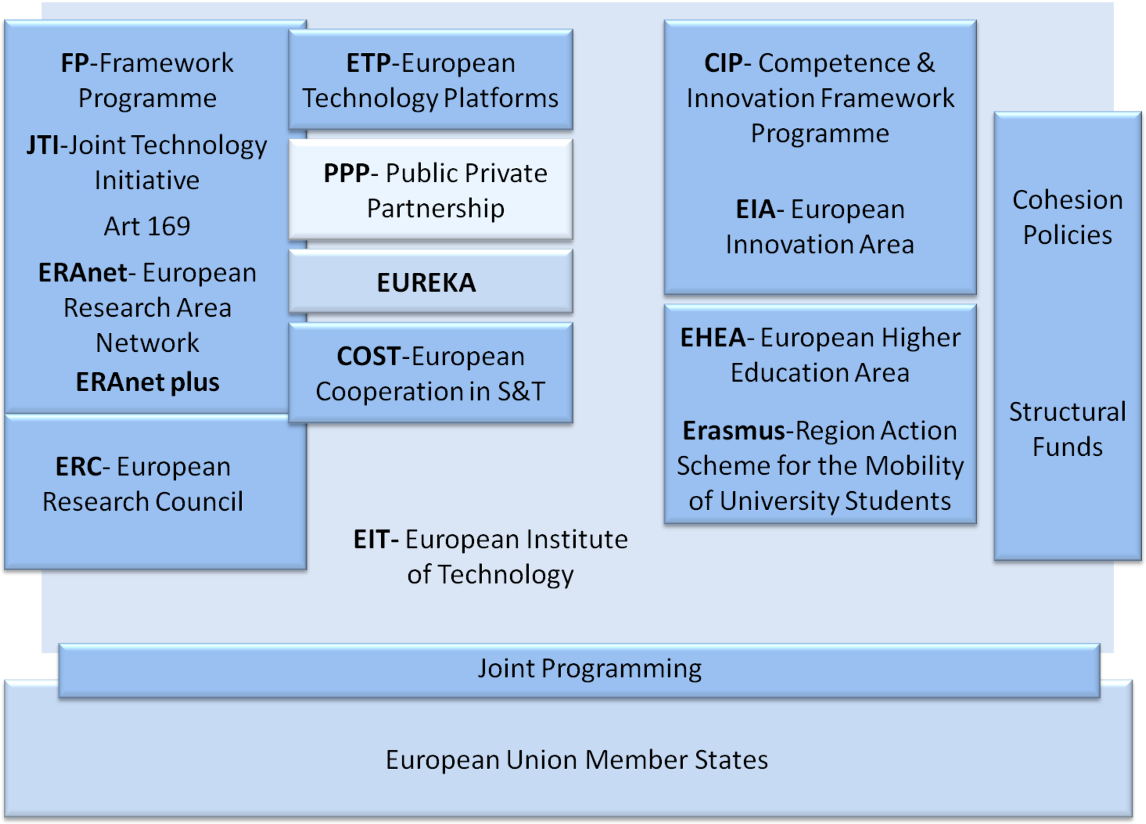

Figure 18: European Union system for a union of innovation[8] .

According to the study *the universities in Europe are undergoing reforms to improve performance while they increasingly link up to transnational networks*. The universities in Europe have developed links between themselves based on FP research collaborations with the centre in Central and Northern Europe. Other universities have more peripheral roles with the large countries like France, Italy and Spain playing a more central role.

Since 2005 with the implementation of ERA-oriented instruments for coordinating research like ERA-NET and ERA-NET plus the coordinated level of research at European level has increased. Furthermore, at national levels, research programmes are increasingly open to non-resident researchers. Also notable, is the progress made in Europe since 2003 towards large scale pan-European research infrastructures.

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8 Figure based on schematic provided by Clément Goossens, Eindhoven University of Technology, Government Affairs

In order to have the scientific and technological outputs of R&D activities and the high tech outcomes related to them, bibliometric indicators and patents were used in the Commission's document.

In Figure 19 the scientific specialisations based on scientific publications for the period 2004-2006 for EU-27 and US is shown[9]. According to the report "*a scientific specialisation index can be computed on the basis of the ratio between the share of a scientific field in the total number of publications of a country and the share of this field in the total number of publications in the world*. *This specialisation index is constructed so that it is centred on zero and stays within a range of +100 to -100. A positive value for a given field in a particular country points to the fact that the field has a higher weight in the portfolio of this country than its weight in the world*". It is pointed out that only in 'astronomy' the EU-27 has significantly higher share in the total world publications. Figure 20 shows the EU Specialisations in high-growth scientific disciplines.

Regarding patent applications, the United States and Japan inventions are concentrated to a higher degree than in the EU-27 in enabling technologies (biotechnology, ICT and nanotechnology). At the same time Asian countries are continuously increasing their share in ICT patents. Biotechnology, ICT and nanotechnology were considered to be technologies that work as enablers for inventions in other industries and have therefore received much attention.

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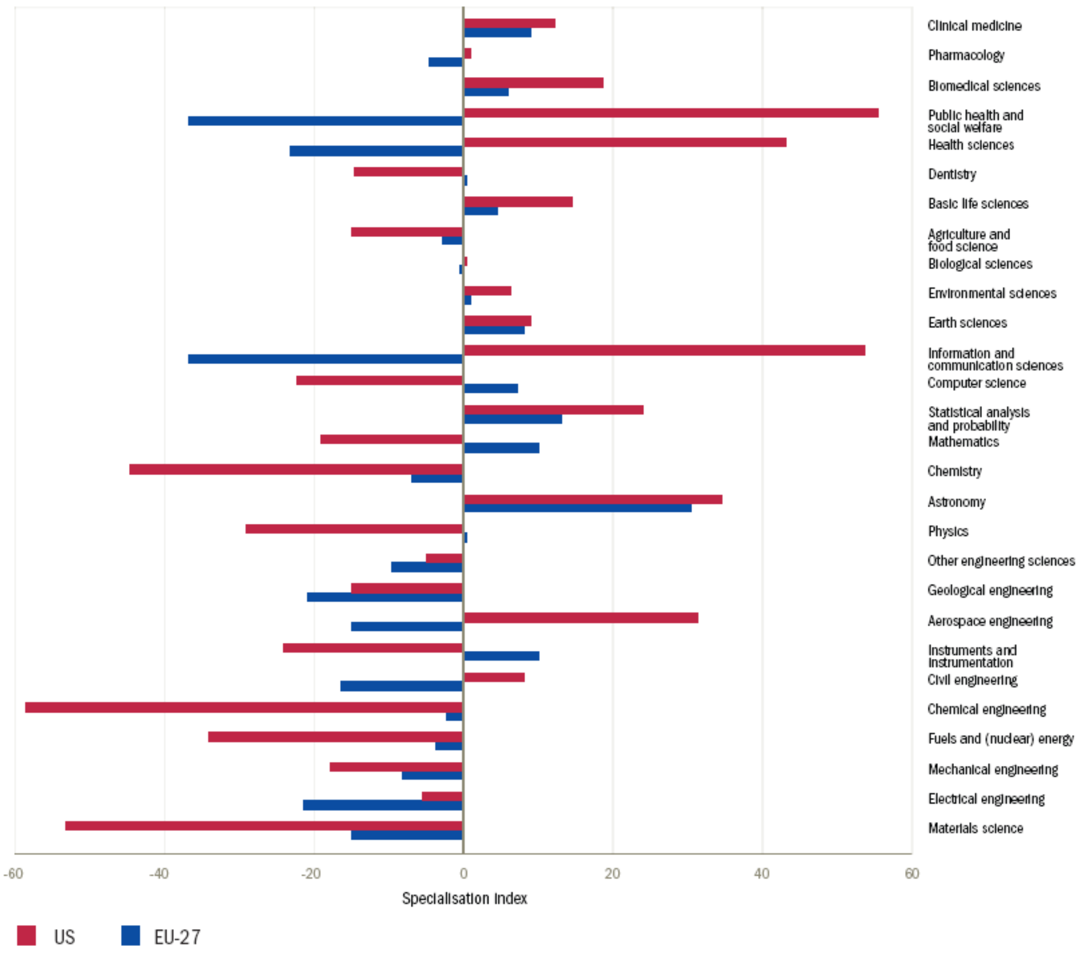
[9] European Commission, A more research-intensive and integrated European Research Area. Science and Technology Competiveness key figures report 2008/2009, pp.65.



Source: DG Research
Data: Thomson Scientific/CWTS, Leiden University
Note: [1] Social sciences and multidisciplinary sciences are not included

STC key figures report 2008

Figure 19: EU-27 and US – Scientific specialisations based on scientific publications, 2004-2006[10].

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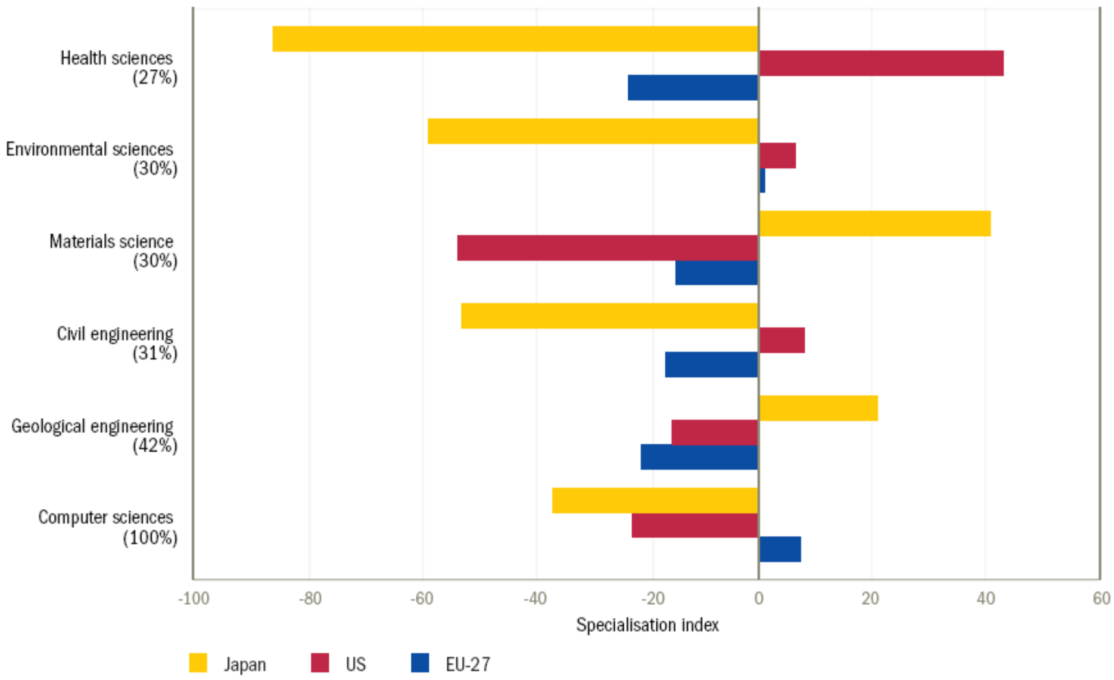
[10] European Commission, A more research-intensive and integrated European Research Area. Science and Technology Competiveness key figures report 2008/2009, pp.65.



Source: DG Research
Data: Thomson Scientific/CWTS, Leiden University

STC key figures report 2008

Figure 20: EU Specialisations in high-growth scientific disciplines, 2004-2006; in brackets: growth rate (%) of the number of scientific publications between the periods 2002-2004 and 2004-2006[11].

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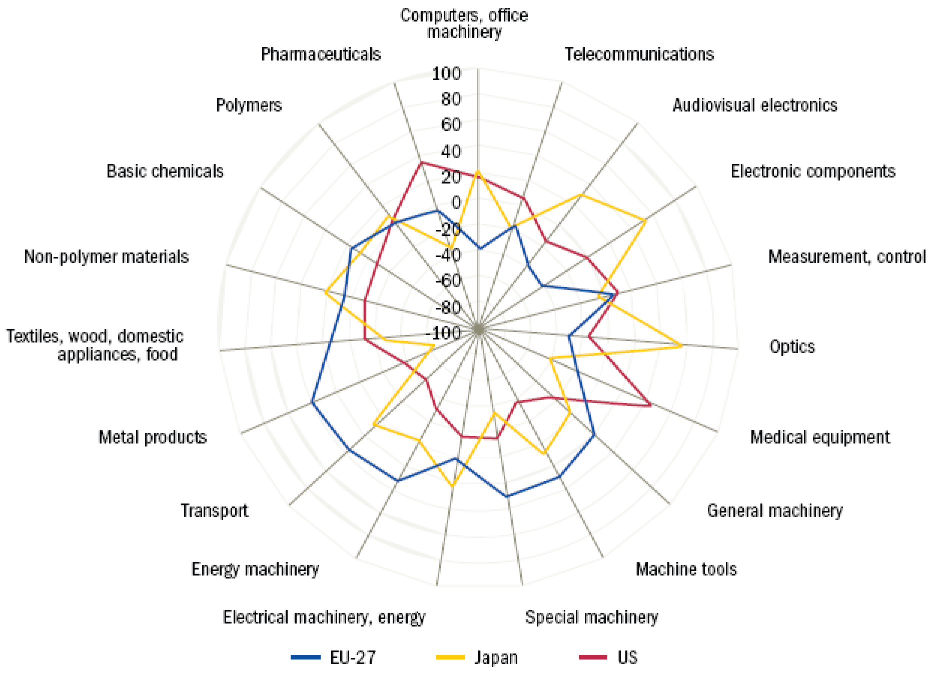
[11] European Commission, A more research-intensive and integrated European Research Area. Science and Technology Competiveness key figures report 2008/2009, pp.65.



Source: DG Research
Data: Fraunhofer ISI, EPO, WIPO

STC key figures report 2008

Figure 21: EU Technology specialisations (2004-2005)[12].

Figure 21 shows the technology specialisations in EU-27, US and Japan and Figure 22 shows the technological specialisations in different regions in EU-27.

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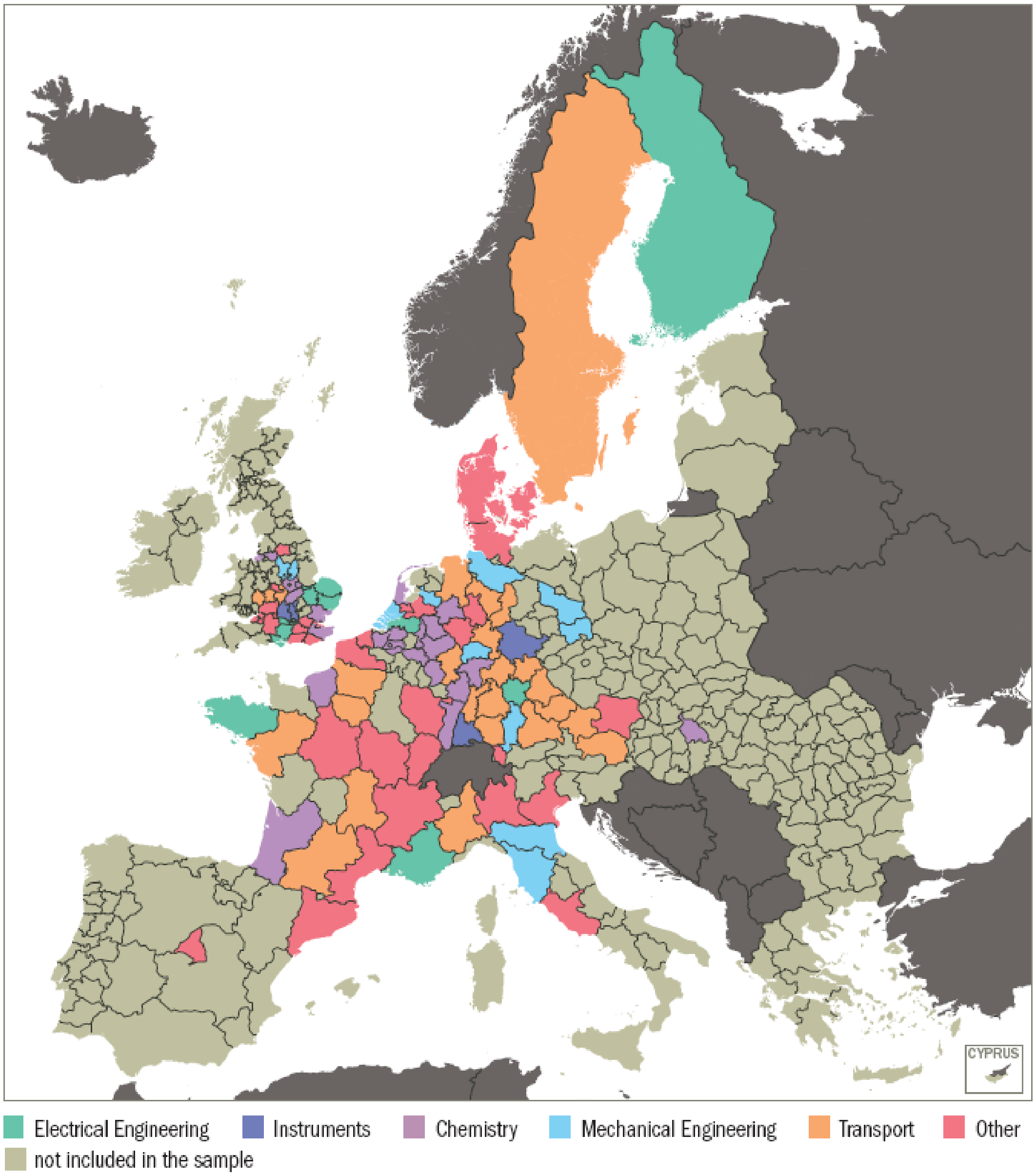
[12] European Commission, A more research-intensive and integrated European Research Area. Science and Technology Competiveness key figures report 2008/2009, pp.65.



Source: DG Research
Data: Fraunhofer ISI, EPO
Note: [1] Denmark, Sweden and Finland are included at country level

STC key figures report 2008

Figure 22: EU-27 Technology specialisations with highest numbers of EPO patent specialisations, 2001-2003[13].

From the Key enabling technologies the technological specialisation in EU-27 in Biotechnology and ICT can bee seen in Figure 23 and Figure 24 respectively.

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[13] European Commission, A more research-intensive and integrated European Research Area. Science and Technology Competiveness key figures report 2008/2009, pp.73.

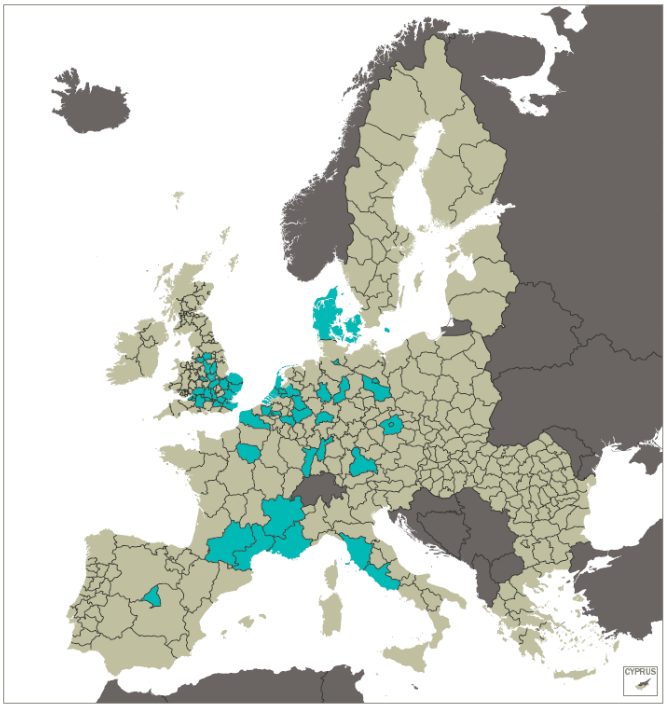

Figure 23: EU-27 Technology specialisations in Biotechnology, 2001-2003[14].

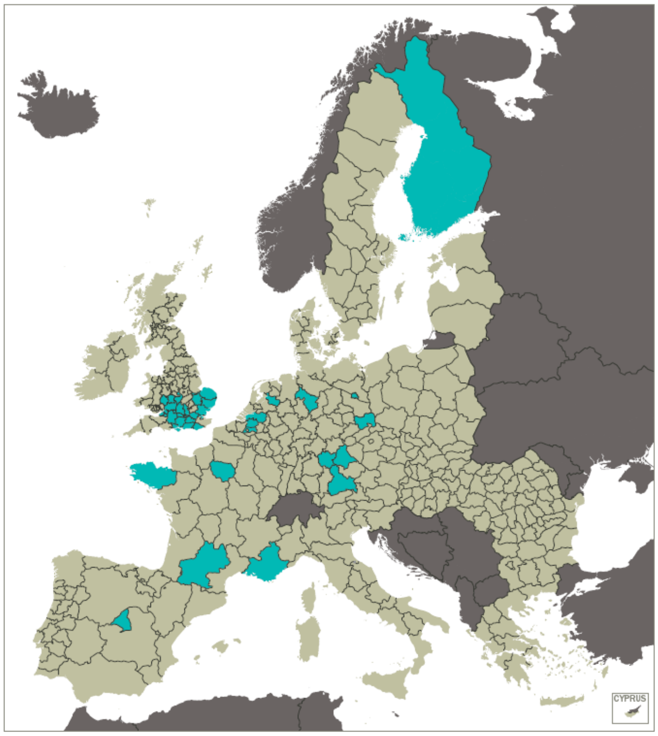

Figure 24: EU-27 Technology specialisations in ICT, 2001-2003[15].

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[14] European Commission, A more research-intensive and integrated European Research Area. Science and Technology Competiveness key figures report 2008/2009, pp.74.

[15] European Commission, A more research-intensive and integrated European Research Area. Science and Technology Competiveness key figures report 2008/2009, pp.75.

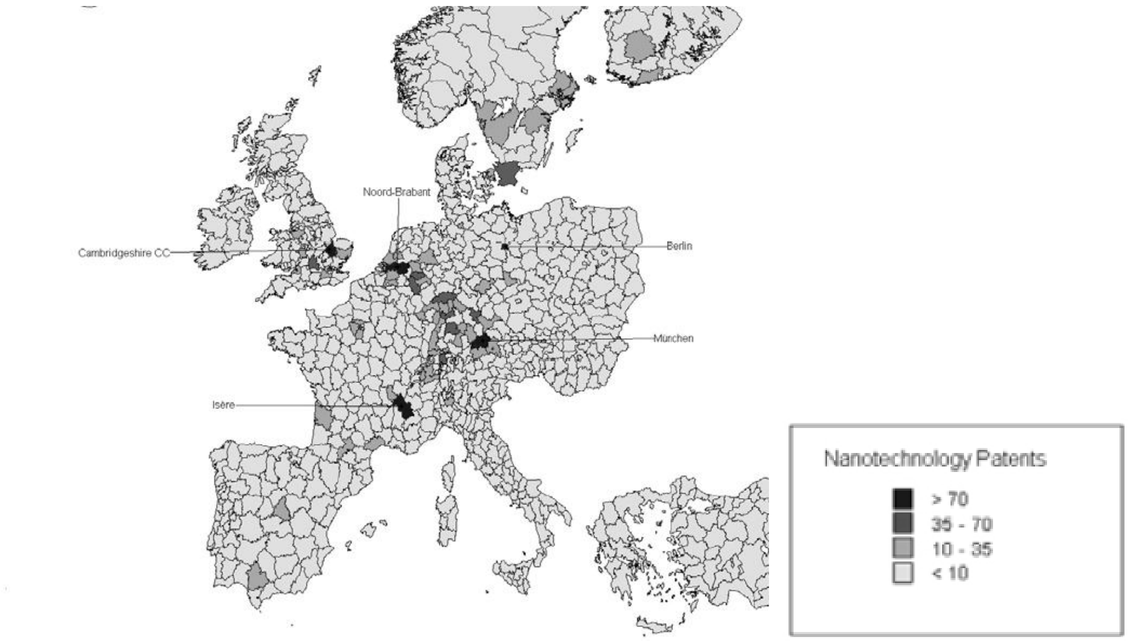

Figure 25: Number of Nanotechnology patents in Europe until 2005[16].

The next steps in Europe are mainly focused on the overall governance of the European Research Area. This enhanced governance is called the “Ljubljana Process” according to which the enhanced governance is based on a shared European Research Area vision for 2020. The “knowledge triangle” of research, innovation and higher education is a centre of making Europe a leading knowledge economy. In this vision the “Fifth Freedom” is highlighted across Europe as free circulation for researchers, knowledge and technology. The modernization of research, education and innovation is essential and requires that relevant policies and programmes are jointly designed amongst public authorities involving relevant stakeholders. The ERA should provide coordinated support to researchers and institutions engaged in excellent research.

Favorable conditions from all actors in research are essential for achieving S&T capacity building and for having access to world-class research infrastructures in a pan-European setting as well as being able to participate in open and well coordinated research programmes across sectors and boarders. This includes a bottom-up approach in research finding via ERC and national funding organizations open to European individual scientists and teams across national borders. Furthermore, it is essential to strengthen links for coordinated cooperation in a globalised world outside ERA.

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[16] OECD data, DSTI/DOC (2009) 7, Nanotechnology: An Overview Based On Indicators And Statistics, STI WORKING PAPER 2009/7

As a result new initiatives have emerged: researchers targeting to create a European Partnership for Researchers; research infrastructures aiming at providing a legal framework for Member States to develop and fund pan-European research infrastructures; knowledge sharing targeting on the management of intellectual property rights; joint programming aim at eliminating the inefficiency of research efforts due to the fragmentation created by the dependent implementation of national and regional programmes in Member States; international S&T cooperation aims at bringing forward a policy framework for Europe at a national and European levels to foster and facilitate international cooperation for S&T activities.

4.2 European Research Council (ERC)

The European Research Council was established on 7 February 2007, by Decision 2007/134/EC of the European Commission. This was done in accordance with Decision 1982/2006/EC of the European Parliament and the Council of 18 December 2006, and in accordance with Decision 2006/972/EC of the Council of 19 December 2006 concerning the Specific Programme: ‘Ideas’, for the implementation of the seventh framework programme from 2007-2013.

It is expected to provide a pan-European approach and mechanism with a clear differentiation from national activities. This is essential in selecting and supporting the best *frontier researchers* –scientists, engineers and other researchers- who through their curiosity and thirst for knowledge will make new discoveries and be at the frontier of technological and scientific breakthroughs.

ERC will have to face various challenges, in particular in emerging and fast-growing fields, in which science and technology are often closely interlinked. Exploiting new fields of technology closely linked to scientific knowledge in creating innovation is still weak in Europe and the ERC will help to strengthen Europe’s position. At the same time, it will have to stay at the forefront of a global system where there is scientific and technological competition from Asian countries.

ERC is the first European funding body to support a bottom-up research mechanism, which ensures the channelling of funds into innovative areas of research with more flexibility. Its aim is to stimulate scientific excellence by complementing other funding initiatives in Europe, while being a chief component of the ‘Ideas’ and ‘FP7’ programmes. Its vision is to substantially strengthen and structure the European research system, in the long term.

The ERC consists of a Scientific Council, which defines its activities, and a Dedicated Implementation Structure (fully operational since 15 July 2009), which implements the activities.

There are two kinds of instruments in the ERC, both of which operate from a bottom-up mechanism, and which are awarded on a competitive basis:

ERC Starting Independent Research Grants (max. €2 million for 5 years)
ERC Advanced Investigator Grants (max. €3.5 million for 5 years)

ERC structure has 25 panels for the evaluation of grant proposals covering all fields of science, engineering assigned to three main domains: Social Sciences and humanities (6 panels), Physical Sciences and Engineering (10 panels) and Life Sciences (9 panels). In particular, it has panel PE9 for Universe Sciences, which covers the following topics: astro-physics/chemistry/biology, solar and interplanetary physics, planetary systems sciences, interstellar medium, formation of stars and planets, stars and stellar systems, the galaxy, formation and evolution of galaxies, clusters of galaxies and large scale structures, and high energy and particles astronomy (X-rays, cosmic rays, gamma rays, neutrinos).

4.3 European Institute of Innovation and Technology (EIT)

The European Institute of Innovation and Technology was established on 11 March 2008, by Regulation (EC) No 294/2008 of the European Parliament and of the Council, to foster the integration of research, innovation and higher education (also known as the 'knowledge triangle'). Its main objective being the contribution to 'innovation capacity'[17], by facilitating and improving the networking in the innovation process while addressing relevant long-term challenges for innovation in Europe as well as being a key driver of sustainable growth and competitiveness.

The institute has a governing board (top-down operation), which steers its activities as well as selects and evaluates partnerships, designated as Knowledge and Innovation Communities (KICs). The relation of the KICs and the institute operates through contractual agreements. The governing board designated the first three KICs on 16 December 2009 in Budapest:

Climate change mitigation and adaptation: Climate-KIC
Sustainable energy: KIC InnoEnergy
Future information and communication society: EIT ICT Labs

These are the instruments of the institute, which operate on a bottom-up basis. They are funded by national/regional grants, community grants, participant's resources and an annual EIT grant. To help launch the EIT and the KICs the European Union has contributed € 308.7 million for the four year period of 2009-2013.

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[17] "the EIT's objective is to contribute to sustainable European economic growth and competitiveness by reinforcing the innovation capacity" Regulation (EC) No 294/2008

According to the European Commission "EUROPE 2020" {, 2008 #34} the EIT is expected in the next 10 years to promote partnerships between education, business and innovation.

4.4 European Technology Platforms (ETP)

The European Technology platforms are based on a bottom up approach led by industry. They bring together various stakeholders with common thematic interests to define medium to long-term objectives for research and technological development, as well as roadmaps on how to achieve them. The technology platforms address these challenges by:

- shared vision of stake holders;
- positive impact on a wide range of policies;
- reduced fragmentation of research and development efforts;
- mobilisation of public and private funding sources.

There are more than thirty technology platforms currently launched. For space two dedicated platforms exists the European Space Technology Platform (ESTP) and the Integral Satcom Initiative Technology Platform (ISI). Platforms conserved with the Key Enabling Technologies (KETs) are listed in Table 3 and a short description and contact details of the platform as well as the commissions responsible can be found in Annex ??? {European Commission, 2009 #209}.

Acronym	Name	Strategic Research Agenda (SRA) priorities
Space		
ESTP	European Space Technology Platform	• non-dependence; • multiple-use and spin-in; • enabling technologies;
ISI	Satcom Initiative Technology Platform	• new technologies, with lower costs and faster deployment, • innovative services and integrated applications, within both commercial and institutional domains, • design of flexible satellite missions, • interfacing with terrestrial networks, with urban and in-building coverage, • Internet protocol-based approach, • open standards with worldwide promotion, • dual-use technologies, • satcom support to Galileo and GMES, • harmonising spectrum availability across European and internationally, • exploiting higher frequency bands, • harmonising the regulatory framework.
Photonics		
Photonics21	Photonics21	• information and communication; • industrial production and manufacturing and quality; • life sciences and health; • lighting and displays; • security, metrology and sensors. Additionally two cross-cutting topics have also been defined: • design and manufacturing of photonic components and systems, and • photonics education, training and research infrastructure.
Advanced Materials		
EuMat	Advanced Engineering Materials and Technologies	• multifunctional engineering materials with gradient properties; • engineering materials for challenging application conditions; • multi-material (hybrid) systems where advanced materials are

		combined with more conventional/structural materials; • related production technologies; and • multi-scale modelling.
Micro- and Nano-electronics		
ENIAC	European Nanoelectronics Initiative Advisory Council	• health and wellness; • mobility and transport; • security and safety; • energy and the environment; • communications, and e-society.
Nanotechnology		
Nanomedice	Nanotechnologies for Medical Applications	• nanotechnology-based diagnostics including imaging; • targeted drug delivery and release; • regenerative medicine.
ENIAC	European Nanoelectronics Initiative Advisory Council	See under Micro- and Nano-electronics
Photonics21	Photonics21	See under Photonics
FTC	Photonics, Future Textiles and Clothing	See under Biotechnology
Biotechnology		
White Biotechnology		
SusChem	European Technology Platform for Sustainable Chemistry	• industrial biotechnologies; • materials technology; • reaction and process design; • horizontal issues.
FTC	Future Textiles and Clothing	• 'From commodities towards specialties'; • 'New textile applications'; • 'Towards customisation'.
Green Biotechnology		
Food	Food for Life	• delivering a healthier diet; • developing quality food products; • assuring safe foods that consumers can trust; • achieving sustainable food production; • managing the food chain.
PLANTS	Plants for the Future	• healthy, safe and sufficient food and feed; • plant-based products, chemicals and energy; • sustainable agriculture, forestry and landscape; • impact; boosting biodiversity; and enhancing the aesthetical value and sustainability of the landscape; • vibrant and competitive basic research; • competitiveness, consumer choice and governance;
Red Biotechnology		
Nanomedice	Nanotechnologies for Medical Applications	See under Nanotechnology
Information and Communication Technologies (ICT)		
eMobility	Mobile and Wireless Communications Technology Platform	• strengthening research and development in telecommunications systems.
EPoSS	European Platform on Smart Systems Integration	• shared view of research needs of the smart systems integration sector. • smart system applications are: automotive, information and telecommunications, medical technologies, RFID, safety and security, cross-cutting issues.
NEM	Networked and Electronic Media	• bringing together broadcasters, telecom operators, manufacturers of professional equipment, manufacturers of consumer electronics, academia and standardisation bodies. • cover existing and new technologies, including broadband, mobile and new media across all ICT sectors, to create advanced personalised services.
NESSI	Networked European Software and Services Initiative	• develop a strategy for software and services driven by a common European Research Agenda.
ARTEMIS	Advanced Research and Technology for Embedded Intelligence and Systems	• industrial systems; large, complex and safety-critical systems, which embraces automotive, aerospace, manufacturing, and growth areas such as biomedical; • nomadic environments; • private spaces; • public infrastructure;

Table 3: European Technology Platforms related to Space, KET's and ICT.

5 Conclusions and Recommendations

5.1 Findings and Conclusions

Over more than a decade society has been transformed by concepts such as the 'knowledge based society', 'Era of Openness' and 'i-conomy'[18]. These concepts, in the world of globalisation and networked intelligence, have transformed the way governments, educational and research institutions, companies and societies, function. Innovation is a key component at the heart of this new momentum. The "Europe 2020" proposal of the president of commission is referring to smart growth with a view to have an "Innovation Union". In this context collaboration and virtual networks are essential ingredients to enable functionality. Without innovation, companies, sectors and societies may die out. To achieve innovation, approaches like multidisciplinary, cross- and inter-sectoral, and intergovernmental have transgressed the once well defined borders of traditional thinking. Approaches have to adapt to the complexity of science and technology relationship and be able to model in a simplified way this relationship. In the space sector state-of-the art technologies are essential for successful science missions and innovation is a fundamental enabling factor. In order to benefit from innovation and to further stimulate it, it is necessary to think and answer questions like: how do you choose which technologies, which people to bring together, which institutions to collaborate with, and with which mechanisms?

This study uses a stepwise approach where, initially, the terms science, technology, and innovation, and their accompanying interrelationship are described, defined and analysed. Different sectors were studied and exhibited different approaches to these concepts. These sectors where split to: a) conservative sectors and b) dynamic sectors. Partnerships and institutions at national and European level for science, technology and innovation were further studied. From these analyses the following conclusions can be drawn:

Science Technology and Innovation

- "Science and technology", nowadays, are mostly used side by side. It is recognised, that there is an overlap and common territory between the two, and when boundaries, between science and technology, are drawn they

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[18] "i-conomy" is a new term introduced by Máir Geoghegan-Quinn, Commissioner for Research, Innovation and Science in her speech delivering the 2010 Guglielmo Marconi lecture at the Lisbon Council's innovation summit, Innovation Summit of the Lisbon Council Brussels, 5th March 2010, SPEECH/10/68 where she mentioned:
"My job, in short, is to work with the Member States, business and other stakeholders to transform Europe into a really vibrant innovation economy, what I call as 'i-conomy' "

are often arbitrary. Scientific and technological advancements are also often pursued simultaneously by the same person, group, or institution, and through the use of the same means.

- “Science and technology” are clearly differentiated in ESA terminology and are used in a different way than by others. The term science refers to what is widely known as pure or fundamental science, for space and earth observation. On the other hand, when the word technology is used, it also covers the pure or applied science that leads to knowledge which can be translated into technological developments.
- Various definitions of Innovation exist and are used by different entities and directorates of the European commission. Nevertheless the notion of open innovation models is widely accepted.
- The science and technology relationship is multidimensional but can be described by the simplified “push-pull” model. The “technology push” and “need pull” model is often used to describe the driving forces behind innovation. The “push” component regards technology as being the driving force that acts as a facilitator behind scientific innovation whereas the “pull” component regards the scientific needs to be the driver for technological advancements. The main characteristics of the ESA science – technology relationship can be captured by the “technology push” and “science pull” model.
- For many years, it has been known that certain technologies can be used as a core for different scientific and industrial developments, but it is only recently that these have been identified as ‘key enabling technologies’, which are: Nanotechnologies, Micro and nanoelectronics, advanced materials and biotechnology. According to science and technology reports, countries like China, Japan and US are also focusing on enabling technologies, and in particular on biotechnology, ICT and nanotechnology.

Innovation in Different Sectors

- Different sectors perceive innovation in different ways and implement it at different levels around two main components: 1) incremental by improving existing products, services etc. or, 2) breakthrough by making a complete change from existing practices. Based on this, they are classified into two categories: conservative or fast sectors. Examples of conservative sectors are space, aeronautics, transport, energy, pharmaceutical, while examples of fast sectors are ICT and biotechnology.
- The construction sector is one of the most conservative sectors when it comes to innovation. The main problem there is that research leading to innovation is done outside those actively involved in construction and the resulting benefits cannot be easily translated to the language of those that would use it. This means that the sector is not aware of these technologies. An interesting suggested solution to this problem has been the creation of Technology Watch companies. It was also suggested that

these companies are seen as more credible if they are not governmental agencies or those that conduct the research.

- The energy sector has seen large investment over the past years and the legal and social standards imposed by policies are driving factors pushing innovation in this sector.
- The transport sector analysis is also concentrated around the policy aspect as a facilitator for innovation.
- The analysis of the aeronautics sector is performed by looking at the sector from a historical perspective where, in the first years of its creation it experienced breakthrough innovation, whereas in subsequent years it is solely experiencing incremental innovation. Future innovation in this sector is expected to occur through innovation advancements in other areas such as ICT.
- The main characteristic of the pharmaceutical sector is that it is highly regulated. The pharmaceutical sector in the last couple of years has seen a recession in innovation. The factors causing the stall in innovation were given, as well as issues that could improve the innovation drive.
- Fast growth of innovation in the biotechnology sector is attributed, from a technological perspective, to automation and system integration, and in particular, to advancements in sensory technology as well as ‘lab on a chip’ principles.
- The ICT sector is a very fast growing sector that has changed our way of life in the last 15 years. This sector is very much dominated by technology push. When new innovative technologies do not make it up to their full potential, the reason can be attributed to inability of capturing properly the user needs, and inability to explain properly to the user the potential of the new technology. At the same time the user needs are constantly changing in this sector, thus, traditional marketing tools fail. Bad marketing decisions fail to capture the user needs and deliver the wrong message, about the technology at hand, to the user. In this case, it is essential, to use the push pull model as a double mirror of innovation, where the user need can always be reflected in the new technologies developed. There is thus a necessity for an efficient marketing strategy as well as tailored research tools.
- From this analysis we can conclude that conservative sectors which are usually mature and well established sectors have a more incremental approach to innovation. In these sectors innovation comes by breakthroughs in other sectors and adaptation or by change on policies. On the other hand fast sectors are typically young sectors recently established that have a more breakthrough approach to innovation as the conservative sectors once had at the early stages of the sectors establishments.

Partnerships and Institutions at European Level

- The European Commission and in particular DG Research and DG Enterprise and Industry have been main actor in the way “technology policy” in Europe has evolved. Concepts such as the “European Research Area (ERA)” and “knowledge based society” have shaped today’s funding instruments as well as policies and institutional reforms, and are important in the global world of science and technology.
- An overview of the European perspective was given for EU 27 showing, in particular, the areas of specialisation in Europe with respect to the key enabling technologies. The steps of Europe with regard to the 2020 vision were highlighted and the new initiatives which have recently emerged, like joint programming and international Science and Technology cooperation, were listed.
- European Universities have been traditionally institutions involved primarily involved in higher education. Their role has changed and they are more and more engaged in innovation and becoming part of the knowledge triangle (education, research, innovation). They are also becoming part of high-tech valleys working close with large industries and SMEs to bring new technologies in the markets.
- There is a multitude of institutions in Europe from which the following were identified due to their European perspective and creation to bridge gaps: European Research Council (created to bridge the gap between national funding bodies for fundamental research and bring a European perspective), European Institute of Technology (created to bring together research, innovation and education and bring R&D to the market), European Technology Platforms (aiming developing a coordinated scientific research agendas of key stakeholders in various areas).
- European Institute of Technology was created in order to foster the knowledge triangle (education, research and innovation) and is expected in the next 10 years to promote partnerships between education, business and innovation.
- Currently over thirty European Technology Platforms exist that bring together leading industries, public authorities, academic community, consortia from EU projects, financial community and civil community, including users and consumers. European Technology Platforms focusing on KET’s involve stakeholders from different disciplines in establishing R&D needs and priorities in these areas.

5.2 Recommendations

Concepts

- A clear distinction should be made when the terms “Science” and “Technology” are used since, in the ESA context, there is a clear distinction between the two terms, in contrast to others who mostly use “Science and Technology” side by side. In ESA the term “Science” refers to what is widely known as pure or fundamental science, for space and earth observation. On the other hand, when the word technology is used, it covers the pure or applied science (space and non-space) that leads to knowledge which can be translated into technological developments for space.

- The following definition for “space innovation” should be used in the space sector and by ESA: *"Innovation is the use of new, or existing, ideas, discoveries and inventions in the space sector, stemming from other sectors (spin in), and vice versa, the use of new, or existing, ideas, discoveries and inventions in other sectors, stemming from the space sector (spin out), to create economic and social benefits. Innovation also consists of scientific, technological, organisational, financial and commercial steps, which are intended to, or actually, lead to the implementation of innovations by space-non-space partnerships (spin together).”* Innovation is characterised by three stages: a) incremental, b) breakthrough and c) utilisation.
- The basic mechanisms in the ESA science and technology relationship can be described by the “technology push” and “need (science) pull” model. In this model, science (in the ESA terminology) asks scientific questions, which drive the technology to develop, whereas in technology push technological advancements allow science to use them as means for its advancement. Nevertheless, it is recognised that in practice this model is simplistic and more complicated models might be need to fully describe the relationship.
- The time scale from the moment the ”need pull” is identified (a mission is approved) which “pushes” the technology to develop, to the time all technologies need to be integrated, is very short. Therefore, it is essential that technologies are also developed independently before the “need” is identified. This independent development (“technology push”) should be based on “potential future user needs”.
- The Key Enabling Technologies (KET) identified, by the EC, as nanotechnologies, Micro- and nanoelectronics, advanced materials and biotechnology should be considered comprehensively by ESA’s research and development programmes. Concerning this, the Information and Communication Technologies (ICT) should also be considered, creating the “ESA Enabling Technologies” concept. These categories are essentially very broad and specific subcategories should be identified in consultation with space and non-space experts in these fields in order to identify the ones mostly relevant for the space sectors to develop coherent roadmaps.
- At low Technology Readiness Levels (TRL), such new technologies do not need to be developed exclusively by space funding schemes. This may allow the utilisation of funding from the non-space sector by jointly investing in KET’s building blocks.

Cooperation

- Public and private partnerships should be set up for co-financing research and development in Key Enabling Technologies, since they require large investments that ESA alone would not be able to afford.
- ESA already works together with the European Commission in the Framework Programme in particular under the Space component. This cooperation should be expanded to other components of the Framework Programme in particular related to investments in KETs. This can be done either by co-financing together with the Commission or simply coordinating programmatically.
- ESA should consider creating new, or strengthening existing, partnerships with the European Commission and in particular with DG Research, DG Enterprise and Industry, Joint Research Centre (JRC), as well as the European Research Council (ERC). The basis for this cooperation should be to bring together and align funding means, time scales as well as programmatic content, by jointly defining roadmaps.
- ESA is currently actively involved in two space European Technology Platforms (ETP) and should continue and expand this coordination with other platforms, especially those involved within the thematic areas of KET's.
- ESA should consider partnering with other sectors for the development of KETs. Examples of these sectors are Energy, Automotive, Aerospace, Healthcare, and Telecommunications. The European Technology Platforms can be a good platform to find common ground in the various scientific research agendas.
- Space science research, in the ESA terminology, is still mostly handled at a national level, with some coordination at the European level. National space research programmes for science and technology should open up and coordinate with each other. Programmatic partnerships should be created between ERC, ESA and national programs. This would allow *frontier research* at a pan-European level in space research.
- The knowledge triangle (education, research, innovation) has become an essential component for modernisation to reflect today's demands. ESA should partner with Knowledge Innovation Communities (KICs) of the European Institute of Innovation and Technology (EIT).

Mechanisms

- The space sector and ESA invest in research that leads to technological developments needed for future missions but they also need to continue and strengthen investing more on basic and applied research underlying generic and disruptive technologies that are not directly related today to future missions. New mechanisms should be developed that allow "technology push" development, of enabling technologies, based on "potential future user needs". Adequate mechanisms involving the ESA science community should be developed to capture these “potential future user needs”.

  - Effective mechanisms should be developed for: a) monitoring “potential future user needs” and b) informing the user of potential benefits of new technologies under development. In this process the ESA science community should be involved, as well as the non-space science community. Technology push fails when the potential of a technology is not understood by the user and when his needs are not properly captured at all times. Therefore, it is necessary to develop adequate ‘marketing’ strategies to be able to assess these needs in a double mirror push-pull innovation model, so that the push technologies capture the needed features, functionalities and the potential of the new technologies is properly communicated to the user at an early stage.
  - Workshop organisation with potential users during the course of the development of technology push under e.g TRP and GSTP could be a way of capturing various user needs at an early stage and informing them about the potential of new technologies.
- ESA should proceed to apply for participation in research and technology development under the non-space components of the Frameworks Programme. This participation, by performing research and development in ESA laboratories, should be enhanced.
- Two scenarios are foreseen for co-financing under the Framework Programme non-space component. One option is to use ESA existing funding tools and make a funding co-alignment. The other option is to crate new specific funding programmes for this specific purpose.
  - The first scenario would be to use existing programmes like TRP, GSTP funding in combination with FP funding for key enabling technologies at low TRL levels in order to balance the high expenditures needed for these technologies and can be used for technology push. This scenario already partially exists, firstly, by the Agency’s participation in FP programmes (non-space), and secondly, by contractors of TRP, GSTP etc in their individual strategies, but in an uncoordinated manner. Thus there is the need to develop a coherent coordination mechanism.
  - The second scenario, would be to develop new funding programmes in order to be able to co-finance frontier research where basic and applied science lead to technological breakthroughs that are not necessarily related to an ESA mission at present. A new Science and Technology Research Programme can be envisaged where roadmaps are created together with other funding bodies, like DG Research for the key enabling technologies ,where industrial, research institutes and universities partnerships are fostered. In such a programme, non-terrestrial partnerships should be another essential component.

- An effective technology watch ‘Technowatch’ construction is necessary in order to be able to identify new and disruptive technologies early enough; a ‘Technowatch’ that can facilitate spin-in, spin-out and spin-together. ESA does currently have mechanisms which are used as observatories for following science that is likely to produce technology. This could be institutionalised with clear targets and responsibilities in a more integrated model. The possibility of having a Technowatch, independent from ESA or joint with other technology watch institutions, should also be considered. It is suggested that a Technowatch should be an independent body as they are seen as more credible when they are not governmental agencies or those that conduct the research.
- The use of the open innovation model that the space sector inevitably needs to utilise efficiently to achieve technological breakthroughs and scientific innovations needs flexible and modern models of dealing with IPRs. Current IPR mechanisms of ESA and other funding and developing bodies need to be examined closely as IPR treatment is one of the most essential components of the success or failure of an open innovations system. The current ESA IPR system where the IPR stays with the agency for space use does provide the basis for open innovation in technology development with non-space sectors as they can essentially use the IPR in other markets.

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80. André Spithoven, Bart Clarysse, and Mirjam Knockaert, 'Building Absorptive Capacity to Organise Inbound Open Innovation in Traditional Industries', Technovation 30, no. 2: 130-41, http://www.sciencedirect.com/science/article/B6V8B-4X9D57D-1/2/e6f39ef6adc0a0cdffffe208260c3c20.
81. Eric C. Wang, 'Determinants of R&D Investment: The Extreme-Bounds-Analysis Approach Applied to 26 Oecd Countries', Research Policy 39, no. 1 (2010): 103-16, http://www.sciencedirect.com/science/article/B6V77-4Y0TDNM-1/2/67ae39126985f4fb381e5079fffcd7f9.
82. "Life science and biotechnology – A Strategy for Europe", Communication from the Commission to the Council, the European Parliament, the Economic and Social Committee and the Committee of the Regions, COM(2002), 27, Brussels.

ANNEX: Definitions

Sectoral Innovation Watch (SIW) [19] is a tool for monitoring and analysing innovation performance in different sectors of activity. It provides policy makers and stakeholders with a better understanding of sectoral drivers, barriers and challenges for innovation across the EU. Such insights are essential for effective innovation policies at regional, national and European level.

The Sectoral Innovation Watch is financed by the Commission in the framework of its Europe INNOVA initiative[20].

Technology Categories[21]

Definition: The four manufacturing industry technology categories are defined as follows (NACE codes are given in brackets):

1. High-tech: office machinery and computers (30), radio, television and communication equipment and apparatus (32), medical, precision and optical instruments, watches and clocks (33), aircraft and spacecraft (35.3), pharmaceuticals, medicinal chemicals and botanical products (24.4).
2. Medium-high-tech: machinery and equipment (29), electrical machinery and apparatus (31), motor vehicles, trailers and semi-trailers (34), other transport equipment (35), chemicals and chemical products excluding pharmaceuticals, medicinal chemicals and botanical products (24, excluding 24.4).
3. Medium-low-tech: coke, refined petroleum products and nuclear fuel (23), rubber and plastic products (25), non-metallic mineral products (26), basic metals (27), fabricated metal products except machinery and equipment (28), building and repairing of ships and boats (35.1).
4. Low-tech: food products and beverages (15), tobacco products (16), textiles (17), wearing apparel, dressing and dyeing of fur (18), tanning and dressing of leather, manufacture of luggage, handbags, saddlery and harness (19), wood and products of wood and cork, except furniture (20), pulp, paper and paper products (21), publishing, printing and reproduction of recorded media (22), furniture and other manufacturing (36), recycling (37).

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[19] http://ec.europa.eu/enterprise/policies/innovation/facts-figures-analysis/sectoral-innovation-watch/index_en.htm

[20] http://www.europe-innova.eu/web/guest;jsessionid=737E6711B0B8E3BDBCCB4443F1B082A7

[21] European Commission, A more research-intensive and integrated European Research Area. Science and Technology Competiveness key figures report 2008/2009, pp.157.

ANNEX ??? European Technology Platforms

5.2.1 Space

There are two ETP's directly related to space, the European Space Technology Platform (ESTP) and the Integral Satcom Initiative Technology Platform (ISI).

The European Space Technology Platform (ESTP) was launched in 2005 and the objectives of the platform are to be achieved via three strategic pillars:

- non-dependence; development of strategic space technologies needed for Europe's non-dependence;
- multiple-use and spin-in; synergic actions with the non-space sector in areas of mutual interest (e.g. embedded systems, photovoltaics, fuel cells, nanotechnologies and robotics);
- enabling technologies; support the implementation of EU policies by developing needed technology (e.g. in the area of security/defence).

The ESTP has undertaken contacts with other ETPs such as Robotics, EuMat, Hydrogen, Photovoltaics. In particular ESTP collaborates with the ISI ETP.

Website
http://www.estp-space.eu

Communications
Strategic research agenda (2006)
http://estp.esa.int/upload/ESTP_SRA_1.0-July2006.pdf

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The Integral Satcom Initiative Technology Platform (ISI) ETP was launched in 2006 the strategic research agenda focuses on identifying challenges of the community related to technical and regulatory barriers, standardisation and market condition. These will be tackled by developing activities on:

- new technologies, with lower costs and faster deployment,

- innovative services and integrated applications, within both commercial and institutional domains,
- design of flexible satellite missions,
- interfacing with terrestrial networks, with urban and in-building coverage,
- Internet protocol-based approach,
- open standards with worldwide promotion,
- dual-use technologies,
- satcom support to Galileo and GMES,
- harmonising spectrum availability across European and internationally,
- exploiting higher frequency bands,
- harmonising the regulatory framework.

Website
http://www.isi-initiative.org

Communications
1. ISI European Satcom flagship
2. ISI research programme and challenges
3. ISI strategic research agenda

These documents can be found in http://www.isi-initiative.org

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5.2.2 Photonics

The Photonics21 ETP was established in 2005 to foster cooperation and a common identity in its industry. The platform brings together the leading photonics industries and R&D stakeholders. Its objective is to establish development and deployment of photonics in five key industrial areas: ICT, lighting and display, manufacturing, life sciences and security. These are grouped into five application sectors:

- information and communication;
- industrial production and manufacturing and quality;
- life sciences and health;

- lighting and displays;
- security, metrology and sensors.

Additionally two cross-cutting topics have also been defined:

- design and manufacturing of photonic components and systems, and
- photonics education, training and research infrastructure.

Website
http://www.photonics21.org

Communications

1. Vision document (2004): ‘Photonics for the 21st century’
   http://www.photonics21.org/pdf/visionpaperPh21.pdf
2. Strategic research agenda (2008): ‘Towards a bright future for Europe’
   http://www.photonics21.org/pdf/sra_april.pdf
3. Photonics in Europe: Economic Impact
   http://www.photonics21.org/pdf/Brosch_Photonics_Europe.pdf

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5.2.3 Advanced Materials

The Advanced Engineering Materials and Technologies (EuMat) ETP was established in 2006 to bring together industry and important stakeholders in the process of establishing R&D needs and priorities in this area. It bring together participants form different disciplines, industry, public authorities, academic community, consortia from EU projects, financial community and civil community, including users and consumers. EuMat focuses on five priority research areas:

- multifunctional engineering materials with gradient properties;
- engineering materials for challenging application conditions;
- multi-material (hybrid) systems where advanced materials are combined with more conventional/structural materials;
- related production technologies; and
- multi-scale modelling.

Website
http://www.eumat.org

Communications

1. Vision document (2006): ‘Roadmap of the European Technology Platform for Advanced Engineering Materials and Technologies’ http://www.eumat.org
2. Strategic research agenda (2006) Part 2 of the ‘EuMaT roadmap’ http://www.eumat.org

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5.2.4 Micro- and Nano-electronics

The European Nanoelectronics Initiative Advisory Council (ENIAC) ETP was established in 2004 to bring together industry, research centres, universities, financial organisations, regional and Member State authorities, and the EU. It aims at developing jointly a visionary programme and foster collaboration for the next-generation production processes. ENIAC focuses on six main application domains:

- health and wellness;
- mobility and transport;
- security and safety;
- energy and the environment;
- communications, and e-society.

The operational costs of the platform (secretariat) are currently financed by AENEAS an industrial association established in 2006, which is progressively taking over the activities of ENIAC including the implementation of the strategic research agenda. ENIAC coordinates with other platforms, and especially with ARTEMIS, in the field of design automation, and with EPOSS, to better coordinate the development of critical nanoelectronics technologies required for subsystem integration.

Website
http://www.eniac.eu

Communications

1. Vision document (2004): Vision 2020 — Nanoelectronics at the centre of change
   http://www.eniac.eu/web/SRA/e-vision-2020.pdf
2. Strategic research agenda (2007)
   http://www.eniac.eu/web/downloads/SRA2007.pdf

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5.2.5 Nanotechnology

There is no single ETP that deals exclusively with nanotechnology. ENIAC, Photonics, Future Textiles and Clothing (FTC) and Nanotechnologies for Medical Applications (Nanomedicine) mention aspects of nanotechnology in their targets.

In particular the Nanotechnologies for Medical Applications (Nanomedice) ETP was established in 2005 to prevent the luck of coordination between industry and academia –together with the EC- in this fast growing field. Nanomedice addresses the development and innovation needs in nanotechnology for health. It aims to strengthen the competitive, scientific and industrial position of Europe in the area of nanomedicine. The strategic research agenda identifies three main areas for research:

- nanotechnology-based diagnostics including imaging;
- targeted drug delivery and release;
- regenerative medicine.

Nanomedicine is in close contact with other ETPs, and in particular, the platform cooperates with the Innovative Medicines Joint Undertaking (IMI), Photonics (Photonics 21), Smart System Integration TP (EpoSS) and Sustainable Chemistry (SusChem).

Website
http://www.etp-nanomedicine.eu

Communications

1. Vision document (2005) 'Vision paper and basis for a strategic research agenda for nanomedicine'
   http://www.etp-nanomedicine.eu/public/press-documents/publications/etp-nanomedicine-visionpaper/at_download/file
2. Strategic research agenda (2006) 'Nanomedicine: nanotechnology for health
   http://www.etp-nanomedicine.eu/public/press-documents/publications/strategic-researchagenda/at_download/file

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5.2.6 Biotechnology

The ETPs that mention biotechnology as part of their focus are: Future Textiles and Clothing (FTC), European Biofuels Technology Platform (EBTP), Food for Life (Food), Nanotechnologies for Medical Applications (Nanomedicine), Plants for the Future (PLANTS), European Technology Platform for Sustainable Chemistry (SusChem).

White Biotechnology

The European Technology Platform for Sustainable Chemistry (SusChem) was established in 2004 and its strategic research agenda focuses on four sections: four sections:

- industrial biotechnologies, focusing on the development and production of novel, innovative products and processes in a cost and eco-efficient manner, and the discovery and optimisation of strains and biocatalysts;
- materials technology, focusing on materials for mankind's future surroundings, which will be designed to enhance the quality of life, with

special attention to the role of nanoscience, and the related nanotechnologies;
- reaction and process design, focusing on the identification, design and development of appropriate products and processes that will help achieving them;
- horizontal issues, focusing on ensuring that EU citizens benefit t from the development and use of innovations based on the SusChem SRA by addressing environmental, health and societal concerns associated with new products and processes; and stimulating support for innovation.

Website
http://www.suschem.org

Communications
1. Vision document (2005):'The vision for 2025 and beyond' http://www.suschem.org/content.php?_document[ID]=2049&pageId=3599
2. Strategic research agenda (2005) http://www.suschem.org/content.php?_document[ID]=2049&pageId=3599
3. Implementation action plan(2006) http://www.suschem.org/content.php?_document[ID]=2049&pageId=3599

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The European Biofuels Technology Platform (EBTP) was created in 2006. The main areas of technology development cover three main areas: biomass production and supply, conversion processes and end use, fuel/engine optimisation. It aims at building on synergies with other ETPs including Plants for the Future, SusChem and European Rail Research Advisory Counsil (ETRAC).

Website
http://www.biofuelstp.eu

Communications
1. Vision document (2006) Biofuels in the European Union: a vision for 2030 and beyond http://www.biofuelstp.eu/downloads/biofuels_vision_2030_en.pdf
2. Strategic research agenda and strategy deployment document (2008)

http://www.biofuelstp.eu/srasdd/080111_sra_sdd_web_res.pdf

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The Future Textiles and Clothing (FTC) ETP was established in 2004 and its strategic research agenda focuses on three major areas:

- ‘From commodities towards specialties’, for which the key research priorities identified include new speciality fibres and fibre-composites for innovative textile products, functionalisation of textile materials and related processes and bio-based materials, biotechnologies, and environmentally friendly textile processing;
- ‘New textile applications’, for which the research priorities include new textile products for improved human performance, new textile products for innovative technical applications, and smart textiles and clothing.
- ‘Towards customisation’, which should focus on mass customisation for clothing and fashion, new design and product development concepts and technologies, and integrated quality and life cycle management concepts.

Website
http://textile-platform.eu

Communications

1. Vision document (2004)
   http://textile-platform.eu/textile-platform/?block %5B47 %5D %5Bsudir %5D= Keydocuments&page_name=Downloads
2. Strategic research agenda (2006): ‘The future is …textiles’
   http://textile-platform.eu/textile-platform/?block%5B47%5D%5Bsubdir%5D=Keydocuments&page_name=Downloads

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Green Biotechnology

The Food for Life (Food) ETP was established in 2005 and its strategic research agenda is defined across six interacting areas:
ensuring that the healthy choice is the easy choice for
consumers;

- delivering a healthier diet;
- developing quality food products;
- assuring safe foods that consumers can trust;
- achieving sustainable food production;
- managing the food chain.

Website
http://etp.ciaa.eu

Communications

1. Vision document (2005): 'European Technology Platform on Food for Life — The vision for 2020 and beyond'
   http://etp.ciaa.eu/documents/BAT%20Brochure%20ETP.pdf
2. Strategic research agenda (2007): 'European Technology Platform on Food for Life — Strategic research agenda 2007–20'
   http://etp.ciaa.eu/documents/CIAA-ETP%20broch_LR.pdf
3. Implementation action plan (2008)
   http://etp.ciaa.eu/documents/Broch%20ETP_IAPlan_1.pdf
4. Layman's version of vision and SRA, May 2008
   http://etp.ciaa.eu/documents/CIAA_Booklet%20ETP_fi nal.pdf

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The Plants for the Future (PLANTS) ETP was established in 2004 and its strategic research agenda identifies five challenges:

- healthy, safe and sufficient food and feed; with a focus on developing and producing safe and high quality food; creating food products targeted at specific consumer groups and needs; and producing safe, high quality, sufficient and sustainable feed;
- plant-based products, chemicals and energy; with a focus on enabling research; biochemicals; industrial feedstocks and biopolymers; and bio-energy;
- sustainable agriculture, forestry and landscape; with a focus on improving plant productivity and quality; optimising agriculture to further reduce its environmental
- impact; boosting biodiversity; and enhancing the aesthetical value and sustainability of the landscape;
- vibrant and competitive basic research; with a focus on advanced genome resources and plant breeding; novel uses of genomic diversity; improved GM technologies; multilevel precision phenotyping, systems biology; computational biology and modelling; and basic plant processes;
- competitiveness, consumer choice and governance; with a focus on public consumer involvement; ethical issues; safety and legal issues; and financial environment.

Website
http://www.plantetp.org

Communications

1. Vision document (2004) ‘Plants for the future: 2025. A European vision for plant genomics and biotechnologies’
   http://www.epsoweb.org/Catalog/TP/Plants %20for %20the %20future-Dec04.pdf

2. Strategic research agenda (2007)
   http://www.epsoweb.org/Catalog/TP/Launch_25June07/TP_SRA_Summary.pdf
3. Detailed SRA and first action plan (2007)
   http://www.epsoweb.org/Catalog/TP/Launch_25June07/TP_SRA_PART_II+III.pdf

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Red Biotechnology

The Nanotechnologies for Medical Applications (Nanomedice) mentioned under the section nanotechnology covers the red biotechnology.

5.2.7 Information and Communication Technologies

The ETPs mainly dealing with the ICT's are: Mobile and Wireless Communications Technology Platform (eMobility), European Platform on Smart Systems Integration (EPoSS), Networked and Electronic Media (NEM), Networked European Software and Services Initiative (NESSI). Other platforms closely relates with ICT's are Advanced Research and Technology for Embedded Intelligence and Systems (ARTEMIS) and European Technology Platform on Robotics (EUROP).

Mobile and Wireless Communications Technology Platform (eMobility) was established in 2004 and aims at strengthening research and development in telecommunications systems.

Website
http://www.emobility.eu.org

Communications

1. Strategic Research Agenda, Revision 7 (2008)
   http://www.emobility.eu.org/SRA/eMobility_SRA_07_090115.pdf
2. Strategic Applications Research Agenda, Version 1 (2008)
   http://www.emobility.eu.org/SAA/Strategic_Applications_Agenda_v1-0.pdf

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European Platform on Smart Systems Integration (EPoSS) was established in 2006 and the strategic research agenda of the ETP formulates a shared view of research needs of the smart systems integration sector. The sectors identified as most relevant for smart system applications are: automotive, information and telecommunications, medical technologies, RFID, safety and security, cross-cutting issues.

Website
http://www.smart-systems-integration.org

Communications

1. Vision document (2006): 'Towards a vision of innovative smart systems integration'
   http://www.smart-systems-integration.org/public/documents/eposs_publications/060516_Vision_Paper_final_mit Deckblatt.pdf
2. Strategic research agenda (2007): 'Implementing the European research area for smart systems technologies'
   http://www.smart-systems-integration.org/public/documents/eposs_publications/EPoSS_SRA_1_3
3. Strategic Research Agenda (2009)
   http://www.smart-systems-integration.org/public/documents/publications/EPoSS%20Strategic%20Research%20Agenda%202009.pdf

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The Networked and Electronic Media (NEM) ETP was established in 2005 to bringing together various of stakeholders, including broadcasters, telecom operators, manufacturers of professional equipment, manufacturers of consumer electronics, academia and standardisation bodies. It aims to cover existing and new technologies, including broadband, mobile and new media across all ICT sectors, to create a new and exciting era of advanced personalised services.

Website
http://www.nem-initiative.org

Communications

1. Vision document (2007): 'NEM vision 2020'
   http://www.nem-initiative.org/Documents/NEM-V-002.pdf
2. Strategic research agenda (2007)
   http://www.nem-initiative.org/Documents/NEM-SRA-050.pdf
3. NEM strategic research agenda coverage by FP7 — Call 1
   http://www.nem-initiative.org/Documents/NEM-SRA-051.pdf

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The Networked European Software and Services Initiative (NESSI) ETP was established in 2005 and aims at developing a strategy for software and services driven by a common European Research Agenda.

Website
http://www.nessi-europe.eu

Communications

1. Vision document (2005)
   http://www.nessi-europe.eu/Nessi/Portals/0/Nessi-Repository/Publications/Flyers/2005_09_Vision_V2.pdf
2. Strategic research agenda
   Vol. 1: Framing the service economy (2006)
   Vol. 2: A strategy to build NESSI (2008)
   Vol. 3: The short-, medium- and long-term roadmaps (2008)
   http://www.nessi-europe.eu/Nessi/Publications/NESSIDocuments/tabid/590/Default.aspx

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The Advanced Research and Technology for Embedded Intelligence and Systems (ARTEMIS) ETP was established in 2004 and the strategic research agenda focuses on four application contexts:

- industrial systems; large, complex and safety-critical systems, which embraces automotive, aerospace, manufacturing, and growth areas such as biomedical;
- nomadic environments; enabling portable devices and on-body systems to offer users access to information and services while on the move;
- private spaces; such as homes, cars and offices, offering systems and solutions for improved enjoyment, comfort, well-being and safety;
- public infrastructure; major infrastructure such as airports, cities and highways that embrace large-scale deployment of systems and services that benefit the citizen.

Website
http://www.artemisia-association.eu

Communications
Strategic research agenda (2006), http://www.artemis-etp.eu

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The European Technology Platform on Robotics (EUROP) ETP was established in 2005 and its strategic research agenda identifies six application scenarios:

manipulation robots, robotic co-workers, logistics robots, security robots, robots used for exploration or inspection, and edutainment.

Website
http://www.robotics-platform.eu

Communications
1. Vision document EUROP, the European Robotics Platform — Glossy Brochure (2005)
   http://www.robotics-platform.eu/documents.htm
2. Strategic research agenda (2009)
   http://www.robotics-platform.eu/cms/index.php?idcat=8

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ANNEX ??? Selected Countries

5.2.8 Finland

Finland is often regarded as a global precursor in the area of innovation policy. It has a strongly developed cooperation between many different actors and also sees its largest funding bodies cooperating (TEKES the Finnish Funding Agency of Technology and Innovation, SITRA and the Academy of Finland, and VTT the leading governmental research and innovation institution).

One of the key elements in Finnish science and innovation policy is its high visibility in the political arena. The Prime Minister and the Parliament hold key roles. The Prime Minister chairs the Science and Technology Policy Council, which is responsible for the innovation system as a whole, and devises national policies on innovation, technology and science. The Parliament has the Committee for the Future as one of its 15 standing committees, which keeps an active dialogue with the Government about future challenges and possible solutions, and has a role in future policy-making with emphasis on research.

The Finnish Parliament has held technology assessments, typically containing foresight elements, on such topics as: regional innovation environments, social capital, challenges of global information society, gene-therapy technology, nuclear energy technology, and more. Recently the Academy of Finland and TEKES have joined efforts in the Finnsight2015 (http://www.finnsight2015.fi) exercise to support the priority setting of basic and applied research. In parallel with this foresight activity, SITRA started its own national foresights network in late 2005, to recognise the changing trends and key challenges to which decision-makers should already be paying attention. The Finland Futures Research Centre, the Technical Research Centre of Finland (VTT), the Systems Analysis Laboratory of Helsinki University of Technology, Lappeenranta Technical University and other university research groups as well as private consultants have also carried out a number of sectoral and regional foresight studies.

The Academy of Finland is a science-oriented funding institution, under the Ministry of Education. Its mission is to promote excellence in scientific research through long-term funding based on reliable evaluation, expertise and international cooperation. It consists of an Academy Board, an Administrative Office and four research councils: Biosciences and Environment, Culture and Society, Health, and Natural Sciences and Engineering.

The Finnish Funding Agency of Technology and Innovation (TEKES) is an application- and innovation-oriented funding institution, under the Ministry of Science and Technology, and the key actor in Finnish policy for science and innovation. It funds mainly applied research intended for challenging and

innovative projects, where half of its funding is dedicated to research within specific strategic areas, in which TEKES has programmes, with the goal that some may lead to global success stories.
The Finnish national fund for R&D (SITRA) is also an application- and innovation-oriented funding institution, which is an independent public foundation under the Finnish Parliament. It has the task to promote economic growth and future success of the nation through competitiveness and the development of international cooperation. Its operations are divided into two different kinds: research and education collaboration, and venture-capital funding.

Across the Nordic countries, some common topics in the field of foresight studies for the period 2002-2006, which emerged from the Nordic Foresight Forum questionnaire survey were[22]:

- information and communication technology (ICT) cluster
- ICT and networking
- nanotechnology
- hydrogen foresight, energy foresight studies
- biotechnology
- science and technology prioritizing research
- the FinnSight2015 science and technology study

The same survey also enquired about future topics in foresight studies for the period 2006-2015. These were, amongst others:

- energy and climate change
- health care and ageing population
- nanotechnology
- participative foresight

In terms of Nordic foresight cooperation, there are three main institutions, under the Nordic Council of Ministers, for managing Nordic research and innovation:

- Nordic Innovation Centre (NICe)
- Nordic Energy Research
- NordForsk

The Nordic Innovation Centre (NICe)[23], which is an application- and innovation-oriented funding institution and instrument of the Nordic Council of Ministers, was funding three Nordic-level foresight studies by 2006: the Nordic Hydrogen Energy Foresight, the Nordic Biomedical Sensor Foresight, and the Nordic ICT Foresight. The aim of the institution is to promote an innovative and knowledge-intensive Nordic business sector.

Nordic Energy Research is an independent application- and innovation-oriented

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[22] "Foresight in Nordic Innovation Systems" p.22

[23] Since its establishment in 2004, NICe can be seen as the successor of the previous Nordic Industrial Fund

funding institution which aims to further support and develop markets for the Nordic energy sector. It specifically strives to contribute to the maintenance of high levels of energy efficiency and sustainability in the Nordic system as well as maintaining the region's leading status in terms of renewable energy technology R&D.

The only one of these three Nordic research and innovation institutes that is a science-oriented funding institution is NordForsk[24], operating under the Nordic Council of Ministers for Education and Research. It is an independent institution responsible for cooperation within research and research training, with the aim to promote research of supreme international quality.

Finland distinguishes itself from its Nordic partners through the tight coordination which exists between actors in its innovation system. Particularly, the coordination between TEKES and SITRA makes Finland a leader in the field of innovation policy.

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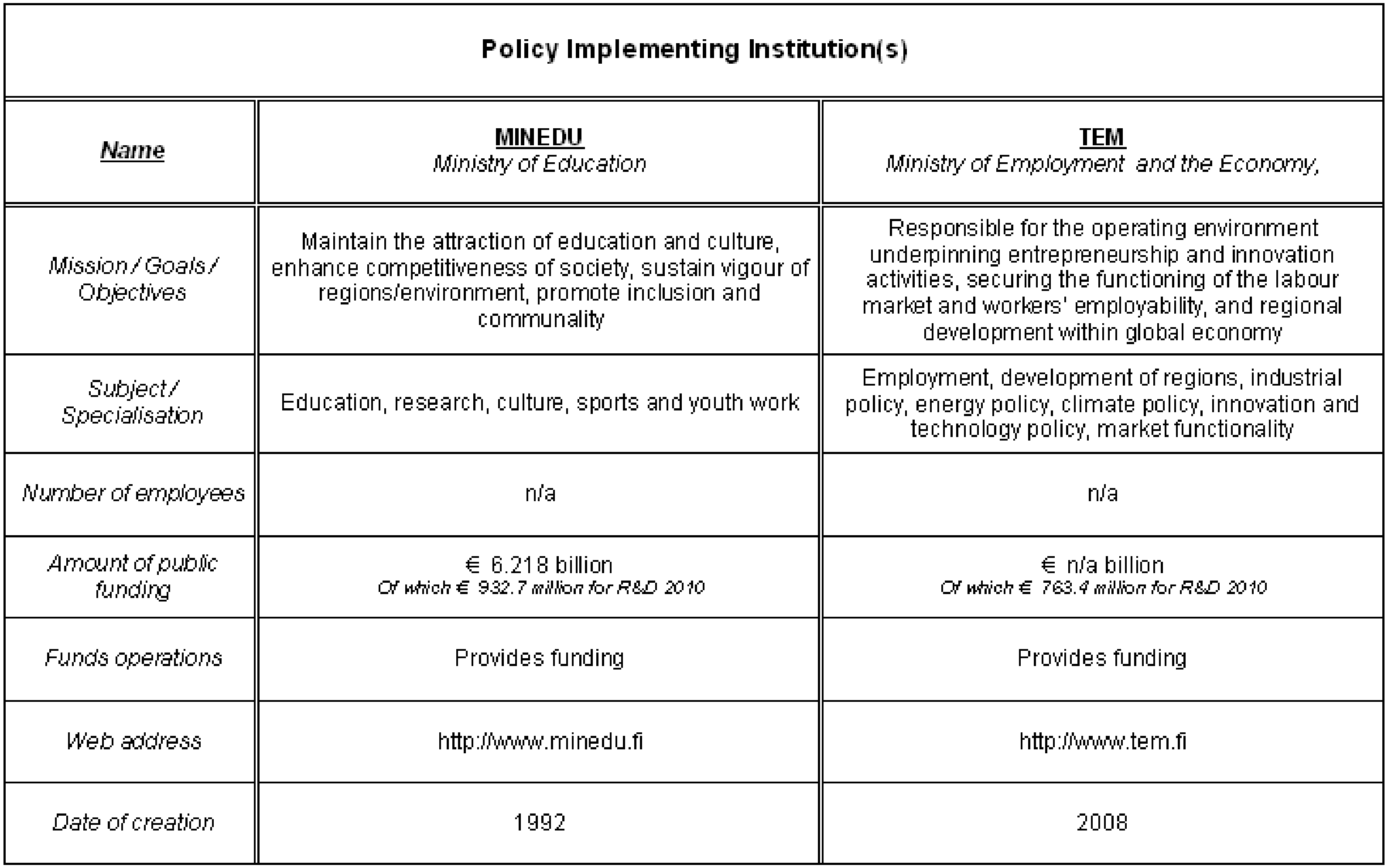
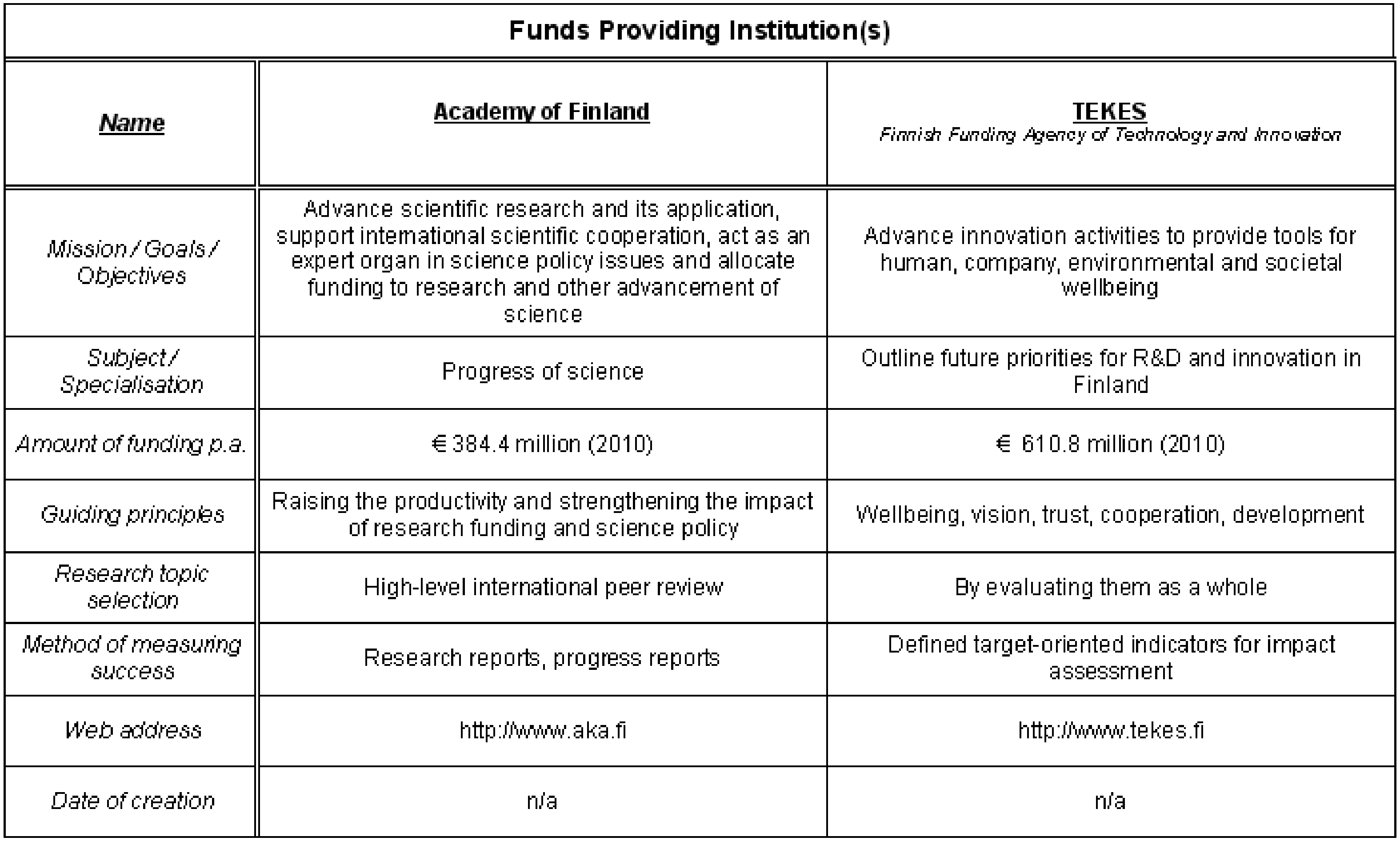
[24] Established in 2005, replaces the Nordic Science Policy Council and Nordic Academy for Advanced Study (NorFA).



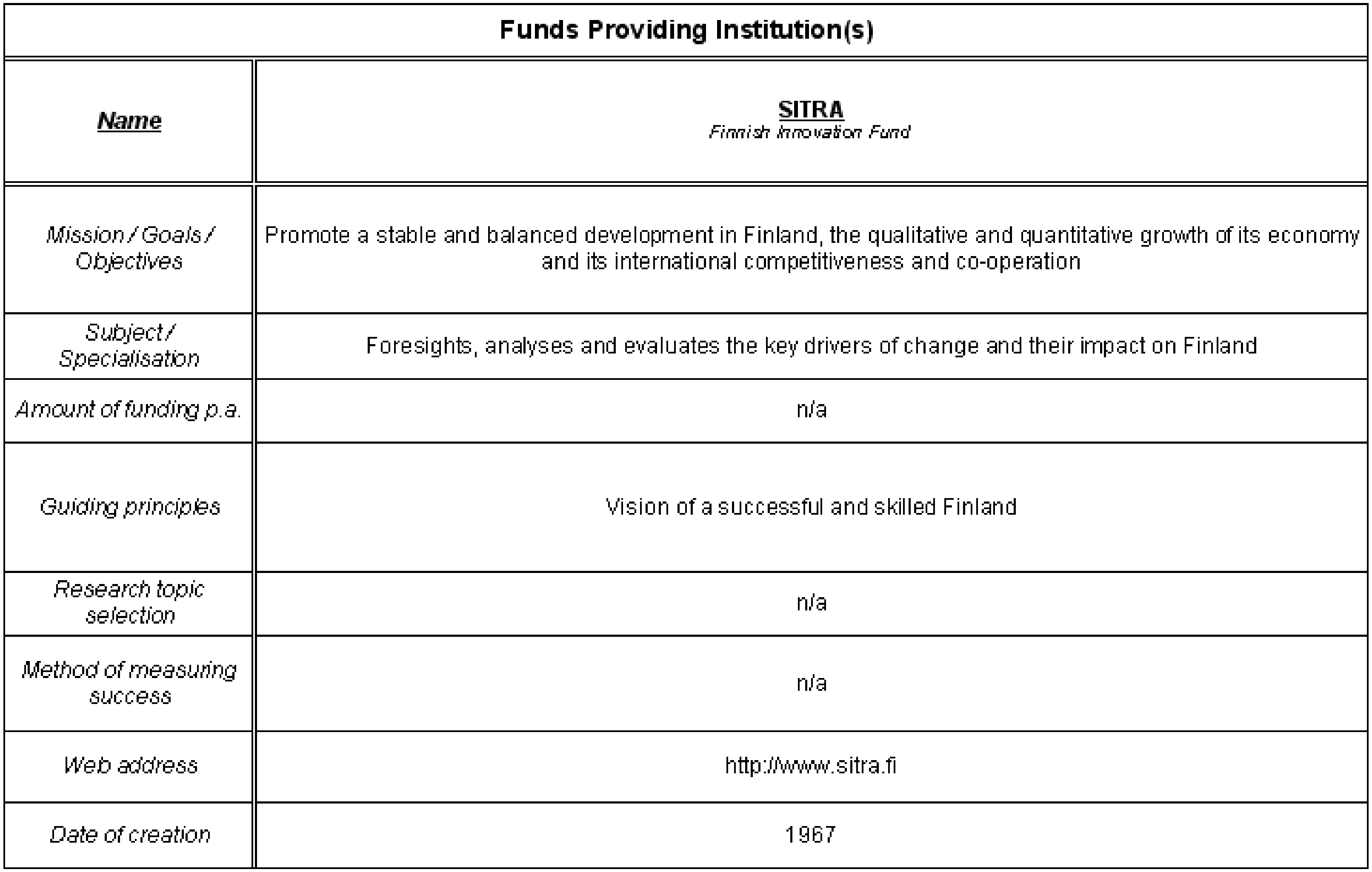
Policy Implementing Institution(s)

Name	**MINEDU** *Ministry of Education*	**TEM** *Ministry of Employment and the Economy,*
Mission / Goals / Objectives	Maintain the attraction of education and culture, enhance competitiveness of society, sustain vigour of regions/environment, promote inclusion and communality	Responsible for the operating environment underpinning entrepreneurship and innovation activities, securing the functioning of the labour market and workers' employability, and regional development within global economy
Subject / Specialisation	Education, research, culture, sports and youth work	Employment, development of regions, industrial policy, energy policy, climate policy, innovation and technology policy, market functionality
Number of employees	n/a	n/a
Amount of public funding	€ 6.218 billion *Of which € 932.7 million for R&D 2010*	€ n/a billion *Of which € 763.4 million for R&D 2010*
Funds operations	Provides funding	Provides funding
Web address	http://www.minedu.fi	http://www.tem.fi
Date of creation	1992	2008



Funds Providing Institution(s)

Name	**Academy of Finland**	**TEKES** *Finnish Funding Agency of Technology and Innovation*
Mission / Goals / Objectives	Advance scientific research and its application, support international scientific cooperation, act as an expert organ in science policy issues and allocate funding to research and other advancement of science	Advance innovation activities to provide tools for human, company, environmental and societal wellbeing
Subject / Specialisation	Progress of science	Outline future priorities for R&D and innovation in Finland
Amount of funding p.a.	€ 384.4 million (2010)	€ 610.8 million (2010)
Guiding principles	Raising the productivity and strengthening the impact of research funding and science policy	Wellbeing, vision, trust, cooperation, development
Research topic selection	High-level international peer review	By evaluating them as a whole
Method of measuring success	Research reports, progress reports	Defined target-oriented indicators for impact assessment
Web address	http://www.aka.fi	http://www.tekes.fi
Date of creation	n/a	n/a



Funds Providing Institution(s)

Name	**SITRA** *Finnish Innovation Fund*
Mission / Goals / Objectives	Promote a stable and balanced development in Finland, the qualitative and quantitative growth of its economy and its international competitiveness and co-operation
Subject / Specialisation	Foresights, analyses and evaluates the key drivers of change and their impact on Finland
Amount of funding p.a.	n/a
Guiding principles	Vision of a successful and skilled Finland
Research topic selection	n/a
Method of measuring success	n/a
Web address	http://www.sitra.fi
Date of creation	1967

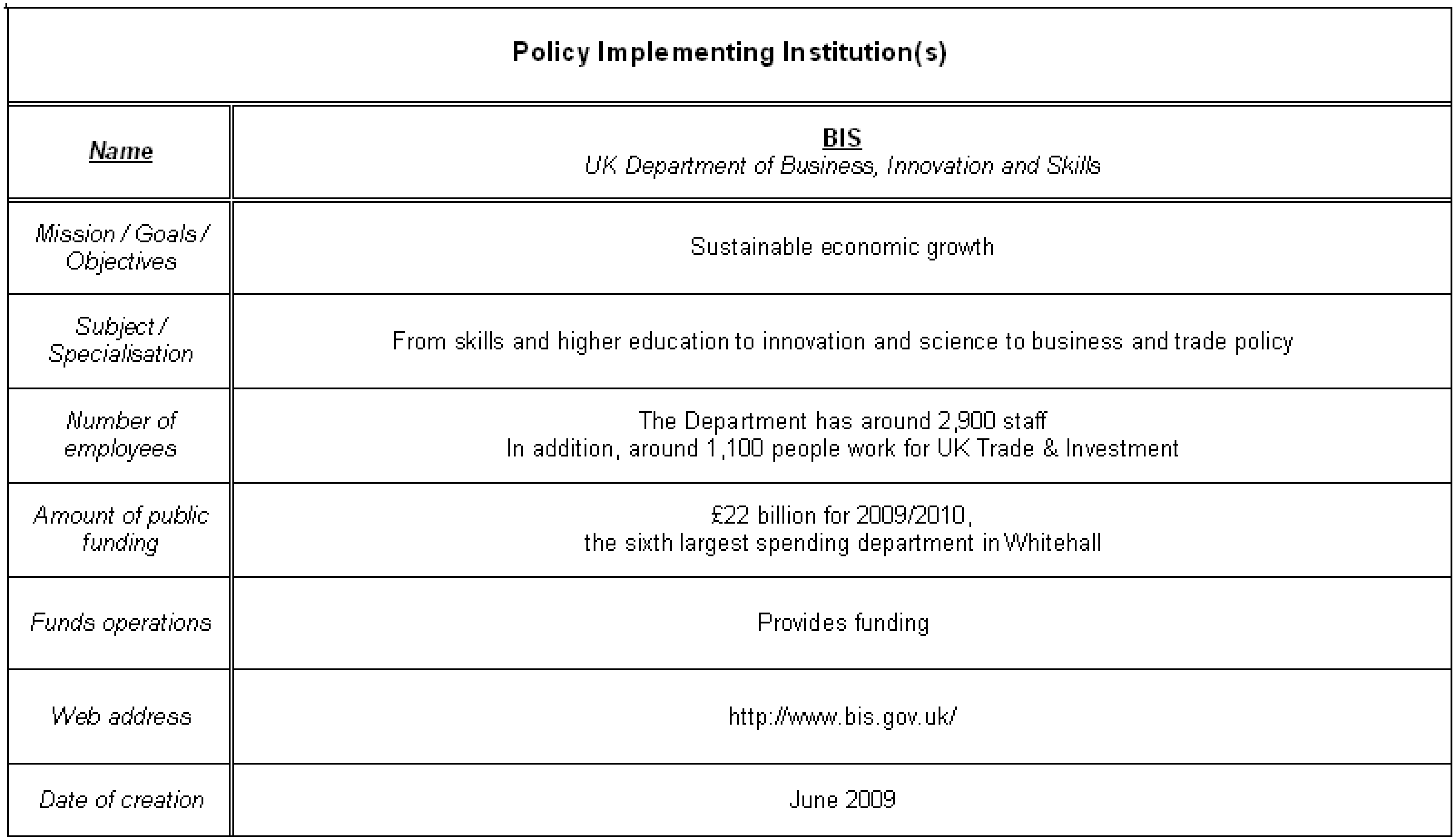
5.2.9 United Kingdom

The United Kingdom Department of Business, Innovation and Skills (established on 5 June 2009, from the merging of the Department for Innovation, Universities and Skills, DIUS, with the Department for Business, Enterprise & Regulatory Reform, BERR) is responsible for the allocation of the Science Budget via the seven Research Councils, which in turn support research & development in Higher Education Institutes (HEIs), and through their own instruments and research centres. The overall coordination of research council policy is the responsibility of RCUK (Research Councils UK), established as an equal and strategic partnership between the seven Research Councils.

The seven Research Councils are:

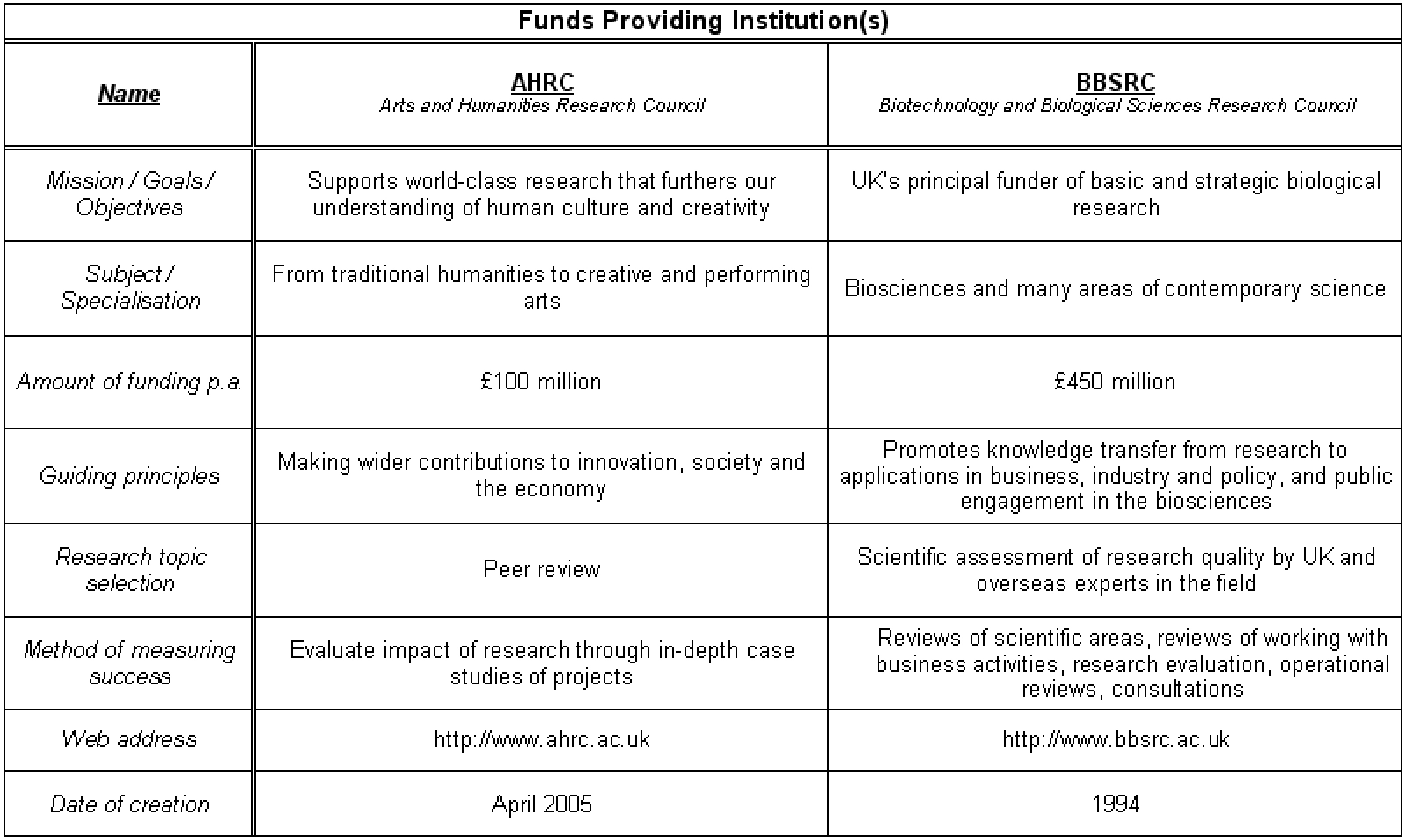
- Arts and Humanities Research Council – AHRC
- Biotechnology and Biological Sciences Research Council – BBSRC
- Economic and Social Research Council – ESRC
- Engineering and Physical Sciences Research Council – EPSRC
- Medical Research Council – MRC
- Natural Environment Research Council – NERC
- Science and Technology Facilities Council – STFC

The information was collected from ERA WATCH and relevant government websites and was processed by ESPI, It is included in the Tables below.

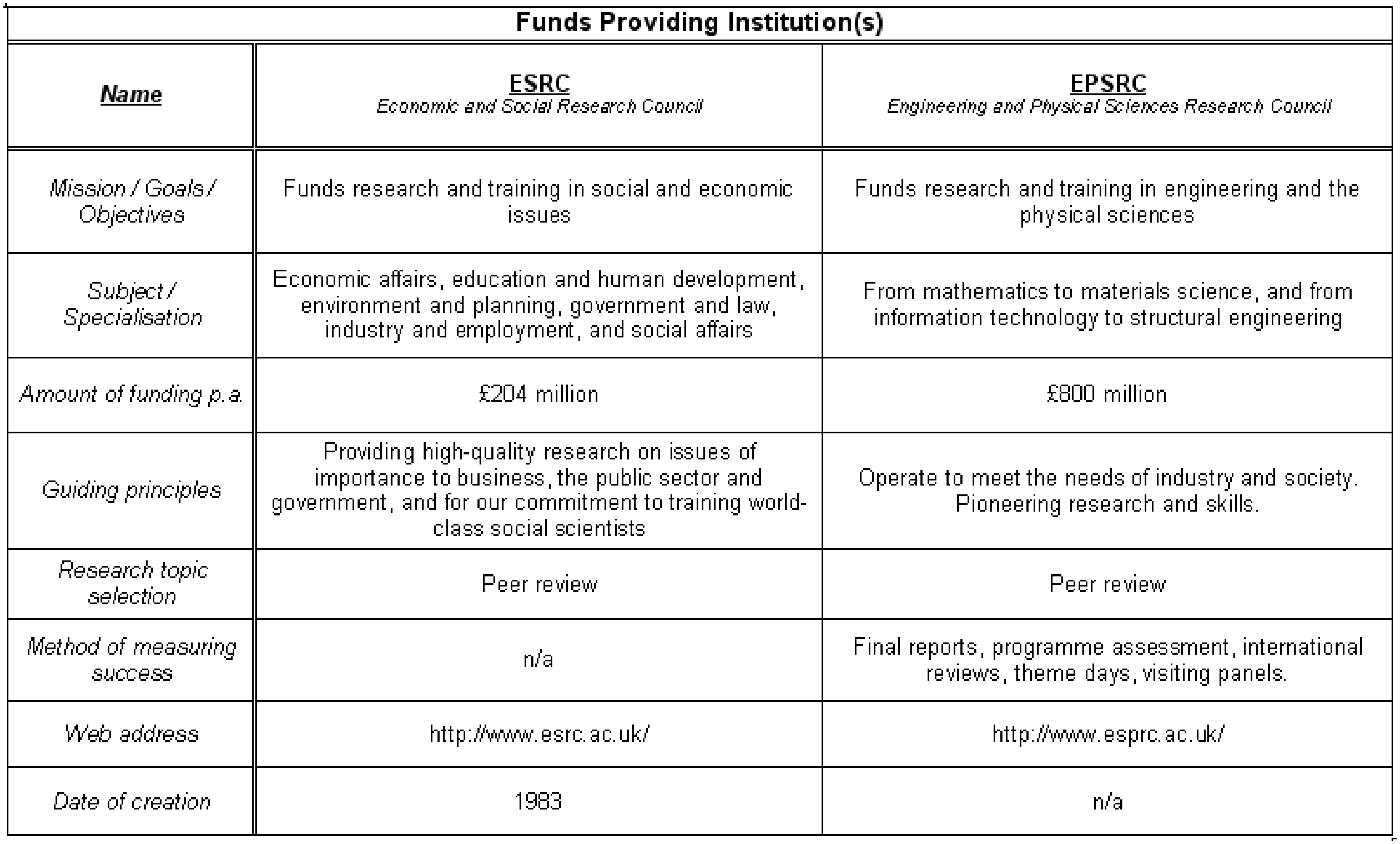


Policy Implementing Institution(s)

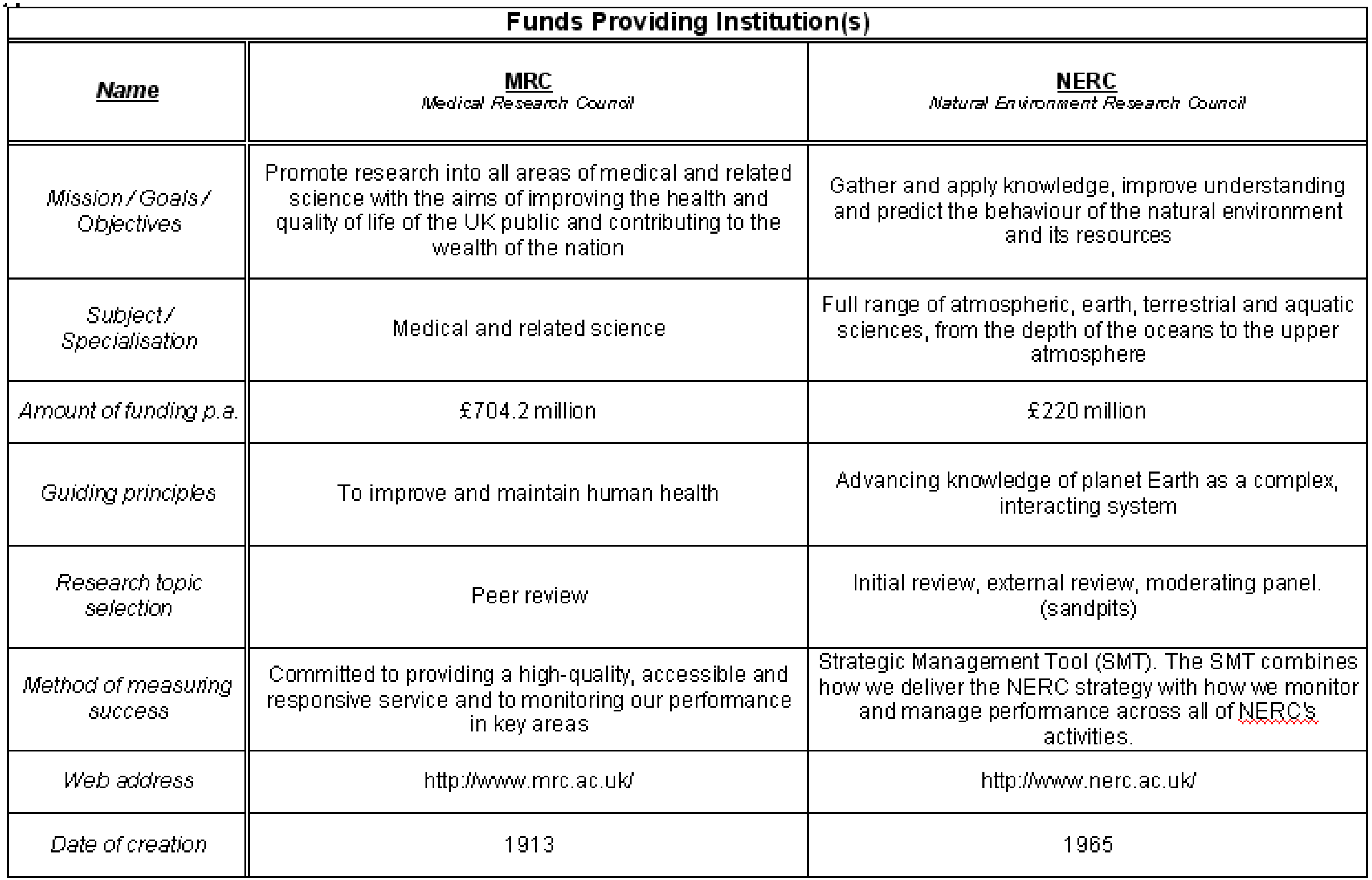
Name	**BIS** *UK Department of Business, Innovation and Skills*
Mission / Goals / Objectives	Sustainable economic growth
Subject / Specialisation	From skills and higher education to innovation and science to business and trade policy
Number of employees	The Department has around 2,900 staff In addition, around 1,100 people work for UK Trade & Investment
Amount of public funding	£22 billion for 2009/2010, the sixth largest spending department in Whitehall
Funds operations	Provides funding
Web address	http://www.bis.gov.uk/
Date of creation	June 2009



Funds Providing Institution(s)		
Name	**AHRC** *Arts and Humanities Research Council*	**BBSRC** *Biotechnology and Biological Sciences Research Council*
Mission / Goals / Objectives	Supports world-class research that furthers our understanding of human culture and creativity	UK's principal funder of basic and strategic biological research
Subject / Specialisation	From traditional humanities to creative and performing arts	Biosciences and many areas of contemporary science
Amount of funding p.a.	£100 million	£450 million
Guiding principles	Making wider contributions to innovation, society and the economy	Promotes knowledge transfer from research to applications in business, industry and policy, and public engagement in the biosciences
Research topic selection	Peer review	Scientific assessment of research quality by UK and overseas experts in the field
Method of measuring success	Evaluate impact of research through in-depth case studies of projects	Reviews of scientific areas, reviews of working with business activities, research evaluation, operational reviews, consultations
Web address	http://www.ahrc.ac.uk	http://www.bbsrc.ac.uk
Date of creation	April 2005	1994

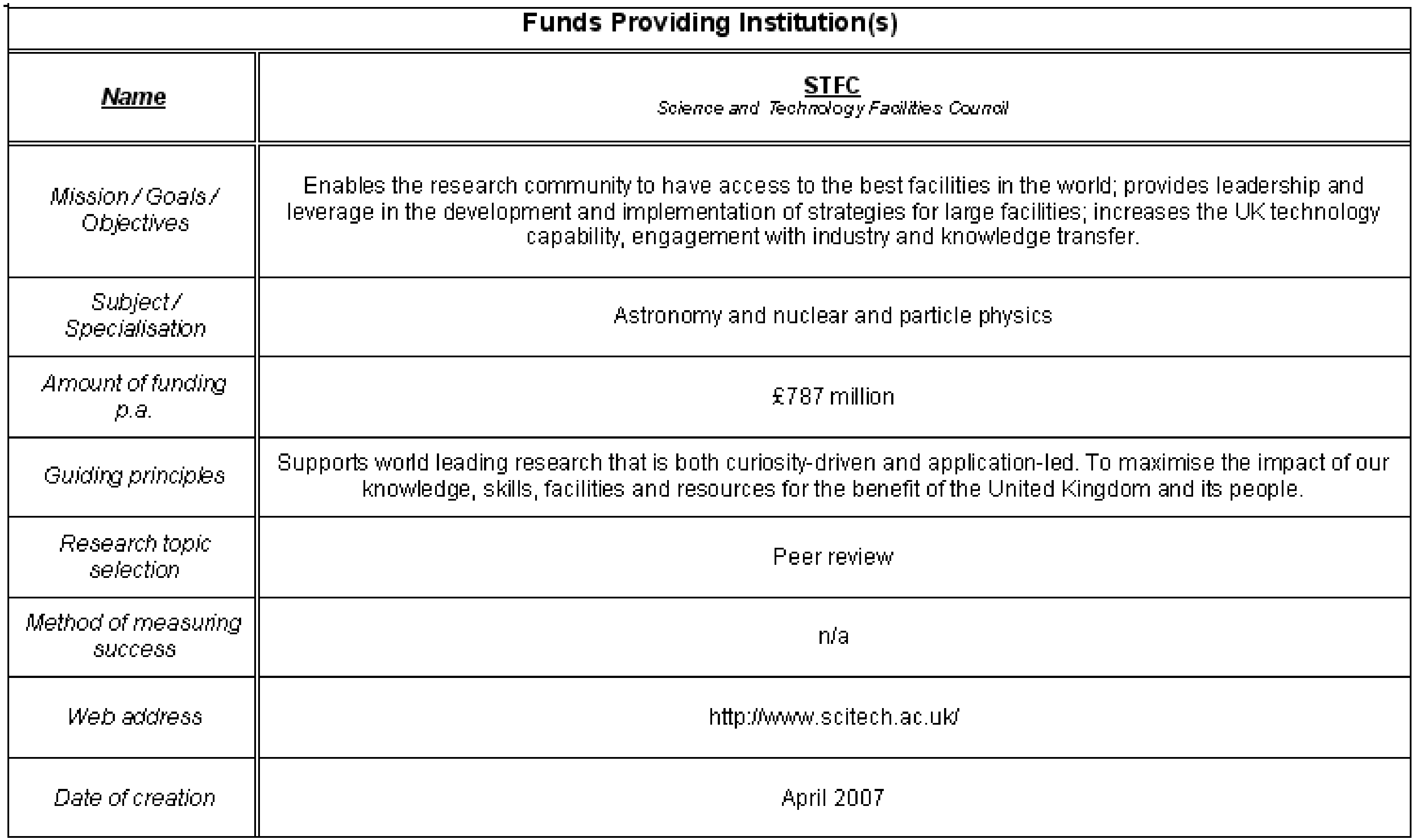


Funds Providing Institution(s)		
Name	**ESRC** *Economic and Social Research Council*	**EPSRC** *Engineering and Physical Sciences Research Council*
Mission / Goals / Objectives	Funds research and training in social and economic issues	Funds research and training in engineering and the physical sciences
Subject / Specialisation	Economic affairs, education and human development, environment and planning, government and law, industry and employment, and social affairs	From mathematics to materials science, and from information technology to structural engineering
Amount of funding p.a.	£204 million	£800 million
Guiding principles	Providing high-quality research on issues of importance to business, the public sector and government, and for our commitment to training world-class social scientists	Operate to meet the needs of industry and society. Pioneering research and skills.
Research topic selection	Peer review	Peer review
Method of measuring success	n/a	Final reports, programme assessment, international reviews, theme days, visiting panels.
Web address	http://www.esrc.ac.uk/	http://www.esprc.ac.uk/
Date of creation	1983	n/a

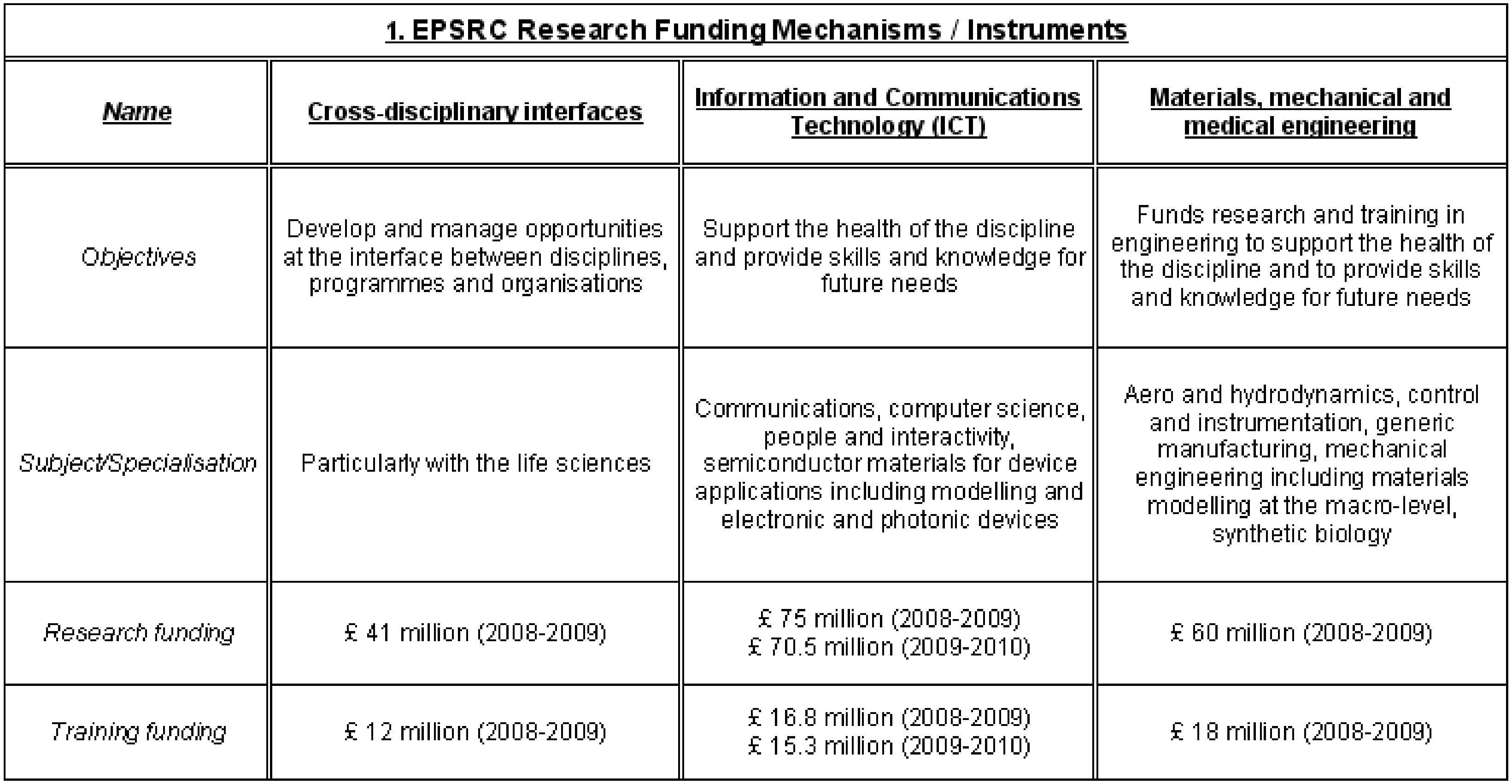


Funds Providing Institution(s)

Name	**MRC** *Medical Research Council*	**NERC** *Natural Environment Research Council*
Mission / Goals / Objectives	Promote research into all areas of medical and related science with the aims of improving the health and quality of life of the UK public and contributing to the wealth of the nation	Gather and apply knowledge, improve understanding and predict the behaviour of the natural environment and its resources
Subject / Specialisation	Medical and related science	Full range of atmospheric, earth, terrestrial and aquatic sciences, from the depth of the oceans to the upper atmosphere
Amount of funding p.a.	£704.2 million	£220 million
Guiding principles	To improve and maintain human health	Advancing knowledge of planet Earth as a complex, interacting system
Research topic selection	Peer review	Initial review, external review, moderating panel. (sandpits)
Method of measuring success	Committed to providing a high-quality, accessible and responsive service and to monitoring our performance in key areas	Strategic Management Tool (SMT). The SMT combines how we deliver the NERC strategy with how we monitor and manage performance across all of NERC's activities.
Web address	http://www.mrc.ac.uk/	http://www.nerc.ac.uk/
Date of creation	1913	1965

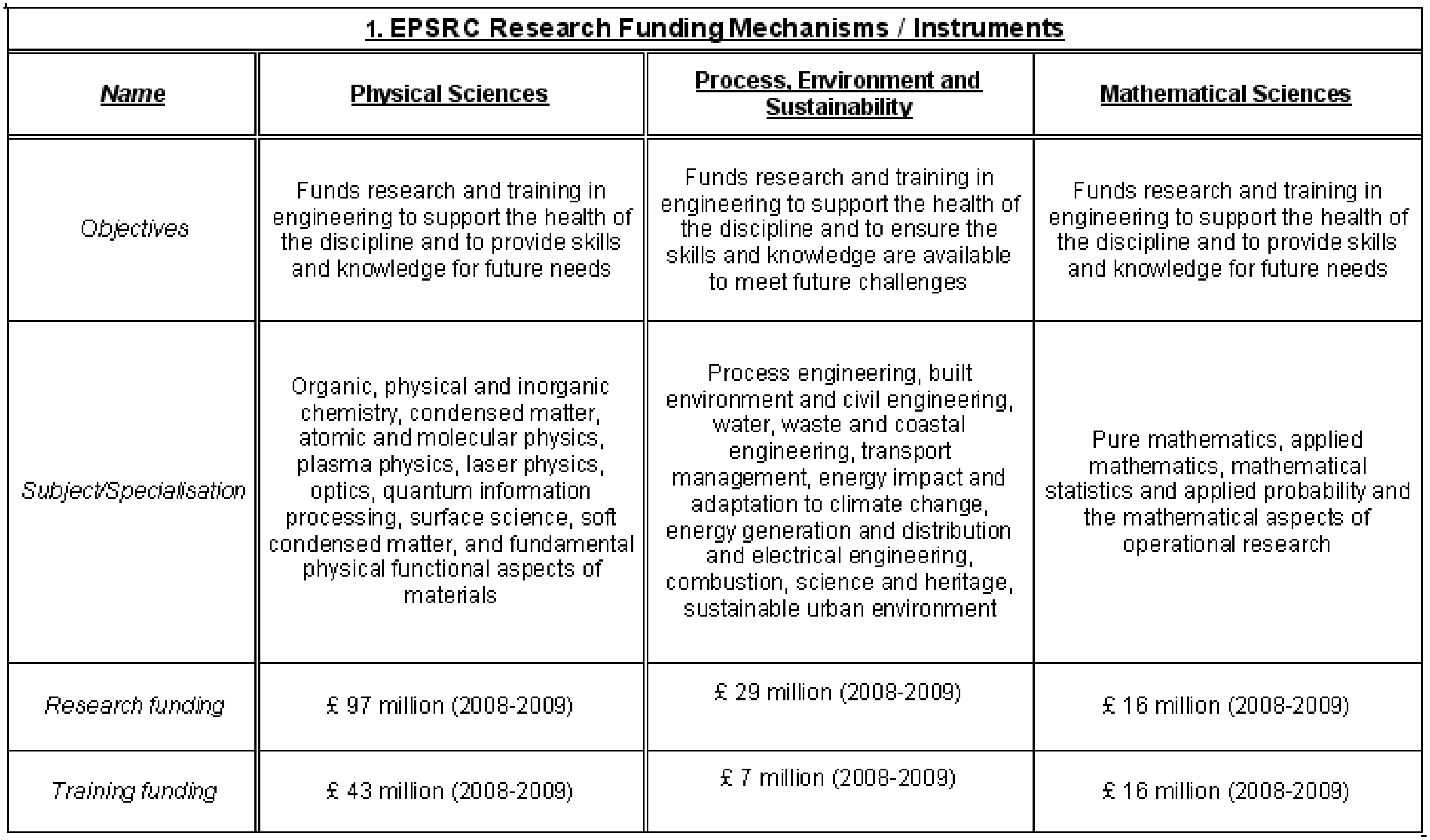


Funds Providing Institution(s)	
Name	**STFC** *Science and Technology Facilities Council*
Mission / Goals / Objectives	Enables the research community to have access to the best facilities in the world; provides leadership and leverage in the development and implementation of strategies for large facilities; increases the UK technology capability, engagement with industry and knowledge transfer.
Subject / Specialisation	Astronomy and nuclear and particle physics
Amount of funding p.a.	£787 million
Guiding principles	Supports world leading research that is both curiosity-driven and application-led. To maximise the impact of our knowledge, skills, facilities and resources for the benefit of the United Kingdom and its people.
Research topic selection	Peer review
Method of measuring success	n/a
Web address	http://www.scitech.ac.uk/
Date of creation	April 2007



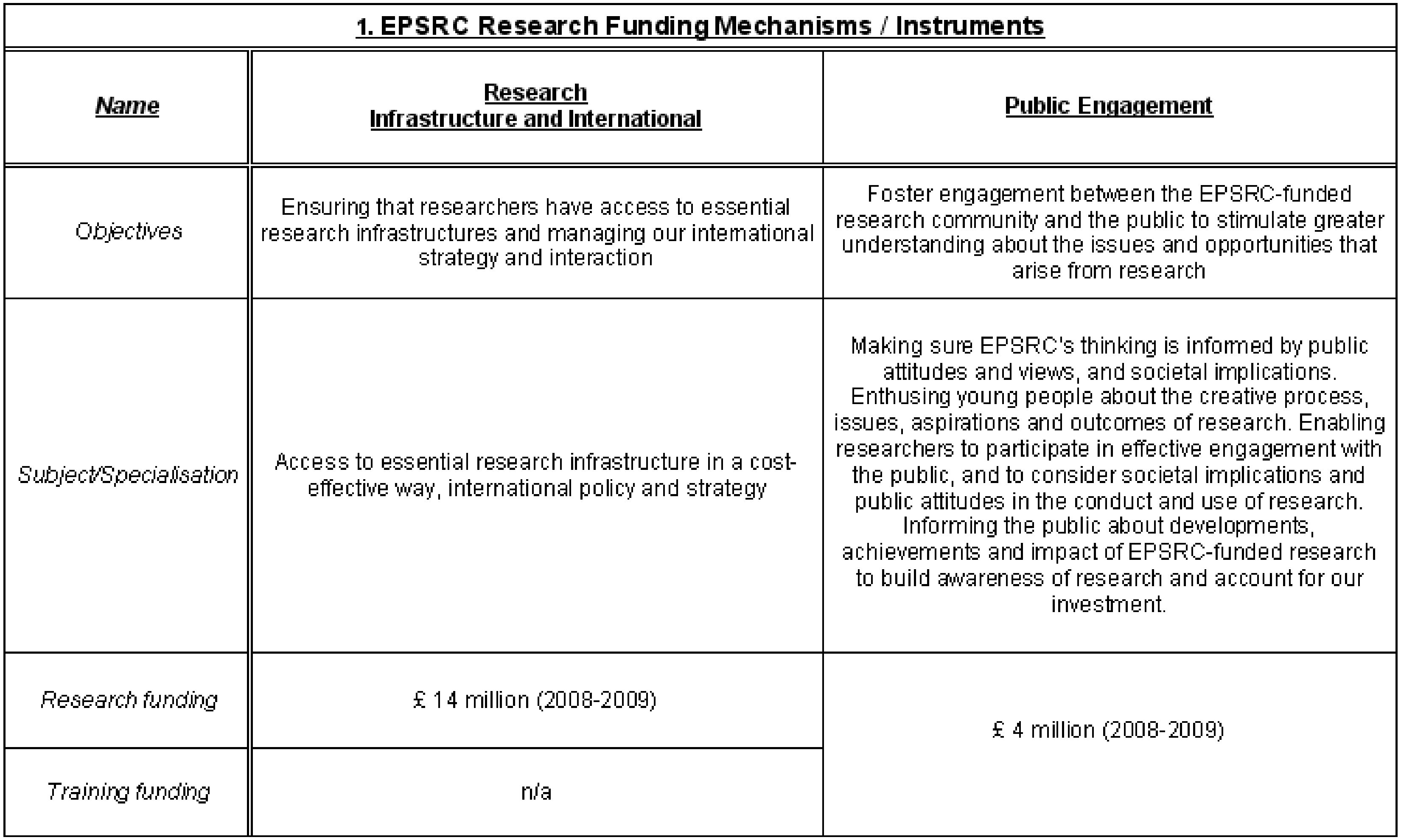
1. EPSRC Research Funding Mechanisms / Instruments

Name	**Cross-disciplinary interfaces**	**Information and Communications Technology (ICT)**	**Materials, mechanical and medical engineering**
Objectives	Develop and manage opportunities at the interface between disciplines, programmes and organisations	Support the health of the discipline and provide skills and knowledge for future needs	Funds research and training in engineering to support the health of the discipline and to provide skills and knowledge for future needs
Subject/Specialisation	Particularly with the life sciences	Communications, computer science, people and interactivity, semiconductor materials for device applications including modelling and electronic and photonic devices	Aero and hydrodynamics, control and instrumentation, generic manufacturing, mechanical engineering including materials modelling at the macro-level, synthetic biology
Research funding	£ 41 million (2008-2009)	£ 75 million (2008-2009) £ 70.5 million (2009-2010)	£ 60 million (2008-2009)
Training funding	£ 12 million (2008-2009)	£ 16.8 million (2008-2009) £ 15.3 million (2009-2010)	£ 18 million (2008-2009)



1. EPSRC Research Funding Mechanisms / Instruments

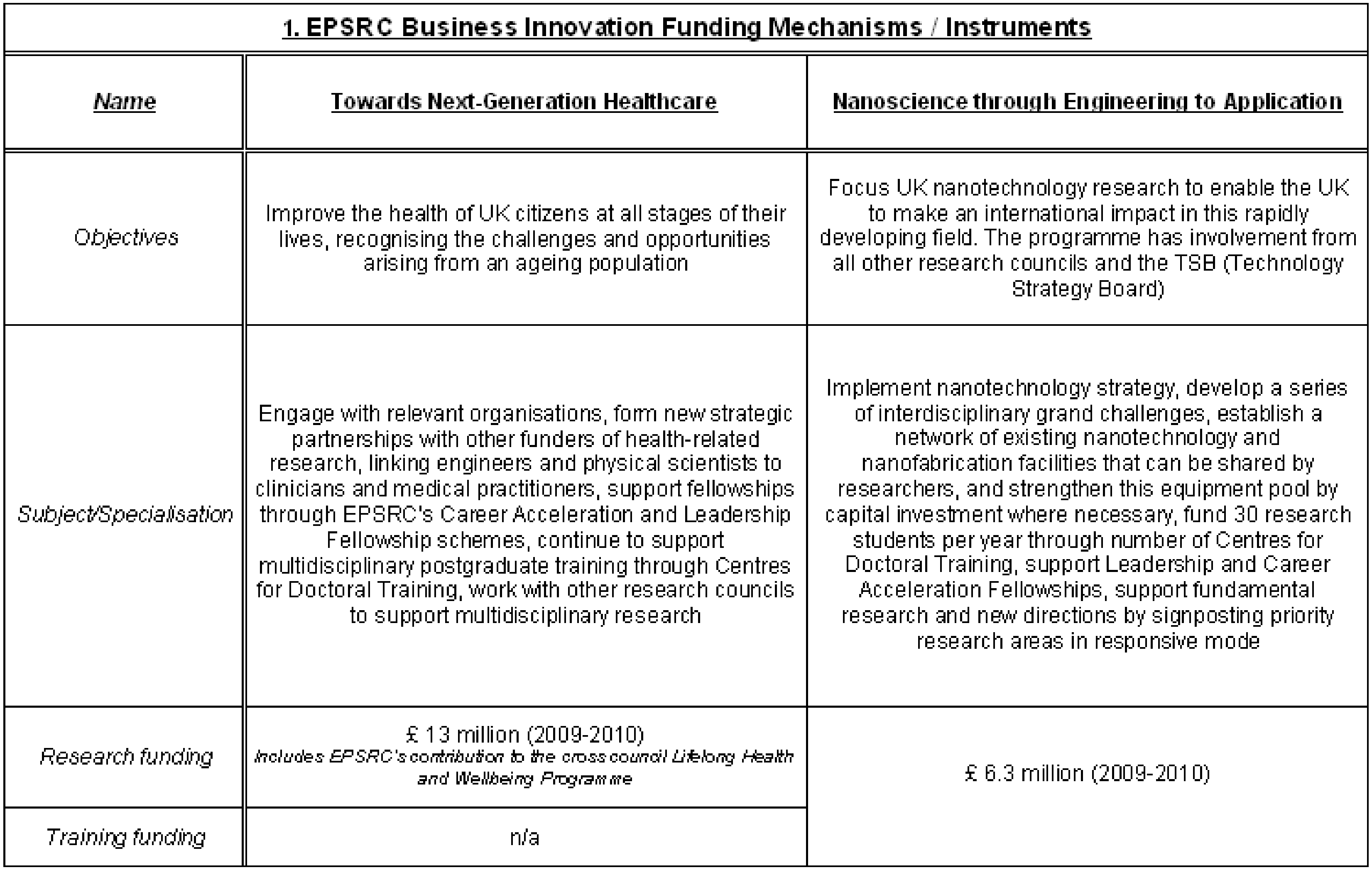
Name	**Physical Sciences**	**Process, Environment and Sustainability**	**Mathematical Sciences**
Objectives	Funds research and training in engineering to support the health of the discipline and to provide skills and knowledge for future needs	Funds research and training in engineering to support the health of the discipline and to ensure the skills and knowledge are available to meet future challenges	Funds research and training in engineering to support the health of the discipline and to provide skills and knowledge for future needs
Subject/Specialisation	Organic, physical and inorganic chemistry, condensed matter, atomic and molecular physics, plasma physics, laser physics, optics, quantum information processing, surface science, soft condensed matter, and fundamental physical functional aspects of materials	Process engineering, built environment and civil engineering, water, waste and coastal engineering, transport management, energy impact and adaptation to climate change, energy generation and distribution and electrical engineering, combustion, science and heritage, sustainable urban environment	Pure mathematics, applied mathematics, mathematical statistics and applied probability and the mathematical aspects of operational research
Research funding	£ 97 million (2008-2009)	£ 29 million (2008-2009)	£ 16 million (2008-2009)
Training funding	£ 43 million (2008-2009)	£ 7 million (2008-2009)	£ 16 million (2008-2009)



1. EPSRC Research Funding Mechanisms / Instruments

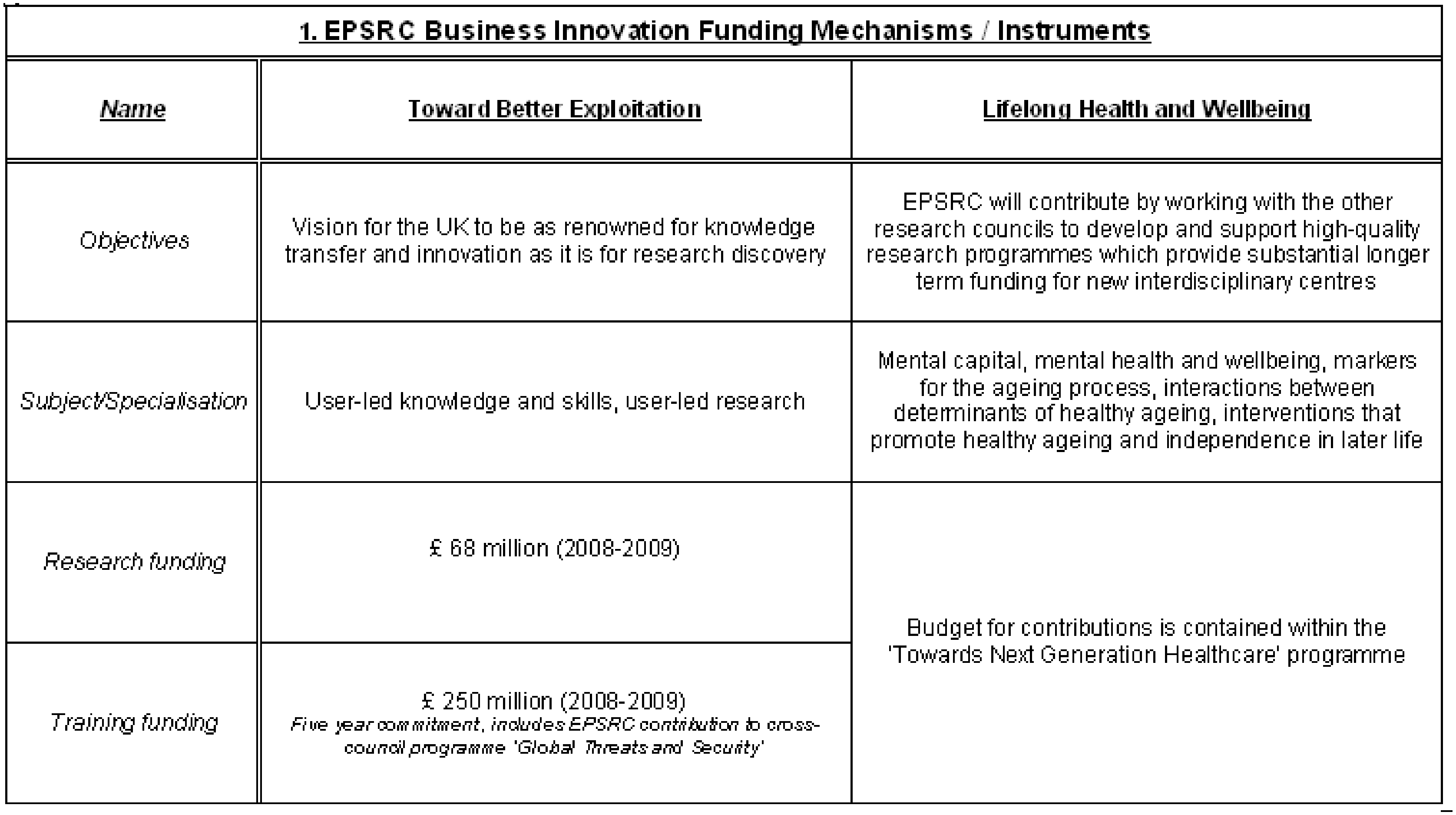
Name	**Research Infrastructure and International**	**Public Engagement**
Objectives	Ensuring that researchers have access to essential research infrastructures and managing our international strategy and interaction	Foster engagement between the EPSRC-funded research community and the public to stimulate greater understanding about the issues and opportunities that arise from research
Subject/Specialisation	Access to essential research infrastructure in a cost-effective way, international policy and strategy	Making sure EPSRC's thinking is informed by public attitudes and views, and societal implications. Enthusing young people about the creative process, issues, aspirations and outcomes of research. Enabling researchers to participate in effective engagement with the public, and to consider societal implications and public attitudes in the conduct and use of research. Informing the public about developments, achievements and impact of EPSRC-funded research to build awareness of research and account for our investment.
Research funding	£ 14 million (2008-2009)	£ 4 million (2008-2009)
Training funding	n/a	

1. EPSRC Business Innovation Funding Mechanisms / Instruments		
Name	**Digital Economy**	**Energy**
Objectives	Aspects of society and business that could be transformed by the innovative design and use of digital technologies. Led by EPSRC and working closely with ESRC, MRC, AHRC and TSB (Technology Strategy Board)	Led by EPSRC and working closely with BBSRC, ESRC, NERC and STFC to develop and deliver energy research and training within a common strategic framework
Subject/Specialisation	Deliver research that is driven by a real need with the ability to have impact, create a community of new researchers who understand the technology and how people use it and what the impact is, provide a focus for the interaction between researchers and key stakeholders	Energy research capacity, energy multidisciplinary applications
Research funding	£ 46 million (2008-2009) £ 18 million (2009-2010) £ 19 million (2010-2011)	£ 81 million (2008-2009)
Training funding	£ 34 million (2008-2009) *Five year commitment for centres for doctoral training*	£ 27 million (2008-2009) *Five year commitment, includes EPSRC contribution to cross-council programme 'Living with Environmental Change'. Does not include fusion expenditure.*



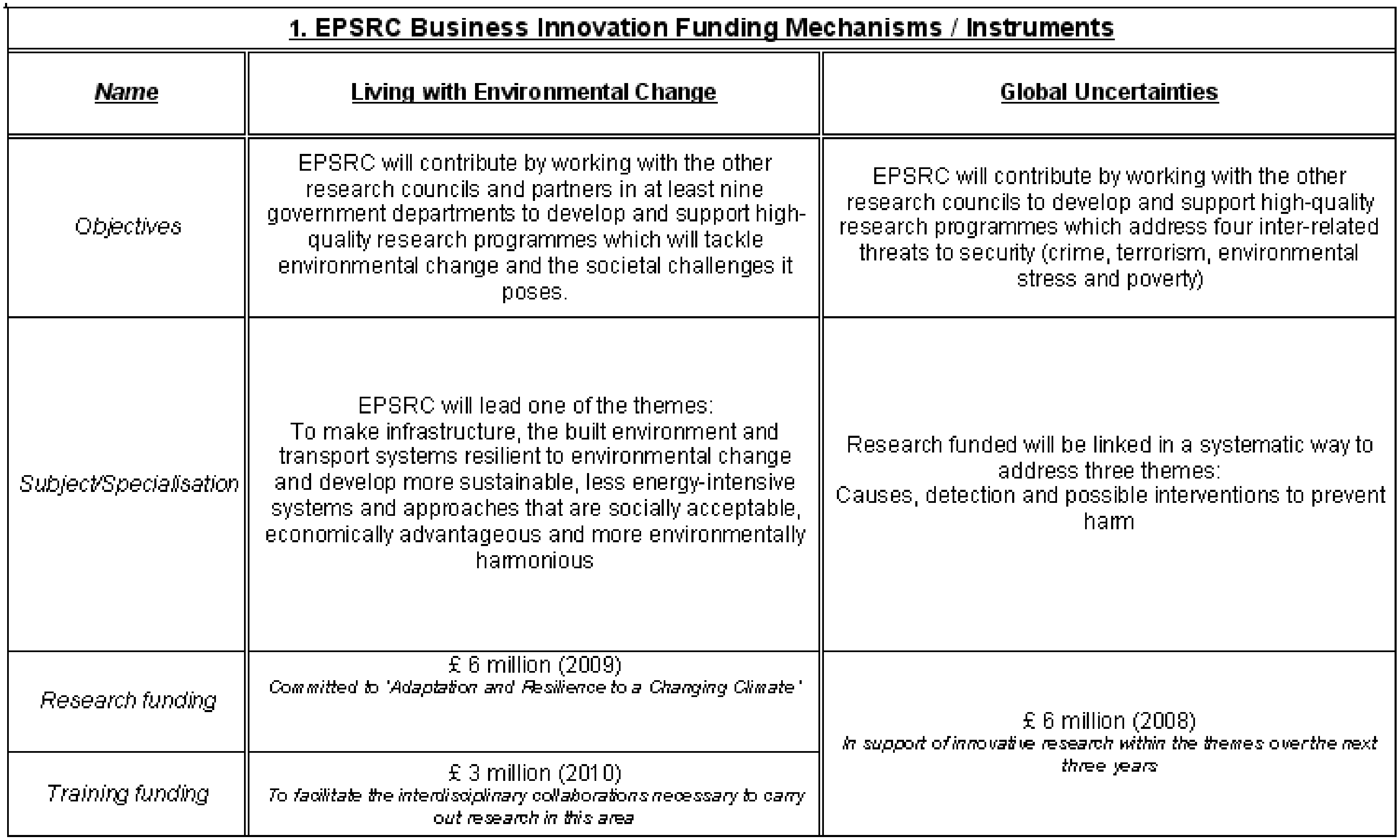
1. EPSRC Business Innovation Funding Mechanisms / Instruments

Name	**Towards Next-Generation Healthcare**	**Nanoscience through Engineering to Application**
Objectives	Improve the health of UK citizens at all stages of their lives, recognising the challenges and opportunities arising from an ageing population	Focus UK nanotechnology research to enable the UK to make an international impact in this rapidly developing field. The programme has involvement from all other research councils and the TSB (Technology Strategy Board)
Subject/Specialisation	Engage with relevant organisations, form new strategic partnerships with other funders of health-related research, linking engineers and physical scientists to clinicians and medical practitioners, support fellowships through EPSRC's Career Acceleration and Leadership Fellowship schemes, continue to support multidisciplinary postgraduate training through Centres for Doctoral Training, work with other research councils to support multidisciplinary research	Implement nanotechnology strategy, develop a series of interdisciplinary grand challenges, establish a network of existing nanotechnology and nanofabrication facilities that can be shared by researchers, and strengthen this equipment pool by capital investment where necessary, fund 30 research students per year through number of Centres for Doctoral Training, support Leadership and Career Acceleration Fellowships, support fundamental research and new directions by signposting priority research areas in responsive mode
Research funding	£ 13 million (2009-2010) *Includes EPSRC's contribution to the cross council Lifelong Health and Wellbeing Programme*	£ 6.3 million (2009-2010)
Training funding	n/a	



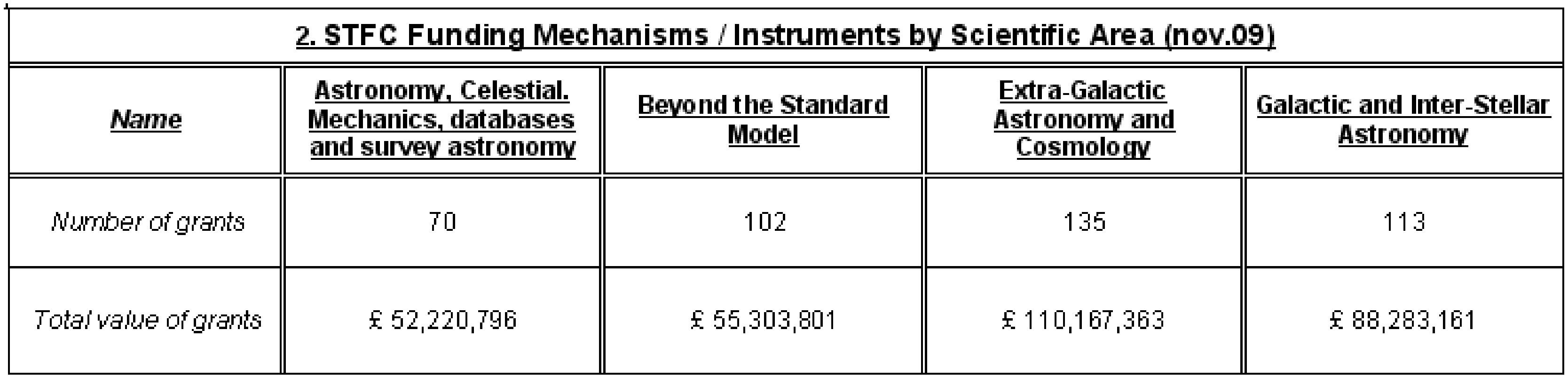
1. EPSRC Business Innovation Funding Mechanisms / Instruments

Name	**Toward Better Exploitation**	**Lifelong Health and Wellbeing**
Objectives	Vision for the UK to be as renowned for knowledge transfer and innovation as it is for research discovery	EPSRC will contribute by working with the other research councils to develop and support high-quality research programmes which provide substantial longer term funding for new interdisciplinary centres
Subject/Specialisation	User-led knowledge and skills, user-led research	Mental capital, mental health and wellbeing, markers for the ageing process, interactions between determinants of healthy ageing, interventions that promote healthy ageing and independence in later life
Research funding	£ 68 million (2008-2009)	Budget for contributions is contained within the 'Towards Next Generation Healthcare' programme
Training funding	£ 250 million (2008-2009) *Five year commitment, includes EPSRC contribution to cross-council programme 'Global Threats and Security'*	



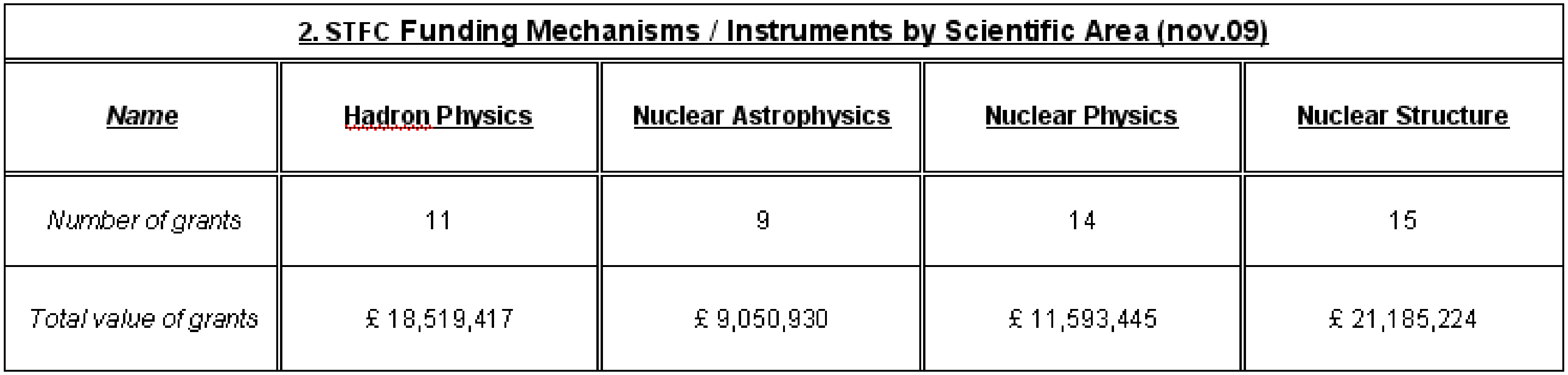
1. EPSRC Business Innovation Funding Mechanisms / Instruments

Name	**Living with Environmental Change**	**Global Uncertainties**
Objectives	EPSRC will contribute by working with the other research councils and partners in at least nine government departments to develop and support high-quality research programmes which will tackle environmental change and the societal challenges it poses.	EPSRC will contribute by working with the other research councils to develop and support high-quality research programmes which address four inter-related threats to security (crime, terrorism, environmental stress and poverty)
Subject/Specialisation	EPSRC will lead one of the themes: To make infrastructure, the built environment and transport systems resilient to environmental change and develop more sustainable, less energy-intensive systems and approaches that are socially acceptable, economically advantageous and more environmentally harmonious	Research funded will be linked in a systematic way to address three themes: Causes, detection and possible interventions to prevent harm
Research funding	£ 6 million (2009) ***Committed to 'Adaptation and Resilience to a Changing Climate'***	£ 6 million (2008) ***In support of innovative research within the themes over the next three years***
Training funding	£ 3 million (2010) ***To facilitate the interdisciplinary collaborations necessary to carry out research in this area***	



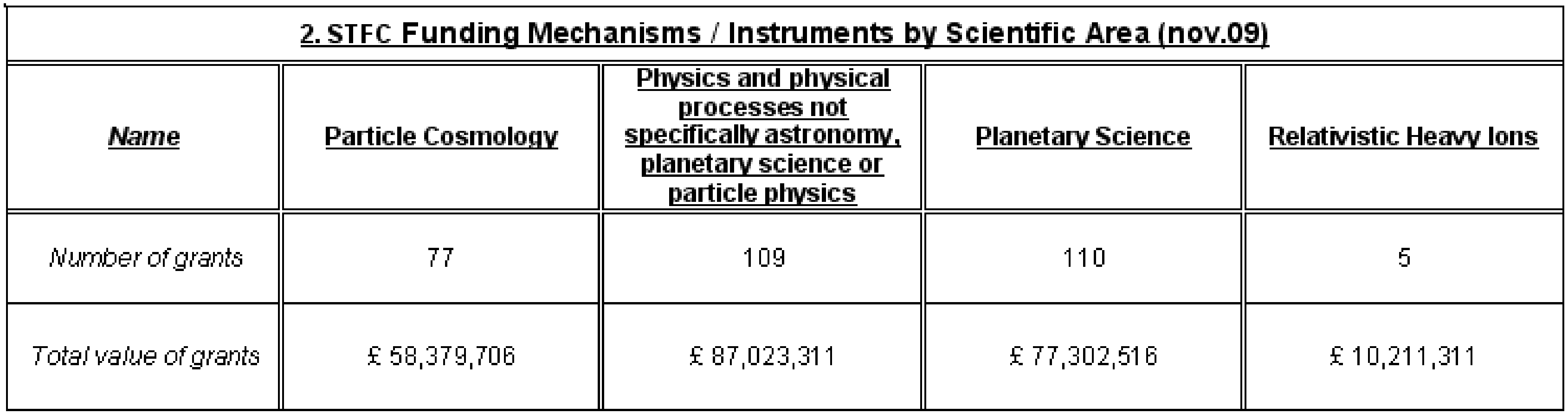
2. STFC Funding Mechanisms / Instruments by Scientific Area (nov.09)

Name	**Astronomy, Celestial. Mechanics, databases and survey astronomy**	**Beyond the Standard Model**	**Extra-Galactic Astronomy and Cosmology**	**Galactic and Inter-Stellar Astronomy**
Number of grants	70	102	135	113
Total value of grants	£ 52,220,796	£ 55,303,801	£ 110,167,363	£ 88,283,161

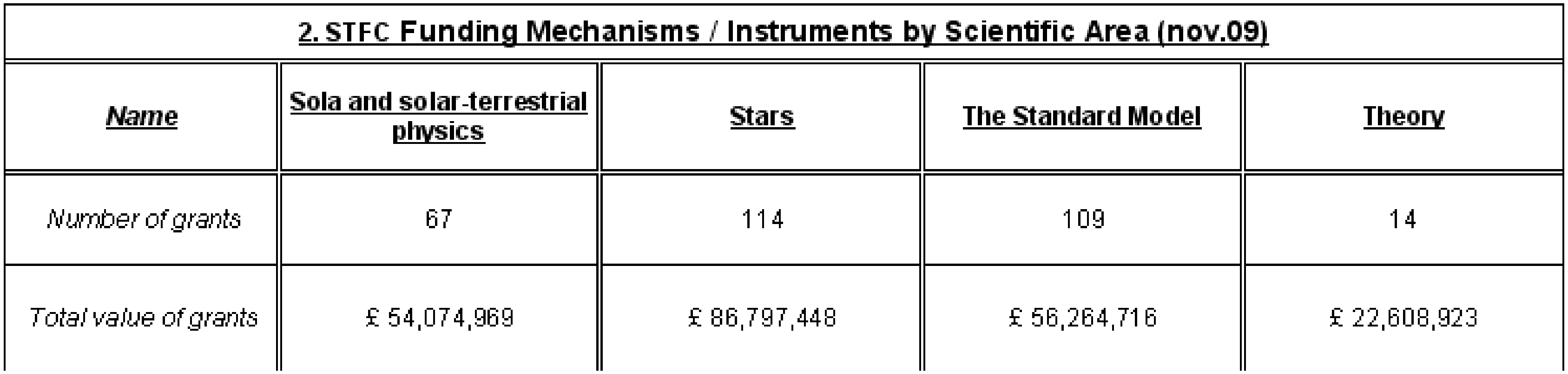


2. STFC Funding Mechanisms / Instruments by Scientific Area (nov.09)

Name	**Hadron Physics**	**Nuclear Astrophysics**	**Nuclear Physics**	**Nuclear Structure**
Number of grants	11	9	14	15
Total value of grants	£ 18,519,417	£ 9,050,930	£ 11,593,445	£ 21,185,224



2. STFC Funding Mechanisms / Instruments by Scientific Area (nov.09)				
Name	**Particle Cosmology**	**Physics and physical processes not specifically astronomy, planetary science or particle physics**	**Planetary Science**	**Relativistic Heavy Ions**
Number of grants	77	109	110	5
Total value of grants	£ 58,379,706	£ 87,023,311	£ 77,302,516	£ 10,211,311



2. STFC Funding Mechanisms / Instruments by Scientific Area (nov.09)				
Name	**Sola and solar-terrestrial physics**	**Stars**	**The Standard Model**	**Theory**
Number of grants	67	114	109	14
Total value of grants	£ 54,074,969	£ 86,797,448	£ 56,264,716	£ 22,608,923

5.2.10 The Netherlands

The Netherlands has four main funding bodies for research & development, which fall under two ministries, the Ministry of Education, Culture and Science (OCW), and the Ministry of Economic Affairs (EZ), with, respectively, nearly 90% of the government's total R&D expenditures in 2008, amounting to nearly € 5 billion[25].

The four main funding bodies are:

- NWO – The Netherlands Organisation for Scientific Research
- STW – Technology Foundation STW
- ZonMW – The Netherlands Organisation for Health Research & Development
- Agentschap – SenterNovem, EVD and Octrooicentrum Nederland merged

The Netherlands Organisation for Scientific Research (NWO), the national research council, was established in 1950 and acts as a funding agency for OCW. Its aim is to ensure that results of scientific research get prompt exposure and gain presence in society as new expertise or practical applications.

The Technology Foundation STW supports and finances research and promotes the utilisation of results to third parties, by operating as an independent part of NWO.

ZonMW is the national organisation for health research and development, appointed by the Ministry of Health and NOW and acts as an intermediary organisation (coordinating and granting) for both.

Agentschap is a very recently established, in 2010, organisation under the Ministry of Economic Affairs, EZ, ensuing from the merging of SenterNovem, EVD and Octrooicentrum Nederland. Its mission is to export excellence in international, innovation and sustainability administration. It works closely with Syntens, the national innovation network for entrepreneurs.

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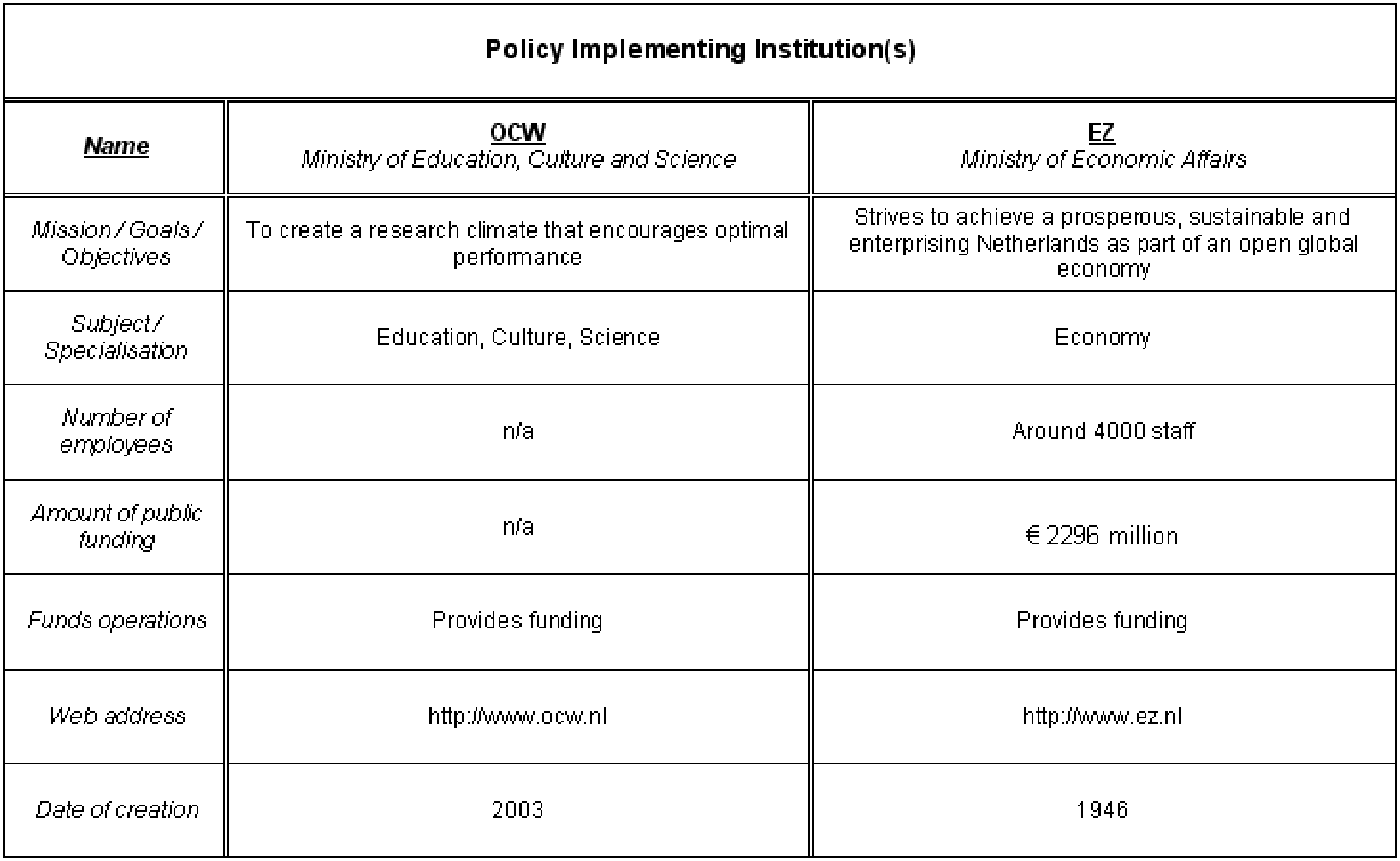
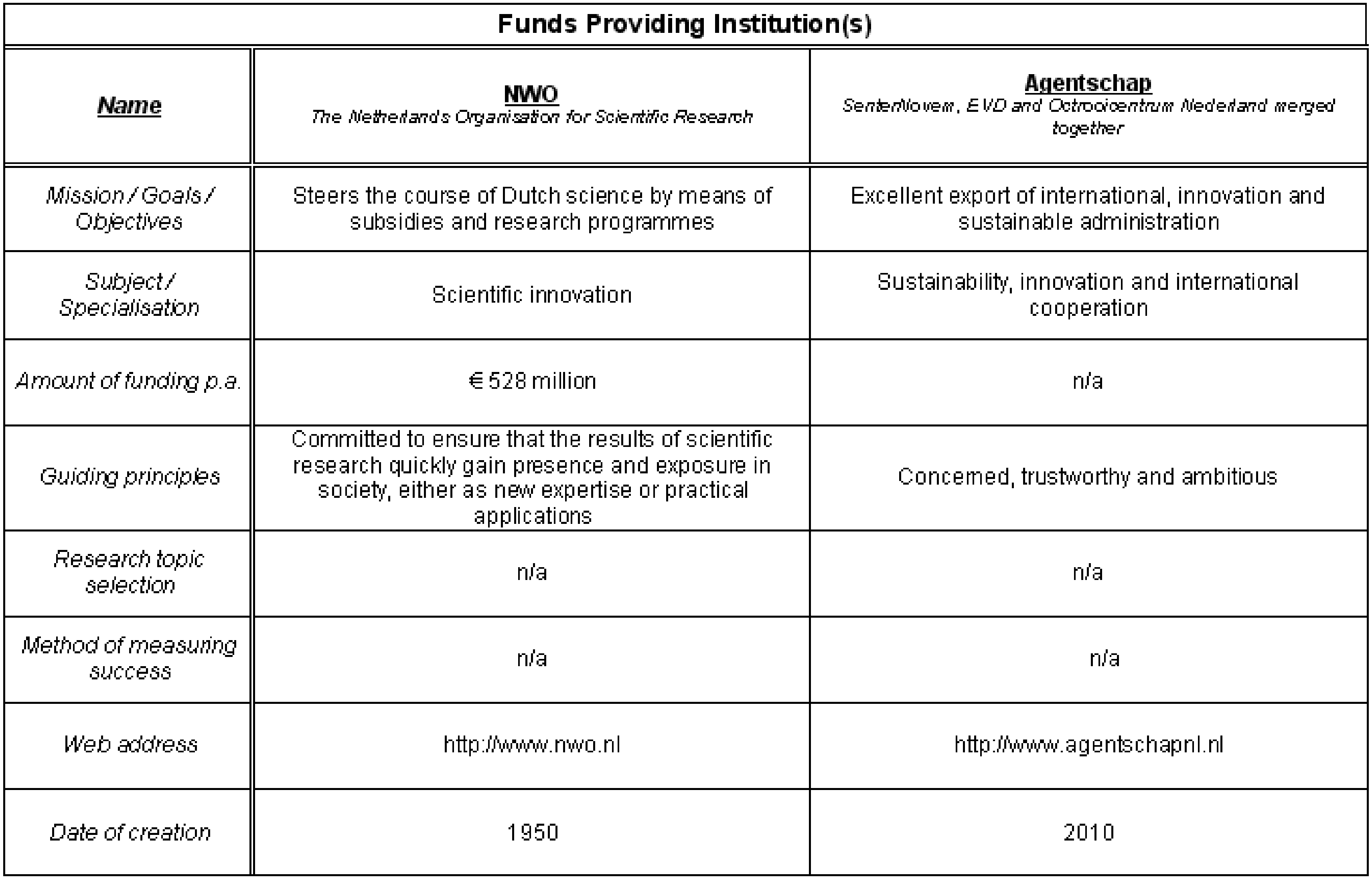
[25] ERAWATCH: Policy Mix Report 2009: The Netherlands. P25



Policy Implementing Institution(s)		
Name	**OCW** *Ministry of Education, Culture and Science*	**EZ** *Ministry of Economic Affairs*
Mission / Goals / Objectives	To create a research climate that encourages optimal performance	Strives to achieve a prosperous, sustainable and enterprising Netherlands as part of an open global economy
Subject / Specialisation	Education, Culture, Science	Economy
Number of employees	n/a	Around 4000 staff
Amount of public funding	n/a	€ 2296 million
Funds operations	Provides funding	Provides funding
Web address	http://www.ocw.nl	http://www.ez.nl
Date of creation	2003	1946



Funds Providing Institution(s)

Name	**NWO** *The Netherland's Organisation for Scientific Research*	**Agentschap** *SenterNovem, EVD and Octrooicentrum Nederland merged together*
Mission / Goals / Objectives	Steers the course of Dutch science by means of subsidies and research programmes	Excellent export of international, innovation and sustainable administration
Subject / Specialisation	Scientific innovation	Sustainability, innovation and international cooperation
Amount of funding p.a.	€ 528 million	n/a
Guiding principles	Committed to ensure that the results of scientific research quickly gain presence and exposure in society, either as new expertise or practical applications	Concerned, trustworthy and ambitious
Research topic selection	n/a	n/a
Method of measuring success	n/a	n/a
Web address	http://www.nwo.nl	http://www.agentschapnl.nl
Date of creation	1950	2010

Funds Providing Institution(s)

Name	**STW** *Technology Foundation STW*	**ZonMW** *The Netherlands Organisation for Health Research & Development*
Mission / Goals / Objectives	Creates opportunities for innovation in science, technology and society	Acts as an intermediary between policy, research and practice
Subject / Specialisation	Works on the interface of science and society	Health
Amount of funding p.a.	€ 50 million in 2005…	€ 100 million
Guiding principles	Bring together researchers and potential users of the results of that research	Only the active exchange of ideas, knowledge and experience can allow the innovation cycle to flourish and help create a cutting-edge society
Research topic selection	n/a	Expert committees advised by independent experts (referees) select suitable proposals
Method of measuring success	n/a	n/a
Web address	http://www.stw.nl	http://www.zonmw.nl
Date of creation	1981	n/a

5.2.11 Sectorial Innovation Watch

The Sectorial Innovation Watch (SIW) is a mechanism for the monitoring and analysing of innovation performance in different sectors. Its aim is to provide policy makers and stakeholders with a better understanding of the sectorial drivers, barriers and challenges that surround innovation across the EU. This is an essential premise to the making of effective innovation policies at regional, national and European levels.

During its first two year phase from 2006-2008, SIW analysed a large number of factors that can drive or hinder innovation in 11 industrial sectors, which, amongst others, included:

- financial constraints,
- human resources and skills,
- knowledge creation and diffusion,
- cooperation between firms and informal networks,
- demand factors,
- competition,
- innovation culture,
- aspects of regulation and taxes.

They identified three major challenges spanning across all of the industrial sectors, namely:

1. the need for further development of human capital,
2. the need for improved support for knowledge creation, diffusion and technology transfer,
3. the need for overcoming financial constraints.

In its second two year phase from 2008-2010, SIW will continue its sectoral analyses, with more emphasis on:

- services sectors
- wholesale
- retail trade
- construction
- eco-innovation
- fast-growing SMEs
- organisational innovation
- lead markets and national specialisation
- greening industries

It will also takes into consideration important linkages between sectors through the application of a cross-sectoral approach.

Sectorial Innovation Watch

SIW is implemented by a consortium comprising 11 partners -TNO (NL), Joanneum Research (A), KITeS (I), AIT (A), VTT (F), IWW (D), BTU (D), PRAXIS (EST), Institute for Economic Research (SLO), University of Alcalá (E), Dialogic (NL) - from 8 different Member States and these are described briefly below. It is coordinated by Netherlands Organization for Applied Scientific Research (TNO): Dr. Carlos Montalvo, P.O. Box 49, 2600AA Delft, The Netherlands, Tel.+ 3115 269 54 90, Fax + 31 15 262 43 41, http://www.tno.nl/

5.2.12 High Tech Campus Eindhoven in the Netherlands

The High Tech Campus Eindhoven has become the embodiment of the open innovation philosophy. Over 90 companies and institutes have already established themselves at the site, all in a dynamic mix of multinational companies, small and medium-sized businesses and technology start-up companies. The centre houses thousands of engineers and advanced facilities.

High Tech Campus Eindhoven facilitates open innovation. Campus residents share knowledge, experience, open laboratories and technical infrastructure, enabling better, faster and more cost efficient innovation. It provides an open environment that fuels opportunities for valuable R&D, for successful business partnerships, and a great place to work.

It focuses on crucial technological areas such as Microsystems, infotainment, thigh technology systems, embedded systems, life technology and nanotechnology. With ‘Open Innovation’ as its motto, technological breakthroughs are facilitated by the emphasis on sharing equipment, services and knowledge. Technologically advanced companies are located there including Philips Resaerch, IBM, Atos Origin, FluXXion, ASML, Cytocentrics, NXP, Handshake Solutions, and Dalsa. Other companies are near by like FEI Company and TNO Industrial Technology as well as the Eindhoven University of Technology, one of Europe’s leading universities in science, engineering and technology, as well as other universities like Leuven and Aachen are also very close by. The campus has a dynamic environment and attracts new high-tech companies and excellent research groups. It has been recognised as one of Europe’s technology and innovation incubators where industry and research institutes/universities meet to work on the future.

The Holst Centre is one of the initiatives located at the campus. Its aim is to be internationally recognised and a leading R&D centre in the fields of wireless autonomous transducer solutions, system-in-foil, with strong industrial participation. The planned structure of the centre is an open one: other participants will be sought out and welcomed in a healthy balance between industry and knowledge institution. The available research infrastructure at the campus (i.e. MiPlaza clean rooms and associated facilities) is very attractive for the programme lines envisaged by the Holst Centrer, which will work intensively with innovative SMEs.

5.2.13 France

France possesses two main funding bodies for research and development, under the Ministries of, Higher Education and Research, and of, Economy, Industry and Employment, which were established recently (ANR the National Agency for Research, and OSEO innovation responsible for funding SME R&D).

The National Agency for Research, established in 2005, has as its mission the funding of exploratory research projects under the thematic priorities defined by the Government. The agency’s call for proposals is structured around seven themes, through which the majority of its funding is distributed.

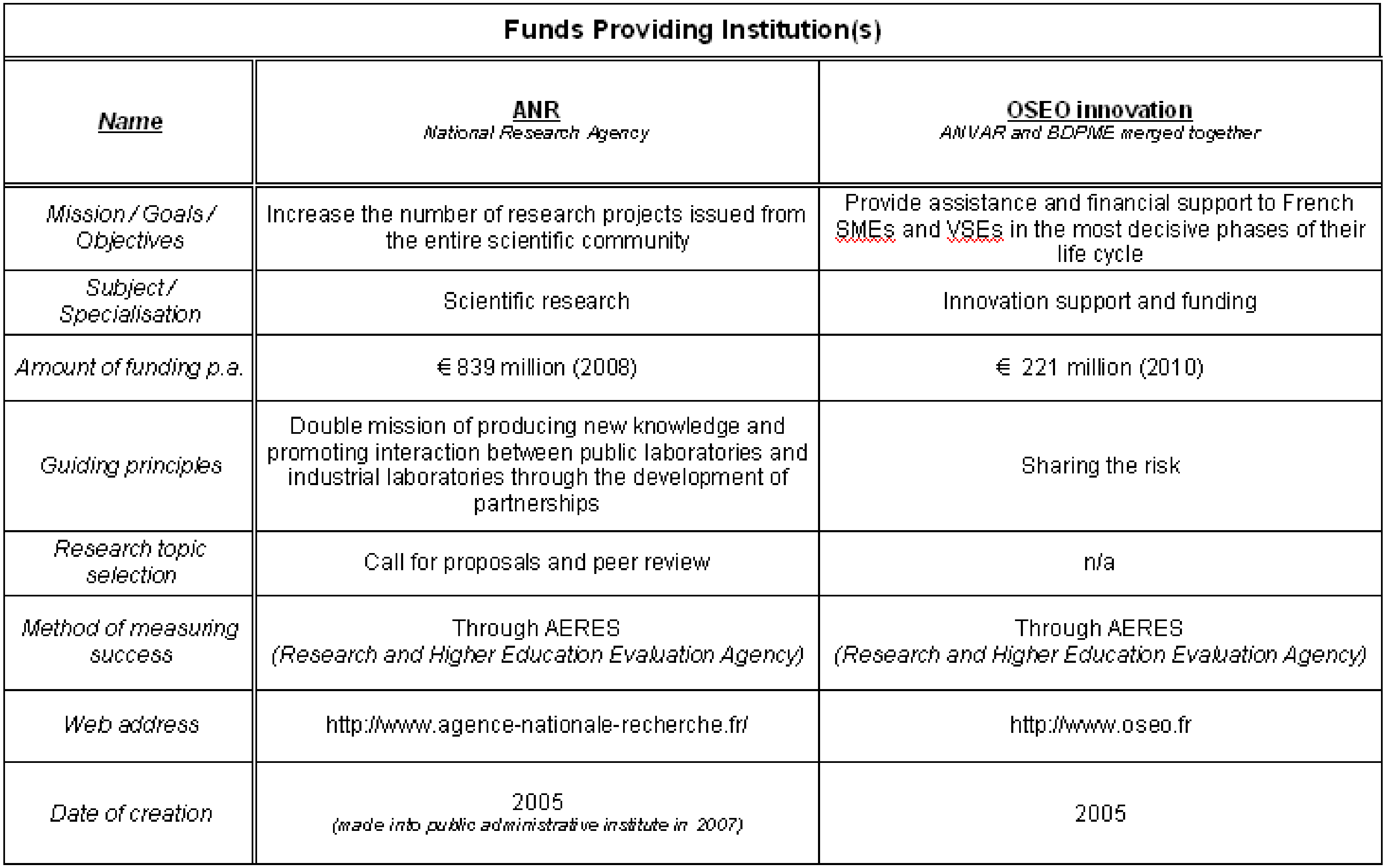
The OSEO group was formed in 2005 by the merging of ANVAR (French innovation agency) and BDPME (SME development bank) with a mission of general interest to support regional and national policies. It has three instruments:

- OSEO Innovation
- OSEO Finance
- OSEO Guarantee

OSEO innovation is the programme concerned with research & development, and contains the dissolved (in 2008) Agency for Industrial Innovation (AII) from which an industrial strategic innovation instrument ensued in early 2008: Strategic Industrial Innovation (ISI), which had a total funding allocation of € 300 million for partnership-based projects in 2008.

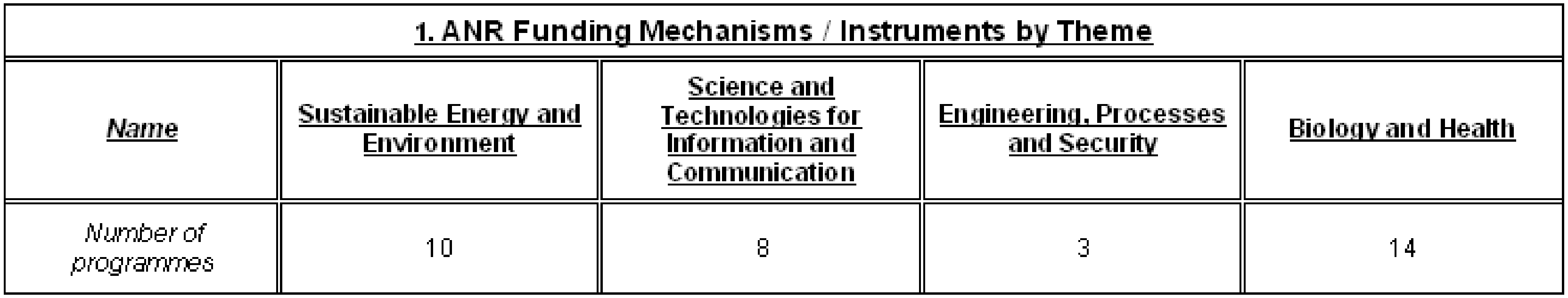
Policy Implementing Institution(s)

Name	**MESR** *Ministry of Higher Education and Research*	**MINEFE** *Ministry of Economy, Industry and Employment*
Mission / Goals / Objectives	Prepares and executes government policy	Prepares and executes government policy
Subject / Specialisation	Research, innovation, higher education and professional insertion	Economy, finance, employment, professional training, consumer affairs and fraud control, foreign trade, industry, postal and electronic communications and tourism
Number of employees	n/a	n/a
Amount of public funding	€ 29,172 billion	€ 16,329 billion
Funds operations	Provides funding	Provides funding
Web address	http://www.enseignementsup-recherche.gouv.fr/	http://www.minefe.gouv.fr/ http://www.economie.gouv.fr/
Date of creation	2007	2007



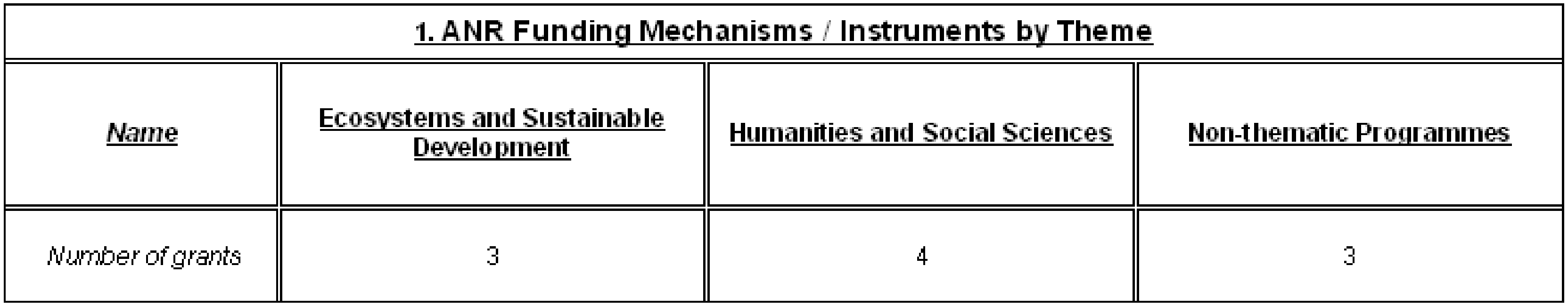
Funds Providing Institution(s)

Name	**ANR** *National Research Agency*	**OSEO innovation** *ANVAR and BDPME merged together*
Mission / Goals / Objectives	Increase the number of research projects issued from the entire scientific community	Provide assistance and financial support to French SMEs and VSEs in the most decisive phases of their life cycle
Subject / Specialisation	Scientific research	Innovation support and funding
Amount of funding p.a.	€ 839 million (2008)	€ 221 million (2010)
Guiding principles	Double mission of producing new knowledge and promoting interaction between public laboratories and industrial laboratories through the development of partnerships	Sharing the risk
Research topic selection	Call for proposals and peer review	n/a
Method of measuring success	Through AERES *(Research and Higher Education Evaluation Agency)*	Through AERES *(Research and Higher Education Evaluation Agency)*
Web address	http://www.agence-nationale-recherche.fr/	http://www.oseo.fr
Date of creation	2005 *(made into public administrative institute in 2007)*	2005



1. ANR Funding Mechanisms / Instruments by Theme

Name	**Sustainable Energy and Environment**	**Science and Technologies for Information and Communication**	**Engineering, Processes and Security**	**Biology and Health**
Number of programmes	10	8	3	14



1. ANR Funding Mechanisms / Instruments by Theme

Name	**Ecosystems and Sustainable Development**	**Humanities and Social Sciences**	**Non-thematic Programmes**
Number of grants	3	4	3

Acknowledgments

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