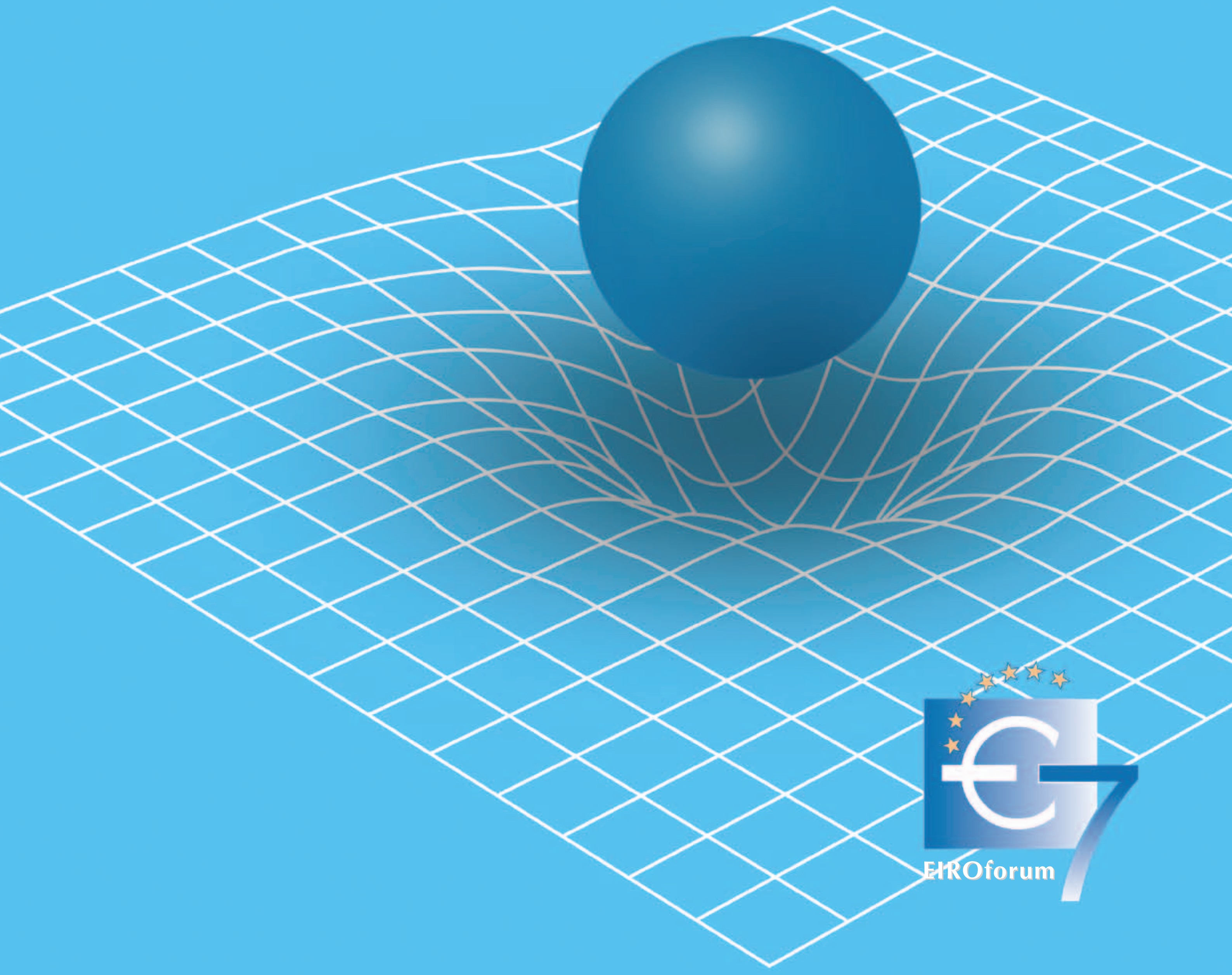
Towards a Europe of Knowledge and Innovation

World-class research as the centrepiece of the knowledge-based economy

Perspectives from the EIROforum on Europe's route towards the Lisbon targets



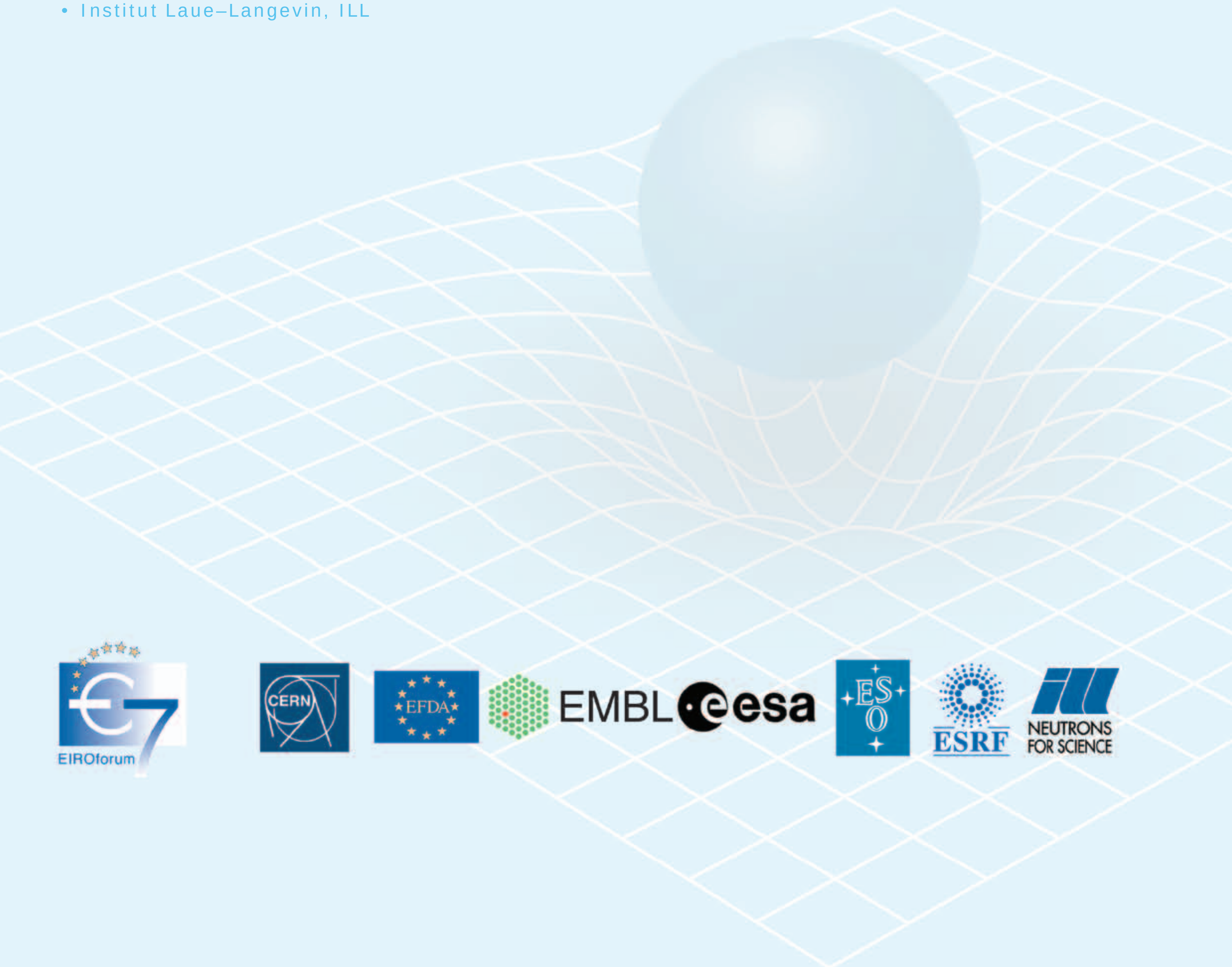
EIROforum

EIROforum, serving European science

The EIROforum is a partnership between the seven European intergovernmental scientific research organisations that are responsible for infrastructures and laboratories. As world leaders within their respective fields of science, the seven member organisations of the EIROforum constitute the vanguard of European science, enabling European scientists to engage in truly cutting-edge research and be competitive on a global scale. These organisations have a vital role to play in the future of European research.

The seven EIROforum members are:

- European Organisation for Nuclear Research, CERN
- European Fusion Development Agreement, EFDA
- European Molecular Biology Laboratory, EMBL
- European Space Agency, ESA
- European Southern Observatory, ESO
- European Synchrotron Radiation Facility, ESRF
- Institut Laue–Langevin, ILL



Foreword

The EIROforum Vision for Science and Europe

I am proud that the European Space Agency currently holds the chair of the EIROforum, the partnership comprising Europe's seven intergovernmental research organisations that operate large infrastructures for science.

Science underpins a healthy and wealthy society. Not only does science lie behind all technological advances, but – in addition – the inspiration of scientists challenges and drives new technological development. In addition, spin-offs from technical advances for modern science often lead to unpredicted benefits well beyond any original intended use. Scientific research is a major technology driver for Europe and the international scientific organisations of EIROforum play a major part.

Science inspires because it questions our understanding of ourselves and our world. Where do we come from? What are we made of? How did life evolve? How did the universe begin? How did our planet form? Are we alone? Will we be able to sustain life in the future? From biology, through materials sciences and energy research to fundamental physics and cosmology, the EIROforum organisations pursue grand questions that have always concerned humankind.

Science is a team effort and frequently needs special facilities. Big questions often need big teams and big facilities. Europe long ago solved the problems of providing these through intergovernmental European science research organisations, now grouped in EIROforum. These organisations serve to bring together scientists from all over Europe to work with facilities that are not only world-leading but are also beyond the means of many if not all of the individual nations in Europe.

The process of European scientists working together has been going on for fifty years since the formation of the European particle physics research organisation, CERN. Now, in many areas, the work is done and the facilities offered by the EIROforum organisations ensure that Europe leads the world.

The EIROforum organisations are a symbol of the new Europe; they present visible proof that Europe and Europeans working together can achieve more than any individual national effort. As the European Union borders expand and the peoples and countries of Europe come together, there is a fundamental role for the EIROforum organisations to play in conjunction with the institutions of the European Union in the evolving environment.

That is why the EIROforum has decided to launch this document, in order to present to the main stakeholders and promoters of science policy in Europe and to the general public, our vision for the years to come.

Jean-Jacques Dordain
Director General of ESA

EIROforum

CERN EFDA EMBL esa ESO ESRF NEUTRONS FOR SCIENCE

Executive Summary

Over the last 50 years, a number of countries in Europe have established a series of strong, intergovernmental research organisations and facilities to address a wide range of fundamental questions in the natural sciences. These organisations have evolved to become world-leaders within their respective areas of inquiry and competence and constitute an important, forward-looking element of Europe's research effort. The success of the organisations demonstrates the true potential of European research and proves the validity of the idea of pan-European collaboration in science.

In 2002 seven of Europe's major intergovernmental research organisations came together to form the EIROforum partnership with the aim to exploit synergies between its members. The EIROforum members and their fields of interest are:

- The European Laboratory for Particle Physics (CERN): nuclear and particle physics;
- The European Fusion Development Agreement (EFDA): fusion research;
- The European Molecular Biology Laboratory (EMBL): molecular biology;
- The European Space Agency (ESA): space research;
- The European Southern Observatory (ESO): observational astronomy;
- The European Synchrotron Radiation Facility (ESRF): biology, chemistry, materials and physics research employing synchrotron X-rays;
- Institut Laue-Langevin (ILL): biology, chemistry, materials and physics research employing neutron beams.

The vision of EIROforum is to create a climate in Europe in which relevant, competitive scientific research can be undertaken in an efficient, cost-effective and successful way.

However, this cannot mask the fact that, in a global competition, European science in general needs to be strengthened in the face of strong global competition. This is the basis for the establishment of the European Research Area (ERA) as a way to counter fragmentation, to assemble critical mass, to achieve better utilisation of resources, etc. The ERA serves as a key element of Europe's strategy towards the realisation of the Lisbon goals of becoming the world's most dynamic, knowledge-based economy by the year 2010. This document reviews the challenges to science implied by the Lisbon goals and presents both a number of proposals and conditions that must be fulfilled for science, including the EIROforum organisations, to be able to support Europe's ambitious drive towards the future.

Supporting the knowledge-based society

It is evident that science as a whole has a significant role to play in support of a society which has placed knowledge creation at the heart of its vision. Because the EIROforum partner organisations have developed essential communication tools, such as the World Wide Web and the Grid concept of distributed computing, they can, collectively and individually, give focus and support to the European scientific community, in developing these strategies.

Interfacing with society

Developing and exploiting the benefits of the knowledge-based society can only happen in an overall framework of dialogue and public engagement with science.

The challenge is to build on the well-documented public interest in science, using all forms of communication to foster dialogue and interest, to serve the dual purpose of enhancing public understanding of science and securing the future workforce for Europe's R&D undertakings. In particular a dedicated effort to improve science education in Europe's primary and secondary schools is crucially important. It is therefore proposed that a pan-European Partnership for Science Education be established in order to find common solutions to these problems. The Partnership would involve the education authorities of the member states, science centres, key teaching networks, the EIROforum organisations, the European Commission, Academies of Science and learned societies, each of whom would undertake agreed actions at an appropriate scale and of a sufficiently wide scope in order to improve science education.

Regrettably, the collective nature of science and the fact that research is increasingly conducted by Europe-wide research teams, is not reflected in media reporting. This leads to a lack of visibility of science in its 'European dimension'. The low visibility of European science is the outcome of the low priority given to public science communication by most European research institutes, combined with the communication obstacles resulting from the multiplicity of languages in Europe and the organisation of the media and news services along national lines. By contrast, research institutes in the USA maintain a high level of public communication with a resulting high degree of public visibility. New initiatives are needed to help Europe's universities and science institutes to achieve the visibility they need and, indeed, deserve. One such initiative would be to establish a European Science Press Agency to cover developments of science in Europe and make its reports available in several languages to newspapers, radio, television and various World Wide Web sites.

Securing adequate human resources

For Europe to become and remain a world leader, it is also essential to have available a large body of highly educated and experienced S&T personnel with access to sophisticated and technologically advanced facilities and infrastructures. Current demographic and cultural trends, paired with human resource policies entrenched in local, regional and national regulations and practices make it difficult for Europe to mobilise its best young talent for European research. The challenge is to provide the intellectual, cultural and financial incentives to retain European researchers and to attract non-European researchers in the research and development areas considered by Europe to be of high priority. Key issues are attracting and retaining talent, which requires clear career perspectives, and fostering mobility via practices that encompass well-organised recruitment procedures, the accompanying social security measures and adequate professional incentives. On a European scale, the task is to devise career path and mobility 'systems' that function as an integrated whole.

The EIROforum proposes to engage constructively in this area in conjunction with the European Commission and others, setting out concrete measures in support of European initiatives to address this fundamental problem.

The aim is to create an overall environment that is conducive to high quality scientific research, but there is a link between the recruitment and retention of talent and the creation of a pan-European area of competition and cooperation. EIROforum therefore supports the proposal put forward for a European Research Council, as an autonomous, science-driven agency endowed with a significant fund to support competitive research at world-level.

EIROforum and European Industry

The challenge for Europe is to maintain, and indeed increase, its international competitiveness in high technology areas and, at the same time, to secure European self-reliance by ensuring that its technology edge remains sharp and its competence base remains strong. The EIROforum organisations can play an important role in addressing this challenge because they aim at knowledge creation through fundamental, often long-term, research using the most advanced scientific instruments. They are at the cutting edge of research in their respective fields and use, develop, integrate and spawn advanced technologies.

For certain high-technology areas in which European industry is falling behind, the EIROforum organisations together with Europe-based companies could consider common policy tools, such as a 'Technology Platform' or a large integrated project, in order to benefit from the potential of a more unified and less dispersed market.

Looking beyond Europe

In addition to providing the foundation for our independence, scientific and technological competence is a precondition for global competitiveness and the key to successful partnerships. In order to benefit from global collaboration, Europe must build and secure its own competence in science and technology and be ready and able to act as a single entity to reap the full benefits.

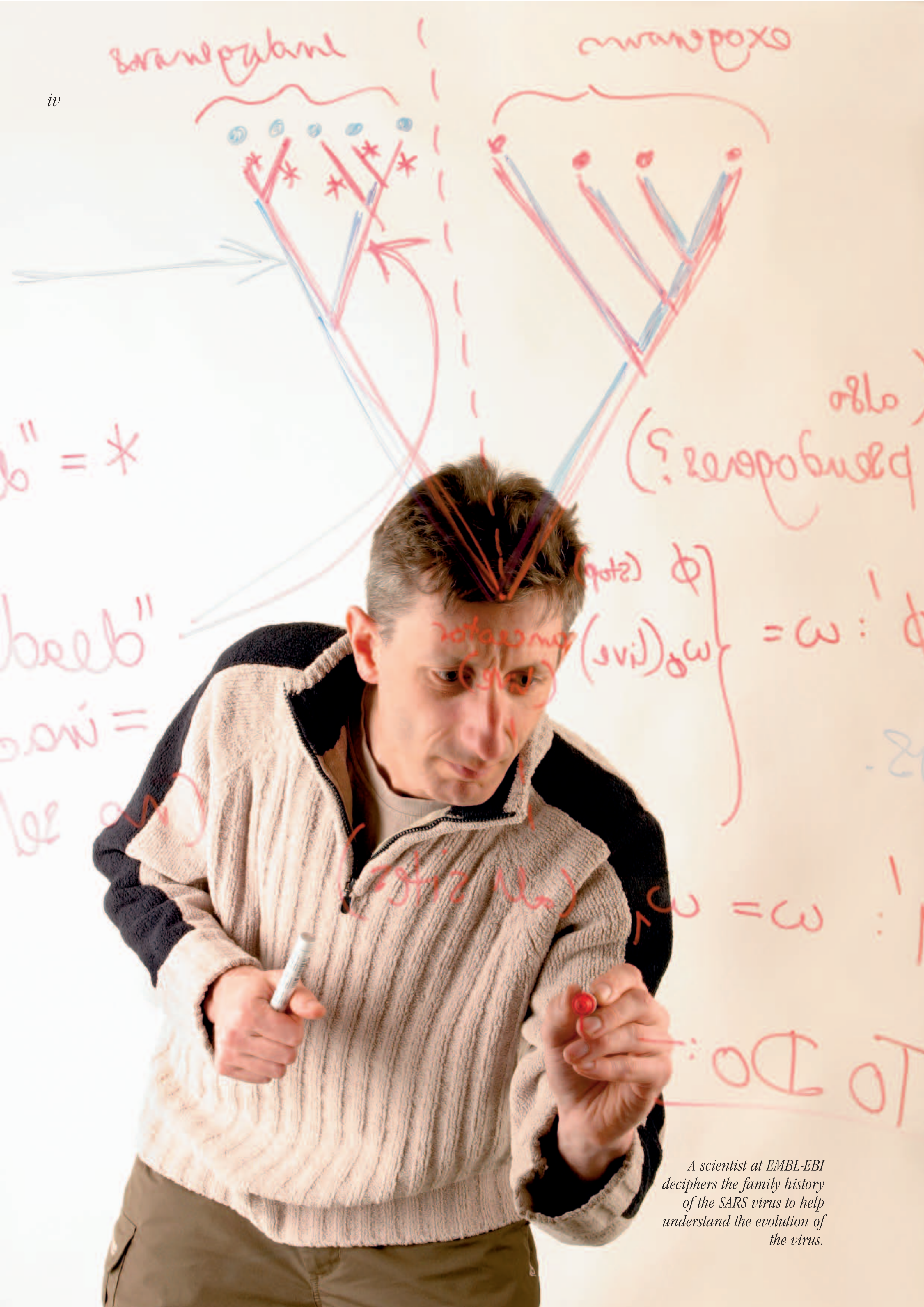
By virtue of their activities and their inherent multicultural character, the EIROforum member organisations can play important roles in projecting Europe's image and aspirations and in serving as interfaces between Europe and the wider world. In particular, the EIROforum partners can

- provide a scientific, technological and cultural bridge between Europe and other regions of the world;
- link to bilateral cooperation agreements between the European Union and third parties;
- serve as Europe's focal point for appropriate international or global scientific projects.

EIROforum and the European Research Area

The continuing success of European science is critically dependent on its researchers being able to gain access to Europe's global centres of excellence, such as the EIROforum partner organisations. Therefore these centres must be maintained and reinforced.

Over recent decades each of the organisations has successfully created an effective and functioning ERA in its respective discipline. They are therefore well placed to help foster the wider ERA. Hence, the EIROforum organisations should participate more actively and in accordance with their status in the development of the European Research Area and its governance. At present, however, European science policy discussions and decision-making is predominantly in the domain of national organisations and the European Commission and has not yet embraced the views and uniquely relevant experience of the EIROforum organisations. In fact, the EIROforum organisations are not being involved in many European science policy discussions and decision-making processes precisely because they are European and not national organisations.



A scientist at EMBL-EBI deciphers the family history of the SARS virus to help understand the evolution of the virus.

For the ERA to develop and enable the future research infrastructures needed by Europe's scientists, coordinated decisions at a European level are necessary. A major challenge will be to establish a coherent system of governance for European research enabling a fruitful relationship between the individual EIROforum organisations on the one hand and the bodies established to facilitate the open method of coordination on the other. A further challenge is to ensure that the means exist for the creation and operation of new infrastructures; especially those that are to be established in scientific fields in which no intergovernmental organisation currently exists.

Whatever decision mechanisms may be established, they must fulfill the needs and respect the pace of modern science. This implies flexibility, responsiveness and inclusiveness. Flexibility is needed to allow a dynamic approach. Being responsive means reacting, in a timely manner, to new challenges, such as may arise as new fields of science emerge. Establishing major scientific facilities requires society to invest significant resources. Decisions must, of necessity, be taken through a political process. But the decision mechanism must be inclusive, in the sense of integrating, and according high priority to, the best available scientific advice, based on experience.

New structures for the organisation and management of research at the European level must therefore take full account of the experience, expertise and scientific authority of the EIROforum organisations, as embodied in their international conventions.

The members of the EIROforum Council hope that this paper will serve as a useful contribution to the ongoing debate about the Lisbon goals and the related science policy issues. We believe that this debate and its outcome are crucial to the future of our Continent.

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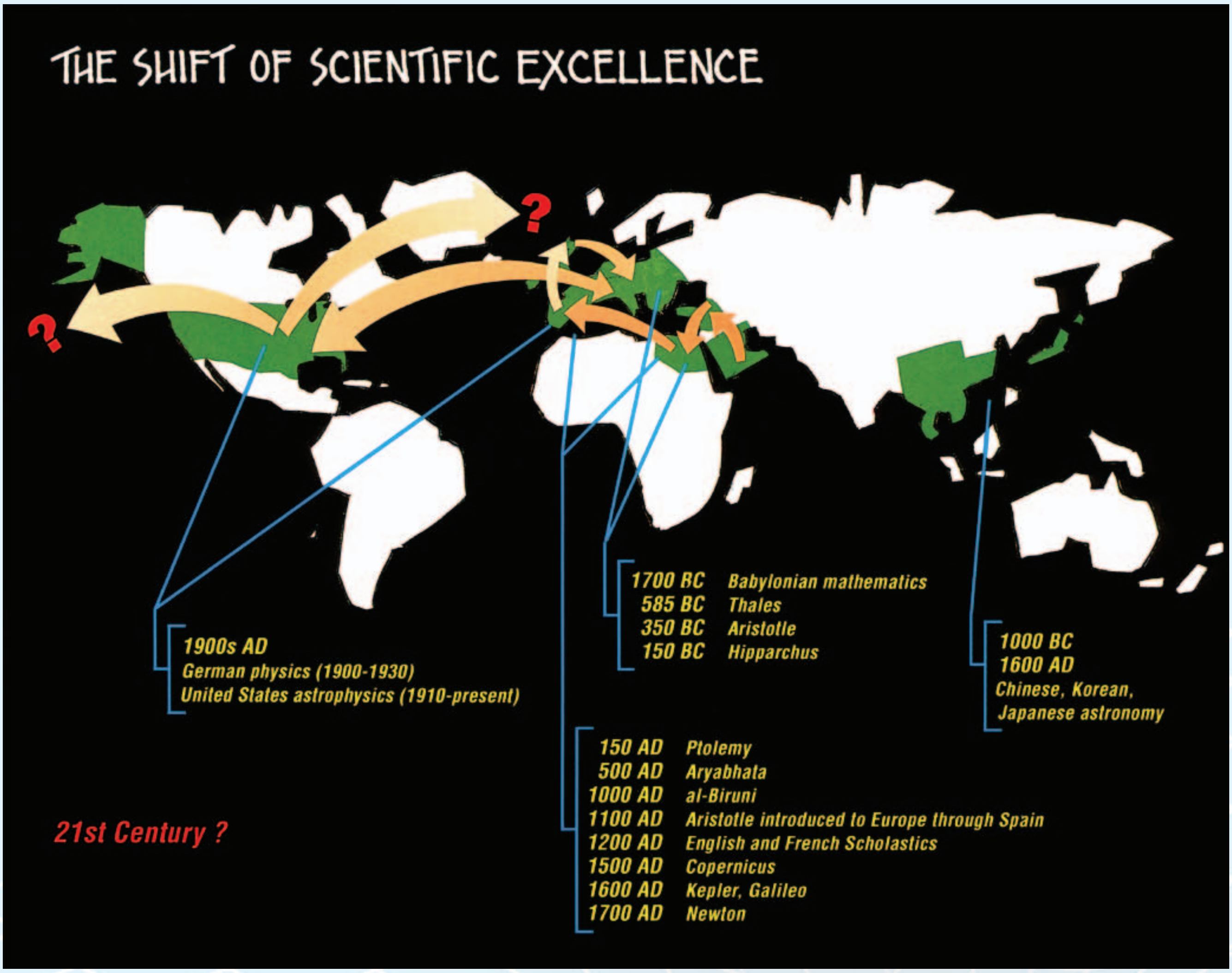


Increasingly scientific competence dictates our ability, as individuals and as nations, to execute free and informed choices, reflecting our cultural roots and traditions as well as the principles of freedom and democracy. In the words of Robert Gilpin[1], science is becoming 'the most critical single factor in military power, economic growth and public'. More recently, UK Foreign Secretary Jack Straw wrote[2]: 'S&T drive our economic prosperity, our social development and provide some of the tools and solutions to help with the global challenges of our common futures.... Increasingly S&T shape foreign policy, shape diplomacy, shape the way we interact with the world, shape the world of the 21st century'.

The strategic importance of scientific leadership is of course recognised worldwide as is documented by the above illustration, from a NASA document, illustrating the global shift of 'scientific excellence' – in astrophysics – over time as perceived from a US perspective. (Courtesy NASA)

[1] *Gilpin, R: 'France in the Age of the Scientific State', Princeton University Press, 1968.*
[2] *Straw, Jack: 'National viewpoint – Science shapes foreign policy, diplomacy and our very world', Research Europe, p.13, 169, 2004.*

1. Introduction

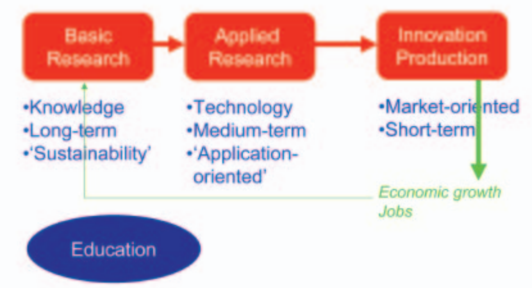
The role of science

At its meeting in Lisbon in March 2000 the European Council, facing the challenges posed by globalisation and the emergence of the knowledge-based economy, set out an ambitious and visionary ten-year economic strategy. This 'Lisbon strategy' was conceived to turn the European Union into the world's most dynamic and competitive knowledge-based economy by the year 2010. Under the strategy, a stronger economy will drive job creation that should ensure, alongside the formulation of social and environmental policies, sustainable development and social inclusion. Important elements of the strategy include promoting growth-oriented economic policies[3], fostering competitiveness (as the key to generating and maintaining growth and employment), delivering more and better employment and ensuring sustainable growth[4].

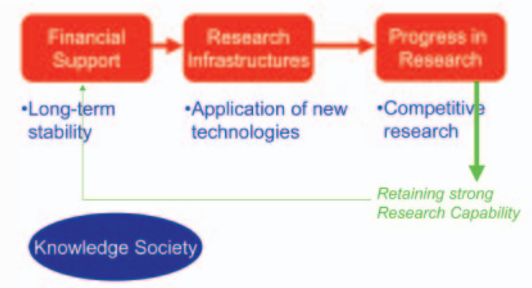
While much political effort is invested in market reforms, at the heart of the concept of a knowledge-based economy are the creation of knowledge and the subsequent exploitation of that knowledge in pursuit of economic growth and/or benefits for society. These are unquestionably in the domain of science.

It is evident that science pervades our everyday life. It has the capability to provide the foundation for longer, healthier and safer lives, and to liberate men and women from dangerous and physically debilitating work. Yet the Lisbon strategy adds a crucially important perspective to the role of science, by placing it at the centre of Europe's modernisation drive. Science is an indispensable part of the innovation chain; it is therefore an essential element of the education system that must ensure an adequate recruitment base of scientists, without which the strategic targets will not be met. Furthermore, as an integral part of a European culture, shaped by the Renaissance and characterised by a rational, knowledge-based approach to problem solving, science constitutes a strong conceptual framework for dealing with the problems of life and of society. Without a widespread public understanding of this aspect of science, we will be unable to develop and maintain the scientific foundation upon which the knowledge-based society must rest.

The economy-science chain



The science-economy chain



The model illustrates the interdependence between science and the economy as main elements of the 'innovation train', with basic research providing the knowledge base for applied research and innovation, leading to job creation and economic growth. A major precondition for this is a well functioning education system with close links to both science and innovation.

On the other hand, the fundamental requirements for basic research to thrive are satisfactory funding with long-term stability and the availability of the relevant research infrastructures. Both elements are intimately dependent on general economic progress in society.

The conclusions of the Lisbon Council meeting included the creation of the European Research and Innovation Area (or European Research Area (ERA) as it is often known) as a central component of its new strategy[5]. The ERA was proposed by the former European Commissioner for Research, Philippe Busquin, but has roots extending back to personalities such as Altieri Spinelli, Ralf Dahrendorf, Etienne Davignon and Antonio Ruberti. A detailed description of the aims of the ERA has

[3] *Encouraging investment in material and human capital, including research and development, while seeking to maintain macroeconomic stability and to continue the structural reform of product, capital and labour markets.*

[4] *'The Union in 2004: Seizing the Opportunities of the Enlarged Union, Operational Programme of the Council for 2004 submitted by the incoming Irish and Dutch Presidencies', Council of The European Union 16195/03, 2003.*

[5] *This was confirmed by the Research Council (on 15 June 2000), preceded by a resolution by the European Parliament on 18 May 2000.*

Various Kinds of Science

A monolithic view of science fails to do justice to the multi-facetted character of the scientific endeavour. Certain discoveries and insights avail themselves to swift exploitation in terms of new products and services. Indeed much research is aimed directly at developing specific technologies for which there appears to be a demand in society. Other types of research are aimed primarily at knowledge creation. In some areas of science, it is impossible to draw a clear line between these aims. Indeed different views on science can be highly relevant and science does not lend itself to a 'one-size-fits-all' approach.

Due to ever-increasing economic pressures, ever-faster product-cycles and justifiable concerns about international competitiveness, much attention is given to technology development as an important source of innovation. Europe obviously needs to gain and/or maintain international competitiveness in fields of high technology.

Equally, fundamental research is a major and specific human effort with a long-term perspective for society. If our technological edge is to remain sharp in the future and if we are to remain true to our cultural heritage, great care must be taken not to neglect fundamental research. As mentioned, the primary goal of fundamental research is knowledge creation; this constitutes what is perhaps one of the most important sources of cohesion in any society and, at the same time, is central to the Lisbon strategy.

It is important to realise that fundamental research operates 'internally' on significantly longer time-scales than technology development. The training of scientists is a very long process. Maintaining a convincing scientific effort requires adequate ongoing support and sustained investment.

The long time-scales, as well as the long-term importance, of basic science are well illustrated by some examples. The great advances in physics during the early decades of the 20th century, relativity theory, quantum mechanics and nuclear physics were carried out as 'blue-sky research', but led to technologies (including electronics and lasers, information and communication technologies (ICT), earth observations, space-borne navigation systems, nuclear power, nuclear medicine, etc.) that, decades later, were to be of crucial importance for the economies and welfare of our peoples and societies. A similar time-lapse can be observed in molecular biology. This is now one of the fastest evolving scientific disciplines with a direct and enormous impact on innovation and product development. However, several decades have elapsed since the discovery of the structure of DNA, driven by the basic 'quest for knowledge', and today, when this knowledge can be exploited for the benefit of humankind. Looking towards the future, fusion power generation has yet to become a significant component in the energy needs of society.

been given elsewhere[6], but its essence is to establish a 'single market' for research in Europe. The aim is that this will overcome national fragmentation of research effort, achieve critical mass, increase researcher mobility, foster new ways of collaboration and thus enable a better use of available resources both now and in the future.

The Lisbon strategy was subsequently reinforced in two ways. Firstly, by the decision of the European Council at its meeting in Barcelona (March 2002) to raise the investment in R&D to the level of 3% of GDP by the year 2010. Secondly, by the Bologna Process[7], that aims to establish a European Higher Education Area, which will have a potentially far-reaching impact on issues such as the mobility of researchers and the quality of education.

A European dimension in science

The Lisbon strategy, underpinned by the ERA concept and the Bologna process, implies integration of many of the activities that are presently organised nationally. Scientific research relies on the creation, rapid dissemination and integration of new information and ideas and has thus, by its very nature, to be an international undertaking. For this reason, parts of the European research enterprise have been at the cutting edge of collaboration, a process that has led to the creation of the research organisations that constitute the EIROforum.

Still, in Europe much scientific research is carried out by individuals or by relatively small teams of scientists that are dispersed throughout universities and research institutes. For this reason, research funding is widely scattered and is often provided in small packages aimed specifically at these individuals and teams. Furthermore, historically, science funding and management has been seen largely as a national task, with insufficient attention given to any European dimension. There are two reasons why this view is problematic. First, science funding is given as a result of peer review, and optimal research quality is only assured if peer review works well. Europe's scientists have noted that the national research communities in even the largest European countries are too small to provide a sufficiently expert and wide-ranging peer review. It is for this reason that European scientists have launched an initiative in support of the creation of a pan-European fund for research excellence, often referred to as the European Research Council[8]. The second reason is that scientists everywhere, and in all disciplines, often rely on the existence of, and access to, research infrastructures to carry out their research. Different scientific disciplines require access to different infrastructures. For example, astronomy needs telescopes and satellites, high-energy physics needs particle colliders and sophisticated detectors, fusion needs specialised devices such as tokamaks for magnetic confinement, molecular biology needs access to sophisticated, high-brilliance X-ray sources and, together with the social sciences, very large and accessible electronic data resources and collections of research material. Clearly, in Europe, it makes no sense to duplicate these essential components of the research enterprise in each individual country; indeed on cost grounds alone this would not be achievable.

[6] 'Towards a European Research Area, Communication from the Commission to the Council, the Parliament, the Economic and Social Committee and the Committee of the Regions', COM (2000)6, European Commission, 2000.

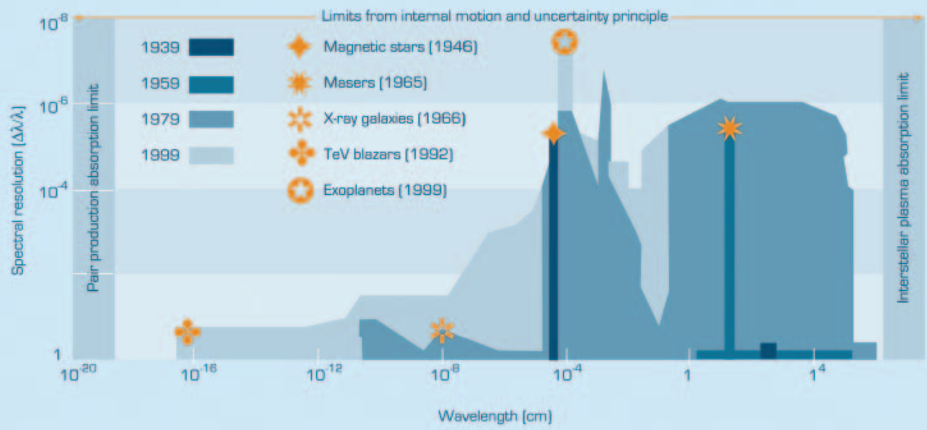
[7] The Bologna Process aims to deliver European higher education around two main education cycles. Furthermore, mobility is fostered by using a Joint European Diploma Supplement issued to all graduates and the use of a credit system (ECTS or compatible) also functioning as a credit accumulation system, making it possible to gain credits within informal and non-formal education and thus encompassing the ideas of lifelong learning. See also 'The Bologna Declaration of 19 June 1999 – Joint Declaration of the European Ministers of Education'.

[8] Recently, this received a strong endorsement as a key recommendation of the 'Kok-Report' – 'Facing the Challenge: The Lisbon Strategy for growth and employment, Report from the High Level Group chaired by Wim Kok', the European Commission Office for Official Publications, 2004.

The importance of research infrastructures

In many areas of science, the ability to undertake new research is critically dependent on access to advanced instruments. Indeed the development of and access to new instruments, technologies and methods are fundamental to achieving progress in science.

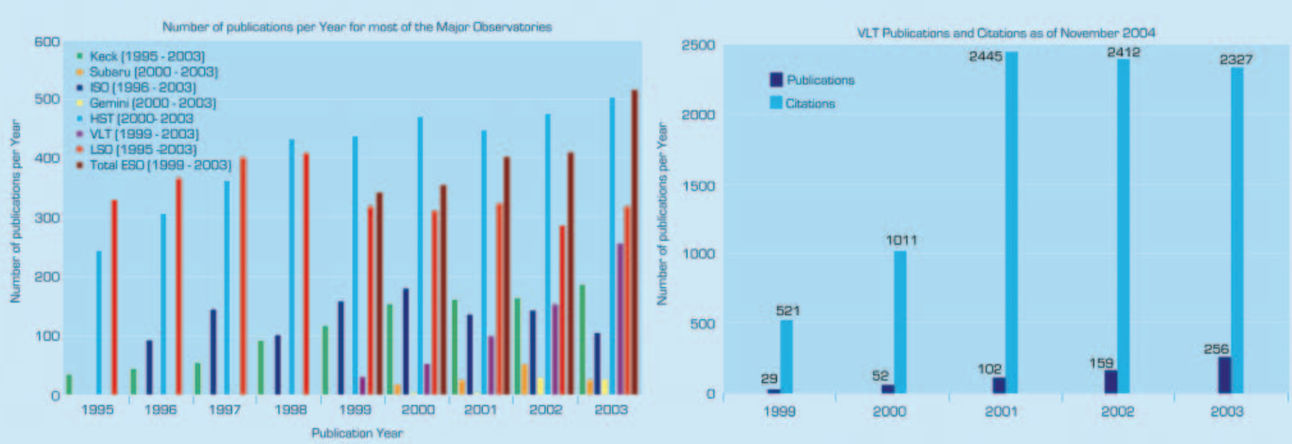
The resources needed to realise major research infrastructures have led European countries to join forces and establish a number of common facilities, the first of which was CERN (established in 1954). Importantly, with time, these infrastructures – operated by the EIROforum partner organisations – have not only remained cornerstones for European science, but have also played a pivotal role as international meeting places, as incubators for new research ideas and in the creation of new international research teams.



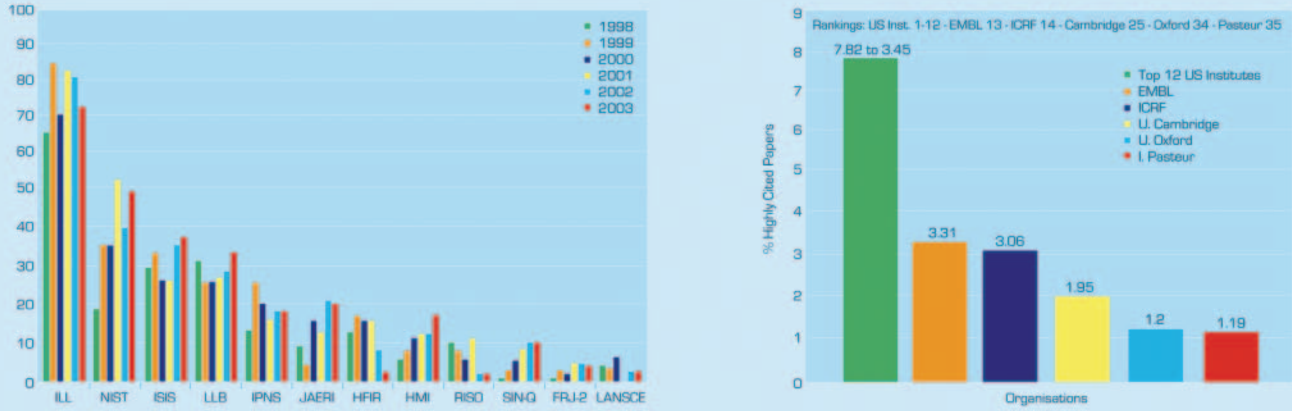
Some of the most important – if frequently unexpected – discoveries in the 20th century were the result of new scientific instruments expanding the available parameter space, e.g. by offering improved spectral, spatial or time resolution and/or enabling access to 'new' spectral domains. Shown here are some of the major astronomical discoveries of the last century made possible by increased spectral resolution of the measurements as new instruments became available. (Courtesy Martin Harwit/Physics Today)

Furthermore, they form an integral part of the network of research facilities and research institutes across the continent, with very fruitful interaction between the individual parts, in terms of both science and technology development. As 'science machines' and by virtue of the catalytic effect that they have had on the respective research communities, these infrastructures have laid the base for a vibrant and strong scientific environment in Europe.

Indeed, the scientific return has been immense as can be seen from statistics regarding publications in peer-reviewed scientific journals, both with respect to the number of scientific papers and the highly-cited pieces of work.



Scientific publications are often considered one of the key indicators of scientific productivity. The figure shows the number of publications per year for most of the major astronomical observatories in the world, including the two European observatories, operated by ESO: La Silla and the VLT Observatory at Paranal. The second figure shows the number of refereed papers based on ESO Paranal (VLT/VLTI) data published per year, and corresponding citations as of November 2004.



Left: The number of scientific articles based on data obtained at the leading neutron facilities from 1998 to 2003 in Nature, Science, Physical Review Letters, PRB, PRE, JACS and J. Mol. Biology is a clear testimony to the importance of the ILL facility. Right: A similar picture emerges for EMBL in molecular biology (Source: ISI)

As science progresses, the need arises from time to time for a new, more powerful research infrastructure. In many cases this will require substantial resources in terms of capital and highly skilled personnel, but often at the outset, the specialist knowledge is held by only a small group of individuals. Subsequently, establishing the critical mass of researchers and support staff needed for the successful execution of a project is a major challenge. Only organisations of a reasonable size and with stable long-term financial support can bring together the necessary human resources to carry out projects for the creation of large research infrastructures.

The Intergovernmental Research Organisations

The European Intergovernmental Research Organisations, represented in the EIROforum are:

- The European Laboratory for Particle Physics (CERN)
- The European Fusion Development Agreement (EFDA)[9]
- The European Molecular Biology Laboratory (EMBL)
- The European Space Agency (ESA)
- The European Southern Observatory (ESO)
- The European Synchrotron Radiation Facility (ESRF)
- Institut Laue-Langevin (ILL)

A detailed description of each of the organisations is given in the Annex to this document. Even though each organisation is different and was set up to achieve a different scientific end, they share many general characteristics. Firstly, the existence of each organisation and the style and form of its operation is based on an international treaty, convention or agreement. Secondly, each was established by a group of member-states in order to carry out tasks that exceeded the capability of any individual nation.

[9] *While JET is now used under the EFDA, it was established originally as a legal entity and still shares many of the characteristics of the other EIROforum organisations.*

As mentioned, the EIROforum organisations were brought into being to design, build and manage cornerstone infrastructures required by various research communities, in addition to carrying out cutting-edge research. In their fields they not only carry out world-class research, but also serve large communities of scientists and enable individuals and research teams from Europe, and further afield, to perform the most complex experiments that would otherwise be prohibitively expensive. The organisations act as magnets, attracting some of the best young researchers back to Europe after their training elsewhere, usually in the USA. They provide a powerful reason for mature research scientists to remain in Europe providing them with essential tools to enable European research to be fully competitive. These scientists are world-class researchers, enabling the EIROforum organisations to act as flagships for the research community and to be examples of how top-quality research can be organised in Europe.

The existence of these organisations has enabled each participating country to target its investments within specific scientific disciplines and has created focal points for their scientific communities distributed in universities and national research laboratories. In addition the organisations have become strong centres for technological development with which both research institutes and national industries can interact.

Hence, these organisations are, and will continue to be, essential elements for the success of European science. They are collectively a natural and obvious pillar to support the development of the concept of the ERA. Finally, working closely with both the European Union and the various national institutions, the EIROforum partner organisations play a vital role in forging collaborations on a continental scale.

Together, they have considerable experience in the organisation and running of some of the most successful European scientific organisations. They are therefore in a position to provide expert input to policy makers and funding agencies on how to select, construct and organise the next generation of European research infrastructures as well as on the broader scientific policy issues that will inform the future development of the European Research Area.

The EIROforum partnership

The EIROforum provides the platform for partnership and collaboration between the European intergovernmental scientific research organisations mentioned above[10]. It also pools the substantial expertise of each member organisation in basic research and in the management of large international projects, combining and developing them for the wider benefit of European scientific research and technological development.

Through thematic working groups, the EIROforum has been able to identify and exploit common interests and abilities in detector development, grid-technology, human resources, public outreach and education. Joint scientific symposia have also been organised. The selected themes have crossed over the boundaries between established disciplines and have enabled the thematic working-groups to be fertile breeding grounds for multidisciplinary collaboration between the organisations. The first joint initiatives have already had considerable impact, for example in the area of science education in Europe's schools.

[10] *The EIROforum partnership is based on a Charter, which was signed on 12 November 2002 in Brussels by the Directors General (or equivalent) of the partner organisations.*

The EIROforum Council is comprised of the Directors General (or equivalent) of the participating organisations. The EIROforum is, therefore, an authoritative and representative participant in the creation of the European Research Area. On 27 October 2003, members of the EIROforum Council and the European Commissioner for Research, representing the European Commission, signed a Statement of Intent, that expressed full support for the continued development of the European Research Area and outlined a basis for the relationship between the signatories in working towards that goal[11].

The structure of this document

In what follows EIROforum Council offers its views on some of the pertinent issues that must be dealt with in the context of the European Research Area. It is published at a critical juncture in time – as we approach the mid-term of the European efforts to fulfill the Lisbon goals while facing continuing changes in Europe, for example, by the Constitutional Treaty and other initiatives to further European integration. The paper will first set out the vision of EIROforum for the future of European science and identify some key strategic issues that will enable the EIROforum and its partner organisations to continue to make a constructive contribution towards the architecture and construction of the ERA. Then a review of the challenges that the Lisbon strategy and the creation of the European Research Area pose to science in Europe, will lead to the presentation of some practical proposals in areas where EIROforum can make significant and useful contributions in helping to achieve progress. The arguments will be based on the following eight tenets:

- Improving the recruitment and mobility of researchers and countering loss of talent to institutes outside Europe is a requirement for the success of the European Research Area.

- The knowledge-based society implies great promises and challenges for all. Science plays a pivotal role in realising some of the concepts inherent in the notion of the knowledge-based society.

- The interface between science and society is critically important. If humankind is to be able to reap the benefits of the knowledge-based society and if science is to continue to develop in ways that benefit society, citizens and those elected to represent them must be in a position to make informed judgements and decisions on socio-scientific issues.

- Creating a single market for research implies open competition between individual scientists or groups of researchers. This competition must be driven only by the excellence, timeliness and promise of the research proposals and not by the imposition of national criteria or by the geographical location of the scientist.

- Technological competence is not only a requirement for industry itself to prosper and develop in the world-market, but is also a precondition for the continued progress of European science. A better interplay between science, technology development and industry is therefore of crucial importance.

- Building bridges to other regions of the world, while securing European autonomy is key to the evolving Europe. Science can act as an enabler for both.

[11] *The agreement foresees consultations, exchanges and secondment of experts, the possibility of joint projects and the further development of the collaboration by the conclusion of additional bilateral agreements.*

- In the perspective of the ERA, questions on science policy making and the governance and funding of science assume renewed importance. New structures may be necessary, but care must be taken to take full account of existing experience and of models of governance that have proved to be successful.

- If European research is to be fully competitive on a global scale, it is of vital importance that adequate resources, both in terms of human and financial support, are assured.

2. The Vision

As noted in the previous chapter the substantial expertise of each partner organisation of the EIROforum, in both basic research and in the management of large international projects, makes the EIROforum itself an authoritative voice in the development of European scientific research and technological development. Using this voice it is our vision to

Create a climate in Europe in which relevant, competitive scientific research (basic and applied) can be undertaken in an efficient, cost-effective and successful way.

Our vision is particularly relevant to the creation of the European Research Area, a concept that is seen as essential in dealing with some of the challenges raised by the Lisbon strategy and in fostering the required environment for competitiveness in research. During the coming years, the ERA should be fully developed to facilitate the attainment of the Lisbon goals. Our view of the ERA is that it is a framework and facilitator for close cooperation between all the participants on the European research scene; it has the aim of positioning European scientific research and technological development at the forefront. The ERA is based on what might be called ‘organised pluralism’ (rather than ‘centralism’), on collaboration and partnership, but also on free competition between researchers in pursuit of excellence. The unrestricted exchange of ideas and information, a high degree of mobility[12] of research and development personnel, better interaction between academia and industry and a strong public support for fundamental research are all essential elements of the ERA.

In achieving this vision we believe that there are three necessary pre-requisites associated with the EIROforum organisations and their basic remit. They are:

- The role of global centres of excellence, such as the EIROforum partner organisations, must be maintained and reinforced.

  The EIROforum organisations have all proved to be success stories in Europe and in the world at large, in that they have made very positive contributions to the excellence of European scientific research. As long as the individual organisations continue to be relevant to the pursuit of their respective fields of scientific research they should be maintained and reinforced as centres of excellence at a level which will enable the European scientific community to exploit its full potential.

- The EIROforum collaboration aims to exploit synergies between its members and will engage in wider partnerships for the benefit of Europe.

  The technical collaboration within EIROforum is now beginning to show its potential. For example, three EIROforum members, the European Synchrotron Radiation Facility, the European Molecular Biology Laboratory and the Institut Laue-Langevin, together with the French Institut de Biologie Structurale, are collaborating in research on macro-molecular structures. They have set up a ‘Partnership for Structural Biology’, covering the whole chain from cloning and expression to data acquisition and evaluation. The Partnership has already begun to attract further partners and associates.

[12] *‘Mobility’ here refers both to geographic mobility and the need for R&D practitioners to be able to transfer their skills to new scientific and technological areas (sectoral mobility).*

The benefit of cross-disciplinary and cross-institutional collaboration lies not only in achieving synergies, but also in creating catalytic effects, especially in areas of broader 'external' collaborations. Thus, while the primary mission of the EIROforum organisations is to provide research infrastructure(s) for their respective user communities, the experience of the past fifty years has shown that, repeatedly, the infrastructure of those organisations is also extremely valuable for the support of several secondary scientific missions. In collaboration with teams from universities and national research institutes, EIROforum organisations are playing significant roles in fields such as:

– Promoting public awareness and understanding of science, and, more generally engaging in a dialogue on the role of science with the public at large;
– Encouraging interest in the study of science by students in schools and interacting with science teachers to facilitate relevant, attractive and modern science education in Europe's primary and secondary schools;
– Supporting and encouraging interest in European science by the European printed and electronic media;
– Encouraging technology and knowledge transfer, innovation, and spin-offs.

We believe that there is a significant potential for the EIROforum organisations to look for further common actions in many of these fields. These might sometimes be found among the EIROforum organisations themselves, but it is important that the organisations should also remain open to collaboration, where it is useful, with national research institutes, academies, universities and industry.

- The EIROforum organisations should participate more actively and as of right in the development of the European Research Area and its governance.

Several conditions must be satisfied for a region like Europe to become consistently successful at conducting scientific research and translating the benefits of that research into economic growth. The requirements include an excellent education system at all levels and sufficient financial incentives for researchers. Thus the quality of school and university systems, the overall economic reward structure of society, and the interplay between academia, laboratory and industry, all have important roles to play.

The past fifty years have also shown that in many disciplines modern research requires a cooperative infrastructure, beyond the scale of what can be provided for any single university team, however brilliant it may be. In some cases the constraint is purely financial – world-class scientific instruments such as accelerators, reactors, large tokamaks and telescopes are simply too expensive for single user or single group use. However, it is becoming increasingly common that the constraint is determined by the very nature of the facility itself, which must be a shared endeavour and not be under the 'control' of any single group – for example, there are today many disciplines that have a requirement to set up very large, well-organised and well-managed data repositories together with access tools so that different groups can gain access to both historic and more recently acquired data.

The EIROforum organisations are important elements in the modern European research environment. In some cases the main role of the organisation is to provide an infrastructure for a very broad range of scientific teams from many fields to carry out their research – ESRF and ILL are good examples. In other cases a well-defined research community sees the organisation as its home and expects it to coordinate the European evolution of its discipline through the Council of that organisation – CERN and ESO are the clearest examples. Whatever its detailed structure and mission, most of the organisations are governed by a council[13] in which representatives of European governments (the vast majority being drawn from the 25 member states of the European Union) meet to decide on policy.

While we fully recognise that the EIROforum organisations are but one element in the complex space of European research, we believe that it is essential that these organisations should participate more actively and as of right in the development of the European Research Area and its governance. After all, over the past few decades each of these organisations has successfully created an effective and functioning ERA in its own discipline. It is essential to ensure that the highest-level advice on European research policy comes, primarily, from researchers of recognised worldwide excellence, whether they are working in Europe or elsewhere, in universities, in national institutes or in EIROforum (or similar) organisations.

In order to create the climate foreseen in our vision a number of different actions will be needed. In the following chapter we review the challenges of the Lisbon strategy and make some specific proposals for action.

[13] *EFDA has a Steering Committee which comprises representatives of European governments or research institutes, together with the European Commission.*

3. Challenges and Proposals

The creation of knowledge, which is at the heart of the Lisbon strategy, is an integral part of the remit of science. Science is, thus, right at the centre of Europe's modernisation efforts and has an important role to play in facilitating the achievement of the Lisbon goals. In this chapter we review the challenges of the Lisbon and Barcelona decisions, as they present themselves to European science, and make some specific proposals. Although the chapter has been divided into sections, it will be evident that many of the challenges and possible solutions are interlinked. For example the attainment of so-called critical mass, the recruitment and retention of personnel and the challenges of the knowledge-based society cannot be divorced from the overall question of science education and the public understanding of science. We hope that this interplay, and the role that the EIROforum organisations can fill, will become clear in what follows.

Critical mass to remain at the forefront

In many fields of science in order to remain a world leader it is essential to have available as many highly educated and experienced personnel as possible with access to sophisticated and technologically advanced facilities and infrastructures.

The USA, and to some extent Japan, with their wealth and technological prowess, are often able to achieve these goals alone, but no individual European country is of sufficient size (often referred to as 'critical mass') either in human or in economic resources, to compete on a global scale. However, Europe as a whole does have the critical mass to assemble the necessary resources, and this is reinforced qualitatively by its cultural and scientific diversity, that can bring significant added value to trans-national collaborations. The EIROforum organisations are, each in their own right, examples of how Europe has been able to assemble the necessary levels of financial and human resources to become world-class in such diverse fields as space research, fusion energy research, high-energy physics, materials science and molecular biology. It is evident that building new sophisticated and technologically advanced facilities and infrastructures requires European solutions. It also demands adequate time scales for expert personnel to gain, maintain and update their specific expertise, especially in fields where the expertise is held by a very small group of people.

Recruitment and retention of personnel

In 2001 there were 5.7 full-time equivalent researchers per 1000 of the workforce in Europe[14] (3.5 for acceding countries), compared to 8.1 in the USA[15]. Furthermore, the number of graduates in physics, for example, actually fell by 17% in Europe between 1997/1998 and 2001/2002[16]. According to the European Commission, in order to achieve the objective of investing 3% of European GDP in research, an extra half million researchers will be required. Given the timescale for the achievement of these goals and the timescale necessary for the education and training of research scientists, this increase seems to be out of reach, at least without an all-encompassing, concerted effort across Europe and covering all the areas described in this document.

[14] *Community Research: Key Figures 2003-2004, p 44, European Commission, 2004.*

[15] *The level of public funding per researcher in Europe, currently 171 kEuros in the EU-15 and 156 kEuros in the EU-25, has also been well below that in the USA, currently 182 kEuros and in Japan, 212 kEuros. (Source 'Towards a European Research Area – Science, Technology and Innovation – Key Figures 2003-2004', European Commission 2004).*

[16] *'Europe needs more scientists – Provisional Findings of the High Level Group', European Commission, 2004.*

An extremely worrying sign is the continued drain of some of Europe's best scientists, who, having obtained their degrees, leave to pursue careers in the United States. Some 400,000 European science and technology graduates now live in the USA and many more leave each year. A survey published by the European Commission in November 2003[17] showed that only 13% of European science professionals working abroad currently intend to return home. The loss of European scientists to the United States of America is not new; in the 1950s and 1960s it was recognised as an 'exodus'. At that time the USA invested billions of dollars in mostly defence-related research projects and, as a consequence, it created clusters of scientific and technological excellence distributed across the country. These centres of excellence were staffed with the best scientific minds available and Europeans were welcomed to join. America's investment, in both applied and basic research, laid the foundation for the technology explosion of the 1980s and 1990s. This attracted even more highly trained Europeans, some of whom possessed exceptional entrepreneurial spirit. Today, throughout the USA, research facilities and universities are able to recruit young talented Europeans, who are attracted by the generous funding, the quality of the facilities and the meritocratic culture. On the other hand, Europe struggles to interest pupils in science subjects at school and has difficulty in enrolling young students to study scientific disciplines at university. A further difficulty is that, in Europe, careers in science and engineering are not as well recognised by society as they might be.

One cannot, and indeed should not, keep young and bright researchers from going abroad, because the experience gained is invaluable and enables them to acquire a comprehensive world view of science. However, Europe needs to give these scientists good reasons and incentives to return to the continent that gave them their initial scientific training.

It is well recognized that human resource policies and practices can have a significant influence on performance in the area of scientific research. In general terms, it is our view that the current conditions of employment for researchers in Europe are not sufficient to enable us to make the most of their full potential.

Scientific research, by its very nature, cannot easily be pursued effectively in a static environment; spending a whole career in a single institute or organisation is unlikely, other than in exceptional circumstances, to sustain the intense focus that is needed to succeed in cutting-edge research. Researcher mobility can provide a means whereby a continuous revitalisation process becomes accessible. At present, however, numerous obstacles or inhibitors exist, at institutional, political and personal levels that can make it a daunting and somewhat unrewarding prospect for researchers to offer themselves for mobility.

At the institutional level, there are examples where mobility is positively discouraged for essentially short-term reasons, without any regard being paid to the longer-term benefits. Furthermore, in cases where mobility, say in the form of secondment or a sabbatical, is allowed, returning to the organisation can sometimes be very difficult, due to inadequate reintegration policies. Equally, rather than a period of secondment being viewed as a positive attribute, in some instances the period spent away is not (fully) recognised for seniority purposes and the outcome is a delay in salary advancement or promotion.

At the political level, inhibitors include difficulties in relation to the retention or continuity of social benefits, such as social security insurance and pensions. Other factors may consist of obstacles to the integration of family members during the

[17] *Executive summary and Conclusions of the project relating 'Brain Drain – Emigration Flows for Qualified Scientists' under the European Commission request and coordinated by MERIT, http://europa.eu.int/comm/research/press/2003/pr2511en.html*

period of mobility and often include, for example, a restriction on a spouse's access to employment and difficulties with immigration procedures for family members.

At the personal level, there is the perceived difficulty of finding appropriate education facilities for children so that they do not fall behind their peers and can be reintegrated into their normal education system when they return home. Additionally, despite the fact that in the European Union a spouse is normally permitted to work, it is often impossible to find employment because of, for example, language difficulties or recognition of diplomas; the resultant loss of income can militate against a decision to undertake a period of secondment.

Thus, the challenge is to provide the intellectual, cultural and financial incentives to retain European researchers and to attract non-European researchers in the research and development areas considered by Europe to be of high priority. Key issues are, attracting and retaining talent, which requires clear career perspectives, and fostering mobility via practices that encompass well-organised recruitment procedures, the accompanying social security measures and adequate professional incentives. The task is to devise career path and mobility 'systems' that function as an integrated whole. One option might be to think in terms of modular, Europe-wide tenure track schemes, allowing periods of service in industry, academia and at major research facilities and perhaps also of a Europe-wide social security system for researchers.

The solution to the problem of not only recruiting but keeping and repatriating researchers is an issue of human resource management, encompassing, inter alia, training, contractual aspects, appraisal and career prospects. Each of these is a crucial element to be taken into account when planning a research career over the medium and long term. The present lack of standard human resources practices in career management for researchers across Europe has, potentially, a negative impact on the attractiveness of research careers for young graduates and on the mobility of researchers within the European area where they see little possibility for professional development. In many organisations and institutes fixed-term contracts are offered to young scientists. This practice, which of course encourages mobility, results in a scientist's professional development taking place in several institutions, with a concomitant need to maintain close links with his or her home-country institute.

Developing solutions to these issues requires an ability to understand, among many other elements, the educational, vocational and social systems of the various European countries. It implies also that significant efforts are made to facilitate the adjustment of staff and their families to a foreign country and to assist them in resolving related administrative questions with which they may not be wholly familiar.

The international character of the EIROforum organisations has led them to address these issues in a systematic way over many years. While some of the practices developed within the organisations are specifically designed to suit the particular needs and circumstances of the organisation in question, the EIROforum partners have developed significant experience and know-how in tackling many of these issues that are critical to the success of European research. The EIROforum recommends a more extensive use of specific instruments to deal with these issues on a European scale. These may take the form of Europe-wide approaches or the development of mechanisms to foster better 'transferability' between national systems. We believe that such instruments should also target particular groups in our society that tend to be under-represented in the research population, such as young people, women and ethnic minorities. Below, we review some points that we believe warrant particular attention.

Welcoming young people

CERN

CERN has actively sought to exploit the possibilities opened by the Marie Curie programme and has signed a contract to be host laboratory for three projects under the Marie Curie Early Stage Training programme in July 2004. In order to do so, a number of discrepancies between the European Commission requirements and CERN's own regulations had to be overcome.

A number of programmes are operated by CERN to attract students and young graduates, ranging from a local apprentice programme to the summer students, technical students, administrative students, doctoral students and fellows, programmes. These programmes have recruited some 435 young persons mostly from CERN's member states for periods ranging from two months to three years.

About ten other specific programmes are carried out in cooperation with ministries, institutes or international collaborations where CERN is the host for students or young graduates paid from external funds.

EFDA

Several national laboratories, which are associates of the EFDA, offer opportunities in education and training to young researchers. For example, courses and summer schools in fusion technology and plasma physics are organised in several European countries for graduate level students and recently graduated researchers. In addition, many professional staff from these laboratories have teaching responsibilities in academic institutions, mainly universities, and around 200 to 250 graduate and Ph.D. students perform their research at the laboratories.

EMBL International Ph.D. Programme

The EMBL International Ph.D. programme provides advanced, interdisciplinary training in molecular biology and its associated scientific disciplines. University graduates admitted to the programme receive theoretical and practical training, and pursue a research project under the supervision of an EMBL faculty member monitored by a Thesis Advisory Committee. In recognition of the high quality of the programme EMBL has been granted the authority to award the Ph.D. on its own or jointly with universities, while also maintaining the option of a student receiving the degree solely from a national university. Joint degree arrangements are in place with 18 universities in 13 countries. In 2003, 179 Ph.D. students participated in the international Ph.D. programme, 7% of them coming from countries outside Europe.

ESA – The Young Graduate Trainee Scheme

Each year, a number of posts are opened for young graduates looking for their first job. These posts, generally in science and engineering, are awarded for one year. Trainees are assigned a tutor who is responsible for their scientific and/or technical training and helps them get to know the internal procedures and structure of the organisation. Within an equal opportunities framework, a similar programme exists with the aim of recruiting young female scientists and engineers (known as NOW – New Opportunities for Young Women) and, where they show high potential, actively seeking out a permanent post for them in the organisation.

ESO

In addition to the ESO Student Programme (primarily for 'post-graduates' in astronomy and astrophysics, preparing for a Ph.D.), ESO has concluded a bilateral programme for on-the-job training of engineers with one of its member states. The trainees stay at ESO for one year, free of charge, and ESO provides training in astronomy-related technologies specially designed to meet the needs of industry and research organisations.

EMBL bioinformaticians are developing databases and tools for their research and as a service to the Life Sciences community.

Young People

EIROforum believes that a particular effort should be made not only to attract young people to study science and engineering, but to initiate young graduates into the research profession and help them launch themselves in the job market. For example, within the EIROforum organisations various programmes exist for offering fixed-term posts to young graduates, who have little or no professional experience. The aim is for them to become familiar with the organisations, consolidate their knowledge in science or engineering and enable them to develop their expertise for the benefit of the European Research Area. The EIROforum organisations have a particular expertise in cooperating with universities, sometimes through national institutes, and these programmes provide a bridge between university and professional life. They have the additional advantage of creating a feeling from the outset of belonging to the European scientific community.

Women in Science

A far-reaching equal-opportunities policy is needed to make science more attractive to girls and young women, who are often poorly represented in European university science departments. One of the objectives of a pro-active equal opportunities policy is to improve performance with regard to the recruitment and retention of women in scientific and technical areas by making it easier, not to say possible, for women to progress in such a career. It has been found that women have more difficulties reconciling work and family life when there are additional constraints of expatriation. Given the overall need to encourage mobility within Europe, this problem clearly needs to be addressed. Based upon the extensive experience of its member organisations, EIROforum is well placed to participate in the development of good practice, which

Scientist sorting mosquitoes to find new ways to combat malaria at EMBL.

Welcoming young people – 2

ESRF and ILL

A specific programme (HERCULES), is organised every year through collaboration between the ILL, ESRF and the University of Grenoble. Its aim is to provide training for students, postdoctoral, and more senior scientists from European and non-European universities and laboratories in the field of neutron scattering and synchrotron radiation, Each year about 100 students attend this training programme on the ILL/ESRF site. ESRF and ILL also have Ph.D. programmes similar to the that of EMBL.

would add credibility and visibility to such an equal opportunities policy and facilitate its adoption throughout the ERA.

Recognition of Diplomas

The promotion of international mobility of students and graduates has created the need to develop methods to recognise and establish equivalences between diplomas and degrees obtained in different countries. However, as this is an area of national competence, a scheme of higher education diploma and degree equivalence has proved difficult to obtain. Fortunately the EU member states have com-

Equal Opportunities

The EIROforum organisations are pursuing equal opportunity actions to actively increase the number of women employed. Here are some examples of the measures that have been taken to help women pursue their careers while also having families:

- *The recording of recruitment statistics is general practice to ensure that the proportion of women that applied to a position and were interviewed is in line with the percentage of female recruits. ESRF and ILL issue annual reports on gender equality to their staff representatives. An on-site crêche is planned.*
- *EMBL has the highest percentage of women; 42 % of EMBL staff is female and more than 15 % of the EMBL leadership are women. This is an exceptionally high number that reflects first of all the higher number of qualified female biologists compared to other natural sciences, but it is also due to an active recruitment policy and measures such as the provision of on-site child care facilities for children starting at the age of 3 months, especially in regions where adequate child care facilities and all-day schooling is not available.*
- *ESA has proposed an action plan to foster equal opportunity employment focusing on the following main lines of action:*
  - *Recruitment: proactively attract more female candidates in science and engineering;*
  - *Education: increase the pool of qualified women by engaging girls in scientific subjects early in their education;*
  - *Balancing work and family life: implement policies that help women to be able to combine maternity and motherhood better with having a career; address problems that are brought about by expatriation that particularly affect women;*
  - *Career support and professional development: offer training in personal development and leadership for women, mentoring and networking;*
  - *Awareness: use seminars and internal communication to raise awareness for the problems that women are facing and the measures that have been implemented to facilitate the balance of work and family life;*
  - *External communication: convey the message of an equal opportunity employer.*

mitted themselves to support the Bologna Process that should significantly alleviate this problem.

So far, several sources of information have been developed but none meet all the criteria needed to provide a single reference that can be used. Some of them are very general and focus mainly on higher education; others are more specific, but cover only few countries and focus on higher technical education. While the available sources do not classify the diploma levels of the different countries according to a common reference system, the approach of the EIROforum partners has been to try to group qualifications within career paths (listing precisely the kind of national qualification that is required for the specific function and grade in question). Keeping in line with the Bologna declaration, and on the basis of practices used within the organisations, EIROforum partners plan to continue the work with the various sources of information complementing each other. It remains important for each organisation to keep abreast of developments in the European educational area and to be able, for the future, to create and work to common standards for higher education.

Mobility of researchers

In order to encourage mobility within the European Research Area, EIROforum welcomes the Commission's Mobility Portal initiative. The Portal can be a very good tool to help researchers who are looking for information on job opportunities and grants. EIROforum members are ready to use the portal to publicise information about opportunities in their own individual organisations.

EIROforum also offers its help, in partnership with the Commission and other key players, in two very promising projects:

- A European Researchers' Charter that aims to promote career perspectives for European researchers and guarantees working conditions.
- A Code of Practice for the recruitment of researchers with the aim of laying down good practice to improve recruitment procedures and ensuring that vacant posts are given proper visibility.

The EIROforum proposes to engage constructively in building the European Research Area by considering joint actions with the European Commission and others, setting out concrete measures in support of the initiatives to alleviate these problems.

EIROforum has noted with great interest the document drawn up at the request of the Commission on the mobility of researchers in Europe[18]. EIROforum is prepared to be involved in the processes of assessment and implementation of this European strategy in order to determine how far obstacles have been overcome, national policies have improved and how far international organisations have contributed to this process.

Europe has world-class research centres such as those operated by the EIROforum organisations and these are performing rather well in repatriating scientists. This is probably due to their special, and in some cases unique, scientific environment that enables young people to have early scientific independence, to access outstanding facilities, to receive somewhat better funding and in some cases have support for entrepreneurship. In other words, the EIROforum partners provide an integrated environment and the interdisciplinary culture for science that is among the best in the world.

[18] *Final report of the high-level expert group on improving mobility of researchers (4 April 2001); Communication of the Commission on 'Mobility strategy for the European research area' (COM (2001) 331 final of 20.06.2001); first and second report on implementation of this communication (SEC (2003) 146 of 04.02.2003 and SEC (2004) 412 of 01.04.2004).*

Provision of and access to knowledge, everywhere and at any time, as well as life-long learning, both formal and informal, are constituent elements of the knowledge-based society.

The knowledge-based society

The concept

The concept of the knowledge-based society encompasses the creation, dissemination and exploitation of knowledge and information. It assumes that each individual citizen is able to make use of, and to help develop, society's collective base of knowledge.

The transition from societies based on agriculture and industrial production to ones based on knowledge transforms the criteria for employability and social innovation. In such a society, the well-being of individuals and organisations tends to depend increasingly on the ability to acquire and use knowledge and information.

Because the potential for employability is a vital component of social inclusion, the transition to a knowledge-based society and economy will affect each and every European citizen. It will also have a profound effect on the competitiveness of many European companies, as their underlying business models are transformed. Finally, the transition will have tremendous effects on all European countries, since it will affect their global competitiveness and their capacity for economic and social innovation. A recent Irish survey[19] stated that '...with between 70 and 80 per cent of economic growth now estimated to be due to new and better knowledge, our future prosperity is critically dependent on policies that foster the continuous generation of knowledge and pursuit of learning.'

Science contributes to the knowledge-based society in many ways. It is a primary source of new knowledge (knowledge creation) and contributes to technological developments that improve the dissemination of knowledge across a wide spectrum. Equally important, various areas of science provide tools to enhance our understanding of both cognitive processes in humans and the social impact of the broad availability of information, and of new delivery mechanisms. This helps to improve the ways in which knowledge is made available to, and used by, the public.

Education for a knowledge-based society

A major element of the Lisbon strategy is to help Europeans to acquire and continually enhance their knowledge, skills and abilities. This will enable them to live and work in a society, where, in order to sustain social and economic development, as well as job-creation, there is a demand for a skilled and information-literate population.

The European Council has not only set out the need to transform the European economy, but has also defined a challenging schedule for the modernisation of Europe's education systems. By 2010, Europe should be the world leader in terms of the quality of its education and training systems. To achieve this, the Heads of State and of Government have agreed on a set of objectives covering the various types and levels of education and training (formal and informal) aimed at implementing the reality of lifelong learning.

These objectives imply that national educational systems have to be improved in areas such as teacher training, the distribution of basic skills, the integration of Information and Communication Technologies (ICT), the effectiveness of investments, lifelong guidance for individuals, the flexibility of education systems to make learning accessible to all, student and teacher mobility and citizenship education.

[19] *O'Hare, D: 'Building the Knowledge Society – Report to Government', the Information Society Commission, Department of the Taoiseach, Dublin, Ireland 2002.*

Thus, education and training must encompass both the further, and lifelong, development of existing scientists and – if the estimated researcher requirements are to be met – new candidates for scientific training at the secondary and tertiary levels of the education system.

The EIROforum partners are already very active in offering opportunities for fellowships, graduate traineeships and training courses. They also host and participate in symposia, conferences, and workshops and contribute to the dissemination of information within and beyond the scientific community. These are all areas in which they could contribute even more. For example a closer liaison with universities and other research institutes would give fresh opportunities to share knowledge and possibly resources, in order to enhance the quality and scope of training offered to undergraduate and postgraduate students.

Technologies for the knowledge-based society

The EIROforum partners can make important contributions to key technologies needed for the knowledge society. As the history of the World Wide Web has shown, the very nature of these organisations requires them to be in the vanguard of the development of tools for sharing information and knowledge across borders. The organisations have real requirements in this area, and they tend to have access to the necessary infrastructure, including advanced computer networks, a few years ahead of their general availability.

It is therefore no surprise that these organisations continue to be very active in the development of so-called Grid technology and e-Science. The approach, applied in Framework Programmes 5 and 6, whereby Grid consortia, which were initially dominated by the research community, were expanded to incorporate many more industrial and commercial suppliers and users of the technology, has proved to be very successful and should be continued. This applies equally to the infrastructure needed to deploy Grids, to developments in the underlying technology (such as the Semantic Web and Semantic Grid), and to the deployment of Grids into multiple application areas. In this context the move towards Web Service Grids is to be welcomed, since it will bring together the scientific vision of worldwide collaborative ICT services and the industrial reality of Web Service software.

In this context, one of the areas in most urgent need of attention, and which could profitably form the basis of a major effort under FP6 and FP7, is the investigation and validation of concepts to ensure that Europe is able to deploy authentication and authorisation tools which operate across multiple national borders and educational systems. It is essential to build ‘single sign-on’ procedures that work across Europe for the benefit both of our research community and, subsequently, of our whole economy.

For many scientific disciplines, the importance of Grids and e-Science lies not so much in their potential to provide huge processing power, but rather in their ability to support widespread access to well-maintained and well-catalogued repositories of data. If the data in these repositories are to be really valuable they must be ‘well curated’, to ensure that they are of good quality, and provided with detailed metadata descriptions of their nature. While merely important for searches by humans, good metadata catalogues are essential for supporting automatic data access tools. As soon as scientific researchers have learned how to develop and maintain such data repositories, one can expect that commercial applications will not be far behind.

The role of science in the knowledge-based society

It is evident that science as a whole has a significant role to play in support of a society which has placed knowledge creation at the heart of its vision. From the technological perspective, the exponential growth in information sources will require continuous developments in the areas of analysing, interpreting, storing and disseminating information in a multi-faceted way in order to satisfy a variety of demands. The challenge for the scientific community will be to contribute, within its areas of competence, to defining the direction, the pace and the degree of knowledge creation required. Thereafter, scientists must contribute to the development of appropriate strategies to meet these requirements.

Because the EIROforum partner organisations have developed essential communication tools, such as the World Wide Web and the Grid concept of distributed computing, they can, collectively and individually, give focus and support to the scientific community, in developing these strategies. EIROforum can also provide a forum for the essential exchange of views between the scientific community and policy-makers.

The Word Wide Web and the new concepts of distributed computing are pivotal to the knowledge-based society.

Prof. Malcolm Longair in a public lecture in connection with the OECD Global Science Forum meeting in Munich, December 2003.

Interfacing with society

Developing and exploiting the benefits of the knowledge-based society can only happen in an overall framework of dialogue and public engagement with science. As the primary generator of knowledge, science must be perceived as an integral part of our society and of our culture. While public interest in science is well documented (see, for instance, the relevant Eurobarometer surveys[20]), many surveys indicate that citizens consider themselves insufficiently informed about it. The challenge is to build on the potential which is available, using all forms of communication to foster dialogue and interest in science, to serve the dual purpose of enhancing public understanding of science and securing the future workforce for Europe's R&D undertakings. In particular a dedicated effort to improve science education in Europe's primary and secondary schools is crucially important.

In essence, science can be seen from at least four different perspectives. As

- An edifice of knowledge, under continuous construction
- A human endeavour
- A unique and powerful way of interrogating the natural world around us
- A powerful way to promote human welfare and technological progress in a sustainable and appropriate manner

A full appreciation of each of these features is necessary in order to understand the true importance of science education, both in providing fundamental knowledge and as a key to rational thinking. Given the challenges facing us in the years to come, the latter, in particular, is of crucial importance in strengthening the basis on which our society rests; namely, democracy, tolerance and rationality. While science education is clearly the area with which science should interact, the wider concept of 'education through science' could prove to be a decisive tool in the struggle against social exclusion, fear, intolerance and superstition. In terms of the Lisbon goals, science can contribute actively to European growth by contributing to its education environment and is important for the development of European society.

The interaction between science and society is complex, but essentially happens at three different levels.

Public science communication

Public science communication provides information on science as it happens on a daily basis within the research establishments. However, it goes beyond the mere communication of new research findings and the merits of exciting technology because human relations and role models are important. Likewise, public awareness and engagement in science can contribute to fostering awareness of a common European culture and demonstrate the power of European integration. Unfortunately, surveys in the European media reveal the disturbing picture that the coverage of science has a low priority compared to other stories and that science coverage is heavily biased towards science conducted primarily in the USA.

The collective nature of science and the fact that research is increasingly conducted in cross-border collaborations, sometimes involving Europe-wide research teams, is not reflected in media reporting, leading to a lack of visibility of science in its 'European dimension'[21]. This low visibility of European science is the outcome of the low priority given to public science communication by most European research

[20] *'Europeans, Science and Technology', EUROBAROMETER 55.2, European Commission, 2001 and 'Candidate Countries Eurobarometer on Science & Technology 2002.3', European Commission, 2003.*

[21] *Madsen, C: 'Astronomy and Space Science in the European Print Media', in Heck, A and Madsen, C.: 'Astronomy Communication', Kluwer Academic Publishers, 2003.*

'Science on Stage'

'Science On Stage' is based on the very successful 'Physics On Stage' concept that was introduced in 2000. It is directed towards science teachers and pupils in Europe's secondary schools. The project addresses the content and format of science teaching in European schools, seeking to improve the quality of teaching and to find new ways of stimulating pupils to take an interest in science. It aims to facilitate the exchange of good practice and innovative ideas among Europe's science teachers and to provide a forum for a broad debate among educators, administrators and policy-makers about the key problems in science education today.

The project also makes available to the European science teaching community the considerable combined expertise of the EIROforum organisations, in order to promote the introduction of 'up to the minute' science into the curriculum and thus to convey a realistic image of modern science to pupils.

'Science on Stage' is not only concerned with basic science, but also with the crossover between different science disciplines – a trend, becoming more and more important in today's science, that is not normally reflected in school curricula. A key element of the programme is to give teachers an up-to-date 'insiders view' of what is happening in science and to tell them about new, highly diverse and interesting career opportunities for their pupils.

Innovative and inspirational science teaching is seen as a key component in stimulating young people to deal with scientific issues, whether or not they finally choose a career in science. Hence 'Science On Stage' aims to kindle the interest of young people through schoolteachers, who can play an important role in reversing the trend of falling interest in science and scientific research.




1) Exchange of ideas at the Physics on Stage Science Festival fair. 2) The European Commissioner for Research, Philippe Busquin, MEP Christian Rovsing and the CERN Director General, Luciano Maiani in the audience at Physics on Stage 1, held at CERN in the year 2000. 3) HRH Prince Johan Friso of the Netherlands and Mrs. Maria van der Hoeven, Dutch Minister of Education, Culture and Science visiting the Physics on Stage 3 Festival, at ESTEC in 2003. 4) Mr. Miguel Cabrerizo, recipient of the first EIROforum European Science Teaching Award, handed over at the Physics on Stage 2 Festival at ESTEC in 2001.

institutes, combined with the communication obstacles introduced by the multiplicity of languages in Europe and the organisation of the media and news services along national lines. By contrast, research institutes in the USA maintain a high level of public communication with a resulting high degree of public visibility.

To counter this, the EIROforum partner organisations have established strong communication departments that can use all the instruments of modern communication including, in some cases, centralised 'production units' with communication networks in the member states. At the same time, the Alpha-Galileo news server, which relays institutional press releases on a European scale, has had some effect. However, these efforts will not be sufficient to overcome the current imbalance in science coverage by European media. It is therefore important to consider broader initiatives that involve all the major players in the field to establish structures that are resilient and muster critical mass.

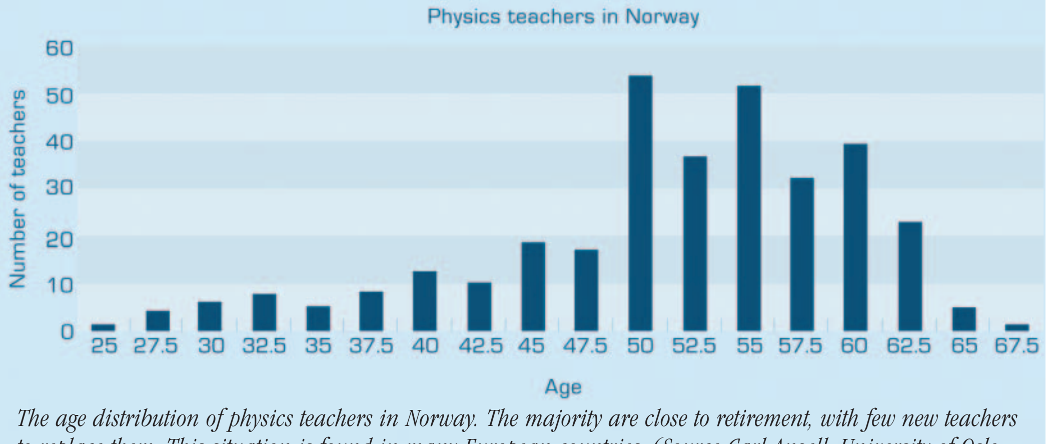
One such initiative would be to establish a European Science Press Agency with the specific task, as a 'story-producing' agency, to cover developments of science in Europe and make its reports available to newspapers, radio, television and various World Wide Web sites.

This idea has already been presented to a number of forums and in a number of documents[22], but it has yet to be implemented.

Science education

Positive actions directed at pupils and students or through teachers, who can act as multipliers of positive action, can provide a high motivation for students to follow a scientific career. Showing the activities accomplished at research institutes can also stimulate interest in science. In addition, direct contacts between young people and active researchers (acting as role models) can address social issues such as, gender, social exclusion (e.g. of ethnic minorities). There is no doubt that science has a strong potential, not only for questioning and understanding nature, but also for ameliorating conflicts in society, by stressing qualities such as universalism, truth, modesty, critical questioning and creativity. This potential must be tapped, both for the sake of science and for society at large, but also the initiatives for the public understanding of science must be accompanied by targeted efforts to alleviate the urgent and increasingly serious recruitment problems, in the shape of dedicated activities at secondary school level.

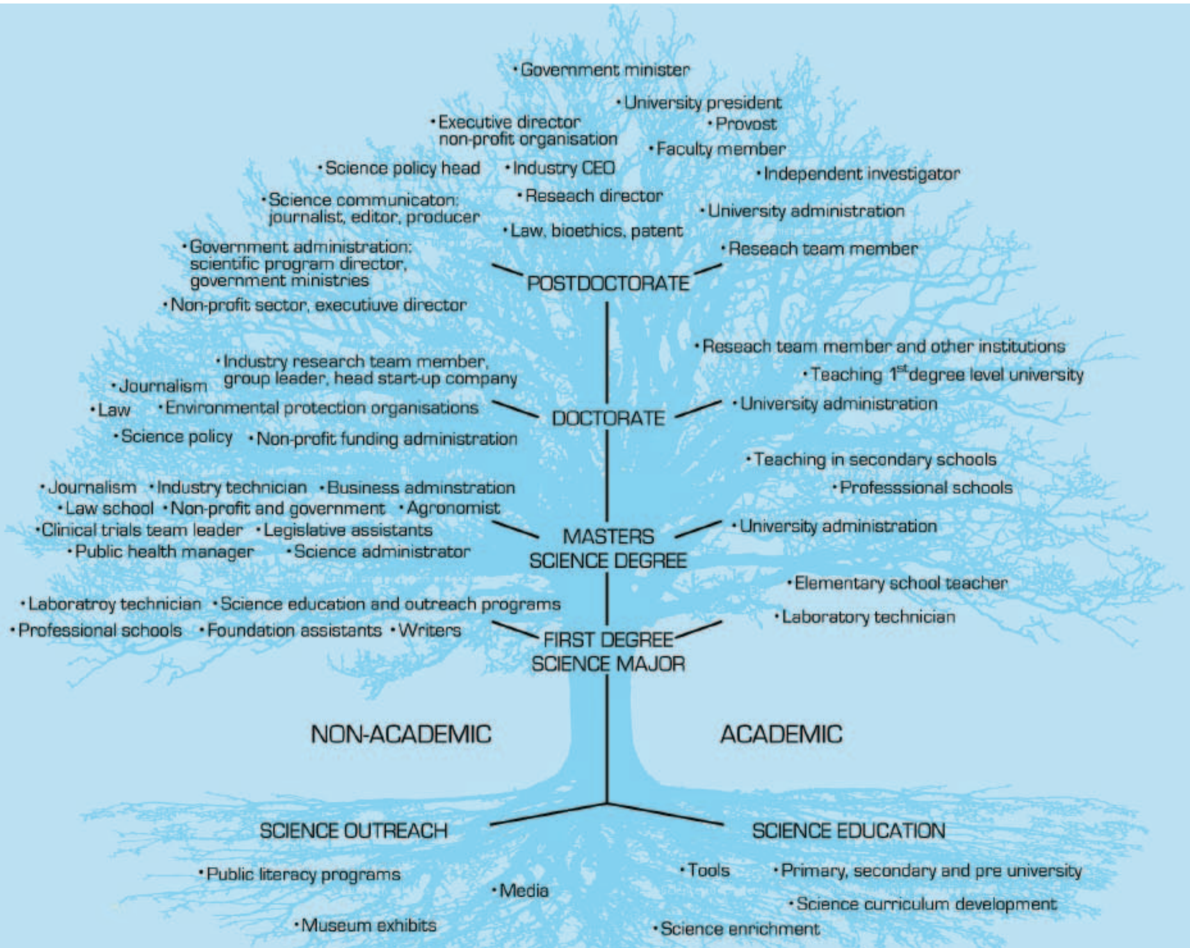
The suggestion of an imminent recruitment crisis is borne out by several recent surveys that give rise to grave concern. Firstly, the SAS report by



The age distribution of physics teachers in Norway. The majority are close to retirement, with few new teachers to replace them. This situation is found in many European countries. (Source Carl Angell, University of Oslo, Norway).

[22] *'Science and Society Action Plan', European Commission, 2002,*
'European Research Advisory Board: Advice 2001–2002', European Commission, 2002 and
'Science Communication in Europe', ESF Policy Briefing, European Science Foundation, 2003.

Sjöberg[23], now followed by the global ROSE survey by Sjöberg et al.[24], provide dramatic documentation for the amount of disinterest – even disenchantment – in the current formal science education at school among 15-year-old children. Secondly, the MAPS survey by Troendle et al.[25] shows an overall 17 % decline in physics graduates over the period 1997/98–2001/2002. Finally, the falling number of science teachers is of serious concern. For example[26], between 1993 and 1998 the number of new science teachers in the UK fell from 553/year to 181/year. Similar trends can be observed in other European countries[27]. All the available data raise questions about the quality of the science teaching that can be offered to school children in the years to come – with potentially dire conse-



Science for all!

The Tree Paradigm (initially proposed by Geoff Montgomery) is often used in discussions of science training and careers, showing that 'rooted deeply in our culture, with a trunk of more formalised education and training, students branch out into a wide variety of useful, legitimate and valued scientific, engineering and technological associated activities, with research creating outward and upward growth.' However, if the 'branching out' is understood to cover a wide range of societal activities, the model can be used in the wider context of public understanding of science. Indeed, scientific literacy is important for all citizens, not only to cope with their daily lives, but also to be able to have an informed view of socio-scientific matters. At the same time, in a modern, democratic society, science cannot flourish without a satisfactory level of popular support (after 'Toward a New Paradigm for Education, Training and Career Paths in the Natural Sciences', HSFB Bureau Europe and ESF, 2001).

[23] *Sjöberg, S: 'Science and Scientists – The SAS Study: Cross-cultural evidence and perspectives on pupils' interest, experience and perceptions', Acta Didactica, 1, 2002.*

[24] *Sjöberg, S: 'Relevance of Science Education', http://folk.uio.no/sveinsj/, publication pending.*

[25] *Troendle, G, Lee, D and Huber, MCE: 'Mapping Physics Students in Europe', European Physical Society, 2004.*

[26] *Caracostas, P: 'Shared Governance through Mutual Policy Learning' in Edler, J., Kuhlmann, S. and Behrens, M. (eds) 'Changing Governance of the Research and Technology Policy', p. 35, Edward Elgar (UK), 2003.*

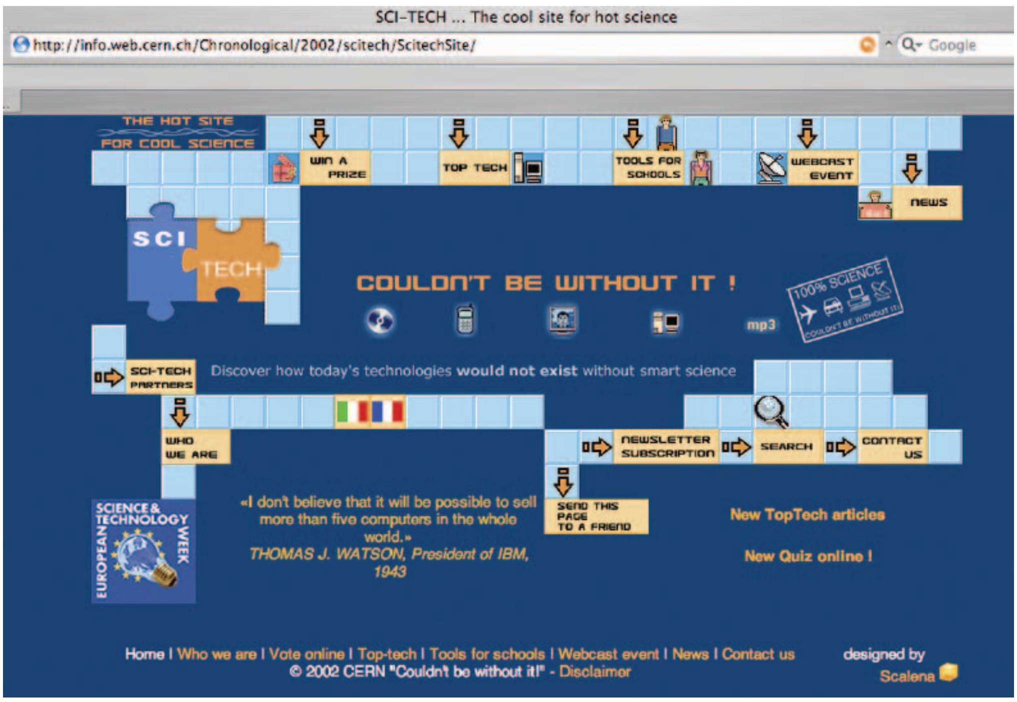
[27] *Ockels, W and Wilson, H: 'Mapping the Crisis', report, Physics on Stage Proceedings, p 7, ESA SP-497, 2001.*

quences for the ability of society to sustain its current level of economic, technological and social activity, not to mention the attainment of the Lisbon goals.

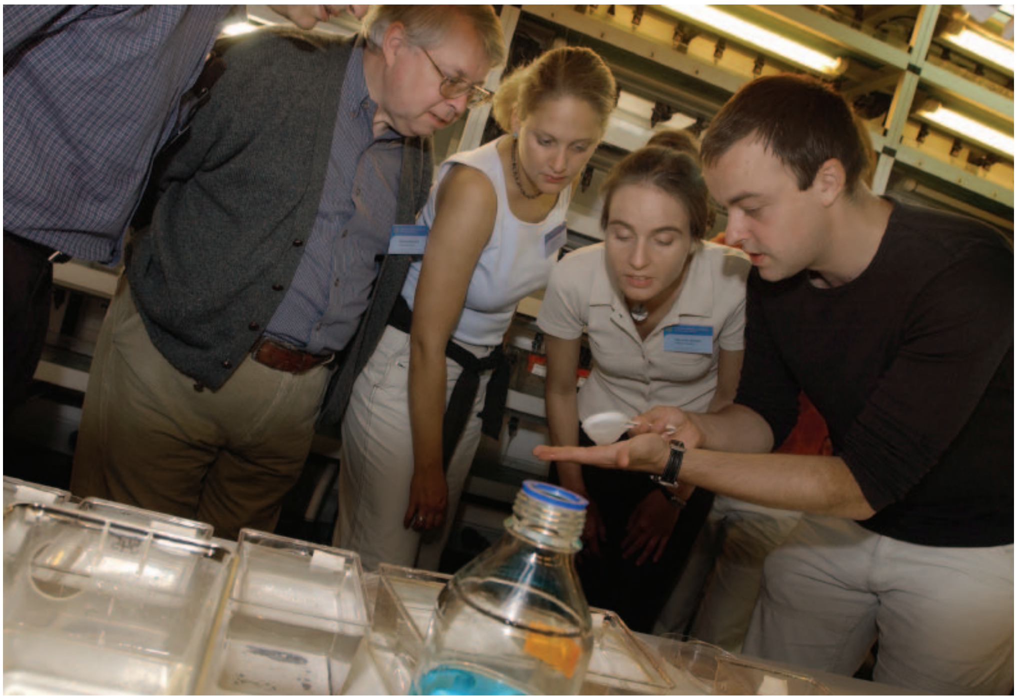
It seems, therefore, that there is a need for a multifaceted approach to improving science literacy and public awareness of science. Efforts must include a major revision of the curriculum and the way science teaching is delivered in Europe's schools. EIROforum fully endorses the ideas expressed by the High Level Group on Increasing the Human Resources for Science and Technology in Europe, chaired by Prof. José Mariano Gago. In particular, bringing real science into the classroom can serve as an effective tool in stimulating the interest of young people in scientific questions. In parallel, there is a strong need to help science teachers to meet the didactic and cognitive challenges of science teaching in the new century and to help them to bring contemporary science into the classroom.

The founding fathers of the organisations that form the EIROforum did not foresee that these organisations would become active in the field of science education. Nevertheless, it is clear that, within these bodies as centres of world-class research, specific knowledge and expertise has been concentrated; this is potentially of great benefit for teaching at all levels. Hence, through their educational offices, the organisations have produced

The Venus Transit 2004 Programme carried out by ESO allowed many thousands of people to take part in a unique scientific observation.



'Sci-tech/Couldn't be without it!' was an internet-based educational programme for young people, carried out by the EIROforum partners as part of the European Science Week and with support by the European Commission. The programme focussed on the links between fundamental science and popular everyday technological items.



In-service training for biology teachers at the EMBL ELLS facility.

teaching materials[26], embarked upon various educational programmes such as summer schools for teachers, the European Learning Laboratory for the Life Sciences and have helped to foster teacher networks (e.g. the European Association for Astronomy Education). Last but by no means least, they have brought life to a major, joint educational activity under the name 'Physics on Stage' (now changed to 'Science on Stage', to reflect a broader disciplinary coverage), that aims to facilitate close interaction between active scientists and teachers as well as to facilitate the exchange of best practice among science teachers from all over Europe. It is

Open House at CERN in Geneva – an estimated 33 000 people visited CERN during the most recent event, on 16 October 2004.

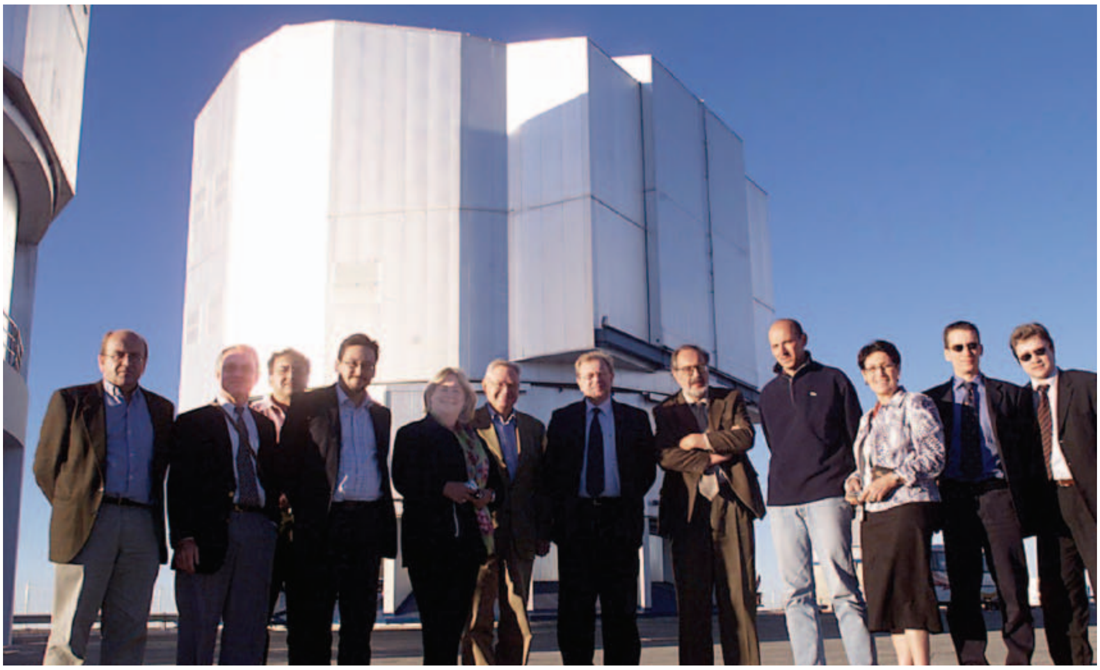
[28] *Such as the ESA/ESO Astronomy Series, the ESO/EAAE 'Journey across the Solar System' and 'The Virtual Microarray' from EMBL.*

notable that many of these activities have been conducted in collaboration with the European Commission.

The organisations have worked on a programme to coordinate and consolidate the above activities at a level where they will have a real Europe-wide impact. The programme, called the EIROforum European Science Teachers' Initiative (ESTI), is yet to be implemented. ESTI pursues a particular strategy in support of the effort to tackle the imminent recruitment problem. However, it has become clear that the complexities of the overall issue of increasing science literacy and stimulating the interest in science and technology call for a highly differentiated, but concerted, approach, involving the expertise of a wide group of contributors.

It is therefore proposed that a pan-European Partnership for Science Education be established in order to find common solutions to these

The European Union Contest for Young Scientists is an initiative by the European Commission. It gives science students the opportunity to compete at European level with other prizewinners from national competitions from across Europe and beyond. EIROforum welcomes this excellent initiative and in 2004 supported the effort as part of the joint actions under the Statement of Intent between the European Commission and the EIROforum. EIROforum sponsored special prizes of a one-week visits to each EIROforum organisation. The award ceremony took place at an event in Dublin in September. Seen in the picture below are the prizewinners invited to visit CERN, EFDA and ESRF.



Members of the South America and MERCOSUR Delegation of the European Parliament visiting the ESO Paranal Observatory in Chile.

The EIROforum stand at the 2002 FP-6 Launch Conference in Brussels.

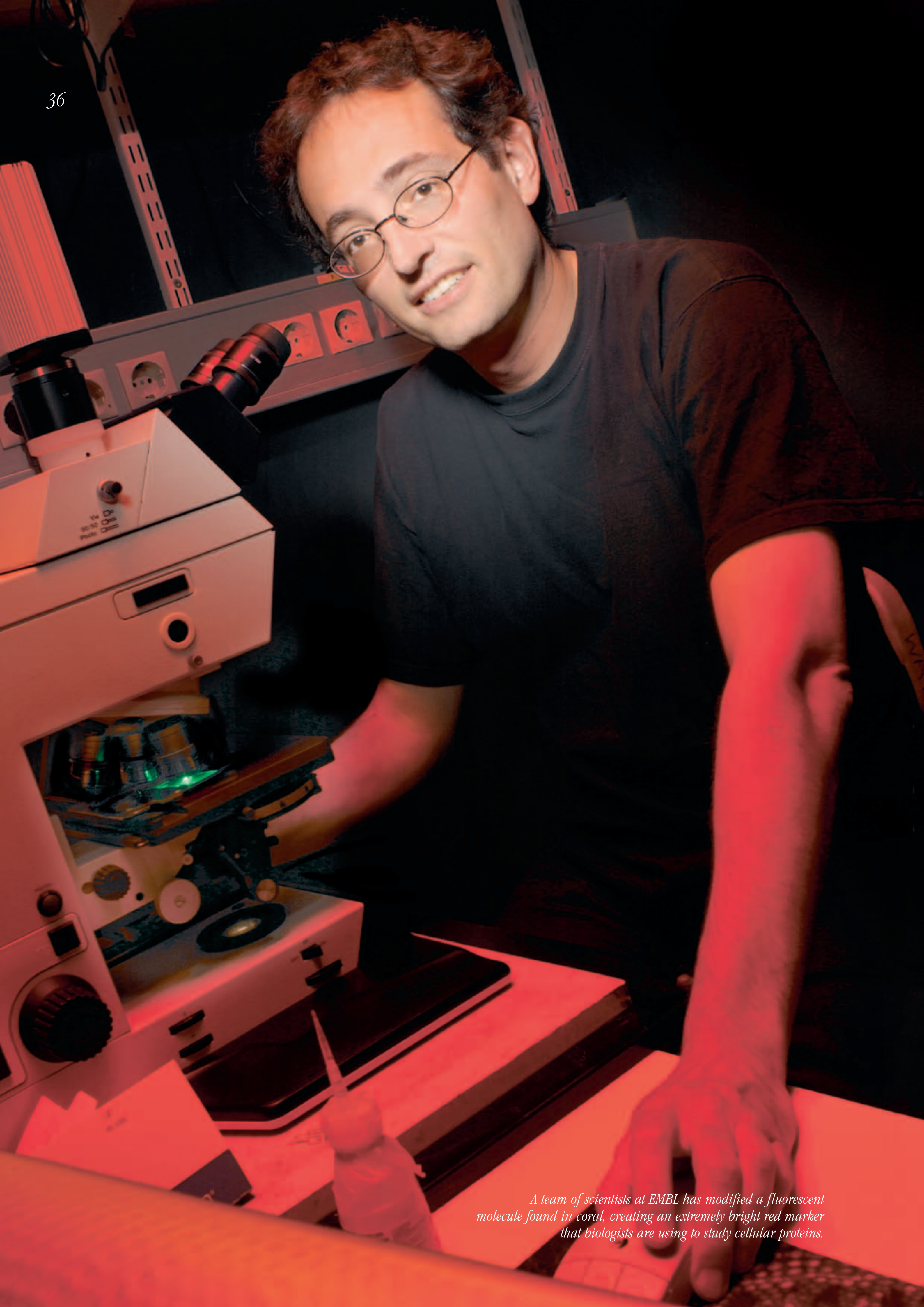
problems. The Partnership would involve the education authorities of the member states, science centres, key teaching networks (such as the EU-Schoolnet, STEDE), the academies of science and the learned societies, the EIROforum organisations and the European Commission each of which would undertake agreed actions at an appropriate scale and of a sufficiently wide scope in improving science education.

Public dialogue

The EIROforum partners have already, either individually or jointly, organised exhibitions and public activities including 'Open days', international web-casts and internet-based 'ask a scientist' query services. All of these activities constitute important opportunities for the organisations and their staff to interact with both with the local communities and with the citizens at large.

Dialogues with decision-makers have taken the form of events organised at the European Parliament (the European Science Policy Briefings) as well as high-level briefing events carried out in the member states of the EIROforum organisations. These events have involved political decision-makers as well as members of national scientific communities, representatives of industry and the media.

Clearly, the leading European scientific organisations provide the back-bone for the large European research establishments and could be used by the decision makers as one of the consultative groups to help define the policy and the future scenarios in this area.



A team of scientists at EMBL has modified a fluorescent molecule found in coral, creating an extremely bright red marker that biologists are using to study cellular proteins.

Pan-European competition in science

As noted above, the number of researchers in Europe will have to grow considerably if the stated goals are to be met, but how these new researchers are deployed and supported will have a major impact on the quality of the resulting research. The key issue is to attract and retain researchers by creating an overall environment that is conducive to high-quality scientific research. However, there is a link between the recruitment and retention of talent and the creation of a pan-European area of competition and cooperation. It is, in a sense, fortuitous, that the deficit in the required number of researchers coincides with the current moves towards closer European integration, as careful planning on a European scale can increase the effectiveness of the available research effort. Moreover, it should be possible to promote excellence in research through genuine competition on a continental scale.

Whilst, to date, the European Commission has put emphasis on trans-national cooperation in science, the EIROforum organisations have used peer-reviewed competition as the main instrument for ensuring that their research infrastructures are used in an optimal way. It should be noted that, in our experience, whilst competition provides fertile soil for excellence, it also fosters international cooperation as researchers establish teams according to their scientific interest rather than their nationality. We therefore strongly believe that European science can gain considerably from the development of genuine pan-European competition.

Today, there is insufficient competition at the European level, since researchers are still largely exposed to competition and assessment within their own countries. The best talent from each nation must be assured a place in Europe's research effort, in contrast with the current situation in which research positions, opportunities, support and funding are determined largely within national boundaries. A Europe-wide approach will also make it easier to achieve research groups of sufficient size and the positions and research opportunities will be better able to reflect Europe-wide needs. With better opportunities, it should be possible to keep the best research talent in Europe, instead of exporting it, as is currently all too often the case.

Because much research is, and always will be, done in national universities and similar academic institutions, a strong system of Europe-wide grants needs to be introduced to encourage this research and the students who will become the next generation of researchers. European initiatives should try to promote coordination between national programmes through the national Research Councils and similar agencies, but, in addition, establishing close links between the ERA and the European Higher Education Area will be an essential element in assuring the future of Europe's research.

Interaction between the best researchers and research groups, wherever they are in Europe, should be supported. This must include free competition between groups without the imposition of requirements concerning the national make-up or geographical location of the members of individual groups. To enable this competition, a Europe-wide peer-based system of assessment and support will be required, conducted by the European Fund for Research Excellence (often given the name 'The European Research Council'), currently under consideration. The members of such a Research Council should themselves be chosen purely on the basis of scientific excellence, and should include non-European scientists as required, in order to assure the best available overall expertise.

'…attractive careers in the public sector and academia need to be in place and marketed as such to future generations if the entire ERA and knowledge-based economy are to be realised. This is absolutely key to the future prosperity and competitiveness of the European zone.'[29]

[29] *'Increasing Human Resources for Science and Technology in Europe – Provisional findings of the High Level Group', executive summary, European Commission, 2004.*

Any European researcher or research team should be able to apply for grants and support, with no consideration given to nationality or national balance; only in this way can excellence be guaranteed. Such a Europe-wide programme could include prestigious awards, support for ambitious research projects of high risk, but of high potential return, and support for well-coordinated teams that may be dispersed over Europe, but might also reside at one location. While some of these objectives are already embodied in the various activities of the Marie-Curie Fellowship Programme, the proposed European Fund for Research Excellence could play a key role in supporting research at the highest level. In this regard, EIROforum has expressed its support[30] for the proposal put forward by the Expert Group, chaired by Prof. Federico Mayor[31] for an autonomous, science-driven fund in support of competitive research at world level. As such, it clearly fills a gap in the existing system of research funding in Europe.

Since it is likely that some European scientists to whom such grants are awarded will also use the research facilities of the EIROforum partner organisations, care must be taken to ensure adequate coordination between the awarding of a research grant and the possibilities to use these facilities.

[30] *Response of the EIROforum to the draft report of the European Research Council Expert Group, www.eiroforum.org/efpolicy/efpolicy_3.html, EIROforum, 2003.*

[31] *'The European Research Council, A Cornerstone in the European Research Area', The Danish Ministry of Science, Technology and Innovation, 2003.*

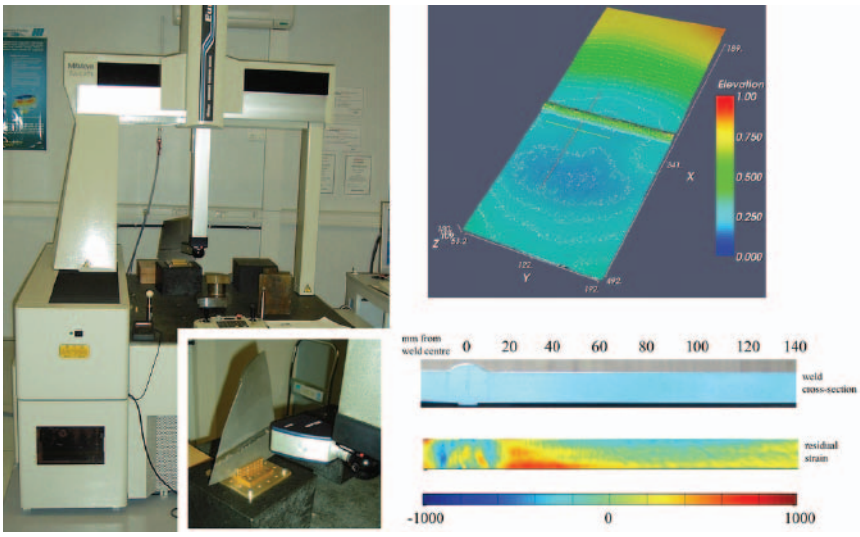
Producing the giant mirror blanks for the ESO VLT gave European industry global leadership in the manufacturing and polishing of large optical mirrors.

Technology in industry

Supporting innovation

A considerable amount of research and development is devoted specifically to satisfying the near-term demands of society and is carried out in specific industries, including telecommunications, pharmaceuticals, energy, transport and consumer products. This research is subject to ever-increasing economic pressures, ever-faster product cycles and justifiable concerns about international competitiveness. These elements, together with security and, increasingly, environmental considerations, provide strong drivers for technological development. Fundamental research on the other hand is often highly dependent on the continued development of new technologies and furthermore, can itself lead to the creation of radically new and different technologies.

Because of relatively modest institutional funding and reluctance to focus resources on the creation of elite institutions, most European universities and research centres have real difficulties in competing on the world stage. The consequent limitation in high-profile basic research has severe consequences for the economic and industrial development of Europe: For example Europe’s patent portfolio is undoubtedly weaker than it should be and in turn the creation of new start-up companies and small businesses is seriously affected. The so-called ‘brain-drain’ is not a purely academic problem. Because science drives economic growth particularly in the information technology, biotechnology and pharmaceutical sectors, billions of Euros and tens of thousands of jobs are at stake[32].



Facility for Materials Engineering

FaME38 provides support to enable European materials engineers to make the best use of the advanced neutron and synchrotron X-ray scientific facilities at ILL and ESRF. The Institut Laue-Langevin (ILL) and the European Synchrotron Radiation Facility (ESRF) are respectively the leading European centres for research using neutron and synchrotron X-ray beams. They share a joint site in Grenoble, France, and provide advanced research facilities for users from European universities, research institutes and industries.

FaME38 supports a variety of materials engineering applications. A state-of-the-art laboratory is available with metrology tools including a coordinate measuring machine (CMM). The CMM (left) may be used to digitise and inspect specimens with an accuracy of 2 micrometres. Seen here is a digitised steel weld used in marine industry applications (top right). The model is then used to optimise experiments to determine the residual stress and strain (bottom right). Through detailed knowledge of the residual strain field, the fatigue behaviour can be more fully understood and measures can be taken to reduce in-service failures.

32 *A European Commission Press Release on the occasion of the publication of the third European report on Science & Technology indicators 2003, indicated that Europe’s trade deficit in high-technology products rose to about 48 bn Euros in the year 2000 (http://www.cordis.lu/indicators/).*

Innovation and spin-offs – 1

Understanding genomic information

One of the major challenges of post-genomic biology is to understand how genetic information results in the concerted action of gene products in time and space to generate biological function. Dissecting the genetic and biochemical machinery of a cell is a fundamental problem in biology. Proteins usually act in large complexes and each protein can be involved in a number of functional molecular machines. The identification of the components of these machines has been greatly advanced by two complementary methods that were developed at EMBL. The first is a biochemical technique using specific tags for rapid, non-invasive purification of macromolecular complexes. The second is a set of novel mass spectrometry techniques. The combination of both has made EMBL one of the leading centres for proteomics. The technology was used to start the EMBL spin-off company Cellzome AG.

CERN and the World Wide Web

During the late 1980s the particle physics community working at CERN was constructing the Large Electron-Positron Collider (LEP) and its related experiments. As a very distributed community, it had been using e-mail extensively since about 1983, but the tools for sharing and structuring their common information left much to be desired. In order to address these issues Tim Berners-Lee, then a researcher working at CERN, developed the fundamental ideas, protocols and initial prototypes of the World Wide Web (WWW). In 1991, an early WWW system was released to the high-energy physics community via the CERN programme library. It included a browser, web server software and a library, implementing the essential functions necessary for developers to build their own software; immediately a range of universities and research laboratories started to use it. CERN placed the work in the public domain in 1992 and the explosive growth of the Web was assured. Nowadays, the WWW has expanded from its original scientific environment and is now used by a large fraction of the world's population.

Thin metallic film coatings

Particle accelerators require an extremely high vacuum in order to operate. Thin metallic-film coatings of non-evaporable 'getters' have been developed as local pumping devices for any vacuum vessel geometry where conventional vacuum pumps are unsuitable. The getter material is coated onto all internal surfaces of a vacuum chamber and activated passively during a standard bake-out procedure. Activation temperatures can be as low as 180 °C, which is particularly suitable for aluminium chambers. The coating blocks the out-gassing of the walls, transforming them from a source of gas into a vacuum pump.

Using the same technique extremely clean, reproducible and smooth niobium surfaces have been created on the copper walls of superconducting accelerating structures, combining the advantageous properties of bulk copper with a thin layer of superconducting niobium.

The getter technology has been licensed by CERN. It is in use at the ESRF and several industrial applications of controlled, clean and smooth coatings of metal films on metallic surfaces of any shape are being investigated.

Clearly, Europe cannot afford to fall further behind its competitors. Growth will come from industries that are science-based, and therefore Europe needs its scientific community to increase its economic performance.

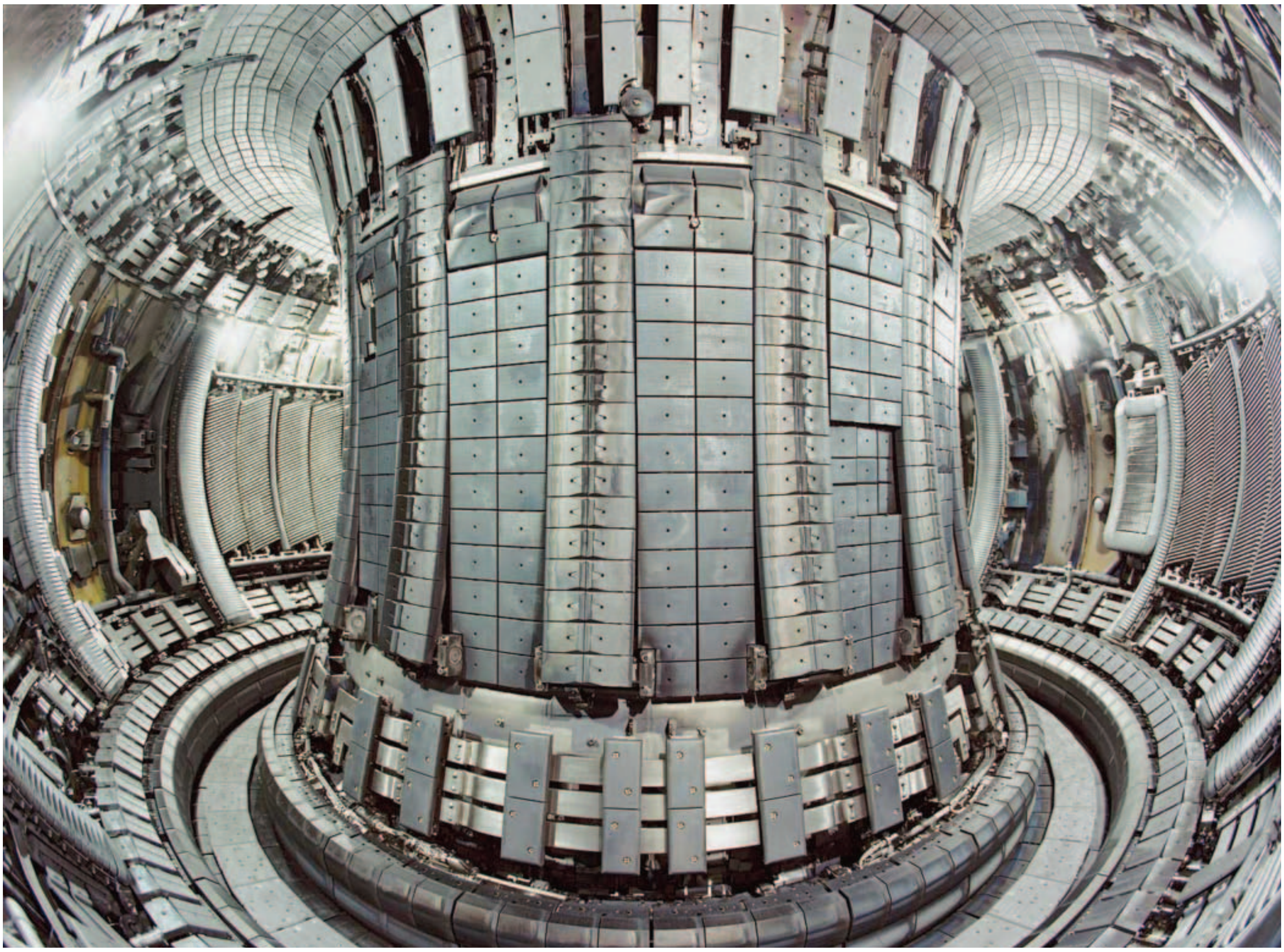
The challenge for Europe is to maintain, and indeed increase, its international competitiveness in high-technology areas and, at the same time, to secure European independence by ensuring that its technology edge remains sharp and its competence base remains strong. Due to the high demand for continued technology development in support of research, and so that scarce and valuable resources are not wasted, it is essential to focus on the correct choice of technologies.

The EIROforum organisations can play an important role in addressing this challenge because they aim at knowledge creation through fundamental, often long-term, research using advanced scientific instruments. They are at the cutting edge of research in their respective fields and use, develop, integrate and spawn advanced technologies.

A sustainable energy option

Fusion is one of the few sustainable energy options for the long-term needs of the world. Indeed, fusion offers the prospect of safe operation and environmental compatibility, as well as a widely available and secure fuel supply. Once developed, it will have a major role in the energy-production balance alongside other energy-generation technologies satisfying these important requirements.

Thus, fusion has huge potential as a new energy source for the future and research to bring this to fruition is carried out on an international scale. Seen here is the interior of JET, located in the UK and currently the most powerful magnetic comfinement fusion device in the world.



Innovation and spin-offs – 2

Non-invasive imaging

Non-invasive imaging relies mainly on detecting ionising radiation from controlled sources. The technologies of several different particle detectors, together with the related electronic read-out and image analysis software, have found applications in fields as diverse as medical imaging via Positron Emission Tomography (PET) and the security scanning of containers using X-rays. CERN is participating in the development of high-resolution, full-body combined PET and CT scanners, and in the standardisation of the related medical images. It has licensed various aspects of the scanner and detector technology, including scintillating crystals (such as BGO and LuAP), and avalanche photodiodes and GEM chambers.

Advanced optical systems

The development of Shack-Hartmann wavefront sensors was a key technological development that allowed Active Optics to succeed in practice. It combined the original optical testing device with CCD detectors, and allowed the optical alignment and shape of the main optics of the New Technology Telescope (NTT) and, later, the Very Large Telecope (VLT) to be verified and corrected in real time. A key optical component of the Shack-Hartmann wavefront sensor is the lenslet array which contains 400 lenslets, each 1.0 mm and, eventually, 0.5 mm across. Here ESO worked with the Paul Scherrer Institut in Switzerland to develop the master and Jobin-Yvon France to manufacture the final copies.

Several commercial systems based on Shack-Hartmann wavefront sensors have been developed for optical testing, for example from Imagine Optic in France (for optical testing), Zeiss in Germany (for eye surgery), Spot Optics in Italy (for optical alignment and testing) and BfI Optilas in Germany for laser beam profile measurement.

Shack-Hartmann wavefront sensors are presently in wide-spread use in adaptive optics systems. Here, ESO has again worked together with several firms to achieve state-of-the-art systems by developing the technological and manufacturing know-how of industry. For example, an ESO development contract for lenslet arrays, placed with the Finnish-Swiss firm Heptagon, allowed the firm to reach specifications that went far beyond anything that had been achieved previously.

Technology transfer

The First Joint ESRF/EIROforum Workshop on Technology Transfer

This event was organised by the Industrial and Commercial Unit of ESRF in February 2004 to improve the efficiency of Technology Transfer policies and to enable institutes to discuss this important issue. The workshop brought together participants from the EIROforum partner organisations, the European Commission, the European Patent Office as well as from universities and private companies. Participants came from Denmark, Finland, France, Germany, the Netherlands, the Slovak Republic, Spain, Sweden and the UK .

Another aspect of this is linked to technology transfer. This is the process whereby technology, expertise, know-how or facilities are utilised for a purpose not originally intended. Technology transfer often results in the commercialisation of new products or techniques through licensing or product/process improvement – although this usually takes two to three years to be achieved. Innovation is the engine that drives the world economy and billions of Euros are spent each year by industry, government agencies, universities and research centres in the development of all kinds of technologies – many of which have a potential for commercialisation that is not, as yet, fully recognised. There is therefore a compelling need to promote the spread, throughout Europe and the rest of the world, of technologies and knowledge developed during the pursuance of large scientific programmes. However these, often sophisticated, technologies need to be integrated into the market economy by adapting them to the prevailing demand.

The EIROforum organisations have contributed to technology transfer through procurement, through the common use of their facilities, through collaboration with similar projects, through the exchange of personnel, through collaborative agreements, through patenting and license agreements and through technology spin-off. Indeed technology transfer is gaining in importance, both for research facilities, such as those operated by the EIROforum partners, and for industry. For this reason, the organisations will continue to enhance their efforts in this area, in particular, efforts to identify technologies that are developed within the organisations for their own needs, but which have the potential to be exploited by industry. A good description of the current efforts and their value to society is given by Autio et al.[33] Notwithstanding the fact that helping to improve industrial effectiveness is not a principal mission of the EIROforum organisations, it is often the case that a small amount of external funding can prove very useful to facilitate technology transfer. Indeed this has often been demonstrated by several Framework Programme projects.

33 Autio, Bianchi-Streit, and Hameri: 'Technology Transfer and Technological Learning through CERN's Procurement Activity', CERN 2003, preprints.cern.ch/cernrep/2003/2003-005/2003-005.html).

Innovation and spin-offs – 3

Technology transfer associated with fusion R&D

The continuous interaction between the fusion research community and industry has led to many spin-off technologies, including plasma-processing techniques, surface treatments, improved lighting, plasma displays, vacuum technology, power electronics and metallurgy. In addition, fusion laboratories have spawned start-up technology companies, such as those based in the Culham Innovation Centre established on the same site as JET.

Technology transfer from space to Earth

Thanks to ESA's Technology Transfer Programme, innovative adaptations of space-developed technologies, transferred to 'earth' applications are enhancing the quality of life for many, bringing economic benefits to society and contributing to industrial competitiveness. The continuous effort to find new opportunities and markets for space-based technologies eases the burden imposed on public resources by adapting technologies developed for one sector for use in another. There is a growing sense that technology transfer can help to provide solutions to problems that, while important to only certain segments of society, nevertheless provide a degree of hope in facing adversity. Examples are the creation of a UV suit for children, known as 'Moon-Kids', who, because they suffer from Xeroderma Pigmentosum (XP), must not be exposed to UV light and are not able to play outside. Also, the invention of a system of injecting medication without needles has helped both to overcome a fear of injections and to avoid contamination. Another example of technology transfer has been the development of a system to detect anti-personnel mines.

Further examples, presented at the K2001 Fair, organised by the APME (Association of the Plastic Manufacturer in Europe), include:

- *Astronaut suit technology used for protective clothing for fighter pilots, fire fighters, chemical spillage cleanup teams, emergency services, motorcyclists and divers.*
- *Wafer-thin, thermal insulation film developed to protect spacecraft is now being used for high-performance insulation on Earth, for example in the tomograph with its vacuum chamber being cooled to minus 270 degree C.*
- *Films developed to record every impact from microscopic dust particles and micrometeoroids on spacecraft can be used in early detection of car accidents.*
- *Materials and systems developed for vibration damping in the space station can be used to reduce vibrations in trains resulting in higher speed and improved comfort.*
- *Carbon fibre developed for satellites is now used in aircraft and Formula-1 racing cars.*
- *Industrial robots are produced from the same carbon fibre composite material resulting in 80% weight reduction and twice the operational speed with even higher precision.*

The various modules for CERN experiments, some of which are of truly gigantic dimensions, are produced all over Europe. The Autio survey (see page 45) shows that over 50 % of CERN's procurement budget is spent in high-technology fields, prompting the development of a significant number of new products and services by CERN suppliers for the open market.

Intellectual property

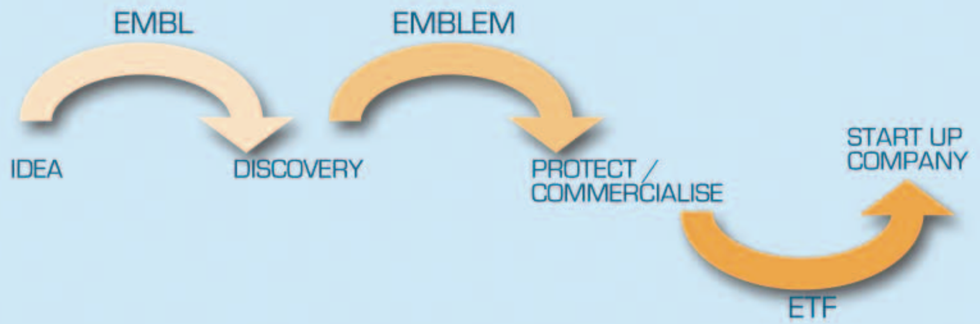
An important aspect of technology transfer relates to intellectual property protection. This is a complex and delicate issue and expectations vary from one field to another. In general, the organisations do not wish to patent everything, since much fundamental scientific progress depends on the continuous improvement of ideas that are in wide circulation among the whole research community.

Nevertheless, the organisations are working to strengthen the understanding of intellectual property issues amongst their staff and to ensure that breakthroughs, that are likely to have a strong impact outside their original field of use, receive appropriate protection.

Always in need of access to some of the most advanced technologies, the EIROforum organisations have, however, experienced difficulties as a result of companies withdrawing from certain market sectors. This has led to the need to source certain technology requirements from outside Europe, in particular from the USA, and has led to a scarcity in the required technical competences at all levels.

Technology Transfer at EMBL

A major reason for society to support basic research in the life sciences is because an understanding of living organisms and how they function in relation to their environment, gives rise to new developments in health care and new treatments for disease. EMBL is actively engaged in developing its discoveries to the point where they can be effectively exploited by society. An EMBL-owned company, EMBL-Enterprise Management (EMBLEM), is responsible for all aspects of technology transfer. EMBLEM identifies existing and emerging intellectual property (IP) at EMBL and works closely with the inventor(s) to define potential fields of application. The identification of IP is conducted in a non-invasive manner in order to maintain the open and collegiate basic research atmosphere of EMBL. The inventors are free to decide whether or not they wish to protect and commercialise their IP. Once identified, IP is analysed by EMBLEM to determine its potential for technical and commercial exploitation. If the analysis gives a positive result, a strategy is developed to protect, market and commercialise the technology. EMBLEM's current intellectual property portfolio includes over 150 patents and patent applications and more than 50 copyrights and trademarks spanning molecular tools, techniques and instruments as well as software programs and databases. The mandate of EMBLEM is to spread the benefits of technology transfer to the EMBL member states and beyond, and not merely to create wealth for a specific region or country. Concomitant with this, EMBLEM has been active in creating a pan-European technology transfer network and serves as a source of advice and 'best-practice' for the EMBL member states in technology transfer matters. The company works with EMBL scientists in all aspects of technology transfer up to and including the formation of spin-off companies. The success of EMBLEM is mirrored in the high licensing ratio of the patent portfolio (around 40%) and in the currently more than 140 global licensees of EMBL technologies (about 60% Europe, 35% USA, 5% rest of the world). In addition, EMBL and EMBLEM have been involved in eight start-up companies in the past five years.



In order to facilitate the creation of start-up companies at EMBL as well as in its member states, EMBLEM, together with EMBL venture capital partners, has established the EMBL Technology Fund (ETF). Managed by EMBL-Ventures, the ETF is a true early-stage venture capital fund with a capital of over 26 million Euros provided by major institutional investors in Europe. The investment focus of the ETF covers all aspects of the life sciences from diagnostics, bioinformatics, target validation and drug design to technology platforms, medical devices and therapeutics.

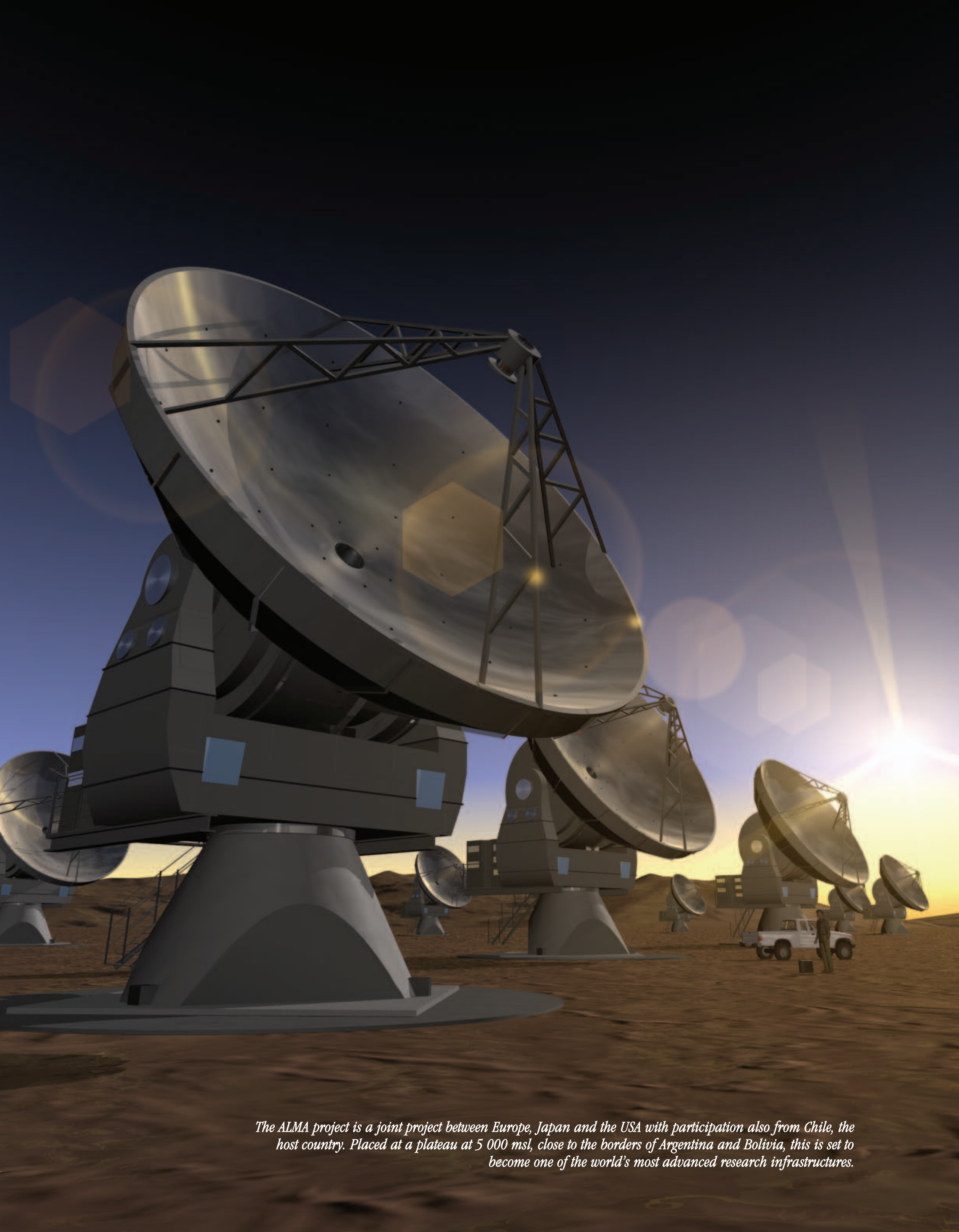
Working hand in hand with industry

Closer links between the EIROforum organisations and European industry should therefore create a relationship from which both parties can derive substantial benefits. To achieve this, the EIROforum members are ready to make their considerable experience available to industrial research and development and can help to:

- Ensure a better interplay between science and European industry;
- Identify technologies inside the organisations of potential use to European industry;
- Establish joint activities that will enhance the capabilities of European industry;
- Spawn innovation centres that can act as incubators for new technologies;
- Utilise expertise from the new EU and former Soviet-bloc countries;
- Help develop a unified approach, which would assist European industry (a partnership scheme or possibly a 'technology platform', e.g. for detector development);
- Identify and promote coordination and synergy among leading-edge technologies;
- Promote and expand the use of technologies for communication (e.g. GRID technology), energy production, environmental protection, medicine, biology, etc.
- Encourage industrial capacity building and increased industrial competence;
- Develop a long-term strategy for training in specific skills needed for the achievement of technological competence;
- Promote education in various specific fields of technology.

As an example, 'Instrumentation' is an integrated discipline that has a wider scope than the sum of its constituent parts of electronics, mechanics, and computing. European industry is comparatively weak in this area. However, together with Europe-based companies, the EIROforum organisations could consider common policy tools, such as 'Technology Platforms' or a large integrated project, in order to benefit from the potential of a more unified and less dispersed market.

This would benefit European industry (primarily small to medium-sized companies) and, in turn, enable the development of new instrumentation, an area that needs European suppliers in order to secure the necessary research.



The ALMA project is a joint project between Europe, Japan and the USA with participation also from Chile, the host country. Placed at a plateau at 5 000 msl, close to the borders of Argentina and Bolivia, this is set to become one of the world's most advanced research infrastructures.

International aspects

Maintaining an open and freely accessible Europe is a requirement for the attainment of the Lisbon goals. The role of science and technology both in our relations with the world at large and as an enabler of international exchange cannot be underestimated.

Increasingly, scientific understanding and capability dictate our ability, as individuals, as nations and as a continent, to make free and informed choices that reflect our cultural roots and traditions as well as the basic principles of freedom and democracy. In addition to providing the foundation for our independence, scientific and technological competence is a precondition for global competitiveness and the key to successful partnerships. In order to benefit from global collaboration, Europe must build and secure its own competence in science and technology and be ready and able to act as a single entity to reap the full benefits.

Their character, their visibility and their scope enable the activities of the EIROforum member organisations to be interwoven with Europe's external relations at various levels, for example, by

- Providing a scientific, technological and cultural bridge between Europe and other regions of the world;
- Linking to bilateral cooperation agreements between the European Union and third parties;
- Serving as Europe's focal point for international scientific projects (such as the European/North American/Japanese ALMA project, and ITER – the next step towards fusion energy production).

Examples of the above include CERN as a genuine global player in particle physics research; ESA, with its wide range of global activity and its collaborations with space agencies throughout the world; the de facto recognition of ESO as the international benchmark for ground-based astronomical observing facilities; EFDA-JET as the leading facility in the world for fusion research, thereby providing an example of European scientific and industrial prowess and ambition. Both ESA and ESO maintain a permanent physical presence outside Europe. Several of the organisations conduct significant research operations in non-European countries and, through their scientific eminence each of the organisations has relations beyond the borders of Europe. These links actively contribute to the international visibility and standing of our continent in policy areas of importance to the long-term and sustainable development of European society. All of the EIROforum organisations attract world-class research and development personnel from throughout the world. This notwithstanding, we believe that there is a case for enhanced collaboration in basic research with nations outside of Europe.

The CERN/South America School for Particle Physics

CERN, in collaboration with the Centro Latino Americano de Física (CLAF) and others, has organised two biannual Schools of High-Energy Physics, in Brazil in 2001 and in Mexico in 2003, and a further one is being organised at Malargüe in Argentina in March 2005. The school aims to teach various aspects of particle physics to young (less than 30 years old) postgraduates who are close to the end of their Ph.D. thesis. Some 60 students have attended each of these Schools.

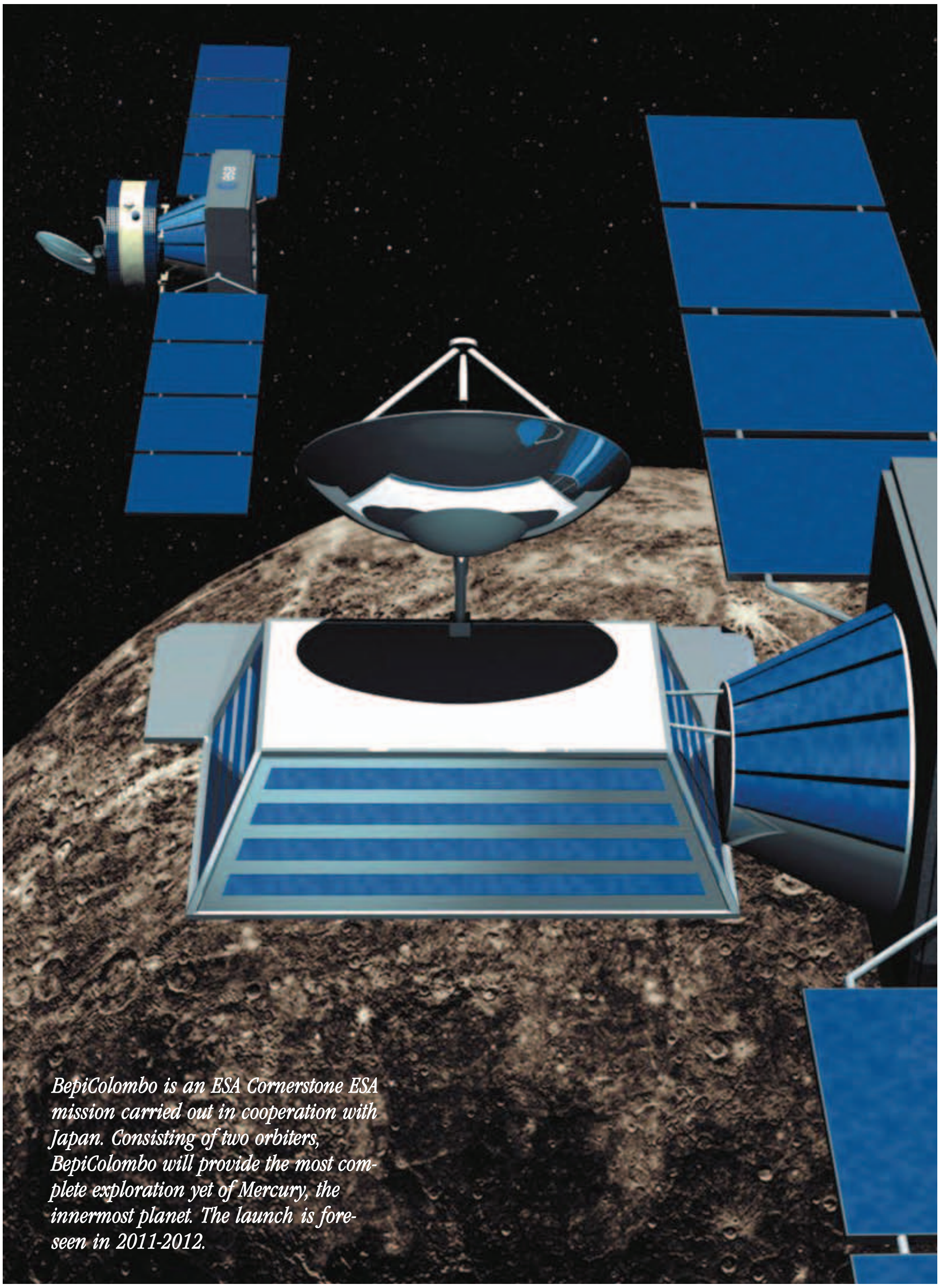
ESO and Chilean Astronomy

Under its agreement with the Republic of Chile (the 'Convenio' of 1964, amended in 1995), Chilean astronomers enjoy privileged access to ESO's facilities. Furthermore, ESO has set up a fund to support the development of astronomical research, including relevant technologies, in Chile. The fund is administered by a joint committee with representatives from the Chilean government and ESO and supports projects proposed by academic institutions or individual scientists in Chile. In addition ESO provides assistance to local communities, mainly through educational grants. Support to Chilean science is also given through the ALMA programme. Furthermore, the ESO Centre in Santiago constitutes a vibrant, scientific hub and meeting place between European and Chilean scientists.

Such collaboration should be understood not just from a short-term utilitarian perspective, but indeed in the wider context described above.

By virtue of their activities and their inherent multicultural character, the EIROforum partner organisations can play important roles in projecting Europe's image and aspirations and in serving as interfaces between Europe and the wider world.

This can be achieved, for example, by coordinating certain activities with the European Commission (e.g. where bilateral agreements involving third-country participation in the Framework Programme include parallel activities), by an open and coordinated human resources policy (scholarships, Marie-Curie Programme) and by the use of Grid technology and communication networks as integrating tools between science carried out within the EIROforum organisations and within scientific institutes in the developing regions and the third world.



BepiColombo is an ESA Cornerstone ESA mission carried out in cooperation with Japan. Consisting of two orbiters, BepiColombo will provide the most complete exploration yet of Mercury, the innermost planet. The launch is foreseen in 2011-2012.

The EIROforum partners have demonstrated their capacity to create all the necessary technical, scientific and political partnerships necessary for their activities and the accomplishment of their mandate. These partnerships range from ad hoc and short-term cooperation in specific areas to more strategic and long-term framework agreements. For example, the European Space Agency has forged approximately 300 formal partnerships that have contributed greatly to the success of its programmes, while strengthening Europe's global leadership in science and technology. Partnerships with other space powers such as the United States of America and Russia are numerous insofar as there is a strong convergence of scientific and research interests, while links with space-faring nations, such as Japan and China, as well as G88 countries, such as India and Argentina, are steadily increasing. The Agency has, moreover, forged specific and far-reaching cooperation arrangements with neighbouring states, such as the Czech Republic and Hungary (through the so-called ECS agreements), with Canada ('Cooperating State' status) and with the European Union (through the 2004 Framework Agreement). In practice, international cooperation is possible with any legal entity, be it a government, an international organisation (e.g. UNESCO, FAO, EU), or an institute (e.g. laboratory, university).

Thus, each within its specialist area, the EIROforum member organisations can act as focal points both for Europe's aspirations and as constructive elements in a multifaceted external policy for the continent.

The European Council at Barcelona set out the goal that by 2010, Europe's research spending should reach the level of 3 % of GNP. This picture shows the final press conference on 16 March 2002 (Courtesy: The Central Audiovisual Library of the European Commission, © European Community, 2004).

Funding collaborative projects

Following the dramatic setback for fundamental science in Europe due to the wars of the last century, Europe has made great efforts to regain lost ground. Investing in major common research infrastructures, such as those operated by the EIROforum partners, has been central to this strategy. The process has revealed both weaknesses and strengths in the way in which resources are mobilised in Europe. The weaknesses include long reaction times and complicated decision processes based on ad hoc solutions. It is also clear, that in spite of previous efforts, European research is suffering from severe underinvestment when compared to other developed regions of the world. The effects of this are clearly visible and the long-term consequences for our continent are dire, if the problem is not resolved soon.

It is clear that adequate funding is a pre-condition for improving European competitiveness in research and technology. As noted earlier, the Barcelona declaration established a spending level of 3 % of GDP in Europe as a goal to be reached by 2010 at the latest. This means an increase of 50 % over the current situation. Some discussion has taken place over the relative shares to be borne by public and private funds, including the question of whether a 1:2 ratio (as seems to be the most common position) is indeed the most suitable model, given the specific social model that prevails in Europe. It is, however, beyond the scope of this document to discuss the further implications of this. This notwithstanding, we note that the current Stability and Growth Pact, to which many of the EU member states must adhere, may appear to have an adverse impact on public research spending as governments strive to meet a multitude of demands from society, related to the upkeep of the welfare state, while obliged to limit budget deficits even on relatively short timescales. This is unfortunate, because investments in research provide the very foundation for the future development of our societies.

Furthermore, Europe must reconsider the funding mechanisms employed in support of research. So far, in most of the EIROforum organisations the main part of the funding has come from their member states, with the European Union contributing funds at the level of a few per cent[34]. The overall need for increased investments, as expressed at Barcelona, and the rising cost of establishing new research infrastructures, for example, may require new solutions, including mixed funding between the interested nations, the European Union and industry. The challenge is how to achieve them.

An important strength of the European funding tradition, however, has been our ability to secure long-term stability of funding, once projects have been agreed. Crucially this has taken account of operations, maintenance and in some cases investment for development during the lifetime of the research infrastructures. As a result, some of the existing European research infrastructures display extraordinarily high degrees of efficiency in terms of ‘operating time’ available for scientific use (i.e. as opposed to time ‘lost’ to maintenance) and thus offer very high rates of return for the scientific community.

While decisions on infrastructures may be taken in a more coordinated way in the future, these decisions must ensure that the long-term support for a facility is provided at adequate levels. Existing programmes for funding of research infrastructures in general by the European Union[35] neither meet this requirement, nor represent a level of financial commitment that is necessary for Europe to continue to develop its research potential and thus safeguard the scientific and competitive value of

[34] *With the exception of EFDA-JET that receives substantial funding under the EURATOM Treaty, including the direct actions allocated through the Framework Programme.*

[35] *As dispensed through the main (non-EURATOM) part of the Framework Programme.*

investments already made. While member-states are clearly called upon in this regard, new funding mechanisms involving the European Union may be needed.

Therefore, and because EIROforum fully supports the underlying vision embodied in the concept of the European Research Area, the partnership with the European Commission, expressed in the Joint Statement of Intent that was signed in October 2003, should be strengthened. In particular

- Articles 169 and 171 of the current Treaty[36] lay the foundations for support of major collaborative efforts, involving the Commission and the EIROforum organisations;

- Areas of collaboration might include specific projects such as Grid activities, development of virtual data repositories (bioinformatics databanks, virtual observatories), where specific expertise is available within the EIROforum organisations, but where these activities have a broad added value for Europe;

- The Principle of Additionality[37] for the co-funding of projects should be maintained.

- As a consequence of the enlargement of the European Union, Community support, through the instrument of structural/cohesion funds, should be made available to new member countries to enable them to participate in existing European research programmes, should they wish to do so.

Furthermore, as is seen in the EIROforum collaboration, important synergies can be found in multidisciplinary collaborations supported by the European Commission and often involving many partners outside the EIROforum itself. Major benefits for society at large can be achieved from such collaborations, but under current financial arrangements, the EIROforum organisations cannot, on their own, fund such activities, when outside their core missions. In such cases, close collaboration with the European Commission can provide solutions, and have indeed already been initiated, albeit at a very modest level.

[36] *We note with great satisfaction that the Constitutional Treaty contains provisions for placing Union research on a much broader footing (Article III-146) and for enabling a wider collaboration between the Union, its member-states and beyond to facilitate the ERA (Articles III-150-155).*

[37] *Ensuring that an increase in funds from European sources is not countered by a similar reduction in national support.*

The Way Forward

As a key instrument of the Lisbon strategy, the purpose of the European Research Area (ERA) is to both enable and stimulate the coordination of, and collaboration between, the various research efforts in Europe. The ERA has sometimes been compared to the single market for goods, services, labour and capital, initiated by the Single Act in 1986. The objective of strengthening European competitiveness in research has led to new partnerships and initiated a process that is changing the research landscape in Europe. The process cuts across existing frameworks, mostly organised at national level, and raises important questions about organisation, management and funding.

With regard to organisation and management, a key question is whether existing structures are adequate to facilitate the dynamic development of a single 'research market' throughout the continent. This is a matter of how research is currently organised and managed and whether, and to what extent, the existing instruments of governance can achieve the institutional structures necessary, or are appropriate for the level of coordination between national groups and between disciplines, that will be needed to cope with the challenges of the future. Of importance also is the question of how new major infrastructures, that exceed the funding capabilities of individual countries, are selected for funding with respect to location, construction and operation.

At present, most cross-border collaboration is either organised under bilateral (or multilateral) agreements between states, or established under agreements between individual institutes. The EIROforum organisations provide examples of the intergovernmental approach, established by means of international conventions and governed by Councils comprising representatives of their respective member states. Whilst these organisations are thus 'owned' by the supporting governments, in some cases their conventions empower them with responsibilities that go beyond simply running research infrastructures; for example the responsibility to organise collaborations within their respective scientific disciplines. With this remit, some of the EIROforum organisations have evolved to become focal points for, and leaders of, their respective disciplines and, as a consequence, their Councils have assumed a wider role than simply that of a supervisory board. However, they cannot, and do not, claim responsibility for the governance of science as such. This notwithstanding, the following observations may be helpful for finally achieving a fully integrated European Research and Innovation Area.

In a sense, the EIROforum organisations long ago created a European Research Area, albeit within their respective areas of science. If the ERA is to become truly successful, these organisations must be integrated into it in such a way that enables the unique expertise that they each possess to be exploited, respects their scientific authority (both with regard to their member states and their scientific areas) and preserves the high degree of disciplinary organisation achieved through decades of work. At the same time, for the ERA to develop and in view of the rising costs for new research infrastructures, coordinated decisions at a European level are necessary. The European Commission supports the main instrument for this, described, perhaps imprecisely, as the 'open method of coordination' among the member states.

A major challenge will be to establish a coherent system for determining Europe's research policies, including defining the relationship between the EIROforum organisations on the one hand and the bodies established to facilitate the open method of coordination on the other[38]. At present,

[34] *Such as the European Strategi Forum on Research Infrastructures (ESFRI).*

Knowledge-based society

Mobility

Coordinated decisions

New Infrastructures

funding

repatriation

education

next-generation scientists

Competitiveness

Technology Transfer

Innovation

Future technologies

however, European science policy discussions and decision-making is in the domain of national organisations and the European Commission and has not yet embraced the views and uniquely relevant experience of the EIROforum organisations. In what may appear to be a paradox, in fact the EIROforum organisations are not being involved in many European science policy discussions and decision-making processes precisely because they are European and not national organisations.

A further challenge is to ensure that the means exist for the creation and operation of new infrastructures; especially those that are to be established in scientific fields in which no intergovernmental organisation currently exists.

The EIROforum organisations represent true European 'success stories'. In this sense they have not just put European scientists at the forefront of their research disciplines, but also demonstrated the feasibility of the particular model (with variations of detail) of organisation and governance. Of course, in a Union that increasingly moves towards a communitarian approach, the intergovernmental model may not be a goal in itself. Nevertheless, it cannot be disputed that this model has introduced a dynamic into the process of European integration – in fact, for a long time it has been the only route to integration in research. We believe that this dynamic must be preserved, because it is essential to the further development of European science. At the same time, the current way of taking decisions about the creation and operation of large, pan-European, research infrastructures would benefit from reinforced coordination in Europe. Indeed, if the European Research Area is to come to fruition and if European research is to develop in an optimum way, a better coordination involving an overall European perspective will be required. This applies both to the creation of new large research infrastructures and to the establishment of new modes of collaboration, involving national research facilities, universities, research institutes and the cornerstone research infrastructures.

Whatever decision mechanisms may be established, they must fulfill the needs and respect the pace of modern science. This implies flexibility, responsiveness and inclusiveness. Flexibility is needed to allow a dynamical approach. Being responsive means reacting, in a timely manner, to new challenges, such as may arise from emerging fields of science; project lead times of the order of a decade or longer for new research infrastructures or major projects are at odds with the aim of attaining and keeping a competitive lead in research. Finally, establishing major scientific facilities requires society to invest significant resources. Decisions must, of necessity, be taken through a political process, but the decision mechanism must be inclusive, in the sense of integrating, and according high priority to, the best available scientific advice, based on experience.

In conclusion, the way forward towards a true and successful ERA requires that:

- Structures for the organisation and management of research at the European level takes full account of the experience, expertise and scientific authority of the EIROforum organisations;

- Europe's global centres of excellence, such as the EIROforum partner organisations, must be maintained and reinforced in order to allow researchers the access needed to ensure the continuing success of European science; and

- Means should be ensured for the creation and operation of new European infrastructures; including scientific fields in which no intergovernmental organisation currently exists.

Virtual Infrastructures

Research infrastructures in the natural sciences are often thought of as 'machines' located at a special-purpose laboratory, needing large teams of scientists, engineers and technicians for their design, operation and evolution. However, in addition to such physical infrastructures, modern research techniques in different scientific fields increasingly require the use of more distributed or virtual infrastructures.

For example, in many areas it is becoming both important and feasible to preserve the 'collected wisdom' of the discipline or subdiscipline in well-managed data collections. The necessary management (or curation) includes aspects such as making the data available permanently, immediately and with high reliability; ensuring that sufficient network bandwidth and server power is available to sustain the access demands; defining the format of the data; defining the format of, and ensuring the availability of metadata that describe the contents of the data (especially in order to enable meaningful automatic searches through the data); putting procedures in place to guarantee the scientific quality of the data; controlling access to the data in accordance with the agreed policies of the community.

The prime example of such a data collection centre is the European Bioinformatics Institute (EMBL-EBI) at Hinxton. It is the central European repository and supplier of biology data services for both the academic and industrial life sciences communities. The EMBL-EBI serves researchers in molecular biology, genetics, medicine, agriculture and biotechnology in both academia and the chemical and pharmaceutical industry. It does this by building, maintaining and making available databases and information services relevant to the life sciences.

But, in multiple fields of research, including the social sciences and the humanities, many disciplines and subdisciplines are also trying to sustain well-managed data collections, and, although the copies of each underlying database have ultimately to be located somewhere, in some cases there is no single physical location – constituting a truly distributed infrastructure.

The impressive development of the 'machines' at the classical infrastructures has led to a 'data explosion' calling for innovative ways to process, explore and exploit the data which are generated, and researchers now increasingly turn to the Grid model of distributed computing and resources for help. The Grid model exploits recent advances to provide a virtual ICT infrastructure, and is in many ways an evolution from the World Wide Web (originally developed at CERN). Not surprisingly, CERN is also playing a leading role in this development, since it must handle the huge mass of data coming from the experiments at the Large Hadron Collider (LHC) when it starts up in 2007.

The EGEE project, co-funded by the EC, is led by CERN and aims to develop the pan-European (and global) infrastructure so that scientists from many disciplines are provided with flexible access to shared computing resources. It will allow disciplines including physics, biology and earth observation, to work on a geographically distributed Grid, supporting distributed data- and processor-intensive scientific computing models, and the shared use of databases of up to a Petabyte (10^{15} bytes) in size (equivalent to the data content of a pile of CD-ROMs standing about a mile high).

A logical development of the Grid model leads to virtual research infrastructures such as the Astrophysical Virtual Observatory (AVO), in which existing astronomical data centres and archives join to form an inter-operating and federated whole. This new astronomical data resource will form a Virtual Observatory (VO) in which the digital Universe resident in the new archives can be seamlessly explored across the entire frequency spectrum. In much the same way as a real observatory consists of telescopes, each with a collection of unique astronomical instruments, the VO consists of a collection of data centres each with unique collections of astronomical data, software systems and processing capabilities.

The AVO Project is currently working in a coordinated way with other international VO efforts in the US and the Asia-Pacific region as part of an International Virtual Observatory Alliance to define essential new data standards giving the VO concept a global dimension. Building on the work and successes of the AVO Project, the partners will join with all astronomical data centres in Europe to form the European Virtual Observatory (Euro-VO).

EGEE, AVO and Euro-VO are all examples in which EIROforum organisations, supported by the EC, are taking the lead in research and development in fields that have huge potential benefit for Europe as a whole.

4. Scientific Trends and New Programmes

The EIROforum partner organisations cover a broad spectrum of scientific activity. In what follows, we describe some of the trends within these activities as well as new research infrastructures needed to support a vibrant and fully competitive European research effort during the coming decades.

Trends in Astrophysics

We live in a truly exceptional age of discovery in astronomy and cosmology. Revolutionary advances have taken place in our knowledge in these fields, ranging from our local galactic environment to the entire Universe. Following the discovery of the first planets outside our solar system a decade ago, well over a hundred are now known. At the other end of the scale, the large-scale properties of the Universe have been determined with astonishing precision over just the last few years. The existence of pervasive dark matter has been confirmed, and new discoveries have revealed the existence of a mysterious dark energy that dominates the expansion of the Universe.

While several of the classic questions of the last century have been answered, a whole host of new and profound questions has arisen. Will we find earth-like planets, capable of sustaining life, as we know it? How do stars and planets form and how do they evolve? What are the dark matter and dark energy that comprise 96% of our Universe? The ultimate question can now begin to be addressed: What is the origin and fate of our Universe?

A future research infrastructure in Astronomy

The European Southern Observatory is engaged in a design study for the next generation of ground-based Extremely Large Telescopes (ELTs). Dubbed OWL (for the eponymous bird's keen eyed vision, but also currently as an acronym for 'overwhelmingly large'), the concept is conceived as a 100 metre diameter optical and infrared, adaptive telescope.

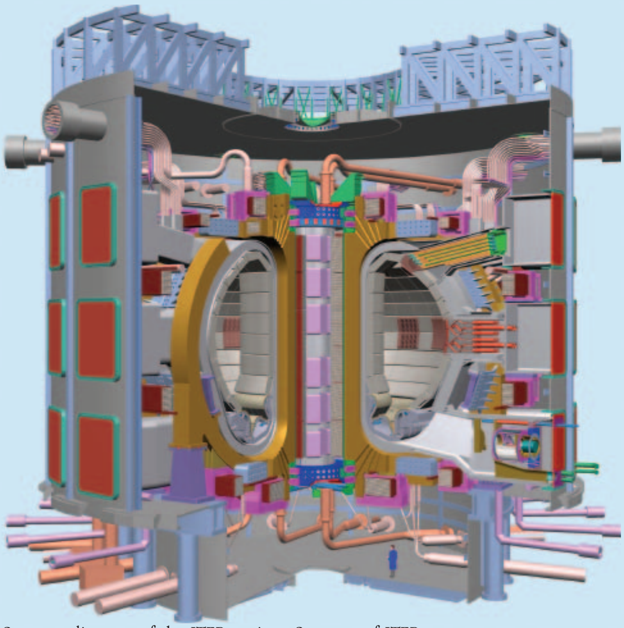
With milli-arc second resolution and limiting magnitude V~38, OWL will be capable of measuring directly the variation in the rate of expansion of the Universe throughout its history, providing unrivalled, essential information about 'dark matter' and 'dark energy'. It will be able to image extra-solar planets and determine the composition of their 'atmospheres', and thereby, possibly, reveal the existence of biospheres. It will peer into the deepest reaches of the universe and witness the birth of the very first stars and galaxies. It may, eventually, revolutionise our perception of the universe as much as Galileo's telescope did.

The capital investment is estimated at one billion euros; science operations could start around the middle of the next decade, subject to timely funding. A worldwide search for a suitable site has begun.

OWL's successful completion and performance rely on industrialised production of long lead-time, state-of-the-art subsystems and components, such as segments and opto-mechanical modules, and on a targeted set of advanced technologies for active subsystems. European industry has shown a strong interest in being associated with the project.

Further information is available at www.eso.org/projects/owl/

Fusion Infrastructures for the Future



Cutaway diagram of the ITER project. Courtesy of ITER.

The development of fusion relies on strong international collaboration, as exemplified by JET – the world's leading fusion experiment. This collaboration encompasses the tokamak concept, improvements (such as stellarators and spherical tokamaks), materials science and development, and other aspects of fusion science and technology. Two major international ventures on fusion energy development – ITER and IFMIF – are foreseen to proceed apace in a coordinated way, with the detailed engineering design of IFMIF starting in parallel with the realisation of ITER.

ITER (meaning 'the way' in Latin) is the essential next step in the fusion programme. It will provide the information required to construct and operate the first electricity-generating power station based on magnetic confinement of high-temperature plasma. ITER began in 1985 as a collaboration between the then Soviet Union, the USA, Europe (through EURATOM) and Japan. Conceptual and Engineering Design Activities led to an acceptable detailed design in 2001, underpinned by R&D by the ITER Parties to establish its practical feasibility. These Parties (with the Russian Federation replacing the Soviet Union and with the USA opting out between 1999 and 2003) have since been joined in negotiations on the future construction, operation and decommissioning of ITER by Canada (who terminated their participation at the end of 2003), the People's Republic of China and the Republic of Korea. The construction cost of the project is expected to be approximately 4.7 billion euros. ITER is now awaiting a site decision – the candidate host parties are the European Union (candidate site: Cadarache in France) and Japan (Candidate site: Rokkasho) – which would allow organisational structures to be established and construction to commence. An international ITER Organisation would be responsible for, and technically oversee, all aspects of the project, including its construction, operation (expected to begin in 2015 and last 20 years) and, ultimately, decommissioning of the plant. The Parties will also form their own legal entities to provide 'in-kind' hardware contributions (involving both laboratories and industries) during construction. In addition, the legal entities will ensure the involvement of national laboratories, linked through world-wide networks of experimental physicists and engineers, for the joint exploitation of ITER.

A Materials Research Programme is also required in order to provide high-performance, low-activation and radiation-resistant materials and to test and verify their performance under conditions as close as possible to those of a fusion power plant. This programme should run in parallel with ITER to ensure the materials are ready when required. The materials' tests could be undertaken by the International Fusion Material Irradiation Facility, IFMIF, currently being designed under IEA auspices.

Finally, it should be noted that the earlier commercialisation of fusion as a source of electricity should be possible if key steps are combined or taken in parallel. If this were to be achieved, the total funding required to reach the long-term objective could be reduced substantially, but at the cost of increased short-term funding. Specifically, if it proves possible to save one generation of fusion devices, an attractive option would be to combine the generations after ITER and IFMIF into a single step designed as a credible prototype for a power-producing fusion plant, but not, in itself, being optimised fully, either technically or economically.

More information is available at http://www.iter.org/

ESO's telescopes and instruments are at the forefront of worldwide research, and are playing major roles in today's rapid developments. One of the world's most advanced searches for extra-solar planets is taking place at ESO's La Silla observatory. At ESO's Paranal observatory, the Very Large Telescope (VLT) is making it possible to study the earliest known galaxies as well as the black hole at the centre of the Milky Way. And the VLT Interferometer (VLTI) is breaking entirely new ground with infrared observations of unprecedented sharpness. The organisation's new and planned projects include the Atacama Large Millimetre Array (ALMA), the world's largest telescope operating at millimetre and submillimetre wavelengths, which will be used to study the formation of stars, planets and galaxies, and an extremely large optical/IR telescope with a segmented primary mirror of up to 100-m diameter, capable of detecting earth-like planets around nearby stars.

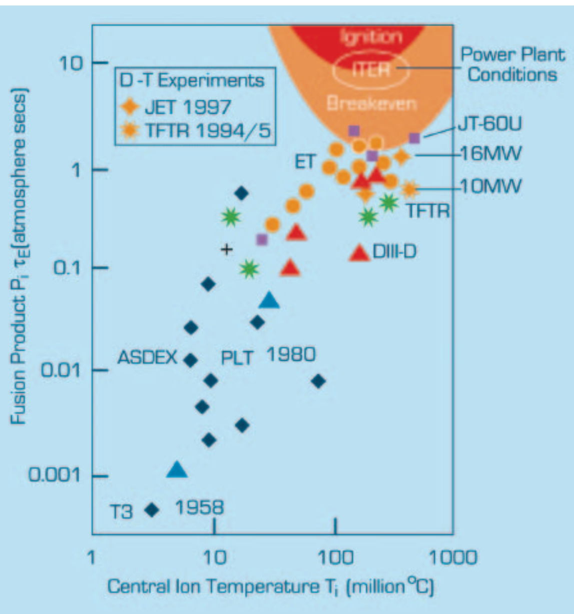
Among the key technologies required to address these questions are further developments of adaptive optics systems, interferometric techniques, systems to deal with large amounts of data located in different repositories (the Virtual Observatory) and the exploitation of synergies between ground-based and space-borne activities.

The coming decades promise great advances in astronomy and cosmology, and ESO's facilities will be at the cutting edge of these exciting fields of fundamental research.

Trends in Fusion Science and Technology of the Future

The objective of fusion is the creation of power plants which provide the energy needs of society – and fulfill requirements such as operational safety, environmental compatibility, social acceptability, economic viability. Over the last decade, there has been significant scientific and technological progress. In short pulses, up to 16 Megawatts of fusion power have been produced, the requirements for generating much higher levels of fusion power are known, and fusion power plants are within reach.

ITER – the next step on the way to fusion power generation – is designed to demonstrate the scientific and technological feasibility of a fusion power plant. Emphasis is placed on sustained fusion power production and extraction, and the integration of key fusion technologies and the demonstration of the inherent safety features of a fusion reactor. The science of ITER is that of long pulse burning plasmas in which fusion dominates the power balance. This covers fluid turbulence, magnetohydrodynamic stability, atomic and molecular physics, plasma-wave interactions, specialised diagnostics, real time control and material science. All this is underpinned by a variety of cutting-edge technologies. ITER will also test many of the main features needed for a fusion power plant – components tolerant to high heat fluxes, large-scale reliable superconducting magnets, blanket modules, and safe remote handling and



The Figure shows progress towards high fusion performance (efficiency of power production) and high temperature from many experiments around the world, giving confidence in the prediction of the behaviour of ITER, a 500 Megawatt fusion power device.

Future Research Infrastructure Needs in Materials Science

Besides the establishment of new research infrastructures, the refurbishment and upgrade of existing ones can be very beneficial, since at comparatively low cost important gains in performance are possible. The complete overhaul of the ILL reactor has given a new long-term perspective to the ILL as the world's leading neutron facility. This is now followed by a thorough upgrade of the Institute's instrumentation and infrastructure ('Millennium Programme').

The ESRF, after ten years of operation, is preparing a long-term plan aimed at a significant upgrade of the X-ray source and the scientific infrastructure (especially X-ray optics and detectors), in order to keep the Facility at the forefront of research with synchrotron radiation and to exploit its specific strengths. Furthermore the experimental programme is being developed by combining different experimental techniques and by moving towards partnerships of enhanced scientific collaboration (for example in the fields of material sciences and soft condensed matter).

disposal of irradiated components. ITER's operating conditions will be close to those that will be experienced in a power plant, and will show how they can be optimised, and how hardware design margins can be reduced to control cost.

There is also significant R&D devoted to the realisation of fusion energy generation at power plant scales. Prototypes of most key components needed for ITER have been tested successfully. There is also R&D for application on a demonstration power plant beyond ITER. This concentrates on blankets (which provide shielding against neutrons, produce tritium fuel from lithium, and allow energy extraction for efficient electricity generation; full-scale blanket modules will be tested on ITER) and low activation structural materials (whose performance needs to be qualified when subjected to extensive neutron irradiation of the type encountered in a fusion power plant). An appropriate high-energy, high-intensity neutron source, such as IFMIF (the International Fusion Material Irradiation Facility) could provide such tests.

Trends in Materials Science and Technology

Materials scientists employ an extremely wide variety of experimental tools in their studies of increasingly complex and sophisticated materials. In addition to conventional laboratory techniques, there is a major trend towards the use of the advanced microscopic probes provided at central facilities for synchrotron X-ray and neutron scattering. Engineers and materials scientists appreciate the unique information available from these non-evasive measurements of, for instance, microstructure and residual strain within the bulk of materials.

In parallel with the development of these new experimental tools available for the characterisation and investigation of materials there is a very rapid increase in the number of classes of material under study. Catalysts, ceramics, superconductors, glasses, polymers, biomaterials, materials for electronics, magnetic materials, metals and alloys, and semiconductors all benefit increasingly from neutron and synchrotron X-ray investigation. However, one special class of material is receiving particular attention at synchrotron radiation and neutron centres – the nanomaterials where the capabilities of X-rays and neutrons to probe at the micron and nanometer level is leading to very real advances in the design and exploitation of new materials.

Over the last few years, the world has been awakened to the potential of nanoscience and nanotechnology to change profoundly the way we live. This 'revolution' is not only the concern of scientists and engineers, but is also having a real impact on many sectors of industry, including electronics, telecommunications, chemicals, transport, energy and the environment. Politicians have also been working hard to keep up with the latest developments and now promote and support research that will benefit both society and the economy. There are great expectations for the future of nanomaterials; most countries around the world have already initiated various nanomaterials science and technology programmes.

As material systems and device structures are becoming nano-sized and nanostructured, a new demand and challenge to characterise precisely and reproducibly their structure, properties and functions is rapidly emerging. A detailed knowledge of the chemical, electronic and magnetic structure of nanomaterials is a prerequisite to tailor their functions in a controlled way. Advanced analytical techniques provided by modern synchrotron radiation and neutron sources will certainly play an important role in this endeavour. These techniques should and will become common tools for nanotechnology laboratories in the near future[34].

[34] *For detailed information, you may consult the GENNESYS web site at http://www.gennesys.net/ .*

Future Research Infrastructures for the Life Sciences

At the beginning of the 21st Century there is general agreement on the central role played by research and development in the Life Sciences, both in generating knowledge and in the application of this knowledge to improving the quality of life. It is therefore in Europe's strategic interest to create and maintain centrally shared resources to provide optimal support for its Life Scientists.

The types of infrastructure needed in the Life Sciences include those related to genome sequencing, transcriptomics, proteomics, imaging, structural biology, model organism resource facilities and bioinformatics services and databases. Experience has shown that these research infrastructures have to be situated in a high-quality research environment, in other words, embedded in centres of excellence. Many Life Science infrastructures are such that only one or a few are required to serve Europe's entire Life Science community, making them natural targets for European coordination to avoid unnecessary duplication of effort and cost. Life Science infrastructures are different in nature from those required by physical sciences. With the exception of sources of synchrotron radiation, produced at facilities shared by physicists, biologists and material scientists, Life Sciences do not need large machines. Rather, they require large-scale collections of data or of research materials that are expensive to generate but that, once produced, can be made useful to the entire international community.

There are already examples of such infrastructures. EMMA, the European Mouse Mutant Archive, was set up to collect and distribute all the genetically different mouse strains. Modern techniques mean that researchers now create more new mouse mutants in one year than had existed prior to the year 2000. These mutants are often the best models of human disease that are experimentally accessible. Similar archives of mutant strains of other model organisms, such as baker's yeast, fruit flies, nematode worms or of human cell lines would be extremely useful, as would accessible collections of research reagents required for working with these organisms. In the context of drug discovery and the study of infectious diseases, it is also essential that Europe maintains facilities for working with Primates where no other suitable experimental models are available.

The other types of archive required by life scientists are databases. Currently, the European Bioinformatics Institute collects, curates and makes available the world's collections of DNA and protein sequence, molecular structure, genome sequence, genetic variation and gene expression data, i.e. the core biomolecular data. It also develops and makes available bioinformatics tools to enable researchers to work with these data. Smaller, more specialised, databases elsewhere store much more detailed information on individual model organisms, such as the mouse. All these databases are growing, most exponentially, and they all need to be interconnected in order to be of maximum benefit. A European-scale solution to funding these databases as they expand and become interoperable needs to be found.

Furthermore, there are many new sorts of data, coming from functional genomics, that will need to be made available to the community if they are to be useful. These include proteomic data, ecogenomic data and imaging data at many different resolutions. We need to do research on how to store and analyse these complex datasets as well as on how to design new infrastructures for their collection, curation and distribution.

Trends in Molecular Biology

In the last 50 years three successive and overlapping revolutions in molecular biology have brought us close to a fundamental understanding of the complex phenomenon of life. This is an objective that is comparable to understanding the ultimate makeup of inanimate matter or the large-scale organisation of the cosmos. Understanding life is also related to a profound, ongoing revolution in technology: in medicine, agriculture, and industrial production.

The first revolution of modern biology, classical molecular biology, was based on biochemistry and structural biology and led to the discovery of the structure of DNA in 1953. This discovery triggered a new, informational and reductionist view of biology that focused on understanding the fundamentals of the flow of genetic information.

The second revolution, classical eukaryotic molecular biology, took centre stage in the 1970s and 1980s using new methods to isolate and manipulate DNA as well as eukaryotic genetics. It became possible to study higher levels of biological complexity using molecular approaches. Research focused on selected model organisms. Many advances were made. We learned, for example, that the genes of eukaryotic organisms have a fundamentally different structure than those of bacteria that had been studied earlier. Furthermore, both the logic governing and the mechanisms of gene control in eukaryotes turned out to be different from the bacterial paradigms. There were also advances in understanding some rather abstract areas of biology, for example the identification of the genes controlling the spatial organisation and patterning of developing embryos.

The third revolution, now in full swing, is genomics and functional genomics. Genomics focuses on the description of the genome and its implementation in the organism. Instead of studying genes and proteins one at a time, biologists can now look at the expression of all the genes in an organism simultaneously, and can study proteins in the context of the large macromolecular complexes in which most of them exist and carry out their functions. The genomics revolution is based largely on technical developments, but the intellectual impulse can be traced to genome sequencing, above all the human genome sequencing project, that led to the production of data in quantities that had not previously been seen in the Life Sciences. This necessitated considerable advances in bioinformatics, greatly broadening the application of computers and computational methods to the Life Sciences. The fruits of this revolution will include a much more detailed description of cell function. We should obtain a complete picture of, for example, the differences between a liver cell and a brain cell, or the difference between a normal liver cell and a cancerous one.

The two trends that make up the genomics revolution, data production and computational applications, are being combined to produce the logical next step, systems analysis. Biologists have realised that living systems need to be considered as collections of functional modules which are dynamic, subject to many regulatory inputs and that interact with each other in a process of self-assembly to constitute living systems. The properties of these systems and of their modules are often not predictable from a simple consideration of their component parts. Biologists are broadening their palettes to incorporate modelling and simulation approaches to help them understand system function.

Ever more complex systems are beginning to yield an integrated understanding of, for example, the transition from the growth phase to the division phase, the pattern formation system of the embryo, the formation of very specific and functionally distinct organs, such as the leaves and roots in a plant, or the heart and

Future Research Infrastructures in Particle Physics

Because of the size of the financial investments involved and the long timescales required, the design and construction of the infrastructures required for particle physics, consisting primarily of particle colliders and the associated detectors, have to be planned globally.

In very general terms, progress in particle physics depends on the development of technologies enabling, at a realistic cost, the creation in the laboratory of the conditions of energy density that are ever closer to those prevailing at the time of the Big Bang. The next step in this progress is planned for 2007 when CERN's Large Hadron Collider (LHC) is expected to start operation. The LHC represents a major step forward in energy density and will allow particle physicists to explore new territory; where there are good reasons to believe that fundamental discoveries can be made.

After the LHC it seems likely that the next accelerator required by the global particle physics community will be a linear electron-positron collider. The timescales involved are long, with serious design studies probably needing 5 years and then a further 8–10 years from getting the go-ahead to detecting the first particle collisions. In the case of linear colliders there are complex choices to be made among several different designs for achieving greatly improved acceleration; global efforts are under way to try to reach consensus among the researchers and governments involved about the way to proceed.

As part of the worldwide optimisation involved in such decisions it is useful to realise that there are some other smaller-scale infrastructures that will be requested by particle physicists. These may include machines that generate intense beams of muons or neutrinos. In Europe, studies of many of these options are being developed in the context of the European Strategy Group for Accelerator R&D (ESGARD see www.esgard.lal.in2p3.fr), with strong links to the FP6-funded CARE project and related design studies.

Furthermore, CERN is developing plans to enhance the initial stages of its own accelerator complex over the next few years. The LHC is not one single collider, but is rather a chain of accelerators, of which the oldest will celebrate its 50th birthday in 2009. Even if very little of the equipment dates from 50 years ago, it is thought to be highly desirable, for reasons of improved reliability and efficiency, to carry out a complete renovation of the oldest elements in the near future.

brain of a human. In sum, systems biology represents a profound transition, away from the 'one gene – one function' way of thinking towards viewing living systems as a whole. The challenge now is to understand the modules of living systems quantitatively, both in terms of the principles of control theory and of their evolution.

Far from being descriptive, this new view of life is predictive in emphasis. It requires quantitative studies, integration of information, computational approaches (modelling and simulation) as well as broad programmes of technologically complex experimentation, much of it in the reductionist mode of 'classical' molecular biology. It demands close collaboration between scientists with expertise in a combination of approaches: experimental, computational and engineering. The aim is both to infer the logic of the system's operation and to re-engineer the system to test the validity of our understanding. The excitement of obtaining a new understanding of the principles underlying living systems is combined with the promise of a multitude of applications in both medicine and biotechnology.

Trends in Particle Physics

Everything in the Universe is made from a small number of basic building blocks, the so-called elementary particles that are held together by a few fundamental forces. Some of these particles are stable and form the normal matter that we see and feel, while others live for only fractions of a second and then decay into the stable ones. All of these elementary particles coexisted for a few moments after the Big Bang.

Since then, only the enormous concentration of energy that can be reached in an accelerator, such as those at CERN, has enabled researchers to study many of these particles. Studying particle collisions can be thought of as 'looking back in time', recreating the environment that existed close to the origin of our Universe. The theories and discoveries of thousands of physicists over the past century have created a remarkable picture of the fundamental structure of matter that we call the Standard Model of Particles and Forces. This model requires twelve matter particles and four force-carrying particles to summarise all that we currently know about the most fundamental constituents of matter and their interactions.

The Standard Model is by now a well-tested physics theory, used to explain and exactly predict a vast variety of phenomena. High-precision experiments have repeatedly verified subtle predicted effects. Nevertheless, physicists know that it cannot stand alone, and that is why they are searching for new physics beyond the Standard Model that they hope will lead them towards a fully-consistent 'theory of everything'.

While the Standard Model is currently the best description we have of the world of quarks and other particles, it does not and is unable to answer important questions such as:

- What is the origin of the mass of particles?
- Can the electroweak and the strong forces be unified?
- What is 'dark matter' made of?
- Why are there three generations of matter and where did antimatter go after the Big Bang?

Because higher collision energies allow one to probe in the laboratory closer to the conditions of the Big Bang, and because the LHC represents a very significant step forward in collision energy, particle physicists are eagerly waiting for the outcome of the experiments that will be performed at the LHC. This will surely have a major influence on how particle physics develops during the coming decades.

The LHC is the next step in a voyage of discovery that began a century ago. At that time scientists had just discovered all kinds of mysterious rays, including X-rays, cathode rays, alpha and beta rays. The big questions were: Where do the rays come from? Are they all made of the same thing, and if so of what? These questions have now been answered, giving us a much greater understanding of the Universe. Along the way, the answers have changed our daily lives, giving us television, transistors, medical imaging devices and computers.

At the beginning of the 21st century, we face new questions, which the LHC is designed to address. Who can tell what new developments the answers may bring?

Trends in Space Science

The MARS EXPRESS Spacecraft.

European space science has blossomed in recent decades. Initially, astronomy took the lead with missions using different wavelength ranges to explore the Universe. These included all regions from the infrared to the high-energy domain. Later, solar-system exploration took over the lead although an active astronomy programme was still maintained. Comets, the Moon, the Saturn satellite Titan, Mars and later Venus and Mercury, captured the attention of European scientists. Moreover, the Sun and its relation to our planet Earth received a lot of attention and scientific effort. Most recently, ESA's Science Programme has targeted the area of fundamental physics, in particular the detection and observation of gravitational waves.

Initially, from the planning point of view, ESA's Science Programme decided on missions to be implemented on a case-by-case basis. Later, in the early eighties, a long-term plan was introduced through the selection of both flagship and medium-sized missions. The largest missions, those requiring specific technology developments, were selected through direct discussions with the scientific community via the advisory structure of the Programme. The medium-size missions were selected through a competitive process following a call for proposals to the scientific community. This long-term planning approach is still maintained and is being implemented under the name Cosmic Vision.

In the discussions on missions to be developed for launch in the time period 2015–2025, i.e. Cosmic Vision 2020, European scientists have begun the process by identifying the themes to be pursued. In the area of solar-system exploration, research on plasma physics in the Earth's magnetosphere should be complemented with data taken at different scales, or even from other planets such as Jupiter. Moreover, the giant planets, and particularly their moons, together with sample return missions or subsurface measurements in minor bodies, or Mars, are attracting attention for the future. In the area of space astronomy, the study of extra-solar planets, their discovery, formation mechanisms and the characterisation of their atmospheres was one of the selected topics. In addition, astronomers are interested in a deeper understanding of the very beginning of the Universe, as well as its lesser-known constituents, such as dark matter and dark energy, and its evolving high-energy elements, such as the environment of black holes, their structure and their role in the structure of the Universe. Finally, in the area of fundamental physics from space, attention is being focused on quantum gravity, matter in the form of Bose-Einstein condensates and more sensitive gravitational wave detectors leading eventually to the measurement of primordial gravitational waves.

It should be noted that all areas share many of the same scientific objectives. For example, the formation and characterisation of extra-solar planets are of interest to astronomers as well as planetary scientists, while astronomers and fundamental physicists target the behaviour of matter in extreme environments or the analysis of gravitational waves data.

The ESA Science Programme

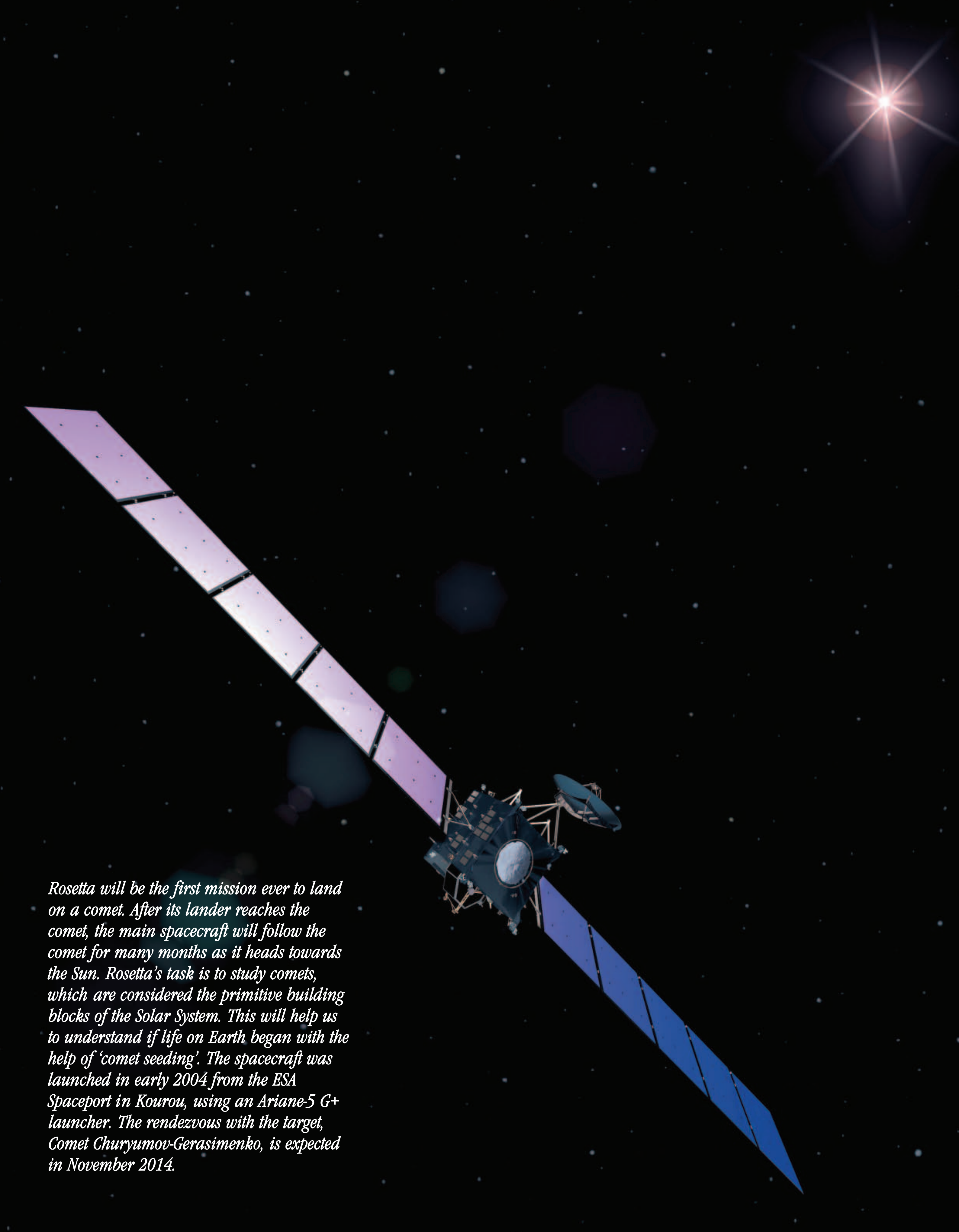
ESA has, historically, two main roots, launchers (ELDO) and space research (ESRO). The second root provides and has always provided the inspiration. 'Life in the Universe' can be considered as a unifying theme, but it must be seen as two-sided. On one side the focus is on life, i.e. one wants to study the origins of life, its preservation and possible threats, the possibility that Man might leave the Earth and explore new worlds; on the other side the focus is on the Universe, i.e. one wants to understand the drama of the development of intelligent life and the grand laws that govern the whole process.

There are various programmes in ESA dealing with inspirational themes. The Science Programme, the oldest and the only mandatory programme, has, in particular, been charged with studying the science of the Solar System (the Sun, the heliosphere, the magnetosphere and the Sun-Earth connection) and science of everything else outside of the Solar System (the Galaxy, the Universe). With hindsight, it can be safely said that the mandatory character of the programme, i.e. the fact that, in order to become a member of ESA, any European country must agree to pay a share of the costs of the science programme, proportional to its GNP, has preserved classical space science in Europe and has avoided one more example of brain drain.

Two types of mission have been developed:

- Solar-system missions, which generally are distinguished according to their target, and mostly consist of service modules carrying largely independent instruments; and
- Astronomical missions, which are generally distinguished according to the wavelengths at which they operate, or the problems they study, and mostly consist of a facility instrument, which feeds photons to focal plane units studying the various aspects of the radiation.

Importantly, the science programme of ESA is operated through a bottom-up approach. Although there are a few exceptions, the vast majority of its missions have been proposed and selected by the scientific community, represented by an agile and continuously renewed advisory structure, consisting of three working/



Rosetta will be the first mission ever to land on a comet. After its lander reaches the comet, the main spacecraft will follow the comet for many months as it heads towards the Sun. Rosetta's task is to study comets, which are considered the primitive building blocks of the Solar System. This will help us to understand if life on Earth began with the help of 'comet seeding'. The spacecraft was launched in early 2004 from the ESA Spaceport in Kourou, using an Ariane-5 G+ launcher. The rendezvous with the target, Comet Churyumov-Gerasimenko, is expected in November 2014.

advisory groups (the Astronomy Working Group, the Solar System Working Group and the Fundamental Physics Advisory Group) and the top-level Space Science Advisory Committee (SSAC), whose recommendations are presented to the decision-taking body, the Science Programme Committee (SPC), on which the member states are democratically represented, each having but one vote. The recommendations of the SSAC have seldom been rejected by the SPC.

A second important aspect of the Science Programme is its robustness. So far, no formally approved mission has ever been dropped. Even the Magnetospheric Cluster Mission, which was lost in the failed Ariane 501 launch, was remade at great sacrifice to the other scientific communities, which found, at that time, the scientific solidarity that is their pride.

These two characteristics of a bottom-up approach to, and the robustness of, the programme have given it a strength and a reliability that belies the size of its budget. The Science Programme of ESA deals with NASA as an equal partner, in spite of its budget being ten times smaller. In some fields of research ESA has either gained uncontested leadership (astrometry, spectroscopy – especially at IR, X-ray and Gamma wavelengths, and magnetospheric physics) or has shared it with NASA.

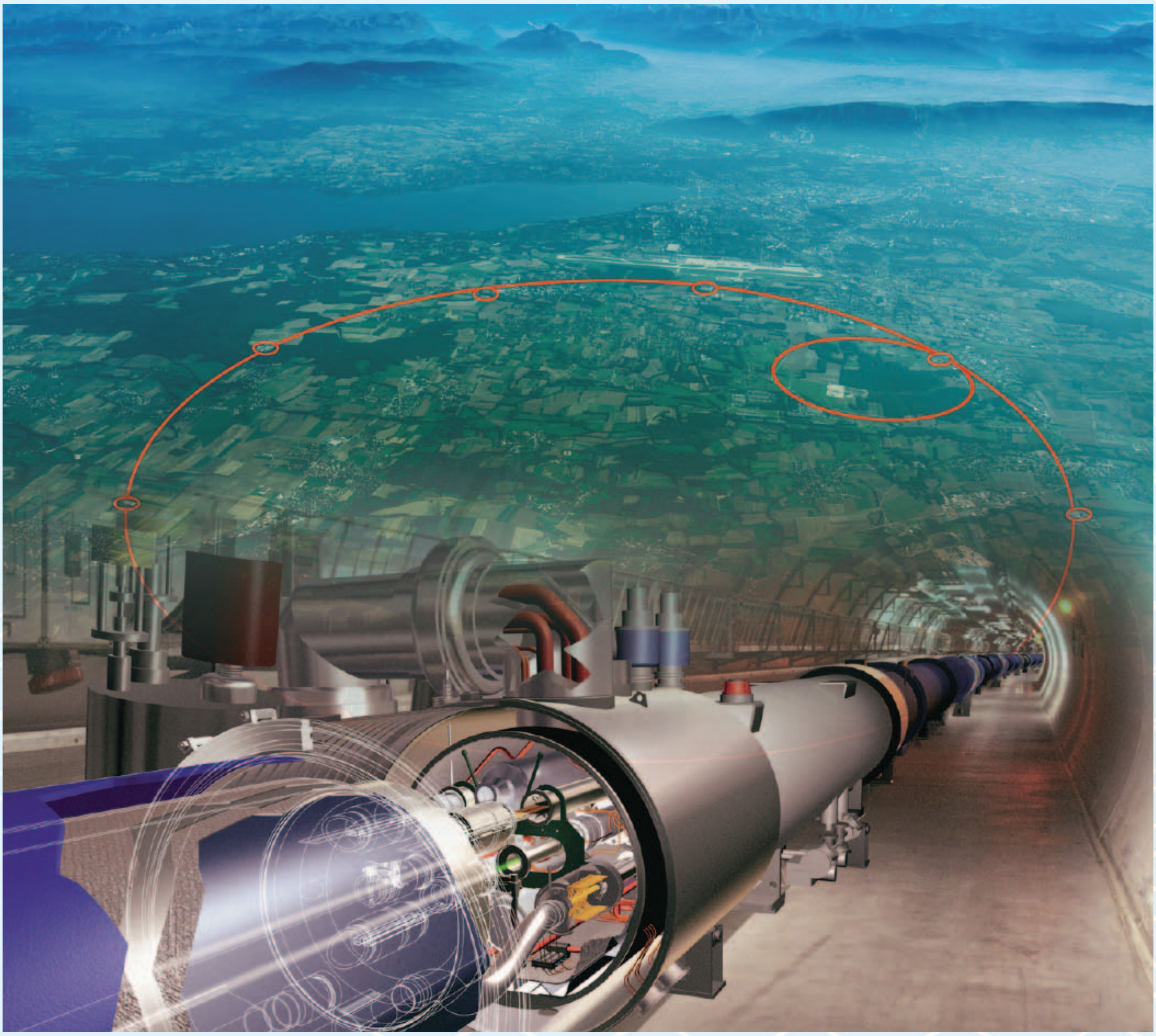
The policies which lead the Agency to these achievements were, and still are, inspired by two principles:

• Never do in space what you can achieve from the ground;
• Never do at ESA what member states can do by themselves.

On the basis of the second principle, the Science Programme has, historically, always preferred that national institutes or consortia of institutes provide the scientific payloads and that they are nationally funded. Unfortunately, in spite of the magnificent achievements, the buying power of both the Science Programme, and even more that of the space science programmes in the member states, have been declining since 1995. Thus, a European programme with decreasing means finds itself facing increasing crises (both in number and size) due to the lack of support for payloads in the member states. This is clearly a major problem that the Science Programme is trying to find creative ways to solve. However, it would be a major loss for European science and a failure of European science policy if the Agency were to short-circuit the national institutes and provide itself payloads.

5. List of Acronyms and Abbreviations

AVO	The Astrophysical Virtual Observatory (see also VO)
ALMA	The Atacama Large Millimetre Array
CARE	Coordinated Accelerator Research in Europe
CT	Computed Tomography Imaging
ECS	European Cooperating States
EGEE	Enabling Grids for E-science in Europe
ELLS	The EMBL European Learning Laboratory for the Life Sciences
ELDO	The European Launcher Development Organisation
ERA	The European Research Area
ETF	The EMBL Technology Fund
EMBLEM	The EMBL-Enterprise Management
ESFRI	The European Strategy Forum for Research Infrastructures
ESGARD	The European Strategy Group for Accelerator R&D
ESRIN	The ESA European Space Research Institute
ESRO	The European Space Research Organisation
ESTI	The EIROforum European Science Teaching Initiative
ETF	The EMBL Technology Fund
FaME	Facility for Materials Engineering
GEM	Gas Electron Multiplier (chamber)
GENNESYS	Grand European Initiative on Nanoscience and Nanotechnology using Neutron and Synchrotron Sources
HERCULES	Higher European Research Course for Users of Large Experimental Systems
ICT	Information and Communication Technologies
IFMIF	International Fusion Material Irradiation Facility
IP	Intellectual Property
ITER	The International Thermonuclear Experimental Reactor
JET	The Joint European Torus
LEP	The Large Electron-Positron Collider
LHC	The Large Hadron Collider
NTT	The New Technology Telescope
OWL	The Overwhelmingly Large Telescope
PET	Positron Emission Tomography
R&D	Research and Development
S&T	Science and Technology
SPC	The ESA Science Programme Committee
SSAC	The ESA Space Science Advisory Committee
STEDE	Science Teacher Education Development in Europe
VLT	The Very Large Telescope
VLTI	The Very Large Telescope Interferometer
VO	The Virtual Observatory



Annex

The European Laboratory for Particle Physics (CERN)

CERN is the world's largest particle physics centre. It straddles the French-Swiss border close to Geneva.

Physicists come to CERN to explore what matter is made of and what forces hold it together. The laboratory exists primarily to provide physicists with the necessary tools for their research, namely colliders, which accelerate particles to almost the speed of light and then bring them into collision, and detectors to make the particles produced by the collisions visible.

Founded in 1954, the laboratory was one of Europe's first joint ventures and is now run by 20 European member states, but many non-European countries are also involved in different ways.

The current member states are Austria, Belgium, Bulgaria, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Italy, the Netherlands, Norway, Poland, Portugal, the Slovak Republic, Spain, Sweden, Switzerland and the United Kingdom. Member states have special duties and privileges. They make a contribution to the capital and operating costs of the CERN programmes, and are represented in the Council, responsible for all-important decisions about the organisation and its activities.

Some states (or international organisations) for which membership is either not possible or not yet feasible are observers – these are the European Commission, India, Israel, Japan, Russia, Turkey, UNESCO and the USA. Observers are able to attend Council meetings and to receive Council documents, but do not participate in the formal decision-making procedures of the organisation.

Scientists from 220 institutes and universities in states, which are neither members nor observers participate in CERN programmes. They currently include: Algeria, Argentina, Armenia, Australia, Azerbaijan, Belarus, Brazil, Canada, China, Croatia, Cyprus, Estonia, Georgia, Iceland, Iran, Ireland, Mexico, Morocco, Pakistan, Peru, Romania, Serbia, Slovenia, South Africa, South Korea, Taiwan and Ukraine.

Physicists and their funding agencies from both member and non-member states are responsible for the financing, construction and operation of the detectors on which they collaborate. CERN spends much of its budget on building new machines (such as the Large Hadron Collider), and it can only partially contribute to the cost of the detectors and experiments.

CERN employs some 2500 people, representatives of a wide range of skills – physicists, engineers, technicians, craftsmen, administrators, secretarial staff, etc. The scientific and technical staff designs and builds the laboratory's intricate machinery and ensures its smooth operation. It also helps prepare, run, analyse and interpret the complex scientific experiments.

Some 6500 visiting scientists, half of the world's particle physicists, come to CERN for their research. They represent 500 universities and over 80 nationalities.
CERN's top priority at the present time is to complete the construction of the Large Hadron Collider (LHC), which is a particle accelerator which will probe deeper into matter than ever before, and which is due to switch on in 2007.

More information is available at http://www.cern.ch/

The European Fusion Development Agreement (EFDA) – JET

The Joint European Torus (JET) is the flagship of the Community Fusion Programme, coordinated by EURATOM (the European Atomic Energy Community), supported by experiments and researchers at all European laboratories, and at the forefront of the world's quest to develop nuclear fusion. JET – based at the Culham Science Centre, Oxfordshire, UK – is the world's largest tokamak (a toroidal, doughnut-shaped vacuum vessel of major radius 2.96 m with a D-shaped cross-section 2.5 m by 4.2 m) containing a plasma of approximately 80 m^3 volume which carries a current (up to 5 MA) and can be confined for up to 60 s by strong magnetic fields (up to 4 T).

JET was constructed to cost and schedule. The design team started in September 1973 and within two years had prepared a design proposal. In June 1978, the JET Joint Undertaking was established to construct and operate JET and in just 4 years from the start of construction, experiments began. These concentrated on optimising the heating and fuelling systems (high-energy neutral beams, waves at the ion cyclotron frequency, cryogenically-cooled solid pellets) and bringing deuterium plasmas up to thermonuclear conditions. Then, in 1991, JET became the first facility to produce a significant amount of controlled fusion power (nearly 2MW) using a deuterium and tritium mixture – the fuels of a fusion power station.

Subsequently, the interior of the vacuum vessel was modified to include a 'pumped divertor' (comprising four large current carrying coils which modify the magnetic field configuration in the vicinity of a target structure and cryo-pump) to facilitate access to operation with high levels of plasma confinement, to handle higher levels of power and particle exhaust, and to improve plasma density and purity control. Experiments in this magnetic configuration allowed JET to make major contributions to the definition of the size, heating requirements, divertor design, operating conditions and technology basis of ITER, the next step in the fusion programme.

During 1997 JET operations included a three-month campaign of highly successful experiments using a range of deuterium-tritium fuel mixtures. The results were of major significance and set three world records:

• 22 MJ of fusion energy in one pulse;
• 16 MW of peak fusion power;
• a 65% ratio of fusion power produced to total input power.

In spring 1998 the fully remote handling installation of an ITER-specific divertor was completed successfully and on time, demonstrating another technology vital for both ITER and future power plants. Experimental work continued in 1999, in particular to characterise the effect of the new divertor to control impurities and plasma density and to develop operating scenarios with higher levels of central confinement.

Since 1st January 2000, the collective use of the JET Facilities by the European fusion laboratories has been carried out under EFDA, the European Fusion Development Agreement, a framework between EURATOM, member states of the European Union and Switzerland in the field of controlled thermonuclear fusion. The EFDA Associate Leader for JET has the overall responsibility for the implementation of the JET activities. The UK Atomic Energy Authority (UKAEA) operates the JET Facilities on behalf of EFDA. The experimental campaigns are conducted by Task Forces comprising scientists from all EU fusion laboratories. The experimental programme has helped consolidate the ITER design, define ITER auxiliaries and optimise scenarios for ITER operations. A third period of JET operation with tritium in October 2003 produced significant results on particle transport and tested specialised diagnostics for 'burning plasma' studies. A programme of Facility upgrades will enhance the capability of JET for its experimental campaigns of 2005/6.

JET, a world-wide centre of excellence, is now a European users' facility attracting over 300 scientists from European laboratories/institutions, together with collaborators in the US, Japan, the Russian Federation and the People's Republic of China. JET is a prototype of the European Research Area, bringing together European competencies in a joint and focused programme in much the same way as ITER is expected to operate.

More information is available at http://www.efda.org/
and http://www.jet.efda.org/

The European Molecular Biology Laboratory (EMBL)

The EMBL (European Molecular Biology Laboratory) was established in 1974. It was set up to promote the development of molecular biology throughout Europe, and is supported by eighteen member states including most of Western Europe and Israel. EMBL consists of five facilities: the main Laboratory in Heidelberg (Germany) with outstations in Hamburg (Germany), Grenoble (France), Hinxton (UK) – the European Bioinformatics Institute (EBI), and an external Research Programme in Monterotondo (Italy).

EMBL is one of the top research institutions in the world and the flagship of European molecular biology, ranking as the highest non-US institute in research performance in its field in a study by ISI Science Indicator for 10992–2002. It currently has 1200 employees from 60 nations and a network of several thousand alumni throughout the world. EMBL is a world-renowned international centre for advanced training and has been granting PhDs since 1997.

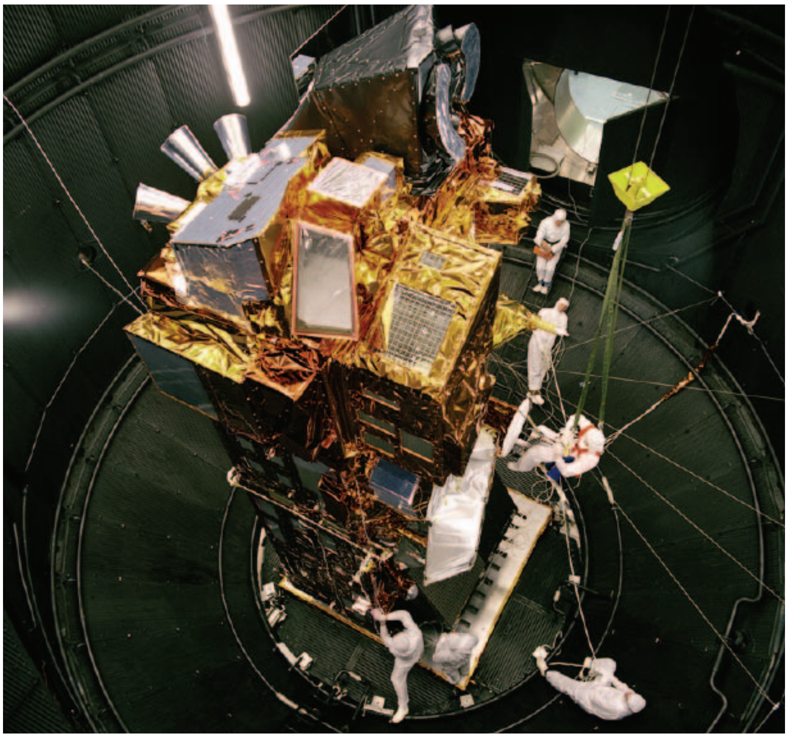
EMBL was founded with a fourfold mission: to conduct basic research in molecular biology, to provide essential services to scientists in its member states, to pro-

vide high-level training to its staff, students, and visitors, and to develop new technologies and instrumentation for biological research.

EMBL has a unique system of staff turnover that enables it to produce a constant stream of highly qualified researchers, at all levels of seniority, who leave EMBL and, for the most part, take up permanent academic or industrial positions in the member states. In its research programmes, EMBL emphasises integration, interdisciplinarity and collaboration, and this outlook is reflected in a growing network of partnerships with universities and research institutes in the member states.

More information is available at http://www.embl.org/

The European Space Agency (ESA)



ESA is Europe's gateway to space. Its mission is to shape the development of Europe's space capability and ensure that investment in space continues to deliver benefits to the people of Europe. The Agency's projects are designed to find out more about the Earth, its immediate space environment, the solar system and the Universe, as well as to develop satellite-based technologies and promote European industries. ESA's Space Programme has helped put Europe at the forefront of scientific discovery about our solar system and the Universe, and this, in turn, has led to breakthroughs in many scientific areas.

ESA is adapting itself continuously to an environment which its very successes transform: the emergence of new user communities, the introduction of new public and commercial services, the advent of new operators, citizens' dependence on services using new space systems, etc. ESA is one of the only space agencies in the world to combine responsibility for:

- The 'basic' activities required to develop and maintain the fundamental elements on which a space policy depends – access to space, the technology base, industrial capabilities, ground facilities;
- 'Inspirational' activities such as sciences (Earth-, space-, life-, and physical-sciences) and human as well as automated exploration;
- 'Utilitarian' activities that involve developing space systems to support public service (meteorology, environment, disaster management, education, energy, agriculture, etc.) and commercial offerings (telecommunications, navigation and satellite imagery) for the benefit of citizens.

This feature is a source of strength both for ESA and Europe, providing a basis for the technical and industrial synergies, which have been the key to European efficiency.

The general objectives for ESA are, therefore, to:

- Consolidate Europe's strategic capabilities, by reinforcing and expanding the science and technology base, as well as maintaining and generating key industrial technical capabilities needed for the future;
- Develop space-based solutions opening up new services;
- Place the European space industry on a level footing with the competition on commercial markets.

The targeting of these general goals, spells out specific objectives:

- Meet the new needs of (an enlarged) Europe, including the area of defense, requiring a growing volume of space activity in Europe;
- Integrate ESA within its political, industrial, technical and international environment to further develop its role as Europe's Space Agency, capable of responding at the same time to the needs of its member states, those of the European Union and those of user communities, including the defence sector, while being an influential partner on the international scene.

In real terms, ESA aims to increase its activities; examples are the Galileo deployment, imagery and chemistry satellites, starting the monitoring for Environment and Security, broadband satellite aiming at narrowing the digital divide in the frame of the Union's enlargement, etc.

Specifically, related to science, the increase in activity will relate to a threefold objective to:

- Develop new technologies, explore new ideas, encourage further inspirational activities and attract young talents;
- Open up cooperation with Central and Eastern European countries;
- Extend cooperation with China and India who wish to develop their scientific activities.

More information is available at http://www.esa.int/

The European Southern Observatory (ESO)

ESO, the European intergovernmental organisation for Astronomy, was created in 1962 to ‘establish and operate an astronomical observatory in the southern hemisphere, equipped with powerful instruments, with the aim of furthering and organising collaboration in astronomy...’
ESO is supported by 11 member states: Belgium, Denmark, Finland, France, Germany, Italy, the Netherlands, Portugal, Sweden, Switzerland and the United Kingdom. Several other countries have expressed interest in joining ESO.

ESO operates world-leading observational facilities at two sites. Since 1999, it runs the world’s prime optical/infrared astronomical facility, the European flagship Very Large Telescope Array (VLT) at the Paranal Observatory. The VLT consists of an array of four 8.2-m as well as four 1.8-m telescopes. A number of the array telescopes can be used in combination as a unique, giant interferometer (VLTI). A 2.6-m and a 4-m telescope, dedicated to large-area sky surveys at optical and IR wavelengths respectively, will be installed in 2005 and 2007.

In addition, ESO operates the La Silla observatory (inaugurated in 1969), where state-of-the-art medium-sized telescopes are in operation, including two 4-m-class telescopes. One of them is equipped with a unique ultra-high-precision spectrograph, capable of measuring radial velocities of stars with a precision of one metre per second and thus ideally suited to detect the gravitational effect of extra-solar planets on their ‘mother stars’.

More than 1600 proposals are submitted each year for the use of the ESO telescopes.

ESO is the European partner of the intercontinental project for the construction of the Atacama Large Millimetre Array (ALMA), comprising a series of 12-m antennas for observations in the submm/mm waveband. This facility is currently under erection at the high altitude plateau of Chajnantor (5000 metres above sea level) in the Chilean Andes range.

Finally, ESO is engaged in design studies for an extremely large optical/IR telescope with a primary mirror of up to 100 m diameter.

The ESO Headquarters is located in Garching, near Munich, Germany. This is the scientific, technical and administrative centre of ESO where technical development programmes are carried out to provide the La Silla and Paranal observatories with the most advanced instruments. The Headquarters also houses the Hubble Space Telescope/European Coordinating Facility, operated jointly by ESO and ESA. There are also extensive astronomical data facilities incorporating data from the main ESO telescopes as well as of the Hubble Space Telescope. ESO has a total staff of approx. 600. ESO's budget for 2004 is 102 million Euros.

ESO regularly issues Press Releases about research achievements based on data gathered with ESO telescopes by astronomers all over the world. It also publishes educational material, organises exhibitions and produces a quarterly journal, The Messenger. ESO has participated in several major European educational projects, primarily targeting the secondary school systems of Europe.

More information is available at http://www.eso.org/

The European Synchrotron Radiation Facility (ESRF)

The European Synchrotron Radiation Facility (ESRF) is a major experimental research facility that operates a powerful source of X-ray light and thirty beamlines for basic and applied investigations across a wide range of scientific and industrial fields.

The synchrotron light source is a storage ring for 6-GeV electrons, of 850 m circumference, equipped with more than 50 insertion devices (magnetic arrays which cause the circulating electrons to emit synchrotron radiation of extremely high brilliance).

The various ESRF beam lines, arranged around the storage ring in an annular Experimental Hall, are optimised for specific techniques and permit research in fields such as biology and medicine, chemistry, earth and environmental sciences,

materials and surface science, and physics. A further thirteen beamlines, drawing synchrotron radiation from the bending magnets of the storage ring, have been set up and are operated by national organisations (Collaborating Research Groups).

The facility is located in Grenoble, France, sharing a common site with the Institut Laue-Langevin and an outstation of the EMBL. The ESRF is organised as a non-profit company (‘société civile’) under French law on the basis of an intergovernmental agreement signed in 1988. The Contracting Parties to this agreement are France, Germany, Italy, United Kingdom, Spain, Switzerland, Benesync (Belgium and the Netherlands) and Nordsync (Denmark, Finland, Norway, Sweden). Other contributing partners associated to the ESRF are Portugal, Israel, Austria and, in the course of establishing a consortium, organisations from Poland, Czech Republic and Hungary). In 2003, the annual budget of ESRF was 73 million Euros and its staff complement 564.

Each year the ESRF’s scientific and technical experts welcome thousands of scientists from about 600 research organisations who come to Grenoble to conduct their experiments. More than 1600 applications for beam time are received each year, of which about half are retained by the review committees, resulting in about 1200 different experimental sessions per year.

ESRF’s beam lines are mostly used by academic researchers, but are also available for industrial users (who may work with academic researchers or buy their own beam time for proprietary research). Firms that have used ESRF for research purposes include pharmaceutical, chemical, petroleum, plastics, metals and alloys, and electronics companies.

More information is available at http://www.esrf.fr/

Institut Laue-Langevin (ILL)

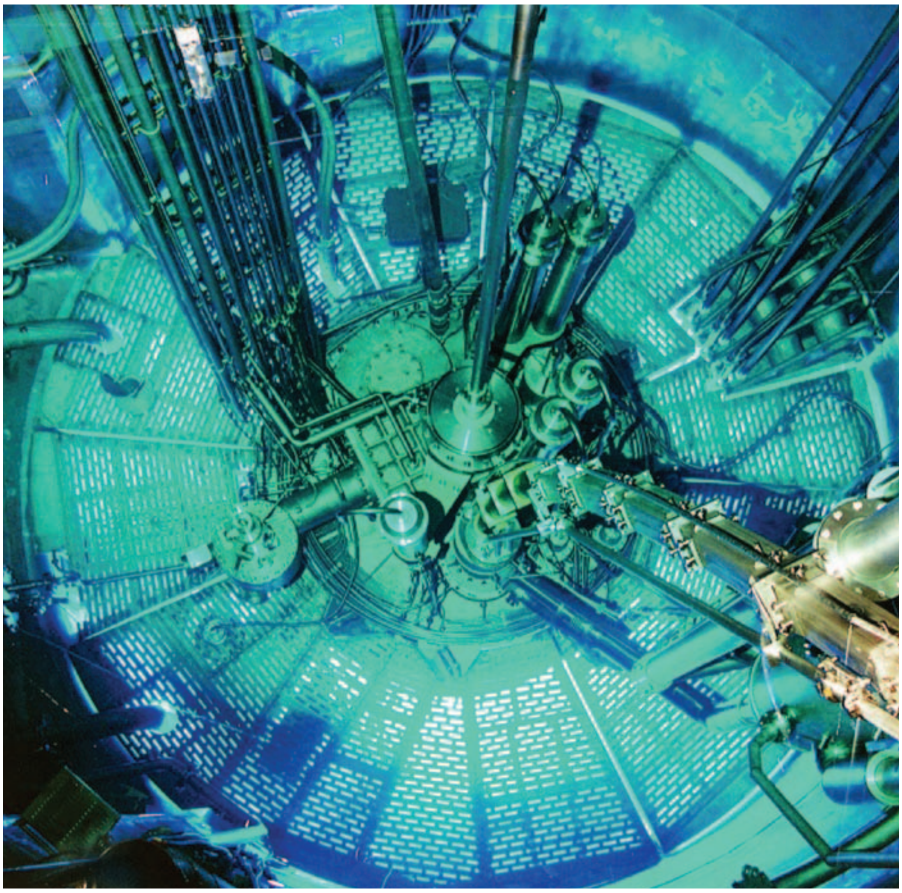
The Institut Laue-Langevin (ILL), situated in Grenoble in the heart of the French Alps, is an international research centre using neutrons to probe the microscopic structure and dynamics of a broad range of materials from the molecular, atomic and nuclear point of view. It is directed by three founding countries – France, Germany and the United Kingdom – whose grants to the Institute’s budget of approximately 60 million Euros per year are enhanced by Scientific Membership contributions from Austria, the Czech Republic, Italy, Russia, Spain and Switzerland. The ILL’s research reactor of 57MW power became operational in 1972 and was extensively refurbished in 1992–1994. ILL is constituted as a non-profit company (société civile) under French law.

The ILL was founded to provide scientific communities in its member countries with a unique flux of neutrons and a matching suite of experimental facilities comprising some 40 instruments for the study of a wide range of problems in condensed matter. The Institute has ever since been an exceptional centre of research operating the most intense neutron source in the world.

Over 2000 visiting scientists, performing a total of 750 experiments per year, bear witness to the scientific success of the facility. Most of these scientists are from academic institutions in the member countries but a significant number of industrial partners use the beam-lines either on a contractual basis or in collaboration with universities or research institutes.

Neutron beams contribute to scientific research across the widest possible range of science. They are a unique probe of the structure and dynamics of condensed matter in fields which range from the life sciences and soft matter to materials and magnetism. They also allow investigation of the fundamental properties of nuclear structure relevant to the understanding of matter on the scale of quarks to the cosmos. One of the major challenges of the 21st century will be the investigation of matter on the nanoscale – intelligent materials, biochips, biosensors, high Tc superconductors, all of which are domains eminently suited to the investigation of structure and dynamics by neutron scattering.

Further information on the ILL can be obtained at http://www.ill.fr



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