European Strategy Forum
on Research Infrastructures

ESFRI

EUROPEAN ROADMAP FOR RESEARCH INFRASTRUCTURES

Report 2006

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>The mandate

In the context of developing Research Infrastructures of European interest, the Council of the European Union welcomes the development of a strategic roadmap for Europe in the field of Research Infrastructures and the role of the European Strategy Forum for Research Infrastructures (ESFRI) in this context.

This roadmap should describe the scientific needs for Research Infrastructures for the next 10-20 years, on the basis of a methodology recognised by all stakeholders, and take into account input from relevant inter-governmental research organisations as well as the industrial community.

The Council stresses that this roadmap should identify vital new European Research Infrastructures of different size and scope, including medium-sized infrastructures and those in the fields of humanities and bio-informatics, such as electronic archiving systems for scientific publications and databases.

Extract from the Competitiveness Council Conclusions, 25 – 26 November, 2004.

>Foreword

Dear Ministers,
Dear Commissioner,

In 2002 you set up ESFRI, the European Strategy Forum for Research Infrastructures, as the body where your senior representatives meet for informal consultations on strategic issues related to Research Infrastructures. During the second semester of 2004, you called for the development of a European roadmap for the construction of the next generation of large-scale Research Infrastructures and requested ESFRI to establish this roadmap in close collaboration with the European Commission.

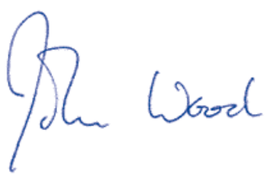
ESFRI is very proud to present the first European roadmap for new, large-scale Research Infrastructures, based on an international peer-review, which was adopted by ESFRI at its meeting of 28 – 29 September, 2006. In the annex to this letter you will find the actual roadmap, which includes a short description of each of the projects and an estimation for the construction costs. Some are evolving projects while others need firm financial commitments from the start. The role of ESFRI in fostering incubation and stimulation will be exercised to bring as many of these projects to a point where decisions by ministers are possible. This requires in the first place discussions and decisions at national level in particular as regards the lead role one country or several countries may wish to take for certain projects. These reflections might encourage the development of national roadmaps and the earmarking of dedicated national budgets for the construction of Research Infrastructures with a European/international dimension, which ESFRI would welcome.

As said above, ESFRI is willing to continue its role (as indicated in the ESFRI charter) as incubator for the decision-making (and negotiating) process for the projects of the roadmap. For this reason it invites you to investigate whether you could instruct your ESFRI delegates to participate in exploratory discussions about the realisation of some of the proposed projects. ESFRI also welcomes the active role which the European Commission intends to play in this context under the Seventh Framework Programme (FP7).

The European roadmap is the result of two years of intensive work, a period during which a number of other points arose, which I would like to bring to your attention.

1. The European roadmap is a first exercise at European level and is the result of wide stakeholder consultation. It is the intention of ESFRI to update the document as of next year to allow it to be improved and integrate new ideas where and when appropriate.
2. Almost 1000 high-level experts from all fields of research were involved and consulted in the process of preparing the roadmap, of which 200 were involved in the peer-review. Their input was of crucial importance to give the end product credibility and quality.
3. The roadmap covers a very broad spectrum of scientific fields. However, it has become apparent that not all fields of science are equally well structured and organised. Therefore, the communities that are less well structured should be stimulated to integrate further and be more proactive at European level so that they can become more effective in the future.
4. Research Infrastructures are one of the crucial pillars of the European Research Area, in particular for capacity building.
5. The members of ESFRI would like to draw your attention to the field of energy. Given the importance of this topic, policy-makers and the science community are called upon to develop clear ambitions in this area. ESFRI is willing to contribute to this.
6. Although not covered explicitly in the roadmap, there is an underlying concern about the numbers and quality of well-trained young researchers who will be available to ensure that Europe continues to play a leading role in a number of projects covered by the roadmap. Commitment to leading Research Infrastructures for the long term will help highly qualified young people see that there is an exciting future if they pursue a research career.
7. Many of the projects plan for a lifespan of several decades. It is essential that, from the start, thought is given to the sustainability of funding over the full lifetime of a project and not just the capital spending.
8. Several of the projects on the roadmap are of a scale and scope that requires a global approach. For this reason, ESFRI will enter into a dialogue with the OECD Global Science Forum, to allow for the identification, planning, discussion and monitoring of such projects.
9. During the preparation of the roadmap, ESFRI had several and effective interactions with Intergovernmental Organisations (such as CERN and ESA). Consequently, in this first edition of the roadmap, ESFRI has not detailed space-based and particle physics Research Infrastructures which are dealt with in ESA and CERN Council documents respectively..

We look forward to a constructive dialogue with you on the roadmap as well as on the specific actions which are required as a result of it.



John Wood
ESFRI Chair

	Projects (in alphabetical order per discipline)	Estimated Construction Cost (M€) *	First possible operations for users	Indicative Operational/ Deployment Cost (M€/year)
Social Sciences & Humanities	CESSDA	30	2008	6
	CLARIN	108	2008	10
	DARIAH	10	2008	4
	EROHS	43	2008	12
	ESS : European Social Survey	9	2007	9
	SHARE	50	2007	< 1
Environmental Sciences	AURORA BOREALIS	360	2010	18
	EMSO	150	2011	20
	EUFAR	50 - 100	2007	2 - 4
	EURO ARGO (GLOBAL)	76	2010	6
	IAGOS-ERI (GLOBAL)	20	2008	6
	ICOS (GLOBAL)	255	2010	13
	LIFE WATCH	370	2014	70
Energy	HIPER	850	2015	80
	IFMIF (GLOBAL)	855	2017	80
	JHR	500	2014	30
Biomedical and Life Sciences	EATRIS	255	2010	50
	European Bio-banking and Biomolecular Resources	170	2009	15
	INFRAFRONTIER	320	2007	36
	Infrastructure for Clinical Trials and Biotherapy Facilities	36	2007	5
	Integrated Structural Biology Infrastructure	300	2007	25
	Upgrade of European Bio-Informatics Infrastructure	550	2007	7
Material Sciences	ELI	150	2013	6
	ESRF Upgrade	230	2007-2014	NA
	ESS: The European Spallation Source	1050	2017	80
	European XFEL	986	2013	84
	ILL 20/20	160	2012-2017	NA
	IRUVX-FEL	760	2006-2015	70
	PRINS	1110	2008-2013	256
Astronomy, Astrophysics, Nuclear and Particle Physics **	ELT: The European Extremely Large Telescope	850	2018	40
	FAIR	1186	2014	120
	KM3NET	220-250	2015	NYD
	SKA: The Square Kilometre Array (GLOBAL)	1150	2014-2020	100
	SPIRAL2	137	2011	7
CDT	EU-HPC	200-400	2008	100-200

NYD = not yet defined

NA = not applicable - already covered within the current budget

CDT = Computer and Data Treatment

Description
Facility to provide and facilitate access of researchers to high quality data for social sciences
Research Infrastructure to make language resources and technology available and useful to scholars of all disciplines
Digital infrastructure to study the sources in cultural heritage institutions
Central and distributed facility to promote and ensure cooperation and integration of data, technologies and policies
Upgrade of the European Social Survey (set up in 2001 to monitor long term changes in social values)
Data infrastructure for empiric economic and social science analysis of the on-going changes due to population ageing
European Polar Research Icebreaker
Multidisciplinary Seafloor Observatory (5 sites)
Long Range Tropospheric Aircraft (options: C130 or Airbus 400M)
Ocean Observing buoy system (deployment over 12 years)
Climate Change Observation from 20 commercial aircrafts (deployment)
Integrated Carbon Observation System (deployment/operation over 20 years)
Infrastructure for research on the protection, management and sustainable use of biodiversity
High Power long pulse Laser for "fast-ignition" Fusion
International Fusion Materials Irradiation Facility
High flux reactor for Fission Reactors Materials Testing
Network of new research centres to translate basic discoveries into clinical interventions in major diseases
Network of existing and new biobanks (samples and data from patients and healthy persons) and molecular resources
Distributed infrastructure for the archiving and phenotyping of mice as models for studying human diseases
Network of clinical research centres, clinical trials and biotherapy facilities for therapeutic innovations
Network of centres for integrated structural biology (protein production, NMR, crystallography, microscopy)
Shared platform for data resources in the Life Sciences (based on a major upgrade of EBI)
Extreme Light intensity short pulse Laser
Upgrade of the European Synchrotron Radiation Facility (in 7 years)
European Spallation Source for neutron spectroscopy
Hard X-ray Free Electron Laser in Hamburg
Upgrade of European Neutron Spectroscopy Facility (in 2 phases)
Infrared to soft X-rays complementary Free Electron Lasers (in 5 users facilities)
Paneuropean Infrastructure for Nanostructures and Nanoelectronics
European Extremely Large optical telescope
Facility for Antiproton and Ion Research
Underwater Neutrino Observatory (in design phase)
Square Kilometer Radiotelescope Array (in two phases)
Production and study of rare isotope Radioactive beams (toward the future facility EURISOL)
Integrated European High Power Computing Service (2 - 4 high-end centers)

* For several projects the cost indicated will still need further review on the basis of more detailed technical and financial studies to be carried out
** Proposals related to particle physics and space science can be found under the CERN and ESA respective websites

>The European Roadmap is the result of two years of intensive work at European level

It has been compiled following wide stakeholder consultation and it is the intention of ESFRI to update the document next year, in the first instance, to allow it to be improved and to integrate new ideas where and when appropriate.

Excellence and Research Infrastructures

Europe has a long-standing tradition of excellence in research and innovation, and European teams continue to lead progress in many fields of science and technology. However our centres of excellence often fail to reach critical mass in the absence of adequate networking and cooperation. There is therefore a need to bring resources together and build a research and innovation area equivalent to the "common market" for goods and services.

Role of ESFRI

As a result ESFRI was asked to develop a truly long term European view on the development of Research Infrastructures of pan-European interest and thus contribute to achieving the knowledge growth as set out in the Lisbon strategy. For several months, ESFRI worked on developing its incubator and stimulation role, and has identified key projects through a large consultation.

The Projects

All projects included in the roadmap are of pan-European interest and of scientific excellence. They will however have reached different degrees of maturity from technical aspects to institutional development, from the organisation of user communities to financial commitments. We are not indicating these maturities in a comparative form, because this was considered to be fraught with problems especially as several funders with differing national priorities will be involved. An assessment of maturity cannot be an indication of any form of priority, given that many of the projects have up to 20 years to mature, while others can progress relatively quickly.

Wide participation of Experts

Almost 1,000 high-level experts from all fields of research were involved and consulted in the process of preparing the roadmap. Their input was key to give the end product credibility and quality. There is no doubt that starting from scratch to produce it in two years has been a formidable task and every attempt has been made to make the exercise transparent and fair.

The Challenge of the Future

It is becoming increasingly important to plan future large scale Research Infrastructures on timescales approaching one or two decades.

Several national roadmaps mapping out their aspirations on a 10-20 year timescale have been produced or are in the process of being produced by individual countries in Europe and around the world. However since many of the anticipated infrastructures will be funded and managed as truly European facilities, ESFRI took the initiative to propose a synthesis to be put at the disposal of the various decision-makers.

Research Infrastructures of pan-European relevance provide unique opportunities for world-class research and training as well as to stimulate knowledge and technology transfer, in brief for European capacity building.

Global Dimension

Several of the projects on the roadmap are of a scale and scope that requires a global approach. For this reason, ESFRI will enter into a dialogue with the OECD Global Science Forum, to allow for the identification, planning, discussion and monitoring of such projects.

Experience Gained

Inevitably this first attempt may be imperfect, since methodologies for assessing major scale infrastructures differ for different fields and in general there is not yet an established common approach for creating such a roadmap. Some rules of engagement had to be decided during the process, and some important fields have not yet been fully engaged. If nothing else, this roadmap shows that the research community is not short of ideas that will open up new and unexpected areas of knowledge. If all the projects described are realised fully or in part, they will clearly add to European integration and inspire future generations to work together for the benefit of society, helping Europe to remain a major player in the international research arena.

Also, it has become apparent that some fields of research should be stimulated for further integration and be more proactive at European level so that they can become more effective in the future.

Target Audience

Now that the first European roadmap for new large-scale Research Infrastructures is ready, ESFRI hopes that the target audience of the roadmap, policy-makers, funders, industry and society, will in a common effort, translate the projects into concrete actions. It welcomes the active role which the European Commission intends to play under the Seventh Framework Programme. At the same time ESFRI will take stock of the lessons learnt to be ready for the preparation of an early update of the roadmap.

More to come

ESFRI will be involved in a number of events following the publication of the roadmap to disseminate it to as many key stakeholders as possible. ESFRI encourages constructive debate. Therefore such comments and suggestions on how the roadmap could be improved for decision-makers in the future are warmly welcomed. These should be communicated through the national ESFRI delegates who will ensure that the comments represent the views of their respective state.

EUROPEAN ROADMAP
FOR RESEARCH INFRASTRUCTURES

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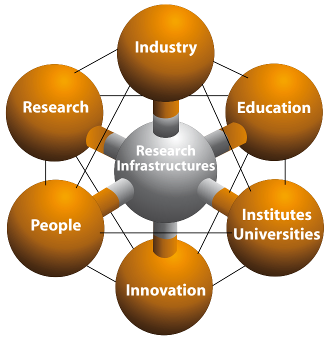
>Key challenges facing Europe in the XXI century: the contribution of Research Infrastructures

> *Being willing is not enough; we must do.*
>
> Leonardo da Vinci (1452 - 1519)



Despite the fact that the XXI century has begun with extraordinary technological and scientific breakthroughs occurring almost daily, Europe still faces significant obstacles if it is to fully realise the benefits of the European Research Area and its instruments as they contribute to the quality of life and wealth creation in the future.

Facing key challenges

Society faces many future challenges. These include global warming, energy production, water supplies, a sustainable environment, the threat of terrorism, quality of life for an ageing population, in addition to social issues such as the continuing divide between rich and poor which can lead to instabilities in society. Research Infrastructures are one key instrument in bringing together a wide diversity of stakeholders to look for solutions to many of the above-mentioned problems. They can be seen as a focal point for such interactions, in addition to inspiring new research ideas and attracting young enquiring minds.

Achieving Excellence in Research and Education

In October 2005, at the Hampton Court informal meeting, Heads of State called for urgent action to achieve world-class excellence in both research and education.

Europe should therefore not only develop the three corners of the knowledge triangle (innovation, education, research), but also complete this picture by reinforcing the links between the main actors (people, academia, industry), obtaining a strong knowledge "diamond", where Research Infrastructures are at the centre and act as the natural bridge between the different corners. Since activities in these facilities and related networks lie at the frontiers of science, they stimulate the interest of young people to embrace scientific careers. The need to strengthen the quality of European research, innovation and education systems is further documented in the Commission's Annual Progress Report on the Strategy for Growth and Jobs.[1]

Unique opportunities

Research Infrastructures provide unique opportunities to train skilled people while stimulating knowledge and technology transfer. They will contribute substantially to attracting and training more than 400,000 young scientists which Europe needs to reach 3% of GDP investment in research.

Research Infrastructures have the ability to create rich research environments and attract researchers from different countries, regions and disciplines. Thousands of researchers and their students from universities, research institutes or industry, from Europe and outside Europe, use Research Infrastructures each year. About 55% are researchers from universities, 20% are from public laboratories, and 20% are from non-European research institutions, while 5% are from industry.

Contribution to capacity building

Another contribution to *capacity building* is related to the fact that about 15% of the institutional researchers use the facilities in collaboration with industry, and that the construction and maintenance of facilities creates important supply and demand effects. Such innovation capacities can be seen through the public-private mobility of researchers and the new technologies applied in building top-level research installations or spin-off products and/or start up companies.

The benefit of cross-disciplinary and institutional collaboration lies in creating catalytic effects and the personal interactions of researchers coming from different countries, disciplines and work places are an essential asset.

Ensuring Socio-economic Impacts

Research Infrastructures clearly stimulate industrial impacts. Pan-European Research facilities play an outstanding role in building the interface between science and industry. They also contribute to many other *socio-economic impacts*. The landscape of Europe shows that, where pan-European Research Infrastructures have their site, often "technology clusters" of associated industry or so-called technology parks can be found. Such strategic centres for transfer of knowledge offer either better possibilities for interdisciplinary research contacts or greater attraction to high-tech firms. As a result, this can be an opportunity to increase the public-private interaction also in the funding of research activities.

1. http://ec.europa.eu/growthandjobs/annual-report_en.htm

>Origin and Purposes of the ESFRI Roadmap

"Progress comes from the diversity of cultures."

Pierre Joliot (1932 -)

A vision of new Research Infrastructures arises from an assessment of the fundamental challenges facing Europe and of the unprecedented developments and opportunities in science.

New Research Infrastructures are required to monitor and predict such changes, and to help develop new sustainable production and consumption schemes. In addition some research questions can only be answered by a European and global response.

This century can be described as the "century of complex systems". Life sciences are undergoing a profound transformation, triggered by the recombinant DNA revolution and fuelled by advances in high-throughput analytical techniques such as genomics and proteomics. A pan-European capacity to generate and handle the volumes of information needed in the life sciences and to translate this information into effective interventions is needed if the benefits for human health are to be realised.

Discoveries in astronomy concerning the nature of dark energy or the emergence and evolution of the first stars and galaxies have generated a need for more complicated and expensive research instruments than ever before. Nuclear physics has been revolutionised by the recent ability to enhanced acceleration beams. The next generation of infrastructure at the cutting edge of nuclear physics and astronomy makes it necessary to pool both intellectual and financial resources.

If EU industry is to compete in an increasingly globalised world, it must lead in high tech production. It must assimilate new "hybrid" technologies such as nano-sciences, bio- or information technologies. This requires pan-European collaborations to succeed and to get access to high quality international Research Infrastructures. In many cases researchers from a wide range of backgrounds meet around such facilities and this meeting of minds is a rich ground for spawning new areas of interest and looking at problems in a new way leading to new insights.

This century will be marked by our ability to look at complex and interacting systems (e.g. environment, energy and human behaviour) requiring expertise from many disciplines to solve. Experimental methods and analysis will be keenly aligned with real-time computer simulations that will refine their models and set new experimental parameters significantly faster than can be obtained by direct human interaction.

The strength and international visibility of Europe is strongly enhanced by a number of world class Research Infrastructures, developed thanks to specific international initiatives, started earlier than the creation of the EU, in the fields of Particle Physics, Molecular Biology, Astronomy and Space, as well as in Materials Sciences or Biology and in Fusion research[1].

In addition, most of the large Research Infrastructures now operating with open access in Europe have been built and are mainly funded by single countries. They are "national" in financial terms, but pan-European in scientific terms. They act, in fact, as "Agencies" increasingly transferring resources between Member States, in the form of services given to European researchers[2].

However, today the EU risks losing its international leadership in several fields because many of the critical facilities are nearing the end of their useful life, as shown by a recent survey. Moreover the costs of many envisaged new facilities, or their major upgrade, cannot be met by individual countries as in the past.

The survey gives Member States an overview of what different research communities see as desirable for making progress their areas. By looking at the whole roadmap and assessing it within an international context, decision-makers can work jointly to plan and realise future investments in a timely and coherent way.

New facilities thus afford the opportunity to aid European integration.

The development of a common policy for access to and the provision of new and improved Research Infrastructures gives equal opportunities to all Member States, including those without large research capacities[3].

Member States and the European Commission recognised the need for a strategic approach and therefore formed the European Strategy Forum on Research Infrastructures (ESFRI) in 2002. Its objectives are to support a coherent and strategy-led approach to policy making and to facilitate multilateral initiatives leading to the better development, construction and use of major research facilities.

This is the origin of the roadmap!

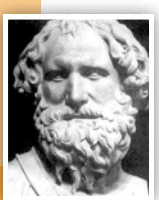
ESFRI has initiated several actions, and, in particular, with a mandate from the EU Council, worked for the past two years to prepare the present first edition of the roadmap to provide an overview of the needs for infrastructures of pan-European interest for the next 10 to 20 years.

The roadmap is not a priority list. Its aim is to facilitate discussion and allow for coherent planning. It will also stimulate other groups to look at pan-European initiatives of a similar nature that might be added in future editions.

All projects included in the roadmap have had to have a strong scientific case first and foremost. They may have different degrees of maturity in terms of institutional or financial perspectives but their inclusion in this report implies that they are supported by at least one European Member State and have great potential at pan-European level.

1. CERN, EMBL, ESO, ESA, ESRF, ILL, EFDA: these are represented through EIROforum www.eiroforum.org
2. See the recent constitution of ERF European association of national Research Facilities.
3. Researchers can participate in international projects e.g. through trans-national access, and have the opportunity to interact at international level, transferring their acquired knowledge back to their own countries.

>Which Research Infrastructures are considered?



Had we a place to stand upon, we might raise the world.

Archimedes (287 - 212 BC)

In the roadmap, we deal with facilities, resources or services of a unique nature that have been identified by pan-European research communities to conduct top-level activities in all fields.

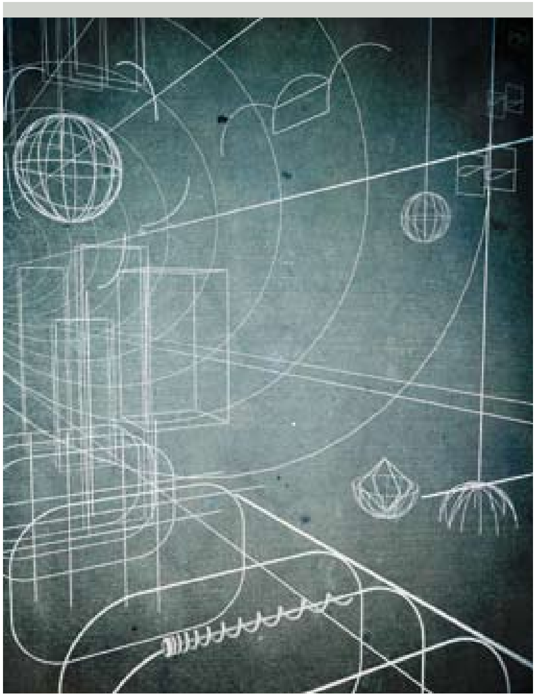
This definition of Research Infrastructures, including the associated human resources, covers major equipment or sets of instruments, as well as knowledge-containing resources such as collections, archives and databases. Research Infrastructures may be "single-sited", "distributed", or "virtual" (the service being provided electronically). They often require structured information systems related to data management, enabling information and communication. These include technology-based infrastructures such as grid, computing, software and middleware.

In all cases considered for the roadmap, these infrastructures must apply an "Open Access" policy for basic research, i.e. be open to all interested researchers, based on open competition and selection of the proposals evaluated on their sole scientific excellence by international peer-review.

In most cases the effort and resources required to build these infrastructures, and to make them available as a service to the general pan-European user community, are well beyond those available to single institutions or even countries. Therefore there is the need for an international approach including the prerequisite to ensure long term sustainability of open access, at no cost to the researcher.

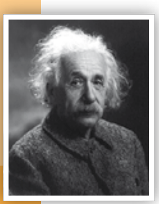
The importance of pan-European infrastructures is well established in areas such as fusion energy, space or particle physics. Today, it is rapidly increasing in other areas, which, until now, were mainly supported by national institutions. For example, light and neutron sources, databases for genomics or social sciences, observation networks for environmental sciences, centres for development of new materials or nano-electronics, are now at the core of world-level research.

In all these fields, the projects considered in the roadmap are characterised by quite high costs (compared to the normal research costs of a particular discipline) for construction and operation. They also need a long lead time and extensive expertise to be developed, as well as a sustainable institutional frame to be open to and used by the largest interested community of scientists work and customer industries.



Disciplines like astronomy or space sciences can be important on a global level to foster technological advancement and attract the young to further education and to pursuing an academic career.

>The global dimension



This is the duty of every man to give back to the world as much as he received from it.

Albert Einstein (1871 - 1955)

Research is without borders, and it is the scientist's everyday experience to forge working collaborations with peers anywhere in the world, even against political and social constraints.

As the frontiers of research are pushed back, research facilities are increasingly becoming more complex and more expensive, to the point where a single government or indeed a single continent cannot find within itself the financial resources for their realisation. The construction and management of new Research Infrastructures thus becomes a global endeavour. Aligning funding cycles and priorities, setting up governance structures, preserving "open access" based on excellence, concluding political negotiations on site selection, are just a few of the challenges that policy-makers face due to the emergence of global Research Infrastructures.

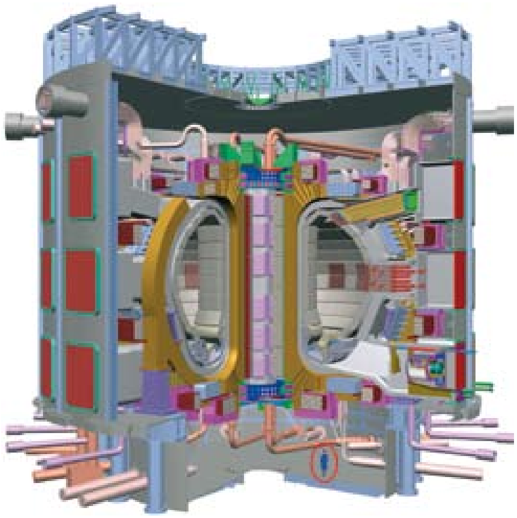
Many scientific fields address questions on a global scale and need institutional arrangements and extended infrastructures able to provide the long term continuity that their fields require.

In Europe, and in other parts of the world, governments have, during the last few years, taken initiatives to create roadmaps for their Research Infrastructures. In ESFRI, it has been important to bring together people representing their different national initiatives to see if they can pave the way, together and on a more global scale, for the best possible infrastructure surroundings for the research community.

In December 2005, ESFRI invited representatives from the US, Japan, Australia and South Africa to participate in the European Research Infrastructures Conference in Nottingham, UK. Those representatives presented their respective national roadmaps and debated with ESFRI the possible ways to cooperate.

Global projects continue to emerge, for example in the field of high energy physics with the International Linear Collider, in the field of radio-astronomy with the SKA project[1], as well as in the fields of translational medical research, bioinformatics, functional genomics, environment, biodiversity, marine sciences, clinical trials, cultural heritage, etc. This has been taken into account in developing this roadmap.

Fields of research like the earth or social sciences need, by definition, to be conducted on a global scale, thus needing institutional arrangements and extended infrastructures capable of giving the longer term continuity that these research fields require.



ITER is the experimental step between today's studies of plasma physics and tomorrow's electricity-producing fusion power plants. It is an international project involving the People's Republic of China, the European Union and Switzerland, India, Japan, the Republic of South Korea, the Russian Federation, and the United States of America, under the auspices of the IAEA.

Research Infrastructures of a global nature are needed to support the international collaborative activities of researchers, including standardisation and integration of data collected in different countries, reflecting the nature and complexity of global challenges.

The availability of distributed computing and data networks adds to the capability of widening the extent and diversity of the data collection and data elaboration. The e-infrastructure dimension of global projects is therefore an essential aspect.

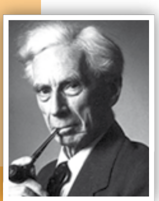
Participation in international projects is seen as key to access of state-of the-art facilities especially in some fields where there is potential for growth.

ESFRI hopes that this roadmap will reinforce dialogue and relations with international fora, such as the Global Science Forum, and other International Research Organisations, where new Research Infrastructures of international relevance are discussed.

ESFRI is conscious of the challenges, linked with international projects, in terms of funding cycles and decision-making processes, of site selection, of governance and management, but agrees that such challenges should be met in accordance with the opportunities offered.

1. See in the project list.

>Who is the roadmap for?



> *Science may set limits to knowledge but should not set limits to imagination.*
>
> **Bertrand Russell** (1872 - 1970)

In its role as an incubator for informing Member States, Associated States and the European Commission, ESFRI is aware that this roadmap will be of use to a wide audience.

Policy-makers

A number of European States have recently realised that they require a policy for major infrastructures and a national roadmap. The roadmap will allow policy makers to make better decisions in a wider European context in which national policies may be developed and possibly where it will be better to join a project at a pan-European level rather than try to develop an independent national facility.

Researchers

The roadmap corresponds to an analysis of the research community needs for the next 10 years. It is therefore appreciated that researchers will comb the roadmap and the supporting documents[1] to check whether their needs have been recognised. They are encouraged to support this initiative and to express their support through their national delegate. ESFRI has looked critically at the maturity of the projects, using several criteria. This assessment is given as an aid to project coordinators on how a project is perceived within a European context and whether further preparatory work is necessary. For the emerging ideas, researchers should ensure that their own Member State is brought to the point where the respective ESFRI delegate feels confident to bring a project forward to the next revision.

Funders

While the job of giving exact timings and costs is not that easy for any particular project, the roadmap with its supporting documents does allow financial phasing to be planned more effectively. As projects mature, starting dates and costs become more realistic. Funders and funding models will vary from project to project. The role of Member States will remain central for the financing of these. Some may involve input from the European Investment Bank.

Industry

There are exciting opportunities for European industry to become involved in the proposed projects either as suppliers or users.

As *Technology Platforms develop*, ESFRI expects future editions of the roadmap to reflect the Research Infrastructures needs of industry where there is some open access to all researchers.

Society

There is no doubt that large scale Research Infrastructures affect society in a number of ways. First, large investments have to be balanced alongside the potential socio-economic benefits to the region and to the whole of Europe. Normally the decision to invest raises the profile of that particular area of research that transcends national boundaries. They also act as a focus for stimulating interest in young people. In addition, the Pan-European nature of such projects has a very positive effect on European and international integration.

Society has a right to be informed about the type of research being undertaken, especially where it might result in long term impacts on the quality of life.

1. The Roadmap Working Group reports are available under the ESFRI website : http://cordis.europa.eu/esfri/

>The roadmap: the landscape and its Projects

It takes a long time to bring excellence to maturity.

Publilius Syrus (~100 BC)

All the scientific and technological domains have been assessed by different expert and roadmap working groups[1]. These experts were nominated by ESFRI delegations to carry out their duty in a personal capacity and were selected on the basis of their scientific expertise, their contribution to science policy and their international reputation. The experts included some of Europe's and the world's outstanding scientists.

Hearings related to potential projects were also organised, where the maturity of proposals was analysed based on interviews with scientists and managers of research organisations.

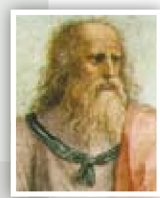
The input of the expert groups was coordinated by three roadmap working groups which covered all the main scientific and technological domains. Their findings (to facilitate the work) are organised according to seven main topics:

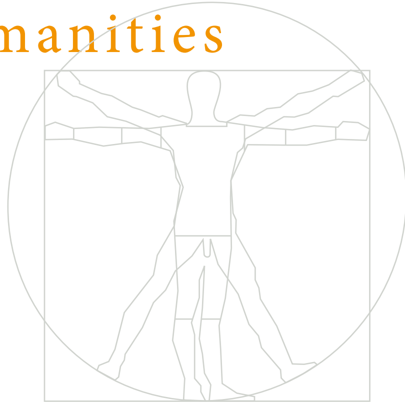
- Social Sciences and Humanities
- Environmental Sciences
- Energy
- Biomedical and Life Sciences
- Materials Sciences
- Astronomy, Astrophysics, Nuclear and Particle Physics
- Computation and Data Treatment

The following is an overview of the different needs identified for each topic, along with the description of each of the projects considered capable of responding to the needs.

1. For the complete list of the participants see in the Annexes.

Social Sciences and Humanities





> *The knowledge of words leads to the knowledge of things.*
>
> **Plato** (427 - 347 BC)

The social sciences and humanities contribute actively to and are necessary instruments for our understanding of the profound social, political and economic life in Europe as well as for the process of European cohesion and occurring changes. In effect the disciplines make significant contributions to important areas like strengthening employment, modernising our social welfare and education systems, and securing economic reform and social cohesion as part of a knowledge-based economy.

The emergence of **new sophisticated digital resources, computer networks, and software tools** influences to a great extent the sense of the human record, the way it is understood and the way those understandings are communicated. At the same time, one basic hallmark of the social sciences and humanities is the variety, complexity, incomprehensibility, and intractability of the entities that are studied. Digitising the products of human culture and society therefore poses intrinsic problems of complexity and scale. The complexity of the record of human cultures – a record that is multilingual, historically specific, geographically dispersed, and often highly ambiguous in meaning – makes digitisation difficult and expensive.

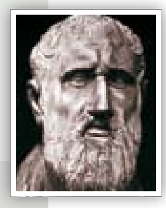
- The present major task is therefore to create pan-European infrastructural systems that are needed by the social sciences and humanities to **utilise the vast amount of data and information** that already exist or should be generated in Europe. Today the social sciences and humanities are hampered by the fragmentation of the scientific information space. Data, information and knowledge are scattered in space and divided by language, cultural, economic, legal, and institutional barriers.
- A similar situation is found for **comparative social science research**. As a consequence too much of the research is based on data from a single nation, carried out by a single-nation team of researchers and communicated to a single-nation audience. This state of affairs is preventing the development of a comparative and cumulative research process integrating the European Research Area.
- Information for research purposes is however not a scarce resource in Europe, neither for the social sciences nor for the humanities. **Well-developed official statistical systems** combined with a variety of academically driven data gathering programmes and activities produce a wealth of data and information about various aspects of European societies. This also includes **simulation systems and collections of multimedia content** – images, text, moving images, and audio.

However, the majority of these resources are country- or region specific. They are produced to meet national requirements and collected by means of national and language specific instruments based on local methodologies and classifications. They are normally documented in local languages only and rarely published for general use outside the country of origin. On top of this, nation-specific access restrictions often prevent information from travelling abroad.

The answers to these challenges should focus on the need for European-wide data, interoperability of data and languages to harmonisation of data access policies, the standardisation of digitation processes as well as interoperability between the humanities and the social sciences in general. Many of these needs can be reached through extensions of functions and resources already existing at a national level in several European countries. In some cases the model service might even be present at a European level, but would need to be extended in scope, strengthened or multiplied to other disciplines. Concerted efforts on a European scale are needed to bring about the necessary changes.

> *In pages 31–36 projects are presented addressing the needs for European computation data and modelling, for data integration and language tools as well as proposals for better coordination as an enabling structure.*

Environmental Sciences

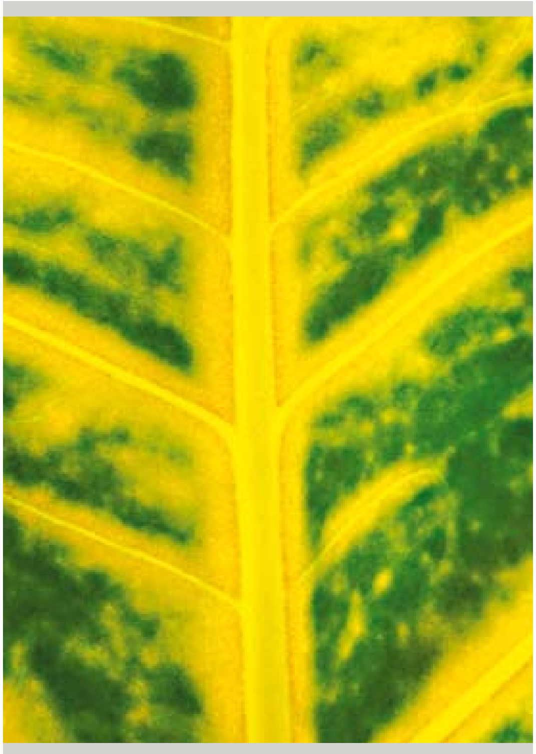


> *The goal of life is living in agreement with nature.*
>
> **Zeno** (335 BC - 264 BC)

The Roadmap Working Groups identified three main challenges:

- The Environmental science or **earth system research** community is focussing on the promotion of sustainable management of the natural and human environment and its resources. Current emphasis is on the prediction of climate, ecological, earth and ocean systems changes, on tools and technologies for monitoring, prevention and mitigation of environmental risks and pressures. International cooperation in this area is crucial given the fact that problems have a transboundary, regional or global dimension. European-wide cooperation is further motivated by the fact that critical mass is needed given the scale, scope and high level of complexity of environmental research. Pan-European research facilities and open access to scientifically useful data collected for various purposes are essential to fulfil this challenge.
- In the field of **environmental monitoring, natural hazards and natural resources** both single sited and distributed infrastructures have been identified as essential components to analyse and understand the past, and to observe, monitor and analyse the present, in order to predict the future developments of the earth system (atmosphere, oceans, land surface, cryosphere, and human activities). Within this approach one has to take in account the European Global Monitoring for Environment and Security (GMES) initiative. An intrinsic link must be established between research on environment and GMES.

Pan-European research infrastructure initiatives should further contribute to the implementation of international commitments of EU and Member States such as the United Nations Framework Convention on Climate Change, Kyoto and Montreal protocols, post-Kyoto protocol initiatives, the UN Convention on Biological Diversity, etc.



Biodiversity is essential for sustaining human life and well-being and has a vital role to play as a provider of natural capital, goods and services. Effective actions are needed to meet the EU's 2010 policy target to halt the current biodiversity loss. Biodiversity Research Infrastructures are required to support cross-sectoral policies that depend on the sustainable use of biodiversity, support the ecosystem approach to the management of fisheries, aquaculture, forests and agricultural systems, and to develop and assess methods to achieve sustainable lifestyles that reduce the negative impact on biodiversity. One of the main challenges is to develop infrastructures collecting data from distributed sources in harmonised ways and making them accessible to the research communities. In other cases centralised infrastructures may be required creating critical mass of researchers and facilities, e.g. providing controlled experiments on the relationship between biodiversity and ecosystem functions, developing new technologies for biodiversity assessment, etc.

> *Individual projects are presented in pages 37–43.*

Energy

> *Thoughts create a new heaven, a new firmament, a new source of energy, from which new arts flow.*

Philipus Aureolus Paracelsus (1493 - 1541)

Towards a new energy era

The EU leads the world in the efficient use of energy, in promoting new and renewable forms of energy, and in the development of low carbon emission technologies. All these aspects rely on a multitude of test facilities and Research Infrastructures. The EU needs to have a strong base in these aspects, to be able to maintain the lead in the global search for energy solutions.

The overall goals and main challenges towards a new energy era are, in equal measure, the security of energy supply, its sustainable use, environmental protection, and economic growth, while controlling energy demand. A sustainable energy future is possible if we develop and deploy the full mix of energy technologies

The approach to energy problems must be systematic and address the production, transport, transformation and final uses of energy. To meet these aspects in a sustainable way, for the demands of over 450 million consumers, Europe will need to invest in new systems and in the replacement of older infrastructures by investing around one trillion euro over the next 20 years. Unless Europe can make energy production and use more competitive in the next 20 years, around 70% of the EU energy requirements (compared to 50% today) will be met by imported products. In parallel, if nothing is done, world energy demand and CO_2 emissions are expected to rise by about 60% by 2030. This might cause an increase of between 1.4 and 5.8 degrees in global temperature by the end of the century if we do not reduce our consumption of fossil fuels drastically, or capture and sequestrate the green house gases which are produced. All regions in the world will face serious consequences for their economies, societies and ecosystems.

Towards an intelligent mix of energy technologies

- **Fossil fuels** cover about 75% of Europe's energy supply. While their share in Europe's Energy system is by far the highest, their use is also the major cause for global warming. Coal reserves are abundant, but gas and oil prices are rising due to the decrease of easily accessible resources.

  The goals of new technologies include: increasing availability of reserves and recovering of fossil fuels like oil and natural gas, improving the efficiency of transforming them into cleaner energy, and reducing both production costs and environmental impact.

- **Nuclear energy** is part of a much wider debate, and the nuclear industry is currently supplying one-third of the EU's electricity, with important aspects on the security of future energy supplies, the single market, public acceptance and greenhouse gas emissions. Regardless of future trends, existing installations, based on *fission*, will continue to be operated and test facilities are needed to develop aspects such as the reliability of construction materials, and the management of radioactive waste and stocks of spent fuel in a safe and environmentally sound manner. The JHR[1] high flux reactor will help with materials and fuel testing.

- **Fusion** has the potential for promising safety and environmental properties but still needs many years to reach the energy market. Strong R&D in recent decades has made it possible to design an experimental reactor as part of the world fusion programme, and top-level Research Infrastructures such as *ITER* aim the proof-of-principle for nuclear fusion as a viable energy source. The *IFMIF* "global" project will help to simulate the very high integrated fluxes of neutrons in a fusion reactor and the life-time evolution of different materials.

  Another approach is *Laser fusion*, now recognised as a promising technology to explore as a possible complementary route to the magnetic-confinement approach of ITER. The *HiPER* project[1] relates to a new Fast Ignition approach to laser fusion.

- **Renewable Energy sources** (wind, photovoltaic, solar, bio fuels, biomass, biogas, ocean energy, hydropower, geothermal) have the limitation of being much more "dilute", but the growth in the capability of collecting and transforming them, e.g. in electrical power, helps to diversify and integrate them in the overall energy supply and its local use with little adverse environmental impact, with an enormous growth potential. However, current trends in the uptake of these renewable energy technologies are still limited and require greater efforts also in terms of R&D and demonstration facilities.

In the near future, *hydrogen*, as an energy carrier derived from a number of other fuels, and *fuel cells*, as energy transformers, are expected to play a major role, for both mobile and stationary applications. Specific demonstrators will help market forces to be activated.

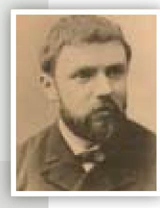
The **integration of different energy technologies**, e.g. to gain grid access, to ensure overall availability, as well as to increase the overall efficiency, is also an important element also to be developed for sustainable energy systems.

Several *European Technology Platforms* have recently emerged to help in the development of these energy technologies and are in the phase of developing their Strategic Research Agendas. In the near future the identification of the needs for new Research Infrastructures will be further elaborated, and the next update of the roadmap is likely to consider more proposals in this domain.

> *The energy-related projects are described in pages 44–46.*

1. See in the project list.

Biomedical and Life Sciences



> *This is with logic that we can demonstrate, but it is with intuition that we find.*
>
> **Henry Poincaré** (1854 - 1912)

The Life Sciences have undergone a profound transformation in recent years, which is still ongoing. It was triggered by the recombinant DNA revolution and amplified more recently by genomics, proteomics and other high-throughput analytic approaches. This transformation encompasses:

- **Unification of previously distinct biological disciplines**: molecular approaches have illuminated the multiple aspects of the dynamic organisation of living matter across widely disparate scales; from the molecule through molecular assemblies and machines, the sub-cellular organelles, the developing organism and its ceaseless restructuring as it functions, malfunctions and ages. This unification now encompasses pluri-organismic entities and interactions (symbiosis, parasitism, infection and immunity…); it is spreading into the study of populations of organisms, ecological systems, and the biosphere.
- **Unification of understanding across the tree of life**: The diversity of life, probably numbering more than 10 million distinct species, is counterbalanced by their common descent through evolution, which is reflected in the persistence of shared lineages of molecules, biochemical pathways, regulatory processes and signals. This shared heritage vastly accelerates the transfer of knowledge concerning highly diverse organisms, from microbes to humans.
- **Transition in the focus, from traditional models to all organisms**: Genomics and modern RNA-based "reverse" genetics have empowered biologists to study in depth not just simple systems (e.g. viruses and microbes) or model systems that have been studied for many years intensely, but virtually any organism, all the way to humans. This has opened up new avenues of comparative biology, highly valuable for understanding the panorama of the living world, but also for designing cures and improvements, as in the new frontiers of regenerative and synthetic biology.

- **Unification of Biology and Medicine**: The same transition is bringing medicine into a profound integration with basic biology. This is the promise and excitement of translational research, whereby the understanding gained from and the tools developed in basic biology become the springboard for novel approaches to understand, preserve and repair the healthy functioning of the human body.
- **Emergence of Biology as an information science**: Ever since the development of convenient and high-throughput methods for sequencing and synthesis of DNA and proteins, for protein structure analysis, for high resolution imaging and for other methods of data capture on a large scale (the "-omics" revolution), Biology (including Medicine) has become an information science.

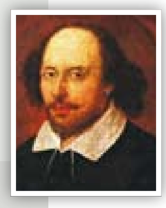
  Modern science is inconceivable without recourse to well structured, continuously upgraded, massively enriched at an exponential rate and freely accessible databases. Indeed, bioinformatics is now a prerequisite for all experimental and applied biology, including drug discovery, human genetics and epidemiology. Similarly, structural biology is now forging a critical path between genetic information and its utilisation for beneficent interventions.
- **Interaction between Biological and Medical Sciences (BMS) and the other Sciences**: The same process of restructuring and vastly expanding scope and depth of the life sciences has begun to breach the boundaries between BMS and the sister sciences. Included in the long list of novel interdisciplinary approaches and tools are now well-known examples such as biological and functional imaging at various scales; chemical biology; bioengineering, and the coming advances in nanobiotechnology. The new field of systems biology is arising as a fusion of quantitative experimental and "-omics" biology, modelling and simulation, grounded in the computational and mathematical sciences, and control theory rooted in physics.

The massive restructuring and expansion of the BMS in what has been called "the century of biology" are accompanied by major infrastructural requirements. A token of this realisation is the degree to which new or upgraded infrastructures for the life sciences are coming to dominate the infrastructural investment plans in other continents e.g. in the Australian government's plans for Research Infrastructures, where the major focus is on the life sciences.

The infrastructures required are often (but not invariably) multi-sited. Instead of massive physical projects or collections of new instruments, they are mainly data collection, storage and access systems which not only require long term maintenance and operation, but also continuous upgrades. The bioinformatics infrastructure for example is one that will continue to expand requiring successive investments for major upgrades, and will remain the depository of biological information for as long as we now can foresee.

> *Related projects are presented in the pages 47–52 as well as the multidisciplinary facilities on the next section.*

Materials Sciences



"A mote it is to trouble the mind's eye."

William Shakespeare (1564 - 1616)

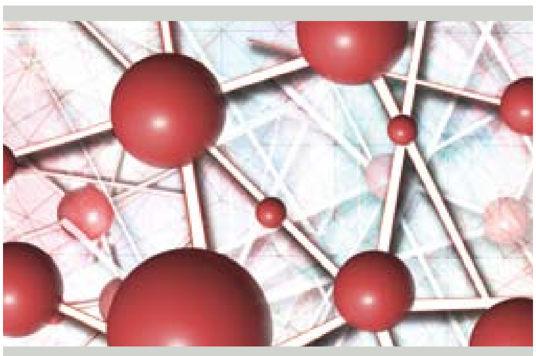
The continuous growth of knowledge and innovation in new and advanced materials, from steel blades to biological materials, including fluids and plasmas, has been fuelled by the capability to observe, design and assemble or manipulate them at ever increasing definition of scale. This has supported a century-long durable and effective industrial and economic growth based on increasingly sophisticated new products, from catalysers or cell phones to new pharmaceutical drugs, accompanied by continuous improvements in traditional products, from car engines to glass cover for housing or fabrics for clothing.

It is now increasingly possible to operate at the nanometer scale, observing and manipulating, as well as designing, atom by atom, increasingly complex materials.

Most techniques can be available in relatively small laboratory environments (like the atomic force microscope, or the atomic-layer deposition chambers), but, when it comes to operating with increasing definition on larger pieces of materials, the need is to be able to "illuminate and reach" all atoms of the materials under investigation. This requires "large facilities" capable to provide the adequate "brilliances", much like the need for a strong light to explore a dark environment.

The overall situation of the main Research Infrastructures in this field in Europe can be summarised as follows:

- **Photon Sources**: Light photons are only one, but the most flexible, of the many complementary "probes" which can be used. Large related instruments are Synchrotrons, Integrated Laser Laboratories or High Power Lasers. A recent technological breakthrough is adding the Free Electron Lasers (FELs) capable not only of much higher brilliances but also of short time "flashes" opening the dynamic "filming" of atom-related properties. Photon sources are needed over a large range of "colours", from the far Infrared range up to the Hard X-Rays. High power lasers and Synchrotron light are also used to produce and study plasmas, e.g. the conditions for energy production by fusion, or to produce devices through lithography.



The new capabilities offered by *FELs* will allow the exploration of a new terra incognita. State of the art 3^{rd} generation synchrotron sources will be surpassed in peak intensity by 8-9 orders of magnitude and by 3-4 orders of magnitude in average intensity and short-time capabilities, pushing research to new frontiers and opening novel areas of research. In the new FELs area, the international European XFEL effort aims at the measurement of the structures of clusters and single macromolecules, with atomic definition, while the IRUVX-FEL consortium initiative opens a new way for nationally supported projects to join in a highly competitive European initiative.

Europe is well endowed with *synchrotron sources*, thanks to a continuous effort made by several EU countries. The International Hard X-ray source *ESRF* in Grenoble, started in 1994, and six specific *UV-Soft X-ray sources* cover an increasing user community of about 10,000 researchers, in areas ranging from structural biology to archaeology. The evolution in users' requirements and improvements in technology fuels a continuous upgrade of all facilities, and the Roadmap is proposing in particular the upgrade of ESRF.

The frontier of laser science is progressing at an extremely steep gradient in many different directions, opening new perspectives in basic research (ultra-relativistic intensity regime) as well as in applied areas (particle acceleration, development of efficient, compact secondary sources of electron, ions and photons). A high power, short pulse laser installation *ELI* appears thus appropriate to maintain or even increase the European leadership in this very rapidly evolving domain. Important societal applications will greatly benefit from it (compact accelerators, hadron and radiation therapies, medical imaging, etc…).

- **Neutron Sources**: The use of neutrons as a probe of matter is strongly complementary to photons as they are unique to detect and measure very important aspects of materials and biological matter. Infrastructures for neutron spectroscopy use low energy neutrons. Their magnetic moment allows the detection of magnetic structures, while their small momentum allows the measurement of thermal and mechanical properties, and the differential measurement of Hydrogen and Deuterium in important sites of biological matter. Due to the great transparency of materials to neutron, neutron radiography of large and thick machinery is possible, to study directly some important engineering aspects in operating conditions, e.g. in rotating machinery.

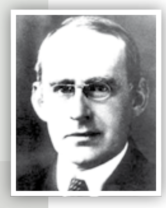
Beams of neutrons can be generated either by fission in nuclear reactors or by spallation by the impact of protons on targets. The EU has been leading in both types of neutron sources in the past 20-25 years[1], but new and increasing competition from the US and Japan is now rapidly decreasing this advantage. EU users of neutron spectroscopy are about 5000, and are increasing in biophysics and nanoscience.

To maintain the EU leadership, the *European Spallation Source* represents a high priority on an international basis, as well as the upgrade of the instrument suite of the international source *ILL*.

> *Related projects are described in pages 53–59.*

1. See the ENSA (European Neutron Scattering Association) website: http://neutron.neutron-eu.net/n_ensa

Astronomy, Astrophysics, Nuclear and Particle Physics



> *I ask you to look both ways. For the road to a knowledge of the stars leads through the atom; and important knowledge of the atom has been reached through the stars.*
>
> **Sir Arthur Eddington** (1882 - 1944)

Through the years, scientific progress has generated many new fundamental questions which are today on the agenda of astrophysics, astroparticle physics, particle and nuclear physics, and are in many ways interconnected. In the course of these developments, the facilities in fundamental physics and astronomy have become much larger, technically more complicated and very expensive. More than ever before it has become a necessity to join intellectual and financial resources to realise these projects.

In **Astronomy** discoveries in recent years have induced new fundamental problems. These include the nature of Dark Energy and Dark Matter, the emergence of the first stars and galaxies in the universe and their evolution, the description of gravity, and planet formation around other stars. To tackle these and other questions new instruments are required to provide data across the electromagnetic spectrum:

- Current *ground-based optical astronomy* can now use as largest instruments a set of 8-10 m telescopes, but it has become clear that the challenge of the new fundamental questions require still larger collecting area and angular resolution. The *Extremely Large Telescope* (ELT) is the follow-up project of the current generation of optical telescopes. With segmented mirrors and adaptive optics it seems possible to construct telescopes with diameters of up to 100 m.

  For various reasons the present development concentrates on the 30-50 m class telescopes which represent a natural intermediate step towards large sizes.

- In *radio astronomy* the next generation telescope should be the *Square Kilometre Array* (SKA). The SKA will have a collecting area of one million square metres distributed over a distance of at least 3000 km. This area, necessary to collect the faint signals from the early universe, will result in a 100 times higher sensitivity compared to existing facilities. The radically new concept of an "electronic" telescope will allow very fast surveys. Thus it will be possible to tackle many important problems, e.g. tests of the theory of relativity or the formation and evolution of galaxies. The site for SKA will be outside Europe.

- *Neutrino astronomy*: The *Cubic Kilometre Neutrino Telescope* (KM3Net) will consist of thousands of optical sensors distributed in a volume of about one cubic kilometre in the depth of the Mediterranean Sea. The sensors detect the light which is produced in the water by charged particles originated from neutrinos and the earth. It is aimed to monitor the universe continuously – together with the ICECUBE neutrino detector currently under construction on the South Pole.

- **Nuclear physics** has been revolutionised by the recent development of the ability to produce accelerated beams of radioactive nuclei. For the first time it will be possible to study reactions between the 6,000 to 7,000 nuclei we believe exist rather than the 300 stable ones that nature provides. Modern nuclear physics has two main aims. At the larger scale one wants to understand the limits of nuclear stability by producing exotic nuclei with vastly different numbers of neutrons and protons. At the smaller scale one wants to explore the substructure of the constituent neutrons and protons, for it is in the interaction of their constituent parts that the ultimate description of nuclei must lie. Such a description is much needed in order to reduce uncertainties on the nuclear data upon which design and operation of fission reactors are based.

  There are two approaches to producing radioactive beams – the "In-Flight Fragmentation" and the "ISOL (isotope-separation on-line)" techniques. The In-Flight production technique is fast and can produce the shortest-lived radioactive nuclei, whereas the ISOL technique can provide more intense and better controlled beams for detailed studies. So both techniques are complementary.

  The leading In-Flight facility proposed for the *Roadmap* will be the *Facility for Antiproton and Ion Research* (FAIR) planned as an international research centre in Darmstadt.

  The second proposal for the *Roadmap* is *SPIRAL-2*, a major expansion of the SPIRAL facility at GANIL in Caen (FR) which will help to maintain European leadership in ISOL development and is an essential step on the road to EURISOL[1]. Therefore an intermediate step as SPIRAL 2 is required and essential.

> *Related projects are described in pages 60–64.*

Particle Physics and Space Science

Particle physics stands on the threshold of a new and exciting era of discovery. The next generation of experiments will explore new domains and probe the deep structure of space-time. European particle physics is founded on strong national institutes, universities and laboratories and the CERN Organisation. The **CERN Council** created a Strategy Group which elaborated a Roadmap[2] for the needs of the field, with the following major elements (as reference):

- The Large Hadron Collider LHC at CERN will be the energy frontier machine for the foreseeable future and should fully exploit its physics potential.
- It is fundamental to complement the results of the LHC with measurements at a linear collider. In the energy range of 0.5 to 1 TeV, the ILC, based on superconducting technology, will provide a unique scientific opportunity at the precision frontier.
- It is also vital to strengthen the advanced accelerator R&D programme.

As for Space Science, **ESA** has prepared a vision paper[3].

1. EURISOL, intended to be the ultimate ISOL facility, is not expected to start before 2018, since formidable technical challenges have to be tackled.
2. The CERN Council Strategy paper cern.ch/council-strategygroup/
3. The ESA Cosmic Vision paper may be found at www.esa.int

Computation and Data Treatment

I do not fear computers.
I fear the lack of them.

Isaac Asimov (1920 - 1992)

The area of computation in science has been analysed in strong interaction between ESFRI's Working groups and the e-Infrastructures Reflection Group set-up by Country representatives in parallel to ESFRI.

This field covers not only traditional scientific computing (large simulations to address "grand challenges", solving partial-differential equations etc.), but also a much broader range of issues, such as the provision of high capability computing and/or high throughput computing capacity; networking and grid architectures and middleware, as well as other ways of interconnecting computing platforms; software for performing the computation; data management and curation techniques for handling vast masses of data.

The single overriding theme in the context of Research Infrastructures is to improve the *access* to computation and data storage across the full range of scientific research, and to rationalise the efforts needed for building the software and for curation of the data. These require integrated provision of resources, improved networking, sharing of software efforts, and lowering of barriers between groups participating in the development of scientific computing.

In terms of networking, the communication network infrastructures have been developed continuously during the last twenty years as a primary support for the European Research Area. Based on the National Research and Education Networks, all universities and research organisations in Europe are sharing the same communication infrastructure, of which the pan-European component is the GEANT network (www.geant.net). Specific advanced services are available to the research community, like end-to-end optical circuits or virtual private networks functionalities, which answer requests emanating from international research programmes such as the LHC experiments, the networking of astronomical instruments or the clustering of super-computing platforms at the European scale. The networking infrastructure allows also the transnational access to specific Research Infrastructures for all researchers in Europe and worldwide.

Extensions of GEANT worldwide, towards North America, Asia and all other world regions emphasise the global character and the priority role of Europe in this context.

In terms of Computing and Data Management the dramatic growth in the available processing power, memory, and data transmission capabilities has revolutionised many aspects of science. At the same time, improvements in measurement technology have made it possible to gather vast collections of scientifically interesting data. "Moore's law", the empirical statement indicating that the number of components in an integrated circuit doubles every 18 months, is assumed to hold for the next 10-15 years. This means that we can expect further increases in the use of micro processor devices, which could have an impact on the computational power availability, perhaps of orders of magnitude.

- In the general realm of Computing and Networking, it is useful to distinguish *Capability computing and throughput computing*, terms describing different approaches to providing large computational power for applications, as well as Grid architectures and Software.

  Capability computing refers to provision of large low latency machines capable of tackling large scale and closely coupled problems which can not be solved in any other way. Such problems are central to progress across a wide range of scientific fields from traditional science and engineering domains to such key areas as the future of the environment, national security, public health, and economic innovation. *Throughput computing* refers to provision of large numbers of more loosely coupled processors, typically built from commodity systems. Capability computers have a much higher price/performance ratio than loosely coupled throughput computers, but are necessary to address a number of grand challenges which cannot be dealt with by loosely coupled computing units.

- *Grid architectures* aim at connecting large numbers of spatially distributed computers together for solving challenging computational tasks. The grid should be also considered as a preferred access layer to a fabric of resources containing both throughput and capability resources.

- *Software* is the key for computation: without software, computers are useless. While the requirements of different research areas differ, there are strong commonalities between different fields, which calls for a pan-European action.

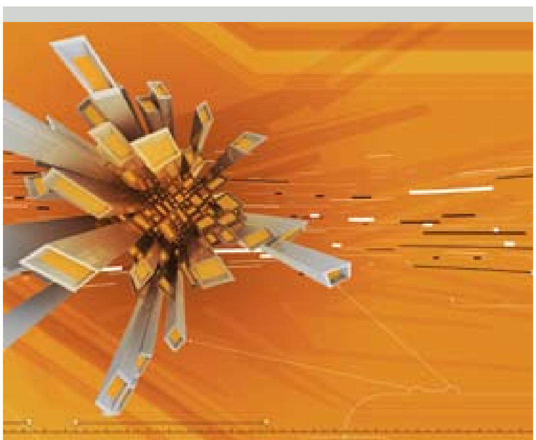
- *Data management and curation* is becoming more and more important. While data quality has always been a key issue in scientific research, new measurement methods have increased the amount of data in many areas by orders of magnitude. This makes data management much more difficult, and curation of the data by humans becomes impossible. Combining data from different sources and measurements is crucial in many areas of, e.g., environmental and medical research, posing difficult issues of data integration.

- **European High-Performance Computing Service**:

  There is a need for a combination of centralised, distributed, and networked aspects, based on a pyramid-like organisation, starting from a few very high-end centres and going down to smaller units.

  This service or collection of services should thus contain both capability and throughput resources. A coordinated, distributed investment in throughput resources would help in rendering investments in capability more effective, making sure that capability computing is allocated to the few cutting-edge applications that really need it.

  > *The related project is described in page 65.*



>Individual Projects

The real voyage of discovery consists not in seeking new landscapes but in having new eyes.

Marcel Proust (1871 - 1922)

The following pages identify 35 projects for new large scale Research Infrastructures based on an international peer review. They are considered as crucial pillars to strengthen the European Research Area, in particular for capacity building.

It is the intention of ESFRI to improve and integrate new ideas where and when appropriate.

How to identify the status of each project?

Each project identified in the roadmap of pan-European interest and of scientific excellence may have reached different degrees of maturity in different fields, which range from technical aspects to institutional development, from involvement of user communities to financial issues. Allocating any form of maturity in terms of timeliness was considered to be fraught with problems especially as several funders will be involved. The following one-page descriptions will help the reader in understanding the key issues tackled by each project.

The information, provided by the principal investigators, is updated up to September 2006. The situation is constantly changing and readers are advised to check the relevant websites on individual projects to find the current status as described by the proposers.

Colour code

The estimated expenditure for the construction of each of the projects for the next 10 years (2006-2016) is identified by a colour code as follows:

Less than 75
From 75 to 150
From 150 to 300
From 300 to 600
From 600 to 1,200

CESSDA

The facility

CESSDA (Council of European Social Science Data Archives) is a distributed RI that provides and facilitates access of researchers to high quality data and supports their use. The CESSDA network of organisations currently extends across 21 countries in Europe. It holds some 15,000 data collections and provides access to over 20,000 researchers. CESSDA already operates within a global data environment. Data access arrangements and agreements are already in place with other data holding organisations worldwide. The international dimension and function is an important element of the proposed major upgrade.

Background

The CESSDA data archives have a long-standing record for the acquisition, support and supply of data range across official government censuses and surveys, election studies, longitudinal and cohort studies, opinion polls, and surveys addressing most issues relating to society and human activity. The CESSDA organisations provide access gateways to important European (and International) data materials and EU investments such as the European Social Survey, the Euro-barometers, the International Social Survey Programme and the European Values Surveys.

What's new? Impact foreseen?

CESSDA needs to create a European "passport", which enables researchers and data alike to move virtually across national and organisational boundaries. A major upgrade is proposed to develop CESSDA from the current situation in which the member organisations work with limited national resources to create a common platform, sharing a common mission, to a fully integrated data archive infrastructure for the SSH. This major upgrade will discover datasets and data-related materials in a cross-national environment; understand in detail the origin, methodology and structure of the underlying data collections; compare and link data from different locations; connect to other experts and share analyses, experiences and knowledge; enforce confidentiality and intellectual property rights whilst maintaining accuracy, security and open access to data sources; preserve and maintain data collections over time; design new research instruments. Although initially looking to serve the CESSDA community, the technologies, tools, resources and standards used are such that they may be exploited in order to be used by other agencies.

Timeline and estimated costs

CESSDA will continue to operate in a distributed way. Construction costs will be zero, given that the purpose is to upgrade rather than construct CESSDA. Decommissioning costs will be zero as it is expected that CESSDA will continue in operation for the foreseeable future. The upgrade costs are 30 M€ covering the upgrading of the existing technical RI (common standards, tools, instruments and services through the creation of middleware); capacity building (a hub for strategic development, maintenance and coordination); supporting less-developed and less-resourced organisations; and extending and deepening the CESSDA network to new and associated CESSDA-Members.

Social Sciences & Humanities

Estimated construction cost (M€)	30 M€
First open access foreseen	2008

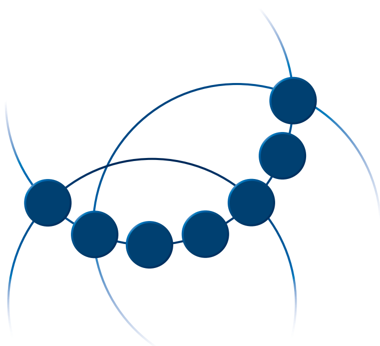
Website

www.nsd.uib.no/cessda

CLARIN

The facility

CLARIN (Common Language Resources and Technology Infrastructure) is a large scale pan-European coordinated infrastructure effort to make language resources and technology available and useful to scholars of all disciplines, in particular the humanities and social sciences. It will overcome the present fragmented situation by harmonising structural and terminological differences, based on a Grid-type of infrastructure and by using Semantic Web technology.



Background

The volume of written texts (either as continuous discourse or, for example, descriptions of objects of cultural heritage) and (more recently) recorded spoken texts is enormous, and it is growing exponentially. The sheer size of this material makes the use of computer-aided methods indispensable for many scholars in the humanities and in neighbouring areas who are concerned with language material.

What's new? Impact foreseen?

The CLARIN Infrastructure aims to provide a comprehensive and easily accessible archive of language resources and technology, covering not only the languages of all Member States, but also languages and language issues related to migration.

The tools and resources will be interoperable across languages and domains. They will contribute towards addressing the issue of preserving and supporting multilingual and multicultural European heritage. An operational open infrastructure of web services will introduce a new paradigm of distributed collaborative development and will allow many contributors to add new services ensuring reusability and allowing scaling up to suit individual needs. CLARIN will provide preferably off-the-shelf tools and solutions and the necessary training and advice to customise the resources in order to suit the particular needs of humanities researchers. It will strengthen the European position in standardisation efforts, function as a pivotal and exemplary case for international initiatives and it will help Europe to train young researchers in not only using the benefits of an infrastructure enabling eHumanities, but, more importantly, to contribute to it.

Timeline and estimated costs

A preparatory phase of 12 months will be sufficient. It will allow starting in parallel with first design and implementation work in 2007. In 2008 CLARIN will start with the main construction work, which will go on for five years to meet the needs of the various disciplines and to stability. In parallel to the construction work first services will be offered to allow early tests and feedback strategies. The CLARIN infrastructure is scheduled to reach its full functionality based on fully operational resource and service centres in 2012. The total costs for the five-year period will amount to around 120 M€ based on an estimate of about 20 distributed resource and service centres in Europe.

Social Sciences & Humanities

Estimated construction cost (M€)	108 M€
First open access foreseen	2008

Website

www.mpi.nl/clarin

DARIAH

The facility

DARIAH (Digital Research Infrastructure for the Arts and Humanities) will be based upon an existing network of Data Centres and Services based in Germany (Max Planck Society), France (CNRS), the Netherlands DANS) and the United Kingdom (AHDS). The model is however open and will be able to embrace new fields. It will also profit from European Cultural Heritage Online (ECHO), an Open Access Infrastructure to bring essential cultural heritage online.

Digital Research Infrastructure for the Arts and Humanities

DARIAH

Background

Just like astronomers require a virtual observatory to study the stars and other distant objects in the galaxy, researchers in the humanities need a digital infrastructure to digitise, get access to and study the sources that are until now hidden and often locked away in cultural heritage institutions. Much of the source material so vital to humanities is scattered across libraries, archives, museums and galleries, and as yet only a fraction is available in a digital form.

What's new? Impact foreseen?

DARIAH aims at providing an infrastructure for the entire field of the arts and humanities and access to cultural heritage of Europe. It contributes therefore to creating a common understanding of the cultural diversity and its history in Europe. It will help to cross cultural boundaries and to create a new European coherence based on mutual understanding and on true integration of the uniquely rich European traditions. This aspect is particularly relevant in education.

Research and development will find rich primary data for scholarly interpretation which will also allow not only for comparative research over time periods, cultures, languages, or regions, but trigger the possibility of novel research questions, that with traditional access to cultural heritage sources dispersed over a multitude of different sites and institutions could up to now not be approached. Likewise, due to its distributed and modular architecture the proposed infrastructure can build on and integrate existing endeavours and will also help to enhance national infrastructures.

Timeline and estimated costs

DARIAH will be based on partner organisations that have national infrastructures in place and are already collaborating. A core group of national institutions will directly contribute to DARIAH by offering their existing infrastructures (thus ensuring a quick take-up within three years at most).

Preparatory cost is estimated at 6 M€ and construction cost at 10 M€.

Operational cost is estimated at 4 M€ per year.

Social Sciences & Humanities

Estimated construction cost (M€)	10 M€
First open access foreseen	2008

Website

www.dariah.eu

EROHS

The facility

EROHS (European Resource Observatory for the Humanities and the Social Sciences) will operate both as a central and distributed facility with a strong physical hub working in close conjunction with a number of spokes across Europe, harnessing European expertise through a coordinated yet decentralised network. It will be organised to promote and ensure cooperation and integration of data, technologies and policies.

Background

EROHS is an instrument for planned cooperation and integration. EROHS will in some areas be based on mature existing resources and infrastructures, supporting, promoting and extending their scope – and will in other areas facilitate the development of new infrastructures based on the need of the humanities and the social sciences by bringing together national initiatives, organisations and individuals in order to provide upgraded and enhanced European-wide actions.

What's new? Impact foreseen?

The proposed research infrastructure – EROHS – is aiming at organising the communication, coordination, documentation and sharing of information in ways that will set standards for Research Infrastructures worldwide and make Europe the world leader in this area. It will provide Europe with the tool to realise the vision of open, distributed, well coordinated, well documented, on-line access to data for the humanities and the social sciences. Through EROHS more researchers will be introduced to the possibilities created by existing infrastructures. Training and seminar activities organised by EROHS will also be to the advantages of both existing and emerging Research Infrastructures. Emerging infrastructures will be important stakeholders of EROHS, be they national or pan-European infrastructures. EROHS will also strengthen the national infrastructure. By using the same model in different nations, national hubs will be linked both to each other as well as to the international hub.

Timeline and estimated costs

EROHS will gradually become active in more and more areas. The costs will therefore increase year by year during the first five years of EROHS life time, from 5 M€ for the first year to 12 M€ for the fifth year. The personnel costs will in the initiating phase cover approx 10 employees increasing to approx 15 working full time in the EROHS-hub and the outreaching activities cover travel and meetings as a part of EROHS' broker function and mediator function. Decommissioning costs will be zero as it is expected that EROHS will continue in operation for the foreseeable future.

Social Sciences & Humanities

Estimated construction cost (M€)	43 M€
First open access foreseen	2008

Website

www.erohs.org

The EUROPEAN SOCIAL SURVEY

The facility

The ESS was set up in 2001 to monitor long term changes in social values throughout Europe and produce data relevant to academic debate, policy analysis and better governance. It now covers 27 European countries. A long term pan-European instrument such as the ESS requires long term funding commitments. A major upgrade is now sought to fill debilitating gaps in the present programme.

Background

The ESS has a complex network of management and advisory committees, representing national teams and founders on the one hand, and academic specialists on the other. It covers the whole of the EU (apart from Latvia, Lithuania and Malta), and includes both associated countries and a number of accession and candidate countries. It was built as a multi-funded enterprise. Its costs have been shared between the EC, the ESF, and 27 national academic funding bodies. Two-thirds of the ESS is now provided by the nations and one third from the Commission. ESS data are made publicly available on the web as soon as they are available – with no prior "privileged" access. This makes the publication of each dataset a major event in the European social science calendar.

What's new? Impact foreseen?

The purpose of the proposed major upgrade is to unify, regularise and secure the funding for the RI as a whole over an extended period, though naturally with periodic reviews. A large and complex time series such as the ESS requires such continuity of funding, which is a prerequisite of appropriate planning. But a major upgrade would also help to fill debilitating gaps in the pre-sent programme of work – allowing much-needed new programmes of work on:

- compiling and harmonising aggregate context variables for survey analyses;
- experimenting with alternative (technical and traditional) methods of translation to improve equivalence;
- investigating and mitigating longstanding problems in the collection and classification of occupation and education;
- improving the capacity to pilot and pre-test new questions on emerging issues of public concern;
- experimenting on a multinational basis with methods of improving response rates.

All this work would be in addition to designing and coordinating the biennial ESS and to the conduct of fieldwork, coding and keying in some 30 European nations.

Timeline and estimated costs

The total annualised cost of the ESS infrastructure at present, combining all sources of finance amounts to around 6 M€ per year. The major upgrade proposed would bring the total annual costs to around 9 M€ per year (a 50% overall increase). If the ESS were to assure funding for three further rounds, including its infrastructure responsibilities, the overall commitment would be around 54 M€ over 6 years.

Social Sciences & Humanities

Estimated construction cost (M€)	9 M€
First open access foreseen	2007

Website

www.europeansocialsurvey.org

SHARE

The facility

SHARE (Survey of Health, Ageing and Retirement in Europe) provides data infrastructure for fact-based economic and social science analyses of the on-going changes in Europe due to population ageing. The original 8-country survey has already being expanded to cover two new Member States; ideally SHARE will be expanded to all 25 Member States of the EU.

Background

Preliminary data collection started in 2002, and in 2004 a first wave of data on the economic, health and family conditions of about 27,000 respondents aged 50 and over were collected in 11 European countries. The participating countries covered all EU15 regions. The data is harmonised cross-national. The second wave of data collection is currently going on and includes Poland, the Czech Republic, and Ireland. A third wave of data collection specialises on the life histories of the SHARE.

What's new? Impact foreseen?

The first wave of SHARE data was collected in 2004 and the second wave is currently fielded in 2006, further waves are envisaged from 2008 onwards bi-annually. In the years in-between these waves, experimental modules will be tested, such as the collection of life-histories in 2007. The 24 months between the end of wave t and the end of wave t+1 can roughly be divided into 12 months of preparation and 12 months of data collection (including experimental modules). The SHARE data infrastructure is accessible free of charge through an archive operating as internet platform.

Timeline and estimated costs

Costs are roughly proportional to the number of participating countries and the number of waves. Preparatory costs amount to approximately 250 k€ per country and wave (=3.75 M€ for 15 countries). Construction costs (i.e. data collection) amount to about 400k€ per country/per wave (=6 M€ for 15 countries). Annual operating costs for the entire SHARE infrastructure (data distribution and documentation) amount to some 300 k€ per year. Hence, one wave of the bi-annual data collection in 15 countries thus costs about 10.5 M€. Three waves in all 25 Member States cost about 51 M€. There are no decommissioning costs. Current funding is from EU, NIA (National Institute on Ageing) and national sources, and such cost sharing is also expected in the future.

Social Sciences & Humanities

Estimated construction cost (M€)	50 M€
First open access foreseen	2007

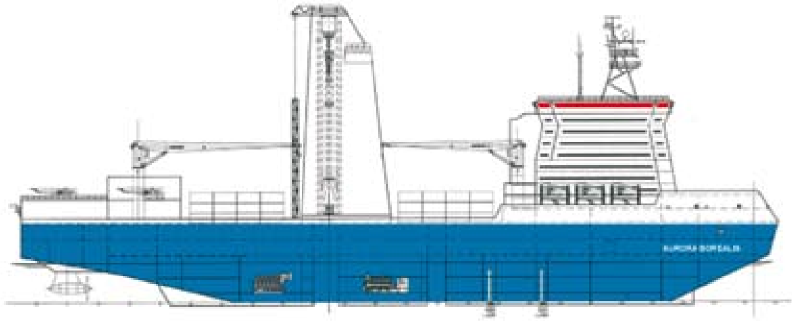
Website

www.share-project.org

AURORA BOREALIS

The facility

AURORA BOREALIS will be a powerful research icebreaker vessel (31,000 tonnes displacement 196 metres long) with 50 megawatt azimuth propulsion systems and deep drilling capability for use in extreme conditions in excess of 4,000 m water depth. It will have high ice performance to penetrate autonomously into the central Arctic ocean with 2.5 metres of ice cover, during all seasons.



Background

Polar research and the properties of northern and southern high latitude oceans are subjects of intense scientific and environmental attention, since they underlie rapid and dramatic change. The Polar Regions react more rapidly and intensely to global changes than other regions of the Earth. News about the shrinking Arctic sea-ice cover, potentially leading to an opening of sea passages to the north of North America and Eurasia, and of the calving of giant table icebergs from the Antarctic ice shelves are the latest examples of these changes. Many of the necessary data can only be collected by dedicated research vessels, from permanently manned stations or during multidisciplinary expeditions with substantial logistical demands. Therefore complex interdisciplinary experiments can only be conducted under close international co-operation. AURORA BOREALIS could act as a base to support such research efforts and fulfil the scientific needs and political obligations of European governments.

What's new? Impact foreseen?

The AURORA BOREALIS will be the most modern and innovative research vessel in the world and will open new horizons for Europe in polar and marine research. The research icebreaker AURORA BOREALIS is planned as a multipurpose vessel. During the times when it is not employed for drilling in the Arctic, it can operate worldwide as a research vessel. The possibility to flexibly equip the ship with laboratory and supply containers, and the variable arrangement of other modular infrastructure, free deck-space and separate protected deck areas, will allow it to cover the needs of most disciplines in marine research. The ship can be deployed as a research icebreaker in polar seas because it will meet the specifications of the highest ice-class for polar icebreakers. The facility, when built and in operation, will provide the world's first international drilling and all season research icebreaker. It will further the international advantage that European research has in the polar areas and it will contribute to Europe's world-leading experience in constructing excellent icebreakers.

Environmental Sciences

Estimated construction cost (M€)	360 M€
First open access foreseen	2010

Website

www.esf.org/epb | www.europolar.org

Timeline and estimated costs

Preparatory phase: 2006-2008 (6 M€).

Construction phase: 2008-2010 (360 M€).

Operation: 2010 onwards (17.5 M€/year).

Decommissioning: 2045 approx.

EUROPEAN MULTIDISCIPLINARY SEAFLOOR OBSERVATION

The facility

EMSO deep sea-floor observatories are deployed on specific sites offshore European coastline to allow continuous monitoring for environment and security. They will be organised in a unique management structure at European level (and part of a global endeavour in sea-floor observatories), for long term monitoring of environmental processes related to ecosystem life and evolution, global changes and geo-hazards. EMSO will be a key component of GMES and GEOSS.


Stock Exchange

Environmental Sciences

Estimated construction cost (M€)	150 M€
First open access foreseen	2011

Website

www.ifremer.fr/esonet/emso

Background

Implementation of EMSO is based on evolution of existing systems by connecting previously autonomous systems, and providing power and long-term real-time data capability, integrating in the wider system of mobile and re-locatable seafloor lander platforms. Development of seafloor observatories with multi-disciplinary capability (geophysical, including seismological, oceanographic and environmental) has been pioneered under the EC GEOSTAR project. Recent major technical advances have been made in the EC projects: ASSEM and ORION-GEOSTAR-3 (a deep-sea geophysical, oceanographic and environmental network). Experience in underwater cable connection by submersibles and ROVs has been gained in the deployment of the ANTARES and NEMO neutrino arrays. Establishing the network of seafloor observatories requires a fulfilment of a critical mass at European level overcoming national fragmentation.

The EMSO development is based on synergystic collaboration between the academic community and industry for the development of technology, both presently working within the European Seas Observatory Network of Excellence (ESONET). This synergy allows each partner to increase its own know-how, to improve marine technology and set strategies to be competitive with countries such as USA and Japan.

What's new? Impact foreseen?

The basic scientific objective is to make real-time long-term monitoring of environmental processes in the geosphere, biosphere and hydrosphere of European seas. Major advances in our understanding of environmental processes require us to identify temporal evolution and cyclic changes and to capture episodic events related to oceanic circulation, deep-sea processes and ecosystems evolution. Long-term monitoring will allow the capture of episodic events such as earthquakes, submarine slides, tsunamis, benthic storms, bio-diversity changes, pollution and other events that cannot be detected and monitored by conventional oceanographic sea-going campaigns. Cabled sea-floor observatories are needed to collect long time series of simultaneous data relative to: seismology, geodesy, sea level, fluid and gas vents, physical oceanography, biodiversity imaging at different scales. A network of observatories around Europe will lead to unprecedented scientific advances in knowledge of submarine geology, the ecosystem of the seas and the environment around Europe. This research infrastructure will be the sub-sea segment of the GMES initiative and will significantly enhance the accessibility of observational data for the ESONET Community. Very rapid advances in technical knowledge are anticipated. This will place European SMEs in an excellent competitive position for installation of such systems around the world.

Timeline and estimated costs

Surveys, Cables, junction boxes and boreholes in 5 different places will be gradually implemented from 2007 to 2011.

Preparatory costs: 50 M€, Construction Costs ~100 M€ for 5 sites, Operational costs 20 M€/year.

EUFAR

The facility

The facility, EUFAR, will be a Heavy-Payload fleet of airborne research in Environmental and Geo-Sciences.

Background

National management of research aircraft in Europe has resulted in a diverse fleet of small to large size aircraft. The EUFAR members are operating more than 30 instrumented aircrafts, with a sampling speed from 30 to 200 m/s, a payload from 80 to 4,500 kg, and a ceiling from the boundary layer up to 21 km. All aircraft of the European fleet however are limited to a practical endurance of 5 hours. For tropospheric research there is at present no heavy-payload and long-endurance aircraft in the European fleet. This situation precludes European scientists from performing research over oceanic, polar and remote continental areas, which are especially crucial for climate studies.

What's new? Impact foreseen?

The use of a C130 or an A400M aircraft would allow to overcome present space and payload constraints making it feasible to distribute the development of instrumentation among external laboratories. Such an option has many benefits in term of innovation. One single aircraft operator can hardly maintain expertise in all the scientific fields of environmental research. At the national level, operators of large aircraft, mainly in the UK, Germany and France capitalise on their national academic community of experts in environmental research. With a heavy payload aircraft, such a mobilisation of experts can be extended to the European level, in particular from countries which are not operating research aircraft, hence increasing significantly the level of expertise. The EUFAR initiative therefore stands only if it is designed as a pan-European project.

Timeline and estimated costs

Two main aircraft alternatives are being considered and the time table depends on the choice. If a C130 is selected the plans for research modifications of the frame have already been validated by the NSF and NASA in the US and they can be finalised within a year. If an A400M is selected, the prototype will not be available before the year 2009, and modifications for research will have to be adapted to the frame of the A400M, significantly different from that of a C130. As already demonstrated, the life time of such an infrastructure is ~25 years, with a potential of 15,000 flight hours.

Preparatory cost ~1 M€.

Acquisition and implementation cost ~50 M€ (C130) or ~100 M€ (A400M).

Operation Cost ~2 M€/year.

Environmental Sciences

Estimated construction cost (M€)	50 - 100 M€
First open access foreseen	2007

Website

www.eufar.net

EURO-ARGO

The facility

The EURO-ARGO array is the European component of a world wide in situ global ocean observing system, based on autonomous profiling floats. The ARGO objective is to develop a global array of floats (spaced 300 km apart, on average) throughout the ice-free areas of the deep ocean. It is estimated that some 3,000 floats are required to reach this objective. The floats are battery powered, with a design life of between 3/4 to 5 years, i.e. about 800 floats must be deployed per year to maintain the target array. The data are transmitted in real time by satellite to data centres for processing, management, and distribution. The EURO-ARGO objective is to provide a sustained European contribution to the international ARGO programme.

Environmental Sciences

Estimated construction cost (M€)	76 M€
First open access foreseen	2010

Website

www.coriolis.eu.org

Background

ARGO is an international programme for global in situ ocean observations. It is endorsed by the WMO's Climate Research Programme, the Global Ocean Observing System (GOOS), and the Intergovernmental Oceanographic Commission. This observing programme is complementary to the remote sensing observations from satellites (particularly altimetry). The deployment of the global array is under way, with significant contributions from the USA, Japan, China, India, Canada, Australia, and several European countries. The challenge is to complete it and to maintain it on a sustained basis.

What's new? Impact foreseen?

The ARGO programme has become the primary source of data on the ocean interior. The ARGO array constitutes a cost-effective alternative to research cruises, and voluntary ships observations. The array is a unique source of information on the role of the ocean in the climate system (global heat and moisture balance); it provides the data required by operational ocean monitoring systems; it improves significantly extended weather forecasts to seasonal range; it is a unique source of data for scientific study of the Earth system. It is recognised as an essential component of the GMES initiative and GEOSS.

Timeline and estimated costs

The ARGO array was initiated in 2000 (first deployments) and is expected to reach its world target of 3000 floats in operation during 2007. The individual lifetime of a profiling float being around 4 years, the maintenance of the infrastructure would consist in 800 floats deployed per year over the period 2007-2010, with full implementation over the extended period of 2011-2020.

The European contribution will consist in the deployment of ~250 floats per year as well as the operation of the CORIOLIS Data Centre (one of the two Global Data Assembly Centres) to collect, validate and deliver the data to users.

Because of the multi-year research objectives linked with the EURO-ARGO infrastructure, a twelve-year period has been considered as a typical lifetime, including the build-up period of four years. The budget requested for this period would be ~76 M€.

IAGOS-ERI

The facility

IAGOS-ERI uses, as platforms, commercial passenger aircrafts and proposes an integration of routine aircraft measurements into a Global Observing System – a European Research Infrastructure, to establish and operate a sustainable distributed infrastructure for regular observations of atmospheric composition from a fleet of initially 10-20 in-service aircrafts. This will be achieved by installing autonomous instrument packages, certified for commercial aircraft (Airbus).

Environmental Sciences

Estimated construction cost (M€)	20 M€
First open access foreseen	2008

Website

www.fz-juelich.de/icg/icg-ii/iagos

Background

The proposed RI draws on and further develops the experience gained in MOZAIC (Measurement of Ozone and Water vapour by Airbus In-service air Craft). MOZAIC utilised long haul aircraft to measure ozone and water vapour and later also carbon monoxide and total nitrogen. The instruments were carried by 4 European airlines. The flight routes of the MOZAIC aircraft covered a large fraction of the Northern Hemisphere and parts of the Southern Hemisphere.

What's new? Impact foreseen?

The particular value of routine measurements from commercial aircraft is that they provide fundamentally calibrated long term observations of critical chemical species, aerosols and clouds in the upper troposphere and lower stratosphere, a region which is critical for climate change and which is otherwise data-sparse. The use of commercial aircraft allows the collection of highly relevant observations on a scale and in numbers impossible to achieve using research aircrafts, and where other measurement methods (e.g. satellites) have technical limitations. Besides providing improved technology for sustainable operation and improved global coverage, IAGOS develops new instruments for regular high quality measurements of CO_2, NO_x, stratospheric H_2O, aerosol and cloud particles. Regular vertical profiles of CO_2 will provide a unique set of information for the validation of regional and global carbon cycle models used for the verification of CO_2 emissions and Kyoto monitoring.

Timeline and estimated costs

The preparatory phase for the new infrastructure is covered by the ongoing design study IAGOS. Thereafter, operation can start immediately. The newly developed CO_2 and aerosol equipment will be added with a delay of 1-2 years for certification. Operation is envisaged to continue at least for 10 years. Because of its nature, the need for investment is modest and concerns the special instrumentation to be installed on the different aircrafts and the cost for aircraft modification. The total cost of these investments scales closely with the number of aircrafts to be operated. The operational costs scale with the number of aircrafts equipped.

Preparatory cost 5-7 M€ (mostly covered by the IAGOS-DS).

Construction cost 14 M€ total for instrumentation of 20 aircraft during the first 9 years.

Operation cost (total) 6 M€/year at full operationality, 50 M€ over 10 years.

Decommissioning cost 0.4 M€ for removal of the instrumentation from all aircraft (20 k€ each).

ICOS

The facility

ICOS (Integrated Carbon Observation System) is an infrastructure for co-ordinated, integrated, long-term high-quality observational data of the greenhouse balance of Europe and of adjacent key regions of Siberia and Africa. Consisting of a centre for co-ordination, calibration and data handling in conjunction with networks of atmospheric and ecosystem observations, ICOS is designed to create the scientific backbone for a better understanding and quantification of greenhouse gas sources and sinks and their feedback with climate change.

Environmental Sciences

Estimated construction cost (M€)	255 M€
First open access foreseen	2010

Website

www.carboeurope.org

Background

Unlike meteorological parameters that have been routinely collected by meteorological services for 50 years and for which global satellite observations exist for 30 years, with secure commitments for the future, there is no co-ordinated system to measure atmospheric greenhouse gas concentrations in Europe. Only about half of the anthropogenic CO_2 emissions accumulate in the atmosphere, while the remainder is taken up by land and oceans on average in similar proportions. However, these sinks vary strongly in time and space. Quantifying present-day carbon sources and sinks and understanding the underlying carbon mechanisms are pre-requisites to informed policy decisions. This is fundamental to develop strategies to manage carbon emissions.

What's new? Impact foreseen?

Better understanding of vulnerability and regional feedbacks between climate and biosphere is the prerequisite for predicting the response of the earth system to global change. Research priorities for the coming years in the field of global and regional climate-biosphere feedbacks cannot be addressed without dense, consistent, long-term, integrated observations of trace gases and relevant environmental tracers and ecosystem parameters as those provided by ICOS. The ICOS observational data and secondary data products form the basis for improved understanding and adequate human action. ICOS will significantly enhance the observational basis and accessibility of observational data in benefit to the applied and basic scientific community.

Timeline and estimated costs

ICOS must be operating during the Kyoto commitment period 2008-2012 and beyond. Possible timetable for implementation: most elements are already existing in a research mode, and can be easily transferred into ICOS. Major milestones are decisions about location of the ICOS-Centre facilities, and then their installation and equipment. Once the decision about funding and the location of the ICOS-Centre is made, the preparatory phase will take about 3 years. ICOS would be operational after 5 years, with a 20 years perspective. Preparatory costs 5 M€, total costs for implementation and operation over 20 year: ~250 M€. Decommissioning cost : 7 M€.

LIFE WATCH

The facility

LIFE WATCH will construct and bring into operation the facilities, hardware, software and governance structures for research on the protection, management and sustainable use of biodiversity. It will consist of facilities for data generation and processing, a network of observatories, facilities for data integration and interoperability, virtual laboratories offering a range of analytical and modelling tools; and a Service Centre providing special services for scientific and policy users, including training and research opportunities for young scientists.

The infrastructure has the support of all major European biodiversity research networks.

Background

Changes in biodiversity are having serious effects on the capability of European ecosystems to provide essential services, which in turn affects the quality of life of citizens and social and economic aspects of sustainable development. It is increasingly important to develop novel approaches to understand and sustainably manage our environment so that spatial requirements for human activities and for protecting the natural environment are balanced. EU-projects and GBIF have made much progress in providing access to interoperable databases, but large-scale analytical and modelling developments cannot benefit from these resources to a full extent. Targeted collective action is needed to accelerate data generation and to bring data and services in a (virtual) analytical modelling laboratory environment. It is now urgent to complement remote earth observations (GMES, GEOSS) with an infrastructure effort on biodiversity covering ground-level terestrial and (coastal) marine ecosystems, species-level and genetic components.

What's new? Impact foreseen?

LIFE WATCH will boost many developments, in fact biodiversity is a cross-border phenomenon, and the pan-European approach of the facility will lead to substantial synergies. The new infrastructure will integrate the full potential of taxonomic (collection-based) and ecosystem information with genomic data from other sources in an international (virtual) laboratory environment. The wealth of large data sets from different (genetic, population, species and ecosystem) levels of biodiversity opens up new and exciting research opportunities. Comparative data mining in large-scale data sets allows for studying patterns and mechanisms across different levels of biodiversity. The large-scale approach supports understanding (and managing) the impacts of climate change (such as changing precipitation patterns, droughts and fires, storms, sea level rise and others) on the distribution, adaptation and functions of biodiversity. Complex and multidisciplinary problems require scientists to collaborate in virtual organisations. Biodiversity e-Science enables "distributed large scale" research. This will be the only way to participate in new developments of science in this area. The facility will support the research necessary to meet the policy objectives in the "EC Communication: Sustaining ecosystem services for human well-being" (2006) and is a major component of the European contribution to GEOSS.

Timeline and estimated costs

Preparation phase 2005-2008, Construction 2008-2014, Test and operation 2014-2032.

Construction costs: ~370 M€.

Total operation costs 70 M€/year.

Environmental Sciences

Estimated construction cost (M€)	370 M€
First open access foreseen	2014

Website

www.lifewatch.eu/

HiPER

The facility

HiPER will be a large scale laser system designed to demonstrate significant energy production from inertial fusion, whilst supporting a broad base of high power laser interaction science. This is made feasible by the advent of a revolutionary approach to laser-driven fusion known as "Fast Ignition". HiPER will make use of existing laser technology in a unique configuration, with a 200 kJ long pulse laser combined with a 70 kJ short pulse laser.

Background

High power lasers enable the physics of matter at extreme densities and temperatures to be studied in the laboratory, with applications ranging from fundamental science, to new technological opportunities (e.g. compact particle accelerators and laboratory based astrophysics) and high impact industrial exploitation (e.g. inertial fusion energy).

Energy production from Inertial Fusion was proven in the 1980s, with laser driven inertial fusion due to be demonstrated in the laboratory in the period 2009-2012. To date, however, research in inertial fusion has been limited to the defence sector due to the scale of the laser facilities needed to initiate the process. The advent of Fast Ignition completely changes the landscape, removing the dependence on defence programmes, using a method which breaks the scientific link of radiation driven implosions. Construction of HiPER would allow Europe to lead the world in this field, taking advantage of these transformational events.

What's new? Impact foreseen?

The technique of "Fast Ignition" is a revolutionary approach to inertial fusion, calculated to lead to an order-of-magnitude reduction in the scale (and thus cost) of the laser facility. Recent demonstration experiments have been published in a series of articles in Nature and have led to the 2006 American Physical Society award for Excellence in Plasma Physics. The unique laser configuration creates the opportunity to provide a world-leading, broad-based research infrastructure in Europe. This type of laser fusion facility will open up a wide range of applications in laboratory astrophysics, nuclear physics, atomic physics, plasma science and material studies under extreme conditions.

Timeline and estimated costs

Based on the ongoing conceptual design work and experience with LIL-PETAL, the construction cost of the facility is estimated at ~800 M€, with a preparatory cost of ~55 M€ (including completion of PETAL), and an annual operating cost of ~80 M€. The present scientific and technological basis of the facility allows a 3-year detailed design phase to start immediately, with construction envisaged for the turn of the decade for delivery to users by 2015-2017.

Energy

Estimated construction cost (M€)	850 M€
First open access foreseen	2015

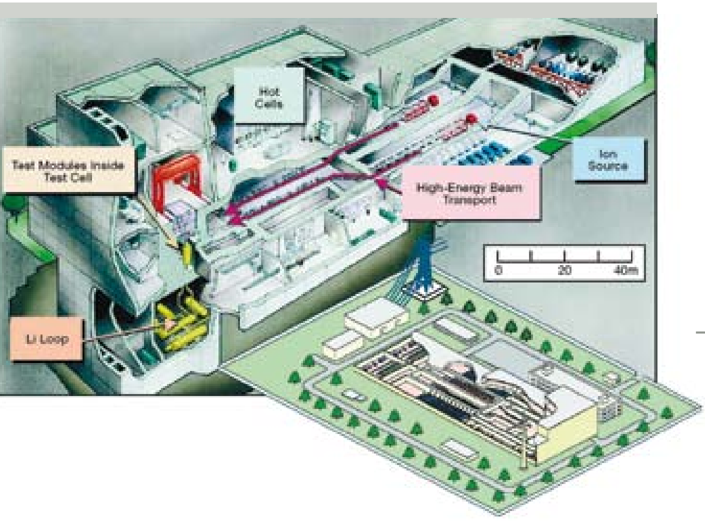
Website

www.hiper-laser.org

IFMIF

The facility

IFMIF (International Fusion Materials Irradiation Facility) is an accelerator-based very high flux neutron source utilising the deuteron lithium-stripping reaction with the aim to provide timely a suitable data base on irradiation effects on material needed for the construction of a fusion reactor. Although IFMIF does not rely on aggressive innovative technologies, its beam power of 2 x 5 MW is by far the most intensive that has ever been built.



Energy

Estimated construction cost (M€)	855 M€
First open access foreseen	2017

Website

www-dapnia.cea.fr

Background

As the qualification of materials under fusion-specific conditions for lifetimes of at least 10-15 MWy/m^2 is a critical requirement on the path to fusion power, the timely availability of a suitable neutron source, IFMIF, has become a major element in fusion strategy scenarios. A series of international workshops held over many years developed a consensus view that an accelerator based D-Li source with an energy spectrum peaked at 14 MeV is the best choice for a high performance materials irradiation facility. IFMIF will achieve this using two 40 MeV deuteron continuous-wave (cw) linear accelerators, each delivering a 125 mA beam current. Both beams strike a common flowing lithium target, thus providing an intense neutron flux of about 1018 n/m^2/s.

What's new? Impact foreseen?

The primary mission of IFMIF will be to generate timely a materials irradiation database for the design, construction, licensing, and safe operation of a Fusion Demonstration Reactor (DEMO). This will be achieved through testing and qualifying materials performance under neutron irradiation that simulates service up to the full lifetime anticipated for DEMO. The source requirements include high availability, fusion adequate neutron spectrum and temperature controlled high flux irradiation (20-50 displacements per atom per full power year) of more than thousand qualified specimens. In addition, various in-situ experiments and tests of blanket elements will be an important use of the facility, and will complement the tests of blanket test modules in the International Thermonuclear Experimental Reactor (ITER).

Timeline and estimated costs

For construction: ~2012 to 2017 (first phase) first operation: ~2017 with one beam; 2017-2020 (second phase), lifetime 20-30 years. Preparation costs ~88 M€, starting around 2007 and lasting about 5-6 years to validate long term reliability of some large scale components, conceptual design and costs. Construction ~770 M€, operation costs ~141 (over first 3 years), 78.5 M€/yr from the 4th year. Decommissioning ~50 M€.

JULES HOROWITZ REACTOR

The facility

This new research reactor will allow high flux irradiation experiments dedicated to the study of the materials and fuel behaviour under irradiation with sizes and environment conditions relevant for nuclear power plants in order to optimise and demonstrate safe operations of existing power reactors as well as to support future reactors design.

Background

Major European power companies need to develop expertise to implement modern research reactors with improved capabilities (larger neutron flux, on line instrumentation, specific safety capabilities) consistent with scientific and modelling state of the art as well as industrial and public needs. This is consistent with the assessment performed within the FEUNMARR thematic network (Future European Union Needs in Material Research Reactors, 5th FP, 2002), "given the age of current Material Test Reactors (MTRs), there is a strategic need to renew material testing reactors in Europe. At least one new MTR shall be in operation in about a decade from now".

What's new? Impact foreseen?

JHR meets industrial and public needs and supports major stakes in the European energy policy. JHR is a flexible experimental infrastructure providing high neutron flux (twice larger than the maximum available today in MTRs), supporting advanced modelling development with highly instrumented experiments and, operating experimental devices with environment conditions (pressure, temperature, flux, coolant chemistry…) and coupled phenomena (mechanics, irradiation corrosion…) relevant for the different present and future power reactors technologies.

This irradiation experimental capability will address material ageing and plant life management, design evolutions for water reactors (in operation for all the century), fuel performance and safety margins improvements, fuel qualification in incidental or accidental situations, fuel optimisation for high temperature reactors, and innovative material & fuel development for future reactors. This raises challenging scientific and technological issues to be addressed by a modern experimental irradiation infrastructure like JHR.

Timeline and estimated costs

JHR is now a mature project; detailed design, public consultation and safety files have been completed and construction phase has been launched early in 2006 for a start of operation scheduled in 2014. JHR will be built and operated by a consortium of government agencies and industrial partners from several European states. Construction costs ~500 M€, yearly costs 24-33 M€, decommissioning preparation costs are estimated at ~80 M€.

Energy

Estimated construction cost (M€)	500 M€
First open access foreseen	2014

Website

www-cadarache.cea.fr/fr/actualite/RJH/BAT%20RJH%20A5.pdf

EATRIS

The facility

EATRIS (European Advanced Translational Research Infrastructure in Medicine) will first establish a small number of research facilities distributed in Europe, with the task of translating basic discoveries into clinical practice. Each node of the network will include cutting-edge technologies for translational research and will cover one of the major disease fields: cardiovascular diseases, cancer, metabolic syndrome, brain disorders and infectious disorders. In later steps, additional dedicated centres are expected to join the EATRIS partnership.

Background

Despite tremendous progress in the life sciences and increasing investments of the pharmaceutical industry into research and development, we are observing a widening gap between discovery and translation into medical products and applications. New results from basic science are not translated into clinical practice and patient care – or the translation is slow and incomplete. Translation of laboratory findings into diagnostic, therapeutic and preventive clinical applications indeed poses a major challenge for modern biomedical sciences. It requires considerable know-how and infrastructure for preclinical development in areas such as identification of target molecules, novel biomarkers, assays, screening of molecular and chemical libraries, diagnostic procedures, gene-based therapies, medicinal and computational chemistry, antibody production, *in vitro* and *in vivo* validation, toxicological analysis and production of therapeutic agents under Good Manufacturing Practice conditions. Such a task can only be mastered in a dedicated translational R&D infrastructure that links and engages both clinical and basic scientists as well as strong industrial partners.

What's new? Impact foreseen?

As a first step, a small number of European centres dedicated to translational research will be established, that will closely interact to constitute the core of EATRIS. The five to ten centres will offer pan-European access, will encompass interdisciplinary expertise and will focus on the following major areas, chosen because they cover some of the largest and most important disease areas in Europe: Cancer, diseases of the cardiovascular system, brain disorders examined by advanced imaging, metabolic syndrome and infectious disorders studied using high security laboratories. They constitute model centres, which will develop joint programmes for translation, clinical validation, data management, quality assurance, monitoring/auditing and training, education and exchange. They will establish close links with the "Network of Distributed Infrastructures for Clinical Trials in Europe" and programmes for early diagnosis and prevention, as well as access the "European Biobanking and Biomolecular Resources Infrastructure" and "Bioinformatics Infrastructure for Europe". During later stages, additional dedicated centres are expected to join. This strategy is needed to secure for the European Union an international top position in the most important fields of translational medical research. It will also considerably strengthen the economic potential of health care markets in Europe.

Timeline and estimated costs

Preparatory phase: 2007 (5 M€).

Construction phase: 2008-2010 (255 M€).

Operation: 2010-2012 onwards (50 M€ per year).

Biomedical and Life Sciences

Estimated construction cost (M€)	255 M€
First open access foreseen	2010

Website

www.eatris.eu

EUROPEAN BIOBANKING AND BIOMOLECULAR RESOURCES

The facility

A pan-European and broadly accessible network of existing and de novo biobanks and biomolecular resources. The infrastructure will include samples from patients and healthy persons, molecular genomic resources and bioinformatics tools to optimally exploit this resource for global biomedical research.

Background

Following the rapid progress of genomic research in humans and their ancestors, biomedical and health research has expanded from the study of rare monogenic diseases to common, multifactorial diseases. However, most complex diseases are elusive as they do not root in single defects, but are caused by a large number of small, often additive effects from genetic predisposition, lifestyle and the environment. Discovery, i.e. separating the signal from the noise, will depend critically on the study of large collections of well-documented, up-to-date epidemiological, clinical and biological information and accompanying material from large numbers of patients and healthy persons, so-called biobanks. Biobanks are widely considered as a key resource in unravelling the association between disease subtypes and small, but systematic, variations in genotype, phenotype, and lifestyle.

What's new? Impact foreseen?

This project aims to build a coordinated, large-scale European infrastructure of biomedically relevant, quality-assessed sample collections, to enhance therapy and prevention of common and rare diseases, including cancer. In this area of unique European strength, valuable and irreplaceable national collections typically suffer from underutilisation due to fragmentation. Major synergism, gain of statistical power and economy of scale will be achieved by interlinking, standardising and harmonising – sometimes even just cross-referencing – a large variety of well-qualified, up-to date, existing and de novo national resources. The network should cover: (1) most human blood, sample and DNA banks, (2) molecular resource centres for human and model organisms of biomedical relevance, (3) bioinformatics centres to ensure that databases of samples in the repositories are dynamically linked to existing databases and to scientific literature.

Timeline and estimated costs

Preparatory phase: Years 1-3 (70 M€ in total).

Construction phase: Years 2-7 (100 M€ in total).

Operation: total over years 3-10 (15 M€ per year).

Biomedical and Life Sciences

Estimated construction cost (M€)	170 M€
First open access foreseen	2009

Website

www.biobanks.eu

INFRAFRONTIER

The facility

***Infrafrontier* will organise two complementary and interlinked distributed infrastructures. (1) "*Phenomefrontier*" will provide a European platform equipped with the latest technologies, in particular *in vivo* imaging and data management tools, for the phenotyping of medically relevant mouse models; (2) "*Archivefrontier*" will provide a European resource for state-of-the-art archiving and dissemination of those mouse models and will consist in a major upgrade of the European Mouse Mutant Archive (EMMA).**

Background

Medically related Life Sciences use the mouse as a model system to understand the molecular basis of health and disease in humans. An essential task for Biomedical Sciences in the 21st century will be the generation of mouse mutations for every gene in the mouse genome, creating a huge and vital resource of models for the study of human disease. Over the next decade, we can expect that tens of thousands of mouse disease models will become available, all of which will ultimately require phenotyping, archiving, and dissemination to the research laboratories. However the current capacity to achieve this goal is limited. Indeed, existing facilities across Europe can offer capacity for the dissemination and analysis of around a few hundred disease models per year. It is thus necessary to organise phenotyping, archiving, and distribution of mouse models on a well-concerted, large-scale, pan-European level.

What's new? Impact foreseen?

The goal of the "*Phenomefrontier*" part of the project is to provide a European platform offering access to comprehensive phenotyping to every laboratory, including the latest *in vivo* imaging technologies using non-invasive methods, as well as informatics tools to handle the phenotype data. Facilities will be upgraded and new ones will be constructed for assigning phenotypes to new mouse models from different pipelines. Archiving and distribution of mouse models under highest quality standards as well as dissemination of knowledge are the main goals of the second part, "*Archivefrontier*", of the project. "*Archivefrontier*" will consist in a major upgrade of the existing European Mouse Mutant Archive (EMMA). New facilities will be constructed. New mouse models will be archived, including attached data sets within an upgraded database. New methods to optimise and speed up the freezing of biological materials, will also be implemented. Altogether, these two parts of the project will enable European laboratories to make effective use of the mouse models in the global effort to understand the logic complex systems and human disease.

Timeline and estimated costs

Preparatory phase: 2006-2007 (50 M€).

Construction phase: 2007-2017 (270 M€).

Operation: 2007 onwards (36 M€/year).

Biomedical and Life Sciences

Estimated construction cost (M€)	320 M€
First open access foreseen	2007

Website

www.eumorphia.org | www.emma.rm.cnr.it

INFRASTRUCTURES FOR CLINICAL TRIALS AND BIOTHERAPY

The facility

This infrastructure will (1) interconnect existing national networks of clinical research centres and clinical trial units; (2) upgrade or create new facilities for the evaluation of innovative biotherapy agents; (3) make available professional data centres allowing high quality data management across the European Union; (4) establish connections with disease-oriented patient associations and registries, and disease-oriented investigators networks in order to foster patients' enrolment.

Background

The development of therapeutic innovations requires access to large populations of patients. Infrastructures supporting patient enrolment in clinical trials, data management, quality assurance, monitoring, ethics and regulatory affairs are required for quality and credibility of data and successful performance of clinical trials. Such networks covering clinical research centres and clinical trial units were recently created at national level in some Member States of the European Union. However the need for harmonisation and the ability to conduct multi-centre projects is even greater at the European level. A pan-European infrastructure network should bridge the fragmented organisation and improve the quality and efficiency of clinical research.

What's new? Impact foreseen?

An initial core network (ECRIN) of six national partners already started identifying bottlenecks to multinational clinical studies across the borders of the European Union, and preparing it to become an EU-wide infrastructure. A major upgrade of this infrastructure will provide a fully functioning network of distributed infrastructures for clinical trials in the EU. It will first strengthen the coordination team and European correspondent teams to run the infrastructure, namely to provide a co-ordinated support to clinical studies, including support in the interaction with ethics committees, competent authorities, adverse event reporting, drug dispensing, circulation of biological samples, study monitoring and data management. It will integrate a network of centres able to produce and evaluate clinical grade biotherapy agents. It will set up to 10 data management centres allowing remote data entry (EMEA/FDA-compliant) with the corresponding data centre staff. It will also extend the network, currently including six Member States, to additional ones within the EU. For Europe, this infrastructure will promote bottom-up harmonisation, spread quality standards, spread best practices and provide a network of harmonised high quality competence centres. For public sponsors, this infrastructure will help address scientific, public health and research or development challenges. For industry sponsors, harmonisation of practice within Europe and improved quality will facilitate the conduct of industry-driven drug development, and will provide support to SMEs. This project should lead to long-term structuring effects, affecting the organisation of clinical research, at national and European levels, promoting shared and harmonised policies.

Timeline and estimated costs

Preparatory phase: 2006 - 2007 (1 M€).

Construction phase: 2007 - 2008 (35 M€).

Operation: total over years 1-6 (5 M€ per year).

Biomedical and Life Sciences

Estimated construction cost (M€)	36 M€
First open access foreseen	2007

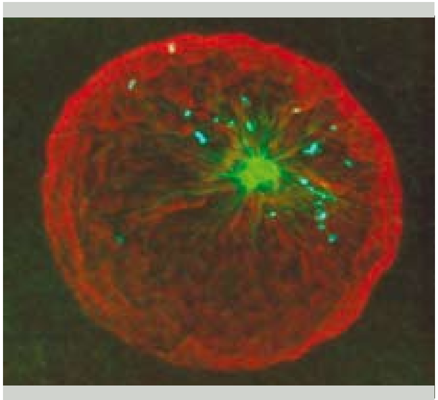
Website

www.ecrin.org

INTEGRATED STRUCTURAL BIOLOGY INFRASTRUCTURE

The facility

The new infrastructure will consist of distributed Centres for Integrated Structural Biology. All Centres will maintain a set of core technologies such as protein production, NMR, crystallography, and different forms of microscopy. However, each Centre will have a specific biological focus that will drive the development of technological and methodological expertise, notably for production and analysis of functional complexes. The network of Centres will be organised in order to obtain multi-scale structural data and translate these data into functional knowledge.



Background

One of the grand challenges in biology is to combine integrated structural biology with cell biology so that an atomic level dissection of the cell can be reconstituted into a functional system (3D cellular structural biology). A major challenge is to move structural biology from the study of single protein molecules to the study of the more complex systems used by cells with the long-term aim of using structural biology, together with cell and systems biology to be able to describe in detail how a cell functions. New facilities will have to be developed to understand the complexity of the molecular networks and processes on which cells depend. It is essential to include a temporal component in such studies. Europe is extraordinarily well-placed to meet this challenge. Its large, innovative structural community is internationally renowned and well organised for pan-European collaborations as evidenced by the fact that 15 large scale structural biology projects are currently financed by the EU.

What's new? Impact foreseen?

This challenge will be addressed by setting a pan-European infrastructure for Integrated Structural Biology based on new centres or major upgrades of existing ones. The Centres will develop complementary expertise and instrumentation depending on their focus areas, but all will maintain a set of core technologies. In the wet-lab these must include protein/macromolecular complex production using parallel technologies as well as the generation of organelles, cellular samples and functional characterisation. In the dry lab these will include NMR, X-ray and electron crystallography, cryo-EM and tomography, plus electron, scanning probe and different forms of light microscopy. Each Centre will have a specific biological focus (e.g. viruses, membrane proteins, ion channels, large transient complexes, enzymes, filamentous proteins). The Centres will thus develop complementarities, taking into account originality, the importance of the biological questions being addressed and the relevance to European priorities, such as human health, the environment, therapeutic innovation and biotechnologies. The Centres will be open to the European academic and industrial world and will provide, on a project basis, access to production and experimental facilities. The Integrated Structural Biology Infrastructure will provide a central framework for 21st century biology and pharmaceuticals.

Timeline and estimated costs

Preparatory phase: 2007-2009 (50 M€).

Construction phase: 2010-2013 (250 M€).

Operation: 2008-2013 (25 M€ per year).

Biomedical and Life Sciences

Estimated construction cost (M€)	300 M€
First open access foreseen	2007

Website

www.strubi.ox.ac.uk

UPGRADE OF EUROPEAN BIOINFORMATICS INFRASTRUCTURE

The facility

The infrastructure will be a secure but rapidly evolving platform for data collection, storage, annotation, validation, dissemination and utilisation, consistent with the unique requirements of shared resources in the life sciences.
The new infrastructure will be based around a substantial upgrade to the existing European Bioinformatics Institute (EBI) handling primary data resources. It will also integrate secondary data resources that are distributed across Europe and make the most of the diverse expertise of its scientists.

Background

The world's body of bioinformatics data is and will remain a critical input for all biomedical sciences and related industries, even more so in the current era of high-throughput data collection in genomics, proteomics etc. and requirements for large scale integrated analysis, for example for systems biology. The value of the data that is being collected far exceeds the cost of storing and providing access to it, however investment in infrastructure has not kept pace with the very rapid rate of data growth. In addition to this fast increase, new categories of data are emerging, e.g. three-dimensional dynamic images, high-throughput mass spectrometric proteome identification, phenotypic and physiological data, polymorphism and chemo genomic data.

What's new?
Impact foreseen?

The proposed infrastructure will ensure free provision of this essential bioinformatics data input to the entire scientific community. It will encompass an interlinked collection of robust, well-structured and evaluated core databases, capable of accommodating the ongoing massive accumulation and diversification of data pertinent to the biologist. It will permit the integration and interoperability of diverse, heterogeneous, potentially redundant information that is essential to generate and utilise biomedical knowledge. It will encompass the necessary major computer infrastructure to store and organise this data in a way suitable for rapid search and access, and will provide a sophisticated but user-friendly portal for users. It will be embedded in a database-related research programme that supports the development of critically important standards, ontologies and novel information resources. It will also link to secondary data resources that are distributed across Europe such as organism specific knowledge resources and, as appropriate, speciality and emerging databases of wide interest (e.g. image collections).

Timeline and estimated costs

Preparatory phase: Years 1-7 (80 M€).

Construction phase: Years 1-7 (470 M€).

Operation: total over years 1-7 (7 M€ per year).

Biomedical and Life Sciences

Estimated construction cost (M€)	550 M€
First open access foreseen	2007

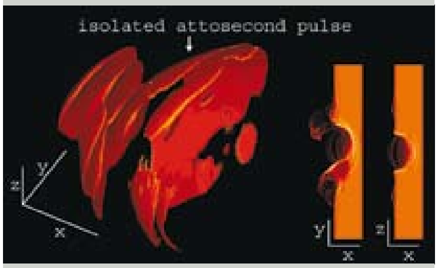
Website

www.ebi.ac.uk

ELI

The facility

ELI will be a research infrastructure open to European scientists dedicated to the investigation and applications of laser matter interaction at the highest intensity level, i.e. more than 36 orders of magnitude higher than today's state of the art. ELI will comprise three branches: Ultra High Field Science that will explore laser matter interaction up to the nonlinear QED limit, Attosecond Laser Science will make possible temporal investigation at the attosecond scale of the electron dynamics in atoms, molecules, plasmas and solids and the High Energy Beam Facility devoted to the development of dedicated beam lines of ultra short pulses of high energy particles up to 100 GeV and radiation for European users. ELI will have a large societal benefit in medicine, material sciences and environment.



Material Sciences

Estimated construction cost (M€)	150 M€
First open access foreseen	2013

Website

www.extreme-light-infrastructure.eu

Background

In few years laser intensities have increased by 6 orders of magnitude. The laser intensities are so large that the laws of optics change in a fundamental way. This new optics field is called Relativistic Optics. Among the important by-products of this field are the generation of particle, x-ray and green γ-ray beams over reduced dimensions (>1,000). The wealth of discoveries made in the relativistic regime justifies the need to go to higher level. ELI's mission, conceived as an European effort, consists indeed in reaching the ultra-reactivistic regime. One important aspect of ELI, is the possibility to produce ultra-short pulses of photon, electron, proton, neutron, muon, neutrino in the attosecond regime on demand. Time-domain studies will help us to unravel the attosecond dynamics in atomic, molecular physic and plasma physics. In materials, ELI could help us to understand the damage mechanisms involved in materials exposed to high neutron fluxes (nuclear reactors) or in medicine with new drugs and therapies.

What's new? Impact foreseen?

ELI will be the first facility in the world dedicated to laser-matter interaction in the highest intensity level: the ultra-relativistic regime. It will be the gateway to new regimes in physics but also, will promote new technologies such as Relativistic Microelectronic with the development of compact laser-accelerators delivering >100 GeV particles and photon sources.

Timeline and estimated costs

ELI conceptual design calls for three stages. They will be made available as they are completed, with a preparatory cost of 14 M€. The Front End at the PW level, the second one at the 50 PW and the final stage, above the 100 PW. It is foreseen a two-year design study followed by five years for the construction. The project cost is estimated at 138 M€, with operation and maintenance at 6 M€/year.

ESRF Upgrade

The facility

The European Synchrotron Radiation Facility (ESRF), located in Grenoble, France, is a joint facility supported and shared by 17 European countries and Israel. It operates the most powerful high energy synchrotron light source in Europe and brings together a wide range of disciplines including physics, chemistry and materials science as well as biology, medicine, geophysics and archaeology. There are many industrial applications, including pharmaceuticals, cosmetics, petrochemicals and microelectronics.

Material Sciences

Estimated construction cost (M€)	230 M€
First open access foreseen	2007 - 2014

Website

www.esrf.fr

Background

The ESRF's 6 GeV storage-ring light source built in the early nineties was the first insertion-device-based ("third generation") synchrotron radiation (SR) source. The ESRF has been extremely successful, both in terms of technical innovation and also where the very large volume of new and exciting science is concerned. With some 5,500 scientific user visits each year, resulting in more than 1,300 refereed publications, the ESRF is recognised as one of the world's most innovative and productive synchrotron light sources. This success is also measured by requests for beamtime from the community of users of the ESRF, consistently greatly exceeding the available beamtime.

What's new? Impact foreseen?

The longer term upgrade programme builds on the achievements of the ESRF with the aim of maintaining a leading scientific position over the next 10 to 20 years. New and refurbished beamlines are proposed to answer new scientific needs, underpinned by a longer-term programme to maintain and refurbish the accelerator complex at the heart of the ESRF's activities. Advances in fields such as X-ray optics and detectors, many of which originated at the ESRF, now allow this ambitious renewal programme covering all aspects of the ESRF's activities. The performance of the beamlines will be enhanced by several orders of magnitude. New scientific areas will be addressed with new highly specialised nano-focus beamlines, with even brighter "hard" X-ray beams, and by renewing beamline components such as detectors, optics, sample environment and sample positioning. The new and upgraded beamlines will be exploited in a scientific programme focussed on five broad scientific areas: nano-science and nano-technology, pump-probe experiments and time-resolved diffraction, science at extreme conditions, structural and functional biology and soft matter, and X-ray imaging.

Timeline and estimated costs

The upgrade programme is estimated to cost 232 M€ and to take approximately 7 years to implement. It is planned to carry out the programme with minimal disruption to existing research, and the running costs will be only slightly increased.

EUROPEAN SPALLATION SOURCE FOR PRODUCING NEUTRONS

The facility

ESS will be the world's most powerful source of neutrons. Its built-in upgradeability (more than the initial 20 instruments, more power, more target stations) makes it the most cost-effective top tier source for 40 years or more. A genuine pan-European facility, it will serve 4,000 users annually across many areas of science and technology.

Material Sciences

Estimated construction cost (M€)	1050 M€
First open access foreseen	2017

Website

http://neutron.neutron-eu.net/n_ess

Background

Fine analysis of matter requires the complementary use of diverse "probes" and techniques: light rays, neutrons, NMR, computer modelling and simulations and so on. Intense beams of low energy neutrons create entirely new opportunities, including movies of nano-scale events, for real time, real size, in situ, in vivo and parametric measurements to elucidate structures, dynamics and functions of increasingly complex inorganic, organic and biomaterials and systems. The ESS is a strategic project for Europe.

What's new? Impact foreseen?

Neutron beams produced by reactors are inherently intensity-limited. The ESS R&D and design phase (>50 M€; all major European labs, >100 top scientists) has shown the feasibility of MW spallation sources. In line with the global neutron strategy endorsed by OECD ministers in 1999, the US has now commissioned its facility, based on the ESS design, and Japan will follow suit in 2007/2008. The initial long pulse configuration of ESS provides substantially higher power, maximum complementarity and the largest instrument innovation potential. Its unique upgradeability guarantees a long-term top position. ESS will also offer new modes of operation and user support to maximally facilitate industry, next to university and research lab users.

The higher flux will allow advanced and more effective investigations of ultrathin and laterally confined structures for ICT reading devices, active site structures in enzymes, technologies for storing hydrogen, multicomponent complex fluids in porous media for tertiary oil production, the templating of nanostructures for catalysts, medical implants, pharmaceuticals, photonic materials etc. Requirements for novel detectors, instrument and software technologies will be additional drivers of innovation. ESS, a multifunctional facility with applications in many industries, will also have a marked regional impact (new firms in areas of regional specialisation, positive effect on regional as well as European talent pool, etc).

Timeline and estimated costs

The ESS project was initiated in the early nineties. The science case and the preliminary baseline range (design and costing) are ready and allow formal negotiations to start in 2006, in parallel to a decision to complete the detailed engineering design including detailed costing and optimisation. This performance baseline is the basis for go-ahead which can be at the end of 2008 if negotiations are completed.

Start of construction 2009; First neutrons 2016; First user operations 2017/2018.

Preparatory costs 30 M€.

Total expected construction costs ~1,000 M€, operation cost ~80 M€/year.

European XFEL

The facility

The European X ray Free Electron Laser to be built in Hamburg, Germany, will be a world leading facility for the production of intense, short pulses of X rays for scientific research in a wide range of disciplines.

Material Sciences

Estimated construction cost (M€)	986 M€
First open access foreseen	2013

Website

http://xfel.desy.de

Background

The European X-ray Free Electron Laser (European XFEL) project foresees the construction near Hamburg, Germany of a new international user facility for the production and scientific use of ultra-bright and ultra-short pulses of spatially coherent hard X-rays. The facility comprises a superconducting linear accelerator 1.7 km long accelerating electrons up to energy of 17.5 GeV which will distribute up to ~30,000 electron bunches per second into three undulators. These will generate spatially coherent X radiation pulses shorter than 100 fs in duration and with peak power exceeding 10 GW, in a wavelength range from 0.1 nm to 1.6 nm. A further set of 3 undulators will generate hard X-rays down to 0.01 nm wavelength by the spontaneous emission process. The facility includes a set of ten experimental stations with state of the art equipment for the scientific use of the radiation.

What's new? Impact foreseen?

It is anticipated that the availability of X-ray pulses with peak brilliance of up to nine orders of magnitude greater than existing 3rd generation light sources shall allow the performance of presently impossible and potentially revolutionary experiments in a variety of disciplines from condensed matter and materials physics to nanoscience, from plasma physics to chemistry and to structural biology. They include, for example, the follow up of structural modifications at the atomic level on the sub-ps timescale during chemical reactions and phase transformations, the solution of macromolecular structures without the need for crystallisation, the access to presently inaccessible regions of the phase diagram of warm dense matter.

Timeline and estimated costs

The construction costs are estimated in ~986 M€ with additional costs of 50 M€ for R&D, instrumentation and detectors. Construction is expected to begin in 2007 and be completed in 2013, on the basis of an ongoing preparatory phase costing ~30 M€. The yearly operation costs are estimated at ~84 M€ and decommissioning costs at ~100 M€.

ILL 20/20 Upgrade

Artechnique

The facility

The reactor-based laboratory at the Institut Laue Langevin (ILL) is recognised as the world's most productive and reliable source of slow neutrons for the study of condensed matter, and its overall upgrade is the most cost-effective response in the short to medium term to users' requirements.

Material Sciences

Estimated construction cost (M€)	160 M€
First open access foreseen	2012 - 2017

Website

www.ill.fr/Perspectives

Background

The ILL has been and still is a European success story, having been set up with a full complement of beam-lines and experimental instruments from its beginning in the mid 70s, and continuously improved. The near-siting of the European Synchrotron Research Facility has added value for European users having access to complementary techniques and joint support laboratories on the Grenoble site. Recently a more focused and wide-ranging upgrade programme – the Millennium Programme – has been started, to maintain the world level competitiveness and scientific value for the international User Community. The proposal includes optimising the neutron source and its moderators, the neutron delivery (guides and beam tubes) and the neutron instrumentation. Access to new scientific areas will be strengthened through enhanced support facilities for Users. The first such facility, the Partnership for Structural Biology – a joint project with 5 laboratories – opened in November 2005 providing special services, such as the growing of deuterated single crystals, for visiting research teams using the neutron and synchrotron instruments on site.

What's new? Impact foreseen?

The renewal of the neutron production and instrumentation of the Institut Laue Langevin in Grenoble, the so-called 20/20 plan, will give a longer perspective of competitiveness, but extra added value is given by the Partnerships for Materials Science and Engineering, and Soft Condensed Matter. A High Magnetic Field laboratory in collaboration with ESRF is proposed to support instruments on both the neutron and the synchrotron radiation sources. Specific measures will be implemented to facilitate Technology Transfer.

Timeline and estimated costs

This project will be implemented in two consecutive 5-years phases from 2007 to 2011 and from 2012 to 2016. The ILL 20/20 proposal is estimated to cost ~160 M€. Discussions are underway with regional and local governments to obtain support for additional infrastructural aspects proposed for the joint site together with ESRF.

IRUVX-FEL

The facility

Intense light beams from the Infrared to the Soft X-rays are the major probe to study the electronic properties of Matter and will involve a very large user community. The development of Free Electron Lasers allows a new, virtually unexplored, regime of coherent light flashing with femto-second pulses. The IRUVX Consortium will join the resources now in construction and planned in Europe into a unique Research Infrastructure, allowing to offer novel and powerful complementary instruments for the microscopic and the dynamical study, as well as an optimal service to users, prioritising the development and location of the specific beam lines.

Material Sciences

Estimated construction cost (M€)	760 M€
First open access foreseen	2006-2015

Website

www.iruvx.eu

Background

A recent technological breakthrough has allowed developing new light sources based on Free Electron Lasers (FELs) in the infrared to soft x-ray wavelength range, flashing with femto-second pulses, large coherence and high brilliance, producing very collimated beams "illuminating" at atomic level the components of materials to observe both their structure and dynamical behaviour.

What's new? Impact foreseen?

The area is under rapid technical development, with Europe at the forefront. The interaction between matter and electromagnetic radiation in this regime is virtually unexplored. State of the art 3rd generation synchrotron sources will be surpassed in peak intensity by factors of 10^8-10^9, in average intensity and in their short-time flashing capabilities by 10^3-10^4 down to a few femto-seconds, pushing experimental techniques to new frontiers. The photon beams of Soft-FELs will have completely new qualities compared to those of synchrotrons at photon energies between 10 eV and 1 keV. Europe has the unique chance for consolidating its world leadership in a field of highest relevance.

Scientific challenges and opportunities will open for a wide range of scientific disciplines, ranging from nanosciences, materials and biomaterials sciences, plasma physics, molecular and cluster, femto- and nano- physics and chemistry, various connections to life, environmental, astrophysical and earth sciences and the development of technologies ranging from micro electronics to energy. Some novel emerging synchrotron techniques, like holographic coherent imaging or ultra fast pump-probe studies will greatly benefit from the enhanced beam properties. We can today only imagine some of these opportunities and it is likely that the most important use of soft-FELs have not yet even been thought of.

Timeline and estimated costs

Five facilities, in different and scaled phases of development are involved in the proposal. One in operation (FLASH at DESY, Hamburg), one in construction (FERMI @ Elettra, Trieste), two in advanced technical demonstration and technological development phase (4GLS in Daresbury and BESSY in Berlin) and one in conceptual phase (MaxLab in Lund). Other projects may enter the consortium from The Netherlands, France and Switzerland. FLASH and Elettra are approved for a total cost of 237 M€, as well as the development costs of 4GLS and BESSY for a total of 71 M€.

Total implementation has an estimated cost of ~660 M€, a preparatory cost of ~15% of the construction, and an estimated operation cost of 65-70 M€.

PRINS

The facility

The *Pan-European Research Infrastructure for Nano-Structures* (PRINS) is the Research Infrastructure arm of a broader initiative, the ENIAC European Technology Platform.

PRINS will bridge the area between research and market-driven applications and provide Europe with the ability to master the revolutionary transition from Microelectronics to Nano-electronics, i.e. down to the level of individual atoms.

Background

PRINS has been conceived as a distributed infrastructure based essentially in 3 European countries (Belgium, France and Germany) that will jointly address the new challenges in a coordinated and complementary way. Academic access to three pre-existing centres of excellence (IMEC, CEA-LETI and Fraunhofer Microelectronics Alliance, respectively) will be put under a common umbrella. The types of access and the related conditions are explained in more detail in the PRINS Concept Document of 25 January, 2006. These three scientific and technical integration centres will be supported by a complementary network of flexible rapid-prototyping laboratories. Their role will be the validation of innovative device and materials steps in the nanoscale CMOS and beyond-CMOS areas.

What's new? Impact foreseen?

The PRINS research infrastructure will enable European research into the ultimate scaling of electronic components ("Moore's Law"), the combination of digital signal processing with other types of functionality ("More than Moore"), the exploration of novel device concepts ("Beyond Moore") and the integration of components and materials into systems in a package (SiP). PRINS will contribute to realising the goals of the ENIAC Strategic Research Agenda. PRINS will bring together an unprecedented array of equipment and know-how in topics like high-resolution lithography, advanced process steps and modules, electronic systems integration, imaging devices, silicon-based micro-systems, and miniaturised devices addressing the nano-bio convergence. It will give a boost to European RTD performance in the area of Nano-electronics and combined Nano-Structures. The applications that PRINS will generate will serve the future demands of European society, will increase high-skilled employment, will reinforce the competitiveness of European industry and will secure global leadership in high-tech multidisciplinary research.

Timeline and estimated costs

The PRINS infrastructure at the three integration centres will be built in a modular way in the period 2007-2013 for a total cost of ~1,110 M€. The yearly operational costs for the 3 centres combined will be approximately 220 M€. The PRINS business plan additionally includes a combined budget of 250 M€ for the rapid-prototyping laboratories. The infrastructure will be partly operational in 2007, while major research equipment will be brought in until 2013, in response to quickly changing needs and new technologies becoming available.

Material Sciences

Estimated construction cost (M€)	1110 M€
First open access foreseen	2008 - 2013

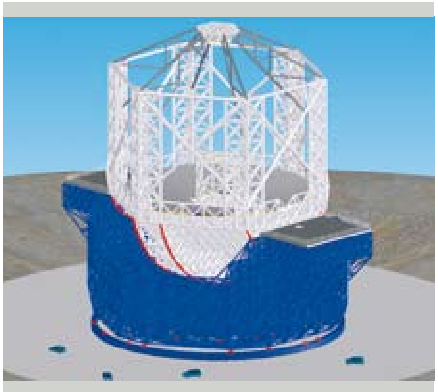
Website

www.eniac.eu/web/about/PRINS.php

ELT - European Extremely Large Telescope

The facility

Extremely Large Telescopes are seen world-wide as one of the highest priorities in ground-based astronomy. They will vastly advance astrophysical knowledge allowing detailed studies of *inter alia* planets around other stars, the first objects in the Universe, super-massive Black Holes, and the nature and distribution of the Dark Matter and Dark Energy which dominate the Universe. The European Extremely Large Telescope project will maintain and reinforce Europe's position at the forefront of astrophysical research.



Astronomy, Astrophysics, Nuclear and Particle Physics

Estimated construction cost (M€)	850 M€
First open access foreseen	2018

Website

www.eso.org/projects/e-elt

Background

Extremely Large Telescopes allow the next major step in addressing the most fundamental properties of the universe. All aspects of known astronomy, from studies of our own Solar System to the farthest observable objects at the edge of the Universe, will be advanced by the enormous improvements attainable in collecting area and angular resolution: it is the opportunity for discovery of the new and unexpected; it promises detailed study of the formation and evolution of planets, stars, galaxies, quasars, black holes, neutron stars, and the first objects to form in the Universe; a better understanding of the Dark Matter which is the dominant form of mass, and of the mysterious "Dark Energy", which in turn controls the future of our entire Universe.

ESO is presently developing the Reference Design of the European Extremely Large Telescope (ELT). In parallel, the ELT scientific aim has been developed and is being refined by the astrophysical community through the OPTICON FP6 programme, while major enabling technologies are being pursued by European research institutes and high-tech companies within the ELT Design Study FP6 programme. These efforts are conducted in close contact with the other similar projects all around the world.

What's new? Impact foreseen?

Astronomy is a technology-enabled science. Recent technology developments, especially in real-time control of complex systems, now allow the next generation of telescopes to be built. The light collection and spatial resolution, in going from the present 8-10 metres to over 30 metres in diameter, will improve on current limits by tens to hundreds of times, providing the critical increase in sensitivity and resolution to enable truly outstanding scientific performance. Astronomical advances improve our understanding of mankind's place in the Universe. Astronomy is known to be the most effective topic attracting young people to science and technology careers. Astronomical telescopes, being large precision opto-mechanical systems in hostile environments, develop advanced technologies in many state-of-the-art areas with spin-offs ranging from medicine to image data processing.

Timeline and estimated costs

The preparatory and design phase of the ELT will last until 2009, with construction expected in the period 2010-2017.

Construction cost for such a large facility will likely be in the 800 M€ range, with a preparatory cost of about 100 M€ already partly covered by the EU. An annual operation cost of ~40 M€ is foreseen.

FAIR

The facility

FAIR will provide high energy primary and secondary beams of ions of highest intensity and quality, including an "antimatter beam" of antiprotons allowing forefront research in five different disciplines of physics. The accelerator facility foresees the broad implementation of ion storage/cooler rings and of in-ring experimentation with internal targets. Two superconducting synchrotrons will deliver high intensity ion beams up to 35 GeV per nucleon for experiments with primary beams of ion masses up to Uranium and the production of a broad range of radioactive ion beams.

Background

The concept for the Facility for Antiproton and Ion Research (FAIR), planned for construction at the GSI Laboratory in Darmstadt, Germany, has been developed by international working groups. In 2001, GSI, together with a large international science community, presented a Conceptual Design Report (CDR). Following an in-depth evaluation by the German Wissenschaftsrat (the science advisory committee of the German government) and its recommendation to realise the facility, the German Federal Government announced in February 2003 approval of the project, with Germany providing up to 75% of the needed funding.

The FAIR project developed significantly since the CDR. About 2,500 scientists from 44 countries submitted Letters of Intent in 2004 and Technical Proposals in 2005 for the experiment programmes at FAIR. Significant R&D has been carried out and detailed design has been developed. A large fraction of this effort is funded by the European Commission. In April 2006 the FAIR Baseline Technical Report with 3,500 pages has been presented.

What's new? Impact foreseen?

FAIR has a broad scientific scope allowing forefront research in nuclear structure physics and nuclear astrophysics with radioactive ion beams, QCD studies with cooled beams of anti-protons, physics of hadronic matter at highest baryon density, plasma physics at very high pressure, density and temperature and atomic physics and applied sciences. It will provide the European science communities with a world-wide competitive facility. The central programme, nuclear physics is in its totality of first class worldwide. FAIR is also unique in areas such as highly-compressed intense heavy-ion beams for plasma physics, and in its unparalleled research programme with cooled antiproton beam and internal-target storage-ring capabilities for QCD studies.

Timeline and estimated costs

The FAIR construction cost (total investment) is 1,002 M€. In addition manpower equivalent to 2,400 person/years is required. The start of the construction is projected for 2007. FAIR shall be constructed in three phases until 2014. The full performance with the parallel operation of all experimental programmes will be reached in 2015. The operation cost is estimated to be 118 M€ per year (price index 2005).

Astronomy, Astrophysics, Nuclear and Particle Physics

Estimated construction cost (M€)	1186 M€
First open access foreseen	2014

Website

www.gsi.de/fair/index_e.html

KM3NeT

The facility

A deep-sea research infrastructure in the Mediterranean Sea will be hosting a cubic-kilometre sized deep-sea neutrino telescope for astronomy based on the detection of high-energy cosmic neutrinos and giving access to long-term deep-sea measurements.

Astronomy, Astrophysics, Nuclear and Particle Physics

Estimated construction cost (M€)	**220 - 250 M€**
First open access foreseen	**2015**

Website

www.km3net.org

Background

Since they are not deflected and can travel cosmological distances without absorption, neutrinos are ideal messengers to study the highest-energy, most violent processes in the universe. However, due to their weak interaction with ordinary matter, huge detectors are required to measure them. A first generation of such *neutrino telescopes* in the Mediterranean Sea is currently in operation or under construction. However, only future installations of cubic-kilometre size will exploit the full scientific potential of neutrino astronomy. These installations can be built in synergy with environmental observation underwater stations (see EMSO).

What's new? Impact foreseen?

The KM3NeT neutrino telescope will be the leading European facility for neutrino astronomy. It will be the only deep-sea installation of this size in the world and only be complemented by the US-led IceCube project that is being installed in the Antarctic ice at the South Pole. Compared to IceCube, KM3NeT will determine direction and energy of the neutrinos with higher precision, it will have a lower energy threshold for neutrino detection, and it will have the major advantage of being able to observe neutrinos originating from the central region of the Milky Way. The design of the KM3NeT neutrino telescope poses substantial challenges concerning e.g. photo-detection, data acquisition and processing, deep-sea technology, installation and maintenance procedures, cost effectiveness and stability of operation. These issues are addressed in a FP6 Design Study (2006-2009), building on technology at the forefront of science.

KM3NeT will be a truly interdisciplinary research infrastructure: it will provide access to neutrino observations for the astronomy, astrophysics, astroparticle and particle physics communities and, in addition, allow for long-term measurements in the deep-sea environment that are of utmost interest e.g. for biologists, geophysicists and oceanographers.

Timeline and estimated costs

By 2009, the Design Study will culminate in a Technical Design Report laying the technical foundations for the construction of the KM3NeT infrastructure. Thereafter, 4 to 5 years time will be required to establish funding, for industrialisation and deployment. KM3NeT data is thus expected to become available concurrently with the data taking of the full IceCube detector. A solid estimate of the construction cost will result from the Design Study; the objective is to achieve a price tag below 200 M€ for a cubic-kilometre installation (salaries not included).

Preparatory cost of about 20 M€.

SKA - Square Kilometre Array

The facility

The Square Kilometre Array will be the next generation radio telescope. With an operating frequency range of 0.1 – 25 GHz and a collecting area of about 1,000,000 m^2, it will be 50 times more sensitive than current facilities. With its huge field-of-view it will be able to survey the sky more than 10,000 times faster than any existing radio telescope. The SKA will be a machine that transforms our view of the Universe.

Background

The development of radio telescopes and radio interferometers over recent decades has helped drive a continuous advance in our knowledge of the Universe, its origins and evolution, and the enormously powerful phenomena that give rise to star and galaxy formation. Radio astronomy also provides one of the most promising search techniques in humanity's quest to determine if life exists elsewhere in the Universe.

What's new? Impact foreseen?

The huge collecting area of the SKA will result in a sensitivity 50 times greater than any existing interferometer, a requirement to see the faint radio signals from the early universe. The radically new concept of an "electronic" telescope with a huge field-of-view and multiple beams will allow very fast surveys. The SKA will be the most sensitive radio telescope ever built and will attack many of the most important problems in cosmology and fundamental physics. Observations of pulsars will detect cosmic gravitational waves and test Einstein's General Theory of Relativity in the vicinity of black holes. The SKA will study the distribution of neutral hydrogen (the most common element in the universe) in a billion galaxies across cosmic history, thus making it possible to map the formation and evolution of galaxies, study the nature of Dark Energy and probe the epoch when the first stars were born. The SKA will be the only instrument that will map magnetic fields across the Universe, allowing us for the first time to study the nature of magnetism. Last but not least, the SKA will study the formation of planetary systems and address the question "does life exist elsewhere in the Universe?".

Timeline and estimated costs

Preliminary design and technology development: 2000-2007; costed system design from 2008-2010; with an overall preparatory cost of ~160 M€.

Phase 1 construction and first data: 2011-2014, completion of the full SKA: 2014-2020.

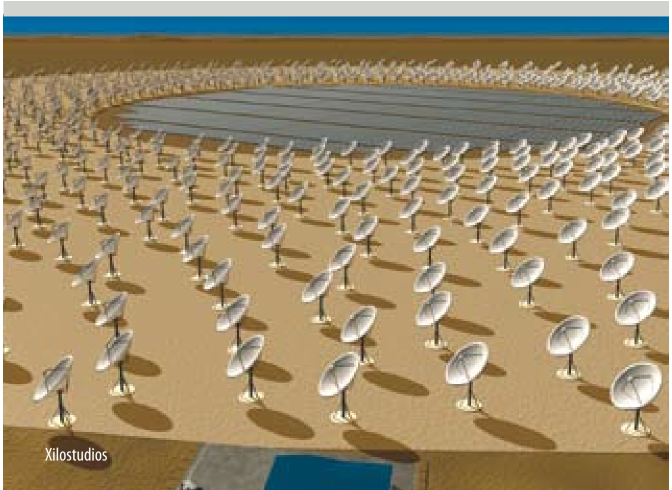
Costs are presently estimated at ~1,150 M€ (capping at 1,000 M€), with an annual operations cost estimated at ~100 M€.

Astronomy, Astrophysics, Nuclear and Particle Physics

Estimated construction cost (M€)	1150 M€
First open access foreseen	2014 - 2020

Website

www.skatelescope.org

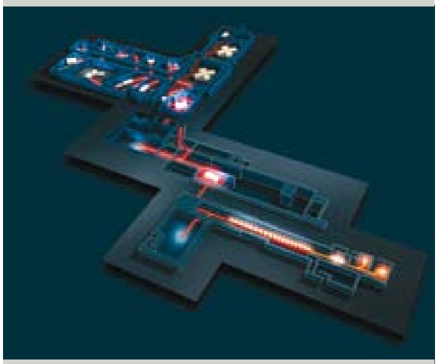


Xilostudios

SPIRAL2

The facility

SPIRAL2 is a new European facility to be built at the GANIL laboratory in Caen, France. The project aims at delivering rare (radioactive) isotope beams with intensities not yet available with present machines. SPIRAL2 will reinforce the European leadership in the field of nuclear physics based on exotic nuclei.



Background

The frontier of Nuclear Physics is advancing through the study of nuclear reactions between diverse types of ions and protons, covering the widest possible range of different nuclei and energies. The approach in SPIRAL2 is complementary to that in FAIR; it is based on the ISOL technique (Isotope separation on line) demonstrated at GANIL in France and is aiming at two orders of magnitude increase of the secondary beams available for nuclear physics studies.

What's new? Impact foreseen?

The SPIRAL2 project is an intermediate step toward EURISOL, the most advanced nuclear physics research facility presently imaginable and based on the ISOL principle. It is expected, that the realisation of SPIRAL2 will substantially increase the know-how of technical solutions to be applied not only for EURISOL but also in a number of other European/ world projects. The scientific programme, prepared by a team of more than a hundred of the world class specialists proposes the investigation of the most challenging nuclear and astrophysics questions aiming at the deeper understanding of the nature of matter. SPIRAL2 will contribute to the physics of nuclear fission and fusion based on the collection of unprecedented detailed basic nuclear data, to the production of rare radioisotopes for medicine, to radiobiology and to material science.

Timeline and estimated costs

The construction costs are estimated to be 130 M€. The construction will last about five years (2006-2010) and operation of the facility will cost about 6.6 M€, with preparatory and decommissioning costs of 6.6 and 10 M€ respectively.

Astronomy, Astrophysics, Nuclear and Particle Physics

Estimated construction cost (M€)	137 M€
First open access foreseen	2011

Website

www.ganil.fr/research/developments/spiral2

EUROPEAN HIGH-PERFORMANCE COMPUTING SERVICE

The facility

A European strategic approach to high-performance computing, concentrating the resources in a limited number of world top-tier centres in an overall infrastructure connected with associated national, regional and local centres, forming a scientific computing network to utilise the top-level machines. This overall architecture will respond both to Capability (high-performance) and Capacity Computing (high-throughput) needs. Different machine architectures will fulfil the requirements of different scientific domains and applications. This can be represented as a pyramid, where local centres would constitute the base of the pyramid, national and regional centres would constitute the middle layer and the high-end HPC centres would constitute the top.

Background

The dramatic growth in the available processing power, memory, and data transmission capabilities has revolutionised many aspects of science. In many application areas, computation is the essential method for achieving high-quality results. Examples include climate research, earth science, nanotechnology, computational chemistry, high-energy physics, life sciences etc. The European research community needs access to adequate computational facilities in order to stay at the forefront of research.

What's new? Impact foreseen?

Effective mechanisms for the allocation of computing time will avoid a fragmented use of the top level computers and speed up adaptation/ development of codes and algorithms for the new computers: an essential step for their effective use. High-performance computing has a strong impact in terms of maintaining the strategic competitiveness of Europe and increasing its attractiveness for foreign researchers and for supporting industrial development. Due to the rapid evolution, the commercially available hardware for HPC has a short life cycle: therefore, large investments in the field need to be carefully planned. The high-end (capability) resources should be implemented every 2-3 years with supporting actions in the national/regional centres to maintain the transfer of knowledge and feed projects to the top capability layer.

Timeline and estimated costs

The following estimated costs cover a full HPC service, including premises for demanding systems and expertise in running them to create a sustainable European high-performance landscape. Preparatory phase for 2006-2007 1-10 M€. High-end (capability) infrastructure (several installations, where an installation can consist of two different architectures, placed in different locations) 100-200 M€ every 2-3 years, starting 2008-2009. Medium level infrastructure 50-100 M€ every 2 years, starting 2007-2008. The estimated cost includes several medium size installations (5-10). Maintenance/upgrade cost 50-100 M€/year (total for both top levels). In addition funding for supporting projects like software development and optimization and training should be conducted in order to obtain the maximum impact and efficiency from the HPC resources. Estimated need is 30-50 M€/year.

CDT

Estimated construction cost (M€)	200 - 400 M€
First open access foreseen	2008

Website

www.hpcineuropetaskforce.eu

>Emerging proposals

During the preparation of the roadmap the experts have also received and identified emerging proposals that may constitute a base for future upgrades of the roadmap itself.

They are listed here below divided by the name of the corresponding ESFRI Roadmap Working Group. At this stage ESFRI does not offer any opinion on whether they will subsequently enter the full roadmap in the future. It is fully expected that future editions will substantially add to this list of emerging proposals.

Biological and Medical Sciences

European Infrastructure for Chemical Biology

Chemical compounds are the traditional products for medical therapies and agricultural/ecological management. Chemical biology is opening new doors for research in the genome era and for direct translation into benefits for basic science and for the health of the public. This infrastructure will incorporate a European Molecular Library Resource Centre (EMLRC) and a European Resource for Ligand Binders against the Human Proteome. An interdisciplinary chemical biology approach will bring together chemists, engineers, informaticians and biologists and create numerous opportunities for innovation and commercialisation.

European Infrastructure for Systems Biology

The focus of biomedical research needs to change from primarily a component-by-component analysis at the molecular level to an understanding of biology as the interaction of complex systems. Such an approach is needed for a much more comprehensive understanding of complex diseases, for which the underlying genetic basis is related to the combined interactions of multiple genes. This paradigm shift in biomedical research cannot be achieved by a few isolated research teams but requires the establishment of a *European Centre for Systems Biology*.

Advanced Light Microscopy for Europe

The goal of this initiative is to establish advanced light microscopy imaging centres in Europe to generate and apply novel advanced technology for non-invasive imaging of biomolecular function in living systems ranging from single cells to model animals. With the explosion in the use of digital imaging techniques in basic research, the funding necessary to establish the required infrastructure and human expertise exceeds considerably both the financial and scientific capabilities of individual laboratories or even of institutions.

European Infrastructure for Synthetic Biology

Synthetic biology is concerned with applying the engineering paradigm of systems design to biological systems in order to produce predictable and robust systems with novel functionalities that do not exist in nature. In essence, synthetic biology will enable the design of "biological systems" in a rational and systematic way. The objective of this infrastructure would be to provide key service functions to the synthetic biology community, to enable standardisation of biological parts on which synthetic biologists can draw, including the provision of reference methods and materials, as well as associated research and top level training.

European Infrastructure for Research in Biomedical Imaging (EIRBI)

A number of *in vitro* techniques are now available to biologists for assessing, at the molecular level, the occurrence of abnormal gene expression that accompanies the development of a pathological state. The field of biomedical imaging is challenged to translate these tremendous achievements into early diagnosis and efficient follow-up of therapeutic treatments as well as developing novel, imaging-guided, drug-delivery and minimally invasive treatments. The establishment of EIRBI is essential to this challenge, and will further maintain the competitiveness of European industries and academic institutions in the field of imaging.

High security laboratories for emerging and zoonotic diseases and threats to public health

Recent crises have shown that infectious diseases are far from being eradicated in humans as well as animals. One of the key issues to address in order to protect human health is the boundary between human and animal pathogens. The scientific challenges are enormous but the biotechnological revolution allows for important breakthroughs to be made. Diagnosis, surveillance and research of such diseases and their agents require the establishment of a European network of high-security laboratories (containment level L3 and L4).

European Infrastructure for the Analysis and Experimentation on Ecosystems (ANAEE)

The continental biosphere plays an important role on global change of the planet by means of its interactions with atmosphere and hydrosphere and also by the fact that most of the continental ecosystems are subjected to severe manipulations through human activities. Predicting and mitigating the consequences of these global changes is a major challenge for ecologists and agricultural scientists as well as socio-economists. Theoretical and mechanistic models, powerful "ecosystem analysers" and long term field experimentations are all needed to analyse, model and predict the consequences of global changes on biogeochemical fluxes and biodiversity. These tools need an integrated, strong and innovative development in a concerted way across Europe. This is the objective of the Infrastructure for the Analysis and Experimentation on Ecosystems (ANAEE).

Physical Science and Engineering

CTA

is an advanced facility for ground based high-energy gamma ray astronomy, based on the observation of Cerenkov radiation. This approach has proven to be extremely successful for gamma rays of energies above few tens of GeV. The facility will consist in an array of telescopes enhancing the all sky monitoring capability.

DACA

DATA CURATION and ANALYSIS for Software and Data Management, is a networked infrastructure developing data analysis methods and software for the use of various sciences. Each node of the network operates in connection with a specific heavy user of data analysis and management methods, and the networks cooperate on the application-independent aspects of the work.

DAΦNE-II

is a major upgrade of the current DAΦNE machine complex, which is presently running at the Frascati National Laboratory of INFN, Italy. The upgrade aims to reach a peak luminosity in excess of 5 x 10^{33} at 1 GeV c.m. and to extend the energy reach of the current machine to 2.4 GeV.

EUFEO

The goal of this initiative is to enable European nanoscience and industry to play a leading role in the future application of bicorrected optic systems. The proposal envisages the construction of a network of research/service centres based on subÅngstrom resolution facilities for use by industry and research.

MYRRHA

MYRRHA is an Accelerator Driven System (ADS) under development at Mol In Belgium and aiming to serve as the basis for the European experimental ADS called XT-ADS. The goal of this facility is to provide protons and neutrons for various R&D applications and in particular to serve as a fast spectrum irradiation facility after having demonstrated ADS feasibility. Its accelerator has been upgraded from 350*5 mA to a 600 MeV*2.5 mA proton linac. The spallation source is based on a windowless liquid Pb-Bi concept that is coupled to a Pb-Bi cooled subcritical fast core of which the main technical specifications are now worked out, and design work is progressing in a European famework.

NANOSCIENCE

The NANOSCIENCE centres will operate under a general coordination at European level, but with high degree of autonomy and characterization, giving a common standard offer of state of the art clean-room, synthesis, growth, nanofabrication, wet-chemistry, combinatorial methods, atomic/molecular models and advanced simulation of nanosystems, with direct access to analytical and photolytographic methods based on particle beams from synchrotrons, free electron lasers and neutron sources.

PALLAS

The PALLAS reactor proposal is devoted to research & development and at the same time producing isotopes. It will have a power in 30-60 MW range and be the successor to the HFR, in Petten and based on the HFR experience and proven technology. The technology enhancements (LEU) of the early 21st century will be incorporated to improve specifications. The peak fast and thermal fluxes are about $5*10^{18}$ $n.m^{-2}$, the double value of the HFR.

PEGASUS

The infrastructure would allow for the first time to acquire continuous Remote Sensing data, at high resolution at an affordable price, usable by the science community to develop many areas of environmental monitoring and beyond. The proposal has an airborne element composed by a number (30 in 2014) of High Altitude Platforms to be deployed across Europe, able to produce complete image coverage at very high resolution connected to a centralized data processing centre, which also integrates information from satellite sensors.

PSI-FEL

Proposal to develop a new concept approach for the generation of the compact electron bunches needed for Free Electron Lasers going to Hard X-rays. This approach, based on emission from a nanostructured surface, could strongly decrease the need of higher energy Linacs and therefore the cost of FELs up to the hard X rays.

Social Sciences and Humanities

CRFB - Corpus of Roman Findings in the European "Barbaricum"

Between the first and the fifth centuries AD the Roman frontier divided Europe in two parts. In order to give an overview of written sources and Roman findings outside the Empire that testify the contacts between Romans and "Barbarians" over whole Europe it is necessary to edit all the findings in a corpus. CRFB improves the scientific cooperation between research institutions, and makes the data accessible in a database. Main catalogues must be printed, as they will form the basic edition for generations (Humanities still use the excellent catalogues from the 19th century). A short version on the Internet is under preparation.

MEDLIB - Medieval European Libraries Network

It is a pan-European network of digitised catalogues and texts based on surviving collections of medieval monastic libraries. The goal is to establish a co-ordinated and centralised database of the contents of medieval monastic libraries throughout Europe. The project has three phases: 1) creation of a register of existing (printed and digitised) catalogues; 2) compilation of unpublished catalogues and the digitisation of these, 3) combination of the information gathered in Phases 1 and 2 and the creation of the centralised network.

The Hanseatic Historical Archives Network, in association with the Wittgenstein Archives (WAB) and MENOTA

It supports development of electronic archival tools and gives access to archival material. It will help historians and librarians and archivists digitise hanseatic archives within a maximum availability network. The technical concept is XML-based treatment of catalogue data and full textual data together with images. WAB is a humanities research infrastructure specialising on philosophy, Wittgenstein research, and editorial philology and text technology. Menota is a co-operative effort of the leading Nordic editorial institutions (archives, libraries and societies). It aims at implementing standards for the encoding and display of medieval primary sources, in the Nordic vernaculars as well as in Latin, and for building a pan-Nordic lexicographical database.

ARTeFACT - the European e-Reference Collection for Cultural Heritage

It is composed of two, equally vital components: a Knowledge Infrastructure that facilitates a Knowledge Community. The Knowledge Infrastructure consists of all technological and organisational instruments that allow the Knowledge Community to interact intensively. The main objective is to establish a reference collection of exemplar objects, enriched with interpretation and attached to it various kinds of background information. Researchers can refer to these special collections and use the "typical" names as a kind of shorthand to convey the existing knowledge on this kind of object and add new knowledge to the concept. During analysis, patterns of change are noted in the collection. These patterns of change can be interpreted to indicate changes in the multidimensional space of technology and of the socioeconomic and/or the cultural settings through time.

EURICA - European Research Infrastructure for Conservation and Analysis

Its tool will consist of the utilisation, adaptation and further expansion of state-of-the-art complementary analytical mobile techniques coordinated with synchrotrons, neutron sources, lasers, ion beams and analytical centres for objects analysis and conservation. It will aggregate both know-how about the analytical techniques and instrumentation and about objects and materials themselves. To facilitate interaction with the Cultural Heritage community, an "Interface Group", involving conservation scientists, archaeologists and art historians will be attached to the Physical Sciences infrastructures involved. EURICA will involve as partners selected museums or Cultural Heritage organisations active in conservation science, which will form a "Target Partners Group". The aim of this group will be to define conservation requirements and needs to be tackled by the physical sciences facilities involved, facilitate their solution and evaluate the outcome for the benefit of the Cultural Heritage community.

ISSP - The International Social Survey Programme

It is a continuing, annual programme of cross-national collaboration. It brings together pre-existing, social science projects and coordinates research goals, thereby adding a cross-national perspective to the individual, national studies. Established in 1984, ISSP has now grown to 39 nations. The programme has an important impact on the cross-national collaboration between social scientists in Europe, contributing to network building, improved science and important knowledge bases for European governments. The collaboration with 15 countries outside Europe brings additional perspectives to the ERA. ISSP is by far the most widely utilised international social research infrastructure with respect to scientific publications 200 new titles are registered every year). Each research organisation funds all of its own costs and secretarial costs are funded by the member organisation elected as secretariat. Funding for the merging of data has to be secured by these archives. Stable long-term funding is required to ensure further development of the programme's substantial and methodological work, and efficient dissemination of the data.

CSES - The Comparative Study of Electoral Systems

It is a collaborative programme of research among election study teams from around the world. Participating countries include a common module of survey questions in their post-election studies. The resulting data are deposited along with voting, demographic, district and macro variables. The studies are then merged into a single, free, public dataset for use in comparative study and cross-level analysis. An international committee of leading scholars of electoral politics and political science develops the research agenda, questionnaires, and study design. The design is implemented in each country by their foremost social scientists. CSES is an ongoing operation already. It has completed two waves (5-years windows). The Third Wave is to be conducted from 2006 through 2010.

GGP - Generations and Gender Programme

It is a system of national Generations and Gender Surveys (GGS) and contextual databases. The GGS is a panel survey of a nationally representative sample of 18-79 year-old resident populations in each participating country with at least three panel waves and an interval of three years between each wave. The contextual databases are designed to complement individual-level survey data in multi-level analyses. The programme aims at improving the knowledge base for policy-making in Europe and developed countries elsewhere. The GGP is a joint multi-country research effort that will better shed light on how each country's policies actually influence population and family changes. The GGP aims at a high level of comparability of data and method.

>Annexes

Methodology used for the elaboration of the roadmap

ESFRI, in its activity towards a European Roadmap has set-up specific Working Groups to analyse topical issues and to report to ESFRI. Three dedicated Roadmap Working Groups (more than 70 representatives from all EU countries) have advised ESFRI in the following areas:

- Physical Sciences and Engineering[1]: chair Carlo Rizzuto (IT)
- Biological and Medical Sciences: chair Ruth Barrington (IE)
- Social Sciences and Humanities: chair Bjorn Henrichsen (NO)

Within the remit of the Roadmap Working Groups, 15 Expert Groups were created during the summer of 2005 to cover specific areas. The membership of the panels totals more than 150 members, listed here after the glossary. These experts were selected on the basis of their scientific competence, ensuring the coverage of the various subfields and an overall geographical balance.

The evaluation of the proposals submitted to ESFRI by the different delegations started in the end of August 2005, after the setting up of the Expert Groups, and following agreed procedures[2]. A relatively small number of proposals came in spring 2006 from some European technology platforms (ETPs) and from international bodies as e-IRG, NUPECC, which have been evaluated by the corresponding RWGs. Space-based and particle physics Research Infrastructures are described in ESA and CERN respective roadmaps.

Expert Groups have given their scientific advice to the RWGs who forwarded to ESFRI those proposals that fitted a coherent and strategy-led approach to European policy making on new Research Infrastructures in specific fields of scientific research. The goal has been to identify new Research Infrastructures (RI) of pan-European interest (or major upgrades to existing ones) open to use by and corresponding to the needs of the European research communities, covering all scientific areas, regardless of possible location.

Each plan/proposal has been analysed in terms of the science case, and the concept case (including the technical case, cost analysis and the maturity of the project), and every proposal has been evaluated according to the two general criteria as they are presented in the procedural guidelines for the Expert Groups:

The Pan-European Scientific Case: The proposed new facility should correspond to well defined and cutting-edge future needs of the extended scientific communities in Europe, with strong potential impacts on scientific developments, support new ways of doing science in Europe and participate to the enhancement of the European Research Area. It should be supported by the appropriate scientific community at European level, should demonstrate its pan-European value, setting the scene for the infrastructure in a European and an international context, as well as its relevance and quality.

- The Concept/Business Maturity: The proposed new research infrastructure should be technologically and financially feasible as an open access facility. This requires a necessary degree of maturity which is defined as (a) the existence of a technical concept for the realisation of the project, and of feasibility studies, including identification of technical challenges and risks, (b) the existence of a reliable estimate about construction, operating and decommissioning costs, including a clear timetable.

In the above context the Expert Groups were asked to identify the proposals according to the following classification:

- Mature Projects
- Emerging Proposals

The Expert and Roadmap Working Groups focussed their discussions more on the mature projects, with the Emerging Proposals deserving attention for the future editions of the Roadmap.

Roadmap Working Groups created for this first edition of the roadmap

Social Sciences and Humanities

This working group set up in addition two expert groups:

- European Research Observatory for Humanities and Social Sciences;
- European Cultural Heritage.

Biological and Medical Sciences

This working group set up in addition three expert groups:

- Genomics, proteomics, bioinformatics and biology;
- Clinical and translational research, imaging and radiation; and
- Biodiversity and environment.

Physical Sciences and Engineering

This working group set up in addition 10 expert groups:

- Astronomy, Astrophysics and Astroparticles;
- Computer Data Treatment;
- Environmental Monitoring, Natural Hazards and Resources;
- Hard X-Rays Sources;
- High Power Lasers;
- Large Neutron Infrastructures;
- Material Testing;
- Nanosciences;
- Nuclear Physics and Particle Physics
- Soft X-ray Free Electron Lasers.

The Expert Group on Computer Data Treatment has been coordinated with the activities of the e-IRG[3] and that on Nuclear Physics with NuPPEC and the CERN Council, as well as the EG on Environmental Monitoring were linked with the relevant Expert Groups in Biology and Medical Sciences and Social Sciences and Humanities

1. A specific support has been given by the e-IRG to the PSE RWG in the field of e-infrastructures.
2. Procedures can be found at http://cordis.europa.eu/esfri
3. e-IRG: see www.e-irg.org

Experience Gained

There is no doubt that the creation of the roadmap has involved a considerable amount of dedicated effort by many people. Not only about 200 people were directly involved in the ESFRI screening process (ESFRI, Roadmap Working Groups, Expert Groups) but also it is estimated that about 800 scientists and managers were involved in the preparation of the 200+ original proposals. The mobilisation of these experts and their dedication testify the extremely high value of this exercise.

Creating roadmaps is not an easy task even at a national level and to achieve the present output in two years at a pan-European level has been a remarkable achievement. From a standing start, many of the working practices had to be developed during the exercise. Also, for both those involved and interested stakeholders some further modifications should be considered when the roadmap is revised in future. An evaluation was therefore performed by ESFRI. The recommendations are as follows :

Referring to the roadmap process itself...

a. The revision of the roadmap should be based on a *clear policy document*; this would avoid future misunderstandings and support the *consultation* with policy-makers;

b. *Cooperation* with intergovernmental organisations and other bodies, e.g. e-IRG, ESF, GSF, as well as with the different research communities should be continued;

c. *Concentrating the work on the RWGs* would improve overall efficiency;

d. The role of each *ESFRI delegate* should be clarified (see also point h.).

Referring to Roadmap Working Groups...

e. *Terms of Reference of the RWGs* should be revised and more clearly explained; a new RWG would be proposed, dealing specifically with *environment*;

f. *Identification of Members of RWGs* should be made more efficient and transparent; potential conflicts of interest require a rigorous approach and continued attention;

g. *Organisation of meetings* should be improved; two-days workshops, with a balance of thematic and synthesis sessions, would reinforce efficiency of the work.

NB: Referring to the Experts Groups, they would be suppressed, giving the opportunity to the RWGs to meet with experts whenever necessary;

Referring to preparation and evaluation of proposals...

h. The need to use an "*entry point*" for proposals to be considered by the RWGs (i.e. the ESFRI delegates) should be again clarified;

i. The "*evaluation template*" should be updated/refined and made available asap;

j. *Hearings* of potential projects should be continued.

Referring to Proposers...

k. A clearer *identification* of the costs and the maturity stages of projects would aid the experts in analysing their proposal;

l. In a number of cases the *structure and institutional capability* of the entities backing the proposals was not clear. Further clarification of legal and institutional issues and of who will ensure their life-long sustainability would alleviate this difficulty.

Referring to Communication issues...

m. A particular attention should be given to an improved *communication policy* and *website*; sufficient *resources* should be devoted to this task, at all levels;

n. *Further work* in cascading the roadmap to stakeholders is now needed to ensure that it is understood and used as a tool for decision makers and not as an imprimatur that such projects will be funded either by the EU or Member States.

Glossary

Antiproton is the antiparticle of the proton. Antiprotons are short-lived in nature, since any collision with a proton will cause both particles to be annihilated in a burst of energy. Their formation requires energy equivalent to a temperature of 10 million °C.

Atomic force microscope (AFM) is a very high-resolution type of scanning probe tunneling microscope. The Tunneling Microscope was invented by Binnig, Quate and Gerber in 1985, and is one of the most advanced tools for the manipulation of matter at nanoscale.

Biobank. A biobank is a repository for human cells, tissues, blood or DNA, which can be linked to data and information on the respective donors. The data could contain information on health and life style. Biobanks are thus key resources to be used for epidemiological studies e.g. trying to identify factors determining the development of multifactorial diseases.

Bioinformatics is a scientific discipline that comprises all aspects of the gathering, storing, handling, analysing, interpreting and spreading of biological information. It involves computers and the development of innovative programmes which handle vast amounts of coding information on genes and proteins from genomics programmes.

Chemical biology is a discipline that studies effects of small molecules on biological processes. Small molecules with specific biological properties may be designed or may be discovered by screening. The approach is highly interdisciplinary and can involve the interaction of, for example, synthetic chemists with protein engineers.

Clinical research is the research based on humans for answering questions about health and disease. This includes the study of individual patients and populations as well as of biological samples and personal data from these patients. It also includes research related to a disease on healthy individuals.

Clinical trials are studies to evaluate the effectiveness and safety of medications or medical devices by monitoring their effects on large groups of people.

Data curation corresponds to all the actions needed to maintain digital research data and other digital materials over their entire life-cycle and over time for current and future generations of users. This covers the processes of digital archiving and preservation but it also all the processes needed for good data creation and management, and the capacity to add value to data to generate new sources of information and knowledge.

DNA (DeoxyriboNucleic Acid) is the molecule that carries the genetic information specifying the biological development of all cellular forms of life (and many viruses).

Electron microscope is a microscope using electrons as probes, that can magnify very small details with high resolving power due to the very small size of electrons. Its magnifying levels reach the atomic definition (the nanometer).

ERA – The European Research Area is a vision for pan-European organisation and co-ordination of scientific research allowing the EU to compete effectively in the global knowledge economy.

FEL a free electron **laser**, generates tunable, coherent, high power collimated light, currently ranging in wavelength from millimeters to the ultraviolet. While a FEL laser beam shares the same optical properties as conventional lasers such as coherent radiation, the operation of a FEL is quite different. Unlike gas or diode lasers which rely on bound atomic or molecular states, FELs use a relativistic electron beam as the lasing medium, hence the term free-electron. Free electron lasers can be used to generate terahertz radiation.

Functional genomics is the knowledge that converts the molecular information represented by DNA into an understanding of gene functions and effects.

Galileo is a proposed satellite navigation system, to be built by the European Union (EU). The system should be operational by 2010.

Gene. A gene is a sequence of DNA (see above) that represents a fundamental unit of heredity.

Genomics, or genomic research, is the study of the complete genetic information (DNA and genes, see above) in a living organism (humans, animals, plants…).

Global Science Forum is a specific body of OECD, gathering 30 member countries, with active relationships to 70 more, sharing a commitment to democratic government and the market economy. Best known for its publications and its statistics, OECD's work covers economic and social issues from macroeconomics, to trade, education, development and science and innovation.

Genotyping is the process of analysing an individual **genotype**, i.e. the particular genetic variations (polymorphisms) existing in an individual DNA sample.

GMES Global Monitoring for Environment and Security is a joint initiative of European Commission and European Space Agency.

High security laboratories are laboratories with the highest level of bio-safety (level 4), for research on pathogens that pose a high risk of aerosol-transmitted infections and life-threatening disease, such as the viruses responsible for the Ebola and Marburg hemorrhagic fevers. These laboratories have special engineering and design features to protect personel and to prevent microorganisms from being disseminated into the environment.

Ion is an atom, group of atoms, or subatomic particle with a net electric charge. The simplest ions are the electron (single negative charge, e^-), proton (a hydrogen ion, H^+, positive charge), and alpha particle (helium ion, He^{2+}, consisting of two protons and two neutrons).

ITER is an international tokamak experiment designed to show the scientific and technological feasibility of a full-scale fusion power reactor. It builds upon research conducted on devices such as TFTR or JET. The programme is anticipated to last for 30 years - 10 years for construction, and 20 years of operation. ITER will be built in Cadarache, France.

Laser (Light Amplification by Stimulated Emission of Radiation) is an optical source that emits photons in a coherent beam. Laser light is typically near-monochromatic, i.e. consisting of a single wavelength or hue, and emitted in a narrow beam. This is in contrast to common light sources, such as the incandescent light bulb, which emit incoherent photons in almost all directions, usually over a wide spectrum of wavelengths.

Laser Fusion is a potential future and alternative mechanism for producing energy by nuclear fusion. The process is based on the heating of a small pellet of fusion fuel (deuterium and tritium) by powerful laser beams to induce thermonuclear ignition and generating energy from the fusion products.

Linac – Linear accelerator. A technology that accelerates charged particles to very high speeds, energies, in a straight line using radio waves.

Moderator. A body of material that surrounds the source of neutrons, spallation or fission. Containing light atoms, for example heavy water or methane, the moderator slows neutrons by repeated collisions to deliver the required energy distribution for neutron scattering experimentation.

Muon (from Greek letter mu (μ)) is a semi-stable fundamental particle with negative electric charge and a spin of 1/2. Together with the electron, the tau lepton and the neutrinos, it is classified as part of the lepton family of fermions. Like all fundamental particles, the muon has an antimatter partner of opposite charge but equal mass and spin: the **antimuon**.

Neutrinos are exotic particles generated in extremely large numbers, for example by the sun, that interact very weakly with matter. Interest in neutrino science stems from the belief that they may answer fundamental questions about the origin and mass of the universe, the "dark" matter. One route to generating an intense neutrino beam, as a basis for neutrino investigation, is through proton collision with a target.

Neutron. In physics, the neutron is a subatomic particle with no net electric charge and a mass of 1.6749×10^{-27} kg, slightly more than a proton. Its spin is ½. Its antiparticle is called the *antineutron*. The neutron and proton are instances of a nucleon. The nucleus of most atoms (all except the most common isotope of hydrogen, protium, which consists of a single proton only) consists of protons and neutrons.

Non-invasive imaging refers to the methods used for obtaining pictures or more complicated spatial representations, such as animations or 3-D computer graphics models, from living systems ranging from single cells to model animals cells and internal human body structures. These methods can in particular be based on X-rays, magnetic resonance, ultrasound waves or fluorescence.

Nuclear Magnetic Resonance (NMR) is a physical phenomenon based upon the magnetic property of an atom's nucleus. All nuclei that contain odd numbers of nucleons and some that contain even numbers of nucleons have an intrinsic magnetic moment. The most often-used nucleons are hydrogen-1 and carbon-13. NMR studies a magnetic nucleus, like that of a hydrogen atom, protium being the most receptive isotope at natural abundance, by aligning it with a very powerful external magnetic field and perturbing this alignment using an electromagnetic field. The response to the field by perturbing is what is exploited in nuclear magnetic resonance spectroscopy and magnetic resonance imaging.

Nuclear waste transmutation is a process by which the radioactive components of waste arising from, e.g. a nuclear reactor, is changed to non radioactive material by neutron capture or fission.

Phenotyping is the process of analysing an individual *phenotype*, i.e. the particular observable characteristics that result from the interaction of an individual genotype with the environment.

Photochemistry, a sub-discipline of chemistry, is the study of the interactions between atoms, small molecules, and light (or electromagnetic radiation).

Photolithography or **optical lithography** is a process used in semiconductor device fabrication to transfer a pattern from a photomask to the surface of a substrate. Often crystalline silicon in the form of a wafer is used as a choice of substrate, although there are several other options including, but not limited to, glass, sapphire, and metal. Photolithography (also referred to as "micro-" or "nanolithography") bears a similarity to the conventional lithography used in printing and shares some of the fundamental principles of photographic processes.

Plasma, in physics and chemistry, is typically an ionised gas, and is usually considered to be a distinct phase of matter in contrast to solids, liquids and gases. "Ionized" means that at least one electron has been dissociated from a proportion of the atoms or molecules. The free electric charges make the plasma electrically conductive so that it responds strongly to electromagnetic fields.

Polarization is a property of waves, important as a specific property of light and other electromagnetic radiation. Unlike more familiar wave phenomena such as water or sound waves, electromagnetic waves are three-dimensional, and it is their vector nature that gives rise to the phenomenon of polarisation.

Positron is the antiparticle or the antimatter counterpart of the electron. The positron has an electric charge of +1, a spin of 1/2, and the same mass as an electron. When a low-energy positron annihilates with an electron, their mass is converted into the kinetic energy of two gamma ray photons.

Proteomics is the study of the structure and function of proteins, including the way they work and interact with each other within the cell and organism.

Scanning Tunneling Microscope (STM) is a non-optical microscope that scans an electrical probe over a surface to detect a weak electric current flowing between the tip and the surface. The SPM can obtain images of conductive surfaces at an atomic scale 2×10^{-10} m or 0.2 nanometre, and also can be used to manipulate individual atoms, trigger chemical reactions, or reversibly produce ions by removing or adding individual electrons from atoms or molecules.

Social Survey to monitor long term changes in social values throughout Europe and produce data relevant to academic debate, policy analysis and better governance.

Spallation is a process in which fragments of material are ejected from a body due to impact or stress. In nuclear physics, it is the process in which a heavy nucleus emits a large number of nucleons as a result of being hit by a high-energy proton, thus greatly reducing its atomic weight.

Structural biology is a branch of biology dedicated to the study of the three-dimensional structures of proteins and other molecules to help understand the function of these molecules in the cell and organism.

Synchrotron. A cyclic accelerator of large radius that can accelerate charged particles, electrons and protons, to very high energy. *Synchrotron radiation* is the highly focussed and intense beams of X-ray, infrared and ultra-violet light employed to probe the basic structure of materials generated in a synchrotron.

Synthetic biology is the engineering of biology: the synthesis of complex, biologically based (or inspired) systems which display functions that do not exist in nature, applicable at all levels from individual molecules to whole organisms.

Systems biology is a new field that seeks to bring together information on genes, proteins, interactions and metabolic pathways, to help understand the function of complex cellular systems and of the whole organism. To accomplish this goal, these efforts must also incorporate not only what we know about biology needs to be incorporated with expertise in physics, chemistry, mathematics, and the computer sciences.

Translational research is the process of bidirectional transfer of knowledge between basic work (in the laboratory and elsewhere) with that in the whole patient. Translational research ranges from exploring fundamental scientific questions and applying the resulting knowledge to the patient, to bringing insights from studies in the patient back to the laboratory in model systems for further exploration.

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History of ESFRI towards a coherent approach to policy-making on Research Infrastructures

The idea to develop a more coordinated approach for policy-making in the field of Research Infrastructures (RIs) in Europe emerged from the Strasbourg Conference on Research Infrastructures, jointly organised by the European Commission, the French Presidency and the European Science Foundation (ESF) from 18 – 20 September 2000. In June 2001, the Research Council invited "the Commission, in close collaboration with the Member States, to explore the establishment of new arrangements to support policies related to RIs".

In February 2002, a high level Expert Group with representatives from all Member States issued a report recommending the creation of a "*European Strategy Forum on Research Infrastructures, ESFRI*". Following this recommendation, Commissioner Busquin wrote a letter to the Research Ministers of the 15 Member States, asking them to nominate representatives to the Forum and to offer operational support from the Commission. The first meeting of ESFRI took place in Brussels on 25 April 2002.

In November 2003 ESFRI was extended to the ten new EU Member States. Seven Associated Countries (associated with the European Community Research Framework Programme) joined at the end of 2004.

The Forum consists today of delegations of one or two senior science policy officials representing the Minister(s) and a senior science policy official representing the European Commission. The members of each delegation are nominated by their Minister(s) for two years and may be reconfirmed whenever appropriate.

Scope of ESFRI

The main scope of ESFRI is to support a coherent and strategy-led approach to policy-making on RIs in Europe and to facilitate multilateral initiatives leading to the better use and development of RIs. The Forum acts as an informal body on issues raised by one or more country delegations. ESFRI gives national authorities the opportunity to be informed of and to explore initiatives concerning the building or upgrading of RIs of European significance. ESFRI acts therefore as an incubator for pan-European RIs.

The Forum develops joint reflection work applicable to the development of strategic policies on RIs. It also helps to identify gaps in research capacity associated with RIs on pan-European level and of related strategic needs.

ESFRI also intends to give periodic recommendations on the management of RIs and related human resources. As policy makers, the ESFRI members have finally to communicate the significance and importance of RIs to a wider public.

Towards a more coherent approach to policy-making

During the NL presidency of the European Union, in the second semester of 2004, ESFRI was asked to prepare a roadmap for new large-scale RIs needed by the EU scientific community.

The ESFRI roadmap on RIs will be the first of this kind in Europe. As the creation of new RIs with several partners from different countries requires long and complex negotiations the stakeholder and decision makers have to measure advantages and disadvantages and analyse the added value of capacity building and the socio-economic returns of RIs. In this context, ESFRI hopes that that its roadmap will be a very useful tool.

ESFRI

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