EIROforum

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EIROforum Position Paper on Scientific Instrumentation for the EU Framework Programme (Horizon 2020)

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Europe's Intergovernmental Research Organisations

CERN | EFDA | EMBL | ESA | ESO | ESRF | XFEL | ILL

Executive summary

Research infrastructures drive scientific excellence. They provide and enable world-leading research in the European Research Area (ERA). In order to serve Europe's aspiration to improve its competitive position in the world with regard to scientific achievements and economic performance, it is essential that research infrastructures are constantly developed, improved, and upgraded.

Whilst many technological advances, essential to the achievement of these goals, are initiated and progressed at research infrastructures (RIs), cooperation with European SMEs and large industries unlocks the potential of these advances. It nurtures innovation and enables cross-sectoral knowledge exchange. The delivery of cutting-edge scientific instrumentation is ensured; whilst in parallel opportunity for other applications in other domains is opened up.

The global market for scientific instrumentation is large and rapidly expanding. The market in Europe for 'big science' RIs is estimated to be worth upwards of €10 billion per annum, alone. There is further potential to expand into much larger world markets for consumer/ technology products and to create new jobs.

The eight European intergovernmental research organisations (EIROs) that constitute EIROforum are constantly developing and maintaining scientific excellence and world leadership in their core scientific activities, serving a large and broad scientific user community with the strong support of their member states. Development and operation of state-of-the-art scientific instrumentation is one of the key pre-requisites of this leadership and needs substantial investment by the EIROs, as with all large research infrastructures, national or international. The associated financial and human investment covers not only the implementation of new scientific instruments but also the development of the necessary enabling technologies.

From an industrial point of view, these high-tech programmes often target niche markets and involve high initial costs and long developmental timelines. From the perspective of RIs, the industrialisation processes can drain resources from their core activities and prime objectives. To fully exploit their innovation potential, it is essential to bridge the gap that exists between RIs and industry in the field of R&D for scientific instrumentation, to reduce risk (both perceived and real), and to create a win-win situation. Practical solutions with incentives must be implemented. This paper provides specific recommendations to address this issue.

All of the EIROs are currently launching new instrumentation programmes or instrumentation upgrades, which will be completed over the next 5 to 10 years and which will critically rely on innovative approaches and new technologies. They are all committed to the formulation and implementation of advanced research programmes and are ideally situated to make propositions for strategic developments in the field of scientific instrumentation. However, these efforts are largely uncoordinated, often leading to parallel or even competing programmes. In order to improve coherence and develop a vision shared across RIs, that brings together individual strengths and resources, EIROforum recommends supporting the development of enabling technologies by the creation of specific calls and programmes in the following critical areas:

- Engagement with European Industry: The European Commission is invited to consider mechanisms that will provide financial and structural incentives for the establishment of closer relations among the R&D programmes of research infrastructures and industry through dedicated actions in the field of scientific instrumentation.

- Enabling Technologies: EIROforum recommends supporting the development of enabling technologies through the creation of specific calls and programmes in the following critical areas: Detector Systems and Sensors; Optics – over the entire electromagnetic spectrum, from far-infra-red to X-rays and including electron optics; Cooling Technologies; Adaptive Systems; and New Engineering Materials.

- Training: Inspired by the Marie Curie Actions, which are at present too limited in FTE for large scale instrumentation projects, the European Commission is invited to consider targeted funding for specific educational, training and networking programmes, fully dedicated to instrumentation activities with the goal of improving the technical and managerial expertise of future researchers and engineers in these domains.

Introduction

Instrumentation is integral to cutting-edge science, playing a key role by enabling increasingly sophisticated development, design and implementation. Novel scientific applications not only rely on the most advanced technologies but also require a long term strategy in terms of procurement and future evolution. As acknowledged by the ESFRI framework, a strong instrumentation programme is a pre-requisite for the competitiveness of European RIs.

In general terms, world-leading instrumentation requires a substantial level of investment, which is often far beyond the capacities of SMEs. Therefore, the most innovative developments rely primarily on the investment made in and by RIs themselves, including the development of new enabling technologies. However, these technologies may offer much wider usage and in order to fully exploit their innovation potential, all the links in the innovation chain in the field of R&D for scientific instrumentation must be strong. Several parallel initiatives have been launched to address the need for this critical interaction between European industries and RIs.

In the context of Horizon 2020, all of these initiatives aim to develop recommendations for the European Commission in order to maximise the benefit to, and encourage synergies between, European industries and RIs when they collaborate to develop instrumentation.

The aim of the present paper is to elaborate specific recommendations from a highly focused perspective regarding the needs of RIs based in Europe, and of their respective scientific user communities, for scientific instrumentation over the next 5 to 10 years.

EIROforum instrumentation landscape

The European Intergovernmental Research Organisations (EIROs) that form EIROforum[1] are world-leading large-scale infrastructures with core activities in basic research and applied science. Together, the EIROforum partners directly serve a scientific community of at least 40,000 researchers, with far greater numbers benefiting in various ways from their scientific and technical output. In addition, the scientific databases of these organisations are used by hundreds of thousands of scientists and engineers in research institutes, universities and commercial companies every month. Together they represent a unique capital of knowledge and expertise in the development of scientific instrumentation and will, in the future, continue to offer a unique opportunity for the successful development and deployment of new cutting-edge instrumentation programmes.

Beyond the promotion of new Research & Development programmes by RIs, increased targeted public funding may be expected to stimulate industrial ventures, with considerable potential for high return beyond their own objectives. These new programmes should include the development of underlying technologies which, with the involvement of industry, can reach out to and benefit broader communities, thus creating new markets.

All EIROs are currently launching new instrumentation programmes or instrumentation upgrades which will be developed over the next 5 to 10 years and which will critically rely on innovative instrumentation programmes. To put the following recommendations into context, a short description of future challenges that each individual EIRO is facing is given in the Annex to this paper.

1 Enhancing EIROforum's engagement with European industry

Technological development at Europe's RIs sparks off the creative energy and expertise of teams of scientists and engineers dedicated to developing world-leading instruments and infrastructure for specific scientific and technical aims. The EIROs also engage with industry at various levels to take ideas or prototypes through to products. However, such engagement is not systematic, and generally happens, if it happens at all, some time after the initial idea has been conceived and refined. This represents a tremendous wasted opportunity both for Europe's researchers and European industry.

It would be far better to bring industry and RIs together right from the start. Industry would gain access to new concepts, processes and motivation for new technologies, while offering a broader vision of how such technologies might be exploited, and the capability to do so. The 'big science' RIs alone present a large and rapidly expanding global market (estimated to be worth upwards of €10 billion per annum just in Europe[2]), and there is the further potential to expand into a much larger world market for consumer/technology products and create new jobs. (There are good historical precedents here, from X-ray detectors developments that have fed into medical scanners to adaptive technologies applied today in auto-focus cameras.) Close partnership at the conceptual stage will

1. See Annex and http://www.eiroforum.org
2. The total annual budgets for all European Research Infrastructures is in the range of €7.9bn - €9.7bn: ERID Watch, Brussels June 2009

bring not only good practice and industrial insight to research infrastructure technology projects, but will also lead to the inclusion of industrial standards right from inception, enabling commercialisation more easily at a later stage. The RIs gain too through better instrumentation, produced more cost-effectively with better safeguards against longer-term obsolescence of components.

What could be done to encourage closer partnership between RIs and industry - all the way through the creative and development process - to bring about a win-win situation both for European science and for the European economy? A key challenge at present in setting up such partnerships is the real, and perceived, risk(s) to be undertaken by industry when involved in such projects. This is particularly the case for expensive prototyping carried out by the micro-companies and SMEs that are often at the heart of supplying very high-level technologies. Moreover, the additional work for RIs in commercialising technology and managing partnerships with industry often competes for resources with the core academic missions of the research infrastructures. This results either in a lower priority for this type of action, or, in the dilution of the core activity that underpins their reputation for excellence.

Recommendation:
The European Commission is invited to provide an instrument which would facilitate collaboration with industry in the field of scientific instrumentation. Specifically to provide resources that would enable the early engagement of RIs with potential industry partners. This would give both sectors the incentive to develop and improve channels of commercialisation.

2 Enabling technologies for RIs: a constant effort and a need for improved coordination

A second challenge in exploiting the full potential of RIs to develop cutting-edge instrumentation and associated enabling technologies is a lack of coordination and longer-term vision shared across the RIs. There are several key areas, detailed below, in which the development of enabling technologies proceeds with little or no co-operation between RIs. To fix this fragmentation of effort requires a European-level strategy to drive the development of enabling technologies of relevance for the scientific programmes of the future. With such a strategy in place, investment would be rationalised by preventing parallel, redundant or, at times, competing programmes… Additionally, certain developments could benefit from the broad spectrum of expertise and capacities already integrated in major research infrastructures. Such a strategy should also incorporate the issue of closer partnership with industry, outlined above. It is expected that Horizon 2020 will aim to address some of these problems by promoting closer collaboration between RIs and with industry.

The following sections provide examples of key areas, which would benefit from a synergetic and coordinated approach. These are domains in which the EIROforum members could together play a strategic role, offering a unique and solid foundation for future coordination in these areas, which would be to the benefit of the scientific communities that rely on these infrastructures for their research.

It should also be noted that the focus here is on instrumentation, while there is also an urgent need to enhance IT infrastructure, for example the GRID and cloud storage.

1. Detectors

Today the development of detection systems and the development of European expertise and associated capacities is a strategic issue that goes far beyond science. All EIROs are involved in detector R&D programmes for which a substantial level of human and financial investment is needed. Most of them critically depend on partnerships with industry which vary in nature according to specific requirements and which may range from the procurement of simple components to the realisation of complete systems. The development of advanced sensor technologies with unparalleled performance must be anticipated and the key areas to be considered are: Radiation Hardness, Power Consumption, High Level Integration with 3D technology, Readout, ASICs (Application Specific Integrated Circuits), Acquisition Speed, Quantum Efficiency, Ultra-low Noise, and Large Format Detectors. Some critical examples are given below:

- Optical sensors (infrared and visible light) development relies upon SMEs and is in general underdeveloped in Europe. Most cutting edge applications use industrial products from the US and Japan, the development of which are often driven by military needs. A dedicated call will provide a significant incentive for collaborations between industry and RIs to produce novel sensors the most sophisticated versions of which will be integrated into new scientific instrumentation. Cost effective variants will obviously find applications beyond their original purpose, such as in laboratory analytical equipment (microscopes), inspection for the food industry, security, etc., and secure an independent European capability in critical high-tech areas.

- Radiation detectors in the UV, X-Ray and Gamma Ray regimes require similar attention with particular reference to radiation hardness, but also high-density integration technologies and high spatial resolution. If properly funded and synchronised with industrial activity, these developments can be expected to have significant impact, for example, in the field of medical applications.

- Particle detectors are of crucial importance for high energy, neutron and fusion scientific experiments and will require highly innovative research programmes. For example, the shortage of Helium 3 is already generating problems with large area neutron detectors and the situation will only become more critical in the future. Today the need for the Helium 3 required for both scientific applications and security is already three times higher than the global production capacity. Its price has increased by a factor of 20 over the past 3 years (the price today is 1,500 Euro per litre.bar). Whilst this problem has already been addressed by the US Congress, there remains a need for dedicated action to develop alternative technologies (scintillators, BF3, B10 convertors), which will benefit both neutron science and other industrial applications such as detectors for security.

2. Optics

Optics embraces a wide range of disciplines. Undoubtedly, the foreseen performance of new optical instruments will rely on the unprecedented quality of their optical components. New manufacturing techniques as well as new metrology and quality control strategies will be needed. A critical requirement for future scientific applications will be state-of-the-art optics; not only for visible light applications, but also for infra-red and X-ray wavelengths. As a specific issue, in the field of X-ray optics, key for many research infrastructures, there has been a notable decline in activity of European industry. For example, the commercial manufacture of high quality X-ray focusing optics remains ill-developed and relies mostly on academic structures. One of the key factors will be the synergic development of advanced metrology tools and methods together with appropriate manufacturing processes. In certain sectors, competition led to declining investments in R&D programmes to preserve margins. (For instance, the German company ZEISS was the world leader in manufacturing X-ray gratings for many. A few years ago they stopped this activity to the profit of a Japanese supplier, with a residual part of the market covered by small European structures.) This particular domain would greatly benefit from support provided through a dedicated programme. Finally, a constant effort is necessary in electron microscopy and new R&D programmes related to electron optics must be envisaged.

3. Cooling technologies

Cooling technologies underpin a large number of applications and functions in all aspects of day-to-day life and are crucial for a majority of scientific instruments such as cooling magnets, optics, detectors, computers etc. Nowadays, the three coolants most frequently used are Helium, Neon and Fluorine. All of these have serious limitations in terms of cooling efficiency, safety hazards, cost and environmental impact. Future scientific applications are expected to be even more demanding on cooling resources and technologies such as ultra-low temperatures, vibration free systems, cooling efficiency, etc. In order to meet these future demands, new solutions must be found to achieve the necessary step-change in technical, economical and environmental performance values.

4. Adaptive Systems

Adaptive systems have been boosted by astronomers aiming at building bigger telescopes. This adaptive technology has already found applications in vision science (ophthalmology), digital cameras, large deformable mirrors etc. The next generation of adaptive systems will require new advanced solutions, based on real time computing, automation and sophisticated signal acquisition chains. All users of RIs will benefit from a state-of-the-art development of adaptive systems for all kinds of applications, in particular the compensation of environmental, mechanical and thermal drifts. A collaborative effort involving industrial partners will not only ensure the appropriateness of the programme but also guarantee successful technology transfer for new areas of applications.

5. New engineering materials

New engineering materials will be increasingly needed to provide the most appropriate solutions to the unprecedented performance requirements of scientific instruments of the future. Performance stability, weight, dimensional precision, etc. will call for the development of materials with tailored thermal, electrical and mechanical properties. Diamond-based technology, as a specific example, is expected to play a major role in optics and detector development; it should be targeted as a strategic programme for development.

Recommendation:
The European Commission is invited to create specific calls and programmes to support the development of enabling technologies in the above field: detectors, optics, cooling technologies, adaptive systems, new engineering materials. All these areas of enabling technologies are identified as critical for the future development of scientific instrumentation, and could also lead to significant developments for the wider domestic or technical marketplace. A majority of these developments are currently led by Japan and the U.S. This could lead to exclusion of Europe from access to, influence over or control of crucial technologies of the future as well as exclude them from the setting of international standards. Successful developments, coordinated with industry, of these technologies would contribute to economic growth in Europe.

3 Education and training

A decisive element for the successful development of innovative instrumentation is the future availability of talented scientists and engineers, ideally with backgrounds in both science and technology. Moreover, the realisation of state-of-the-art scientific equipment with the level of complexity of modern instrumentation requires a high degree of integration. To reach this optimum integration, a deep understanding of all facets is mandatory; from concept and design to manufacture and control.

Europe is proficient in technical and scientific education and training. However, there is a significant lack of synchronisation between undergraduate academic programmes and post-graduate professional training. Most academic programmes target expertise in engineering and science but do not necessarily provide an educational base for a career as an instrumentation project manager. For instance, scientific, technical and business related disciplines are very often decoupled and younger researchers lack a global perspective.

Recommendation:

The European Commission's proposal to extend the Marie Skłodowska-Curie Actions under Horizon 2020 is welcomed. Under this extension the European Commission is invited in particular to provide for specialised training and networking programmes to improve the level of expertise across the domains of research and engineering thereby to develop the skills of personnel working in the field of innovative instrumentation necessary to meet current and future challenges. Their participation in MSCAs would enable the acquisition of the skill profile essential to meet the needs of RIs and industry working together in the field of scientific instrumentation.

Annex

This annex provides a short overview of the challenges each of the individual EIROs is facing in terms of scientific instrumentation in the near to medium future. Many of these challenges are also of relevance to national research infrastructures and their respective user communities. Strong coordination and support for the R&D programmes of all research infrastructures in the field of scientific instrumentation, in partnership with industry when and where possible, are key to the success of these programmes, contributing to the excellence of the science performed in Europe and promoting technology transfer to European industry, thus strengthening Europe's innovation potential.

CERN

The next generation of particle physics experiments will face major challenges in several domains: for hadron collider experiments at the upgraded LHC producing an unprecedented luminosity, the significantly increased event rates, channel occupancies and radiation levels will require new strategies, technologies and integration concepts, in particular for the innermost detector layers. On the other hand, high precision measurements at a future lepton collider (like CLIC) call for detectors with unprecedentedly low mass, finest granularity and extreme resolution. To minimise the detectors' consumption of power, which unavoidably ends up as thermal load concentrated in the centre of the detector, new concepts like power pulsing will need to be conceived and brought to full maturity. This needs to be complemented by innovative and environment friendly cooling technologies with the lowest possible mass budget. The development of even radiation harder and fault tolerant technologies for Integrated Circuits, both digital and analogue, is crucial for measuring and extracting the signals from all these detectors. Finally, the immense quantity of data, measured in multi-petabytes and to be shared with a worldwide community, demands the employment and adaption of the most efficient and cost effective ways for storage, distribution and processing.

EFDA-JET

In the coming years, the experiments conducted by the European Fusion Development Agreement: Joint European Torus in the magnetic confinement fusion community are expected to move in the direction of higher currents, higher stored energy and, in general, to push performance in terms of plasma confinement and neutron yield. The use of tritium as fuel should also be more frequent and become routine in ITER. More devices will have a metallic, more delicate first wall which is expected to pose more significant machine protection issues. Important prerequisites for the success of such experiments are various advances in the measurements and data analysis capability. One very important trend is certainly the increased reliance on imaging, which will have to be extended, in terms of wavelengths, in the direction of both microwaves and soft X-rays. The diagnostics will not only have to deliver more accurate measurements of more parameters also to guarantee higher reliability and resilience to the hostile environment. Better integration of many measurements will be essential for both real time control of the experiments and the interpretation of the results. The increasing quantities of data acquired per discharge will need also new solutions in the fields of data analysis, data mining and high level interpretation.

EMBL

The European Molecular Biology Laboratory is running facilities for X-ray based structural biology at ESRF (Grenoble, France) and PETRA III (Hamburg, Germany), two world-leading synchrotron radiation sources. In addition, EMBL headquarters (Heidelberg, Germany) provide advanced and high throughput light and electron microscopy services, via open core facilities. These facilities serve a large user community of biologists interested in understanding the basic processes of life and disease at the level of individual molecules and the interactions between them. To render more of the important biological systems amenable to structural and functional biology methods, substantial progress in technology development is essential. These are, in particular: X-ray data collection and analysis technologies, needed for the exploitation of ever smaller samples in high-throughput regimes; very stable and intense X-ray sources; and almost perfect X-ray optics to deliver small, well collimated, stable and intense beams to samples of nanolitre volumes and/or micrometre dimensions. For advanced light and electron microscopy, advances in detectors are similarly vital to push sensitivity to the single molecule level and resolution to the molecular dimension. At the same time automation and higher throughput are needed to address biological systems of many components comprehensively. For both structural and functional biology, the handling and imaging of a massively increasing number of samples requires high precision mechanics and liquid handling technologies. Evaluation of growing numbers of samples necessitates more efficient automation and robotics and intelligent image driven computer control systems. The systematic collection, processing, mining and long-term storage of the enormous amounts of data acquired will only be possible with innovative and scalable IT solutions. Sustainable means of providing frequent access – be it direct or remote – will need to be implemented to allow the entire European user community to make the best use of centralized cutting-edge facilities.

ESA

One of the driving factors for space missions is the radiation environment, to which all hardware elements are exposed. The requirements for single event and total dose tolerance of electronic parts often prevent the application of most advanced technologies. With the fast turnaround of component development, the necessary time for qualifications is lagging behind, and therefore is increasing the risk of lots of components not being available at time of need. Furthermore, the market share of radiation tolerant parts is decreasing making it for suppliers less attractive. The European Space Agency is developing together with European industry various highly integrated technologies based on ASIC and FPGA architecture with particular emphasis on radiation tolerant elements. Instrumentation for Astronomy will be required for the entire wavelength spectrum ranging from thermal infrared to Gamma rays. Applications are and will be requiring larger collecting area, higher stability and longer focal lengths, while respecting the basic environmental challenges, including radiation, vacuum and thermal excursions. The focal plane detectors will need to provide high uniformity and high calibration stability, while being able to withstand particle radiation. Instrumentation for planetary exploration and Earth observation will require clever data reduction tools, possibly including novel data selection techniques and transmission/compression techniques. For surface operations sampling mechanisms need to be developed together with versatile instrument suites. Mobile platforms are in need of (semi-)autonomous guidance techniques. Instrumentation for fundamental physics requires various specific payload technologies related to the need for high precision control of the instrument assembly in remote operations following mechanical stress, e.g. due to launch.

ESO

The development of the next generation of instrumentation at the European Southern Observatory for large ground-based telescopes such as for the proposed European Extremely Large Telescope is a major endeavour in science, technology and engineering. Astronomical instrumentation will require advances in a number of areas to meet the scientific challenges in the coming years. Advances in optical and infrared sensors like L3-CCDs, CMOS high speed wavefront sensors, IR avalanche photo diode arrays and large format detector will be required to deliver detectors for Adaptive Optics techniques and to equip very large focal planes. Advances in integrated optics will push interferometry to high sensitivity as well as better angular resolution. Due to the increased size of the telescope extreme adaptive optics is required to compensate for atmospheric turbulence. This technique will require the development of next generation wavefront control computing platforms, wavefront control algorithms and the extension of AO simulation platforms. Large deformable mirrors for extreme AO for ELTs will need to be developed. Advanced instruments like large spectrographs will aim to measure directly the expansion of the universe. To achieve this, those instruments must be able to measure radial velocities with a precision several orders of magnitude greater in precision than is currently possible. This, amongst other challenges, will require low-vibration cryogenics, advanced metrology systems for instrument alignment and precision and the development of new calibration systems like Laser Frequency Combs.

ESRF

The European Synchrotron Radiation Facility is built around one of the world's most powerful X-ray sources, along with 42 various scientific instruments. In 2009, ESRF embarked on a 10-year upgrade programme to preserve its lead and competitiveness in photon science. Driven by new scientific cases in various areas of research such as nanoscience, environment, energy, transport, material engineering and human health, Phase 1 of this programme addresses several instrumentation challenges. Of particular importance will be the routine use of sub-100 nanometre X-ray probes, capable of probing a wide range of materials under real conditions and often in real time. To meet these scientific objectives, completely new X-ray instrumentation must be developed in all relevant engineering areas. Of particular importance is the development of almost perfect X-ray optics, the management of heat-load and associated cooling strategies, as well as the management of mechanical stability of these instruments. An increased level of automation of the instruments is expected to impact their scientific production. Another strategic area is the development of new X-ray detectors and associated electronics, in particular 2-D detectors with unprecedented spatial and temporal resolutions. Finally, aggressive development in the area of software, ranging from instrument control to data acquisition and processing, will be critical to the optimum use of these instruments and related cutting edge scientific production. It must be also stressed that the upgrade programme will rely on a long standing partnership with industry to secure the procurement of the most critical components and to set standards which can be adopted by other synchrotron facilities.

ILL

The Institute Laue-Langevin has been at the forefront of neutron science and techniques for almost 40 years. It operates the most intense slow neutron source in the world, feeding intense beams of neutrons to a suite of 40 high-performance instruments that are constantly upgraded. 700 experiments are performed every year in fields as diverse as solid-state physics, condensed matter physics, material science, chemistry, biology, nuclear physics and engineering. A key factor in this success has been successive campaigns to ensure its instruments enable the community to perform the best possible science. The renewal project – the Millennium Programme – has already delivered 18 new or radically upgraded instruments, and it will deliver 3 more new or upgraded instruments. It includes a strong development of new techniques to increase the efficiency of the instruments, in particular by enhancing the neutron source brightness with directional neutron moderators, optimising ultra cold neutron (UCN) sources, and developing more efficient neutron supermirrors with reduced X–ray emission and long lifetime. Another important challenge is to develop large area 2D neutron detectors based on 3He alternatives: all neutron facilities worldwide are impacted by the 3He shortage; ILL has established a collaborative plan for the design and feasibility studies of a neutron detector based on solid 10B films technology as a substitute to 3He gas.

European XFEL

One of the major challenges for high repetition rate X-ray free-electron lasers is suitable 2-D detectors that can record images with MHz frame rates. Current development projects are limited to about 200 micron pixel size due to the required complexity of the integrated read out electronics in each pixel (e.g. buffer storage space). A large scientific impact can be expected from a further miniaturisation to pixel sizes of 50 microns and smaller by high-density integration technologies for sensors, ASICs, and front-end electronics. At the same time, the radiation hardness of these detectors has to be improved. To exploit the high data rates produced by XFEL facilities, data acquisition, data processing and simulation tools have to be developed and custom tailored to the specific scientific applications and detectors. Of crucial importance for the overall performance is the quality of X-ray optics. Long and radiation tolerant X-ray mirrors with extremely small shape errors are needed to preserve the excellent coherence properties of XFEL radiation. This will require a combination of novel polishing technologies with adaptive mirror correction techniques.

The EIROforum

EIROforum is a partnership of European Intergovernmental Research Organisations (EIROs). The EIROforum partners design, construct, operate and exploit large Research Infrastructures on behalf of the user communities of their Member States and beyond. EIROforum is growing. The European XFEL has recently joined and several other major new organisations have shown interest in joining the partnership, which currently comprises:

CERN	European Organisation for Nuclear Research
EFDA-JET	European Fusion Development Agreement-Joint European Torus
EMBL	European Molecular Biology Laboratory
ESA	European Space Agency
ESO	European Organisation for Astronomical Research in the Southern Hemisphere (European Southern Observatory)
ESRF	European Synchrotron Radiation Facility
XFEL	European X-Ray Free-Electron Laser Facility
ILL	Institut Laue-Langevin

All EIROs operate in a competitive global environment, attracting users from all over the world to the very best scientific and technological resources. As centres of excellence for the development of some of the world's most advanced technologies, they interact with European industry and thus play a crucial role in the innovation process, whilst enabling Europe's researchers to maintain scientific leadership in their fields.

The EIROs have an ongoing commitment with, and through, their user communities to a range of activities contributing to the stimulation of growth through innovation, the promotion of technology transfer and knowledge exchange, the support of training and high-quality capacity building, the execution of research that contributes to addressing the societal grand challenges; and the support of education and public understanding of science.