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AMICI

Accelerator and Magnet Infrastructure for Cooperation and Innovation

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DELIVERABLE REPORT

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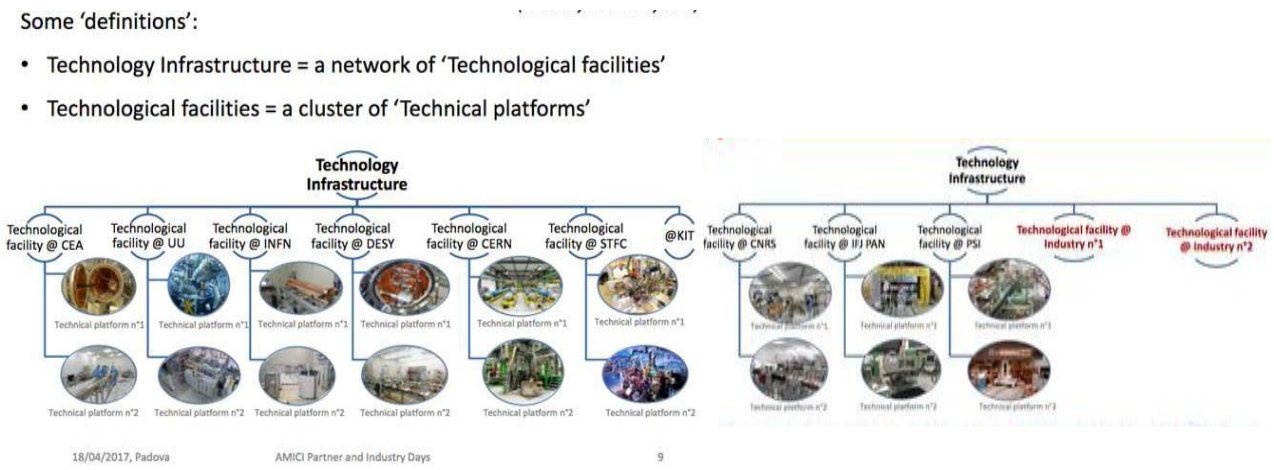
	Name	Partner	Date
Authored by	T. Ekelof	UU	22/10/2019
Reviewed by	P. Vedrine, H. Weise and M. Vretenar [members of WP2.3]	CEA, DESY, CERN	25/11/2019
Approved by	O. Napoly [AMICI coordinator]	CEA	

On the significant role played by the AMICI European Technology Infrastructure for the development and build-up of the Large Research Infrastructures

The AMICI European Technology Infrastructure:



1. INTRODUCTION

Many of the current Technological Facilities in AMICI: CEA, CERN, CNRS, DESY, FREIA, IFJ PAN, INFN, KIT, PSI and STFC, were created as High Energy Physics labs with their own accelerators and High Energy Physics user communities. Modern High Energy Physics is constantly requiring larger and larger accelerators and many of the former smaller High Energy Physics accelerators operated at the laboratories listed above have been shut down during the last few decades, thereby making possible the realization of a few very large High Energy Physics accelerators inside and outside Europe. During the same time several other sciences like e.g. material science, molecular biology and energy research have also developed very large accelerator and magnet based Research Infrastructures.

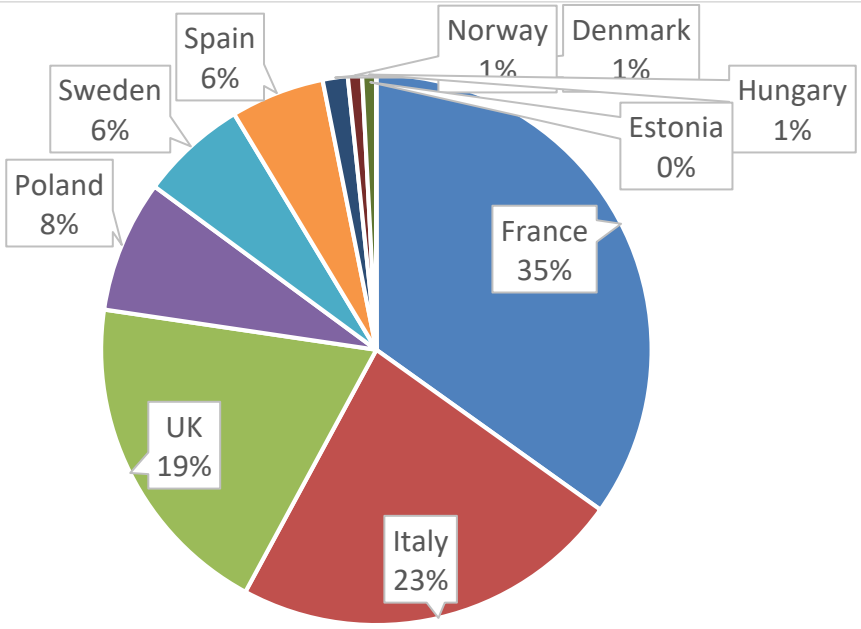
The host laboratories of the few laboratories in the world now hosting, or preparing to host, very large accelerators do not have enough Technical Platform capacity and trained personnel to develop and build their own future accelerator and magnet systems. The contributions in terms of Technical Platforms and trained technical personnel provided by the European Technological Facilities are therefore absolutely necessary for the successful technical development and build-up of the future accelerators and magnet systems for the large international and national infrastructures for research in High Energy Physics, Nuclear Physics, Synchrotron Radiation Science, Spallation Neutron Science, New Energy Sources, Environmental Research and others.

The creation of a new major accelerator research infrastructure requires extensive on-site civil construction work. This work, which will most often be carried out by local civil-construction firms, will, together with the personnel costs of the host laboratory, usually require of the order of half of the construction-project budget. As the European Spallation Source (ESS) linear accelerator is being built up on a 'green field 'site, all required buildings have to be financed

from the construction-project budget. For the High Luminosity Upgrade of the CERN Large Hadron Collider (HL-LHC Upgrade) of the order of 2.2 km underground galleries had to be excavated and equipped. XFEL in Germany is using part of the DESY laboratory site but required extensive civil construction on its 3.4 km long linear accelerator site.

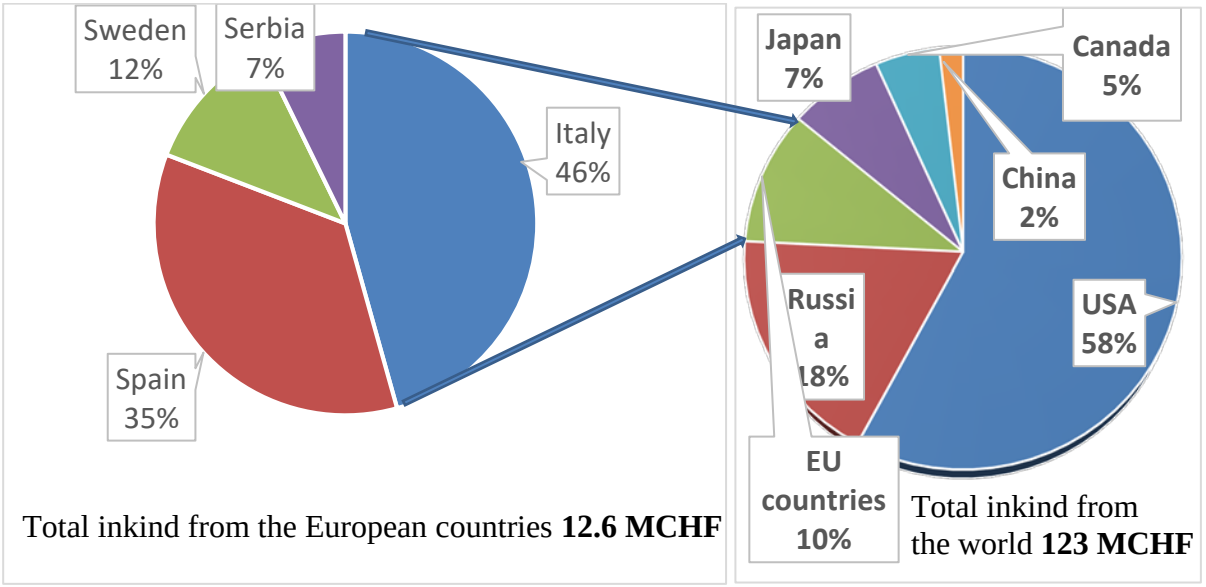
The other half (very approximately) of the construction-project budget is used to finance the contributions in terms of development, prototype design, production and tests, series production of components in industry, installation and commission of the new research infrastructure equipment. These contributions are to a varying degree delivered in-kind by the Technological Facilities. In the three pie charts here below is shown in financial terms the in-kind contributions from the Technological Facilities. The in-kind deliveries represent material as well as intellectual contributions from the Technological Facilities and their scientific, engineering and technical staff to the development and build-up of the new Research Facility. These contributions are of critical importance for the success of the Research Infrastructure projects. Furthermore, the in-kind contributions provided by the Technological Platforms, which are distributed over the European countries, help to achieve a high-tech scientific and industrial return to the European laboratories and industries that is equitably distributed to all regions in Europe, rather than just to the regions located near the sites of the few Research Infrastructures.

*Below is shown the division of the total **ESS Linac in-kind** contribution value of **271 MEUR** on ESS member countries. The total budget for the ESS Linac and its buildings is **570 MEUR.***



Divison of the total ESS linac in-kind contribution **271 MEUR**

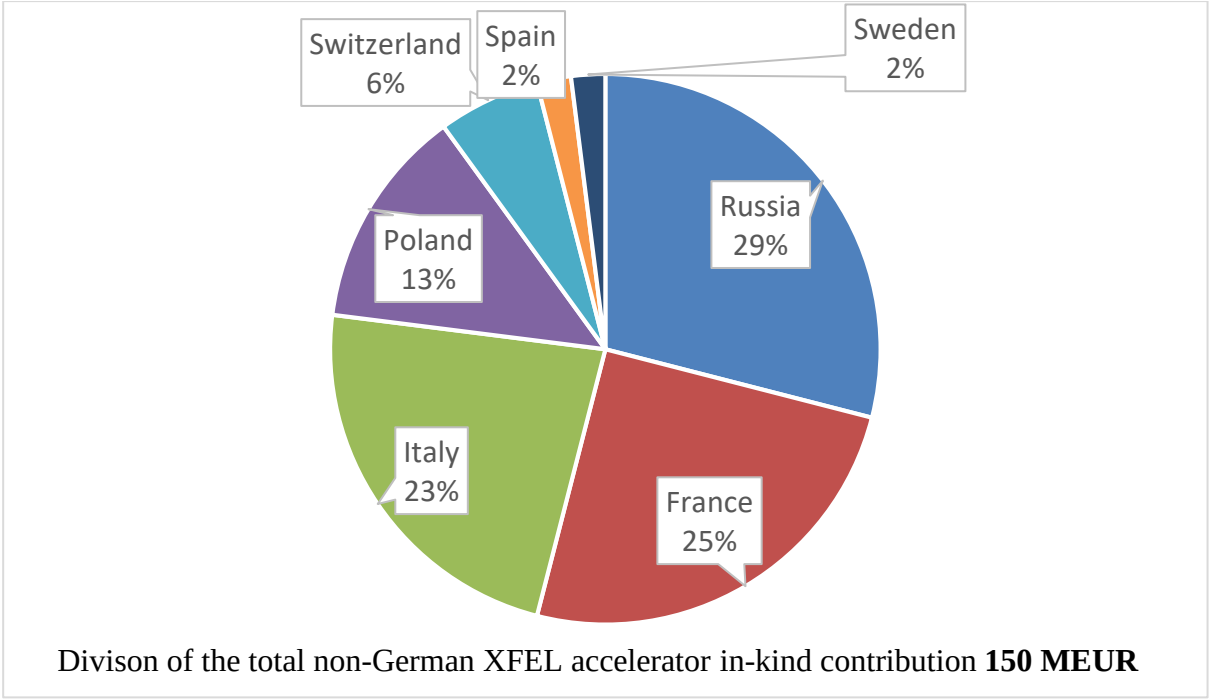
*Below is shown the division of total **CERN HL-LHC Upgrade in-kind** contribution value of **123 MCHF** (right) on the countries participating in the project, of which **12.6 MCHF** (left) is provided by European countries. The total budget of the CERN HL-LHC project including technical work at CERN and civil construction is **951 MCHF***



Total inkind from the European countries **12.6 MCHF**

Total inkind from the world **123 MCHF**

*Below is shown the division of total **XFEL accelerator system in-kind** from non-German countries of **150 MEU**. The total cost of the XFEL accelerator system, excluding civil construction and general infrastructure, is **495 MEU** of which **345 MEU** was contributed by German laboratories.*



Divison of the total non-German XFEL accelerator in-kind contribution **150 MEUR**

2. THE EXAMPLE OF THE EUROPEAN SPALLATION SOURCE (ESS)

A particularly illustrative example of the significant importance of the in-kind deliveries from the Technological Facilities is the ESS linac for which practically all components currently are being developed, built up and tested at a large number of European Technological Facilities. Mats Lindroos, Head of the ESS Accelerator Division, has estimated the extra time and extra cost that would have been required for the ESS linac if one would have had to employ and train all the physicists, engineers and technicians needed for the build-up on the ESS site in Lund of the laboratory premises and technical infrastructure required for the design, prototyping, tests and industrial ordering for the ESS accelerator project. Mats Lindroos' private conclusion is that this would have required about 7 additional years and about 77 MEUR in additional funding, including the funds needed for the salary costs of the extra personnel, for its completion. The nominal total construction time of the ESS linac is ca 12 years. The time when first beams will be delivered to users, currently planned as 2023, would thus have been delayed till 2030. The cost for the components that are now being delivered in-kind would have been 348 MEUR instead of, as now, 271 MEUR. But the maybe most significant gain with the support delivered by the Technology Facilities to the ESS linac is the intellectual contribution from the scientific, engineering and technical personnel at the Technological Facilities to the development, design, construction and build-up of the ESS linac high-tech components, based on the experience and use of the existing Technical Platforms at the contributing Technology Facilities. Thereby is guaranteed not only a successful outcome of the project, but also a high-tech scientific and industrial return in terms of high-tech development and production to European laboratories and industries that is distributed over all regions in Europe, not just around the ESS site.

3. THE THREE DIFFERENT KINDS OF TECHNOLOGY INFRASTRUCTURES

From a census made by the AMICI Task 2.3 among the 10 AMICI Technological Facilities one may conclude that there are three categories of such Facilities:

1. Technological Facilities in the form of a *single laboratory with a large accelerator facility* having a wide research user community. The large accelerator facility requires a technical program of development, production and tests of new equipment to be maintained in order to keep the accelerator facility competitive. This technical program in the host lab is also used to serve *other* major Research Infrastructures. Labs in this category are: CERN, DESY, PSI, INFN Frascati and STFC RAL.
2. Technological Facilities in the form of *national clusters of a number of smaller laboratories* which have smaller accelerator facilities mostly for accelerator and magnet technology developments and in some cases for research and test beams which also have, taken together, a major program of development, production and tests of equipment for large Research Infrastructures. Labs in this category are some of the national laboratories of INFN, STFC and CNRS-IN2P3.
3. Technological Facilities in the form of a *single laboratory with no major research accelerator* but a major program of development, production and tests of equipment for

Research Infrastructures. Labs in this category are Labs in this category are some of the national laboratories of INFN, STFC and CNRS-IN2P3, in particular CEA-Saclay, and FREIA and IFJ PAN.

These three categories have different sustainability boundary conditions. One clear tendency is that the Technological Facilities having an accelerator Research Infrastructure with an associated scientific user community have less problems with sustainability owing to the support to the Facility provided by its accelerator user community.

A trial was made to estimate through the census how much governmental support the Technological Facility function is receiving. This however turned out to be too complex a goal to achieve, in particular for the first of the three categories where it seems to be nearly impossible to separate the cost for the operation of the own Research Facility from the task to provide development, production and tests of equipment for the own Research Infrastructures, on the one hand, and to other Research Infrastructures, on the other.

4. THE CHARACTER OF THE RELATION BETWEEN THE RESEARCH INFRASTRUCTURES AND THE TECHNOLOGICAL FACILITIES

The census gave a picture of how the co-operation between the Technological Facilities and the Research Infrastructures are regulated. As a rule, the co-operation agreement is in the form of a detailed written contract. Normally the Technological Facility will demand the Research Infrastructure to cover the full costs of all purchased equipment components, industrial orders and consumables needed for the work at the Research Infrastructure and in some cases also for the personnel costs. On the other hand, the Research Infrastructure is not asked to pay for rental costs for the laboratory premises, for overhead fees or for the depreciation of existing technical infrastructure at the Research Infrastructure. There is also no provision for a profit to be made by the Technological Facility.

As both parties to such an agreement are contributing to the financing of the common project, the co-operation has the character of a collaboration of mutual interest for scientific and technological research for the benefit of Society rather than that of a commercial agreement. This is natural as the Technological Facility, like any public research institution, in operating as a public service institution having its salary and premises costs covered by public funding and not claiming exclusive Intellectual Properties rights for what it produces. To achieve the same goals operating under fully commercial conditions appears as impossible.

5. THE ESSENTIAL BUT UNKNOWN ROLE PLAYED BY THE TECHNICAL INFRASTRUCTURES FOR THE LARGE RESEARCH INFRASTRUCTURES

This new paradigm for how the very large new Research Infrastructures are being developed, build and maintained in Europe and in the World is not well known by the general public, who usually has the understanding that, e.g., the ESS's Neutron Spallation Source, CERN’s Large Hadron Collider and its upgrade and DESY's X-ray Free Electron Laser are developed and built by ESS, CERN and DESY, respectively, and that is all. The extensive interplay between the large Research Infrastructures and the European Technological Facilities, as illustrated by the

pie charts in this report, including also European high-tech Industry, is to a varying degree unknown on the political and research funding agency level. This implies a problem for motivating public support towards the operation costs of the Technical Facilities and thus for their sustainability.

It is essential for the future of European fundamental science, as well as for the development of European high-tech industry, that the new and important role played by the European Technological Facilities be explained to the national science and technology funding agencies, as well as to the general public, such that the public support to the Technical Facilities can be sustained and developed.

6. THE EXAMPLE OF THE FREIA LABORATORY

One example of this situation is that in Sweden, where the FREIA Laboratory was created in Uppsala as a Technological Facility in 2012 after the shutdown of the TSL national accelerator laboratory there. The build-up and operation till now of FREIA was made possible by a one-off initial investment grant of ca 23 MEUR provided directly from the Government, from ESS, from Uppsala University and from the Wallenberg Foundation.

FREIA now operates with its staff of 30 physicists, engineers, technicians and PhD students and 1000 m^2 area laboratory space as one of the Technical Facilities in Europe, currently with programs of tests of superconducting accelerator cavities for ESS and of superconducting orbit corrector dipoles and crab cavities for the CERNs HighLumi Upgrade and with discussions ongoing for future co-operation with the Belgian radioactive-waste incineration project MYRRHA and the US Fermilab Accelerator Proton Upgrade (PIP II) project. FREIA has till now received only minor financial project support from the Swedish Research Council and the Swedish Industrial Innovation Agency that is on a level insufficient to cover the salary and premises costs for FREIA of ca 1.8 MEUR/year.

This situation implies that FREIA will have to cease all operations in less than 2 years' time unless these two agencies, or some other public agencies, can be made aware of the new conditions for the development and build-up of future large Research Infrastructures in Europe and the need for involving high-tech industry as described here, and agree to provide the support required.

FREIA may constitute a special example but many of the 10 AMICI Research Facilities without own major on-site accelerator facilities report stagnant or decreasing governmental support for their basic operations costs as compared to the earlier period when they hosted accelerators on their own sites.

7. WHAT NEEDS TO BE MADE CLEAR ABOUT THE TECHNOLOGICAL FACILITIES FOR THEM TO BE SUSTAINED BY SOCIETY

What needs to be made clear to the national science and technology funding agencies, as well as the general public, in Europe is:

that experimental fundamental science, which has since the Renaissance been the *long-term* driver of technological, and therefore also commercial and economical, development in Europe,

has now reached a level where the research infrastructures have become so large and so complex that they require the active support of all European Technological Facilities and High-Tech Industry, calling for international coordination and cooperation between the Technological Facilities and sustained support for their operation,

that such co-operation is needed in order to keep the leading position in fundamental scientific research and technological development that the Western World has had until now, but which is now seriously challenged by other upcoming major regions in the world like China and India and this on a time scale that is much shorter than we may currently think,

that the Technological Facilities have the important function of stimulating industrial innovation as well as educating and training young researchers, engineers and technicians in the field of accelerator and magnet technology and

that the Technological Facilities, located in the different European countries, allow the challenging task to develop and build the few major current and future Research Infrastructures – thereby stimulating scientific development and industrial innovation - to be equitably distributed between the different European regions.

8. REQUIREMENTS FOR AND OPPORTUNITIES OFFERED BY INDUSTRIAL PARTNERSHIPS

There is general agreement on that it is important to have national Industrial Liaison Office's and to organize regular international information meetings between Research Infrastructures and Industry, like the Big Science Business Forums, in order to facilitate contacts between industrial companies and the large Research Infrastructures under construction. And this is also sufficient when it comes to identifying companies that can deliver specific raw materials and already commercialized technical products required by the Research Infrastructures.

But providing information and organize industrial forums is *not* sufficient when it comes to requesting industry to develop the new technologies needed by the Research Infrastructures. As such technical development most often implies too high risks to be financed on purely commercial grounds, the tight technical collaboration between the Technological Facilities and high-tech industrial companies constitutes a necessary condition for its execution.

It is both time-consuming, risky and costly for a small to medium size enterprise (SME) to spend the time and the resources needed to alone explore the possibility and commercial interest of developing a brand-new technology proposed by a Research Infrastructure. At that stage it is therefore necessary to involve scientists and engineers who have experience of working with the specific type of Research Infrastructure in question, having at their disposal an adequately equipped network of complementary Technological Facilities that operate in collaboration with high-tech industrial companies.

The Technological Facility offering this type of service needs to have a major part of its salary and premises costs covered by public funding – if it were to have to ask the SME to cover also these costs for the services offered in the co-operation, this again will normally represent too big a cost and risk for the SME. The co-operation would thus not come about as the Technology Facility could not sustain its activity if the co-operation would be required to be built on completely commercial conditions.

On the other hand, given that a Technological Facility has a sustained basic public financing as a base resource it may enter into partnership with industrial companies, offering them to make use of its Technical Platforms to perform investigations and developments of interest for the companies themselves. Such partnerships, or Business Models, reduce the need for public funding of the Technological Facility and help to sustain and develop further the its Technical Platforms. Different examples of such partnerships are described in the AMICI WP4.1 report Section 7.3. One example described is the ongoing partnership between the company Teledyne-e2v and the STFC Daresbury Laboratory in the UK. The company provides hardware, staff resources and finance for the delivery of beam-time at the laboratory's linear accelerator and receives in exchange the right to use part of the accelerator beam-time for its own development purposes. This has allowed the operation of the accelerator, which would otherwise have had to be closed down¸ to be continued and allows the Daresbury Laboratory to use the remaining beamtime for its own projects. Other examples of partnership are those of the company Advance Oncotherapy (AVO) which is using existing Technical Platforms at the STFC Daresbury Laboratory, the revenue of which has enabled the build-up of new Technical Platforms at the Laboratory and the use part of the UK in-kind funding for PIP II, channelled through STFC, to build up Technical Platforms at two UK industrial sites. Such partnership clearly demonstrates the utility provided by the Technological Facilities for scientific research as well as for industrial innovation and development.

9. CONCLUSIONS

It is thus of decisive importance that the European Technological Facilities be sustained. Without that it will not be possible to continue to build world-leading large Research Infrastructures in Europe. Such infrastructures are necessary for keeping Europe's leading position in the scientific, technological and economic development in the world and to maintain a development of high technology in this field equitably distributed over all regions in Europe. In order to achieve this, it will be necessary to make clear to the general public, and in particular to the European science and technology funding agencies, that the motivation for Society to provide the required support for most of the salary and premises costs of the Technological Facilities in Europe, and thereby guarantee their sustainability, is

- that a significant fraction of the advanced scientific research in Europe, on which the further technical and economic development of our Society is critically dependent, is based on the use of large international Research Facilities and that the European Technological Facilities have nowadays become absolutely vital actors for the build-up and upgrade of these Research Facilities and
- that the European Technological Facilities make it possible for modern European industry to meet the demands from the Research Infrastructures to develop qualitatively new technologies that soon constitute the basis also for many new practical applications in Society.

It will, at the same time, be necessary for the European Technological Facilities to better coordinate their efforts and avoid unnecessary duplication such that they together cover, in an optimized and cost-efficient way, all significant needs for the technology developments required by the new frontline Research Infrastructures. Furthermore, the Technological Facilities need to initiate more mutual partnerships with European Industry, offering to industry the use of their on-site Technical Platforms as well as helping the set-up of new Technical

Platforms on industrial sites. For this the handling of Intellectual Property and transfer of knowledge to Industry needs to be further developed, with the goal to enhance the role of Industry as qualified producer of the innovative instrumentation and infrastructure required for the future development of new Research Infrastructures as well as of Society at large.

It is the aim and purpose of AMICI to facilitate a development in this direction by acting as a forceful coordinating platform for the European Technological Facilities.