‘Accelerator and Magnet Infrastructure for Cooperation and Innovation’

Olivier Napoly, coordinator

Introduction and Goals of the Forum

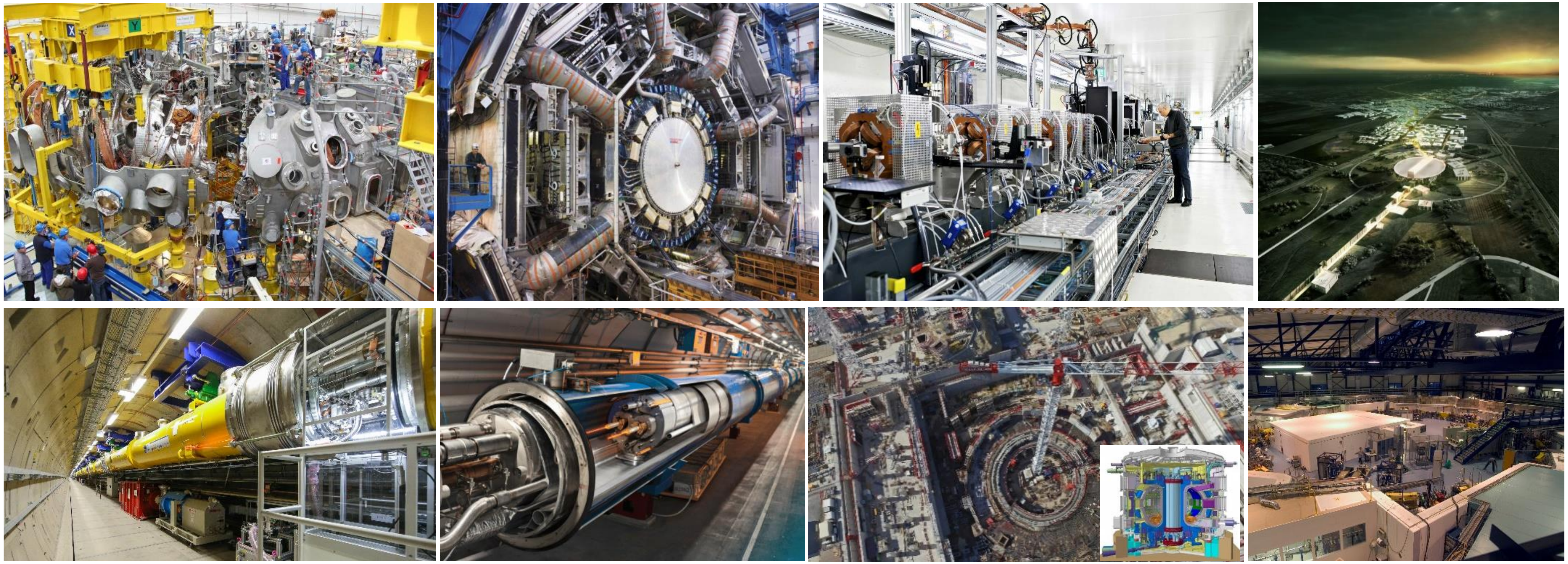
EUROPEAN COMMISSION
DIRECTORATE-GENERAL FOR RESEARCH & INNOVATION
Research infrastructure

HORIZON 2020

AMICI

AMICI is about European leadership in Big Science,

based on accelerator and SC magnet



in a sometimes collaborative, sometimes competitive spirit with our strong N. American and Asian contenders.

Big Science ← Technology → Innovation

*“Large-scale science projects address fundamental questions at the forefront of science and technology. These projects require **large and sustained infrastructures** and a good collaboration on long time scales.*

The European Technology Infrastructure

*In turn, such projects provide unique equipment, challenging request for high **technology and innovation**, stimulating ideas that attract good people, and offer the occasion to bring people closer together.”* Rolf Heuer, *The Role of Big Laboratories*, Phys. Scr. T158 (2013)

AMICI (Jan. 2017 – Oct. 2019)

EUROPEAN COMMISSION
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Research infrastructure

AMICI, for '**Accelerator and Magnet Infrastructure for Cooperation and Innovation**', is an Horizon 2020 '**Coordination and Support Action**' project, funded by the European Commission.

Its general goal is to **propose a model** for the **sustainability** of the **Technology Infrastructure** dedicated to **Accelerators and Superconducting Magnets** in Europe, serving **scientific research** and **innovation**.

From the National Laboratories standpoint, the focus is on sustaining the **Technology Infrastructure,** in parallel with R&D activities, for which European funded programmes existed (CARE, EuroTeV, EuCARD(2), ARIES, etc…) and will continue (ARIES-IP).

From the European Commission standpoint, the focus is on strengthening **innovation,** for which EU needs to catch up with the other regions.

Both aspects are intertwined, and require some level of **strategy** and **cooperation** that AMICI has attempted to bring.

AMICI Consortium

Goals of the Industry Forum (1/2)

The main goals of this Forum, set in the H2020 Grant Agreement, are as follows:

1) to bring together scientists and industry (~50 participants, ~60 % from industry)
2) to present the work done in the different AMICI Work Packages
3) to discuss the long-term strategy for the Technology Infrastructure

AMICI Work Packages

1. Communication

Round Table on Wednesday afternoon
- *A.B. del Cerro Gordo (CDTI)*
- *M. Morandin (INFN)*

2. Strategy

Talks on Wednesday afternoon
- *O. Napoly (CEA)*
- *T. Ekelöf (Uni. Uppsala)*

3. Cooperation

Talks on Wednesday afternoon
- *S. Leray (CEA)*

4. Innovation

Talks on Tuesday afternoon
- *A. Gleeson (STFC)*

5. Industrialization

Talks on Tuesday afternoon
- *P. Fabbricatore (INFN)*
- *S. Grohmann (KIT)*
- *M. Fouaidy (CNRS)*

Goals of the Industry Forum (2/2)

The Forum agenda follows a logical sequence of three themes:

1st Day: ***where we stand***

- reports on the outcome of the work carried out in the AMICI project regarding 'Innovation' and 'Industrialization'
- experience for exploiting AMICI technical platforms
- success stories from some companies who are present.

2nd day, morning: ***the global landscape and future challenges***

- describe the landscape of projects worldwide where involvement of the European technology infrastructure and engagement of industry will be essential
- present the key areas where significant technological developments will be needed

2nd day, afternoon: ***sustaining and exploiting the European Technology Infrastructure***

- the rationale for sustainability from the Big Science point of view
- the proposed organization of a European Technology Infrastructure which can provide new services and opportunities of cooperation with industry.

The round table, at the end, should provide feedback on the outcomes of this logical process, in particular regarding the plans for the future.

Participation of the European Commission

On behalf of the Organization Committee, I would like to express my appreciation of the participation of:

Patricia Postigo-McLaughlin
Project Officer for AMICI, and ARIES
European Commission
DG for Research and Innovation

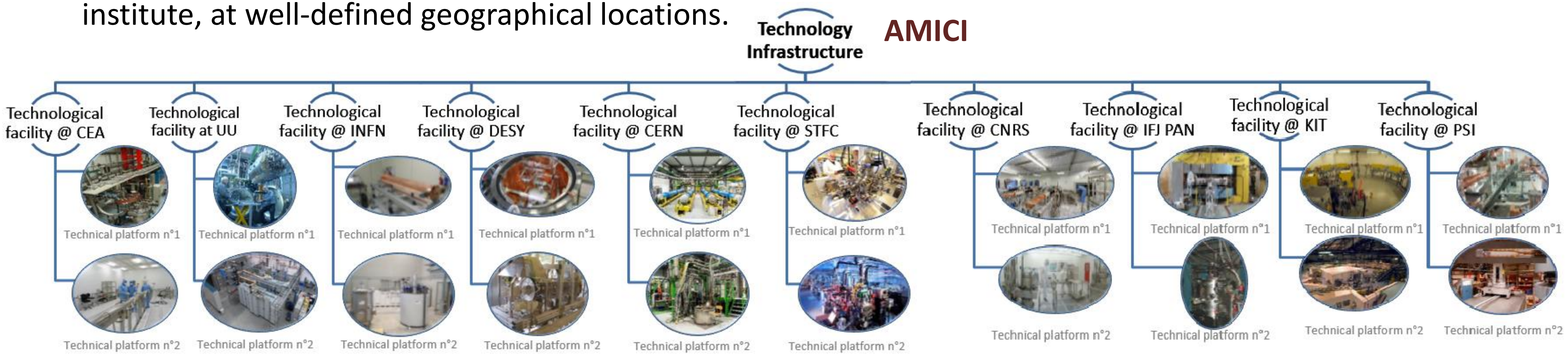
Adam Tyson
Head of Research and Industrial Infrastructures
European Commission
DG for Research and Innovation

Both have a very busy working agenda in Brussels, and they are excused for their limited attendance to the Forum.

A. Tyson will present the view of the EC Commission on Wednesday morning.

AMICI, the European Technology Infrastructure

- **Research Infrastructure** – A Research Infrastructure is a facility aimed at conducting top-level research activities in a given scientific field. AMICI deals with Research Infrastructures built from accelerators or superconducting magnets, for instance the **LHC** at CERN, in the field of particle physics, the **European XFEL** in Hamburg (Germany), in the field of light source sciences, **ITER** in Cadarache (France), in the field of nuclear fusion, the **ESS** in Lund (Sweden), in the field of neutron source sciences.
- **Technology Infrastructure** – A Technology Infrastructure is a network of Technological Facilities that are used for the construction of Research Infrastructures
- **Technological Facility** – A Technological Facility is a cluster of Technical Platforms that belong to an institute, at well-defined geographical locations.



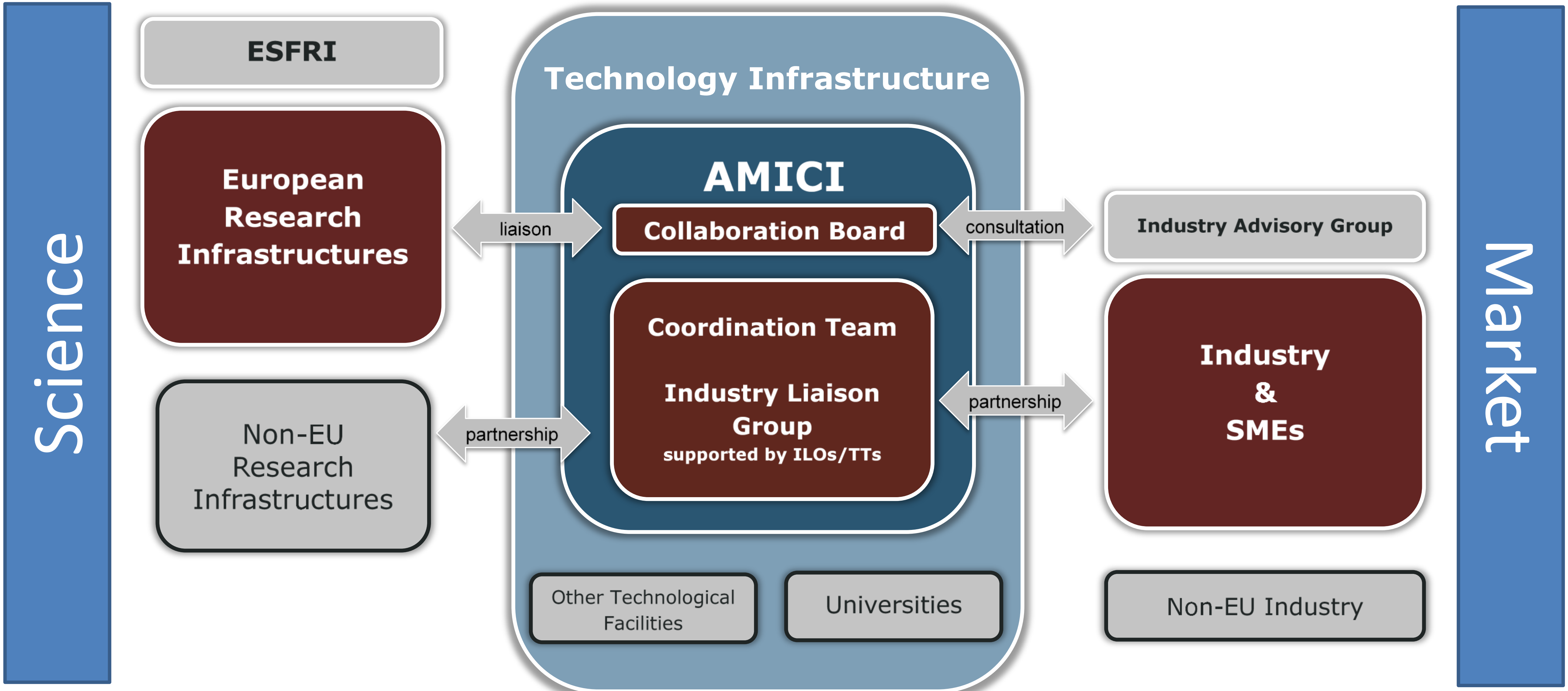
Objectives / achievements

- The different Technical Platforms have been mapped with their characteristics and functionalities
- The global landscape of future accelerator and magnet based RIs has been described
- Key Technological Areas for the construction of future RIs have been identified and the necessary developments in TFs analyzed
- A survey of potential markets for societal applications has been made, showing that innovation activities between AMICI Partners and Lateral Markets, in order to develop accelerator-related societal applications, have favored the healthcare sector, with some representation in the security sector whilst opportunities for potential developments in the energy sector are comparatively unexplored. *The possible role of TFs in their deployment is identified*
- Relations with industry has been analyzed and barriers for a stronger engagement between TFs and industry identified. Propositions to overcome these barriers were made which would result in a transition from a primarily RI-driven model to a broader ecosystem supporting enhanced partnership with Industry
- A new European Standard “Helium cryostats – protection against excessive pressure” has been developed to be submitted to the European Committee for Standardization CEN. This is seen as an example of procedure that could be applied to other cases.
- A possible structure and content for a common data base for materials and components has been proposed, which would allow sharing the knowledge acquired within the TFs

Objectives / achievements

- The conditions for the involvement of the industry in the prototyping phase have been investigated, showing that industry should be associated as early as possible to the design for future products beyond the scope of the specific prototyping activities, and respecting a subsidiarity principle, i.e. favoring developments in industry whenever possible.
- The benefit and conditions of apprenticeship has been evaluated both for industry personnel trained at the Technology Infrastructure and for scientific staff trained at company sites. The importance of well-understood and functional System Engineering and Quality Assurance plans was recognized as another powerful mean to improve the quality of industrial products and services received by the Technology Infrastructure for the construction of Research Infrastructures.
- Conditions for the sustainability of the TFs have been analyzed showing that support from the European science and technology funding agencies is crucial and that a better coordination of efforts, avoiding unnecessary duplication but covering, in an optimized and cost-efficient way, all significant needs for the technology developments required by the new frontline Research Infrastructures would be welcome.
- Founded on a collaboration agreement between core AMICI partners, a networking model between the main stakeholders (Industry, National Laboratories, Universities and Research Infrastructures) has been proposed which would guaranty the sustainability of the European TI, contribute to overcome the identified barriers between TFs and industry and establish an ecosystem that would maintain Europe at the forefront of science and innovation.

AMICI Collaboration Agreement



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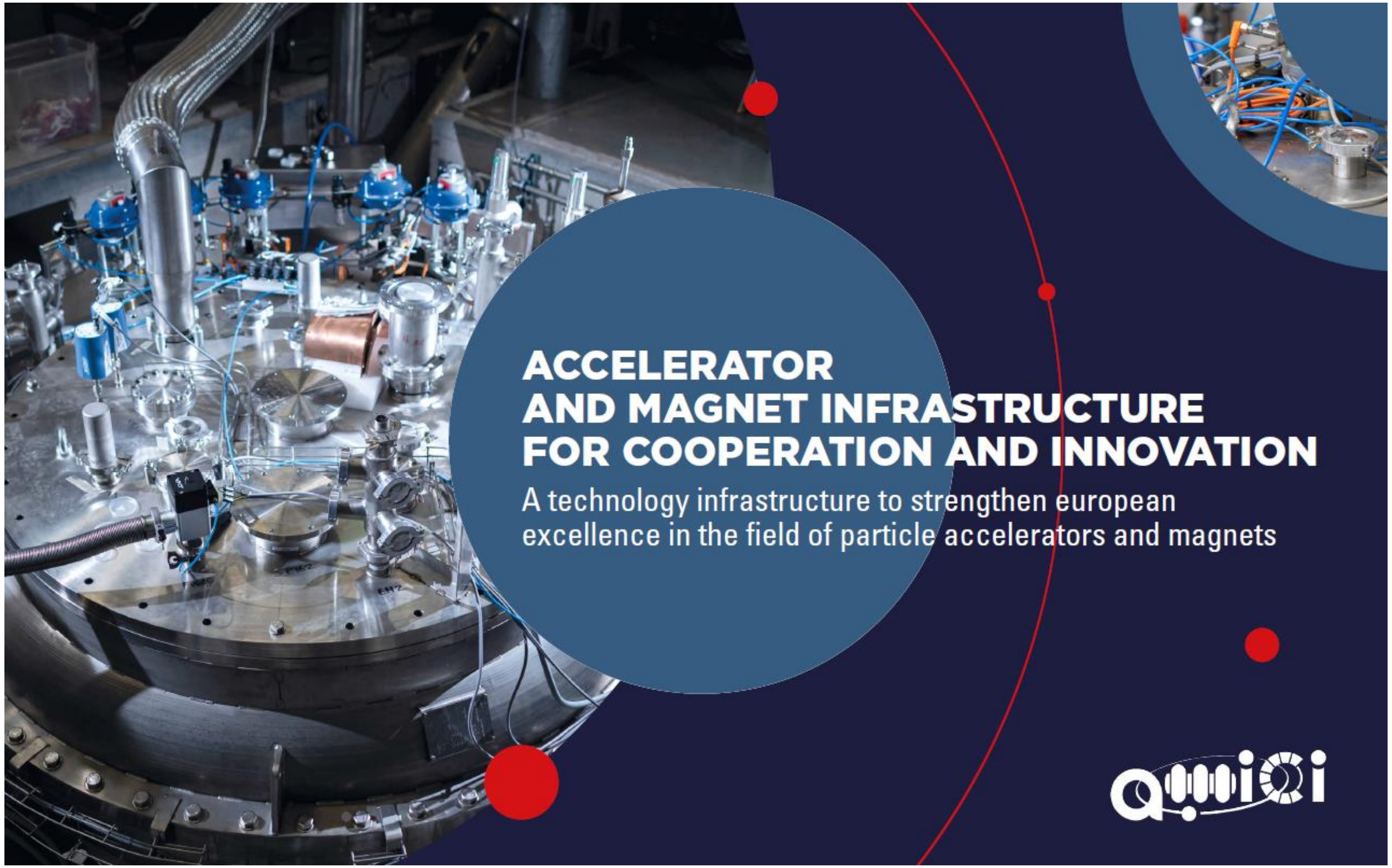

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OBJECTIVES/ACHIEVEMENTS

- The different TPs have been mapped with their characteristics and functionalities.
- The global landscape of future accelerator and magnet based RIs has been analyzed.
- Key Technological Areas for the construction of future RIs have been identified and the necessary developments in TFs determined.
- A survey of potential markets for societal applications has been done, showing that innovation activities between AMICI Partners and Lateral Markets, in order to develop accelerator-related societal applications, have favoured the healthcare sector, with some representation in the security sector whilst opportunities for potential developments in the energy sector are comparatively unexplored. The possible role of TFs in their deployment identified.
- Relations with industry has been analyzed and barriers for a stronger engagement between TFs and industry identified, in particular communications, cost of access, IP and transparency. Some propositions to overcome these barriers were made, which would need cultural changes to be embedded and supported over extended periods of time and resulting in a transition from a primarily RI-driven model to a broader ecosystem supporting enhanced partnership with Industry.
- A new European Standard "Helium cryostats – protection against excessive pressure" has been developed to be submitted to the European Committee for Standardisation CEN. This could be seen as an example of procedure that could be applied to other cases.
- A possible structure and content for a common data base for materials and components has been proposed, which would allow sharing the knowledge acquired within the TFs.
- The conditions for the involvement of the industry in the prototyping phase has been investigated, showing that industry should be associated as earlier as possible to the design, allowing industry setting the basis for future products beyond the scopes of the specific prototyping activities, and respecting a subsidiary principle, i.e. favoring developments in industry when possible.
- Conditions for the sustainability of the TFs have been analyzed showing that support from the European science and technology funding agencies is crucial and that a better coordination of efforts, avoiding unnecessary duplication but covering, in an optimized and cost-efficient way, all significant needs for the technology developments required by the new frontline Research Infrastructures would be welcome.
- A scheme based on a collaboration agreement between the main stakeholders has been proposed which would guaranty the sustainability of the European TI, contribute to overcome the identified.

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BENEFITS FOR SCIENCE

WHAT IF TECHNOLOGY INFRASTRUCTURES DID NOT EXIST?

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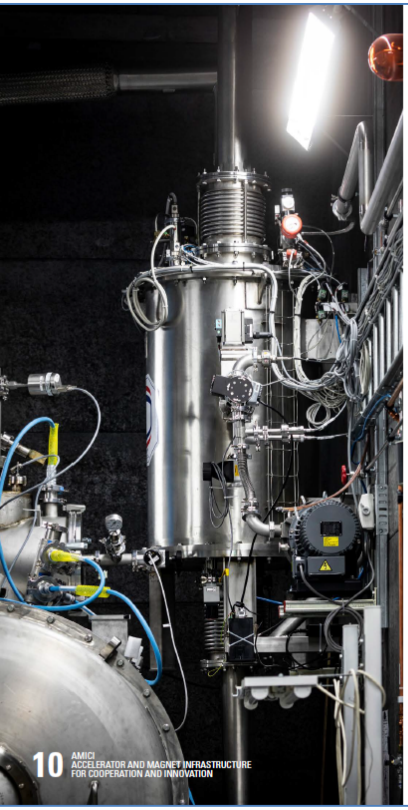

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AMICI PARTNERS FACILITATE EUROPEAN RESEARCH INFRASTRUCTURES

The AMICI partners contribute to the construction of numerous European and international Research Infrastructures (RI). This is possible due to the sustainable use of infrastructure set-up and commissioned for selected RIs. As an example, the successful collaborative construction of the European XFEL required distributed infrastructure at in-kind partners. The needed invest led to extremely valuable Technical Platforms which immediately after finishing XFEL construction could foster the ESS related R&D and are now used during construction phase. Technical platforms are adopted and extended when needed. Participation in several projects following in series helps with respect to sustainability.

Nevertheless, science development and decision making processes can lead to deemphasized use and periods during which knowledge increase and even conservation can become challenging. Therefore all AMICI partners strongly contribute to the development and construction of RIs.

The projects listed above are only a few examples of the prestigious Research infrastructures that AMICI partners build together

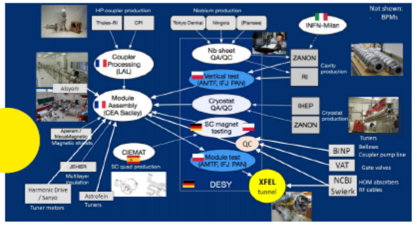
PROJETS	CEA	CERN	DESY	INFN	IFJ PAN	CNRS	STFC	UU	PSI	KIT
CLIC-CTF3		•		•		•	•	•	•	
ELI-NP				•	•	•	•			
ESS	•	•	•	•	•	•	•	•	•	•
European X-FEL	•		•	•	•	•		•	•	•
HL LHC	•	•		•	•		•	•		•
IFMIF	•			•						•
JT-60SA	•									•
Spiral2	•				•	•				
SwissFEL		•	•	•			•		•	

Thanks to the European XFEL project a number of sophisticated and valuable new Technical Platforms exist. These platforms can now be offered to research partners and/or companies providing accelerator components to research facilities worldwide.

In recent years DESY's cooperation with industrial vendors in the field of SRF technology was further emphasized. The companies Research Instruments and Ettore Zanon, both producing superconducting cavities for different research projects worldwide, are time and again customers in the existing Technical Platforms. The European XFEL project helped to qualify both companies in the complete procedures related to production and surface treatment for large series productions.

Companies involved in the European XFEL acquired new skills which enabled them to develop new business opportunities.

Cooperation started at a time when the companies were already prequalified through the very successful mechanical production of a large number of cavities, but knowledge transfer was still needed. This transfer included training of personnel which was partly done at DESY. Since then both companies are perfectly aware of the capabilities offered by the operated Technical Platforms. In consequence requests were made to share the use of DESY infrastructure. This holds especially for R&D projects, small series production, and testing of cavities which requires workshops, assembly areas, cryogenic temperatures and dedicated radiofrequency sources, but also shielded test areas. Larger projects are the quality inspection of niobium sheets needed for cavity production, or the testing of series cavities for ESS.



The construction of the European XFEL was only possible in collaboration of institutes at different sites across nine countries. Many of them are now partners within AMICI.

European XFEL

SUCCESSFUL COLLABORATIONS AROUND THE EU-XFEL RESEARCH INFRASTRUCTURE

FIELD OF THE PROJECT: LIGHT SOURCE

The European XFEL is a research facility of superlatives: It generates ultrashort X-ray flashes—27 000 times per second and with a brilliance that is a billion times higher than that of the best conventional X-ray radiation sources. Smaller, faster, more intense: The European XFEL is opening up areas of research that were previously inaccessible. Using the X-ray flashes of the European XFEL, scientists will be able to map the atomic details of viruses, decipher the molecular composition of cells, take three-dimensional images of the nanoworld, film chemical reactions, and study processes such as those occurring deep inside planets.

https://www.xfel.eu/

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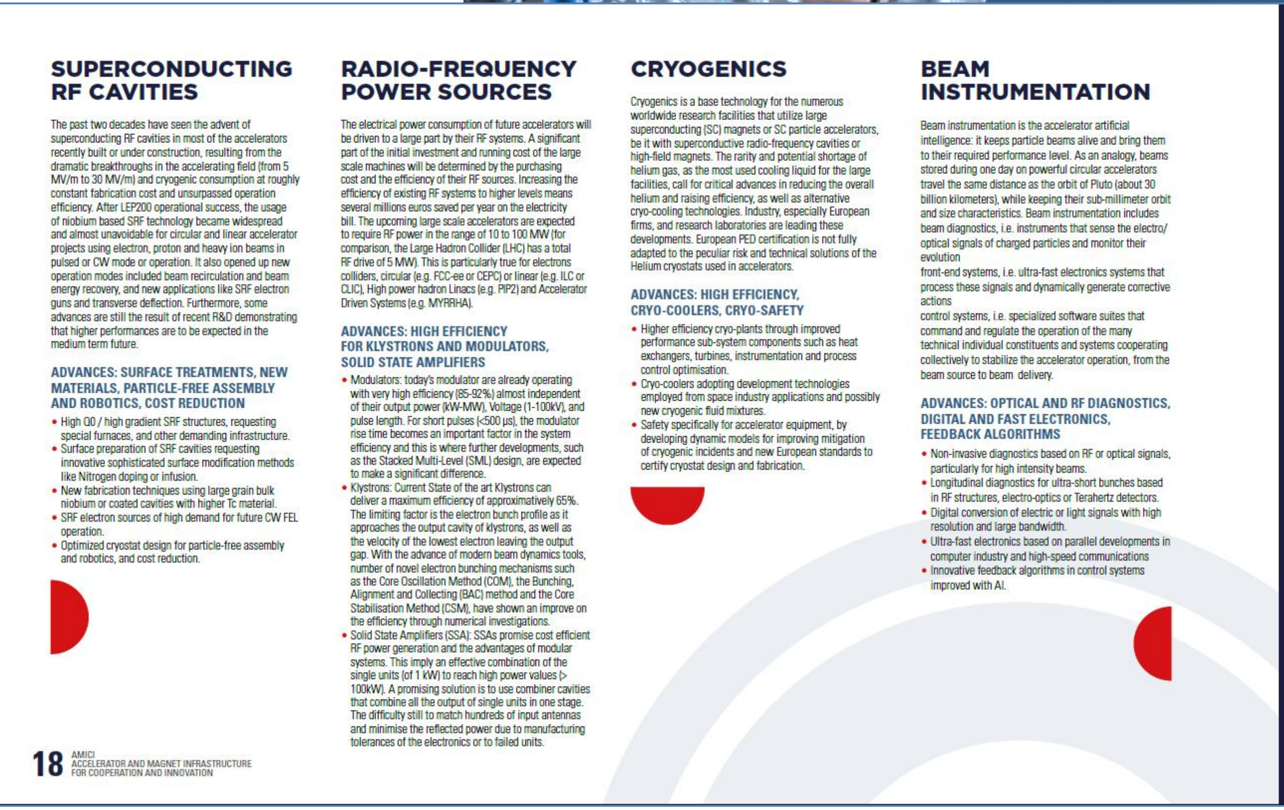

SUPERCONDUCTING RF CAVITIES

The past two decades have seen the advent of superconducting RF cavities in most of the accelerators recently built or under construction, resulting from the dramatic breakthroughs in the accelerating field (from 5 MV/m to 30 MV/m) and cryogenic consumption at roughly constant fabrication cost and unsurpassed operation efficiency. After LEP200 operational success, the usage of niobium based SRF technology became widespread and almost unavoidable for circular and linear accelerator projects using electron, proton and heavy ion beams in pulsed or CW mode or operation. It also opened up new operation modes included beam recirculation and beam energy recovery, and new applications like SRF electron guns and transverse deflection. Furthermore, some advances are still the result of recent R&D demonstrating that higher performances are to be expected in the medium term future.

ADVANCES: SURFACE TREATMENTS, NEW MATERIALS, PARTICLE-FREE ASSEMBLY AND ROBOTICS, COST REDUCTION

- High Q0 / high gradient SRF structures, requesting special furnaces, and other demanding infrastructure.
- Surface preparation of SRF cavities requesting innovative sophisticated surface modification methods like Nitrogen doping or infusion.
- New fabrication techniques using large grain bulk niobium or coated cavities with higher Tc material.
- SRF electron sources of high demand for future CW FEL operation.
- Optimized cryostat design for particle-free assembly and robotics, and cost reduction.

RADIO-FREQUENCY POWER SOURCES

The electrical power consumption of future accelerators will be driven to a large part by their RF systems. A significant part of the initial investment and running cost of the large scale machines will be determined by the purchasing cost and the efficiency of their RF sources. Increasing the efficiency of existing RF systems to higher levels means several millions euros saved per year on the electricity bill. The upcoming large scale accelerators are expected to require RF power in the range of 10 to 100 MW (for comparison, the Large Hadron Collider (LHC) has a total RF drive of 5 MW). This is particularly true for electrons colliders, circular (e.g. FCC-ee or CEPC) or linear (e.g. ILC or CLIC), High power hadron Linacs (e.g. PIP2) and Accelerator Driven Systems (e.g. MYRRHA).

ADVANCES: HIGH EFFICIENCY FOR KLYSTRONS AND MODULATORS, SOLID STATE AMPLIFIERS

- Modulators: today's modulator are already operating with very high efficiency (85-92%) almost independent of their output power (kW-MW), Voltage (1-100kV), and pulse length. For short pulses (<500 µs), the modulator rise time becomes an important factor in the system efficiency and this is where further developments, such as the Stacked Multi-Level (SML) design, are expected to make a significant difference.
- Klystrons: Current State of the art Klystrons can deliver a maximum efficiency of approximatively 65%. The limiting factor is the electron bunch profile as it approaches the output cavity of klystrons, as well as the velocity of the lowest electron leaving the output gap. With the advance of modern beam dynamics tools, number of novel electron bunching mechanisms such as the Core Oscillation Method (COM), the Bunching, Alignment and Collecting (BAC) method and the Core Stabilisation Method (CSM), have shown an improve on the efficiency through numerical investigations.
- Solid State Amplifiers (SSA): SSAs promise cost efficient RF power generation and the advantages of modular systems. This imply an effective combination of the single units (of 1 kW) to reach high power values (> 100kW). A promising solution is to use combiner cavities that combine all the output of single units in one stage. The difficulty still to match hundreds of input antennas and minimise the reflected power due to manufacturing tolerances of the electronics or to failed units.

CRYOGENICS

Cryogenics is a base technology for the numerous worldwide research facilities that utilize large superconducting (SC) magnets or SC particle accelerators, be it with superconductive radio-frequency cavities or high-field magnets. The rarity and potential shortage of helium gas, as the most used cooling liquid for the large facilities, call for critical advances in reducing the overall helium and raising efficiency, as well as alternative cryo-cooling technologies. Industry, especially European firms, and research laboratories are leading these developments. European PED certification is not fully adapted to the peculiar risk and technical solutions of the Helium cryostats used in accelerators.

ADVANCES: HIGH EFFICIENCY, CRYO-COOLERS, CRYO-SAFETY

- Higher efficiency cryo-plants through improved performance sub-system components such as heat exchangers, turbines, instrumentation and process control optimisation.
- Cryo-coolers adopting development technologies employed from space industry applications and possibly new cryogenic fluid mixtures.
- Safety specifically for accelerator equipment, by developing dynamic models for improving mitigation of cryogenic incidents and new European standards to certify cryostat design and fabrication.

BEAM INSTRUMENTATION

Beam instrumentation is the accelerator artificial intelligence: it keeps particle beams alive and bring them to their required performance level. As an analogy, beams stored during one day on powerful circular accelerators travel the same distance as the orbit of Pluto (about 30 billion kilometers), while keeping their sub-millimeter orbit and size characteristics. Beam instrumentation includes beam diagnostics, i.e. instruments that sense the electro/optical signals of charged particles and monitor their evolution

front-end systems, i.e. ultra-fast electronics systems that process these signals and dynamically generate corrective actions

control systems, i.e. specialized software suites that command and regulate the operation of the many technical individual constituents and systems cooperating collectively to stabilize the accelerator operation, from the beam source to beam delivery.

ADVANCES: OPTICAL AND RF DIAGNOSTICS, DIGITAL AND FAST ELECTRONICS, FEEDBACK ALGORITHMS

- Non-invasive diagnostics based on RF or optical signals, particularly for high intensity beams.
- Longitudinal diagnostics for ultra-short bunches based in RF structures, electro-optics or Terahertz detectors.
- Digital conversion of electric or light signals with high resolution and large bandwidth.
- Ultra-fast electronics based on parallel developments in computer industry and high-speed communications
- Innovative feedback algorithms in control systems improved with AI.

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Greetings

Many thanks:

- to the great panel of Accelerator and Fusion Project Leaders, drawing the future of our field, and its technology needs.
- to our industry partners for their strong participation, and for the TT officers.
- to the RI representatives: ALBA, ESRF, ESS, European XFEL, F4E
- to the AMICI Work Package and Task Leaders, for their vision and their hard work.
- to the Forum organizers, Arife Yildirim, Rossana Chiaratti and the program committee.
- to all the speakers.