AMICI
WP2.2: Global landscape
(**CEA**, CERN, INFN, CNRS).

Olivier Napoly
CEA/Irfu

EUROPEAN COMMISSION
DIRECTORATE-GENERAL FOR RESEARCH & INNOVATION
Research infrastructure

HORIZON 2020

WP2.2: Global Landscape

The roadmaps of the different scientific domains using accelerators and superconducting magnets in Europe, such as the ESFRI list and its international equivalents, as well as the roadmaps of the major research laboratories worldwide will be collected and analysed in order to identify the future trends and need. With the additional input from the innovation market survey from WP4, synergies, possible mismatches and potential for innovation will be described. All this will be used to assess the workload, the capabilities and, whenever possible the priorities of the European Technological Infrastructures, constituting Technological Roadmaps, in the different technological domains identified in WP2.1.'

EUROPEAN COMMISSION
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Research infrastructure

HORIZON 2020

Amici

Some relevant documents

IPAC15

Richmond Conference Center
Richmond, Virginia, USA
3-8 May, 2015

Construction Projects and Upgrades
of Particle Accelerators

8th Edition

Information for Industry
Collaborating in the Field of Particle Accelerators

Compiled by Christine Petit-Jean-Genaz
IPAC Conferences Coordinator for Europe

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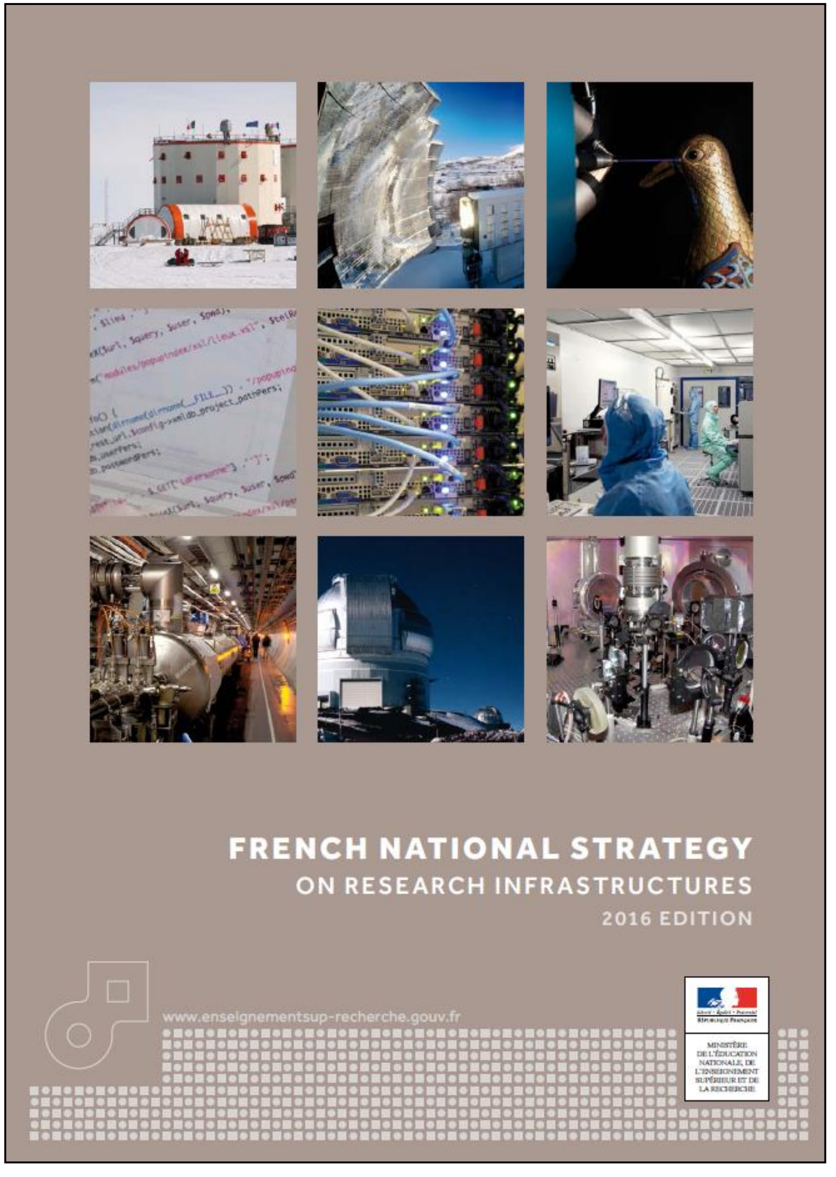

LIST OF RESEARCH INFRASTRUCTURES
NUCLEAR AND HIGH-ENERGY PHYSICS

TYPE	NAME	FULL NAME	ESFRI
IO	CERN-LHC	European Organization for Nuclear Research - Large Hadron Collider	
VLRI	EGO-VIRGO	European Gravitational Observatory - VIRGO	
VLRI	FAIR	Facility for Antiproton and Ion Research	FAIR (2006)
VLRI	GANIL-Spiral2	Grand National Heavy Ion Accelerator (GANIL), Radioactive Ion Production System in Line of 2nd generation (SPIRAL2)	Spiral2 (2006)
RI	*HESS*[1]	*High Energy Stereoscopic System*	
RI	KM3NeT	Kilometre Cube Neutrino Telescope	KM3NET (2006, 2016)
RI	LSST	Large Synoptic Survey Telescope	
Project	*CTA*[2]	*Cherenkov Telescope Array*	*CTA (2008)*

1 RI at the interface with the sector "Astronomy and Astrophysics". RI description can be found in the sector "Astronomy and Astrophysics".
2 RI at the interface with the sector "Astronomy and Astrophysics". RI description can be found in the sector "Astronomy and Astrophysics".

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- **WEST (Tungsten (W) Environment in Steady-state.** It develops the Tore Supra tokamak (built and operated under the auspices of the EURATOM-CEA Association in the 1980s) as direct support for ITER with regards to ITER, although managed in specific frameworks, it must be mentioned for its importance. Indeed, it must show the control of fusion energy via magnetic confinement and allow for the development over time of a new energy source and support industrial application. In the framework of international cooperation, ITER is currently under construction in France, on the Cadarache site and Europe is contributing a large portion of the project. In addition, there is a Euratom Fusion research programme in the framework of the Horizon 2020 programme, intended to coordinate the research activities of member states, of which one section concerns the materials and DEMO, the step that will follow ITER.

Finally, the contribution to the production of electricity via fossil resources will here too support the energy and ecological transition. However, the capture, transport, storage and valorisation of CO_2 will be inescapable. An infrastructure is dedicated to this problem. It is:

- **ECCSEL** (European Carbon dioxide Capture and Storage Laboratory) which is deployed on a European level and which will be listed on the ESFRI roadmap. This is a distributed infrastructure with BRGM as the French node and pilot. ECSSEL will appear as a project.

LIST OF RESEARCH INFRASTRUCTURES ENERGY

TYPE	NAME	FULL NAME	ESFRI
RI	FR-SOLARIS	Solar Thermal Research Infrastructure for Concentrated Solar Power	EU-SOLARIS (2010)
RI	WEST	W(Tungsten) Environment for Steady-state Tokamaks	
Project	ECCSEL-FR	European Carbon Dioxide Capture and StoragE Laboratory Infrastructure	ECCSEL (2008)
Project	SOPHIRA	SOlar PHotovoltaic Research Infrastructure	
Project	Theorem	Testing facilities for Hydrodynamics and Marine Renewable Energy	Marinerg-i (2016)

LIST OF RESEARCH INFRASTRUCTURES MATERIAL SCIENCES AND ENGINEERING

TYPE	NAME	FULL NAME	ESFRI
VLRI	ESRF	European Synchrotron Radiation Facility	ESRF Upgrade Ph 1 (2006) ESRF Upgrade Ph 2 (2016)
VLRI	ESS	European Spallation Source	ESS (2006)
VLRI	ILL	Institut Max von Laue - Paul Langevin	ILL Upgrade Ph 1 (2006)
VLRI	Orphée/LLB	ORPHEE/Laboratoire Léon Brillouin	
VLRI	Soleil	French national synchrotron facility	
VLRI	XFEL	European X-ray Free Electron Laser	XFEL (2006)
RI	EMIR	Federation of the accelerators for the studies of materials under irradiation	
RI	FT-ICR	Very high field FT-ICR mass spectrometer national network	
RI	LNCMI	The National High Magnetic Field Laboratory	EMFL (2008)
RI	LULI-APOLLON	Laboratory for the Use of Intense Lasers	
RI	METSA	Transmission Electron Microscopy and Atom Probe	
RI	PETAL	PETAwatt Aquitaine Laser	
RI	RMN	Magnetic Nuclear Resonance, Very High Fields	
RI	Renard	Research Infrastructure Interdisciplinary EPR National Network	
RI	RENATECH	French national nanofabrication network	
Project	*ERIHS-FR*[1]	*European Research Infrastructure for Heritage Science*	*ERIHS (2016)*

1 RI at the interface with the sector "Social Sciences and Humanities". RI description can be found in the sector "Social Sciences and Humanities".

Some relevant documents

Nuclear and High Energy Physics

Category	Group	Name	Full name
OI	CERN	CERN	European Organization for Nuclear Research
		CERN - LHC	Particle accelerator LHC at CERN
TGIR		GANIL-Spiral 2	Large national accelerator of heavy ions (project Spiral 2 included – laboratories part excluded)
TGIR		FAIR	Facility for Antiproton and Ion Research
TGIR		EGO-VIRGO	European Gravitational Observatory (project VIRGO included)
IR		ANTARES	Astronomy with a Neutrino Telescope and Abyss environmental research

Material and Engineering Sciences

Category	Group	Name	Full name
TGIR		ESRF	European Synchrotron Radiation Facility
TGIR		XFEL	European X-ray free electron laser
TGIR		ILL	European neutron source - Institut Laue Langevin
TGIR		ORPHEE	Orphée reactor. Excluding LLB part (Laboratoire Léon Brillouin)
TGIR		SOLEIL	3rd generation synchrotron radiation source
IR		CESTA Lasers	High-density energy lasers - CEA / CESTA
IR		EMIR	Network of accelerators for material irradiation
IR		LNCMI	Laboratoire des champs magnétiques intenses
IR		LULI	Laboratory for the use of intense lasers
IR		METSA	National network for electronic microsocopy (transmission and atomic probe)
IR		Renard	National network of interdisciplinary RPE (paramagnetic electronic resonance)
IR		RENATECH	Network of nanotechnology centres
IR		RMN	Network of high-field NMR platforms
PROJET		ESS	European spallation source

42 www.enseignementsup-recherche.gouv.fr

Some relevant documents

ESFRI European Strategy Forum on Research Infrastructures

Technological Infrastructures – Importance for ESFRI projects

Brussels, January 2015

John Womersley
Chief Executive, Science and Technology Facilities Council (UK)
Chair of ESFRI

Some relevant documents

Technology Infrastructures

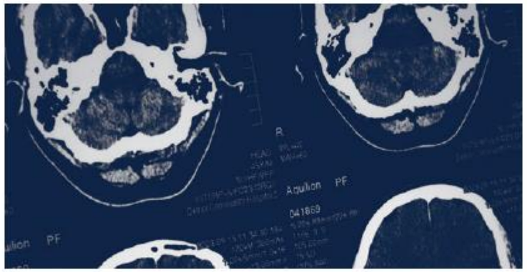
- The European network of capabilities in this area is a key to implementing new RI projects
- Enabling technologies include
  - Particle accelerators
  - Imaging detectors
  - Electronics
  - Magnets
  - Cryogenics
  - Lasers
  - Computing and data-intensive science

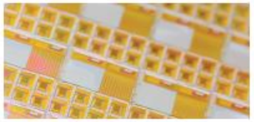
Some relevant documents

ACCELERATORS
FOR AMERICA'S FUTURE

THE BENEFITS OF PARTICLE ACCELERATORS FOR SOCIETY

Physicists have been inventing new types of accelerators to propel charged particles to higher and higher energies for more than 80 years. Today, scientists estimate that more than 30,000 accelerators are in operation around the world—in industry, in hospitals and at research institutions. The following benefits are just a few examples on a growing list of practical applications.





Top: *Electron beams make shrink wrap tougher and better for storing food and protecting other products. Photo courtesy of Fermilab.*

Bottom: *The semiconductor industry relies on accelerator technology to implant ions in silicon chips. Photo courtesy of Fermilab.*

Left: *Superconducting wire designed for particle accelerators enabled the creation of powerful magnets for MRI scanners. Photo courtesy of Fermilab.*

Semi-conductors: The semi-conductor industry relies on accelerator technology to implant ions in silicon chips, making them more effective in consumer electronic products such as computers, smart phones and MP3 players.

Clean air and water: Studies show that blasts of electrons from a particle accelerator are an effective way to clean up dirty water, sewage sludge and polluted gases from smokestacks.

Medical diagnostics: Accelerators are needed to produce a range of radioisotopes for medical diagnostics and treatments that are routinely applied at hospitals worldwide in millions of procedures annually.

Pharmaceutical research: Powerful X-ray beams from synchrotron light sources allow scientists to analyze protein structures quickly and accurately, leading to the development of new drugs to treat major diseases such as cancer, diabetes, malaria and AIDS.

Nuclear energy: Particle accelerators have the potential to treat nuclear waste and enable the use of an alternative fuel, thorium, for the production of nuclear energy.

Shrink wrap: Industry uses particle accelerators to produce the sturdy, heat-shrinkable film that keeps such items as turkeys, produce and baked goods fresh and protects board games, DVDs, and CDs.

DNA research: Synchrotron light sources allowed scientists to analyze and define how the ribosome translates DNA information into life, earning them the 2009 Nobel Prize in Chemistry. Their research could lead to the development of new antibiotics.

Cancer therapy: When it comes to treating certain kinds of cancer, the best tool may be a particle beam. Hospitals use particle accelerator technology to treat thousands of patients per year, with fewer side effects than traditional treatments.

www.acceleratorsamerica.org

U.S. DEPARTMENT OF ENERGY

Some relevant documents

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Accelerators for America's Future

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Oetzi, the Iceman, a unique and well preserved mummy from the end of the Neolithic period, discovered in the Alps in 1991. Radioisotope dating with ^{14}C established the age not only of the mummy but also of many often-minute artifacts associated with his equipment, clothing and food; and of flora and fauna at the site. *Image courtesy of the South Tyrol Museum of Archaeology, www.iceman.it*

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Accelerators for Security and Defense

4

Accelerators are central to a number of current proposals to develop cargo-inspection techniques.

now ubiquitous in the accelerator world. The current need is for development of a fieldable device for testing with defense and security partners.

Relativistic electron beams can generate high-power electromagnetic radiation at various frequencies for directed-energy-specific missions. Examples include free electron lasers, highly directional gamma-ray beams through Compton scattering, and millimeter-wave to terahertz radiation.

Free electron lasers can in principle achieve megawatt average power levels and optical beam quality and wavelengths required for security and defense purposes. In the mid-1990s, the highest average-power FEL had achieved only 11 watts. The Navy, as a user of the FEL at DOE's Thomas Jefferson National Accelerator Facility achieved 2.2 kW, and a subsequent upgrade in 2006 demonstrated 14kW at 1.6microns, a wavelength of particular interest to the Navy.

Free electron laser-based directed energy can expand to a wide range of missions. With increased efficiency and decreased weight, for example, FELs might serve as airborne platforms. With appropriate R&D, such goals appear achievable. Most such improvements would feed back to the basic science programs, potentially leading to lower-cost FEL systems and associated energy-recovery-linac light sources.

A megawatt-class FEL will require several critical accelerator R&D developments. Credible designs exist for two of these: a high-quality ampere-class electron gun and continuous wave injector that can operate for weeks, and ampere-class SRF cavities with higher-mode suppression using high-temperature superconductors. However, demonstration of these designs requires funding. At the conceptual level with simulations, researchers are currently exploring a third critical element, megawatt-level RF couplers. Complete system modeling is underway; but bringing these efforts to the point of comparison to the actual performance of, for example, future 100-kW prototypes, will require major efforts.

Computer animation of the field inside a superconducting accelerator resonator *Image courtesy of DESY*

Cargo Inspection and Interrogation

Security priorities of the last decade have turned to deterring the threat from subnational organizations. Some of these deterrents rely on identifying small quantities of special nuclear material in shipping containers through a signature reaction induced by radiation. Accelerators are a natural choice for producing well-characterized beams of radiation and are central to a number of current proposals to develop active interrogation techniques.

"Standing off" at a distance from the object under inspection by using electromagnetic radiation, including that from accelerators, is of significant interest in security and defense. The recent developments in terahertz radiation at FELs show potential for active interrogation with desirable standoff distances for cargo, improvised explosive devices and biological investigations.

Other interrogation techniques use neutron and proton beams ranging from tens of keV to tens of GeV with radiographic sensitivity to a variety of materials. Standoff with GeV protons to induce fission will require milliampere beam currents, high gradient and high temperature superconducting technologies, as well as compact devices that laser-driven accelerator technology may make possible.

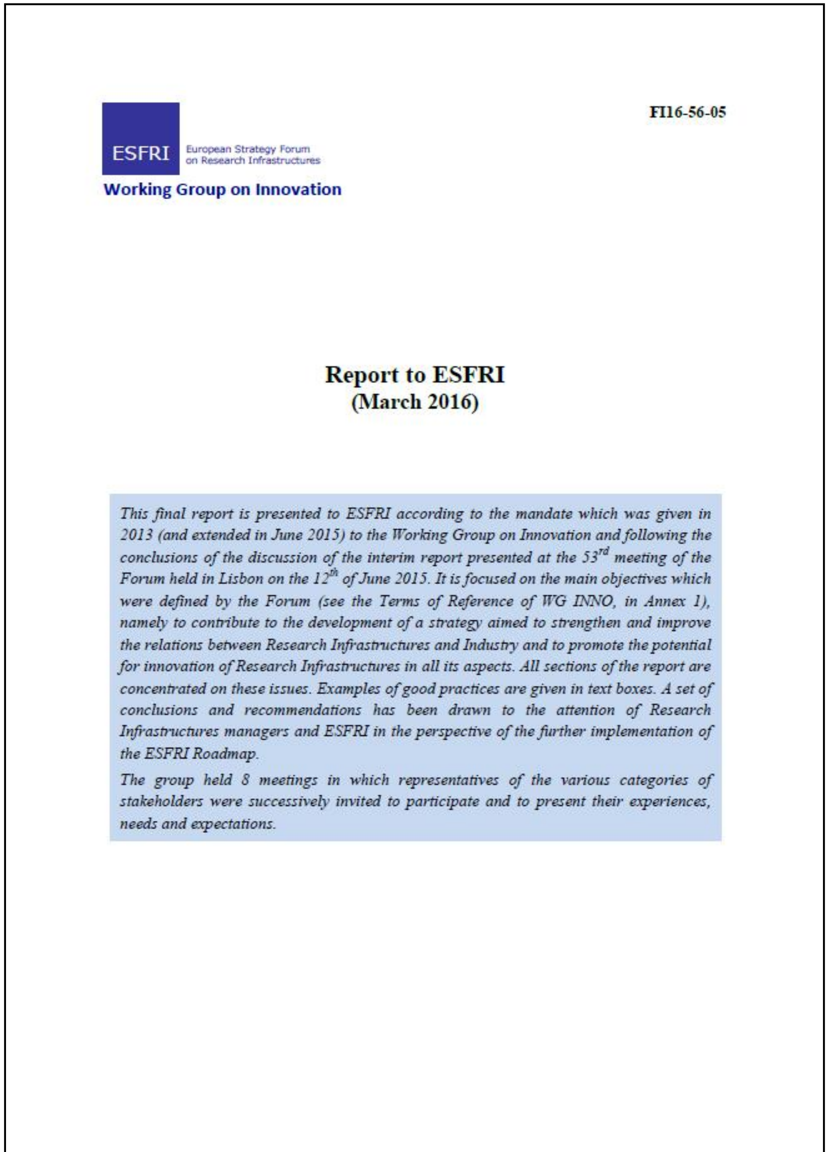
Researchers have proposed more exotic radiography using the low interaction rates of muons to achieve significant standoff. Such proposals would build on developments for muon colliders and neutrino factories, the subject of R&D for possible future basic-science facilities.

Replacement of radioactive sources and materials

In the 1970s, accelerator-based gamma-ray radiation therapy replaced radioisotope-based devices in the United States and Western Europe. However, in much of the rest of the world, ^{60}Co-based teletherapy units are still very common, with over 10,000 in service, according to the International Atomic Energy Agency.

62 *Accelerators for America's Future*

Some relevant documents



FI16-56-05

ESFRI European Strategy Forum on Research Infrastructures

Working Group on Innovation

Report to ESFRI
(March 2016)

This final report is presented to ESFRI according to the mandate which was given in 2013 (and extended in June 2015) to the Working Group on Innovation and following the conclusions of the discussion of the interim report presented at the 53rd meeting of the Forum held in Lisbon on the 12th of June 2015. It is focused on the main objectives which were defined by the Forum (see the Terms of Reference of WG INNO, in Annex 1), namely to contribute to the development of a strategy aimed to strengthen and improve the relations between Research Infrastructures and Industry and to promote the potential for innovation of Research Infrastructures in all its aspects. All sections of the report are concentrated on these issues. Examples of good practices are given in text boxes. A set of conclusions and recommendations has been drawn to the attention of Research Infrastructures managers and ESFRI in the perspective of the further implementation of the ESFRI Roadmap.

The group held 8 meetings in which representatives of the various categories of stakeholders were successively invited to participate and to present their experiences, needs and expectations.

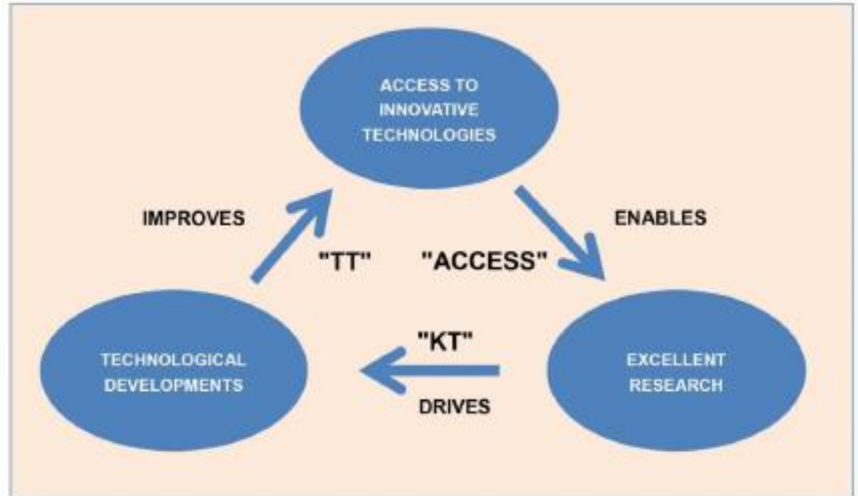


Figure 1. The virtuous circle of innovation

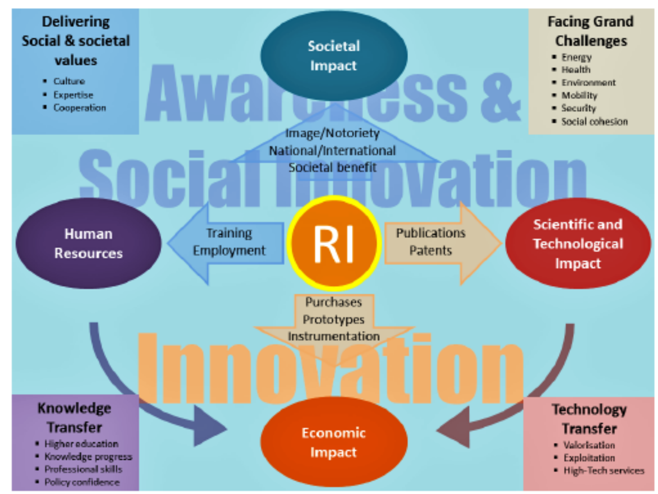


Figure 2. Interactions between RIs and their surrounding techno-scientific, socio-economic and societal environment

Some relevant documents

Current practices in industrial cooperation and innovation during the construction phase [from the survey of ESFRI Landmarks (2015)] – [2]

The "in-kind contribution" approach for building the ESS Neutrons

ESS will be built on a green-field site, a challenge which brings with it great potential, for society, as well as for science. Further scientific and technological advancements will be required to build this unique facility, which is the best of its kind. Within the construction of ESS, a significant amount will be R&D related, which has a high potential for innovation. The construction will generate growth and jobs, advance development and fuel innovation potential in the region and across the EU. With ESS being built as a collaborative project, the growth effect will be shared between the region (Öresund), the host countries (Sweden and Denmark) as well all as the ESS Partner Countries. Most of the necessary skills for its development need to be imported through in-kind contributions (IKC) from participating institutes and companies in the Member States. The IKC approach is intended to foster collaborations between national academia and industry, representing the entire supply chain.

While the management and integration of IKC is challenging for a project organisation, it also provides significant and highly desirable advantages for the ESS itself as well as the member countries. Access to frontier technology that enables the realisation of ESS would otherwise be unattainable, as well experienced technical and scientific personnel and access to unique production facilities and technologies. This is a very important socio-economic driver in that the construction of ESS fuels national innovation potential, competitiveness, and the national GDP of all of the Member States for the long term. This will increase each country's national and cross-national capacity and help create jobs and growth.

Industry as a supplier for the construction of the EUROPEAN XFEL

The development of one of the technologies that are at the heart of the European XFEL, i.e. the superconducting RF (radiofrequency) accelerator technology, was conducted in close collaboration with industry. The need to couple state of the art materials and processes, developed in a publicly-funded research environment, with mass production of components, only possible in an industrial environment, made TT a sine-qua-non condition for the implementation of large accelerator facilities. Over more than 20 years, the TESLA world-wide collaboration, with a very strong European component (led by DESY), in collaboration with industry, developed and refined the technologies allowing the production of 2 km of superconducting RF cavities of extremely demanding specifications. As a result of the DESY leadership in the development of superconducting RF, European industry is today a market leader and a likely supplier of projects using this technology in Europe and in other continents.

Further examples are in the electronics domain: (i) with the extension of the Micro-TCA.4 standard of telecommunications to electronics hardware for the control of complex equipment (such as the European XFEL accelerator), by the DESY controls division in collaboration with industrial partners (to be adopted by the European Spallation Source in Lund (SE) as well); and (ii) with consortia of academic and industrial laboratories in Germany, Switzerland and Italy developing sensors and data handling electronics for innovative MHz frame acquisition rate detectors, under the impulse from the European XFEL.

SKA's global cooperation

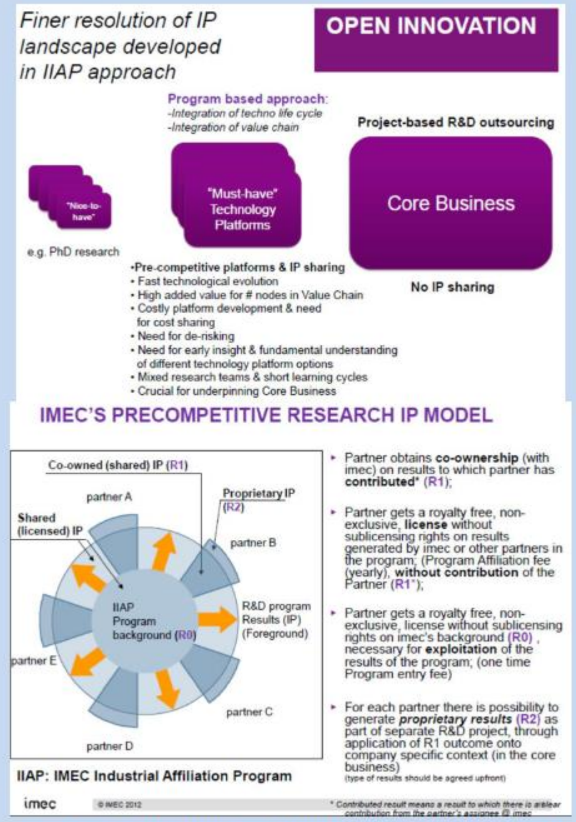
There are several ways in promotion of TT and KT along with the Square Kilometre Array (SKA) project development. For instance, the UK government has created the "Newton Fund Programme" which is administrated by the Royal Academy of Engineering, with the aim to develop science and innovation partnerships that promote the economic development and welfare of developing countries. In the same time, the South African government has launched the "SKA Youth into Science and Engineering project" which has awarded, since 2005 up to date, bursaries in the areas of astronomy, including PhDs, MScs and postdoctoral fellowships.

The University of Manchester, on whose site the SKA HQ is based, is developing a collaboration programme with Chinese Academy of Sciences for the exchange of scientists that will link the construction of FAST (Five hundred meter Aperture Spherical Telescope) in China with the development of the SKA project that will help China enhance its capabilities in development of key components of receivers for science observation. The extremely low noise amplifiers (LNAs), Phased Array Feeds (PAF) and analogue-to-digital converters (ADCs) are among those that have been identified. In addition, SKAO Office has also provided opportunities by offering secondment programme to several Member States, such as a three-year exchange programme with Japanese radio scientists, the yearly-based exchange programme with Chinese secondment on signal system modelling and outreach communications.

ESFRI WG INNO_REPORT TO ESFRI (MARCH 2016) 20

Open Innovation at IMEC

IMEC's experience is an example of a new "precompetitive space" created around the RI where "must-have technological platforms" are offered to industry in a working mode. Effectiveness is firstly due to the fact to be in the same place and work together on shared objectives. The aim is to join: PhD research; technology platforms and core business. This model focuses on bilateral customized "Industrial Affiliation Programmes" (IIAP) where the industrial partners rotate around IMEC rather than using a consortium approach. A specific precompetitive research IP model is used; noticeable is the power of using a unique IP fingerprint.



IMEC acts as a service, not for problem solving or TT stuffs, but for research programmes, properly funded. Also IMEC has "development on demand" but in such a case industry pays the full cost. Mainly big industries are involved, but also SMEs have been attracted by means of an enterprises network.

ESFRI WG INNO_REPORT TO ESFRI (MARCH 2016) 26

Eligibility

WHAT IS A LARGE RESEARCH INFRASTRUCTURE?

The principles that define a large research infrastructure can be stated as follows:

- it must be a tool or a device that has unique characteristics identified by the scientific community that makes use of it as required for conducting high-level research activities. The targeted scientific communities can be national, European, or international, according to the case;
- it must have governance that is identified, unified and effective, and strategic and scientific bodies for steering;
- it must be open to any research community that wants to use it, accessible based on peer-reviewed scientific excellence; it must therefore have suitable evaluation bodies;
- it can conduct its own research, and/or provide services to one (or several) communities of users that integrate the stakeholders of the economic sector. These communities can be present on the site, conduct work there on a one-off basis, or interact remotely.

Moreover, research infrastructures will in the future have to be able to:

- produce a multi-annual budget schedule as well as a consolidated budget that incorporates the full costs;
- make the data produced available, either immediately, or after an embargo period corresponding to the international practices of the field involved.

Work Packages Timeline

	YEAR 1												YEAR 2												YEAR 3					
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	M15	M16	M17	M18	M19	M20	M21	M22	M23	M24	M25	M26	M27	M28	M29	M30
Work Package 1 : Management, coordination and dissemination (CEA)																														
WP1.1 Project management (CEA)	M1.1	D1.1									M1.5	D1.4											M1.5	D1.4					M1.5	D1.4
WP1.2 Organization of the participation of industry (INFN)			M1.3	D1.2																				D1.6						
WP1.3 Administrative and financial project management (CEA)												D1.5												D1.5						D1.5
WP1.4 Communication and outreach activities (IFJ-PAN)		M1.2			M1.4						D1.3																			D1.7
Work Package 2 : Strategy (CNRS)																														
WP2.1 Key technological areas (CNRS)									M2.1															D2.1						
WP2.2 Global landscape (CEA)												M2.2												D2,2						
WP2.3 Accelerator and SC magnet TI sustainability (UU)																		M2.3												D2.3
Work Package 3 : Cooperation (DESY)																														
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WP4.2 Industry survey - magnet technologies (CEA)															M4.2															D4.2
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Figure 3: Gant chart of the project