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European Strategy Forum on Research Infrastuctures

ESFRI

Strategy Report on Research Infrastructures

ROADMAP **2018**

NuPECC LRP2017 Town Meeting,
Darmstadt January 11-13, 2017

ESFRI

- The European Strategy Forum on Research Infrastructures (ESFRI) was established 2002 with a mandate from the EU Council to:
  - *support a **coherent and strategy-led approach** to policy-making on research infrastructures in Europe*
  - *facilitate multilateral initiatives leading to the better use and development of research infrastructures*
- ESFRI brings together representatives of Ministers of the 28 Member States, 12 Associated States, and of the European Commission that are the decision makers and financers of the ESFRI Research Infrastructures
- Indicates strategies for the necessary major financial investment (~20 b€) and long term commitment for operation (~2 b€/year) (+15% of currrent effort)

- The Roadmap identifies ***new pan-European Research Infrastructures or major up-grades to existing ones***, corresponding to the needs of European research communities in the next 10 to 20 years, in all fields of Research

- The Roadmap also identifies the ***ESFRI Landmarks*** that are implemented projects leading in their domain and structuring the European and global landscape.

ESFRI

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Projects Landmarks

ROADMAP 2016

ESFRI PROJECTS

Domain	NAME	FULL NAME	ROADMAP ENTRY (YEAR)	OPERATION (YEAR)	LEGAL STATUS (AS OF 10 MARCH 2016)	CONSTRUCTION COSTS (M€)	OPERATIONAL ANNUAL BUDGET (M€/YEAR)
ENERGY	ECCSEL	European Carbon Dioxide Capture and Storage Laboratory Infrastructure	2008	2016	ERIC under preparation	80-120	1**
ENERGY	EU-SOLARIS	European SOLAR Research Infrastructure for Concentrated Solar Power	2010	2020*	ERIC under preparation	120	3-4
ENERGY	MYRRHA	Multi-purpose Hybrid Reactor for High Tech Applications	2010	2024*		NA	61,2
ENERGY	Windscanner	European WindScanner Facility	2010	2018*		45-60	8
ENVIRONMENT	ACTRIS	Aerosols, Clouds and Trace gases Research Infrastructure	**2016**	2025*		190	50
ENVIRONMENT	DANUBIUS-RI	International Centre for Advanced Studies on River-Sea Systems	**2016**	2022*		222	28
ENVIRONMENT	EISCAT_3D	Next generation European incoherent scatter radar system	2008	2021*		74	6
ENVIRONMENT	EPOS	European Plate Observing System	2008	2020*	ERIC under preparation	53	15
ENVIRONMENT	SIOS	Svalbard Integrated Arctic Earth Observing System	2008	2020*		80	2-3
HEALTH & FOOD	AnaEE	Infrastructure for Anlaysis and Experimentation on ecosystem	2010	2018*		200	2-3**
HEALTH & FOOD	EMBRC	European Marine Biological Resource Centre	2008	2016	ERIC under preparation	4,5	6
HEALTH & FOOD	EMPHASIS	European Infrastructure for multi-scale Plant Phenomics and Simulation for food security in a changing climate	**2016**	2020*		73	3,6
HEALTH & FOOD	ERINHA	European research infrastructure on highly pathogenic agents	2008	2018*		NA	NA
HEALTH & FOOD	EU-OPENSCREEN	European Infrastructure of Open Screening Platforms for Chemical Biology	2008	2018*	ERIC under preparation	7	1,2
HEALTH & FOOD	EuroBioImaging	European Research Infrastructure for Imaging Technologies in Biological and Biomedical Sciences	2008	2017*	ERIC under preparation	NA	1,55
HEALTH & FOOD	ISBE	Infrastructure for System Biology Europe	2010	2018*		30	7,2
HEALTH & FOOD	MIRRI	Microbial Resource Research Infrastructure	2010	2019*		6,2	1
PHYSICAL SCIENCES & ENGINEERING	CTA	Cherenkov Telescope Array	2008	2023*		297	20
PHYSICAL SCIENCES & ENGINEERING	EST	European Solar Telescope	**2016**	2026*		200	9
PHYSICAL SCIENCES & ENGINEERING	KM3NeT	KM3 Neutrino Telescope 2.0: Astroparticle & Oscillations Research with Cosmics in the Abyss	**2016**	2020*		92	3
SOCIAL & CULTURAL INNOVATION	E-RIHS	European Research Infrastructure for Heritage Science	**2016**	2022*		4	5
e-IRI							

*expected **for centralised services

ESFRI LANDMARKS

Domain	NAME	FULL NAME	ROADMAP ENTRY (YEAR)	OPERATION (YEAR)	LEGAL STATUS (AS OF 10 MARCH 2016)	CAPITAL VALUE (M€)	OPERATIONAL ANNUAL BUDGET (M€/YEAR)
ENERGY	JHR	Jules Horowitz Reactor	2006	2020*		1.000	NA
ENVIRONMENT	EMSO	European Multidisciplinary Seafloor and water-column Observatory	2006	2016	ERIC under preparation	108	4 (per site)
ENVIRONMENT	EURO-ARGO ERIC	European contribution to the International Argo Programme	2006	2014	ERIC, 2014	10	8
ENVIRONMENT	IAGOS	In-service Aircraft for a Global Observing System	2006	2014	AISBL, 2014	25	6
ENVIRONMENT	ICOS ERIC	Integrated Carbon Observation System	2006	2016	ERIC, 2015	48	24-35
ENVIRONMENT	LifeWatch	e-Infrastructure for Biodiversity and Ecosystem Research	2006	2016	ERIC under preparation	66	10
HEALTH & FOOD	BBMRI ERIC	Biobanking and Biomolecular Research Infrastructure	2006	2014	ERIC, 2013	170-220	3,5
HEALTH & FOOD	EATRIS ERIC	European Advanced Translational Research Infrastructure in Medicine	2006	2013	ERIC, 2013	500	2,5
HEALTH & FOOD	ECRIN ERIC	European Clinical Research Infrastructure Network	2006	2014	ERIC, 2013	1,5	2
HEALTH & FOOD	ELIXIR	A distributed infrastructure for life-science information	2006	2014	ELIXIR Consortium Agreement, 2013	125	95
HEALTH & FOOD	INFRAFRONTIER	European Research Infrastructure for the generation, phenotyping, archiving and distribution of mouse disease models	2006	2014	GmbH, 2013 ERIC under preparation	180	80
HEALTH & FOOD	INSTRUCT	Integrated Structural Biology Infrastructure	2006	2012	International Consortium Agreement, 2012 ERIC under preparation	285	25
PHYSICAL SCIENCES & ENGINEERING	E-ELT	European Extremely Large Telescope	2006	2024*	Programme of ESO	1.000	40
PHYSICAL SCIENCES & ENGINEERING	ELI	Extreme Light Infrastructure	2006	2018*	AISBL, 2013 ERIC under preparation	850	90
PHYSICAL SCIENCES & ENGINEERING	EMFL	European Magnetic Field Laboratory	2008	2014	AISBL, 2015	170	20
PHYSICAL SCIENCES & ENGINEERING	ESRF UP	Phase I Phase II: Extremely Brilliant Source	2006 **2016**	2015 2022*	Programme of ESRF	180 150	82
PHYSICAL SCIENCES & ENGINEERING	European Spallation Source ERIC	European Research Infrastructure Consortium	2006	2022*	ERIC, 2015	1.843	140
PHYSICAL SCIENCES & ENGINEERING	European XFEL	European X-Ray Free-Electron Laser Facility	2006	2017*	GmbH, 2009	1.490	115
PHYSICAL SCIENCES & ENGINEERING	FAIR	Facility for Antiproton and Ion Research	2006	2022*	GmbH, 2010	1.262	234
PHYSICAL SCIENCES & ENGINEERING	HL-LHC	High-Luminosity Large Hadron Collider	**2016**	2026*	Programme of CERN	1.370	100
PHYSICAL SCIENCES & ENGINEERING	ILL 20/20	Institut Max von Laue-Paul Langevin	2006	2020	Programme of ILL	62	92
PHYSICAL SCIENCES & ENGINEERING	SKA	Square Kilometre Array	2006	2020*	SKAO, 2011	650	75
PHYSICAL SCIENCES & ENGINEERING	SPIRAL2	Système de Production d'Ions Radioactifs en Ligne de 2e génération	2006	2016	Programme of GANIL	110	5-6
SOCIAL & CULTURAL INNOVATION	CESSDA	Consortium of European Social Science Data Archives	2006	2013	Norwegian limited company, 2013 ERIC under preparation	NA	1,9
SOCIAL & CULTURAL INNOVATION	CLARIN ERIC	Common Language Resources and Technology Infrastructure	2006	2012	ERIC, 2012	NA	12
SOCIAL & CULTURAL INNOVATION	DARIAH ERIC	Digital Research Infrastructure for the Arts and Humanities	2006	2019*	ERIC, 2014	4,3	0,6
SOCIAL & CULTURAL INNOVATION	ESS ERIC	European Social Survey	2006	2013	ERIC, 2013	NA	6
SOCIAL & CULTURAL INNOVATION	SHARE ERIC	Survey of Health, Ageing and Retirement in Europe	2006	2011	ERIC, 2011	110	12
e-IRI	PRACE	Partnership for Advanced Computing in Europe	2006	2010	AISBL, 2010	500	120

*expected NA = Not Available

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ESFRI PROJECTS

The ESFRI Projects listed in **Part 1** are individually described in the following pages. They were selected for scientific excellence and maturity and represent strategic objectives for strengthening the European Research Infrastructure system.
Fifteen projects were listed in previous editions of the ESFRI Roadmap – nine in the 2008 update, and six in the 2010 update. Five new entries and one reoriented project integrate the Roadmap 2016. They were selected among the 20 eligible proposals through the evaluation procedure outlined in **Part 1**.
The ESFRI Projects have a maximum term of "residency" on the Roadmap of 10 years. After that term the fully implemented projects may become Landmarks. Non-implemented projects leave the Roadmap: if desired they can be re-submitted with a revised programme and will compete with other new projects.

10 years maximum Term for status of ESFRI-Project

Scientific and maturity evaluation

Pan-European added value

Hearings

Monitoring

Assessment

EPOS

European Plate Observing System

Description

The European Plate Observing System (EPOS) aims at creating a pan-European infrastructure to monitor and unravel the dynamic and complex solid Earth System, by integrating the diverse and advanced research facilities and resources for solid Earth science and relying on new e-science opportunities. EPOS will enable innovative multidisciplinary research for a better understanding of the Earth's physical and chemical processes that control earthquakes, volcanic eruptions, ground instability and tsunami as well as the processes driving tectonics and Earth's surface dynamics. Through integration of data, models and facilities, EPOS will allow the Earth science community to make a step change in developing new concepts and tools for key answers to scientific and socio-economic questions concerning geo-hazards and geo-resources as well as Earth sciences applications to environment and to human welfare.

Background

Solid Earth science is concerned with the internal structure and dynamics of planet Earth, from the inner core to the surface; it deals with physical and chemical processes covering wide temporal and spatial scales, from microseconds to billions of years and from nanometres to thousands of kilometres. Integration of data and services from different disciplines in Earth science is an essential step to unravel and monitor these processes with the final goal of forecasting their impact on the environment. Indeed, the solid Earth science community has chosen to establish an all-encompassing framework including all the different solid Earth disciplines: seismology, near-fault observatories, geodetic data and products, volcanic observatories, satellite data and products, geomagnetic observatories, anthropogenic hazards, geological information and modelling, multi-scale laboratories and geo-energy test-beds for low-carbon energy.

EPOS is developing such a holistic, sustainable, multidisciplinary research platform to provide coordinated access to harmonized and quality controlled data from diverse Earth science disciplines, together with tools for their use in analysis and modelling. EPOS brings together 25 European nations and combine national Earth science facilities, the associated data and models together with the scientific expertise into one integrated delivery system for the solid Earth. This infrastructure will allow the Earth sciences to achieve a step change in our understanding of the planet; it will enable us to prepare for geo-hazards and to responsibly manage the subsurface for infrastructure development, waste storage and the use of Earth's resources.

Steps for implementation

The EPOS implementation phase builds on the achievements of the EPOS Preparatory Phase and will last from 2015 to 2019. During this phase two key outcomes will be achieved: the implementation of the community and integrated services – Thematic Core Services (TCS) and Integrated Core Services (ICS) – and the legal establishment of the EPOS European Research Infrastructure Consortium (ERIC). EPOS will build the new research platform by ensuring sustainability, governance and integration within the whole EPOS delivery framework of the community services (TCS), by developing the integrated services (ICS) for interoperability and data management, by creating optimal conditions for the central coordination as well as designing the access to distributed computational resources, and by ensuring long-term financial and legal sustainability through the harmonization of the EPOS research infrastructure with national priorities and strategies.

With an ERIC to be located in Rome (Italy), EPOS will provide an opportunity for Europe to maintain world-leading European Earth sciences and will represent a model for pan-European federated infrastructure.

A long-term plan for the integration of national and transnational facilities and resources for solid Earth science

TYPE: distributed
COORDINATING COUNTRY: IT
PROSPECTIVE MEMBER COUNTRIES: CH, CZ, DK, EL, ES, FI, FR, IE, IS, IT, NL, NO, PL, PT, RO, SI, SK, TR, UK

PARTICIPANTS: AT, BE, BG, DE, HU, SE

TIMELINE
- **ESFRI Roadmap entry:** 2008
- **Preparation phase:** 2010-2014
- **Implementation phase:** 2015-2019
- **Construction phase:** 2019-2022
- **Operation start:** 2020

ESTIMATED COSTS
- **Capital value:** 500 M€
- **Preparation:** 4,5 M€
- **Implementation:** 32 M€
- **Construction:** 53 M€
- **Operation:** 15 M€/year

HEADQUARTERS
Istituto Nazionale di Geofisica e Vulcanologia-INGV
Rome
Italy

WEBSITE
http://www.epos-eu.org/

ITALY

WWW.ESFRI.EU

An infrastructure for heritage interpretation, preservation, documentation and management

TYPE: distributed
COORDINATING COUNTRY: IT
PROSPECTIVE MEMBER COUNTRIES: BE, CZ, DE, EL, ES, FR, HU, IT, NL, PT, UK

PARTICIPANTS: BG, BR, CY, DK, IE, IL, PL, SE, SI

TIMELINE
- **ESFRI Roadmap entry:** 2016
- **Preparation phase:** 2016-2019
- **Construction phase:** 2020-2021
- **Operation start:** 2022

ESTIMATED COSTS
- **Capital value:** Not Available
- **Preparation:** 2 M€/year
- **Construction:** 4 M€ (Central Hub)
- **Operation:** 5 M€/year

HEADQUARTERS
Proposed in Florence, Italy. To be finalized in the Preparatory Phase with possibly the involvement of ICCROM-International Centre for the Study of the Preservation and Restoration of Cultural Property

WEBSITE
www.e-rihs.eu

ITALY

E-RIHS

European Research Infrastructure for Heritage Science

Description

The European Research Infrastructure for Heritage Science (E-RIHS) will support research on heritage interpretation, preservation, documentation and management. It will comprise: E-RIHS Headquarters and National Hubs, fixed and mobile national infrastructures of recognized excellence, physically accessible collections/archives and virtually accessible heritage data. Both cultural and natural heritage are addressed: collections, buildings, archaeological sites, digital and intangible heritage. E-RIHS will provide state-of-the-art tools and services to cross-disciplinary research communities advancing understanding and preservation of global heritage. It will provide access to a wide range of cutting-edge scientific infrastructures, methodologies, data and tools, training in the use of these tools, public engagement, access to repositories for standardized data storage, analysis and interpretation. E-RIHS will enable the community to advance heritage science and global access to the distributed infrastructures in a coordinated and streamlined way.

Background

Heritage Science has brought about the need of structuring the net of infrastructures operating throughout Europe. Fragmentation, duplication of efforts, isolation of small research groups put at risks the competitive advantage of European heritage science research, promoted so well by the unique cultural heritage. The long-term tradition of this field of research, the ability to combine with innovation, and the integration promoted by EU-funded projects such as EU-ARTECH, CHARISMA and IPERION CH in conservation science, and ARIADNE in archaeology represent the background of E-RIHS.

E-RIHS exploits the synergy of the cooperation among the academy, research centers and cultural institutions. The global lead that the EU holds in this research field, so precariously supported by a combination of national and EU measures, requires a joint and resolved effort. This has been fully recognized by the European Union with the continuous and reiterated support of initiatives aimed at integrating existing Heritage Science infrastructures, as well as, with a focus on Member States' national research programs, the JPI on Cultural Heritage, coordinating efforts of 17 EU national funding bodies supporting heritage science. The enthusiastic reviews of these initiatives testify the success of their action to advance knowledge and to establish a research community, acknowledged as "advanced" in official EU documents concerning conservation, or quickly growing in the field of archaeology as shown by the performance indicators of the relevant project ARIADNE.

This demonstrates beyond any doubt both the scientific and the socio-economic importance connected with Heritage Science: it is a sector and a research community that has achieved the maturity necessary to make the leap towards a permanent European Research Infrastructure that will impact broadly on society and economy.

Steps for implementation

E-RIHS is expected to lead a Preparatory Phase in the years 2016-2019 which will be used to address legal status and governance/management organization. This will lead to application to ERIC (or to other suitable legal form). The establishment of a legal structure and governance and the refinement of the business plan for long-term sustainability will be the three most important deliverables, together with demonstrators of users access as implemented by the consortium availing of the existing infrastructure projects.

Preliminary work will also be done in the framework of the H2020 IPERION-CH project started in May 2015.

E-RIHS will be launched as a stand-alone RI in 2020. Further developments are planned for connecting and including partners and facilities outside EU, and gradually reaching the status of a global distributed research infrastructure.

CTA
Cherenkov Telescope Array

Description
The Cherenkov Telescope Array (CTA) will be an advanced facility for ground-based very high-energy gamma-ray astronomy. With two sites, in the southern and northern hemispheres, it will extend the study of astrophysical origin of gamma-rays at energies of a few tens of GeV and above, and investigate cosmic non-thermal processes. CTA will provide the first complete and detailed view of the universe in this part of the radiation spectrum and will contribute towards a better understanding of astrophysical and cosmological processes, such as the origin of cosmic rays and their role in the Universe, the nature and variety of particle acceleration around black holes and the ultimate composition of matter and physics beyond the Standard Model.

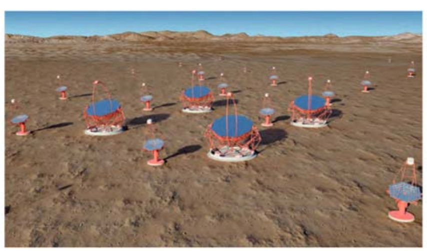
Background
High-energy gamma-rays probe a non-thermal Universe because, apart from the Big Bang, there is nothing hot enough in the known Universe to emit such gamma-rays. These gamma-rays can be generated when highly relativistic particles collide with ambient gas, or interact with photons and magnetic fields (bottom-up process). By studying their energy and flux spectrum, it is possible to trace these cosmic rays and electrons in distant regions of our own Galaxy or even in other galaxies. High-energy gamma-rays can also be produced in a top-down fashion by decays of heavy particles such as the hypothetical dark matter particles. Therefore, gamma-rays provide a window to the discovery of the nature and constituents of dark matter, relics which might be left over from the Big Bang.

The present generation of imaging atmospheric Cherenkov telescopes (H.E.S.S., MAGIC and VERITAS) has in recent years opened the realm of ground-based gamma ray astronomy in the energy range above a few tens of GeV. The Cherenkov Telescope Array will explore our Universe in depth in Very High Energy (VHE, E>10 GeV) gamma-rays and investigate cosmic non-thermal processes, in close cooperation with observatories operating at other wavelength ranges of the electromagnetic spectrum, and those using other messengers such as cosmic rays and neutrinos.

The CTA Research Infrastructure will consist of arrays of Cherenkov telescopes that will be built at two separate sites, one in the southern hemisphere with wide gamma-ray energy range and high resolution to cover the plane of the Milky Way, and the second in the northern hemisphere specialised for lower energies, which will focus on extragalactic and cosmological objects. The array will allow the detection of gamma-ray induced cascades over a large area on the ground, increasing the number of detected gamma rays dramatically, while at the same time providing a much larger number of views of each cascade. The design foresees an improvement in sensitivity of a factor of 5-10 in the current very high-energy gamma ray domain from – 100 GeV to some 10 TeV – and an extension of more than three orders of magnitude in the accessible energy range, up to above 100 TeV.

Steps for implementation
CTA is included in the ESFRI Roadmap since 2008 and it is a priority for scientific communities in astronomy at an international level. It represents one of the "Magnificent Seven" of the European strategy for Astroparticle Physics published by ASPERA, and highly ranked in the strategic plan for European astronomy of ASTRONET. In addition, CTA is a recommended project for the next decade in the US National Academies of Sciences Decadal Review.

After a 5-years preparation phase, CTA is now in a pre-construction phase and is about to transit to the implementation phase. On July 2015, the CTA Resource Board decided to enter into detailed contract negotiations for hosting CTA on the European Southern Observatory (ESO) Paranal grounds in Chile and at the Instituto de Astrofísica de Canarias (IAC), Roque de los Muchachos Observatory in La Palma, Spain. The CTA facility will be operational as a proposal-driven observatory, with a Science Data Centre providing transparent access to data, analysis tools, and user training.



Cherenkov Telescope Array for High-Energy Gamma-Ray Astronomy to probe a non-thermal Universe

TYPE: distributed
COORDINATING COUNTRY: DE

PARTICIPANTS: AM, AR, AT, AU, BG, BR, CA, CH, CL, CZ, DE, EL, ES, FI, FR, HR, IE, IN, IT, JP, MX, NA, NL, NO, PL, SE, SI, TH, UA, UK, US, ZA

TIMELINE
- **ESFRI Roadmap entry:** 2008
- **Preparation phase:** 2011-2016
- **Construction phase:** 2017-2023
- **Pre-operation start:** 2019
- **Operation start:** 2023
- **Legal status:** CTAO gGmbH, 2014

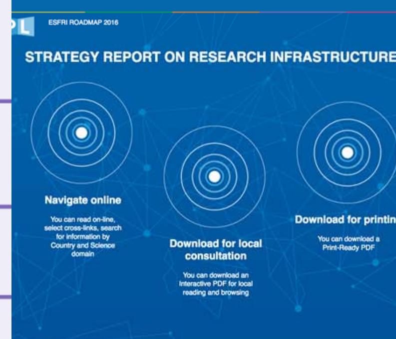
ESTIMATED COSTS
- **Capital value:** 400 M€
- **Preparation:** 8 M€/year
- **Construction:** 297 M€
- **Operation:** 20 M€/year

HEADQUARTERS
Cherenkov Telescope Array Observatory, gGmbH
Heidelberg
Germany

WEBSITE
https://portal.cta-observatory.org

GERMANY

WWW.ESFRI.EU



An advanced telescope for observing the Sun and its magnetic activity

TYPE: single-sited
COORDINATING COUNTRY: ES
PROSPECTIVE MEMBER COUNTRIES: ES, SE, UK

PARTICIPANTS: AT, CH, CZ, DE, FR, HR, HU, IT, NL, NO, PL, SK

TIMELINE
- **ESFRI Roadmap entry:** 2016
- **Preparation phase:** 2011-2019
- **Construction phase:** 2019-2025
- **Operation start:** 2026

ESTIMATED COSTS
- **Capital value:** Not Available
- **Preparation:** 10 M€
- **Construction:** 200 M€
- **Operation:** 9 M€/year

HEADQUARTERS
Instituto de Astrofísica de Canarias
Canary Islands
Spain

WEBSITE
http://www.est-east.eu/

SPAIN

EST
European Solar Telescope

Description
The European Solar Telescope (EST) is a 4-metre class telescope dedicated to study the fundamental processes in the Sun that control the solar atmosphere and its activity and the physical conditions in the heliosphere. EST will be optimized for high-resolution multi-wavelength simultaneous multi-instrument observations of the photosphere and chromosphere, as well as magnetic structures therein. One aim is to address the still unresolved and difficult question concerning the emergence of magnetic fields at the solar surface and transfer of magnetic and kinetic energy from subsurface layers to the solar atmosphere. This is the key question for understanding how the magnetic field is controlling the solar atmosphere and its activity. As the Sun is the only star at which photospheric and chromospheric features can be resolved, these observations will be of astrophysical wide relevance. Understanding the interaction of plasmas with magnetic fields has many technological application, e.g. in fusion nuclear reactors. Space missions are also tributary of data from ground solar telescopes.

Background
The solar physics community was involved in the development of the project from the beginning: i) creation of the EAST consortium, ii) elaboration of the conceptual design study, iii) I3 Trans-National Access network SOLARNET and iv) GREST project. The solar astronomy community is organized through SOLARNET and ASTRONET and operates with success, since the last decades, a set of national observing facilities and infrastructures on the Canary Islands including the Swedish Solar Telescope, the DOT, the VTT, GREGOR and THEMIS, most of which are approaching the end-of life stage. These national observatories shall be decommissioned or reoriented to become test facilities for detector development or to educational programmes, and the research programme shall concentrate to the EST. Key elements of the landscape are the space missions, in particular the ESA Solar Orbiter programme to be launched in 2018, and the US Daniel K. Inouye Solar Telescope (DKIST, formally the Advanced Technology Solar Telescope ATST), currently being built in Hawaii. DKIST is an asymmetric telescope with an observation programme concentrated on the Sun's corona and linked with space missions. EST has the same diameter (4m) but it is symmetric and optimized to detect light polarization as it is mandatory for the study of the emergence of magnetic fields at the solar surface and transfer of magnetic and kinetic energy from subsurface layers to the solar atmosphere. A significant advance can be achieved by obtaining observations, of the lower/cooler part of the solar atmosphere, with greatly improved spatial and temporal resolutions. The behaviour of the solar atmosphere in response to the input of magnetic energy is then observable with space instrumentation. The combination of space and ground-based instrumentation will allow a throughout comprehension of the solar magnetic dynamics.

Steps for implementation
EST will be built in the Canary Islands, where the current aging telescopes are already situated. This will give continuity and increase the importance of the scientific parks existing at present in the islands. Operation of the telescope will progressively implement "queue-mode" observing, which is standard for night-time telescopes, allows optimisation of the observations, and does not require on-site presence of the beneficiary. 30% of the observing time will be through open calls for proposals, and the open access data policy (after a one year proprietary period) allows access to the whole interested scientific community. Siting will be decided between the Tenerife or Roque de los Muchachos both at 2.400 m of altitude in the Canary islands along with sea-level and mainland facilities including the TOSC (Telescope Operation and Science Center) to steer the operation of the EST and the Science Data Center in Germany, to provide data storage and access to the solar physics community.

KM3NeT 2.0

KM3 Neutrino Telescope 2.0: Astroparticle & Oscillations Research with Cosmics in the Abyss

A network of neutrino telescopes in the Mediterranean Sea for astroparticle and oscillations research

Description

The KM3 Neutrino Telescope 2.0 (KM3NeT 2.0) intends to examine astrophysical objects by detecting their high-energy neutrino emission and to investigate neutrino properties by measuring neutrinos produced through cosmic-ray interactions in the atmosphere. The research infrastructure comprises two deep-sea installations with shore stations, located off shore Toulon, France and Capo Passero, Italy. Data are processed and stored on three main computing centres: CCIN2P3-Lyon (CNRS), CNAF (INFN) and the ReCaS infrastructure. The deep-sea installations will also feature user ports for earth and sea sciences, thus offering unique opportunities for interdisciplinary research for continuous, real-time measurements, for example for marine biology, oceanography or environmental sciences.

Background

Neutrinos are unique messengers from the most violent, highest-energy processes in our Galaxy and far beyond. Their measurement will allow for new insights into the mechanisms and processes that govern the non-thermal Universe and will complement high-energy gamma ray astronomy and cosmic ray studies. Neutrinos are extremely light particles and electrically neutral thus travelling in straight lines from their origin to the Earth. They interact weakly and thus can escape dense regions where they are generated. They are inevitably produced in any environment containing protons or nuclei at the typical energies observed in cosmic rays. Neutrinos are ideal for observing the highest-energy phenomena in the Universe and, in particular, pinpointing the hitherto unknown sources of cosmic rays.

The IceCube neutrino telescope at the South Pole has detected a flux of cosmic neutrinos which is assumed to have its origin in extragalactic sources. They might be the same sources that produce the flux of the highest energy gamma rays observed, for instance, by H.E.S.S..

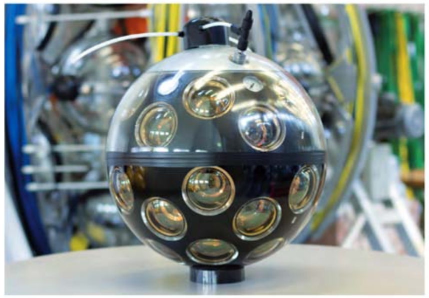
The high-energy neutrino part of KM3NeT 2.0 (ARCA) will detect the neutrino flux reported by IceCube and will provide essential data concerning its origin, energy spectrum and flavour composition. Due to its location in the Northern hemisphere, the ARCA information will be complementary to the IceCube measurements.

The ANTARES experiment, which represents the proof of concept for KM3NeT, has demonstrated that the instrumentation of neutrino telescopes has the capability of studying neutrino oscillations. Therefore, the second major objective of KM3NeT 2.0 (ORCA) is to examine the properties of neutrinos and to determine the neutrino mass hierarchy. The ORCA detector will provide in addition sensitivity to low-mass dark matter and possibly also to the composition of the earth's interior via neutrino tomography.

KM3NeT 2.0 addresses neighbouring disciplines like astrophysics (sources of cosmic rays, high-energy neutrino astronomy), particle physics (neutrino oscillations, search for exotic particles) and cosmology (dark matter), but has also strong connections to Earth and Sea Sciences. To measure deep-water parameters with cabled sensors will add a novel option to the toolbox of oceanographers and marine biologists.

Steps for implementation

KM3NeT appeared on the ESFRI Roadmap in 2006 for the first time. The phase one of the project has led to the engineering of the modular detector and to construction of the final prototypes. The resubmission of KM3NeT 2.0 redefines the previous project and adopts it to the scientific and technological progress which has been made in the last years. It is effectively under construction as a first set of the new detectors is being deployed at this time.



TYPE: distributed
COORDINATING COUNTRIES: NL
PROSPECTIVE MEMBER COUNTRIES: EL, FR, IT, NL

PARTICIPANTS: CY, DE, ES, IE, PL, RO, UK

TIMELINE
- ESFRI Roadmap entry: 2006, 2016
- Preparation phase: 2008-2014
- Construction phase: 2016-2020
- Operation start: 2020

ESTIMATED COSTS
- Capital value: 137 M€
- Preparation: 45 M€
- Construction: 92 M€
- Operation: 3 M€/year

HEADQUARTERS
KM3NeT-HQ
Amsterdam Science Park
Amsterdam
The Netherlands

WEBSITE
http://www.km3net.org/

THE NETHERLANDS

WWW.ESFRI.EU

Periodic monitoring for confirmation of status of ESFRI-Landmark

Scientific impact and good management evaluation

GLOBAL dimension
GLOBAL access
GLOBAL data access

Possible evolution towards GRI

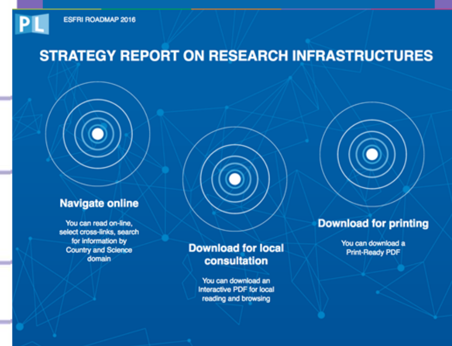
PL

ESFRI LANDMARKS

The ESFRI Landmarks listed in **Part 1** are individually described in the following pages. These are former ESFRI Projects that have reached the implementation stage and are now established as major elements of competitiveness of the European Research Area.
Most of the Landmarks were first identified as ESFRI Projects in the Roadmaps 2006 and 2008. Two Landmarks were selected among the 20 eligible proposals through the evaluation procedure outlined in **Part 1** recognizing that their implementation is underway.
The ESFRI Landmarks need continuous support for successful completion, operation and upgrade in line with the optimal management and maximum return on investment criteria. Periodic review of the Landmarks will be carried out by ESFRI in order to verify the continuous fulfilment of the reference role in their respective domains.

Astronomy

WWW.ESFRI.EU



SKA
Square Kilometre Array

The largest radio telescope on Earth to explore the Universe and the origins of life

TYPE: distributed
COORDINATING COUNTRY: UK
MEMBER COUNTRIES: AU, CN, IN, IT, NL, NZ, UK, ZA

PARTICIPANTS/ENTITY: CA, ES, FR, MT, PT, SE, US, (ESO)

TIMELINE
- ESFRI Roadmap entry: 2006
- Preparation phase: 2008-2017
- Construction phase: 2018-2023
- Operation start: 2020
- Legal status: SKAO, 2011

ESTIMATED COSTS
- Capital value: 650 M€
- Operation: 75 M€/year

HEADQUARTERS
Jodrell Bank Observatory
Lower Withington
United Kingdom

WEBSITE
http://www.skatelescope.org

Description
The Square Kilometre Array (SKA) is a global effort to build the largest radio telescope on Earth, with eventually over one million square metres of collecting area. SKA will be able to look back into the furthest reaches of the cosmos to study the first structures in the Universe, helping to understand some of the most fundamental questions in physics, as well as probing the nature of gravity and cosmic magnetism and exploring the origins of life itself.

The SKA Organisation (SKAO), that became a legal entity in 2011, coordinates the design and the policy making for the SKA. In 2012, the members of the SKAO agreed on a dual site location for the SKA telescope in the deserts of South Africa and Australia, while the site for the Headquarters, to be established in the UK, was decided in 2015. The construction phase will take place from 2018 to 2023 – with early science in 2020 – providing an operational array of telescopes capable of carrying out some of the key science set by the community, before scaling up to the full SKA by the late 2020s.

Activity
The first phase of SKA will use ~200 dishes and ~130.000 low-frequency antennas that will enable astronomers to monitor the sky in unprecedented detail, and to survey the entire sky much faster than any system currently operating. The total collecting area of the full SKA will be well over one square kilometre, or 1.000.000 square metres, obtained with thousands of mid- to high-frequency steerable dishes, each of 15 metres in diameter, in South Africa and around half a million digitally-steerable low-frequency antennas in Australia. The SKA will truly be at the forefront of scientific research with a broad range of exciting science such as observing pulsars and black holes to detect the gravitational waves predicted by Einstein's General Relativity, looking at how the very first stars and galaxies formed after the Big Bang, better than any experiment so far, helping scientists to investigate the nature of the mysterious dark energy, trying to understand the vast magnetic fields which permeate the cosmos, and exploring the origins of life itself.
Moreover, the SKA will challenge information technology developments at the vanguard of the emerging era of Big Data and High Performance Computing. The data analysis software needed will leap a generation in sophistication. The SKA is expected to become the largest public, research data project in the world, producing in its first phase, raw data totalling more than five times the estimated global internet traffic of 2015.

Impact
To date, there are ten nations funding the SKA with membership across five continents: Australia, Canada, China, India, Italy, the Netherlands, New Zealand, South Africa, Sweden and the UK, which represent about 40% of the world's population. Over 100 research and industrial organisations are working together to design the initial phase of the SKA with over 500 researchers and engineers involved around the world. Impact is foreseen through the hosting the SKA Headquarters and telescopes, by increasing activity in pre-construction at the telescope sites in South Africa and Australia, and by involving industry for developing technology solutions in meeting the challenges of SKA.
The SKA project is also expected to generate substantial innovation in key technology areas such as Information and Communication Technology (ICT) and renewable energy as well as to impact on knowledge transfer and human capital development.
A high profile project like SKA truly excites scientists, and the general and non-specialist public worldwide. In fact, astronomy appeals to our natural curiosity, but it is also a stepping-stone to many other fields of science and technology development, including engineering, aerospace, mathematics and the natural sciences, all of which will have profound impact on our future economy and society.

UNITED KINGDOM

E-ELT
European Extremely Large Telescope

The world's biggest eye on the sky to revolutionise our perception of the Universe

TYPE: single-sited
COORDINATING ENTITY: ESO
MEMBER COUNTRIES: AT, BE, CH, CZ, DE, DK, ES, FI, FR, IT, NL, PL, PT, SE, UK

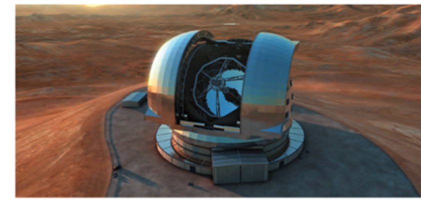
PARTICIPANTS: BR

TIMELINE
- ESFRI Roadmap entry: 2006
- Preparation phase: 2006-2012
- Construction phase: 2014-2024
- Operation start: 2024

ESTIMATED COSTS
- Capital value: 1.000 M€
- Operation: 40 M€/year

HEADQUARTERS
ESO
Garching
Germany

WEBSITE
http://www.eso.org/public/teles-instr/e-elt/



Description
The European Extremely Large Telescope (E-ELT) is a revolutionary new ground-based telescope developed by ESO for the advancement of astrophysical knowledge, allowing detailed studies of objects including planets around other stars, the first objects in the Universe, super-massive black holes, and the nature and distribution of the dark matter and dark energy which dominate the Universe. Equipped with a 39-metre main mirror, the E-ELT will be the largest optical/near-infrared telescope in the world: the world's biggest eye on the sky.

The E-ELT is an integral part of ESO, the EIROforum organisation operating facilities at five sites. The E-ELT programme was approved in 2012 and green light for construction was given at the end of 2014. It will be located at Cerro Armazones, a 3060-metres high mountain in the central part of Chile's Atacama Desert, about 20 kilometres from Cerro Paranal, home of ESO's Very Large Telescope (VLT). The E-ELT first observation is planned for 2024.

Activity
The telescope's primary mirror will be almost half the length of a soccer pitch in diameter and will gather 15 times more light than today's largest optical telescopes. The optical design comprises a three-mirror anastigmat with two flat folding mirrors providing the adaptive optics to correct for the turbulent atmosphere, giving unprecedented image quality. One is supported by more than 6.000 actuators operating at a frequency of 1.000 Hz. The primary mirror consists of 798 hexagonal segments, each 1,4 metres wide. The secondary mirror will have a diameter of 4 metres. The telescope will have several science instruments, with switching from one instrument to another within minutes. The ability to observe over a wide range of wavelengths from the optical to mid-infrared will allow scientists to exploit the telescope's size to the fullest extent.
Science with the E-ELT covers many areas of astronomy – from the Solar System to extra-solar planets, from nearby galaxies to the furthest observable objects at the edge of the visible Universe, from fundamental physics to cosmology. They include discovering and characterising planets and proto-planetary systems around other stars, resolving stellar populations in a representative sample of the Universe, the study of the physical processes that form and transform galaxies across cosmic time, the discovery and identification of distant type Ia supernovae and constraining dark energy by directly observing the global dynamics of the Universe, as well as searching for possible variations over cosmic time of fundamental physical constants.

Impact
The E-ELT is a major technological challenge and triggers industrial interest and preparedness to deliver extraordinary performance, as it occurred to previous ESO projects (notably the VLT). ESO has since many years devolved its instrumentation programme so that science instruments are largely designed and built by national institutes, often in collaboration with industry. In this model, national facilities cover the human resources cost against compensation in guaranteed observing time. The E-ELT will employ advanced technologies and engineering solutions in a number of areas, from gigantic, lightweight high-precision structures, opto-mechanical systems, optical design and control systems. Many of these technologies will be applicable to other areas of technology development. As regards short-term benefits, these are found in spin-off technologies and the inspirational and educational aspects, strengthening the scientific and engineering recruitment base and public awareness of science.
Concerning the contribution to societal challenges, astronomy is basic science in its most fundamental form and its main purpose is to enhance our understanding of the Universe, its evolution and the role of planet Earth as our cosmic home. It does not aim to contribute towards addressing short-term societal challenges, but just as for example quantum physics, the findings in astronomy have a potentially most profound impact on society in the long run, both in technological and cultural terms.

ESO

A particle accelerator facility for research with antiproton and ion beams

FAIR
Facility for Antiproton and Ion Research

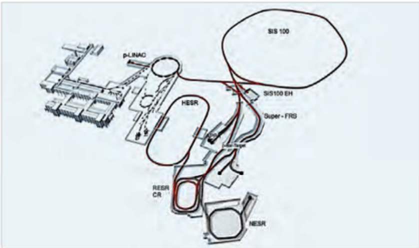
TYPE: single-sited
COORDINATING COUNTRY: DE
MEMBER COUNTRIES: DE, FI, FR, IN, PL, RO, RU, SE, SI, UK

TIMELINE
- ESFRI Roadmap entry: 2006
- Preparation phase: 2005-2010
- Construction phase: 2012-2022
- Operation start: 2022
- Legal status: GmbH, 2010

ESTIMATED COSTS
- Capital value: 1.262 M€
- Operation: 234 M€/year

HEADQUARTERS
FAIR GmbH
Darmstadt
Germany

WEBSITE
http://www.fair-center.de



Description
The Facility for Antiproton and Ion Research (FAIR) is a new accelerator complex providing high-energy, high intensity primary and secondary beams of antiprotons and ions to enable forefront research into the structure and dynamics of matter under extreme conditions, thereby also providing new insights into the evolution of the Universe and the nucleosynthesis in stars and star explosions. FAIR will be constructed in Darmstadt, adjacent to the GSI facility, and will use the upgraded GSI accelerators as injector chain. Within a broad scientific-technological approach, FAIR develops and exploits novel accelerator, detector and computing technologies for unprecedented research into nuclear structure and nuclear astrophysics, physics of hadrons and fundamental physics with antiproton beams, physics of compressed nuclear matter, plasma physics, atomic physics, materials research and biomedical applications.

In 2010, ten countries signed an international agreement on the construction of the FAIR accelerator facility in Darmstadt. These countries are the shareholders of the FAIR GmbH, the established legal entity for the realization of FAIR. In total over 50 countries are involved in the FAIR science program by contributing to the construction and to the exploitation of the FAIR detectors. The FAIR experiments have organized in four large collaborations: APPA, CBM, NUSTAR and PANDA encompassing more than 2.500 scientists in total. FAIR is expected to deliver first beams for science experiments in 2022.

Activity
The heart of the new facility is the superconducting synchrotron SIS100 with a circumference of about 1.100 meters. A complex system of storage-cooler rings and ca 3,2 kilometers of beam transport lines delivers the beams to various experiment stations which house a suite of highly sophisticated detectors. Altogether, the buildings and tunnel sections provide about 135.000 square metres of usable space for the complex scientific-technical infrastructure. The superconducting synchrotron SIS100 is capable of delivering for the science programs high intensity primary beams with energies of up to 11,5 AGeV for uranium and of 29 GeV for protons. Moreover, a broad range of exotic radioactive ion beams and antiproton beams can be provided at the facility. FAIR will enable parallel operation of up to four research programs, thereby allowing a very cost-efficient exploitation of the facility. The scientific scope and instrumentation of FAIR is complementary to that at other existing or planned large accelerator research infrastructures, but none of the other facilities combines the full set of features in one and the same project: large variety of the ion species (from antiprotons to uranium), high beams intensities, high beam energies, cooled antiproton and exotic ion beams, parallel operation.

Impact
In addition to the fundamental science research, FAIR is focussed on applications like radiobiological risk assessments for manned space missions, material sciences, plasma physics studies, and radiotherapy research and development. FAIR has also a potential of broader impact at international level as collaborations in detector and magnet development, e.g. with JINR-Dubna, are already active. This is also reflected by strong and active cooperation between FAIR and many laboratories worldwide optimizing synergies in research and development, and use of existing infrastructures. FAIR is intended to provide research opportunities well beyond an European scope from the beginning, thus catering for scientific communities of countries that cannot afford such large research infrastructure by themselves and would greatly benefit from it.

GERMANY

Nuclear Physics

WWW.ESFRI.EU

The first installation to accelerate exotic nuclei and deliver radioactive ion beams

SPIRAL2
Système de Production d'Ions Radioactifs en Ligne de 2e génération

TYPE: single-sited
COORDINATING COUNTRY: FR
MEMBER COUNTRIES: FR

PARTICIPANTS: BE, CZ, DE, IN, IT, RO, PL, SE, US

TIMELINE
- ESFRI Roadmap entry: 2006
- Preparation phase: 2005-2010
- Construction phase: 2010-2016
- Operation start: 2016

ESTIMATED COSTS
- Capital value: 110 M€
- Operation: 5-6 M€/year

HEADQUARTERS
GANIL
Caen
France

WEBSITE
http://www.ganil-spiral2.eu

Description
The Système de Production d'Ions Radioactifs en Ligne de 2e generation (SPIRAL2) is a new facility to extend significantly the actual possibilities of Radioactive Ion Beam (RIB) physics and related applications. SPIRAL2 will produce the only ion beams of their kind in the world to support research from hadron and isotope therapy to the physics of the atom and its nucleus, from condensed matter to astrophysics. The study of the properties of nuclei forming these beams or their interactions with stable nuclei is a rapidly developing field of contemporary nuclear physics, astrophysics and interdisciplinary research. Novel research in nuclear physics at the limits of stability will be covered at SPIRAL2, including the study of the r and rp-process nuclei, shell closure in the vicinity magic numbers as well as the investigation of very heavy elements. Further research areas will be material sciences, radiobiology, research for hadron and isotope therapy, energy, environment, social sciences, health, engineering, space, ICT as well as Inter and multi-disciplinary research in radiobiology.

SPIRAL2 is part of the GANIL infrastructure, which is the largest research infrastructure in Lower Normandy (Caen, France). Under construction since 2005, it will deliver science from 2018 as a scientific and technologic complement to the existing infrastructure.

Activity
The SPIRAL2 project is based on a multi-beam driver in order to allow both ISOL and low-energy in-flight techniques to produce RIB. SPIRAL2 comprises a linear accelerator (LINAC) and experimental areas with three halls for experiments with high flux of fast neutrons (Neutron for Science, NFS), with very high intensity beams of heavy-ions (Super Separator Spectrometer, S3) and with low-energy exotic nuclei (DESIR) produced at S3 and with SPIRAL1 facility. The construction of a new injector of the SPIRAL2 Linear Accelerator is planned in order to expand a range of available high-intensity beams up to Uranium. In addition, a Radioactive Ion Beam (RIB) production building is foreseen to produce RIB with an intensity that exceed by factor of 10 to 100 intensities available today worldwide. The superconducting light/heavy-ion LINAC, with an potential of about 40 MV capable of accelerating 5 mA deuterons up to 40 MeV and 1 mA heavy ions up to 14.5 MeV/u, is used to bombard both thick and thin targets. The beams could be used for the production of intense RIB by several reaction mechanisms (fusion, fission, transfer, etc.) and technical methods (ISOL, IGISOL, recoil spectrometers, etc.). The production of high-intensity RIB of neutron-rich nuclei will be based on fission of Uranium target induced by neutrons, obtained from a deuteron beam impinging on a graphite converter (up to 1014 fissions/s) or by a direct irradiation with a deuteron, 3He or 4He beam. The post acceleration of RIB in the SPIRAL2 project is assured by the existing CIME cyclotron, which is well adapted for separation and acceleration of ions in the energy range from about 3 to 10 MeV/u for masses A~100-150.

Impact
The impact of SPIRAL2 in the structuring of the European Research Area is enabling a scientific programme based on unique high-intensity beams of light, heavy-ions and neutrons delivered well suited to address the most challenging nuclear and astrophysics questions aiming at the deeper understanding of the nature of atomic nucleus. SPIRAL2 will contribute to the physics of nuclear fission and fusion based on the collection of unprecedented detailed basic nuclear data, to the production of rare radioisotopes for medicine, to radiobiology and to materials science. The SPIRAL2 facility is an intermediate step towards EURISOL, the most advanced nuclear physics research facility presently imaginable and based on the ISOL principle. The realisation of SPIRAL2 will substantially increase the know-how of technical solutions to be applied not only for EURISOL but also in a number of other European and world projects.

FRANCE

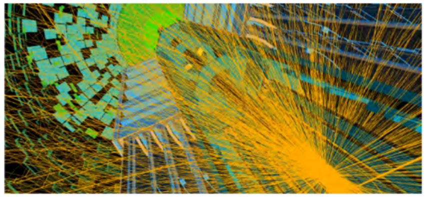
HEP

WWW.ESFRI.EU

HL-LHC

High-Luminosity Large Hadron Collider

An upgrade of the highest-energy particle collider in the world for exploring new physics



Description

The Large Hadron Collider (LHC) at CERN is the highest-energy particle collider in the world. The ATLAS and CMS experiments at the LHC have provided the breakthrough discovery of the so-called Higgs boson. This discovery is the start of a major programme to measure this particle's properties with the highest possible precision for testing the validity of the Standard Model and to search for further new physics at the energy frontier. To extend its discovery potential, the LHC will be upgraded to High-Luminosity LHC (HL-LHC).

The HL-LHC will be implemented over the next decade in order to increase the data sample for ATLAS and CMS by an order of magnitude compared to the integral collected by the end of 2022. For the full development of the physics programme also the experiment's detectors require upgrade as well as the computing infrastructure that will need to handle the substantially increased data rates. The full exploitation of the LHC, including the HL-LHC, was identified as the highest priority for European particle physics, in the update of the European Strategy for Particle Physics approved by CERN Council in May 2013. This recognition has also been adapted in the National Roadmaps of countries all over the world including the USA.

Activity

The accelerator and experimental systems for the HL-LHC project will take a decade to complete. The HL-LHC accelerator relies on a number of innovative technologies including a combination of cutting-edge superconducting magnets, ultraprecise superconducting RF cavities for beam rotation, as well as high-power superconducting links with zero energy dissipation. In addition, the higher luminosity sets novel constraints on vacuum, cryogenics and machine protection, and will require new concepts for beam collimation and diagnostics to maximize the physics output of the collisions. The success of experiments at the HL-LHC relies on innovative instrumentation (radiation-hard detectors, high-granularity calorimeters, and large-area silicon trackers), state-of-the-art infrastructures and large-scale data-intensive computing.

The main physics goals are clear. The first goal is to push further the validation of the Standard Model at the energy frontier, in particular by measuring the properties of the newly discovered Higgs particle and of the longitudinal components of the massive vector bosons with the highest possible precision, and with the aim of establishing whether there are any deviations from the Standard Model predictions. The second goal is to check whether the Higgs particle is accompanied by other new particles at the TeV energy scale, which could play a role in the global picture of electroweak symmetry-breaking or in the solution of the dark matter puzzle.

Impact

The LHC is a unique international infrastructure to study the fundamental constituents of matter and their interactions. The HL-LHC is an upgrade to this already existing facility which will allow the full exploitation of its scientific potential. It defines a long-term programme for at least the next two decades until 2035. The scientific community at CERN consists of over 11.500 users from around the world, the significant majority of whom work on the LHC.

The HL-LHC and its surrounding facilities will require a constant stream of supplies and services. These include civil engineering work and the systems and equipment needed to build and operate the accelerator and the experiments. The HL-LHC will collaborate with many types of industries and businesses to pursue its goals. Knowledge and technology to be developed during the HL-LHC project will make a lasting impact on society. Many young physicists and engineers trained during the project will transfer their expertise to society and industry. The HL-LHC is for all the three aspects – accelerator, detector and computing – a major upgrade of LHC of CERN and will impact the corresponding technologies that are of quite general relevance for other research infrastructures and for the big data and computing paradigm.

TYPE: single-sited
COORDINATING ENTITY: CERN
MEMBER COUNTRIES: AT, BE, BG, CH, CZ, DE, DK, EL, ES, FI, FR, HU, IL, IT, NL, NO, PK, PL, PT, RO, RS, SE, SK, TR, UK

PARTICIPANTS: See
ACCELERATOR COLLABORATION
ATLAS COLLABORATION
CMS COLLABORATION

TIMELINE
- **ESFRI Roadmap entry:** 2016
- **Preparation phase:** 2014-2017
- **Construction phase:** 2017-2025
- **Operation start:** 2026

ESTIMATED COSTS
- **Capital value:** 1.370 M€
- **Operation:** 100 M€/year

HEADQUARTERS
CERN
Geneva
Switzerland

WEBSITE
http://home.cern/

Analytical Physics

WWW.ESFRI.EU

ESRF UPGRADES

Phase II: Extremely Brilliant Source

A unique Synchrotron Radiation Facility to the benefit of science and innovation in condensed and living matter fields

TYPE: single-sited
COORDINATING ENTITY: ESRF
MEMBER COUNTRIES: BE, CH, DE, DK, ES, FI, FR, IT, NL, NO, RU, SE, UK

PARTICIPANTS: AT, CZ, HU, IL, PL, PT, SK, ZA

TIMELINE
- ESFRI Roadmap entry: 2006, 2016
- Preparation phase: 2012-2015
- Construction phase: 2015-2022
- Operation start: 2022

ESTIMATED COSTS
- Capital value: +150 M€
- Operation: 82 M€/year

HEADQUARTERS
European Synchrotron Radiation Facility-ESRF
Grenoble
France

WEBSITE
http://www.esrf.eu

Description

The European Synchrotron Radiation Facility (ESRF) is the world-leading source of synchrotron X-rays operating 43 beamlines with state-of-the-art instrumentation for imaging and studying the structure of matter at the atomic and nanometric scale in all fields of research: it is a truly European facility and a key component of the ERA. The ESRF initiated an Upgrade Programme in 2009, and has completed the initial phase with 19 new and rebuilt beamlines, mostly in the domain of imaging and structural studies, enabling a 3 orders of magnitude gain in performance of X-ray microscopy and imaging experiments.

The ESRF-EBS is the new planned major upgrade project (~150 M€; 2015-2022). Centred on rebuilding the ESRF storage ring by adopting an all-new hybrid multi-bend achromat lattice design, it will deliver unprecedented source brilliance and coherence (~100x). The EBS project also includes the construction of four new state-of-the-art beamlines, a scientific instrumentation programme with ambitious detector projects and a data management and analysis strategy. An instrumentation upgrade is also planned for some more beamlines including the "national beamlines" operated by Collaborating Research Groups. Due to the very high brilliance of the EBS, methods developed also at Free Electron Laser (FEL) Facilities, such as serial crystallography, will be used in the new experimental infrastructures, thus expanding the capabilities for structural biology and material science in Europe.

Activity

The ESRF started operations in 1994 and construction was completed in 1998. Every year, more than 8,000 scientific users across all disciplines of natural sciences use the ESRF and their work generates ~2.000 peer-reviewed publications annually. ESRF has delivered up to now ~254.000 instrument-shifts (i.e. ~17.000 8-hour-shifts per year). Approximately 98% of the beam time at the ESRF is granted through peer-reviewed scientific excellence based access and 2% is acquired for proprietary research. Approximately 30% of all projects submitted to the ESRF involve innovation/industrial technology developments. A transparent scheme monitors beam time distribution among the scientists' countries and aims for a "juste retour" with respect to the shareholders' contributions.
A programme of continuous review and upgrade or replacement of beamlines has been implemented since the beginning. The ESRF provides scientific support to users and carries out the necessary research and development work in synchrotron techniques enabling, among others, Nobel Prizes in Chemistry in 2003, 2009 and 2012. The ESRF has created, together with the ILL and EMBL, a hub of excellence that has stimulated co-location of specialist laboratories such as the Institute for Structural Biology, the Partnership for Structural Biology, the Partnership for Soft Condensed Matter and industrial research collaborations.

Impact

The new ESRF-EBS will enhance the ESRF's impact on science and on partner countries. After a shutdown in 2018-2020, the ESRF-EBS will be the global reference for at least one more decade. Services and contracts placed by the ESRF in member and associated states help secure follow-on industrial benefits. The engineering challenges of the ESRF-EBS will boost industrial capacity in areas such as magnet and detector technology, nano-manipulation, control systems, vacuum technology, precision mechanics and high power radiofrequency technology for accelerators. Developments in data management, analysis tools and open access repositories will further impact science and technology at European and global levels with an impact in the broader field of analytical science and facilities. It is therefore vital that the ESRF continues to be supported to carry on these capabilities as a driving force in the ERA.

ESRF

ILL 20/20

Institut Max von Laue-Paul Langevin

The continuous upgrade of the world's flagship for neutron science for condensed matter physics, chemistry, biology and materials research

TYPE: single-sited
COORDINATING ENTITY: ILL
MEMBER COUNTRIES: DE, FR, UK

PARTICIPANTS: AT, BE, CH, CZ, DK, ES, HU, IT, PL, SE, SK

TIMELINE
- ESFRI Roadmap entry: 2006
- Preparation phase: 2007-2011
- Construction phase: 2012-2016
- Operation start: 2020

ESTIMATED COSTS
- Capital value: 171 M€
- Operation: 92 M€/year

HEADQUARTERS
Institut Max von Laue-Paul Langevin
Grenoble
France

WEBSITE
http://www.ill.eu

Description

The Institut Max von Laue-Paul Langevin (ILL) is an international research centre at the leading edge of neutron science and technology, to support researchers in a variety of fields – condensed matter physics, chemistry, biology, nuclear physics and materials science – and make their combined know-how available to the scientific community. ILL operates the most intense reactor source in the world, supplying neutrons to a suite of high-performance instruments that are constantly developed and upgraded. The continuous instrumentation upgrade programmes aim at increasing the signal to noise performance, adapting the instrumentation to the changing research environment and offering to users new innovative techniques.

The ILL 20/20 project, part of the wide-ranging Millennium Programme, entered the Roadmap in 2006 to support the Preparatory Phase of the overall upgrade of ILL's neutron science facilities to strengthen its world-leading position and provide for the future scientific needs of users in Europe and beyond. Identified as successfully implemented in the 2010 Roadmap, the Millennium phase has been completed. The Endurance phase of ILL20/20 aims at a further renewal of 9 new neutron instruments and experiments linked to neutrons or gamma rays, plus accompanying infrastructure improvements.

Activity

The ILL offers neutron measurements to the scientific community employing 38 instruments installed on the existing source of neutrons at the ILL, 29 operational instruments managed by the ILL and 9 instruments handled by external consortia. Each piece of the instrument suite is designed to be state-of-the-art in each particular research field and undergoes major as well as continuous upgrades to fulfil the world-reference role. The ILL's staff have expertise and experience in neutron production (reactor physics, reactor design and operation, cold and hot source design and operation), neutron beam delivery (beam-tubes, neutron guides including supermirror guides), neutron optics (collimators, monochromators, neutron velocity selectors and choppers), neutron detection and the complete range of neutron instruments for scientific research and sample environment. Some 1,500 researchers from over 40 countries visit the ILL each year, performing over 800 experiments and producing about 600 published papers that put the ILL at the leading edge of neutron science covering all the relevant scientific domains: soft condensed matter (13%), nuclear and particle physics (10%), biology (10%), chemistry (13%), materials science (17%), physics including magnetism and nanoscience (32%), other (instrumentation, cultural heritage, environment; 5%). The ILL's Industrial Liaison Unit provides a single and specialised point of contact for any potential user from industry and services, offering industrial clients a choice of specific modes of access ranging from quick-access proprietary research or a combination with academic access for maximum innovation.
The ILL adopts a pioneering data access policy (PaNdata) to allow the access and treatment of the data generated at the institute. After initial priority access to the data for the scientist(s) carrying out the experiment, the data is publicly accessible and reusable.

Impact

The economic impact of the implantation of the ILL and of the ESRF in Grenoble is very important for France and the Rhône-Alpes region in terms of direct and indirect jobs and activities. Installations at the ILL and ESRF are used by more than 50 French and European companies for R&D work. The implementation of the instrumentation upgrade programmes of ILL will reinforce the potential performances of the R&D tools and favour the competitiveness of the companies specialized in precision mechanics, vacuum and engineering, neutron guides and neutron choppers. Technologies developed by ILL and companies in partnership are often subsequently used by national and international facilities and laboratories.

ILL

Analytical Physics Superconducting Linacs

WWW.ESFRI.EU

European XFEL

European X-Ray Free-Electron Laser Facility

Description

The European X-Ray Free-Electron Laser (European XFEL) will be the world leading facility for the production of high repetition rate ultra-short X-ray flashes with a brilliance that is a billion times higher than that of the best synchrotron X-ray radiation sources. 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 "under extreme conditions" such as those occurring deep inside planets.

The international European XFEL project, with 11 participating countries, is being built in Hamburg and Schleswig-Holstein. Commissioning, with the first beam of the facility, is expected to start in early 2017.

Activity

X-ray free-electron lasers (FELs) are accelerator based light sources that generate extremely brilliant and ultra-short, from few to 100 femtoseconds (fs) pulses of transversely coherent X-rays with very short wavelengths (down to ~ 0.05 nm). The goal is to exploit these X-rays for revolutionary scientific experiments in a variety of disciplines, including physics, chemistry, materials science, and biology. In the US and Japan, FELs are based on room-temperature linear accelerators (warm-LINACS). In Europe, the European X-ray Free Electron Laser (XFEL) Facility exploits the superconducting linear accelerator technology (cold-LINAC). The superconducting technology allows for a very large number of pulses per second, in the case of the European XFEL up to 27,000 pulses per second. Electron bunches shall be accelerated to high energies (up to 17.5 GeV) in a ~2 km LINAC and then passed through (up to 200 m long) undulators, where they will generate bursts of coherent X-rays through the self-amplified spontaneous emission (SASE) process. Initially, 3 photon beamlines and 6 instruments will be built. Eventually, 5 photon beamlines and 10 experimental stations will enable experiments ranging from coherent diffraction imaging to spectroscopy and exploit the high intensity, coherence, and time structure of the new source.

Some expected scientific benefits will consist in studying molecular configuration rearrangements during chemical reactions down to the sub-picosecond (ps) scale, observing the dynamics of fluctuations on unprecedented time and length scales, providing experimental access to regions of the phase diagram of materials currently found only in astrophysical environments. A fascinating perspective benefit is the investigation of the structure of individual macromolecules down to atomic resolution, without the need for crystallization.

Impact

The European XFEL facility expands the leading position of Europe in accelerator based X-ray sources, that are pushing the frontiers of condensed matter physics, materials science, chemistry, structural biology and pharmacology. The specific developments in detector and accelerator technology generate innovation and know-how transfer to industry. The expected fundamental research breakthroughs in materials sciences, chemistry and catalysis, and macromolecular structure, will also generate innovation. The European XFEL provides an opportunity to educate a new generation of scientists to address the frontiers of research on nano-scale materials, and this in a multi-national, open environment, promoting the European dimension of knowledge and its international mobility. Consortia are created among European universites and research centers to develop instrumentation for the XFEL, impacting the coordination of efforts in the fields of research related with health issues, energy and environment.

First Superconducting X-ray Free Electron Laser for high repetition rate ultra-short X-ray flashes for the life sciences and materials

TYPE: single-sited
COORDINATING ENTITY: European XFEL
MEMBER COUNTRIES: CH, DE, DK, FR, HU, IT, PL, RU, SE, SK

PARTICIPANTS: ES

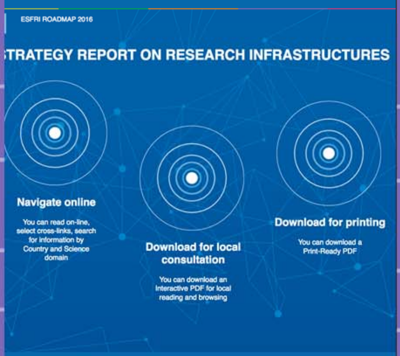
TIMELINE
- ESFRI Roadmap entry: 2006
- Preparation phase: 2006-2009
- Construction phase: 2009-2017
- Operation start: 2017
- Legal status: GmbH, 2009

ESTIMATED COSTS
- Capital value: 1.490 M€
- Operation: 115 M€/year

HEADQUARTERS
European XFEL GmbH
Hamburg
Germany

WEBSITE
http://www.xfel.eu

European XFEL



The world's most powerful neutron source for life sciences, energy, environmental technology, cultural heritage and fundamental physics

TYPE: single-sited
COORDINATING COUNTRIES: DK, SE
MEMBER COUNTRIES: CH, CZ, DE, DK, EE, FR, HU, IT, NO, PL, SE

PARTICIPANTS: BE, ES, NL, UK

TIMELINE
- ESFRI Roadmap entry: 2006
- Preparation phase: 2008-2010
- Pre-construction phase: 2010-2012
- Construction phase: 2013-2025
- Operation start: 2025
- Legal status: ERIC, 2015

ESTIMATED COSTS
- Capital value: 1.843 M€
- Operation: 140 M€/year

HEADQUARTERS
European Spallation Source ERIC
Lund
Sweden

WEBSITE
http://www.europeanspallationsource.se

DENMARK, SWEDEN

European Spallation Source ERIC

Description

The European Spallation Source is a research infrastructure committed to the goal of building and operating the world leading facility for research using neutrons. The ESS will deliver a neutron peak brightness of at least 30 times greater than the current state-of-the-art, thus providing the much-desired transformative capabilities for interdisciplinary research in the physical and life sciences.

ESS officially became a European Research Infrastructure Consortium (ERIC) in October 2015. The facility is under construction in Lund (Sweden), while the ESS Data Management and Software Centre (DMSC) will be located in Copenhagen (Denmark). The foreseen milestones include the beginning of the first on-site Accelerator installations (Sep 2016), facility ready for Accelerator beam on the Target (Dec 2019), the first call for user proposals (2022), the Machine installed for 2.0 GeV performance (Dec 2022), start user programme (2023), and the completion of the 16 construction phase instruments (Dec 2025).

Activity

A total of 16 instruments will be built during the construction phase to serve the neutron user community with more instruments during operations. The suite of ESS instruments will gain 10-100 times over current performance enabling neutron methods to study real-world samples under real-world conditions. The Neutron Scattering Systems (NSS) Project at ESS is responsible for the development and coordination of state-of-the-art instrument concepts for ESS, in collaboration with international partners. Around 40 concepts were developed by ESS scientists and our partners. Of those, 16 concepts have now been selected and approved by the ESS Steering Committee for construction within the NSS project. Our partners from the member countries will lead the construction of most of the instruments, and many will benefit from contributions from two or more participating organisations. The NSS project is coordinating the construction and installation of these instruments, and the associated support systems (such as sample environments and data processing and analysis capabilities) to ensure the highest quality outcomes for the European Community. Selection of the additional 6 instruments will occur once construction of the initial suite of 8 instruments is approaching completion.

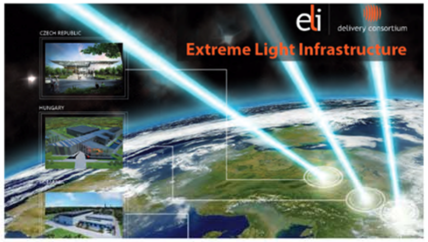
Impact

ESS will be an attractive and environmentally sustainable large compound including industrial and laboratory buildings, office space, and guest accommodation facilities all housed within a significant architectural design that will make an impact on the world's stage. Before the expected world-scale scientific impact can be realised with the operation phase, the construction of the ESS does have a direct economic impact by generating growth and jobs, advance development and fuel innovation potential in the Öresund region and across the EU. With ESS being built as a collaborative project, the growth effect will be shared between the host countries (Sweden and Denmark) and the ESS-ERIC partners. The realisation of ESS enables access to frontier technology, experienced technical and scientific staff as well as unique production facilities and technologies, which would otherwise be unattainable. In addition, the ESS will be a key instrument for addressing the Grand Challenges through novel insights on matter at the molecular and atomic level and applications to energy, carbon sequestration methods, health issues at biology level as well as drug development and delivery strategies, plant water-uptake processes of relevance for agriculture, novel data storage materials, and more.

Analytical Physics

ELI
Extreme Light Infrastructure

The world's fastest and most powerful lasers and secondary radiation sources to unravel light-matter interactions



TYPE: distributed
COORDINATING ENTITY: ELI-DC
MEMBER COUNTRIES: CZ, DE, HU, IT, RO, UK

TIMELINE
- ESFRI Roadmap entry: 2006
- Preparation phase: 2007-2010
- Construction phase: 2011-2017
- Operation start: 2018
- Legal status: AISBL, 2013

ESTIMATED COSTS
- Capital value: 850 M€
- Operation: 90 M€/year

HEADQUARTERS
ELI-DC AISBL
Brussels
Belgium

WEBSITE
http://www.eli-laser.eu/

Description
The Extreme Light Infrastructure (ELI) is a Research Infrastructure of Pan-European interest for experiments on extreme light-matter interactions at the highest intensities, shortest time scales and broadest spectral range. ELI will make available unprecedented power and attosecond resolution of coherent radiation and laser-accelerated particles for fundamental studies in atomic, molecular, plasma and nuclear physics to serve a large variety of scientific applications, ranging from biology, chemistry and medicine to astrophysics in the laboratory.

ELI is based on three sites (pillars, under construction in the Czech Republic, Hungary and Romania) with complementary scientific profile, and a possible implementation of a fourth pillar. Implementation is coordinated by the ELI Delivery Consortium International Association (ELI-DC), International not-for-profit Association under Belgian Law (AISBL) that is acting to establish a European Research Infrastructure Consortium (ELI-ERIC).

Activity
The ELI-Beamlines facility In Dolní Břežany, near Prague, Czech Republic, focuses on the development of short-pulse secondary sources of radiation and particles, and on their multidisciplinary applications in molecular, biomedical and material sciences, physics of dense plasmas, warm dense matter, and laboratory astrophysics.
The ELI Attosecond Light Pulse Source (ELI-ALPS) in Szeged, Hungary will provide ultra-short light pulses with high repetition rate in the spectral range between THz and X-rays. ELI-ALPS will be dedicated to extremely fast dynamics by taking snap-shots on the attosecond scale (a billionth of a billionth of second) of electron dynamics in atoms, molecules, plasmas and solids.
The ELI Nuclear Physics (ELI-NP) facility In Magurele, Romania, will focus on laser-based nuclear physics, using ultra-high intensity lasers and a laser-based gamma source. Applications include nuclear physics experiments to characterize laser – target interaction, photonuclear reactions, and exotic nuclear physics and astrophysics.
A fourth pillar of ELI, the highest intensity pillar, is still in pre-implementation stage as its definition will depend on on-going laser technology development and validation, and will be based on the experience of the three pillars. The laser power is expected to exceed that of the current ELI pillars by another order of magnitude, allowing for an extended scientific programme in particle physics, nuclear physics, gravitational physics, nonlinear field theory, ultrahigh-pressure physics, astrophysics and cosmology (generating intensities exceeding 10^{23} W/cm^2).

Impact
ELI will be the gateway to new regimes in fundamental physics. At the same time, it will also promote the advent of new technologies, such as novel laser-plasma-accelerators expected to be able to deliver particles and photon sources with extremely high energies beyond the physical limits of conventional technologies. Due to its unique characteristics as the first international laser user facility, ELI will offer access to an international community of scientific and – to some extent – industrial users, attracting the world's best scientists to unique research opportunities including physics, chemistry, biology, medicine, materials sciences, and combinations thereof.
Contributions towards addressing the Grand Societal Challenges arise in vast areas, ranging from analytical studies applied to environmental research, climate research, medical diagnostics and treatment, pharmacology, bio-medicine, or from materials research for renewable and nuclear energies, nuclear waste management, and space applications, or from laser-based materials processing on micro- and nano-scales for information and communication technologies, to name only few.

ELI-DC

WWW.ESFRI.EU

EMFL
European Magnetic Field Laboratory

A unique effort to generate the highest possible magnetic fields for use in scientific research

TYPE: distributed
COORDINATING COUNTRIES: DE, FR, NL
MEMBER COUNTRIES: DE, FR, NL

PARTICIPANTS: UK

TIMELINE
- ESFRI Roadmap entry: 2008
- Preparation phase: 2009-2012
- Construction phase: 2009-2014
- Operation start: 2014
- Legal status: AISBL, 2015

ESTIMATED COSTS
- Capital value: 170 M€
- Operation: 20 M€/year

HEADQUARTERS
EMFL
Office Helmholtz Association
Brussels
Belgium

WEBSITE
http://www.emfl.eu/

Description
The European Magnetic Field Laboratory (EMFL) is dedicated to generate the highest possible magnetic fields that can be used for scientific research and make them available to the scientific community. The EMFL unites, coordinates and reinforces all existing European large-scale high magnetic field research infrastructures in a single body. These facilities are the Laboratoire National de Champs Magnétiques Intenses (LNCMI), with its sites for pulsed fields in Toulouse and continuous fields in Grenoble, the Dresden High Magnetic Field Laboratory (HLD) and the High Field Magnet Laboratory (HFML) in Nijmegen. EMFL formally represents and operates tasks, in particular the access program, of the parent laboratories. The UK community, represented by the University of Nottingham joined EMFL at the end of 2015.

The parent organizations of the three RIs have created a legal structure in the form of an International not-for-profit Association under Belgian Law (AISBL) in Belgium. The AISBL statutes were signed in January 2015.

Activity
The LNCMI is a French large-scale facility operated by CNRS and associated to INSA, UPS and UGA, enabling researchers from all over the world to perform experiments in the highest possible magnetic fields. Continuous fields up to 36 Tesla are available at the Grenoble site and pulsed fields up to 180 Tesla at the Toulouse site. The HLD in the Helmholtz-Zentrum Dresden-Rossendorf (HZDR) focuses on modern materials research at high magnetic fields. It serves as a research facility for both in-house and user projects and provides research opportunities for pulsed magnetic fields up to 90 Tesla for routine operation. A record field close to 94,2 Tesla has been reached in 2012. The HLD aims at reaching magnetic fields up to the feasibility limit of about 100 Tesla. The HFML in Nijmegen is committed to generate the highest available continuous magnetic fields. HFML is a Dutch large European research facility open for external researchers and operated by the Radboud University (RU) and the Foundation for Fundamental Research on Matter (FOM). In the HFML resistive magnets with fields up to 37.5 T are available and a 45T hybrid magnet is under development.
The main research activities supported by the EMFL are: magnetic and superconducting materials, strongly correlated electron systems, low-dimensional magnetic materials, nanostructured materials, magnet design and technology, semiconductors and nano-systems, mesoscopic physic, strongly correlated electron systems, molecular magnetism, soft condensed matter.

Impact
The EMFL has developed transportable pulsed magnets and generators allowing fields of up to 40 Tesla to be combined with large neutron, X-ray, or laser sources impacting fundamental science programmes across disciplines. Neutron and synchrotron experiments in pulsed fields allow researchers to reveal the microscopic properties of matter; they are conducted jointly between the EMFL and a number of large facilities that are leaders in their field.
Magnetic fields can help defeat cancer as they are used to trace tumors or to do nanodrug delivery, in combination with Magnetic Resonance Imaging (MRI). EMFL researchers also develop a compact and inexpensive beam delivery alternative for proton beam therapy. EMFL supports applied research for forming, joining, and welding metals by using the large compressive forces produced by very short and intense energy-efficient magnetic-field pulse technology with many extra benefits for economy and environment. Magnetic fields can help scientists reveal the hidden physical properties of neodymium-like or other brand new magnetic materials that can be used to create smaller, more efficient electric motors. EMFL supports the application of high-temperature superconductivity to energy storage and transport, and into developing magnetic levitation and was involved in preliminary measurements demonstrating the enormous technological potential of graphene.

FRANCE, GERMANY, THE NETHERLANDS

ESFRI instruments:

-the Strategy Working Groups
-the Implementation Group
-ad-hoc Expert Working Groups

Experts of the research and innovation in the domain

Experts of e-infrastructures (specific and general)

Experts of research infrastructure management, risk analysis and human capital management

Covering the aspects of *users access strategy* and issues connected to siting, governance and financing

Chaired by a member of the Forum with specific competences or by an Expert, nominated by the Forum and permanently invited to the Forum meetings

ROADMAP 2018
Strategy Report on Research Infrastructures
ESFRI

ROADMAP 2018
Strategy Report on Research Infrastructures

ESFRI

ESFRI instruments: the Strategy Working Groups

Experts of the research domain
Experts of innovation in the field
Experts of e-infrastructures (specific and general)

Covering the subfields and the different communities active in Europe with fair representation of Countries

Chaired by a member of the Forum with specific competences
or
Chaired by an Expert, nominated by the Forum and permanently invited to the Forum meetings

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Strategy Working Groups: ENE, ENV, HF, PSE, SCI, e-Infra

Guarantee the scientific excellence of the Research Infrastructure Projects and Landmarks of the ESFRI Roadmap

Engage, through the Forum, new experts according to the specificity of the new proposals

Consult external, *international REFEREES*, with proven experience and declared absence of conflict of interest

Integrate analysis and external inputs (referees) to complete the evaluation of proposals and rank them on scientific merit, pan-European strategic interest, robustness of technology and e-infrastructure aspects

Enforce the dialogue with the Projects and Landmarks in view of evaluation and monitoring processes on the scientific programme and quality of scientific services

Strategy Report on Research Infrastructures
ROADMAP 2018

ESFRI

The PSE Strategy Working Group

Last name	First name	Country	Affiliation
ABELA	Rafael	Swizerland	Paul Scherrer Institute
ANTIČIĆ	Tome	Croatia	Rudjer Boskovic Institute
ČEH	Miran	Slovenia	Jozef Stefan Institute
CLAUSEN	Kurt	Switzerland	Paul Scherrer Institute
DIETER	Ralph	Germany	BMBF
FAGAS	Georgios	Ireland	Tyndall National Institute
FROISSARD	Philippe	European Commission	European Commision. DG Research.
GENOVA	Francoise	e-IRG Representative	MENESR
GHITA	Dan	Romania	Horia Hulubei National Institute for R&D in Physics and Nuclear Engineering
GONÇALVES	Bruno	Portugal	Instituto de Plasmas e Fusão nuclear
HARRISON	Andrew	United Kingdom	DIAMOND Light Source
HOOIJER	Christa	The Netherlands	FOM foundation
HUOTARI	Simo	Finland	University of Helsinki
KLOO	Lars	Sweden	KTH Royal Institute of Technology
LÉVAI	Péter	Hungary	Wigner Research center for Physics
LYNOV	Jens Peter	Denmark	DTU Technical Univeristy of Denmark
Martinez Pena	Jose Luis (Chair)	Spain	Consejo Superior de Investigaciones Científicas
MATHON	Marie-Hélène	France	MENESR
PETRILLO	Caterina	Italy	Università degli Studi di Perugia
RAMIREZ	Rafael	Spain	Universidad Carlos III de Madrid
TEMST	Kristiaan	Belgium	KU Leuven
VAN SAARLOOS	Wim	The Netherlands	FOM Foundation
ZOCCOLI	Antonio	Italy	Instituto Nazionale de Fisica Nucleare
OBSERVER			
BARTH	Matthias	Observer	DLR
BRACCO	Angela	Observer	NuPPEC
BUTTERWORT	Jonathan	Observer	CERN
ECKHARD	Elsen	Observer	CERN
GIANOTTI	Fabiola	Observer	CERN
MASIERO	Antonio	Observer	ASPERA (then APPEC)
MEYER	Uwe	Observer	JINR
PESCHKE	Christoph	Observer	DLR
RUSAKOVITCH	Nikolai	Observer	JINR

ESFRI instruments: the Implementation Group

Experts of research infrastructure management

Experts of planning of complex enterprises

Experts of risk analysis and human capital management

Covering the aspects of *users access strategy*, issues connected to siting, governance,

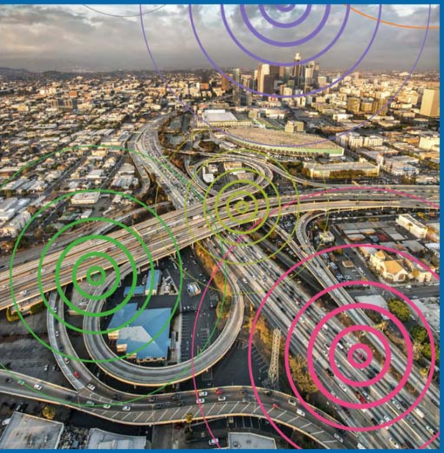
Chaired by a member of the Forum with specific competences:

Odd Ivar Eriksen, Norway

Strategy Report on Research Infrastructures
ROADMAP 2018

ESFRI

Landscape Analysis the ecosystem of Research Infrastructures in Europe and more



- Survey and analysis of the context, in each domain, of the operational national or international research infrastructures ***open Internationally to scientists and technology developers through peer-review of competitive science proposals.***
- Identifies the gaps and the potential evolution of each field in the foreseeable future
- *ESFRI in no case acts as an advocate of specific potential future projects.*

Strategy Report on Research Infrastructures
ROADMAP 2018

ESFRI

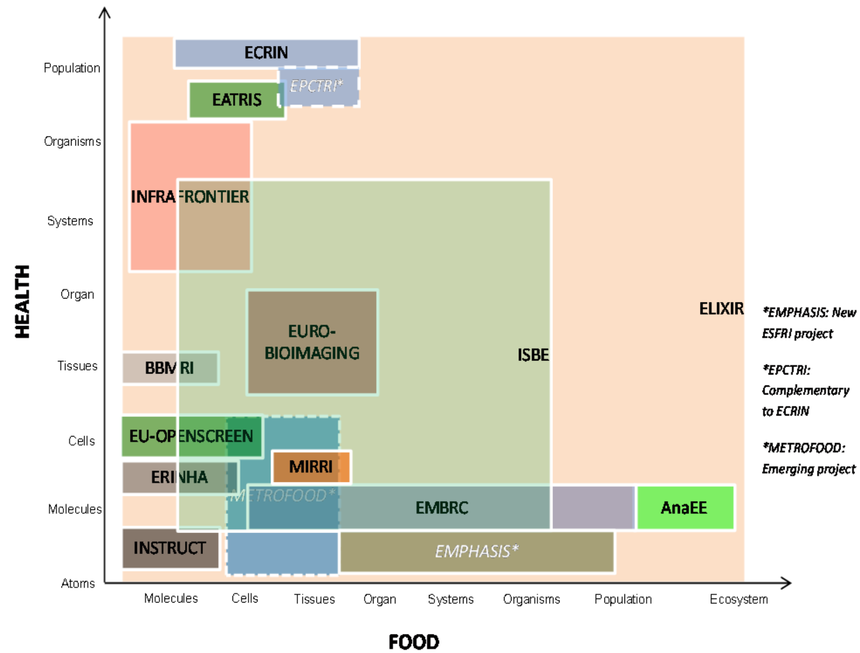
Health and Food Strategy Working Group

Landscape analysis

Criteria

•Scientific and technological knowledge delivered (or contribution to the advancement of science and technology);
•Potential for structuring the ERA and addressing fragmentation;
•Timeliness (urgency; opportunities Europe will lose if delayed);
•Range of scientific communities covered and potential for integration;
•Potential for knowledge and technology transfer, training and increasing capacity;
•The extent to which the new infrastructure responds to the needs and improves the access for scientific communities;
•The extent to which the new infrastructure meets a gap in and connects to HF SWG landscape.

The indicative position of ESFRI RIs relative to the different levels of organisation in the 'Health and Food'



Strategy Report on Research Infrastructures
ROADMAP 2018

ESFRI

Landscape analysis

PHYSICAL SCIENCES AND ENGINEERING

Strategy Report on Research Infrastructures
ROADMAP **2018**

ESFRI

PSE SWG Landscape Analysis (2016)

Over *15 million workers* are employed in the *physics-based sector of economy* of EU-28, representing over *13% of total business economy employment* and about *27% of overall manufacturing employment*, generating (in 2010) about 1.3 trillion € of the Gross Value Added (GVA) contribution to EU economy (data from "The Importance of Physics to the Economies of Europe", 2013).

The physics-based sector expenditure on scientific research and development nears *50 billion € per year*, partially purchased outside the EU.

Research and higher education in physical sciences has, therefore, a very high direct impact in the EU economy, also as prime driver for new methods of large data management and communication.

PSE SWG Landscape Analysis (2016)

PSE covers a wide range of research areas and types of infrastructures from *advanced international/global experiments addressing fundamental knowledge* issues to *user-intense facilities for multi-scale investigation on matter* and applications.

The overall "investment value" of the currently operational RIs in the physics-based sector is of the order of 70 billion € and its operational yearly cost is 10% of initial investment, i.e. approximately 7 billion € per year or about 10% of the cost of external services acquired by the physics sector of economy, corresponding to a fraction of five millionths of the physics sector Gross Value Added.

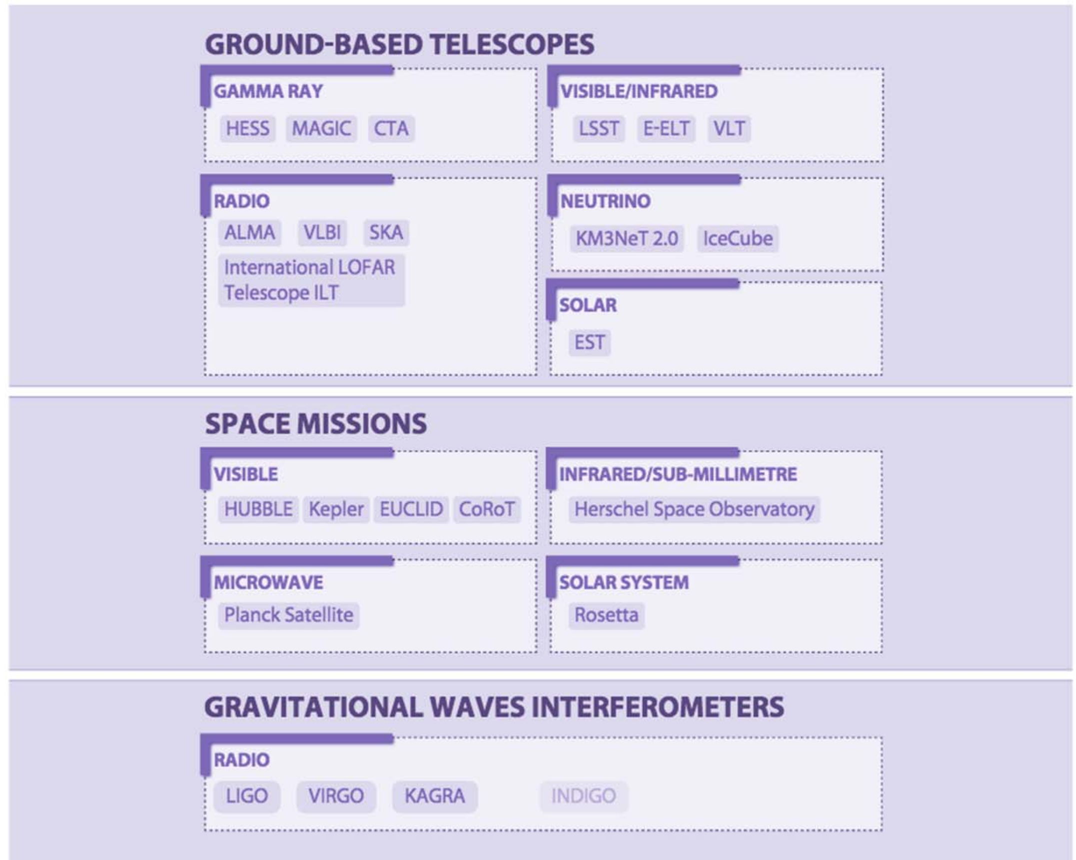
Strategy Report on Research Infrastructures
ROADMAP 2018

ESFRI

Landscape analysis PSE

ASTRONOMY AND ASTROPARTICLE PHYSICS

Figure 1A: main Research Infrastructures in Astronomy and Astroparticle Physics.



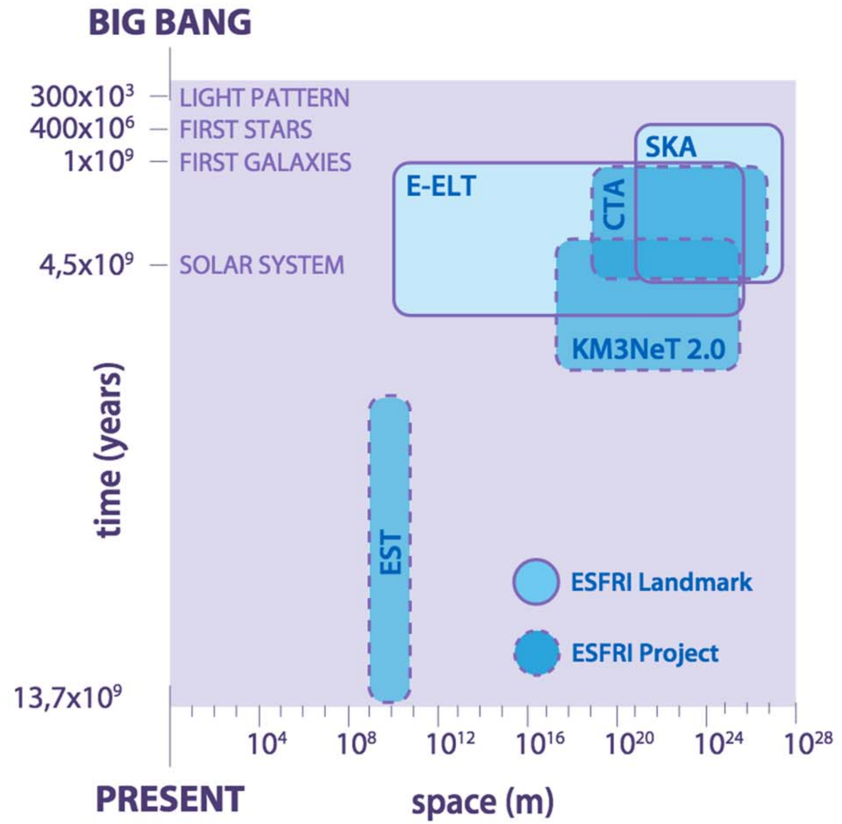
Strategy Report on Research Infrastructures
ROADMAP 2018

ESFRI

Landscape analysis PSE

complementarity, interfaces, overlaps, capacity

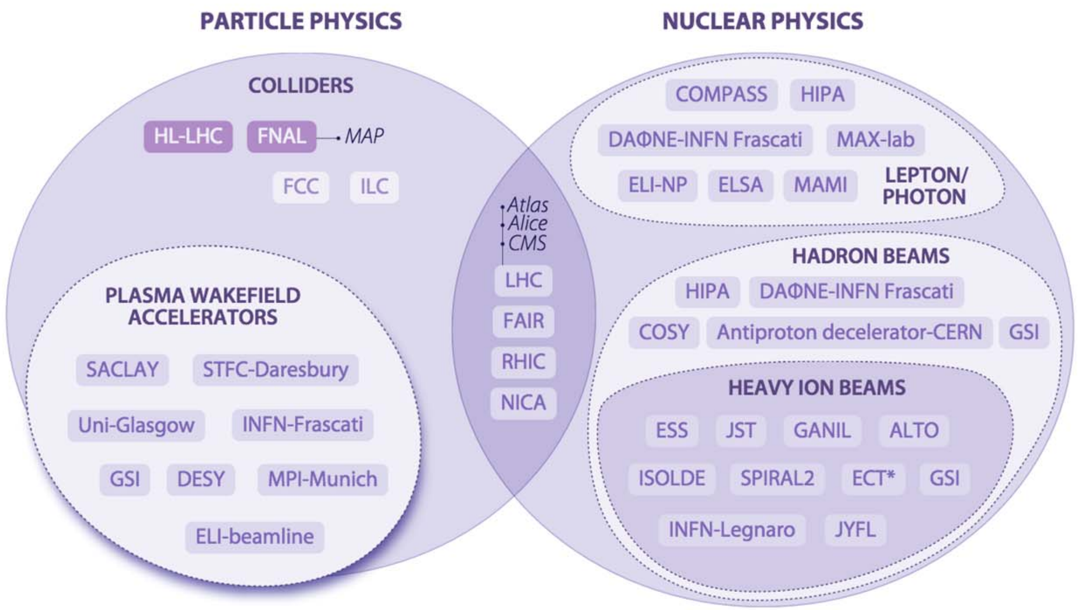
Figure 1B: space and time domain of investigation of the ESFRI Projects and Landmarks in Astronomy and Astroparticle Physics.



PARTICLE AND NUCLEAR PHYSICS

In particle and nuclear physics several very ambitious accelerator and detector projects are going on. Successful completion and commissioning of these systems will enable probing of physics beyond the Standard Model and unknown territories of nuclear landscape. The particle physics roadmap is global and new experiments are designed and planned globally.

Figure 2A: main Research Infrastructures in Particle and Nuclear Physics.



INTERNATIONAL PROJECT COMPLEMENTARY TO ESFRI PROJECTS

NICA, Nuclotron-based Ion Collider fAcility

NICA is an accelerator facility designed to perform a broad range of experiments on hot and dense nuclear and baryonic matter at the JINR in Dubna. It will be able to operate both in collider and fixed target modes and to provide a wide range of collision energies (in the center-of-mass system) and particle types, as using heavy ion beams in the energy range 4-11 GeV/A and proton beams with energy up to 27 GeV for heavy ion collisions and spin physics experiments with polarized proton and deuteron beams.

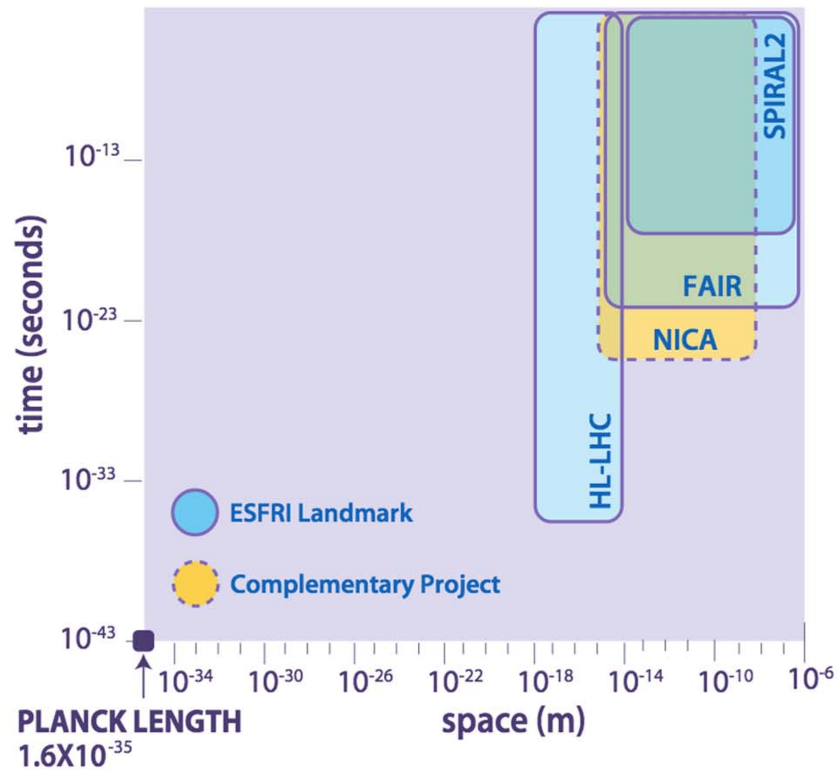
Ultra relativistic heavy ion collisions are a topical subject and one of the most active and lively areas of contemporary nuclear physics worldwide with a large and still growing user community. NICA will explore the regime of relatively low energy but extreme matter density and will have the possibility to investigate, through a beam-energy scan, the existence of a possible "Critical Point" in the QCD phase diagram, where rather novel and interesting phenomena might emerge. The design luminosity of NICA, required for rare signals, is impressively high for a low energy collider and comparable to RHIC and LHC which operate at much higher energies. The accelerator complex and the detector system (the MPD detector) have excellent capabilities for hadronic signals.

For low-mass lepton-pairs, which are critical to address medium modifications of hadrons and questions of chiral symmetry, and open charm and J/psi production, moderately significant measurements will be possible, complementing the much higher statistics experiments possible at CERN and FAIR. Also foreseen are applied physics, biology, material science and energy generation studies.

JINR has made important efforts to reach beyond its traditional community. The construction of NICA and the FAIR/GSI accelerators is in fact tightly linked via a strong collaboration between GSI and JINR on the FAIR project and there is potential for a similar close detector collaboration (MPD/SPD/BM@NICA).

The synergy and complementarity of the NICA and of the ***ESFRI Landmark FAIR*** L and to some extent of the ***ESFRI Landmark SPIRAL2*** L make it very desirable to develop a joint coordinated effort for identifying a strong programme and for offering the best opportunities to international nuclear experimental physics. To this end ESFRI encourages these RIs both to work closely together and to pay special attention to developing NICA as a Global Research Infrastructure concept.

Figure 2B: space and time domain of investigation of the ESFRI Landmarks and Projects.



ANALYTICAL PHYSICS

Europe's capabilities in analytical research infrastructures are second to none, with major investment in new neutron scattering capabilities, new light sources and major upgrades to existing facilities including greatly increased data and e-infrastructure. These new generations of facilities will provide entirely new capability to image and understand the behaviour of materials and molecules at the atomic scale, in-vivo/in operando and in real time ranging all the way from hours to femtosecond.

ANALYTICAL FACILITIES

SYNCHROTRON RADIATION SOURCES

ANKA, Diamond, Elettra, SLS, ESRF, SOLARIS, MAX IV, BESSY II, ALBA, DAFNE, SOLEIL, PETRA-III

LASER FACILITIES

ELI-ALPS, Petawatt, NFFA-SPRINT, ARTEMIS, FORTH, CFEL, T-REX, Laser Magajoule, HiPER, Vulcan

SLOW NEUTRON FACILITIES

SINQ, ILL, RPI, ORPHEE, HOR, BRR, BER II, VIENNA REACTOR, ISIS, JEPPII KJELLER, MLZ, ESS, LVR-15REZ, NCSR DEMOKRITOS

HIGH MAGNETIC FIELD FACILITIES

WHMFC, HHMFL, NHMFL, MagLab, EMFL

FREE ELECTRON LASERS

CLIO, Euro-FEL, FERMI@Elettra, European XFEL, Swiss-FEL, FLASH, SACLA, LCLS (outside Europe)

ELECTRON MICROSCOPY FACILITIES

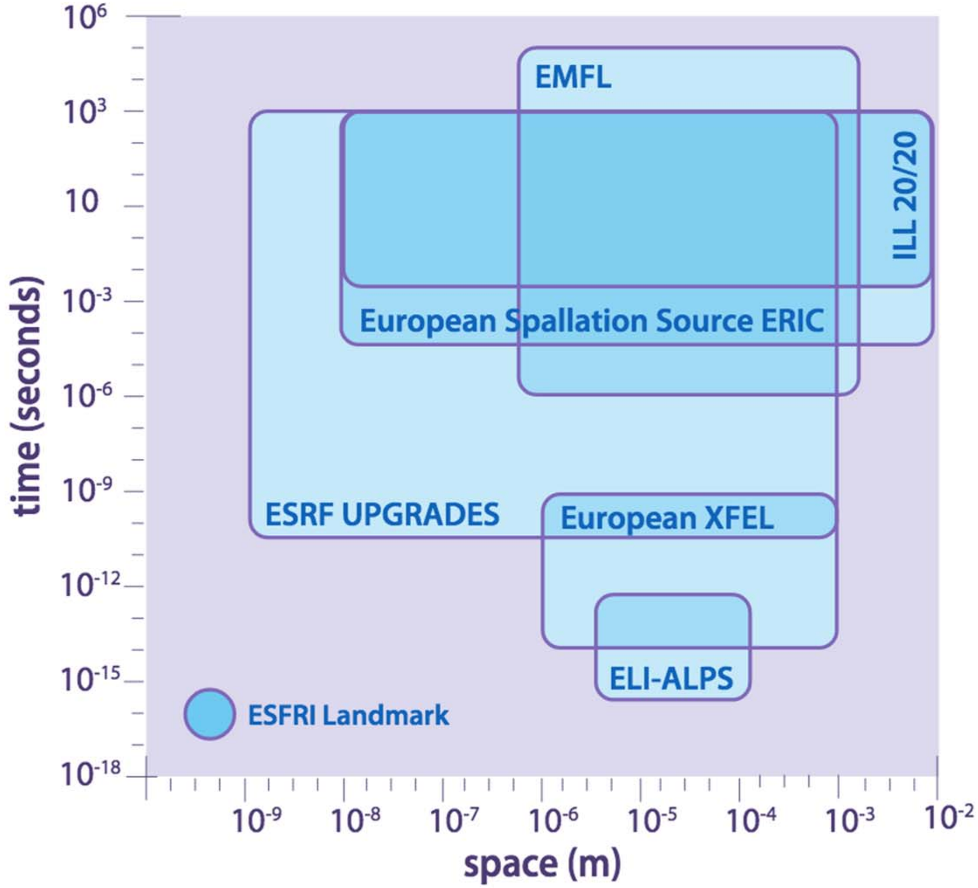
Juelich, Daresbury, SuperSTEM, TEAM (outside Europe)

Strategy Report on Research Infrastructures
ROADMAP **2018**

ESFRI

Landscape analysis PSE

Figure 3B: space and time domain of investigation of the ESFRI Projects and Landmarks in Analytical Physics.



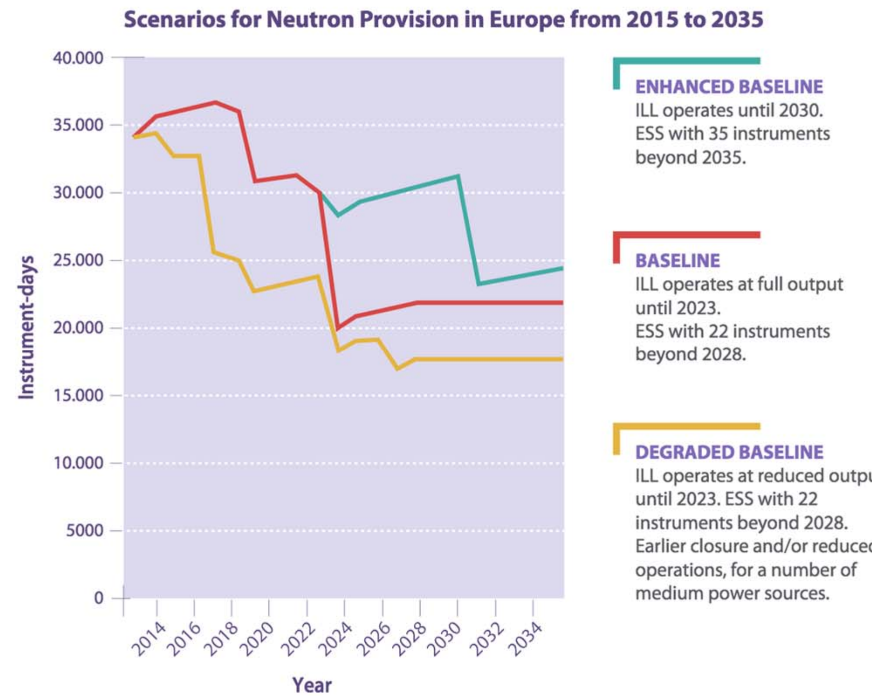
Landscape analysis PSE 2016

Considering the strategic importance of the Physics sector, European industrial policy should be aware both of the potential that can be mobilised by strong support of innovative scientific endeavours and of about the danger of losing the capacity to compete with other world regions if the capabilities of our Research Infrastructures fall behind. Critical technologies, such as detectors, particle accelerators, advanced optics, big data and E-infrastructure are urgently needed to maintain European leadership in a global knowledge-based competitive economy that will see more competing strategic players around the world in the forthcoming years.

Strategy Report on Research Infrastructures
ROADMAP 2018

SLOW NEUTRON FACILITIES: SUMMARY OF THE NEUTRON LANDSCAPE ANALYSIS

ESFRI has mandated an international expert group – the Neutron Landscape Group, NLG – to carry out a thorough analysis of the neutron ARIs operating in Europe, looking at the evolution expected in the coming decades.

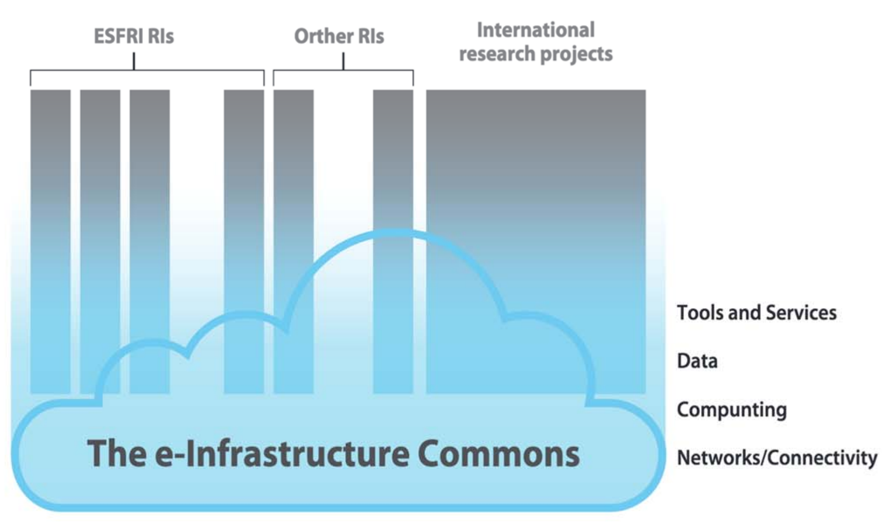


ESFRI

Strategy Report on Research Infrastructures
ROADMAP 2018

ESFRI

E-INFRASTRUCTURES



www.ESFRI.eu

Ad-hoc Expert Working Groups

to analyse key aspects of Research Infrastructures

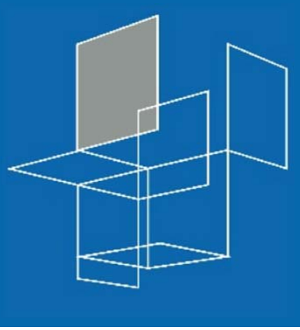
- ESFRI can create ad-hoc Working Groups of experts to develop specific studies on strategic issues and/or to fulfil specific mandates by the EU Council.
- The results of the work of the ad-hoc WGs is evaluated and adopted by ESFRI
- ESFRI may decide, when the results are of general interest, to publish ESFRI Scripta as reference books for the Research Infrastructure community at large, not engaging ESFRI

e-INFRASTRUCTURE

Council's mandate on coordination of Members States' investment strategies in e-Is

convergent policy of funding mechanisms for e-I including ***support and financing of e-I*** for scientific users, providing incentives to researchers to generate ***FAIR and reproducible (+R) data***, as well as the ***development*** of enabling e-tools/e-technologies

building on the EOSC HLEG vision and by ***strengthening the data FAIR+R generator role of RIs*** and the coordination of science and innovation communities also at broad international level as described by the e-IRG roadmap Realising the European Open Science Cloud Report 2016



urgent actions must be taken to support the ***training and hiring of e-I experts/scientists*** and to expand the ***data literacy*** at all levels of education and innovation activities to enable the return from the investment in e-I and RI and maximize societal benefits

Long Term Sustainability expert working-group to prepare recommendations

- Costs of all the stages of the LIFECYCLE of the RI, including decommissioning
- Public perception of VALUE of RI is a key element for sustainability
- Strategic planning of resources according to LIFECYCLE
- Understanding the VALUE of Research Infrastructure investment in economic terms
- Training, impact in forming scientists and international managers of complex undertakings
- Understanding the optimal fraction of GERD to be invested in RIs

Strategy Report on Research Infrastructures
ROADMAP 2018

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Two Parallel and Independent Evaluation Processes

STRATEGY WORKING GROUPS (SWG) IN FIVE SCIENTIFIC DOMAINS EVALUATE THE SCIENTIFIC CASE

1. SCIENTIFIC EXCELLENCE
2. PAN-EUROPEAN RELEVANCE
3. SOCIO-ECONOMIC IMPACT
4. E-NEEDS

IMPLEMENTATION GROUP (IG) ASSESSES MATURITY TO REACH IMPLEMENTATION

1. STAKEHOLDER COMMITMENT
2. USER STRATEGY & ACCESS POLICY
3. PREPARATORY WORK
4. PLANNING
5. GOVERNANCE & MANAGEMENT
6. HUMAN RESOURCES POLICY
7. FINANCES
8. RISKS

Strategy Report on Research Infrastructures
ROADMAP 2018

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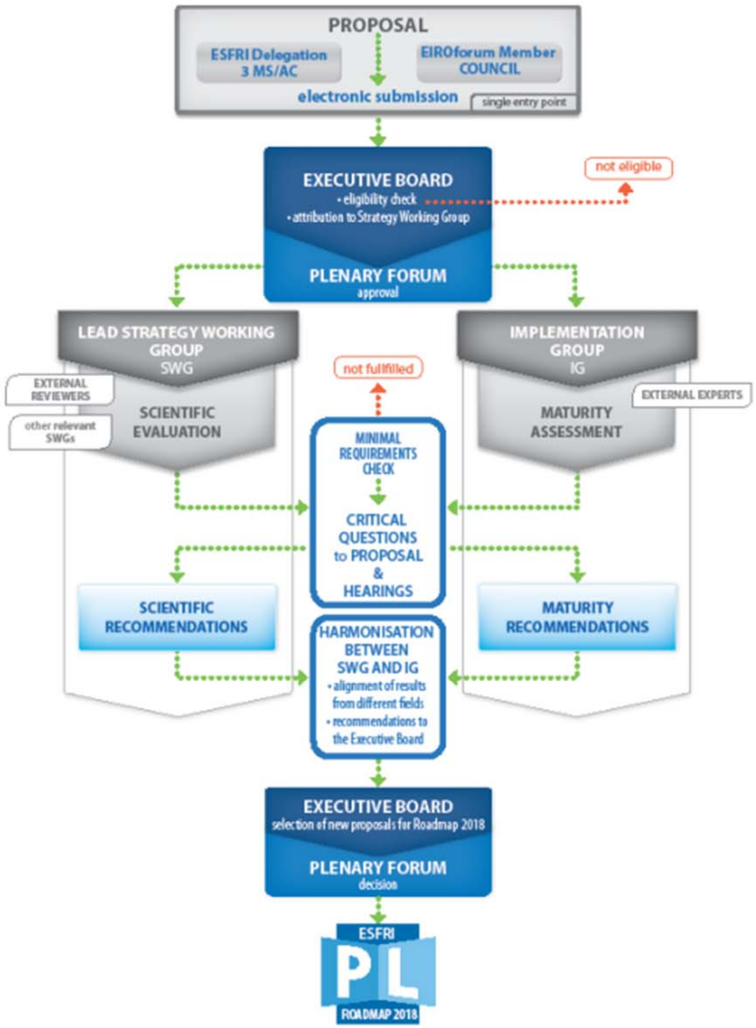

NEW PROPOSALS

- Guide for Proposers & submission form online in January 2017
- Infoday for Proposers in Malaga on 17th January 2017
- only ESFRI Delegations and EIFOforum members can submit until 31st August 2017
- Non European sites are needed/welcome
- International/Global partners are welcome/needed

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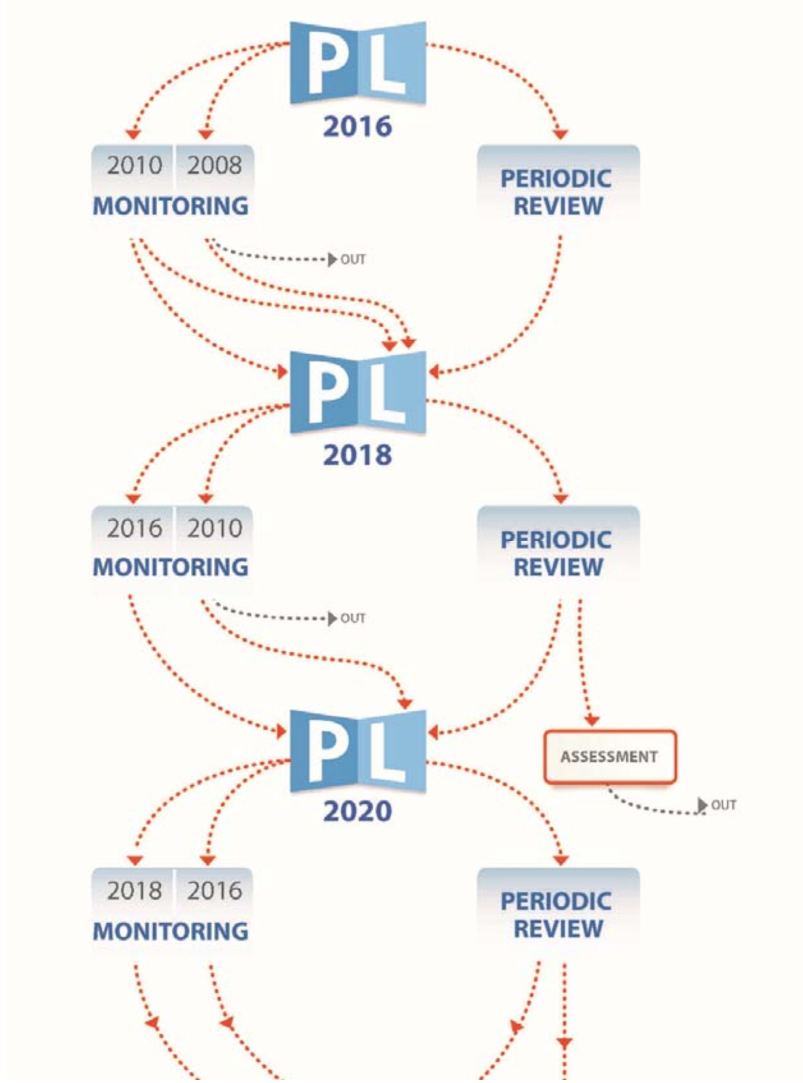
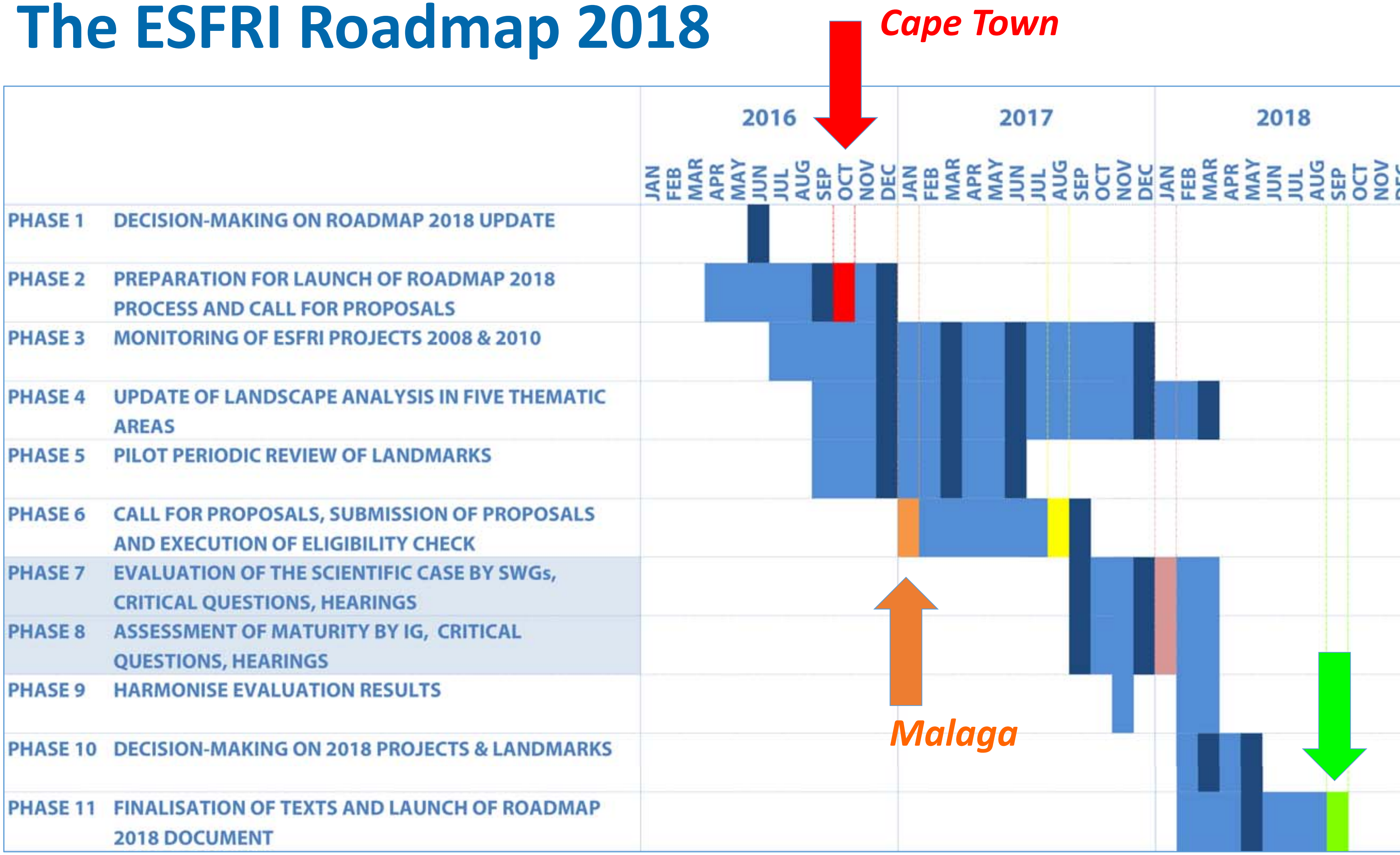


Roadmap Monitoring & Periodic Review

- Guide for Projects & Landmarks in January 2017
- Exchange of Experience Workshop for Projects & Landmarks in Malaga on 17th January 2017
- various publication dates & deadlines for specific questionnaires

The ESFRI Roadmap 2018



Roadmap 2018
Info Day
17.01.2017
Malaga,Spain
2nd Exchange
of Experience
Workshop
18.01.2017
Malaga,Spain
ESFRI