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Deliverable D4.1

Positioning Paper on Access Models

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Abstract

This Positioning Paper on Access Models document describes the developed Access model on data-free and time and frequency reference signals at the point of use of Pan-European Research Infrastructure for Time and Frequency Signal Dissemination defined in *D2.2 Roadmap for the Technical Implementation* of the T&F-reference system and *D3.1 Governance and Sustainability* for different groups of users identified in *D1.2 Requirements and Definitions*. The document also introduces a blueprint showing the uniqueness of the proposed CLONETS Research Infrastructure, its potential international outreach and how users can connect their institutions and equipment to the Pan-European Research Infrastructure for Time and Frequency Signal Dissemination.

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Executive Summary

This *D4.1 Positioning Paper on Access Models* document defines the position of the proposed CLOck NETwork Services for Strategy and innovation for clock services over optical-fibre networks (CLONETS) Research Infrastructure (RI) within the ESFRI Roadmap Landscape Analysis. Consequently, it describes the developed access model on data-free and time and frequency reference signals at the point of use of **Pan-European Research Infrastructure for Time and Frequency Signal Dissemination** defined in *D2.2 Roadmap for Technical Implementation of the T&F Reference System* and *D3.1 Governance and Sustainability* for different groups of users identified in *D1.2 Requirements and Definitions*. The document also introduces a blueprint showing the uniqueness of the proposed CLONETS Research Infrastructure, its potential international outreach and how users can connect their institutions and equipment to the Pan-European Research Infrastructure for Time and Frequency Signal Dissemination.

1 Introduction

This document aims to define a set of service models appropriate to the envisaged user groups and consider the effects of these on CLONETS Research Infrastructure importance.

The future Pan-European Research Infrastructure for Time and Frequency Signal Dissemination consists of a set of National Research Infrastructures for Time and Frequency Signal Dissemination interconnected by the CLONETS Research Infrastructure. While national infrastructures have already been independently built in several European countries and planned in other countries, there is a need for a European-scale Research Infrastructure. The principles, designs and ideas of operation of the future CLONETS Research Infrastructure is a subject of this project.

1.1 Structure of the document

This document includes three areas of outcomes of technical activities of the CLONETS-DS project consortium:

(a) **Identification of the position of the CLONETS Research Infrastructure** on the map of the European Research Area concerning the existing European Research Infrastructure, especially about the regular analysis of the European Strategy Forum on Research Infrastructures (ESFRI) Landscape and further ascertaining the contribution of the CLONETS Research Infrastructure to selected scientific areas that cover the existing European Research Infrastructures.

(b) **Access Model proposal** for users of the CLONETS Research Infrastructure, which will include both the connection of users to the distribution network of precise time and frequency signals, as well as the access of users to the database of data produced by the CLONETS Research Infrastructure.

(c) **Blueprint** showing the proposed infrastructure's uniqueness, potential international reach, and impact on individually selected areas.

The document is compiled as a positioning paper, in which all the areas mentioned above are subsequently developed.

1.2 Input data for Positioning Paper

Inputs to this document are based on the solution of the technical agenda WP1 Science Cases (needs of potential users), WP2 Technical Design (survey of the current state and technical design), and WP3 Governance and Sustainability of the future Pan-European Research Infrastructure for Time and Frequency Signal Dissemination is possible to summarise outputs into the following paragraphs.

1.2.1 Users from relevant areas of research (WP1)

Based on the analysis presented in *D1.2 Requirements and Definitions*, we summarised the main, relevant areas of research where the future Pan-European Research Infrastructure for Time and Frequency Signal Dissemination would have a significant role: Fundamental Science (clocks improvement, precision spectroscopy to search for beyond standard model physics, SI unit second re-definition), Quantum Technologies (real-world [QKD] improvement, new protocols development, entanglement distribution beyond QKD), Earth Observation / Geodesy (height system unification, satellite gravity mission validation, geodetic network consistency), Astronomy (radio interferometry and VLBI in astronomy, laser ranging, pulsar timing), Telecommunication, Position, Navigation, Synchronisation, and Timing.

1.2.2 Technical structure and Governance (WP2 and WP3)

The technical design of the future Pan-European Research Infrastructure for Time and Frequency Signal Dissemination (*D2.2 Roadmap for Technical Implementation of the T&F-reference system*) and Governance (*D3.1 Governance and Sustainability*) of the organisational structure of the infrastructure led to the arrangement which consists of the set of National Research Infrastructures for Time and Frequency Signal Dissemination spread over many countries in Europe that are interconnected by the CLONETS Research Infrastructure.

Note: Terminology

This document uses the term "*National Infrastructure/s*" as a short form of the National Research Infrastructure/s for Time and Frequency Signal Dissemination.

2 Position of CLONETS Research Infrastructure in the European Research Area

The future CLONETS Research Infrastructure will be a European-scale Research Infrastructure, characterised by the following features:

- Based on the model described in *D3.1 Governance and Sustainability,* the Research Infrastructure will be in accordance with European Research Infrastructure Consortium [ERIC] legal entity where members are mainly EU member states.

- It involves strategic partners (institutes, universities, and other organisations) operating unique equipment such as optical clocks and different types of precise atomic clocks and developing and operating the leading-edge techniques for precise time and frequency signals over fibre links.

- Participating scientists and researchers also represent the best European knowledge base in building and operating the most stable frequency generators and accurate clocks, including the transfer of time and frequency signals.

- It has the physical infrastructure (European Core Network for Time and Frequency Signal Dissemination) in a dedicated optical network and deployed devices for transferring and distributing time and frequency signals.

The user community which utilises time and frequency signals includes: research institutes, the project-oriented association of research institutes, universities, other Research Infrastructures, and partially commercial subjects.

2.1 Gap analysis according to ESFRI Landscape 2021

In this sub-chapter, we focus on the survey of gaps in European research infrastructures, according to Part 2: Landscape Analysis of *ESFRI Roadmap 2021* [ESFRI Roadmap]This document analyses in detail the state of play of six key thematic areas. These domains are: (1) Data, Computing and Digital Research Infrastructures, (2) Energy, (3) Environment, (4) Health & Food, (5) Physical Sciences & Engineering, and (6) Social & Cultural Innovation. A separate subsection is devoted to each of these areas. At the end of each subsection, the position of the future CLONETS Research Infrastructure is presented. It is thus possible to identify the degree of necessity of this planned infrastructure from the point of view of the European Research Area [ERA].

2.1.1 Data, Computing and Digital Research Infrastructures Domain

The ESFRI Landscape of the Data, Computing and Digital Research Infrastructures domain is shown in Figure 1. It is divided into three areas: Digital Infrastructures, Data Infrastructures, and Computing Infrastructures.

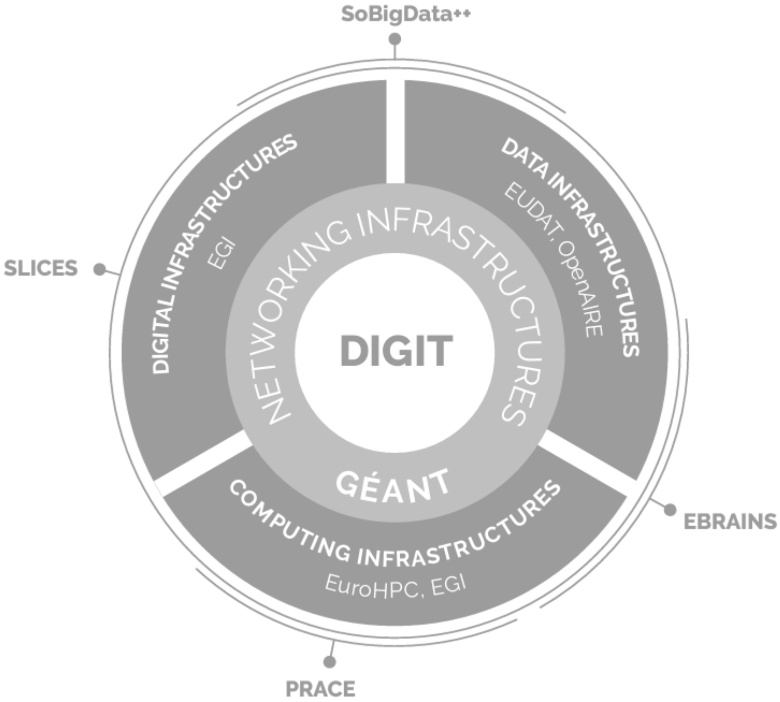


Figure 1. Landscape of the Data, Computing & Digital Research Infrastructures domain (source: ESFRI Roadmap 2021)

2.1.1.1 *Data Infrastructures*

RIs mainly provide shared data storage and facilitate user access in this segment. EUDAT is a collaborative data infrastructure that manages data from European research data centres and community data repositories [EUDAT]. EUDAT aims to support the sharing and to preserve data across borders and disciplines, offering research data management services and storage resources that support diverse research communities and individuals through a geographically distributed and resilient network across 15 European countries. European researchers and practitioners from any research field can store, search, access, and process data in a trusted environment. OpenAIRE is a crucial initiative and is developing a set of mechanisms for implementing and monitoring open science in Europe [OpenAIRE]. They provide services for European Open Science Cloud (EOSC) [EOSC], which include, for example, a set of services that help researchers do open science, Zenodo[Zenodo] (universal repository), Argos (Data Management Plan) [Argos], Amnesia (anonymisation tool) [Amnesia], OpenAIRE Graph (a global contextual catalogue of interconnected research results, which is the basis for intelligent discoveries based on artificial intelligence) [OpenAIREGraph].

2.1.1.2 *Computing infrastructures*

High-performance computing (HPC) infrastructures include high-performance computing optimised for large memory and multi-processing unit (CPU) workloads that can be divided into subtasks distributed across multiple servers. There are also infrastructures for more specialised computing architectures, e.g., at the European level, two crucial infrastructures support HPC: EuroHPC Joint Undertaking (EuroHPC JU) and ESFRI Landmark PRACE [EuroHPC JU] [PRACE]. PRACE offers a pan-European supercomputing infrastructure that provides access to computing and data management resources and services for large-scale scientific and engineering applications at the highest performance levels. PRACE has 26 members representing European Union member states and associated countries.

2.1.1.3 *Digital Infrastructures*

In this segment, Research Infrastructures mainly provide networking and other services related to the digital connectivity of users. Today, every European country has a National Research and Education Network (NREN), which connects research and higher education institutions with high-performance networks and offers a range of related services. NRENs have created the GÉANT consortium, which provides users with highly reliable, unrestricted access to computing, analysis, storage, applications and other resources to ensure that Europe remains at the forefront of research. In Europe, a new infrastructure is also gradually being created that will ensure the security of sensitive data transfers between users. The European Quantum Communication Infrastructure (EuroQCI) will transmit quantum encrypted keys (QKD) for secure communication. This infrastructure is still under construction [EuroQCI].

2.1.1.4 *The benefit of CLONETS Research Infrastructure to Data, Computing and Digital Research Infrastructures Domain*

For HPC infrastructures and high-speed data transfer, both time and frequency from a single source with high accuracy and stability are critical. The instability of local clocks in different places of the communication network and computing centres can limit the research of new methods for high-speed data transmission and data synchronisation. In the same way, such synchronisation e.g., networks that transfer encrypted keys (QKD) is necessary for secure communications and in the future, for the "quantum internet". The lack of synchronisation of high-resolution communication networks may limit the future transmission speeds of high-speed data networks and further define the security of QKD transfer networks. Likewise, synchronisation is essential for data infrastructures. High-resolution timestamps play a vital role in creating shared datasets. Sources of acquired data are distributed in such systems. The acquired data must therefore be provided with time stamps so that the management of the data stores can organise them correctly and with high reliability.

2.1.2 Energy Domain

The ESFRI Landscape of the Energy domain is shown in Figure 2. It is divided into five areas: Energy Systems Integration, Renewable Energy, Efficient Energy Conversion and Use, Nuclear Energy, and Cross-sectional Energy Research Infrastructures.

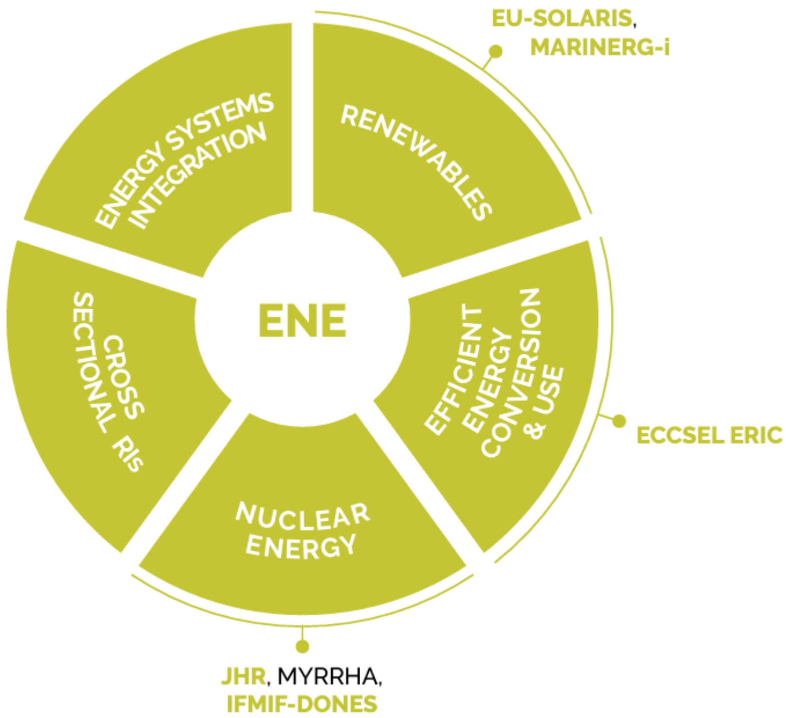


Figure 2. Landscape of the Energy domain (source: ESFRI Roadmap 2021)

2.1.2.1 *Energy Systems Integration*

Advanced energy management systems that can coordinate distributed energy storage in networks are challenging to develop for use with large-scale transmission and distribution networks, and meet different demands (electrical, load, thermal loads, etc.). The future European energy system, with an expected higher penetration of renewable energy sources in the overall portfolio of energy sources, needs a powerful interplay and especially synchronisation between different energy carriers such as electricity, heating, and cooling, e.g., gas and other chemical fuels. Such a system requires management of intermittent generation from renewable energy, variable consumption of all carriers and energy storage. Energy storage is an important technology for stabilising performance fluctuations and defining economically and ecologically sustainable options for energy systems in Europe. Research and development in the field of Smart Grids are aimed at grids that can intelligently integrate the activities of all users connected to it, i.e. generators, energy storage devices and consumers. This integration requires a combination of technologies for network management, information technology and intelligent management of energy generation, transmission, distribution and storage. ESFRI sees a significant gap in design reference architectures and modelling tools for large-scale flexible power grid control systems that include different types of energy and relate to the local scale (distributed generation and low voltage networks).

2.1.2.2 *Renewable Energy*

This category includes research infrastructures focused on solar, wind, geothermal, and ocean resources and renewable fuels. The need for new research facilities is identified, particularly in wind energy integration into the power system and for floating offshore wind farms, which are expected to play a dominant role in exploiting the global wind energy potential. These research facilities will have to be integrated into distribution networks and will require smart management in their implementation for the energy sector.

2.1.2.3 *Efficient Energy Conversion and Use*

This area includes several topics that European research infrastructures must address.

It is clear that there will be a need to focus on energy efficiency in buildings. This area may concern the use of the heat storage potential of buildings to engage intermittent renewable electricity production or the use of waste products from industry for energy production, as well as to increase the efficiency of local resources and savings in buildings. Various large-scale research and pilot projects are underway in Europe, e.g. in the steel industry.

Because supply and demand for electricity must immediately match, problems arise if the electricity system heavily depends on inseparable electricity generation from renewable sources. A method for effectively balancing supply and demand is likely based on electricity storage. Batteries are unlikely because the storage volumes achievable with current lead and lithium-based technologies must be increased. An alternative form of chemical storage of excess electrical energy, for example, in the form of hydrogen, is fundamentally necessary to convert it into electricity when needed.

Although likely, it remains to be seen whether large-scale carbon dioxide capture, storage and utilisation (e.g. Research Infrastructure ECCSEL ERIC) will become an essential part of the energy system [ECCSEL ERIC]. Among the abovementioned topics, further significant investments in the relevant research infrastructure should be considered.

2.1.2.4 *Nuclear Energy*

The field of nuclear fusion and fission is a long-term research topic. The European fusion program has two main goals, to prepare for the successful operation of ITER, the first nuclear fusion device to create clean energy, and to design the first power generation device, the so-called DEMO, which should be put into operation in the middle of the 21st century [ITER] [DEMO]. ITER construction is in full swing, first plasma by 2025 and DEMO operation by the end of 2035. In addition, EUROfusion coordinates the use of all significant European fusion research facilities. In addition to research infrastructures, several infrastructural simulation systems based on HPC participate in the research.

2.1.2.5 *Cross-sectional Energy Research Infrastructures*

Energy networks and systems need detailed and voluminous data and model-based processing from the local to the macroscopic scale. A wide range of interdisciplinary energy-relevant topics need to be addressed, such as: the design of new materials, conversion processes, energy generation efficiency, energy transportation, system design, and operational/life-cycle optimisation. Other examples are process modelling for nuclear repositories, fusion reactor modelling, or energy market modelling through high-resolution renewable energy production forecasts. Distributed Research Infrastructure platforms such as DERlab and ERIC-Lab and the growing number of national laboratories collecting and processing data of complex natural energy systems have the potential to advance the digital integration of distributed and volatile energy resources into real-time energy systems [DERlab] [ERIC-Lab].

2.1.2.6 *The benefit of CLONETS Research Infrastructure on the Energy Domain*

Energy, and especially electricity transmission networks are the key critical infrastructure of Europe. With the massive deployment of renewable sources and the reduction of traditional fossil fuel sources, the need to optimise electricity flows across the continent is growing. Emphasis is therefore placed on research in systems such as Smart Grids, which depend on precise time synchronisation. Also, all energy sources must have their phase precisely synchronised with the network. Ideally, all sources should be capable of external synchronisation to signals from accurate time and frequency sources propagated through any infrastructure (or Research Infrastructure). In the case of insufficient or unavailable synchronisation, resources in the energy network are pushed against each other and energy losses increase. Also, collecting data from sensor networks for creating models and processing forecasts or predicting the development of energy consumption requires precise timing. It is about adding real-time stamps and synchronising metrological devices according to legal time. The future CLONETS Research Infrastructure will be able to provide all this.

2.1.3 Environment Domain

The ESFRI Landscape of the Energy domain is shown in Figure 2. It is divided into four areas: Geosphere, Atmosphere, Hydrosphere, and Biosphere.

2.1.3.1 *Geosphere*

Monitoring of natural hazards, e.g. earthquakes, volcanic eruptions, rock falls, landslides, thawing, tsunamis, avalanches and man-made hazards, e.g. forest fires, landslides and groundwater depletion, but also natural resource monitoring has been identified as an essential component of sustainable development. New Research Infrastructures and data are urgent in geo resources and mining to achieve energy and mineral security in Europe. Rock strain measurement laboratories, deep underground laboratories, green biomining technologies, geochemistry and mineral resource analytical facilities and modelling facilities are key required components. There is also a need for new Research Infrastructures to enable Member States to meet the requirements for scientific research and technological development for the safe management of high- and intermediate-level nuclear waste in accordance with international and European legislation, e.g. the Directive on the Management of Radioactive Waste and Spent Radioactive Waste [Reg2011/70].

2.1.3.2 *Atmosphere*

This area is focused on research on persistent organic pollutants, greenhouse gases, aerosols, clouds and reactive gases and atmospheric dynamics. It is essential to study not only the components of the atmospheric system but to observe them synergistically to understand the processes and linkages fully. A synergistic approach must include in-situ observations, aircraft and satellite observations, and laboratory and model studies to understand atmospheric composition and processes. Long-term records of atmospheric parameters relevant to air quality and climate research must be improved. Also, existing Research Infrastructures must still include atmospheric contamination by older and emerging persistent pollutants. At the same time, there is great interest in the use of low-cost distributed sensors of atmospheric parameters, which have the potential to be used in much higher numbers than the usual expensive and labour-intensive instrumentation. However, the accuracy and precision of the sensors must be carefully evaluated. Here, great emphasis is placed on metrology and the continuity of the measurements. The monitoring data obtained from these sensors is then integrated in real-time from various platforms and is used to develop modelling tools implemented on advanced global cyber infrastructures for computing (HPC Infrastructures) and data sharing (data Infrastructures).

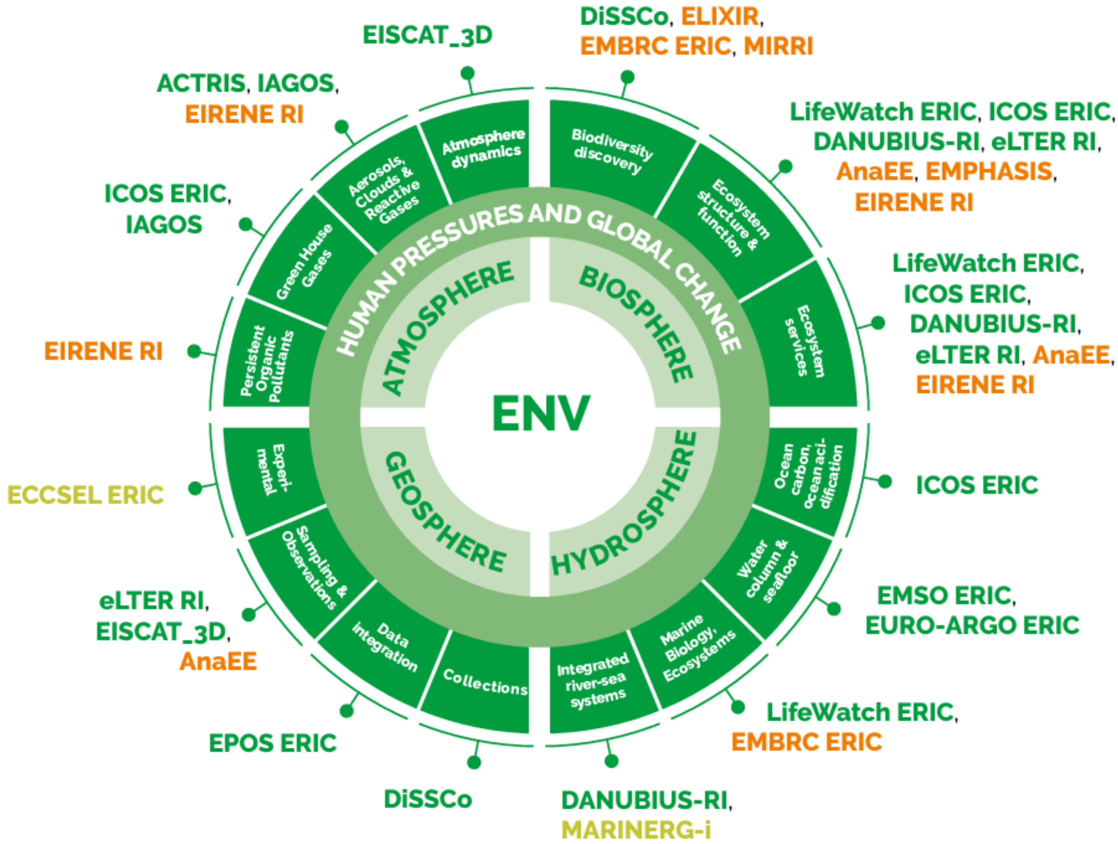


Figure 3. Landscape of the Environment domain (source: ESFRI Roadmap 2021)

2.1.3.3 *Hydrosphere*

Europe needs a dense, highly instrumented freshwater monitoring network, as well as simulation, and experimental platforms. Lake, river and groundwater monitoring and experimental selected sites should serve as calibration, validation and development services for remote sensing applications and ecosystem services modelling. For a comprehensive analysis of changes in aquatic ecosystems, an integrated watershed approach is necessary to understand the impact of various factors and to find measures for sustainable management of water resources. Long-term observation is needed to address scientific and societal challenges operating at different spatiotemporal scales and to understand large-scale processes that can significantly affect coastal and marine areas. This activity can only be achieved at a pan-European level. Thus, the subject of research is integrated river-sea systems, marine biology, ecosystems, water column and seabed, ocean carbon and ocean acidification.

2.1.3.4 *Biosphere*

In this area, the subject of research is the discovery of biodiversity, ecosystem structure and function, and ecosystem services. There are e-Infrastructures for data, analysis and modelling: LifeWatch ERIC, IS-ENES3, and SeaDataCloud [LifeWatch ERIC] [IS-ENES3] [SeaDataCloud]. These e-Infrastructures focus on monitoring biodiversity and ecosystem changes; supporting, developing and implementing key biodiversity variables as ecological data products based on data and metadata standards; data quality; data retention and open data policies. In this area, it will be necessary to focus on environmental contamination, its connection with climate change, and the dangers and risks associated with toxic compounds, especially endocrine disruptors. Test platforms are also required to elucidate the processes that lead to the current adverse outcomes.

2.1.3.5 *The benefit of CLONETS Research Infrastructure on the Environment Domain*

Monitoring the parameters of the Earth and its environment is a crucial area of research in the European Research Area. The future CLONETS Research Infrastructure is a great way to monitor phenomena in the Geosphere. E.g., detecting signals caused by earthquakes or volcanic activity or the consequences of human activity (mining of minerals and fuels) is extremely sensitive to external mechanical action due to the high sensitivity of optical fibres. In Atmosphere and Hydrosphere, accurate time and frequency signals can be used for precise synchronisation of measurement processes. For example, monitoring the level, especially very small changes in the concentration of carbon dioxide in the atmosphere, is done using susceptible methods of laser molecular spectroscopy. Synchronisation of the optical frequency of the measuring spectroscopic lasers is necessary for the long-term reliability and repeatability of the data measured by these systems. To carry out geographical mapping of the distribution of carbon dioxide concentrations, such measuring systems are located in several locations throughout the continent. If they are not precisely synchronised with the optical frequency by distributing the time and frequency signals using the future CLONETS Research Infrastructure, a reliable evaluation of carbon footprint changes cannot be guaranteed, which will have implications for many research studies in the field of Environment. In the same way, the CLONETS Research Infrastructure can be used to monitor changes in the height levels and changes in the Earth's geomagnetic field thanks to its synchronisation using optical quantum clocks (chronometric levelling). A significant impact is the synchronisation of measurement systems in terms of data communication to data collection centres and the synchronisation of HPC Infrastructures, which ensure subsequent processing of large volumes of data to simulate processes in this Environment domain.

2.1.4 Health and Food Domain

The ESFRI Landscape of the Health and Food domain is shown in Figure 4. It is divided into two areas: Health and Food.

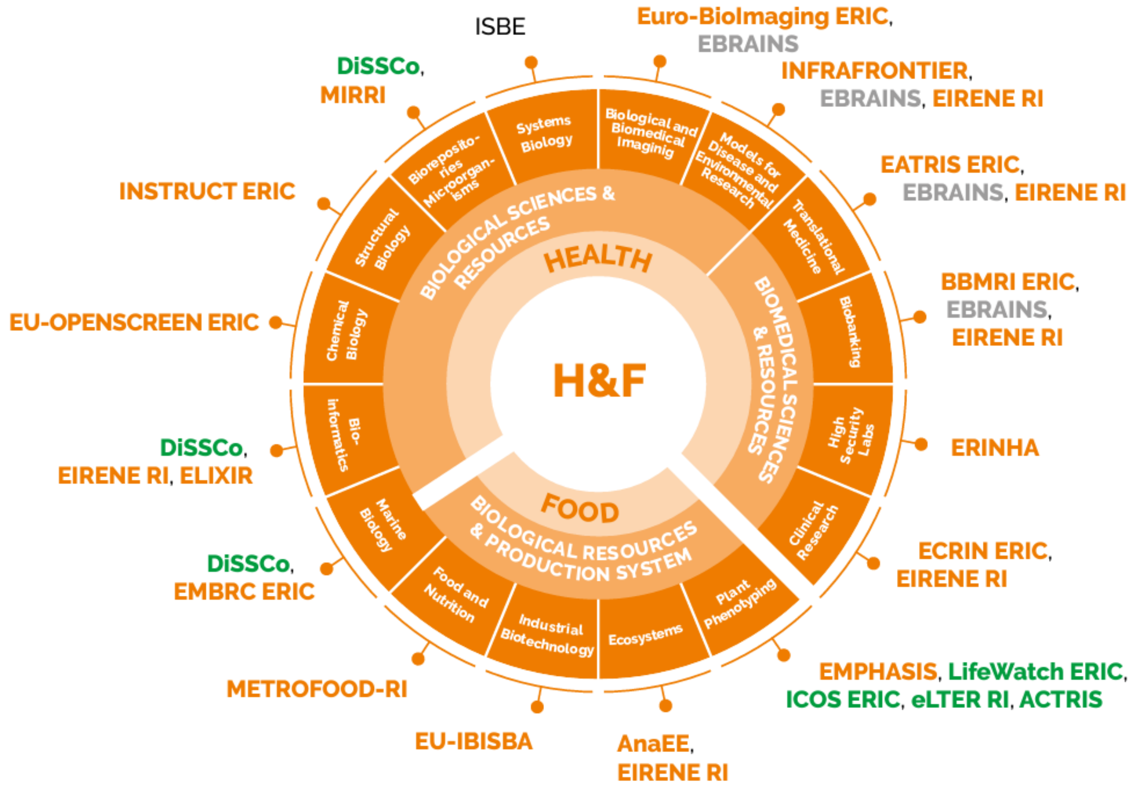


Figure 4. Landscape of the Health and Food domain (source: ESFRI Roadmap 2021)

2.1.4.1 *Health*

For the Health subdomain, challenges include emerging areas: synthetic biology and its connection to health, food and agriculture, programmable bacteria, supporting the translation of new technologies and genetic findings to enable effective disease correction and treatment, gene therapies (genome editing, personalised medicine including cancer and rare diseases), and threats of infections and their impact.

Biomedical Engineering and Electronics will focus on the clinical use of new sensors, various medical devices, and embedded electronics such as wearables and implantable technologies. Biotechnology includes 3D bioprinting and biomedical technologies to bridge the gap between biological science, medicine and biomedical engineering, an interface for preclinical development, and a platform to facilitate and accelerate translation into medical practice.

The complexity and sheer volume of medical and biomedical data being acquired and managed by the Research Infrastructures of the Health subdomain are already staggering and increasing. Together with complex metadata, it presents specific data management issues that must be incorporated into the EOSC architecture and, thus, the Digital Infrastructures domain. Furthermore, rules and guidelines on how to collect and adequately use patient data need to be further developed. The goal is to manage data for precision medicine.

Artificial intelligence is also identified as the future infrastructure for creating opportunities and combining data from different sources for the Health subdomain.

2.1.4.2 *Food*

In the Food subdomain, the challenges include: solving the problem of producing safe, healthy and sustainable food, continuing the pooling of national facilities at the pan-European level in the field of animal genetic resources, phenotyping and breeding, and animal health. Furthermore, in connection with climate change, the challenge will be an adaptation to higher feed efficiency. In the field of instruments, it is the integration of bioimaging, digital imaging, genomics, proteomics and metabolomics facilities, area and veterinary facilities, and experimental farm platforms for animal studies and phenotyping, including aquaculture and animal disease facilities. A significant challenge is also the assembly of pilot plants, demonstration plants and larger-scale facilities to enable access to the production and processing of materials and chemicals (e.g. antibiotics). Another challenge is obtaining energy using biological resources, including plants, algae, marine life, fungi and microorganisms.

High-quality measurement services with traceable metrology in food and nutrition include a cross-section of highly interdisciplinary and interconnected fields throughout the food value chain, including agriculture, sustainable development, food safety, quality, traceability and authenticity, environmental safety and also human health, which are also a common challenge.

Integrated approaches, including e-infrastructures, are needed to systematically predict diagnoses, prevent and treat plant and animal diseases, and develop effective responses to mitigate the impact on agricultural ecosystems.

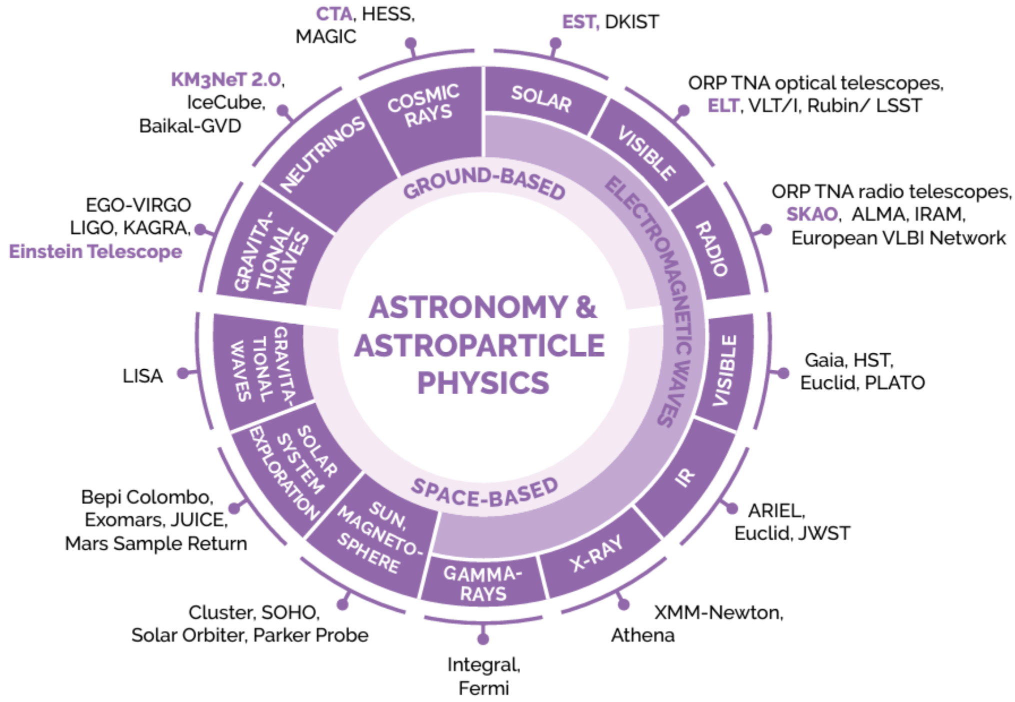
Digital Infrastructure domain technologies are essential for the above areas as well. With increasing opportunities for crop breeding and production, it will be necessary to increase the availability of platforms such as 5G, robotics or artificial intelligence. Furthermore, it will be about developing and implementing new technologies, including machine learning (necessary for, e.g. smart agriculture), common standards enabling the use and reuse of data from agriculture and data science from sensors to predictive models and decision support. All this is necessary for a functional and sustainable intensification of agriculture.

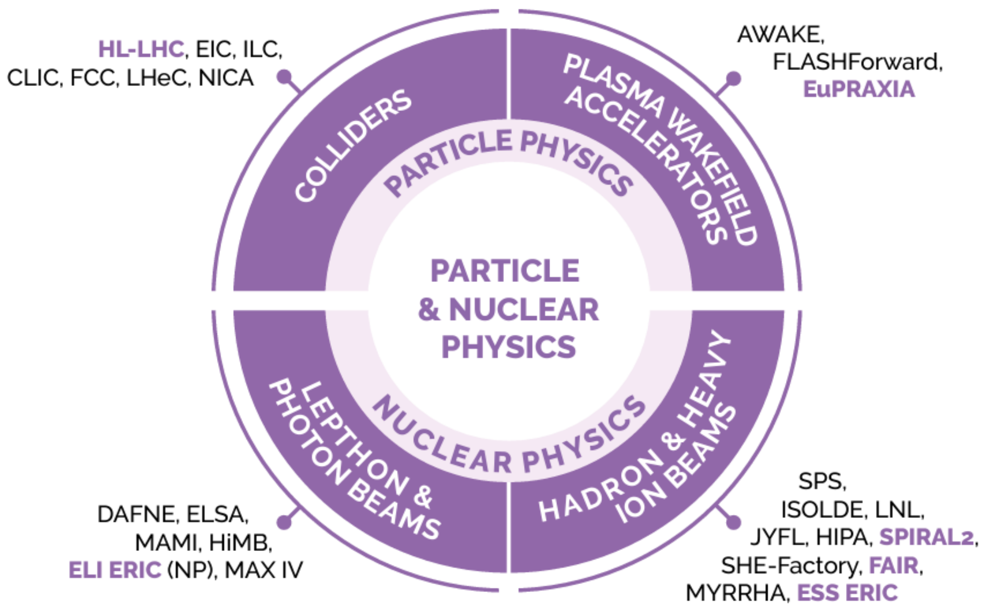
2.1.4.3 *Benefit of CLONETS Research Infrastructure on the Health and Food Domain*

With the development of research infrastructures in the Health domain, it will be necessary to use the distribution of accurate time and frequency signals, especially when introducing new medical devices and embedded electronics and monitoring new medical procedures. The field of surgery can serve as an example. It requires precision in every aspect, including timing. This accuracy allows staff in the operating theatre to make split-second decisions during critical situations with total confidence in their timekeeping. Anaesthetists require similar precision when administering anaesthetics to patients and at the proper intervals. Failure to adhere to these exact timings can lead to complications and failures in patient care. The unavailability of accurate time information can cause the ineffectiveness of medical care. The same applies in the Food sub-domain, where complex infrastructural systems for monitoring the conditions of growing plants or in animal husbandry must have precise time and frequency synchronisation. This requirement is similar to the view of metrological traceability, which allows mutual comparison of measured data under defined measurement conditions and marking produced data with high-resolution time stamps for later processing in data centres or HPC computing. In both sub-domains, it is clear that large volumes of data will need to be processed. The possibility of synchronising acquired data files and timed communication is a condition for implementing faithful computational models and possible deep learning systems.

2.1.5 Physical Sciences and Engineering Domain

The ESFRI Landscape of the Health and Food domain is shown in Figure 5. It is divided into three areas: Astronomy and Astroparticle Physics, Particle and Nuclear Physics, and Analytical Physics.





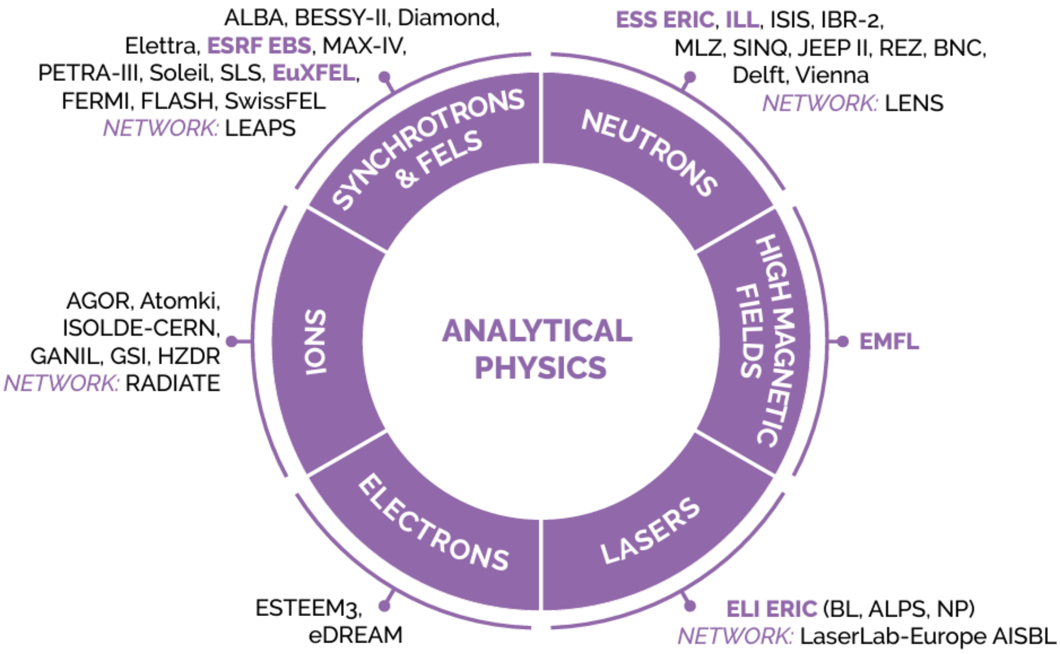


Figure 5. Landscape of the Physical Sciences and Engineering domain (source: ESFRI Roadmap 2021)

2.1.5.1 *Astronomy and Astroparticle Physics*

The goal of Research Infrastructures in this subdomain is to understand the universe and its components, origin and evolution. Activities include integrating information from multiple detection areas, time domain search for life in the Universe, and high angular resolution/adaptive optics for imaging the Universe.

The development of astronomy in the time domain will be supported, particularly by the arrival of the Legacy Survey of Space and Time (LSST) project [LSST]. The new paradigm involves observing and interpreting transient warnings using a network of telescopes and underground or underwater/ice detectors. Especially relevant is the observation of gravitational waves based on the space antenna provided by laser interferometry (as part of the LISA project) and the ESFRI Einstein Telescope project, which is designed as a European third-generation gravitational wave observatory with a significant increase in sensitivity [LISA] [ET].

2.1.5.2 *Particle and Nuclear Physics*

The goal is to understand the behaviour of the fundamental particles and interactions that govern the universe and to search for new physics beyond the Standard Model. The activities are designing and implementing high-field superconducting magnets, high-gradient particle accelerators with breakthrough technologies, sources for high-intensity and high-quality muon beams, high-performance detectors for photons and charged particles, and high-intensity beams of rare isotopes.

New physics can be probed by experiments looking for extremely rare phenomena. Several proposals aimed at weakly interacting particles in the low-mass region could reveal new particles of possible cosmological significance. They require very intense particle beams or lasers. A direct search for dark matter in underground laboratories will require detectors with much larger target masses. In the long term, new detector technology capable of directing detection to an area of interest must be developed.

Advanced and reliable innovative detectors are the cornerstone of nuclear and particle physics research. Over time, they expand into detection and imaging systems for use in many other areas of science and society. New quantum sensing devices are under development, which will significantly increase the accuracy of measurements. Detector technology has high social value and the potential for transferring technology into practice.

2.1.5.3 *Analytical Physics*

The goal is to solve grand societal challenges by exploring the frontiers of fundamental physics and materials science. Activities mainly include obtaining higher brightness and a stronger field, higher temporal and spatial resolutions, in situ and real-world experiments and developing technologies for a range of detector types.

Short-pulse, high-power lasers and their secondary particle and radiation sources focus on high-efficiency, high-repetition-rate laser systems for driving laser-plasma-based particle accelerators and X-ray sources. Addressing these new needs in laser technology becomes a challenge in order to further expand the user community in areas of high industrial and societal impact. The Laser Research Infrastructures strongly interact and impact particle and nuclear physics through the joint development of accelerator technologies.

Interest in using radioisotopes in materials research is growing in ion beam facilities, and institutes such as ISOLDE-CERN and GSI are trying to accommodate this [ISOLDE-CERN] [GSI]. Extensive ion beam infrastructures are complemented by stand-alone ion beam-based techniques such as atom probe tomography and helium microscopy. For high magnetic field devices, coordinated development across Research Infrastructures (CERN, etc.) is needed to develop even higher static and pulsed magnetic fields and improve the required materials (superconductors, copper alloys, reinforcements) and enable a broader portfolio of measurements in short time scales of pulse fields.

2.1.5.4 *Benefit of CLONETS Research Infrastructure in Physical Sciences and Engineering Domain*

The synchronisation by time signal distributed via CLONETS Research Infrastructure will benefit areas of astronomy that exploit observations from multiple sites and/or use various techniques. A prime example is VeryLong Baseline Interferometry (VLBI) infrastructures for astrometry, which will allow improved data analysis with the potential for discoveries and improvements to the celestial reference frame. VLBI has stringent requirements for both short-term and long-term. Pulsar timing is another well-established area expected to benefit, while there is a potential for applications to other fast-growing topics, such as multi-messenger astronomy. CLONETS Research Infrastructure can provide the infrastructure for measuring the gravitational potential of Earth differences between optical quantum clocks located at as-needed locations. It can therefore be used to measure height differences throughout Europe and establish a unification of Europe's height system and, ultimately, satellite gravity mission validation and geodetic network consistency.

The lack of precise synchronisation using CLONETS Research Infrastructure renders it unable to improve the quality of acquired images of space observed synchronously or to further improve the

European height system and a geological survey by detecting very small changes in the Earth's gravity field.

2.1.6 Social and Cultural Innovation Domain

The ESFRI Landscape of the Social & Cultural Innovation domain is shown in Figure 6. It is divided into three areas: Humanities, Social Sciences, and Big Data.

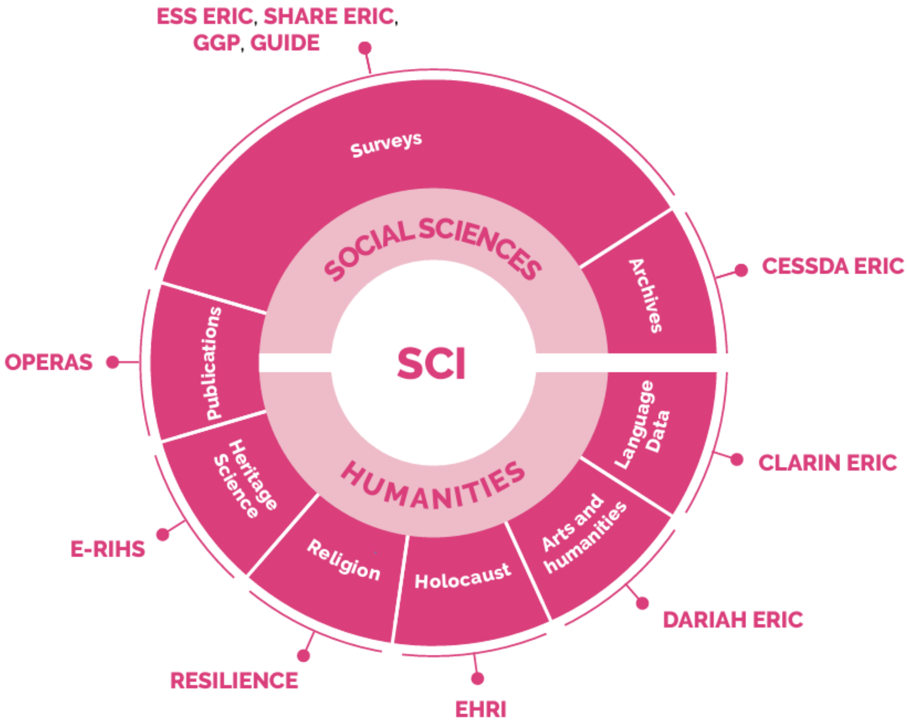


Figure 6. Landscape of the Social and Cultural Innovation domain (source: ESFRI Roadmap 2021)

2.1.6.1 *Humanities*

There is still a huge amount of historical and contemporary cultural data that has not been digitised, and not all available digitised data has been annotated and edited so that it can be incorporated into a Research Infrastructure. This includes: historical manuscripts, papyri, books, films, music, paintings, artefacts, monuments, landscapes, as well as the knowledge about such cultural objects. There is still a large number of contemporary items – political speeches, newspapers, literature, new art forms, audio-visual materials, collections of children's or students' language and social media languages – to be incorporated. And the new text, video, multimedia, and social data are constantly being created.

Another challenge is that many diverse materials are widely distributed across Europe and beyond. Much effort will still be required to incorporate them. Some data is difficult to access outside local communities and sometimes at risk of extinction. An essential challenge for Research Infrastructures is to raise awareness of their existence and services and to provide users – researchers, teachers, museums, and citizens – with access to this data and heritage whenever rights allow. In addition, Research Infrastructures should provide users with access to a state-of-the-art analysis by experts and researchers using digital media and archives.

Already existing technologies and expertise in material sciences, physics and chemistry must be used to better analyse, understand, and preserve cultural heritage objects. New digital techniques also enable the creation of digital copies of historical objects and environments, enabling new types of research without damaging the objects, and historical environments can be digitally recreated and studied.

2.1.6.2 *Social Sciences*

Access to new forms of data for research includes administrative or private sector data or internet transaction data. There is an important trend in social science research to use data not designed for research purposes. Much data already exists in the public and private sectors through digitised administrative procedures or the digitisation of everyday life, which is highly valuable for social science research. Much of this data is personal data, the value of which increases further if this information can be linked across data sources.

Big Data in Humanities and Social Sciences

The development of high-speed data links, storage capacities, and information processing software has allowed some disciplines to access significant amounts of data and new ways of analysing analogue cultural heritage resources. The fields of social sciences and humanities are thus confronted with a momentum that is mainly transforming the entire research profession. Research infrastructures in this area must enable the creation and manipulation of large and highly heterogeneous data sets of a qualitative or quantitative nature, opening new research possibilities and supporting interdisciplinary work. Research Infrastructures contribute to the evaluation of scientific and cultural heritage.

Data storage and digital interactivity have opened up new opportunities for appropriating and managing research resources. As a result, we have seen a diversification in the places of production of digital resources, which has led to the creation of many tools and services available on dedicated platforms. These platforms create clusters to bring together disciplinary and technological skills that offer many benefits to support researchers in the humanities. They then use the information and computing technologies directly because the research data is digital or as an environment enabling access to new processing tools.

2.1.6.3 *Benefit of CLONETS Research Infrastructure to the Social and Cultural Innovation Domain*

In this domain, the main challenge for CLONETS Research Infrastructure is the highly secure delivery of the timing signal over interconnected networks with low jitter so that all systems are synchronised and allow the acquisition and especially the collected data to be tagged with accurate time stamps. This technology is the only way to sort data from this domain, simultaneously insert it into simulation models, and then conduct an exact analysis of the environment from which the data originated. Therefore, this domain's main impact is transferred through the Digital infrastructure domain.

2.2 Importance of CLONETS Research Infrastructure with regard to ESFRI Roadmap Landscape Analysis

We summarise in Table 1 the impact of CLONETS Research Infrastructure on current and future European Research Infrastructures according to the ESFRI Roadmap Landscape Analysis.

Domain/sub-domain name		Overview of Impact on Domain or sub-domain
(1)	**Data, Computing and Digital Research Infrastructures**	
	Data Infrastructures	Time stamps for data sets, synchronisation of data processing
	Computing infrastructures	Time stamps and synchronisation of HPC processes
	Digital Infrastructures	Synchronisation, reliability, and resilience of data communication
(2)	**Energy Domain**	
	Energy Systems Integration	SmartGrids synchronisation, time stamps for data sets
	Renewable Energy	Phase synchronisation of energy sources with network
	Efficient Energy Conversion and Use	Synchronisation of energy storages, time stamps for data sets
	Nuclear Energy	Time stamps for data sets from sensors, synchronisation of HPC
(3)	**Environment**	
	Geosphere	Earthquakes, volcanic activity monitoring, chronometric levelling
	Atmosphere	Synchronisation of sensors and time stamps for data sets
	Hydrosphere	Synchronisation of sensors and time stamps for data sets
	Biosphere	Timing of HPC for Environment domain data processing
(4)	**Health and Food**	
	Health	Biomedical instruments synchronisation, metrology traceability
	Food	Synchronisation of sensors and time stamps for data sets
(5)	**Physical Sciences and Engineering Domain**	
	Astronomy and Astroparticle Physics	Synchronisation of VLBI telescopes, pulsar frequency and gravitational potential measurement
	Particle and Nuclear Physics	Synchronisation of experiments in distributed research facilities
	Analytical Physics	Optical quantum clocks comparison, gravitational potential measurement, GNSS system improvement
(6)	**Social and Cultural Innovation**	
	Humanities	Big data time stamps marking for processing at HPC facilities
	Social Sciences	Big data time stamps marking for processing at HPC facilities

Table 1. Overview of Impact of CLONETS Research Infrastructure on the domain and sub-domain of European Research Infrastructures.

2.3 Impact of CLONETS Research Infrastructure on Horizon Europe Programme

Horizon Europe is the EU's key funding programme for research and innovation. The Horizon Europe programme is organised in three pillars: Excellent Science, Global Challenges & European Industrial Competitiveness, and Innovative Europe.

2.3.1 Fostering EU scientific and technological excellence and strengthening the European Research Area (ERA)

CLONETS Research Infrastructure is the result of long-term cooperation of top scientific teams in the field of basic research in quantum physics, photonics and advanced engineering methods of optical fibre communications. These teams have achieved excellent results in the transmission of precise time and frequency signals and are currently the leaders of this scientific area in the world comparison. The building of this research infrastructure will lead to an even greater deepening of cooperation between teams not only across Europe, but also on a global scale.

2.3.2 Addressing political priorities including ecological and digital transformation and sustainable development goals

The inclusion of CLONETS Research Infrastructure in the European Research Area will contribute significantly to the development of standardisation of measurement processes, not only in the field of basic metrology, but also in a number of other fields. As defined in Section 2.1.3, which is focused on the impact of CLONETS Research Infrastructure on the Environment domain, the deployment of accurate synchronisation of measurement networks of sensors for monitoring environmental parameters will allow better monitoring and the construction of predictive models describing this environment. More efficient and especially accurate synchronisation and generation of time stamps for digital communications across Europe will lead to more efficient security of electronic communications between users. In addition, the processing of large volumes of data generated distributed throughout the continent will have a more reliable temporal continuity thanks to the precisely defined time of creation of the data files thanks to the CLONEST Research Infrastructure.

2.3.3 Supporting the use of innovation, competitiveness and job opportunities in Europe

The availability of accurate time and frequency signals across the entire European continent will, thanks to the CLONETS Research Infrastructure, help to develop innovation, competitiveness and job opportunities in Europe. The possibility of using precise timing, e.g. in the field of telecommunications, will enable the development of new types of communication networks, e.g. 6G. Navigation is also an important area, as the development of autonomous means of transport will require precise time synchronisation, without which objects cannot be guided to an exact position or trajectory. This innovation development will also have a positive effect on the job market, where new jobs will be created in the areas of telecommunications, financial sector, and industry with higher added value (the technology sector).

2.4 Summary

As stated in previous chapters in the European Research Area gap study, the future CLONETS Research Infrastructure has a broad impact on all domains according to the ESFRI Roadmap Landscape Analysis. Although it is an infrastructure that is scientifically strongly connected to the Physical Sciences and Engineering Domain, its future placement on the ESFRI Roadmap may also be as an e-infrastructure. The CLONETS Research Infrastructure will have a distributed character (optical network located on the territory of the member states). Still, it will also have a centralised database, including extensive data sets on the current synchronisation of individual signals of broadcast networks and reference networks.

Based on this study, it is also clear that there is no complex international infrastructure on the European continent, neither research nor commercial, which would allow the transmission of signals from optical quantum clocks over long distances. Therefore, the future CLONETS Research Infrastructure must be established. The European Research Area can rely on a solid reference base for the timing and synchronising of a wide range of leading-edge science experiments.

3 Access Models for CLONETS Research Infrastructure

Access Models for data and signals are the subject of this chapter.

3.1 Access Model for Data

An Access Model for CLONETS Research Infrastructure Data is described in the following section.

3.1.1 Access principles

CLONETS Research Infrastructure needs a well-specified access policy defining how to regulate, grant and support access to (potential) users from academia, business, industry and public services. The access policy has to respect several principles [EuropeanCharter]:

Acknowledgement and co-authorship

Users should acknowledge the contribution of the Research Infrastructure in any output (i.e. publication, patent, data, etc.) deriving from research conducted within its realms. In accordance with good scientific practice, users are encouraged to offer co-authorship to those working at the Research Infrastructure and having made genuine scientific contributions to their work.

Legal conformity

Research Infrastructures must comply with all national and international laws and agreements in states that participate in the operation of the Research Infrastructure and its Point-of-Presence (PoPs).

Costs and fees

The financing model has to guarantee the long-term sustainability of the Research Infrastructure. The access fee should contribute to this goal.

Ethical conduct and research integrity

RI and its users should undertake the necessary actions to adhere to the standard codes of conduct and ethical behaviour in scientific research and to research integrity.

Non-discrimination

The Research Infrastructure shall not discriminate users on personal grounds in granting access.

3.1.2 Types of Access to Data

The document "European Charter for Access to Research Infrastructures" [1] specifies access as "the legitimate and authorised physical, remote and virtual admission to, interactions with and use of Research Infrastructures and to services offered by Research Infrastructures to Users" and distinguishes following types of access according to purpose, acknowledgement, and legal conformity:

Excellence-driven Access

The excellence-driven Access mode is exclusively dependent on the scientific excellence, originality, quality and technical and ethical feasibility of an application evaluated through peer review conducted by internal or external experts. It enables Users to get access to the best facilities, resources and services wherever they are located. This Access mode allows collaborative research and technological development efforts across geographical and disciplinary boundaries.

Market-driven Access

The market-driven Access mode applies when access is defined through an agreement between the User and the Research Infrastructure that will lead to a fee for the access, which may remain confidential.

Wide Access

The wide Access mode guarantees the broadest possible access to scientific data and digital services the Research Infrastructure provides to Users wherever they are based. Research Infrastructures adopting this mode maximise the availability and visibility of the data and services provided.

3.1.3 Database of CLONETS Research Infrastructure Data

Every National Infrastructure for Time and Frequency Signal Dissemination operates its own database that stores data describing the configuration and status of the National infrastructure. Some of these data are internal and serve only for the National Infrastructure operation and management. At the same time, others have a broader scope and should be shared with the CLONETS Research Infrastructure.

Example of stored information:

- status of primary sources
- PoPs (access points) status and trace to the primary source
- categories of services
- gateways/exchange points joining neighbour National Infrastructures
- status of other devices, e.g. regenerators, amplifiers, etc.
- infrastructure topology
- users and their interfaces
- failures and performance incidents
- announcement of planned maintenance that might affect the performance.

Data that should be shared are continuously uploaded to the central database of the CLONETS Research Infrastructure. This database unifies the structure and form of collected data, presents them, operates the access portal, and grants reading and writing rights to infrastructure users and the general public.

The detailed specification of the CLONETS Research Infrastructure database structure and list of all collected data will be designed later in the implementation phase of CLONETS Research Infrastructure.

3.1.4 Interface for Data Access

This chapter describes the access model for the CLONETS database, i.e. data describing the CLONETS Research Infrastructure, its services, points of presence, administration, and current state. The Access model for provided time and frequency signals is discussed in Chapter 3.2.

The CLONETS database can be accessed by two methods:

Web pages

The web interface is the basic method for data reading and, to a limited extent, writing. The technique is suitable mainly for static or slowly changing data. It will offer primary access to a majority of data in a human-readable form.

Network API

A unique API will be designed for automatised data reading and writing. This way, users can also build their own applications to further process and present data. This method is also suitable for a large amount of rapidly changing data.

3.1.5 Public access

The central web of CLONETS Research Infrastructure gives the public access to CLONTES infrastructure description, list of PoPs, information for new users, contacts, etc., to serve as a primary presentation point for the general audience. Publicly available information about projects that utilise the CLONETS Research Infrastructure conducted experiments and use cases is also available. Research and the scientific community might profit from data about the achieved parameters of provided services.

3.1.6 Restricted access

Although the aim is to be as open as possible and allow the right to read all data that are not sensitive due to infrastructure operation or users' privacy, there is necessary to restrict access to many internal, sensitive or user-oriented data. Access to these data is granted individually and requires authentication using a password or a certificate and is dedicated to authorised users with respect to their individual privileges.

For the purposes of restricted data access, we distinguish two categories of users:

Institutes directly involved in CLONETS Research Infrastructure operation and maintenance

These users have access to all data, including that internal data. They also have the rights to write or update selected data into the database, e.g. data that describe the state of the infrastructure or its parts.

Users that utilise time and frequency reference signal

These users have the rights to read data showing reference signal parameters, signal traceability, and other data concerning particular PoPs and the National Infrastructure, e.g., a list of incidents and planned maintenance.

3.2 Access Model for Time and Frequency Reference Signals

Any access to the reference signal is possible only at a PoP operated by National Infrastructure and is granted according to an agreement specifying both technical parameters and limitations of particular National Infrastructure. The agreement also specifies user contribution or fee for signal utilisation with respect to the sustainable operation of the CLONETS Research Infrastructure.

The future user community of CLONETS Research Infrastructure varies in required accuracy, stability and resiliency of time and frequency reference signal (*D2.2 Roadmap for Technical Implementation of the T&F-Reference System*). We can distinguish three types of provided signals:

- optical frequency
- radio frequency
- time signal.

Absolute accuracy and other real-time information of provided reference signal in every PoP is continuously evaluated, stored in the local database, and then collected also in the central database.

3.2.1 Optical frequency signal

Optical frequency (in the C-band, or possibly also in L-band) is generated by a local flywheel locked to an optical clock. The signal is delivered to the user by a frequency-stabilised optical fibre. Each user has to build its own stabilised optical path from CLONETS PoP.

3.2.2 Radio frequency signal (RF)

Radio frequency (typically 10 MHz) is a standard output of the RF atomic clock and provides. The signal is generated at each PoP by a local RF flywheel. This service is typically assumed to be a replacement of the user's own atomic clock.

One of the possible methods to transfer the RF frequency from PoP to the user is the White rabbit technology utilising a dark fibre or two bidirectional DWDM channels in an optical fibre.

3.2.3 Time signal

The time signal is locally generated in the form of 1 PPS (possibly 100 PPS).

One of the possible methods to transfer the 1PPS signal from PoP to the user is the White rabbit technology utilising a dark fibre or two bidirectional DWDM channels in an optical fibre.

4 Blueprint

The partners of the CLONETS-DS project established Blueprint for CLONETS Research Infrastructure. It shows the uniqueness of the proposed CLONETS Research Infrastructure, its potential international outreach, and a list of contacts where users will manage the using the infrastructure for their research and development.

The Blueprint is a separate and graphically enhanced document presenting the CLONETS Research Infrastructure's primary purposes. In this section, we present the text only of the Blueprint. The respective document is available on the Website of the CLONETS-DS project.

4.1 CLONETS Research Infrastructure significance

New upcoming pan-European Research Infrastructure for time and frequency signals dissemination over fibre optical links

Various scientific applications primarily require time and frequency accuracy and/or stability at levels not provided by commercial availability. The CLONETS Research Infrastructure enables the dissemination of these most accurate signals among users of the infrastructure across the countries in Europe.

The CLONETS Research Infrastructure enables scientific progress and innovative potential that would otherwise not be possible, in particular:

(1) comparison of time and frequency precise signals from multiple sources over a long-haul optical network,

(2) generation of time and frequency signals of boundary parameters, which particular research institutions cannot implement despite great efforts research and investments in commercial instrument installations.

Examples of use cases are described in the following sections:

4.1.1 Fundamental Science

SI unit Second re-definition, precision spectroscopy to search for beyond standard model physics, research of clocks

CLONETS can provide absolute frequency references with accuracies at the 10^{-17} level and lower with traceability to the SI second. Therefore, it can be used to perform precision frequency spectroscopy of atomic transitions, including hydrogen, anti-hydrogen, exotic atoms and molecules with the potential of unpredictable future approaches to fibre infrastructure utilisation.

4.1.2 Quantum Technologies

Real-world QKD improvement, new protocols development, entanglement distribution beyond QKD

CLONETS can provide synergies with quantum information technologies, where the distribution of quantum entanglement via optical fibres has a leading role. Highly phase-coherent optical references (>> 1000 km of coherence length) and low-jitter (<<100 ps), high-accuracy (10 ps) time references offer the possibility to extend quantum communication link distances, to improve performance, e.g. existing phase-encoded key-distribution protocols, and to support the scalability of quantum communication networks.

4.1.3 Earth Observation / Geodesy

Height system unification, satellite gravity mission validation, geodetic network consistency

CLONETS can provide the infrastructure for measuring gravitational potential differences between clocks located at as-needed locations and can therefore be used to measure height differences throughout Europe and establish a unification of Europe's height system and, ultimately, satellite gravity mission validation and geodetic network consistency.

4.1.4 Astronomy

Radio interferometry and VLBI in astronomy, Laser ranging, Pulsar timing

CLONETS will benefit all areas of astronomy that exploit observations from multiple sites and/or use multiple techniques. A prime example is VLBI (Very Long Baseline Interferometry) for astrometry, which will allow improved data analysis with the potential for discoveries and possible improvements to the celestial reference frame. VLBI has stringent requirements for short-term and long-term Pulsar timing, another well-established area expected to benefit from the project. At the same time, there is a potential for applications to other fast-growing topics, such as multi-messenger astronomy. Another example is LOFAR (Low-Frequency Array for Radio Astronomy), which is an innovative distributed system for astronomical observations at radiofrequencies below 250 MHz. And there is the field for CLONETS research infrastructure as well.

4.1.5 Telecommunication, Position, Navigation, Synchronisation, and Timing

Optical timescales, position, navigation & timing, PNT, resilience for GNSS, synchronisation of networks (5G to 6G).

CLONETS will benefit future routine, reliable, precise and secure time dissemination. They will be a critical infrastructure for developing applications that rely on precise time and frequency transfer. This case is particularly challenging because satellite-based navigation systems can only exploit optical clocks based at ground stations if the technological capability exists for comparing the optical clocks to two orders of magnitude better than their ideal operating levels.

4.2 How will the CLONETS Research Infrastructure for time and frequency signals dissemination over European continent be synchronised?

The CLONETS Research Infrastructure will use many optical quantum clocks, atomic clocks, radiofrequency time and frequency standards spread across the European continent to synchronise distributed signals. These standards will be interconnected by a backbone network of optical fibres (the so-called European Core Network). The optical fibre routes will have stabilised traffic delays with specialised techniques continuously verified by an international research community of experts in metrology, quantum physics, electronics, photonics and communication technologies. The CLONETS Research Infrastructure will be able to ensure the transmission of signals with stability and/or accuracy exceeding nineteen decimal orders. Within the CLONETS Research Infrastructure member states, National Research Infrastructures for Time and Frequency Signal Dissemination already exist or are being built, consisting of metrological institutes (NMI), research institutes and universities operating optical quantum clocks, as well as operators of national research and education networks (NREN) and other organisations. These national research infrastructures' time and frequency signals will be mutually synchronised through the CLONETS research infrastructure.

4.3 What services can you expect from the CLONETS Research Infrastructure?

Imagine a user running extremely demanding equipment or an infrastructure requiring precise time or frequency signals. In this case, up to three highly stable and accurate reference signals from CLONETS are possible: (1) an optical frequency in the 1500-1600 nm band, (2) a radio frequency of 10 MHz or 100 MHz, and (3) 1 PPS (pulse-per-second) signal. In addition, the user will have access to a database to find time records of mutual stability, absolute accuracy and possible deviations between individual time and frequency standards connected to the CLONETS Research Infrastructure.

4.4 How can you connect your use case to the CLONETS Research Infrastructure?

Although the upcoming CLONETS Research Infrastructure is transnational scale, the access model of the infrastructure is mainly based on the creation of a partnership at the national level amongst the user on the one hand and a national strategic partner of the CLONETS Research Infrastructure on the other (e.g. National Research Infrastructure for Time and Frequency Signal Dissemination). The physical layer of the communication model is the optical transmission via a dedicated optical fibre connecting the user to the nearest access point of the aforementioned national strategic partner of the CLONETS Research Infrastructure. Depending on the type of signal required, it will be possible to use specialised modems to distribute the relevant or relevant types of high-performance signals. For more information, visit the website www.clonets-ds.eu, or you can contact the nearest CLONETS Research Infrastructure representative as listed. You can find the contacts in the following table. We do appreciate your interest.

4.5 List of Representatives

The Blueprint includes a list of contacts of representatives from France, Germany, Poland, Czech Republic, Italy, Spain and United Kingdom.

Country	Partners	Representative	e-mail	Lead	GOV Person
Czech Republic	CESNET, ISI	Ondrej Cip	ocip@isibrno.cz	ISI	Lukas Levak, MEYS CR, Director of R&D and RI
France	CNRS, UP 13, RENATER, Muquans	Christian Chardonnet	chardonnet@univ-paris13.fr	LPL	Elena Hoffert, Elena.Hoffert@recherche.gouv.fr , Jean-Marie Flaud, jean-marie.flaud@recherche.gouv.fr
Germany	PTB, Menlo, TUM, University of Bonn	Dieter Meschede	meschede@uni-bonn.de	Uni-Bonn	Eckhart Lilienthal Eckart.Lilienthal@bmbf.bund.de, Peter Wenzel-Constabel Peter.Wenzel-Constabel@bmbf.bund.de
Italy	INRIM	Davide Calonico	d.calonico@inrim.it	INRIM	Gelsomina Pappalardo, gelsomina.pappalardo@imaa.cnr.it , Caterina Petrillo, caterina.petrillo@unipg.it
Poland	PSNC, Piktime Systems, AGH	Bartosz Belter	bartosz.belter@man.poznan.pl	PSNC	Agnieszka Zalewska, ESFRI Executive Board Member, Institute of Nuclear Physics Polish Academy of Science, Agnieszka.Zalewska@ifj.edu.pl
Spain	University of Granada, Seven Solutions SL	Javier Díaz	javier@sevensols.com	UGR	Inmaculada Figueroa, ESFRI Vice Chair,Deputy Vice-Director General for Internationalisation of Science and Innovation, Ministry of Science, Innovation and Universities, inmaculada.figueroa@ciencia.gob.es , José Luis Martínez Peña, Working

Country	Partners	Representative	e-mail	Lead	GOV Person
					Group Chair, Director, ESS-Bilbao, jlmartinez@essbilbao.org
UK	University College London	Alwyn Seeds	a.seeds@ucl.ac.uk	UCL	Gabriela Maria Pastori, Working Group Chair, Associate Director International, UK Research and Innovation - BBSRC, gabriela.pastori@bbsrc.ukri.org , Andrew Harrison, Chief Executive Officer, Diamond Light Source Ltd, andrew.harrison@diamond.ac.uk

Table 2. List of CLONETS Representatives

5 Conclusions

We have identified the position of the future CLONETS Research Infrastructure on the map of the European Research Area, mainly concerning the regular landscape analysis of the European Strategic Forum for Research Infrastructures. We also looked for the benefits of the CLONETS Research Infrastructure in some selected scientific areas covered by existing European research infrastructures. We also identified the benefits for the critical areas that the European Union has set as priorities in the field of research and development and defined the future position of the CLONETS Research Infrastructure on the ESFRI Roadmap of existing infrastructures. We have designed Access Models for users of the CLONETS research infrastructure, which includes both user connection to the distribution network of precise time and frequency signals and user access to the database of data produced by CLONETS Research Infrastructure. We have also compiled "Blueprint", showing the uniqueness of the proposed infrastructure, potential international reach and impact on individually selected areas in the European Research Area and the field of advanced industry.

References

[Amnesia]	https://amnesia.openaire.eu/
[Argos]	https://argos.openaire.eu/home
[DEMO]	the demonstration power plant based on ITER
[DERlab]	association of research institutes in the field of distributed energy resources equipment and systems https://der-lab.net/
[ECCSEL ERIC]	Carbon dioxide research, https://www.eccsel.org/
[ERA]	https://research-and-innovation.ec.europa.eu/strategy/strategy-2020-2024/our-digital-future/european-research-area_en
[ERIC]	https://research-and-innovation.ec.europa.eu/strategy/strategy-2020-2024/our-digital-future/european-research-infrastructures/eric_en
[ERIC-Lab]	sharing of hardware and software facilities with special focus on real-time simulation https://www.eric-lab.eu/
[EOSC]	European Open Science Cloud https://research-and-innovation.ec.europa.eu/strategy/strategy-2020-2024/our-digital-future/open-science/european-open-science-cloud-eosc_en
[ESFRI]	https://www.esfri.eu/
[ESFRI Roadmap]	*ESFRI Roadmap* – Part 2 Landscape Analysis 2021, https://roadmap2021.esfri.eu/landscape-analysis/
[ET]	Einstein Telescope (ET) is proposed underground infrastructure to host the gravitational-wave observatory https://www.et-gw.eu/
[EUDAT]	EUDAT is Collaborative Data Infrastructure of integrated data services and resources supporting research in Europe https://www.eudat.eu/eudat-cdi
[EuroHPC JU]	https://eurohpc-ju.europa.eu/index_en
[EuroQCI]	https://digital-strategy.ec.europa.eu/en/policies/european-quantum-communication-infrastructure-euroqci
[EuropeanCharter]	European Charter for Access to Research Infrastructures: Principles and Guidelines for Access and Related Services, 2015, ISBN 978-92-79-45600-8, DOI 10.2777/524573 (https://op.europa.eu/en/publication-detail/-/publication/78e87306-48bc-11e6-9c64-01aa75ed71a1/)
[GSI]	Accelerator facility for research purposes https://www.gsi.de/
[IS-ENES3]	Third phase of the distributed e-infrastructure of the European Network for Earth System Modelling https://is.enes.org/
[ISOLDE-CERN]	Isotope Separator On Line Device https://isolde.cern/
[ITER]	Investigation and demonstration of burning plasmas https://www.iter.org/
[LifeWatch ERIC]	Provides e-Science research facilities to scientists investigating biodiversity and ecosystem functions and services to support society in addressing key planetary challenges https://www.lifewatch.eu/

[LISA]	Laser interferometer Space Antenna project https://lisa.nasa.gov/
[LSST]	Legacy Survey of Space and Time https://www.lsst.org/
[OpenAIRE]	https://www.openaire.eu/
[OpenAIRE Graph]	https://graph.openaire.eu/
[PRACE]	https://prace-ri.eu/
[QKD]	https://en.wikipedia.org/wiki/Quantum_key_distribution
[Reg2011/70]	Regulation 2011/70/EURATOM & 2013/59/EURATOM
[SeaDataCloud]	Infrastructure for the management of large and diverse sets of data of the seas and oceans https://www.seadatanet.org/About-us/SeaDataCloud
[Zenodo]	https://zenodo.org/

Glossary

Amnesia	Anonymization of research data sets
Argos	Application for Data Management Plan development
CERN	European Organization for Nuclear Research
CLONETS	CLOck NETwork Services
DEMO	Demonstration power plant based on ITER
DERlab	Association of research institutes in the field of distributed energy resources
ECCSEL	Research Infrastructure of Carbon dioxide research
EOSC	European Open Science Cloud
ERA	European Research Area
ERIC	European Research Infrastructure Consortium
ERIC-Lab	Consortium for sharing of hardware and software facilities on real-time simulation
ESFRI	European Strategy Forum on Research Infrastructures
ET	Einstein Telescope project
EUDAT	Collaborative Data Infrastructure in Europe supporting research
EuroHPC	European High Performance Computing Joint Undertaking
EuroQCI	European Quantum Communication Infrastructure
GSI	Accelerator facility for research purposes
HPC	High-performance computing
IS-ENES3	Distributed e-infrastructure for Earth System Modelling
ISOLDE-CERN	CERN facility for isotope production
ITER	Infrastructure for investigation and demonstration of burning plasmas
LifeWatch	Infrastructure provides facilities in biodiversity and ecosystem functions and services
LISA	Laser Interferometer Space Antenna project
LSST	Legacy Survey of Space and Time project
NREN	National Research and Education Network
OpenAIRE	Non-profit partnership for communication infrastructure
PoP	Point-of-Presence
PRACE	Partnership for Advanced Computing in Europe
QKD	Quantum Key Distribution
SeaDataCloud	Infrastructure for management of data of the seas and oceans
VLBI	Very Long Baseline Interferometry
Zenodo	Universal Open Access repository