

The European Strategy in Research Infrastructures and Open Science Cloud

Konstantinos M. Giannoutakis^(✉) and Dimitrios Tzovaras

Centre for Research and Technology Hellas, Information Technologies Institute,
57001 Thessaloniki, Greece

{kgiannou, Dimitrios.Tzovaras}@iti.gr

Abstract. The European Strategy Forum on Research Infrastructures (ESFRI) was established in 2002, with a mandate from the EU Council to support a coherent and strategy-led approach to policy-making on research infrastructures in Europe, and to facilitate multilateral initiatives leading to the better use and development of Research Infrastructures (RIs), at EU and international level. ESFRI has recently presented its updated 2016 Roadmap which demonstrates the dynamism of the European scientific community and the commitment of Member States to develop new research infrastructures at the European level.

Recently, the European Open Science Cloud (EOSC) initiated activities towards facilitating integration in the area of European e-Infrastructures and connected services between the member states, at the European level and internationally. It aims to accelerate and support the transition to an effective Open Science and Open Innovation in the Digital Single Market by enabling trusted access to services, systems and re-use of scientific data.

This work is focused on the identification of the new features and conclusions of the ESFRI Roadmap 2016 in terms of the methods and procedures that led to the call, the evaluation and selection of the new ESFRI Projects and the definition and assessment of the ESFRI Landmarks. An analysis of the impact of research infrastructures on structuring the European Research Area as well as the global research scene, and of the overall contribution to European competitiveness are also discussed. The EOSC challenges, purpose and initial recommendations for a preparatory phase that will lead to the establishment of the ambitious infrastructure for Open Science are also presented.

Keywords: Research infrastructures · European open science cloud · e-Infrastructures · e-Infrastructure reflection group

1 Introduction

ESFRI has recently fulfilled the commitment made by Member States and the European Commission in the Innovation Union flagship initiative and has implemented 60% of ESFRI projects by the end of 2015. The new ESFRI 2016 Roadmap demonstrates the dynamism of the European scientific community and the commitment of Member States to develop new research infrastructures at the European level. The networks of research infrastructures across Europe strengthen its human capital base by providing world-class

training for a new generation of researchers and engineers and promoting interdisciplinary collaboration.

The objective of Horizon 2020 is to ensure the implementation and operation of the ESFRI and other world class research infrastructures, including the development of regional partner facilities; integration of and access to national research infrastructures; and the development, deployment and operation of e-infrastructures. The major changes in Horizon 2020 with regard to the previous framework programme (FP7) include the emphasis on innovation and the development of human resources, addressing industry as an e-infrastructure supplier and user, more resolve towards service orientation and service integration, and more emphasis on data infrastructure development. In Horizon 2020 the e-infrastructure activities are part of the European Research Infrastructures, including e-infrastructures programme. The indicative budget for e-infrastructures from 2014 to 2020 is 890 million euros.

This paper starts with an overview of the European strategy for RI, with a special emphasis in e-Infrastructures, as defined in the ESFRI Strategy report published in March 2016 and will then show that implementations of some of the facilities stipulated by the Strategy have already started under the H2020 support. Focus is given on the identification of the new features and conclusions of the ESFRI Roadmap 2016 in terms of the methods and procedures that led to the call, the evaluation and selection of the new ESFRI Projects and the definition and assessment of the ESFRI Landmarks. An analysis of the impact of research infrastructures on structuring the European Research Area as well as the global research scene, and of the overall contribution to European competitiveness will also follow. A Landscape Analysis will also be presented that provides the current context, in each domain, of the operational national and international research infrastructures open to European scientists and technology developers through peer-review of competitive science proposals. The e-infrastructures landscape, transversal to all domains, will be also elaborated as approached by the e-Infrastructure Reflection Group (e-IRG).

The work also focuses on recent initiatives and activities supporting the e-infrastructure activities in Horizon 2020 in order to achieve by 2020 a single and open European space for on-line research where researchers will enjoy leading-edge, ubiquitous and reliable services for networking and computing, and seamless and open access to e-Science environments and global data resources. These initiatives are:

- The **European Open Science Cloud** initiative activities, towards facilitating integration in the area of European e-Infrastructures and connected services between the member states, at the European level, and internationally.
- Activities of the **e-Infrastructure Reflection Group (e-IRG)**, focusing on presenting the e-IRG Roadmap 2016, published in December 2016, which gives guidance and recommendations for policy and technical discussions on the main European Open Science Cloud topics.

Ultimately, the guidelines for providing access to RIs are given, and the impact of RIs and the EOSC to European Union and internationally are discussed. It should be noted that this paper extends the work of [9] by introducing the European Open Science Cloud first report, which outlines initial recommendations for the realization of the Open

Science Cloud in Europe, and the updated e-IRG Roadmap 2016 that proposes the recommendations for proper integration of European e-Infrastructures and connected services between Member States.

2 European Strategy for Research Infrastructures

Since 2006, ESFRI focuses on the identification of RIs in Europe across all scientific areas and periodically updates its roadmaps for providing a strategic vision for ensuring the access of RIs to researchers. Generally, the main objectives of ESFRI, as described in [6], are:

- to support a coherent and strategy-led approach to policy making on research infrastructures in Europe
- to facilitate multilateral initiatives leading to a better use and development of research infrastructures acting as an incubator for pan-European and global research infrastructures
- to establish a European Roadmap for research infrastructures (new and major upgrades, pan-European interest) for the coming 10–20 years, stimulate the implementation of these facilities, and update the Roadmap as the need arises
- to ensure the follow-up of implementation of already ongoing ESFRI projects after a comprehensive assessment, as well as the prioritization of the infrastructure projects listed in the ESFRI Roadmap.

With the last roadmap, published in 2016, ESFRI has widened its horizon and scope by adopting a more focused, strategic approach and identifying a limited number of RIs with high added value for European research. The target is to fund a limited number of mature projects that will enhance European research and innovation competitiveness. Thus, as stated in [6], ESFRI added as an important eligibility condition that a proposal required a funding commitment from the submitting Member State or Associated Country along with a political commitment from at least two others. This requirement strengthened the transparency of the submission process and forced a dialogue and crosscheck between the research communities and the concerned governments from the very beginning of the RI project, [6]. This is also ensured by performing a landscape analysis of RIs for identifying their strengths, potential and weaknesses in all fields of research.

2.1 Landscape Analysis and ESFRI Landmarks

The purpose of landscape analysis is to identify the operating open access RIs from national, regional and international infrastructures, as well as groups that provide integrated solutions with open access to the state-of-the-art resources. The impact of the landscape analysis by the ESFRI infrastructures is emphasized by the list of ESFRI Landmarks, that are implemented ESFRI projects (or started implementation under the roadmap) with great success on providing scientific services and competitiveness of the European Research Area.

The key elements of the new ESFRI process, as stated in [6], are:

- definition of clear rules, communication and explanation of the procedure at the start;
- delineation of a window of opportunity: new projects will remain on ESFRI Roadmap for a maximum of ten years;
- evaluation of scientific relevance and project maturity in parallel but separately;
- engagement of international experts and peer reviewers in the evaluation process;
- adoption of a lifecycle approach to the analysis of infrastructures, with *Projects and Landmarks* clearly identified and indication of *emerging opportunities*;
- assessment of the implementation of the inherited projects from Roadmap 2008 and 2010 for monitoring their progress and identifying areas where support is needed;
- recognition and analysis of the overall “Landscape” of the European research infrastructure system and of the complementarity of projects;
- identification of the role of the successful ESFRI infrastructures and definition of the “Landmark list”;
- monitoring of Projects and periodic review of Landmarks, and update of the Roadmap.

Emphasis on new ESFRI projects is always given on excellence, impact, sustainability and continuous report.

2.2 The ESFRI Roadmap 2016 Projects and Landmarks

The new ESFRI roadmap contains 21 ESFRI projects, 9 from the 2008 roadmap, 6 from the 2010 roadmap and five new project (plus one reoriented project). The evaluation process for selecting the new projects was (a) the Strategy Working Groups with respect to their scientific excellence, pan-European relevance and socio-economic impact and (b) their degree of maturity as benchmarked by the ESFRI Implementation Group.

Regarding the ESFRI Landmarks, 29 are listed containing already implemented projects and two new projects that were evaluated and are under construction. The list of the ESFRI projects and the ESFRI Landmarks are presented in [6], and are categorized in the following application categories: Energy (4 projects), Environment (5 projects), Health & Food (8 projects), Physical Sciences & Engineering (3 projects), and Social & Cultural Innovation (1 project).

2.3 Big Data in Research Infrastructures

Data occurring from RIs by experimentation, measurements, observations, data analysis, modelling and simulations are usually large or complex that traditional data processing applications are insufficient to process. Moreover, the analysis of such data is crucial to scientific research and usually require high performance computing or cloud computing capabilities in order to process them.

For this reason, the Research Data Alliance (RDA) addresses a global data policy with direct connections with e-IRG, with specific actions on standardization strategies, like PanData for analytic facilities, [8]. Usually, such data occur from physics experiments, astronomical research, biomedical interests or large scale simulations of complex

systems. The distributed nature of RIs in the domains listed before, enhances the need for effective data access and analysis. Thus, the ESFRI is expected to play a significant role in this general development, by formulating a new generation of big data practitioners and big data engineers.

2.4 ESFRI Evaluation Process

The evaluation process of new projects from ESFRI adopted a transparent approach together with national research authorities and research communities of the new roadmap process. This process is illustrated in Fig. 1, and consists of five distinct steps, as presented in [6]:

- *Review of projects from previous ESFRI roadmaps.* The RIs that were implemented and produced high quality services to the community led to the identification of the ESFRI Landmarks. The lifecycle analysis performed for the identification of scientific key services is now adopted and key issues can now be resolved for the remaining projects.
- *Submission and eligibility of proposals.* Members or Associated countries can submit proposals to the ESFRI Roadmap 2016. New ESFRI Projects have to be competitive and mature, while the ability to be implemented within ten years is crucial. They need to demonstrate government level financial commitment of the proponent Member State or Associated Country plus at least two additional political commitments. This increases the likelihood of success for the projects and enables a more robust and reliable selection process by ESFRI.
- *Evaluation of proposals.* Eligible proposals were assessed through two parallel and independent evaluation processes. The Strategy Working Groups (SWGs) evaluated the scientific case, i.e. scientific merit, relevance and impact, European added value, socio-economic benefit and the needs of interfacing or integrating external e-infrastructure. The SWG identified assigns a minimum of three independent international peer-reviewers who contribute their evaluation on the science aspects of the project. In parallel, the Implementation Group (IG) assessed the maturity, i.e. stakeholder commitment, user strategy and access policy, preparatory work, planning, governance and management, human resources policy, finances, feasibility and risks. The IG similarly assigns international expert evaluators to assess the relevant “maturity” aspects of each project. Based on their own analysis and on the reports from the referees, the SWG and IG identified critical questions and issues to be addressed by each of the eligible proposals. The SWG and IG subsequently reached their conclusions with a joint recommendation per project, and an overall harmonization to align the results from the different areas and formulate a ranking of the projects and recommendations.
- *Decision making.* The executive board proposes a final recommendation on the list of projects and Landmarks that should be included for a final decision.

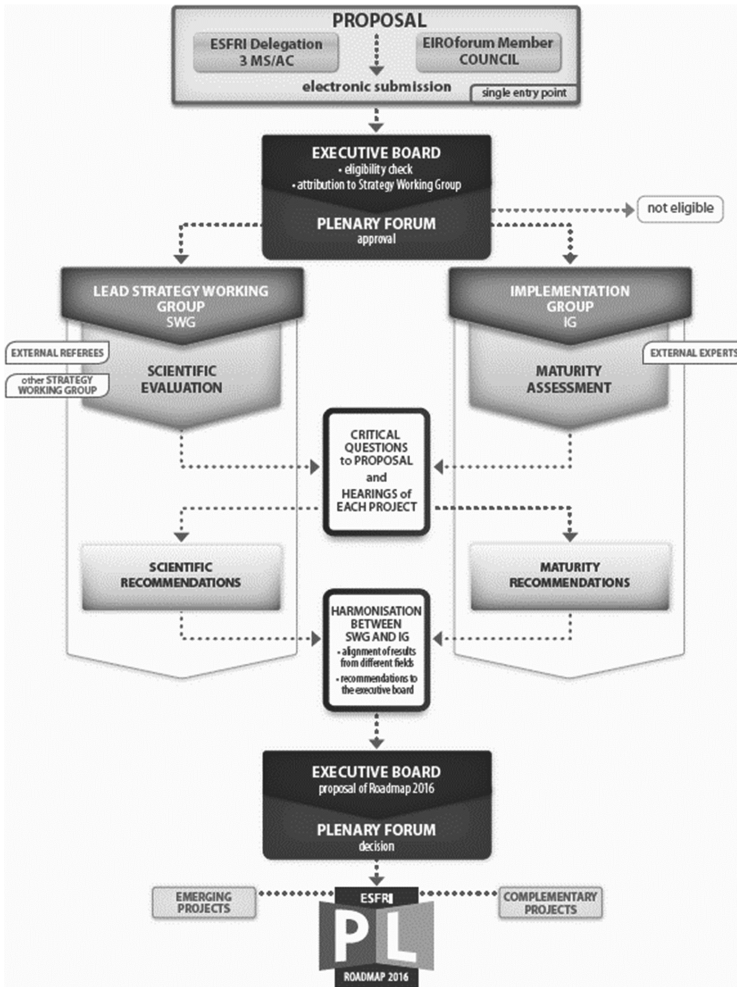


Fig. 1. The ESFRI evaluation process of new projects, [6].

3 e-Infrastructure Activities in Horizon 2020

During the last decades, scientific applications require challenging demands of interoperable data, computational power and collaborations between different scientific fields and researchers. The developed large scale information systems called e-infrastructures and are supported by many initiatives in Europe and worldwide.

The European Commission (EC) is interested on investing through its Framework Programmes in e-Infrastructures since they are considered as key enablers of the European Research Area (ERA). The collaboration among scientific communities of researchers that work together on complex multi-disciplinary problems whose solutions

are highly beneficial for the society and the progress at large are then of high importance, [1].

The corresponding H2020 call for e-infrastructures (H2020-EINFRA-2016–2017) focuses on the open research data, data and computing intensive science, research and education networking, high performance computing and big data innovation, [4]. The following principles are key elements for the project implementations:

- *Service orientation*: The funded projects will contribute to the formulation of a high quality catalogue of services describing the services that they will provide during the lifetime of the projects. A service oriented European e-infrastructure landscape will be supported by adopting new knowledge and innovative ICT solutions by global and multidisciplinary research.
- *Maximizing and assessing the impact of the e-infrastructures*: Projects should have a clear plan for active participation in international fora and research groups/initiatives to promote data and computing infrastructure interoperability.
- *Co-design*: A balanced set of partners with complementary competences and roles should form the consortium of projects that will be funded by this call.
- *Open Research Data*: In order to make research data discoverable, accessible, intelligible, useable and interoperable, this call focuses on open data taking into account the above criteria.
- *H2020 as a catalyst of the European plan for growth and jobs*: This call will promote the use of other funding sources as instrument to support initiatives of European interest to foster growth and jobs.

The call has two themes: “*Integration and consolidation of e-infrastructure platforms supporting European policies and research and education communities*” and “*Support to the next implementation phase of Pan-European High Performance Computing infrastructure and services (PRACE)*” with several topics. More details and the specific topics can be found in [3].

Recent initiatives and activities for supporting the e-infrastructure activities in Horizon 2020 have been formulated. In order to achieve by 2020 a single and open European space for on-line research where researchers will enjoy leading-edge, ubiquitous and reliable services for networking and computing, and seamless and open access to e-Science environments and global data resources, several research groups and cooperation have been instantiated. The distribution of Research Infrastructures in Europe is illustrated in Fig. 2.

4 European Open Science Cloud

Recently, the Commission High Level Expert Group on the European Open Science Cloud (HLEG EOOSC) has drafted a first report for the realization of the European Open Science Cloud. With this initiative, the European Commission with the EOOSC aims to introduce, accelerate and support the Open Science and Open Innovation in the Digital Single Market, thus enabling re-use of geographically distributed scientific data.

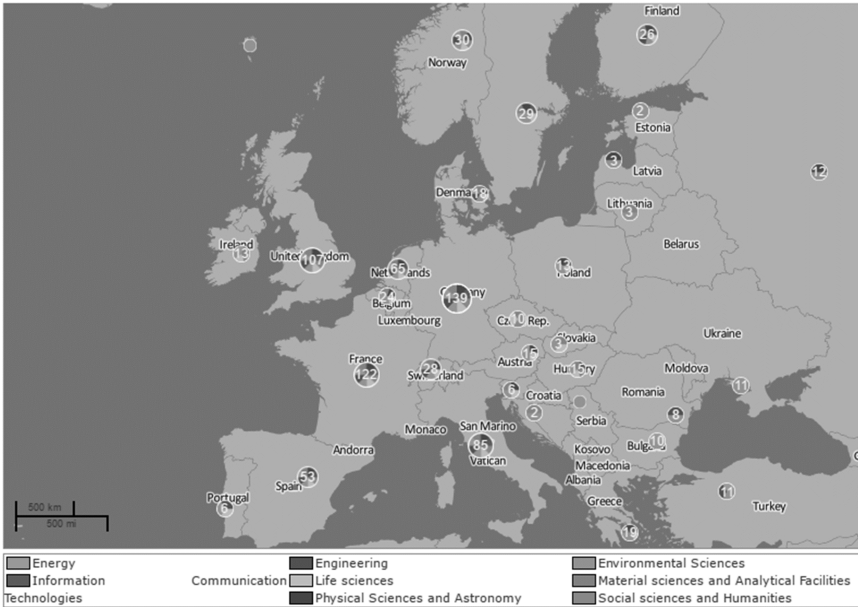


Fig. 2. Research Infrastructures funded by the European Commission (http://ec.europa.eu/research/infrastructures/index_en.cfm?pg=mapri).

The main purpose of EOSC is the re-use of research data and accompanying tools, the access support to the provided services and systems without any social and geographical borders. The professional data management and long term data maintenance is of main concern and is expected to enable the re-use and data driven knowledge discovery and innovation.

It has been reported that approximately 50% of the produced research data are not reproducible, while more than 80% of data are not stored into a secure and sustainable repository, [5]. Since many scientific areas produce huge amount of data especially during the last years, [5], the need for data stewardship and a global data and services framework is of great importance. For example, DNA sequence data is doubling every 6–8 months over the last 3 years and this rate looks to be steady for this decade.

The main purpose of EOSC is to remove all the technical, governmental and human barriers in order to accelerate the re-use of research data and to support the access to services without any social or geographical borders. The main elements for success for the EOSC have been outlined in [2], and are:

- *Open*: EOSC should be open in design, participation and in use. Its open access will promote the development and adoption of open standards, thus enabling collaborative environments with no barriers to participation or resource-sharing. It will enable accessibility, transparency and reproducibility in all stages of the research life cycle. EOSC will foster public-private partnerships with target to turn all investments into economic growth.

- *Publicly funded and governed*: A publicly funded and governed Open Science Cloud will guarantee persistence and sustainability, while ensuring that outcomes are driven by scientific excellence and societal needs. The partnership with private sector actors will encourage the development of innovative services that are conducive to the future Open Science, while guaranteeing the long term and persistent care of resources.
- *Research-centric*: Research community will be engaged in the design of the Open Science Cloud to ensure the development of services according to their needs.
- *Comprehensive*: EOSC will not target a specific scientific discipline or research field. It will promote inter and multi-disciplinary science and encourage innovation and integrated knowledge creation and sharing among all research communities.
- *Diverse and distributed*: EOSC will utilize the Europe's distributed e-Infrastructures for forming a network of actors, resources and services organized nationally and at European level. It will drive a more efficient use of ICT investments across infrastructures and communities, lowering the barriers to adoption for institutions and researchers.
- *Interoperable*: With the adoption of common open standards and protocols for all resources and digital services, the Open Science Cloud will connect the corresponding networks, data, computing systems, tools and services for research with an interoperable way.
- *Service oriented*: It will provide services that address the full research lifecycle, including data gathering, management, analysis, sharing and discovery. The EOSC will be the framework for new innovative methodologies and services that further advance research in the Open Science context.
- *Social*: EOSC will be a socio-technical endeavor that connects diverse communities and promotes the development of human networks. It will enable the sharing of knowledge and facilitate the embedding of Open Science practices into researcher's workflows.

During the preparatory phase, the High Level Expert Group drafted the following recommendations. More details can be found in [5].

- *Policy recommendations*
 - *Take immediate, affirmative action on the EOSC in close concert with Member States*. Member states should take immediate actions to realize the first phase of a federated, globally accessible environment, where researchers can publish and re-use data and tools for research, innovation and educational purposes.
 - *Close discussions about the 'perceived need'*. The preparatory phase should not be long, since there has been a long consultation phase while a variety of services and data are already available.
 - *Build on existing capacity and expertise where possible*. The majority of the services and data already exist as parts of e-Infrastructures and are of high quality. Therefore, it is believed that this preparatory phase will be significantly progressed or completed by the end of 2017.
 - *Frame the EOSC as the EU contribution to an Internet of FAIR Data and Services underpinned with open protocols*. This will allow open and common

implementation together with participation from all stakeholders, including research infrastructure providers, Member States, research institutes and businesses. All providers can start implementing prototype applications for the Internet of FAIR data and Services on the day minimal standards and the minimal rules of engagement are released.

- *Governance recommendations*
 - *Aim at the lightest possible, internationally effective governance.* An inclusive, flexible, transparent and decentralized approach is required in order to establish a lightweight, sustainable and collaborative governance model for the EOSC and its stakeholders.
 - *Guidance only where guidance is.* Due to the large number of expected stakeholders, guidance will be offered for harmonization and sustainability purposes.
 - *Define Rules of Engagement for service provision in the EOSC.* The development of the infrastructure will be guided and governed by a minimal set of protocols and rules of engagement that specify the conditions under which stakeholders can participate.
 - *Federate the gems and amplify good practice.* Based on the consensus that most foundational building blocks of the Internet of FAIR data and Services are operational somewhere, it is recommended that early action is taken to federate these gems. Optimal engagement is required of the e-infrastructure communities, the ESFRI communities and other disciplinary groups and institutes.
- *Implementation recommendations*
 - *Turn the HLEG report into a high-level guide to scope and guide the EOSC initiative.* The first HLEG report should serve as a high level guiding document for the actual development and implementation processes in the Member States and in Horizon 2020 work programme.
 - *Develop, endorse and implement the Rules of Engagement for the EOSC.* The Commission should develop the Rules of Engagement (RoE) for stakeholders that want to provide a component of the EOSC. RoE should be based on the assumption that all data in EOSC are FAIR.
 - *Set initial guiding principles to kick-start the initiative as quickly as possible.* Specific principles have been proposed in order to guide the preparatory phase.
 - *Fund a concerted effort to develop core data expertise in Europe.* A substantial training initiative in Europe is proposed, to locate, create, maintain and sustain the required data expertise. The aim of this training is to train certified core data experts, consolidate and develop assisting material and tools for the construction of data management plans and data stewardship plans, and by 2020 to have in each Member State at least one certified institute to support implementation of Data Stewardship per discipline.
 - *Develop a concrete plan for the architecture of data interoperability of the EOSC.* Concrete actions for Member States are proposed that will ensure data interoperability.
 - *Install an innovative guided funding scheme for the preparatory phase.* For the preparatory phase of EOSC Horizon 2020 funds will be used, but a new funding

mechanism will be established, specifically designed to rapidly prototype, test and reach all goals.

- *Make adequate data stewardship mandatory for all research proposals.* Horizon 2020 projects with achievable requirements, that are data multidisciplinary, that properly address post-project sustainability or otherwise advance the common aims of the EOSC should be streamlined for funding in the EOSC game-changer scheme.
- *Provide a clear operational timeline to deal with the early preparatory phase of the EOSC.* Concrete tasks have been identified to kick start the EOSC: (1) Define the RoE, (2) Create and foster cross-domain collaboration including ESFRIs and e-Infrastructures, (3) Define training needs and models for the training infrastructure, (4) Develop a governance plan for EOSC, (5) Establish minimal technical standards and plan for their long-term maintenance and compliance, (6) Establish guidance and oversight mechanisms for the EOSC game changer scheme, and (7) Establish plans for certified institutes for data expertise and stewardship.

The EOSC reflects the change in the way research is conducted but funding and the long-term perspective is missing. The preparatory phase needs to look into governance, additional funding and sustainability. Incentives are needed for researchers to share and re-use their data and this is closely tied to the quality of services which are key for the uptake and success of the platform. The EOSC must be built upon existing e- and research infrastructures, and it should be a mixed bag of infrastructures, tools and services presented as interoperable virtual environments, “a cloud of services”, for all European researchers to store, manage, process, analyze and re-use research data across geographical, social and technical borders.

4.1 e-Infrastructure Reflection Group (E-IRG)

The e-Infrastructure Reflection Group (e-IRG), founded in 2003, is a European independent body with mission to form a general purpose European e-Infrastructure by providing guidance on the development of a European e-Infrastructure for science and research. Some examples of already established e-Infrastructures across Europe are GEANT (networking - <http://www.geant.org/>), EGI (grid and cloud computing - <https://www.egi.eu/>), PRACE (supercomputing - <http://www.prace-ri.eu/>), EUDAT (European Data Infrastructure - <https://www.eudat.eu/>), IDGF (crowd computing - <http://idgf-sp.eu/>), OpenAIRE (repository for scientific articles - <https://www.openaire.eu/>) and LIBER (Association of European Research Libraries - <http://libereurope.eu/>).

After the publication of the ESFRI Roadmap 2016, the e-IRG group released the e-IRG Roadmap 2016 during the December of 2016, which define a clear route on how to evolve the European e-Infrastructure system further, [7]. The e-IRG group uses the term e-Infrastructure Commons for the e-Infrastructure resources and related services (originally this term was presented in the e-IRG Roadmap of 2012), to target its realization by 2020. e-IRG states that the implementation of the e-Infrastructure Commons will be a large step towards the European leadership in research infrastructures including

e-Infrastructures, the realization of the European Open Science Cloud and the European Data Infrastructure, [7].

The Roadmap proposes some key recommendations, [7], which are briefly:

- RIs and research communities should reinforce their efforts to: elaborate on and drive the e-Infrastructure needs; participate in the innovation of e-Infrastructure services; contribute to standards and take care of their data.
- e-Infrastructure providers should further increase efforts to work closely together to fulfil the complex user needs in a seamless way.
- National governments and funding agencies should reinforce their efforts to: embrace e-Infrastructure coordination at the national level and build strong national e-Infrastructure building blocks, enabling coherent and efficient participation in European efforts; Analyze and evaluate their national e-Infrastructure funding and governance mechanisms, identify best practices and provide input to the development of the European e-Infrastructure landscape.
- European Commission should provide strong incentives for cross-platform innovations and further support the coordination and consolidation of e-Infrastructure service development and provisioning on the national and European level.

Generally, e-Infrastructures can be considered as an essential building block of the European Research Area, while the e-Infrastructure Commons aims to be an essential building block for the EOSC. Representatives from the e-Infrastructures EUDAT, LIBER, OpenAIRE, EGI and GEANT proposed their view of the realization of an e-Infrastructure Commons in [2], where they state that the majority of the needed EOSC services already exists and only technical and policy barriers remain.

5 Access to Research Infrastructures

European Commission, in close cooperation with the ESFRI, the e-IRG group and other EU organizations developed the Charter for Access to Research Infrastructures, for promoting the harmonisation of access procedures and enhanced transparency of access policies in order to enable the remote access of users to the RIs. This document was published in March 2016, [3], and it is accompanied with reference documentation containing complementary material regarding the definition of an access policy for any RI.

The charter promotes access to RIs and interaction with a wide range of social and economic activities, including business, industry and public services, in order to maximise the return on investment in RIs and to drive innovation, competitiveness and efficiency, [3]. The Charter for Access to RIs proposes the following guidelines that each RI have to specify, [3]:

- *Access policy*: The Access Policy should define the access in terms of Access Units, the state of the specific Access mode, clarify the conditions for Access, describe the processes and interactions involved in the Access and elaborate on the support measures facilitating the Access.

- *Access modes*: Three different Access modes have been defined, i.e. excellence-driven, market-driven and wide. Thus, each access to a RI may be regulated according to one Access mode or any combination of them.
- *Access restrictions*: Definition of possible restrictions by means of quota or pre-defined user groups.
- *Access processes and interactions*: The following processes and interactions are defined in the Access to RIs: application, negotiation, evaluation, feedback, selection, admission, approval, feasibility check, setting-up, use, monitoring and dismantling.
- *Support measures facilitating Access*: RIs are encouraged to offer support measures such as guidance through user manuals, provision of user support, provision of accommodation and guidance with immigration procedures.
- *Education and training*: RIs are encouraged to offer education and training, as well as to collaborate with other institutions and organizations that benefit from using RIs for their education and training purposes.
- *Regulatory framework*: A regulatory framework should be defined when providing access to a RI, that should cover Access, intellectual property rights, data protection, confidentiality, liability and possible fees.
- *Transparency*: Each RI should provide transparent information on the RI itself, including its services, access policy, data management policy and the terms and conditions.
- *Research data management plan*: RIs and users should have an agreement on a data management plan outlining how the research data will be handled.
- *Health, safety, security and environment*: RIs should take the necessary actions to ensure the health, security and safety of any user accessing the RI itself, as well as to minimize the impact on the environment.
- *Quality assurance*: RIs are encouraged to set up mechanisms in order to evaluate the quality of the provided access to users.
- *Limitations*: Access to RIs may be limited by the following: national security and defence; privacy and confidentiality; commercial sensitivity and intellectual property rights; ethical considerations in accordance with applicable laws and regulations.

Therefore, all the established RIs have published¹ in accordance with the charter, their individual access policies to foster collaboration among researchers across Europe. International cooperation and access to RIs is strongly encouraged from the European Commission, thus RIs should also define how non-EU members can grant access to their infrastructures.

6 Impact of Research Infrastructures and EOSC

The relationship between academia and RIs contributes to an effective European educational and scientific ecosystem that attracts and supports industry. The optimal distribution of the RIs across Europe (Fig. 2), is of great importance since it contributes in promoting European cohesion, [6]. The knowledge-based economy is effectively

¹ https://ec.europa.eu/research/infrastructures/index_en.cfm?pg=charter_access_ri.

stimulated by strengthening the links between RIs, higher education and research institutions with economic players like industry, services and utilities, [6].

The ESFRI Working Group on Innovation (WG INNO) promoted the industrial capabilities of the RIs on the ESFRI Roadmap in order to push the cooperation of pan-European RIs with industry. This implies promoting partnerships on R&D projects for realizing ecosystems of integrated competences, services and technologies facilitating industrial innovation. Generally, linking the RIs among themselves and allowing the broader social, technological and economical players to acquire information from multiple resources in an effective, efficient and sustainable way, [6].

The success of many RIs leads the G8+5 Group of Senior Officials (GSO) to define a strategy for Global Research Infrastructures (GRI). A well-known example of a GRI is CERN for high-energy physics that is now considered as a globalized infrastructure. The Global Science Forum is responsible for identifying GRI needs and opportunities, including the organizational and long term sustainability aspects. ESFRI acts as a reliable partner at the global level in the practical development of scientific and political initiatives aimed at internationalization of new or existing infrastructures that appear ready to move to a global operation involving access, data policy, and lifecycle management and to consider international governance, [6].

The Commission High Level Expert Group on the European Open Science Cloud expects that when the European Open Science Cloud and the European Data Infrastructure (EUDAT) will be accessible, it will bring benefits for:

- Businesses that will have cost-effective and easy access to top level data and computing infrastructure, as well as a wealth of scientific data enabling data-driven innovation. This will particularly benefit SMEs, which typically lack access to such resources.
- Industry will benefit from the creation of a large-scale cloud eco-system, supporting the development of new European technologies such as low-power chips for high performance computing.
- Public services will benefit from reliable access to powerful computing resources and the creation of a platform to open their data and services, which can lead to cheaper, better and faster interconnected public services. Researchers will also benefit from online access to the wealth of data created by public services.

Making research data openly available can help boost Europe's competitiveness by benefitting start-ups, SMEs and data-driven innovation, including in the fields of medicine and public health.

7 Conclusions

European Commission and the ESFRI group have provided the resources and competence for supporting a strong research and innovation profile for their members, by sharing expensive scientific equipment and e-infrastructures, capitalising on cross-border collaboration and human potential across Europe. The main principles for the European strategy for Research Infrastructures rely on the adoption of a coherent

participation model in European and global RI initiatives, utilization of a continuous collaboration among academia and industry, and on the harmonization of investment in e-infrastructures, as key enablers of a knowledge intensive economy, for and of eScience. A coordinated policy framework of e-Infrastructures, including fast networking, storage, high performance computing, data access and management structures and services has been progressing during the last years.

ESFRI, over the past decade, has improved the efficiency and impact of the European RIs, that are moving towards a sustainable investment for overall competitiveness. With the new published ESFRI Roadmap 2016, new methods and procedures have been adopted, as well as new procedures for the evaluation and selection of new projects and definition and assessment of the ESFRI Landmarks. Enhancing and optimising RIs and their access by scientists and researchers is a key element of competitiveness as well as a necessary basis for dealing with societal challenges. On the other hand, the EOSC initiative puts effort in order to start up a trusted open environment for storing, sharing and re-using scientific data and results supporting Open Science practices. This “cloud for scientists” will set up the standards for the management, interoperability and quality of scientific data that will promote public-private innovation to satisfy the needs of the research communities and increase the global competitiveness of European ICT providers.

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