



Analysis of the Dutch participation in international research infrastructures



December 2023

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in international
research infrastructures**

Credits

NWO took the lead in compiling this report that aims at presenting an overview of the international research infrastructures that the Netherlands participates in, and at providing strategic context and information on their importance for scientific research in the Netherlands. The Permanent Committee for Large-scale Research Infrastructure, provided guidance and advice throughout the process.

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Preface

Access to large-scale research infrastructures is essential for researchers across all domains of academic research. An increasing number of these research infrastructures is established in international collaboration, either because the facilities are of a scale that exceeds the (financial) capabilities of a single country, or because it concerns virtual facilities that link or integrate different national infrastructure nodes. Participation in these international research infrastructures typically requires membership fees. These contributions cover the costs of, for example, coordinating, maintaining and sometimes also operating and upgrading the infrastructure.

The Dutch Research Council, NWO, funds national investments in large-scale research infrastructures through its National Roadmap for Large-scale Research Infrastructure process. NWO is aware of the need for long-term commitments in order to maintain these facilities, but does not provide structural funding for operating national infrastructures or for international memberships. Sustainable long-term funding of memberships is only guaranteed for a very small number of international research infrastructures. With no funding instruments in place, the increasing number of participations comes with challenges. NWO believes it is important to investigate, together with the knowledge institutions, the value of these participations. Following discussions with stakeholders in the Netherlands, NWO took the lead in compiling this report that aims at presenting an overview of the international research infrastructures that the Netherlands participates in, and at providing strategic context and information on their importance for scientific research in the Netherlands.

The drafting of this report was a lengthy process that was already initiated in 2020. Many organisations and individuals have contributed at different stages of the process. The international research infrastructures participated in a survey that was partially conducted jointly with the Swedish Research Council and the Academy of Finland in 2020. Following this initial phase, the process continued in the Dutch context with essential input from the Dutch scientific community. Consecutive consultations took place at the level of the Dutch users of the international research infrastructures, and at the level of Dutch strategic advisory bodies. The Permanent Committee for Large-scale Research Infrastructure provided guidance and advice throughout the process.

The report is very timely in multiple ways. ESFRI has published an update of its European Roadmap for research infrastructures in 2021 and is preparing for a new one in 2025, adding new research facilities that are of interest to the Dutch community and that require decision making. The Ministry of Education, Culture and Science has announced temporary funding for a national portfolio of memberships of international research infrastructures at the level of M€ 10 per year for the period 2023–2031. Considering the increasing number of research infrastructures and the long-term commitments required, there is a need for well-advised and well-informed decisions.

In light of funding limitations, it is not a given that the Netherlands can participate in all international research infrastructures that are considered important for academic research. This report is not meant to set priorities, but the descriptions of the individual memberships provide strategic context that can support the research community and other stakeholders in developing a long-term strategy where choices on participations have to be made.

We would like to thank everyone who contributed to this report: for providing information on behalf of the international research infrastructures, for gathering input from the national community, and for sharing their views. We hope this report will contribute to the development of a sustainable system of funding Dutch participations in international research infrastructures, which will allow the Netherlands to stay engaged at the forefront of science.

Executive summary

Access to state-of-the-art large-scale research infrastructures is key for researchers in all disciplines of academic research. Many of these research infrastructures are international and require significant investments over a period of several years. The Netherlands participates in an increasing number of these international (intergovernmental) organisations that fulfil an important role in developing, building and sometimes also operating large-scale scientific research infrastructures. The research community is the main user of the international research facilities, and decisions to enter into a membership are based on the needs and interests of a specific community.

Considering the long-term commitments that are required and the increasing number of international research infrastructures, there is a need for well-advised and well-informed decisions. To this date there was no overview or strategic information at the national level that covers the full landscape of academic research. The aim of this report is to:

- present an overview of the (current and potential new) Dutch memberships of large-scale international research infrastructures in all fields of academic research;
- showcase the added value of these international participations for academic research in the Netherlands;
- provide strategic context for future decision making on the continuation of memberships or the engagement in new ones;
- aim to make a start with monitoring the added value of the Dutch memberships over time, with a periodic analysis every five years. The second issue of the report is foreseen in 2028.

The Dutch memberships considered in this analysis are those of international facilities on the European ESFRI Roadmap 2021 and in the EIROforum. This list was complemented with memberships of the research infrastructures that have been selected for NWO funding in the past.

The analysis presented in this report is based on fact finding and an extensive consultation of the Dutch scientific community. The fact finding started with a survey that was filled out by the international research infrastructures and that was partly carried out jointly with the Swedish Research Council and the Academy of Finland in 2020. Subsequently, the national consultation was performed at two levels, the user level and the strategic level, which provided insight in the use of and dependence on these research facilities. The survey also yielded a broader national perspective. Each membership is considered in its own context: because of the large diversity in memberships and infrastructures, it is not possible or sensible to aim at comparing or ranking them.

The analysis of the forty-seven memberships confirms the importance of Dutch participation in international research infrastructures. Access to the facilities, data and services provided through these participations is fundamental for academic research across all fields of science. It is not surprising that the majority of these memberships is connected in one way or another to research infrastructures that have been prioritised on the National Roadmap for Large-scale Research Infrastructures.

The descriptions also showcase the value, the diversity, and the complexity of the international infrastructure landscape. With an increasing number of research infrastructures and associated memberships there is a need for coordination, for well-thought-out decisions on participation, as well as for a clear positioning of the different research infrastructures. This can be realised through the development of a national portfolio of memberships of international research infrastructures.

Securing long-term stable funding for the international memberships is a challenge in the Dutch context. It is important to clarify the roles and responsibilities of the different stakeholders, i.e. the relevant government Ministries, NWO and the knowledge institutions. It should be emphasised that all stakeholders in the Netherlands have a joint responsibility for the international memberships.

It is clear that the landscape of international large-scale research infrastructures is dynamic and evolving constantly. The current overview of international participations does not cover all international large-scale facilities that are important for research in the Netherlands. Over the course of time, memberships can be added to the analysis. Criteria for being included in this periodic effort will be further specified in the next few months.

Samenvatting

De Nederlandse wetenschap participeert in een toenemend aantal internationale lidmaatschappen van grootschalige internationale wetenschappelijke onderzoeksinfrastructuren. Tot op heden was er geen overzicht van de (huidige en potentiële nieuwe) Nederlandse lidmaatschappen van grootschalige internationale wetenschappelijke onderzoeksinfrastructuren. Het was onduidelijk wat de meerwaarde van deze internationale participaties is voor het academisch onderzoek in Nederland, en het ontbrak aan strategische context voor toekomstige besluitvorming over voortzetting van of het aangaan van nieuwe lidmaatschappen. In opdracht van NWO is het rapport 'Analysis of the Dutch participation in international research infrastructures' tot stand gekomen om op genoemde punten inzicht te verschaffen.

In kaart gebracht zijn in totaal zevenenveertig lidmaatschappen. Dit zijn de Nederlandse lidmaatschappen van internationale faciliteiten op de Europese ESFRI Roadmap 2021 en in het EIROforum. Deze lijst is aangevuld met lidmaatschappen van de onderzoeksinfrastructuren die in het verleden zijn geselecteerd voor NWO-financiering. Elk lidmaatschap is in zijn eigen context geanalyseerd: vanwege de grote diversiteit in lidmaatschappen en infrastructuren, is het niet mogelijk en niet zinvol om ze te vergelijken of te rangschikken. De resultaten zijn beschreven in narratieven voor ieder van de lidmaatschappen. Op basis daarvan zijn de volgende conclusies te trekken.

Nederlandse deelname aan internationale onderzoeksinfrastructuren is essentieel voor onderzoekers van alle wetenschapsgebieden. Door lidmaatschappen krijgen wetenschappers uit ons land toegang tot de faciliteiten, data en diensten van grootschalige wetenschappelijke onderzoeksinfrastructuren, die fundamenteel zijn voor academisch onderzoek in alle wetenschapsgebieden.

De zevenenveertig narratieven tonen aan hoe waardevol, divers en complex het internationale infrastructuurlandschap is. Er is wel behoefte aan coördinatie, aan weloverwogen beslissingen over deelname (van huidige en potentiële nieuwe lidmaatschappen) en aan een duidelijke positionering van de infrastructuur. Hiervoor is een nationaal portfolio van lidmaatschappen nodig.

Het realiseren van stabiele langetermijnfinanciering voor de internationale lidmaatschappen is een uitdaging. In de Nederlandse context verschillen de verantwoordelijkheden sterk per lidmaatschap. Het is belangrijk om de rollen en verantwoordelijkheden van de verschillende stakeholders, waaronder ministeries en andere overheidsinstellingen, NWO, KNAW en de kennisinstellingen, te verduidelijken. Daarbij dient benadrukt te worden dat alle stakeholders in Nederland een gezamenlijke verantwoordelijkheid hebben.

Het is duidelijk dat het landschap van internationale grootschalige onderzoeksinfrastructuren dynamisch is en zich voortdurend ontwikkelt. Het huidige overzicht van internationale lidmaatschappen dekt niet alle internationale grootschalige faciliteiten die belangrijk zijn voor het academisch onderzoek in Nederland. In de loop van de tijd kunnen lidmaatschappen aan de analyse worden toegevoegd.

Met het rapport is een begin gemaakt aan het monitoren van de toegevoegde waarde van de Nederlandse lidmaatschappen door de tijd heen. Om dit te continueren zal de analyse iedere vijf jaar herhaald moeten worden. Het volgende rapport is voorzien in 2028.

1 Introduction

The Netherlands participates in a number of international (intergovernmental) organisations that fulfil an important role in developing, building and operating large-scale scientific research infrastructures. The landscape is very broad and diverse, and covers all fields of science. It includes single-sited infrastructures like the particle accelerators at CERN and the telescopes of the European Southern Observatory (ESO), life sciences facilities like the European Laboratory for Molecular Biology (EMBL), but also distributed digital infrastructures for almost all disciplines, and European survey and cohort initiatives for the social and health sciences.

Dutch decisions to enter into the membership of an international research facility are based on the needs and interests of specific Dutch research communities that benefit from it. Considering the long-term commitments that are required and the increasing number of research infrastructures, there is a need for well-advised and well-informed choices and decisions supported by the research community to create a portfolio of memberships that is financially sustainable. This requires overview and insight in the value of the Dutch memberships for academic research.

1.1 The Dutch funding landscape for international memberships

The landscape of Dutch memberships is complex, not only because of the diversity in research facilities and the large variation in costs, but also because of the great variety in responsibilities and funding sources per membership. The Dutch Research Council, NWO, has taken the responsibility to create an overview of the Dutch participations by drafting this report, but it is not funding the majority of memberships described. A number of the (very costly) memberships are funded by the Ministry of Education, Culture and Science (OCW), but in most cases it is the responsibility of the scientific community to secure the funding for the international participations. No central responsible body exists, and there is no dedicated funding instrument for membership fees. In some cases, temporary funding can be acquired as part of large project funding, e.g. via the National Roadmap calls. As a consequence, many of the memberships struggle with obtaining stable long-term funding, while engagements come with long-term commitments.

The current role of the different national stakeholders

The Ministry of OCW and other Ministries (LNV, VWS, I&W, EZK)

The membership fees of the intergovernmental organisations (IGO) CERN, EMBL, ESA (science programme) and ESO are provided by the Ministry of OCW. A large number of the other research infrastructures are established as a legal entity that is known as European Research Infrastructure Consortium (ERIC). The membership of an ERIC requires a signature at ministerial level, and thus political support. In most cases this support is provided by the Ministry of OCW, and in a few cases by (or in collaboration with) the Ministry of Agriculture, Nature and Food Quality (LNV), the Ministry of Health, Welfare and Sport (VWS), the Ministry of Infrastructure and Water Management (I&W), or the Ministry of Economic Affairs and Climate Policy (EZK). In most cases the expression of political support does not include any financial commitment. Other legal entities than IGO and ERIC are also possible; an AISBL (Association internationale sans but lucratif) e.g. does not require a signature at ministerial level.

The Dutch Research Council (NWO)

There is no specific funding instrument available at NWO targeted at membership fees. The funding opportunities in the framework of the National Roadmap for Large-scale Research Infrastructure allow the membership fees to be included for a maximum of five years. After these five years, or in case of an unsuccessful project application, funding problems often arise.

Historically, the NWO Domain Science is funding a limited number of memberships, but it is not engaging in new ones. The NWO institutes act as funding bodies for memberships of research infrastructures that are closely linked to their scientific mission.

The Dutch knowledge institutions

The knowledge institutions (such as universities and national research institutes) are the main users of the international research infrastructures. In most cases they are responsible for obtaining funding for the international participations. Realising the commitments at the level of individual universities or research groups is challenging, because of the high costs or because of a lack of ownership in case of a broad user community. For those memberships that are intertwined with the mission of a research institute, the institute will often act as the funding body.

1.2 Link with the National Roadmap and the European ESFRI Roadmap

There is a strong link between the memberships of international research infrastructures and the Dutch National Roadmap for Large-scale Research Infrastructure. The National Roadmap is the result of a national self-organisation process within nine Groups with substantive, thematic or technical commonalities. The vast majority of memberships in this report are directly or indirectly linked to the projects and priorities on the National Roadmap 2021. Therefore the connection with Roadmap priorities and national investments should be considered when analysing the value of the Dutch memberships. The Permanent Committee for Large-scale Research Infrastructure is tasked with advising NWO on formulating the national strategy for investment in large-scale research infrastructures in consultation with the research communities.

In the European context, the ESFRI is a European strategic instrument aimed at coordination and collaboration in the area of research infrastructures. Every few years, ESFRI publishes an update of the ESFRI Roadmap that contains an overview of the European research infrastructure ambitions and the state of affairs and progress in realising them. The ESFRI Roadmap is based on a bottom-up application process. Almost all memberships described in this report relate to a research infrastructure on the ESFRI Roadmap. Infrastructures on the ESFRI Roadmap can apply for a start-up grant from the Framework Programme of the European Commission for their design and preparatory phase. For the coordination, operation and exploitation costs, the European Commission refers to the Member States.

2 Purpose and goal

Access to state-of-the-art large-scale research infrastructures is key for researchers in all scientific disciplines. Many of these research infrastructures are international, and participation requires entering into a membership, often at the national level. These memberships involve significant (financial) contributions over a long period and require long-term strategic planning. Decisions on these participations require agreements with and commitments of the various Dutch stakeholders concerning sustainability, collaboration in the Netherlands and abroad, and strategic priorities. To this date there was no overview or strategic information at the national level that covers the full landscape of international academic research infrastructures.

The aim of this report is to:

- present an overview of the (current and potential new) Dutch memberships of large-scale international research infrastructures in all fields of academic research;
- showcase the added value of these international participations for academic research in the Netherlands;
- provide strategic context for future decision making on the continuation of memberships or the engagement in new ones;
- monitor the added value of the Dutch participations over time (periodic analysis every five years). The second issue of the report is foreseen in 2028.

Given the consequences of entering new or ending existing memberships, it is of the utmost importance that any decision making is done with a clear overview of what is at stake when access to a certain facility is gained or lost. The overarching objective of the report is therefore to satisfy this need for information from all stakeholders involved.

3 Approach

3.1 Organisation and memberships considered

Organisation

The analysis of the memberships of international large-scale research infrastructures is performed under the responsibility of the NWO Executive Board. The Permanent Committee for Large-scale Research Infrastructure was asked to advise on and to oversee the process. This committee is well positioned for this role as its primary task is to formulate a national strategy for Dutch investments in large-scale research infrastructures. Advising about the engagement in or termination of international commitments by the Netherlands is considered one of the tasks of the committee (Terms of Reference), because it is of strategic importance to ensure the coherence between national and international investments.

The analysis is performed by a team at NWO with input from both the international infrastructures and the Dutch scientific community.

Memberships considered

The present analysis includes memberships of large-scale international scientific research infrastructures that the Netherlands already participates in (as a member or observer). The report also contains descriptions and preliminary data on new or emerging international large-scale infrastructures that the Dutch research community is interested in and where a decision on participation is needed in the short term (prospective member).

Participations of (groups of) single researchers or individual research institutes in international research infrastructures are considered outside the scope of this report. Memberships of research facilities that are primarily aimed at applied research have been excluded as well.

For the selection of the memberships, the international facilities on the European ESFRI Roadmap 2021 and those participating in the EIROforum were used as a starting point. This list was complemented with international memberships of the large-scale research infrastructure that have been selected for funding by (parts of) NWO domains in the past. Thus forty-seven memberships have been identified and included in the analysis presented in this report. We realise that the landscape of international large-scale research infrastructures is evolving constantly. Over the course of time memberships may be added, provided they meet certain eligibility criteria. These eligibility criteria will be further specified in the next few months. It is of course also foreseeable that memberships will be terminated.

An overview of the memberships considered is included in chapter 5 of this report. This chapter describes the characteristics of the three research domains and the international large-scale research infrastructures therein. The full list can also be found in Annex 1.

3.2 Method

The analysis of the Dutch participation in international research facilities is set up as a periodic analysis that will be performed every five years. Each membership is considered in its own context: because of the large diversity in memberships and infrastructures, it is not possible nor sensible to aim at comparing or ranking them. The process consists of three stages: (1) fact finding; (2) national consultation; and (3) analysis.

Stage 1: Fact finding: collecting information and composing factsheets

Information was collected via a survey of the international research infrastructures and via desk research. For the first stage, i.e. for interviewing the head quarters of the common facilities, this survey was performed jointly with the Swedish Research Council (VR) and the Academy of Finland (AKA). Sweden, The Netherlands, and Finland decided to coordinate their efforts in order to minimise the workload of the international research infrastructures in answering the questionnaires. An important aim of the survey was to gather comprehensive data from the facilities that provide insight into the Dutch added value from international engagement. The questionnaire included questions on the use of the facility, the Dutch share of the usage, and the Dutch contributions to the research infrastructure, but also more general questions on the delivery of education, training and outreach, and benefits for the society at large. Because of the difference in nature between the centralised and distributed facilities, not all questions were tailored to both infrastructure types. The research infrastructures were asked to respond only to the questions that they could provide an answer to.

The desk research was aimed at extracting general information from documents like statutes, annual reports and other publicly available sources of information. It includes a short description of the organisation and factual information on the organisational form and Dutch membership fees. For each membership, the collected information is summarised in a factsheet that was used as input for the analysis (stage 3). The factsheets for each of the memberships can be downloaded <https://www.onderzoeksfaciliteiten.nl/node/3961>. Note that the data in the factsheets cover the period 2016–2019 and hence do not contain the most recent data. An update is foreseen.

Stage 2: National consultation

This stage of national consultation provides key information for the analysis. Without input from the Dutch scientific community and an understanding of the national context, it is impossible to analyse the added value of the memberships for academic research in the Netherlands.

Consultation has taken place at two levels, the user level and the strategic level:

1 User consultation

Per membership a central contact point from the user community has been identified. This contact point has been asked to consult with the Dutch users of that research infrastructure and to provide input on behalf of the user community. Input was collected via a questionnaire (Annex 2). The community was asked to describe the research activities in the Netherlands carried out with the research infrastructure and to comment on the dependence of these activities on the infrastructure. They were also asked to share their views on alternative facilities in their research area, and to comment on the timeframe in which the infrastructure will remain relevant.

2 Strategic consultation

The strategic consultation was organised via the three NWO Domains and ZonMw. The two NWO Domains that have an advisory structure made up of researchers that represent their research field, the NWO Domain Science and the NWO Domain Social Sciences and Humanities, forwarded the questionnaires to their Round Tables. These strategic bodies could either respond to the consultation themselves, or forward the request to a different body with relevant expertise. All advisory bodies were asked to provide input for those memberships relevant for their field, they could thus decide themselves on which memberships to comment.

Input was collected via questionnaires and the responses were aggregated per membership. The strategic bodies were not asked to compare or rank the different memberships. For some memberships multiple responses have been received as they are relevant for a broad range of research areas.

The aim was to collect the broader strategic context for each of the memberships. Questions address the relation between the membership and relevant (national) research agendas, the value of participation of the Dutch community, its contribution to the research activities in the Netherlands, and the dependence of the community on access to the facility. The questionnaire can be found in Annex 2.

Stage 3: Analysis and narratives

The information from the fact finding and from the national consultation was analysed by a team at NWO, and then consolidated in a narrative per membership. These narratives provide insight in the importance of the participation for its user community (relevance, use, dependence), and in the strategic relevance for the Dutch research field. Elements addressed include the scientific relevance (main criterion), societal relevance (including economic relevance), organisation and management, and the Dutch use in perspective of the Dutch share. Each membership is analysed in its own context, no comparisons between memberships are made. Per membership a conclusion on the importance is formulated, and where applicable points of attention for future monitoring are provided.

The draft narratives and conclusions have been discussed with the Permanent Committee for Large-scale Research Infrastructure. Following this discussion, the drafts have been shared with the nine Groups that coordinate priorities for the national Roadmap process, to ensure that the conclusions are in line with their agendas. As a final step, a fact check has been performed via the national contact points for the memberships.

4 Conclusions and recommendations

Chapter 5 describes the findings for each of the individual memberships, and the characteristics of each of the three scientific domains that we distinguished: Technical and Natural Sciences; Life and Medical Sciences; and Social Sciences and Humanities. This chapter summarises the general findings, conclusions and recommendations.

4.1 Observations

The membership descriptions do not only provide an overview of the Dutch participations, they also showcase the diversity and complexity of the international infrastructure landscape. Especially the differences between centralised and distributed infrastructures stand out. Distributed research infrastructures are often large virtual infrastructures that link or integrate national facilities or nodes from multiple countries, and provide central access to data, resources and services. The national nodes are usually funded in the national context, and the membership fees are used to cover the common coordination costs. For many of these infrastructures, the interplay between national and international activities results in a rather low level of central organisation. Centralised research infrastructures are jointly funded by the member countries. These are usually large organisations with a strong organisational structure and many employees that run the facility. Membership fees are typically factors higher than for the distributed infrastructures.

The differences between distributed and centralised facilities also emerged in the survey of the international research infrastructures (stage 1). Specific questions were difficult to answer for the distributed infrastructures. In particular for the open access digital or data infrastructures, limited information on the (Dutch) use of the facility could be provided. It also turned out to be difficult to distinguish between national and international personnel and activities. The factsheets <https://www.onderzoeksfaciliteiten.nl/node/3961> reflect these limitations.

The characteristics of the different infrastructure types are described in more detail in chapter 5.

There are also differences in the legal organisation structure adopted by the research infrastructures. The most common legal entities are the intergovernmental organisation (IGO), the European Research Infrastructure Consortium (ERIC), and the association internationale sans but lucratif (AISBL), but other structures exist¹. The IGO requires the strongest political support, as it is an organisation by treaty that requires ratification in parliament. The ERIC is a specific legal entity that can be established upon decision by the European Commission. Its members are countries, and signatures at the ministerial level are required for participation. More and more research infrastructures opt for an ERIC as legal entity. The process to establish an ERIC is simpler than the process to establish an IGO. Both the ERIC and the IGO profit from VAT exemption. Other advantages of the ERIC are the access to certain funding instruments in the European Framework Programme(s). Although simpler than an IGO, the lengthy and heavy process to become an ERIC, compared to e.g. an AISBL, can be a disadvantage.

In the description of the memberships, the legal entity itself is not considered an asset. It is however important that the organisation structure is fit for purpose.

¹ The EC announced a new legal entity for digital infrastructures 'EDIC (European Digital Infrastructure Consortium)'.

4.2 Conclusions

- The analysis of the forty-seven memberships confirms the importance of Dutch participation in international research infrastructures. Access to the facilities, data and services provided through the international memberships is fundamental for academic research. The science cases of many different research communities across all fields of science completely depend on these facilities. Moreover, the research infrastructures enable and stimulate Dutch participation in joint research activities, and fulfil an important role in training and educating the next generation of scientists.
- In addition to the scientific benefits, participation also contributes to the positioning of (research in) the Netherlands in a European and global context. In terms of societal and economic benefits, the research infrastructures function as enabler for technology and innovation development. Many of the infrastructures contribute to tackling global and societal challenges, such as climate change, health care or developing better policies. The majority of facilities also have an active outreach programme. For the very large facilities, there often is an economic return to all partners via industrial contracts.
- With an increasing number of research infrastructures and associated memberships, there is a need for coordination and well-thought-out decisions on participation, as well as a need for a clear positioning of the different research infrastructures. This applies in particular to the distributed data infrastructures. Given the multitude of memberships, there is a risk of fragmentation of activities, resource duplication, and service redundancy. At the same time, both complementary and transversal facilities are needed to address a multitude of multi- and interdisciplinary research questions. In general, all domains can profit from a long-term strategy of collaboration both in terms of decision making and long-term planning. At the national level, coordination has been initiated, Among others in the framework of the National Roadmap for Large-scale Research Infrastructure.
- Participation in the international research infrastructures does not only require membership fees, but in most cases there are additional large contributions needed. For the distributed infrastructures, the national nodes that are financed separately in the national context are considered a Dutch contribution to the international infrastructure. Often these national nodes deliver large in-kind contributions to the international component of the infrastructure. Also for the centralised research infrastructures additional national resources are required, e.g. via the development and delivery of instrumentation, via data or expertise centres that provide user support, or via additional contributions to operations.
- For many of the distributed data infrastructures following open & FAIR data policies, data can be accessed and used without registration and free of charge. As a result, there is a limited awareness amongst the users that these infrastructures require large investments and require membership fees.

4.3 Recommendations

- Develop a national portfolio of memberships of international research infrastructures. The long-term commitments required and the limited resources in the Dutch academic landscape, require strategic decision making based on the interest and scientific priorities of the research community.
- Clarify the roles and responsibilities of the different stakeholders in the national context, including the funding responsibilities. It should be emphasised that all stakeholders in the Netherlands have a joint responsibility for the international memberships. Securing long-term stable funding for the international memberships is a challenge. A number of the very

costly intergovernmental organisations are directly funded by the Ministry of OCW. The funding landscape for the other memberships is diverse and complex. Moreover, the responsibilities of the national stakeholders are not always clear. The research community is expected to organise funding, but without specific funding instruments and a sense of national ownership and responsibilities amongst all stakeholders, this is often problematic. This is especially true for memberships with many (diverse) user groups in the absence of a single knowledge institute that is able (or in the position) to take the lead.

- The importance of coordination between research infrastructures stands out. Coordination is being addressed in the context of the National Roadmap 2021, and we recommend to – where possible and relevant – pursue stronger coordination between international infrastructures. In addition, we recommend to stimulate the discussion on the positioning of infrastructures within (adjacent) research fields.
- Increase the visibility of the Dutch participation in international research infrastructure and of the associated national nodes. There is limited awareness of the widespread impact of these infrastructures and their importance for academic research in the Netherlands.

5 Results: description of the memberships

This chapter describes the findings for each of the individual memberships. The layout follows the format of the National Roadmap for Large-scale Research Infrastructure with three scientific domains: Technical and Natural Sciences; Life and Medical Sciences; and Social Sciences and Humanities. For each of these three domains, the characteristics are described and the main recommendations are summarised.

Each membership is analysed in its own context, and a conclusion is formulated. All forty-seven memberships are labelled important, meaning that all research infrastructures deliver an important contribution to the science cases of their user community. Moreover, the majority of memberships discussed are connected to research infrastructures that have been prioritised on the National Roadmap 2021. There are however individual challenges and points of attention, and these have been summarised per infrastructure in the individual narratives.

In light of funding limitations, it is not a given that the Netherlands can participate in all international research infrastructures that are considered important for academic research. This report is not meant to set priorities, but the descriptions of the individual memberships provide strategic context that can support the research community and other stakeholders in developing a long-term strategy where choices on participations have to be made.

5.1 Technical and Natural Sciences

The characteristics of the Technical and Natural Sciences Research Infrastructures

The Technical and Natural Sciences landscape is very broad. The different research areas in this domain each require their own specific research infrastructures of diverse nature. In general, two types of facilities can be distinguished:

- **Centralised facilities** are typical for the Technical and Natural Sciences. These are usually constructed and operated in collaboration with multiple countries and are run by large organisations that host many employees and are very structured in organisational terms. Examples are Big Science facilities that can only be realised in the international context by organisations such as CERN or ESO. To have such facilities requires coordination in view of the technological and scientific complexity of the infrastructure. Many of these facilities are too expensive for an individual country and require long-term commitments at the government level. To cover the costs of building and operating these infrastructures high membership fees are required. The combination of sizable fees and long-term commitments pose a challenge in decision making.
- **Distributed facilities** where the international component concerns coordination and pooling of national facilities (laboratories, monitoring stations, databases, ...). Multiple national facilities constitute a virtual international facility. Investments in national infrastructures, for which separate funding must be provided or acquired, dominate the total costs. An example is the national Ruisdael observatory connected to the international membership of ACTRIS and ICOS.

Landscape and link with the National Roadmap for Large-scale Research Infrastructure

There is a strong link between the international memberships and the infrastructures on the National Roadmap for Large-scale Research Infrastructure. For centralised facilities Roadmap projects often translate into a national contribution to the construction of (certain instruments for) the central facility. For distributed facilities Roadmap projects are typically aimed at realising the national facility or node that is part of the international infrastructure. In some cases the required national investments can be realised with a smaller scale research infrastructure grant, and for a number of long-running memberships no large-scale investments are required in the short term. The latter have not been included in the National Roadmap (ECORD/IODP, ICDP, ING). In the National Roadmap 2021 the Technical and Natural Sciences landscape is clustered in four Groups on the basis of substantive, thematic or technical commonalities. These four Groups are Astronomy and Particle Physics; Materials; Technology; and Geosciences. Within these Groups synergies and complementarities in both the national and international context are discussed. The particle physics, astronomy and astroparticle physics communities have a strong tradition in long-term strategic planning and priority setting for large international research infrastructures. All Dutch memberships that fall within this Group are of centralised facilities as described above, that are built and operated by European or global collaborations of multiple countries. The Netherlands is host country for three of these infrastructures: ILT, JIVE and KM3NeT. Synergies addressed between infrastructures include joining forces to tackle common data-related challenges, and the need for a multi-wavelength or multi-messenger approach in astronomy and astroparticle physics. Synergies also exist at the technological level, e.g. ESA and ESO have working groups to discuss common technologies and their development.

The infrastructures in the Materials Group are mostly complementary: the Dutch materials science community requires access to the full spectrum of state-of-the-art characterisation techniques. Infrastructures include both centralised facilities and distributed facilities that coordinate different national laboratories, like EMFL. Most of the infrastructures and international memberships in this Group cater for a broad range of science cases, both within and outside the materials community. To understand the whole earth system and to address societal questions related to our planet, the geosciences require an integrated approach and complementary data. Studying geosciences requires data of and observatories at oceans and atmospheres, deltas, and the deep subsurface. The national observatories and monitoring networks are typically embedded in a broader European distributed research facility that operates across borders. Data collected in different countries are brought together in databases that provide standardised, high-precision and long-term observations. The research infrastructures lead to enhanced (multidisciplinary) collaboration. A systematic approach also requires access to facilities in the Materials and Life Sciences Groups. There is no specific membership linked to the technical sciences, although a number of the memberships discussed in this section are relevant for and used by technical and engineering sciences. Relevant for this Group is the distributed research infrastructure EuroNanoLab that brings together many national academic nanofabrication centres across Europe, including centres in Amsterdam, Delft, Eindhoven, Groningen and Twente. EuroNanolab is important to create more coherence and synergy in this field of research. EuroNanoLab is not (yet) included in the ESFRI Roadmap.

Link with the broader European context and ESFRI

All the international memberships in the Technical and Natural Sciences are linked to research infrastructures that are projects or landmarks on the ESFRI Roadmap, or – in the case of long-running facilities – to research infrastructures included in the ESFRI landscape. Two memberships in the area of data and computing, PRACE and SLICES, have been included as well in this chapter. These do not relate to specific Groups in the Roadmap but address a broad area of scientific disciplines, including Technical and Natural Sciences, Life and Medical Sciences, and Social Sciences and Humanities. EuroHPC-JU is out of the scope of this report.

Conclusions and suggested actions

The Dutch participation in international research infrastructures is of fundamental importance to the Technical and Natural Sciences domain. The world-class international facilities cannot be realised by a single European country. Participation enables the scientific community to maintain their internationally leading position at the forefront of science. Moreover, the joint research activities, technological co-development and participation in training and education programmes adds further value to the Dutch research activities.

Within the broad Technical and Natural Sciences landscape, there is a great variety of research infrastructures. The large centralised research infrastructures are typical for this domain, while at the same time distributed and digital infrastructures are predominant in certain disciplines. The memberships in this section have been assessed in their own context and are all considered important.

There are a number of memberships that require a decision on participation or continuation in the near future. For these the following is suggested:

- **CTA:** The Dutch community has a scientific interest, is visible in the Science Working Groups, and realised a (moderate) in kind contribution to the CTA construction via grants. While Dutch researchers will be able to apply for the 10% ESO open time, participation in the key science projects will require a membership. Therefore exploring participation in CTA at a level that reflects the interests of the Dutch user community is recommended.
- **ECORD/IODP:** IODP will enter a new phase after 2024 with changes in partnership and equipment. The suggested action is to consider the future IODP programme in light of the interests of the Dutch scientific community when making the decision on the Dutch participation in the next phase of IODP.
- **ESS:** In August 2020 the Dutch observer status of ESS expired and was discontinued. Despite the interest of the community and the scientific value, the sizable long-term financial commitment to participate in this large-scale centralised facility could not be realised at that moment. In November 2022 the ESS offered the Netherlands renewed observer status. Acceptance is pending until there is a clear financial perspective for future membership.
- **PRACE:** It is important to monitor the interaction with EuroHPC-JU. At the moment, the two are complementary and a future strong partnership will create optimal synergies.

Coherence between the different distributed geosciences facilities should be further enhanced in the national context. With the recent Roadmap funding for EPOS-eNLarge, synergies in the data framework for all geosciences infrastructures can be further developed. Coherence also follows from the thematic approach, described in the national Sector Portrait for Earth and Environmental Sciences, where a deep understanding of processes in the different systems is needed to provide humanity with a safe living environment.

List of Memberships

Astronomy and Particle Physics

CERN

European Council for Nuclear Research: a convention-bound organisation that runs the world's largest particle physics laboratory

<https://www.home.cern/>

Countries: CH, AT, BE, BG, CZ, DE, DK, ES, FI, FR, GR, HU, IL, IT, NL, NO, PL, PT, RO, RS, SE, SK, UK, (CY, EE, SI; associate: HR, IN, LV, LT, PK, TR, UA; observer: EU, JP, UNESCO, US)

Legal entity: IGO

CTAO

Cherenkov Telescope Array Observatory: next generation ground-based gamma-ray observatory

<https://www.cta-observatory.org/>

Countries: IT, AT, AU, CH, CZ, DE, ES, FR, JP, SI, UK, ESO, (NL, ZA)

Legal entity: gGmbH (ERIC application stage)

EGO

European Gravitational Observatory: hosts the Virgo laser-interferometric gravitational-wave detector located near Pisa, Italy

<https://www.ego-gw.it/>

Countries: IT, FR, NL

Legal entity: consortium agreement

ESA

European Space Agency: Europe's gateway to space, develops and carries through the European space programme

<https://www.esa.int/>

Countries: FR, AT, BE, CH, CZ, DE, DK, EE, ES, FI, GR, HU, IE, IT, LU, NL, NO, PL, PT, RO, SE, UK, (LV, LT, SI, SK)

Legal entity: IGO

ESO

European Southern Observatory: builds and operates world-class ground-based astronomical observatories at optical, sub-mm and near-infrared wavelengths

<https://www.eso.org/>

Countries: DE, AT, BE, CH, CZ, DK, ES, FI, FR, IE, IT, NL, PL, PT, SE, UK, (host and partner country: CL; strategic partner: AU)

Legal entity: IGO

ILT

International LOFAR Telescope: the world's premier low-frequency radio-interferometric telescope

<https://www.astron.nl/telescopes/lofar/>

Countries: NL, DE, FR, IE, LV, NL, PL, SE, UK (stations in development in BG and IT)

Legal entity: MoU (ERIC application stage)

ING

Isaac Newton Group of Telescopes: the 4.2-m William Herschel Telescope (WHT) and the 2.5-m Isaac Newton Telescope (INT), La Palma, Spain

<https://www.ing.iac.es/>

Countries: ES, NL, UK

Legal entity: collaborative agreement

JIVE

Joint Institute for VLBI ERIC: implements the core data processing and user services that turn the EVN network of distributed radio telescopes into a single observatory

<https://jive.eu/>

Countries: NL, ES, FR, IT, LV, SE, UK (partner countries: CN, DE, ZA)

Legal entity: ERIC

KM3NeT

Cubic Kilometre Neutrino Telescope: next generation neutrino telescopes located in the deepest seas of the Mediterranean

<https://www.km3net.org/>

Countries: NL, AE, AU, CZ, DE, ES, FR, GE, GR, IT, MA, PL, RO, SK, UK, ZA

Legal entity: MoU (AISBL in future)

SKAO

Square Kilometre Array Observatory: next-generation radio astronomy big data facility with radio telescopes in Western Australia and South Africa

<https://www.skao.int/>

Countries: UK, AU, ZA, CH, CN, ES, IT, NL, PT, (CA, DE, FR, IN, JP, KR, SE)

Legal entity: IGO

Materials

EMFL

European Magnetic Field Laboratory: develops and operates world-class high magnetic field facilities

<https://emfl.eu/>

Countries: DE, FR, NL, PL, UK

Legal entity: AISBL

ESRF

European Synchrotron Radiation Facility: the world's brightest X-ray source and centre of excellence for research in condensed and living matter science

<https://www.esrf.fr/>

Countries: FR, BE, CH, DE, DK, ES, FI, FR, IT, NL, NO, RU, SE, UK, (AT, CZ, HU, IL, IN, PL, PO, ZA)

Legal entity: IGO

ESS

European Spallation Source: multi-disciplinary research facility based on the world's most powerful neutron source

<https://europeanspallationsource.se/>

Countries: SE, CH, CZ, DE, DK, EE, ES, FR, HU, IT, NO, PL, UK

Legal entity: ERIC

Geosciences

ACTRIS

Aerosol, Clouds and Trace Gases Research Infrastructure: pan-European high-quality data and information on short-lived atmospheric constituents

<https://www.actris.eu/>

Countries: FI, AT, BE, BG, CH, CY, CZ, DE, DK, ES, FR, IT, NL, NO, PL, RO, SE

Legal entity: ERIC

DANUBIUS

International Centre for Advanced Studies on River-Sea Systems: distributed environmental integrated research infrastructure from river source to sea

<https://www.danubius-ri.eu/>

Countries: RO, AT, BG, CZ, DE, ES, FR, GR, HU, IE, IT, FI, MD, NL, UA, UK

Legal entity: ERIC (application stage)

ECORD / IODP

European Consortium for Ocean Research Drilling / International Ocean Discovery Program: ocean-going scientific drilling projects

<https://www.ecord.org/>

Countries: FR, AT, CA, CH, DE, DK, ES, FI, FR, IE, IT, NL, NO, PT, SE, UK

Legal entity: MoU

EPOS

European Plate Observing System: facilitates the integrated use of data, data products, and facilities from the solid Earth science community in Europe

<https://www.epos-eu.org/>

Countries: IT, AT, BE, CH, DK, ES, FR, GR, IS, NL, NO, PL, PT, RO, SE, SI, UK, (DE)

Legal entity: ERIC

ICDP

International Continental Scientific Drilling Program: coordinates and facilitates continental drilling projects worldwide

<https://www.icdp-online.org/>

Countries: AT, BE, CH, CN, CZ, DE, EE, ES, FI, FR, IS, IN, IL, IT, JP, NL, NZ, NO, SE, UK, US, ZA, UNESCO

Legal entity: MoU

ICOS

Integrated Carbon Observation System: European-wide greenhouse gas research infrastructure that provides standardised and open data

<https://www.icos-cp.eu/>

Countries: FI, BE, CZ, DE, DK, ES, FR, GR, HU, IE, IT, NL, NO, SE, UK

Legal entity: ERIC

Data science

PRACE

Partnership for Advanced Computing in Europe: provides access to Europe's world class High Performance Computing (HPC) facilities

<https://prace-ri.eu/>

Countries: BE, CH, DE, ES, FR, IT, AT, BG, CY, CZ, FI, GR, HU, IE, IL, LU, NL, NO, PL, PT, SE, SI, SK, TR, UK, (HR, LV)

Legal entity: AISBL

SLICES

Scientific LargeScale Infrastructure for Computing/Communication Experimental Studies

<https://www.slices-ri.eu/>

Countries: BE, CH, CY, DE, ES, FI, FR, GR, HU, IT, LU, NL, NO, PL, SE

Legal entity: under development

ACTRIS – Aerosols, Clouds and Trace Gases Research Infrastructure

ACTRIS is an important infrastructure for observation of aerosols, trace gasses and clouds and associated research on air pollution, weather and climate in the Netherlands and internationally.

SYNOPSIS

The Aerosols, Clouds and Trace Gases Research Infrastructure, ACTRIS, is a European network for the observation of aerosols, trace gasses and clouds. These observations are important for the study of air quality, weather and climate research. ACTRIS data will be freely available for non-commercial users and used for enhancing process understanding, model improvement, monitoring of trends and satellite validation. ACTRIS provides central access to quality controlled measurements and to (mobile) measurement equipment. ACTRIS has been established as an ERIC in 2023 with 17 member countries. Atmospheric measurements in the Netherlands are embedded in the national Ruisdael Observatory and ACTRIS provides the international connection for this national network.

USERS PERSPECTIVE

Relevance for the user community

Atmospheric observations are vital to quantify and understand atmospheric composition and air pollution. European data on atmospheric constituents is needed as the atmosphere knows no borders. The quality of Dutch atmospheric research is strongly dependent on European-scale observations and collaborations, and therefore Dutch users consider ACTRIS a crucial infrastructure in the field.

From a technical perspective, ACTRIS facilitates calibration and standardisation of instruments and processing, which enhances uptake of measurements. The international component of the ACTRIS network increases the network's coverage, efficiency, and its relevance for monitoring atmospheric constituents. ACTRIS is a wide scientific community with more than 800 scientists and technicians. ACTRIS is important for the Netherlands, but also vice versa. The Dutch atmospheric community is responsible for dedicated units in calibration centres for scientific instruments.

Topics for which ACTRIS services are important and for which extensive research activities are conducted in the Netherlands are:

- **Air quality:** development of measurement methodologies, modelling of atmospheric chemical processes, transport modelling, data assimilation, forecasting and trend monitoring. Partners: RIVM, KNMI, WUR, RUG, VU, TNO, TUD
- **Weather:** Extreme rainfall, clouds, wind and turbulence, land-atmosphere interaction, weather modelling. Partners: KNMI, WUR, RUG, VU, TUD
- **Climate:** Atmospheric radiation balance, cloud-aerosol interaction, cloud feedback mechanisms. Partners: KNMI, WUR, RUG, VU, TUD
- **Satellite validation:** intercomparison studies, instrument development and improvement. Partners: KNMI, WUR, VU, TNO, TUD

For all research areas it holds that ACTRIS is needed for:

- harmonisation, quality control and quality assurance of instruments and data;
- access to other (mobile) instruments for campaigns in the Netherlands;
- access to data from other European regions;
- exchange of (early career) scientists.

STRATEGIC PERSPECTIVE

Alignment with national research/strategic agendas

ACTRIS is the result of the long-term international collaboration within the atmospheric science community sustained by a series of Framework Programme INFRA projects that started in 2000. ACTRIS has been on the ESFRI Roadmap since 2016 and has been established as an ERIC in 2023. The Dutch contribution to ACTRIS is through the Ruisdael Observatory, which is part of the National Roadmap for Large-scale Research Infrastructure. Measuring, monitoring and modelling efforts conducted in the ACTRIS context align with strategies laid out in the Sector Portrait for Earth and Environmental sciences. ACTRIS activities are relevant for the agendas of the NWA Routes Energy transition, Measuring and detecting: anything, anytime, anywhere, and Quality of the living environment, and link to the EU Mission Climate.

Relation to other (similar) Research Infrastructures

The Ruisdael Observatory is the Dutch national measurement network for atmospheric science. Through ACTRIS, the national measurement network is connected to the European scale. Many Ruisdael facilities operate within the context of ACTRIS. Similarly, ICOS (Integrated Carbon Observation System) is embedded in Ruisdael and extends internationally through the ICOS ERIC. ACTRIS is the only European infrastructure of its kind. An equivalent to ACTRIS is the ARM facility in the USA.

Impact & outreach

Outcomes of collaboration through ACTRIS include societally relevant knowledge such as a better understanding of the impact of climate change and environmental change, including extreme weather, improved forecasting of extreme events, fine-scale wind and solar forecasting and deeper insight into air quality and its relation with public health.

Time period

ACTRIS will remain relevant for the atmospheric sciences in the Netherlands for at least the next decade, and most likely longer. In the second decade the focus might change from process understanding to the study of long-term trends.

CONCLUSION

ACTRIS is an **important** infrastructure for the Netherlands. ACTRIS builds on previous collaborations in the atmospheric sciences and aligns with Dutch and European research agendas and roadmaps. International observation and collaboration is crucial for high-quality atmospheric research and ACTRIS provides the international context to make high quality data and facilities accessible.

CERN – Conseil Européenne pour la Recherche Nucléaire / European Organization for Nuclear Research

CERN is an **important** research infrastructure for Dutch particle physics. The Netherlands has a major involvement in the Large Hadron Collider experiments ALICE, ATLAS and LHCb.

SYNOPSIS

CERN is an intergovernmental organisation that runs the world's largest particle physics laboratory. The mission of CERN is to provide for collaboration among European States in nuclear and particle physics research of a pure scientific and fundamental character. Founded in 1954, the laboratory has its headquarters in Geneva and its site has extended over time from Switzerland into France. CERN operates in particular the Large Hadron Collider (LHC), the largest proton collider ever built, which led to the discovery of the Higgs boson in 2012.

CERN currently has 23 member countries, primarily in Europe, but the facility is used by researchers from all over the world. The Netherlands was one of its founding members together with 11 other European countries. Experimental particle physics research in the Netherlands is coordinated and supported by the Dutch National Institute for Subatomic Physics, Nikhef, a partnership between the Institutes Organisation of the Dutch Research Council (NWO-I) and six universities. Nikhef's main research ambition at CERN is to exploit the discovery potential of the LHC programme through participation in the ATLAS, ALICE and LHCb experiments. Dutch membership of CERN is funded through the Ministry of Education, Culture and Science. On top of the national contribution to CERN, Nikhef pays an annual fee in the order of k€ 600 in total for maintenance & operation costs related to running the ATLAS, ALICE and LHCb experiments.

USERS PERSPECTIVE

Relevance for the user community

The LHC and the LHC experiments are the projects with the highest priority at CERN. The LHC experiments are semi-autonomous and are funded in part by CERN, but mainly through direct funding from the countries participating in the experiments. Data from CERN experiments are freely available to all members of the Collaboration. In addition to particle physics research, accelerator and detector development is also conducted at CERN. Furthermore, research on a smaller scale is conducted within nuclear physics, biomedical engineering, materials physics and e-Science. CERN is the most important partner of Nikhef. In all three LHC collaborations in which Nikhef participates, Nikhef has shown leadership in the design, construction and commissioning of the now successfully running silicon detector systems, Scintillating Fibre detectors, Muon Spectrometer, Data acquisition, etc. Nikhef participates very actively in the data analysis, including calibration and alignment, working towards new physics results; and in theoretical research in order to improve the description and interpretation of the data. Nikhef's missions for LHC participation include to continue studies of the Higgs particle, search for physics beyond the Standard Model (with ATLAS), search for new particles and interactions that affect the observed matter-antimatter asymmetry in the Universe (with LHCb), and to study the physics of strongly interacting matter at extreme densities where the formation of the quark-gluon plasma is expected (ALICE). The High-Luminosity

LHC (HL-LHC) is a major upgrade of the LHC to increase the potential for discoveries after 2029. The HL-LHC will allow physicists to study known mechanisms in greater detail, such as the Higgs boson, and observe rare new phenomena that might reveal themselves. Its development depends on several technological innovations. Nikhef aims to contribute to the upgrades of the detectors by developing an highly advanced tracking technique, which is needed for the HL-LHC era. Nikhef is at the forefront of the LHC computing infrastructure. With SURF, Nikhef participates in the Worldwide LHC Computing Grid and hosts a Tier-1 centre. The Dutch facility FuSE (Fundamental Sciences E-infrastructure) will be the key enabler for the Dutch community to analyse the data and extract the scientific results for the LHC experiments and two other National Roadmap Facilities, KM3NeT and the Square Kilometre Array.

Education & Training

CERN organises seminars and training courses for in-house scientists. Specialist workshops for young researchers cover CERN's areas of expertise (high-energy physics and detectors, computing and accelerator physics). The Summer Student Programme for undergraduate physicists and engineers welcomes several hundred participants from Member and Non-Member States. CERN also hosts PhD candidates who complete their studies with a university, but spend time at CERN. The CERN early-career graduate fellowships include a strong training element.

STRATEGIC PERSPECTIVE

Alignment with national research/strategic agendas

Continued strong involvement in ALICE, ATLAS and LHCb, both in the hardware development and the science exploitation, is one of the main pillars of the Nikhef Strategy 2017–2022, as well as in the new Strategy 2023–2028. In that sense, Nikhef's research is **completely dependent** on the CERN-LHC infrastructure. Membership of this infrastructure is essential in order to exploit a world class particle physics portfolio. Without participation in this infrastructure it is impossible to move forward in the field of particle physics. CERN has a prominent position in the 2020 Strategy Document of the Particle and Astroparticle Physics working group of the Dutch physics research communities. The HL-LHC detector upgrades are included in the National Roadmap for Large-scale Research Infrastructure 2016 and 2021. CERN is governed by a council consisting of member country representatives. The CERN Council is also tasked with developing the European strategy for particle physics. The successful completion of the HL-LHC upgrade of the machine and detectors, and exploiting the full physics potential of the LHC and HL-LHC, remains the focal point of European particle physics as stated in the 2020 update of the European Strategy for Particle Physics. The HL-LHC has landmark status in the ESFRI Roadmap.

Relation to other (similar) Research Infrastructures

The LHC is the highest energy particle collider in the world. Other powerful colliders are the Relativistic Heavy Ion Collider (RHIC) at Brookhaven National Laboratory and (formerly) the Fermilab Tevatron collider. The Fermilab Main Injector can be compared to the CERN SPS (synchrotron accelerator) for fixed target experiments. The main focus now at Fermilab is high intensity beams for neutrino physics. The CERN Neutrino Platform cooperates with neutrino physics experiments across the world, in particular testing prototype detectors for the Deep Underground Neutrino Experiment (DUNE) under construction in the US (partly at Fermilab). Nikhef is involved in the preparatory work for DUNE (protoDUNE). Accelerator facilities at TRIUMF (Canada), GANIL (France) and MSU (US) host experiments using radioactive beams with similar characteristics as at the ISOLDE experiment at CERN. The Netherlands is not a member of the ISOLDE collaboration.

Impact & outreach

Particle physics has become a breeding ground for high-tech developments in the areas of data handling, computational science and medical applications. Both CERN and Nikhef actively promote and support technology transfer and spin-off activities, for instance via the Dutch CERN Business Incubation Centre (CERN-BIC @ Nikhef). 'Amsterdam Scientific Instruments B.V.' is an example of a Nikhef spinoff that designs and builds detector solutions. Nikhef collaborates with companies to translate knowledge into technology to create commercially viable products or services, and sometimes uses their expertise. For instance, under Nikhef contract 'Schelde Exotech' has contributed parts for the ATLAS experiment. Another important contribution from LHC activities to the 'knowledge economy' are the many well educated and trained PhD candidates who pursue a career in other sectors than research, notably in high-tech industries and ICT.

CERN's education and outreach programmes target learners of all ages, in particular high-school students and high-school teachers. The public can access exhibition spaces at CERN free of charge, take part in a guided tour of one of the CERN facilities, or visit occasional travelling exhibitions. CERN also organises virtual visits, where school groups can interact with a particle physicist and see one of the facilities by video link. The Science Gateway is CERN's new flagship facility for science education and outreach that opened in 2023.

Time period

For at least the next decade, and likely until beyond 2040, the LHC will represent the high-energy frontier of particle physics. Continued participation in the LHC experiments will ensure access to the high-energy frontier that does not exist anywhere else world-wide.

CONCLUSION

CERN is an **important** research infrastructure for Dutch particle physics. The Netherlands has a major involvement in the Large Hadron Collider experiments ALICE, ATLAS and LHCb. Continued strong participation in these experiments, in the design and building of hardware as well as in the science exploitation, is one of the main pillars of Nikhef's strategic agenda.

CTAO – Cherenkov Telescope Array Observatory

CTAO is an **important** research infrastructure for astronomy and (astro)particle physics: the Dutch gamma-ray astronomy programme will completely rely on CTA. Exploring participation at a level that reflects the size and the interests of the Dutch user community is recommended.

SYNOPSIS

The CTA Observatory is the most important **future** gamma-ray ground-based observatory for very high energy gamma-ray astronomy. CTAO will be ten times more sensitive than current facilities and will have unprecedented accuracy. CTAO will consist of two arrays of dishes, a southern-hemisphere array at ESO's Paranal Observatory and a northern array on the island of La Palma, Spain. Construction of CTAO will formally start in 2023 and the Observatory is expected to be operational around 2028.

The current CTAO gGmbH with shareholders (members) from 11 countries plus ESO, is charged with preparing the design and the implementation of the Observatory. The Netherlands is currently an associate member. The future CTAO **European Research Infrastructure Consortium** (ERIC) will be responsible for the construction. The ERIC step 2 application has been submitted in 2022 and the construction budget of > M€ 300 has been secured. The ERIC is expected to be established September 2023, and the assets and control over the construction of CTA will be transferred from the gGmbH to the ERIC in the approximate time frame of September 2023 to September 2024.

The data access and data policy are defined by the ERIC. Participation in CTAO is required to access the vast amount of data. A 10% fraction of the time will be for ESO and its member countries (including the Netherlands). The CTA consortium will be controlling the initial Key Science Projects. Dutch institutes are members of the consortium, but in the future the consortium will be reestablished and will more closely follow membership of the CTAO ERIC. A membership of the ERIC will therefore be necessary to participate in the Key Science Projects and to be able to substantially contribute to science harvesting of CTA data after completion of the facility. Since the Netherlands is contributing to the construction of CTA, the Dutch gamma-ray research community is well positioned to make use of CTA, but this depends on securing a future (associate) membership of the CTAO ERIC.

USERS PERSPECTIVE

Relevance for the user community

CTAO is not operational yet, but at UvA and RUG research activities are performed with H.E.S.S. (a CTA predecessor). Research at the RUG covers indirect dark matter detection (astroparticle physics), whereas the research at the UvA concentrates on High Energy Astrophysics, both on Galactic sources and on active galactic nuclei. In the future, the Netherlands will completely rely on CTAO for its gamma-ray astronomy programme: once CTAO is operational other observatories such as H.E.S.S., MAGIC, and VERITAS will be phased out.

Over 1,500 scientists and engineers from more than 150 institutes in 25 countries participate in the CTAO project. This Consortium has developed and detailed CTA's key science goals and will be responsible for the science analysis and publication of scientific results of the Key Science Projects. Dutch scientists are active and visible in the Consortium: they held/hold positions as (past) chair of the CTA multiwavelength working group, deputy coordinator of the dark matter working group, and were represented in the CTA publication board. They also contribute to promoting the CTA science case. The Dutch-led CTA-related chapter in the white paper 'Athena synergies in the multi-messenger and transient universe' is one such example.

To strengthen the Dutch position, the Netherlands is delivering an in-kind contribution to CTA. Preparatory activities have been supported by the bottom-up defined NWO Astroparticle Physics Programme WARP (2013–2017), and recently the Dutch CTA consortium obtained an NWO Research Infrastructure grant. With these grants, the Dutch consortium is delivering an in-kind contribution to a.o. the cameras of the CTA Small Size Telescopes. The NWO proposal was supported by 27 physicists and astrophysicists and was endorsed by the Astronomy Council (Raad voor de Astronomie).

STRATEGIC PERSPECTIVE

Alignment with national research/strategic agendas

The most relevant strategic agendas for CTAO are the 'Strategic Plan for Astroparticle Physics in the Netherlands, 2013–2024' of the Committee for Astroparticle Physics in the Netherlands (CAN) and the 'Strategic Plan 2021–2030 for Astronomy in the Netherlands' of the Astronomy Council, and their European counterparts the APPEC 'European Astroparticle Physics Strategy 2017–2026' and the 'ASTRONET Science Vision and Infrastructure Roadmap 2022–2035'. In the astroparticle physics plan CTAO is one of the five high priority projects. In the astronomy plan, CTAO is mentioned as one of the key facilities to address the questions 'How do compact objects produce energy and accelerate particles?'. In both the APPEC and ASTRONET Roadmaps, CTAO is one of the flagship projects. In the Nikhef strategic plan CTAO is mentioned as an infrastructure in which Nikhef would like to participate and welcomes initiative from the astronomy community because of the lack of sufficient resources on the Nikhef side. CTAO is mentioned in the '2021 National Roadmap for Large-scale Research Infrastructure' and it has Landmark status in the ESFRI Roadmap. The science case of CTAO is related to the route 'Building blocks of matter and fundamentals of space and time' of the Dutch Science Agenda (NWA).

CTAO is a Big Science facility with a Big Science price tag. Given the cost, a full membership of CTAO (>2%) is probably not realistic. The importance of CTAO is however beyond question: CTA is key to address a number of science cases, the Dutch CTA user community is internationally well recognised, and the community managed to obtain a grant to deliver an in-kind contribution to CTAO construction.

Relation to other (similar) Research Infrastructures:

Other gamma ray observatories like H.E.S.S, MAGIC, and VERITAS will be phased out once CTA comes online, NASA's Fermi satellite (at lower frequencies) is already beyond its expected life time. There are complementary gamma-ray observatories that use the water-Cherenkov technique, in particular China's Large High Altitude Air Shower Observatory (LHAASO) and the future Southern Wide-field Gamma-ray Observatory (SWG0). Both are proprietary facilities and are not accessible to non-members.

Access to facilities at different wavelengths is important in the era of multi-messenger and multi-wavelength astronomy and there are synergies between CTA and other flagship facilities like the neutrino observatory KM3NeT, the space-based X-ray observatory Athena and the radio observatory SKA to be exploited.

Impact & outreach

CTAO has extensive educational and outreach activities. It is producing promotional material in different languages, and releases film series via YouTube & social media. It created a 'CTA for Educators' page in English and Spanish to bring the gamma-ray astronomy to education levels from primary to university level. There is also the annual 'Women of CTA' event where three female CTA members present their work and chat with the public. CTA is a highly advanced research infrastructure, deploying state-of-the-art photon detectors, but also requiring advanced computing methods to process the extensive data that CTA will deliver. It is therefore an important training ground for future technology and computational uses.

Time period

The Observatory is expected to be completed around 2028, and the Dutch community aims to participate in CTA at least until 2033.

CONCLUSION

CTAO is an **important** research infrastructure for astronomy and (astro)particle physics. The required investments to become a full member of CTAO are probably too high to be covered by the Dutch user community. This community is well positioned: it is visible within the CTA consortium and is making a modest in-kind contribution to CTAO via investment grants. The Netherlands should keep its position within the CTA consortium to obtain data access and scientifically harvest from its investments. Limited access will be available through applications for the 10% ESO open time. Exploring participation in CTAO at a level that reflects the size and interests of the Dutch user community is recommended.

DANUBIUS

DANUBIUS is an **important** infrastructure for observing and studying landscapes at a systems scale from river sources to seas.

SYNOPSIS

DANUBIUS is the International Centre for Advanced Studies on River-Sea Systems and aims at facilitating studies on the continuum from river sources to seas. DANUBIUS-RI is a distributed infrastructure that brings together a range of facilities and expertise on river-sea systems related to water quantity, sediment balance, nutrients and pollution, biodiversity, ecosystem services, climate change, and extreme events. DANUBIUS-RI has been on the ESFRI roadmap since 2016 and it is expected that the DANUBIUS-ERIC will be operational by the end of 2023. DANUBIUS-NL forms part of the National Roadmap for Large-scale Research infrastructure. Dutch participation in the DANUBIUS-RI will be incorporated through the Delta-ENIGMA project. DANUBIUS will adopt an open access data policy and develop access procedures to instruments and laboratory facilities.

USERS PERSPECTIVE

Relevance for the user community

The DANUBIUS-RI identified challenges and matching research activities to be executed for achieving healthy river-sea systems related to seven strategic research priorities: water quantity, sediment balance, nutrients and pollution, biodiversity, ecosystem services, climate change, and extreme events. These are all highly relevant to the Dutch context and extensive research activities are conducted on these topics by Dutch researchers.

To support research activities, DANUBIUS-RI will offer remote and in-situ observation platforms, experimental facilities, laboratories, modelling tools and resources (including FAIR data) for knowledge exchange along the river source to sea continuum. Members bring in unique and complementary facilities, which avoids duplication of efforts and investments and offers room for the DANUBIUS-RI member states to excel in a specific research area, related research activities and matching facilities.

The Netherlands contributes to DANUBIUS-RI through the Delta-ENIGMA project. The DANUBIUS-NL consortium consists of a combination of members from the Netherlands Centre for Coastal Research (NCK) and the Netherlands Centre for River Studies (NCR), and includes Utrecht University, TU Delft, Wageningen University & Research, Twente University, Royal NIOZ, Deltares and TNO, with cooperation partners IHE Delft and Rijkswaterstaat.

Delta-ENIGMA's primary focus is on the above-mentioned research priority sediment balance, but also links to water quantity, biodiversity, climate change and extreme events. Delta-ENIGMA will build a delta-wide observation network for achieving a thorough understanding of the biogeomorphology of deltas, i.e. how river flow, tides, waves and wind drive the interactions between water, sediment and biota in shaping the delta-landscape. That understanding is essential to predict how deltas will develop in the future under socio-economic and climate pressures, and to develop, mainstream and scale-up sustainable, nature-based management strategies. Delta-ENIGMA will focus on the Dutch delta and coastal segment of the river-sea continuum. The Dutch infrastructure will consist of field monitoring facilities (e.g. Rhine, Western Scheldt, Holland Coast), laboratory experimental facilities (at TUD, WUR, UU, NIOZ), ICT and data facilities, and an impact node (e.g.

Deltares iD-Lab). DANUBIUS-RI facilitates the international connection to upstream segments of the system and to other systems.

State-of-the-art biogeomorphology research in the Netherlands is boosted by the Delta-ENIGMA infrastructure. The relation with the DANUBIUS-RI should become more clear once the RI is operational. The embedding of Delta-ENIGMA within DANUBIUS-RI will strengthen the lead of Dutch biogeomorphology research at the European and international level, facilitate collaborations, offer unique opportunities for young researchers to build a strong international network, and help distribute knowledge on delta development at international level.

Training and education

DANUBIUS-RI will include an e-Learning Office for training and education. This includes: organisation of Master-programmes at several European universities, courses and summer schools, e-learning programmes for postgraduates, joint development of masters and PhD research projects, training courses for administrators and third parties interested in sustainable management, and virtual meetings for academia, administration and industry.

STRATEGIC PERSPECTIVE

Alignment with national research/strategic agendas

DANUBIUS operates at the interface of geosciences and biology and fits well within the Sector Portraits for Earth and Environmental Sciences and the Sector Portrait for Biology. DANUBIUS-NL is part of the Dutch National Roadmap for Large-scale Research Infrastructure and DANUBIUS-RI is part of the European ESFRI Roadmap. The seven research topics in DANUBIUS-RI relate to the Topsector Water and the missions in the KIA Agriculture, Water and Food, and to the NWA Routes: Blue route, Quality of living environment, and Measuring and detecting: anything, anytime, anywhere.

Relation to other (similar) Research Infrastructures

There are no similar Research Infrastructures in the European context. DANUBIUS-RI interacts with other complementary European Research Infrastructures and offers significant collaboration opportunities (examples include LifeWatch, PRACE, EMSO, ICOS, JERICO).

Impact & outreach

The Netherlands is located on an extremely low-lying and vulnerable delta, so the challenges of sustainable delta management are of existential importance. Scientifically, DANUBIUS-RI will facilitate data and facility access, interdisciplinary research, international collaboration and research uptake. Data and results will inform policy makers such as the Ministry of Infrastructure and Water Management, water boards, provinces, and municipalities. Other non-academic users such as consultancy firms, dredging companies, port authorities, drinking water and wastewater treatment companies, commercial laboratories, instrument producers, navigation sector, and NGOs may use the research infrastructure for various reasons. Their potential interest is diverse, ranging from the use of raw data for their own interpretation models and advice, collaboration in the facilities, to aggregated and published data and models for use in advice or in practical technical projects.

DANUBIUS-RI will include a Technology Transfer Office which aims to engage end-users and stakeholders, maximise the research infrastructure's impact and manage intellectual property rights.

Time period

The infrastructure will be relevant for at least a decade. The Delta-ENIGMA project covers a 10-year time period. It is envisaged that the infrastructure and the Dutch contribution to DANUBIUS-RI will continue after this period via a follow-up project.

CONCLUSION

DANUBIUS-RI is an **important** infrastructure for biogeomorphological research in the Netherlands. DANUBIUS-RI will integrate research on the river-sea continuum, of which the Dutch landscape forms part. The Netherlands is located on a low-lying delta and the challenges of sustainable delta management are of existential importance. The RI's research objectives fit well with Dutch research agendas and Dutch researchers conduct extensive research in this field. DANUBIUS-NL will contribute to the RI with field observation, laboratory experiments and numerical modelling efforts focused on the Dutch delta. DANUBIUS-RI enables better integration of data and facilities between countries, and enhances international collaboration and impact.

ECORD / IODP – European Consortium for Ocean Research Drilling / International Ocean Discovery Program

ECORD / IODP is an **important** infrastructure for world-wide collaborations in marine scientific drilling programmes.

SYNOPSIS

The International Ocean Discovery Program, IODP, is a collaboration between 21 countries world-wide for collaborative ocean-going scientific drilling projects. IODP depends on facilities funded by three platform providers: ECORD, NSF, and JAMSTEC-MarE3. The Netherlands, Canada, and 13 other European countries collaborate in ECORD, the European Consortium for Ocean Drilling, which is based on an MoU. In turn, ECORD's collaboration with IODP is also outlined in an MoU. Through ECORD, the Netherlands has access to IODP expeditions. IODP research focuses on three themes: Climate & Ecosystems, Sustainable Resources, and Natural Hazards. The Dutch Earth and Environmental sciences, Life Sciences and the Subsurface Community (i.e. Technical Engineering) conduct extensive research projects within the IODP context. IODP, and ICDP for drilling onshore, are unique global collaborations to facilitate expensive scientific drilling campaigns that would not be possible at the national level. Participation of scientists in IODP expeditions is proportional to the financial contribution to that expedition. Access to data and samples is subject to a moratorium and managed by various IODP partners.

USERS PERSPECTIVE

Relevance for the user community

IODP is an international marine research collaboration that explores Earth's history and dynamics using ocean-going research platforms to recover data recorded in seafloor sediments and rocks and to monitor subseafloor environments.

The IODP expeditions provide integrated, large-scale missions in key localities that individual scientists or groups cannot fund. This allows scientists to obtain data and samples from those parts of the Earth that are not accessible otherwise. IODP's Science Plan entitled 'Illuminating Earth's Past, Present, and Future', is intended to guide multidisciplinary international collaboration on scientific ocean drilling during the period 2013–2023. It was crafted on behalf of earth, ocean, atmospheric, and life scientists. Success of the programme depends on collaborative funding and scientific expertise of the participants. In addition to the science plan, IODP developed a long-term outlook on important research frontiers in scientific ocean drilling entitled: '2050 Science Framework: Exploring Earth by Scientific Ocean Drilling.' The 2050 Science Framework has a 25-year outlook, inspiring state-of-the-art approaches for scientific ocean drilling far into the mid-21st century. Foundational Earth science research is described in seven Strategic Objectives and five Flagship Initiatives with Enabling Elements that encourage innovation and new discoveries. By participating in ECORD/IODP, the Netherlands can participate in drilling projects, collaborate in international and interdisciplinary consortia and take part in the steering of the overall aims and scope of the programmes that will increase our understanding of the fundamental connections among Earth system components while addressing a range of natural and human-caused

environmental challenges facing society. Science team members have exclusive access to the core material following the drilling until the moratorium passes.

Dutch participation in ECORD/IODP has traditionally a strong research focus on the Earth's climate system, and Life on Earth. The Dutch research community uses IODP for extensive research activities in the field of bio-geosciences, in particular on the strategic objectives: Habitability and Life on Earth, Earth's Climate System, The Oceanic Life Cycle of Tectonic plates, Global Cycles in Energy and Matter and Natural Hazards. Over the last 10 years more than 50 PhD and Postdoc projects depended on materials derived from the programme as well as hundreds of MSc and BSc projects, hosted in particular at the Earth Science Departments at UU, VU and at the NIOZ and some activity at the TUD and Naturalis.

Training and education

Both IODP and ICDP (International Continental Scientific Drilling Program) build on intellectual capacity through the promotion of international collaboration, education, and training. Scientists from member countries can participate in trainings (drilling techniques, proposal writing), can apply to workshops and become PIs on drilling initiatives. ECORD sponsors 4 to 5 workshop annually to develop innovative drilling proposals. About 150 early-career scientists per year attend the 3 summer schools and the training course. In addition, ECORD awards 5 to 10 grants to early-career scientists to conduct research on collected IODP data.

STRATEGIC PERSPECTIVE

Alignment with national research/strategic agendas

IODP research relates to research topics in the Sector Portrait for Earth and Environmental Sciences, in particular on the topics climate change and natural hazards, and also fits well with the Sector Portrait Biology, in particular the focus areas 'Adaptation and Evolution' and 'From ecosystem to biodiversity'. IODP is important for Dutch research on the oceans and forms a basis for large science programmes, such as the Gravitation programme NESSC (Netherlands Earth Science Systems Centre). IODP is a global collaboration that was initiated long before the ESFRI Roadmap, although ESFRI mentions IODP as a vital programme for the European Earth science community.

Relation to other (similar) Research Infrastructures

IODP is a unique and global collaboration between ECORD, USA, Japan, China, South Korea, India, Brazil, Australia and New Zealand. The current MoU underlying the collaboration of ECORD with other partners in IODP has been in place since 2013. The end of the current IODP, now planned on 30 September 2024, will represent a major change in the organisation of international activities related to scientific ocean drilling. The development of post-2024 scientific ocean drilling initiatives will be characterised by a transition from a single international programme operating with independent platform providers to an 'alliance' of independent and collaborative programmes, whose internal organisation and mutual collaboration is currently being defined.

ICDP is the onshore counterpart of the sea-going ECORD/IODP expeditions in which the Netherlands participates. ECORD targets marine life, climate and geohazards. In near-shore drilling projects the two programmes join efforts and co-organise these so-called land-to-sea projects. Together with ICDP, ECORD organises the so-called MagellanPlus workshops, whereby it determines the research direction of future drilling topics and campaigns.

Impact & outreach

Scientific ocean drilling targets a broad array of topics that are of interest and importance to society, contributing vital data that will improve climate models, advance earthquake knowledge, and provide insight into the possibility of life on other worlds. ECORD actively promotes its activities to the scientific community and the general public.

Time period

The Netherlands has been involved in ocean drilling expeditions since 1985 and has an active community in the research area. It is expected that ocean drilling remains relevant for at least the next decade, and potentially much longer. The time period of ECORD's relevancy depends on developments in its collaboration with partners, and development of a new science plan. The collaboration agreement of ECORD in IODP is expiring.

ECORD is currently shaping its post-2024 plans building on: 1) a commitment to the 'philosophy' of the successive scientific ocean drilling programmes to date; 2) the legacy of its achievements, success and innovations since 2004; and 3) the need to adopt an innovative approach tailored to meet the needs of the post-2024 international landscape. ECORD and Japan are developing a new programme to facilitate post-2024 Scientific Ocean Drilling using Mission Specific Platforms (MSP). Online scientific workshops are held to review the status of planning of post-2024 Scientific Ocean Drilling, communicate the intention of the new ECORD-Japan programme and collect new ideas for the development of new drilling proposals based on identified knowledge gaps and novel scientific questions to be addressed in the next 5–10 years.

CONCLUSION

ECORD/IODP is an **important** infrastructure for Earth and Environmental sciences, Life Sciences and the Subsurface community (Technical Engineering) in the Netherlands. International collaboration and collaborative funding are the only means to access the seafloor and its subsurface, which holds valuable information on the Earth system. Access to scientific ocean drilling campaigns remains important for the Dutch research community and it is important to monitor developments in the ECORD science plan and its collaboration with other partners. A continued strong participation in ECORD is vital for the Dutch Earth sciences and related communities.

EGO – European Gravitational Observatory

The Virgo detector hosted by EGO (Pisa/Italy) is an **important** infrastructure for gravitational-wave research in the Netherlands and Europe. Research themes that depend on participation in the Virgo Collaboration are of the highest priority for the Dutch (astro)particle physics and astrophysics communities.

SYNOPSIS

The European Gravitational Observatory (EGO) is the consortium that hosts the Virgo laser-interferometric gravitational-wave (GW) detector located near Pisa, Italy. EGO is responsible for the functioning, operation, maintenance and upgrades of the Virgo antenna and its related infrastructure. EGO also promotes an open co-operation in R&D, and fosters European and global collaboration in the field of GW research. EGO was founded in 2000 by the French Centre National de la Recherche Scientifique (CNRS) and the Italian Istituto Nazionale di Fisica Nucleare (INFN). NWO-I, represented by the National Institute for Subatomic Physics Nikhef, joined the consortium in 2007 as observer and associate member. In 2021 Nikhef became full member of EGO.

The purpose of the Virgo detector is to detect gravitational waves from astrophysical sources. The initial Virgo detector was completed in 2003 and, after years of commissioning, was used in observing campaigns from 2007 until 2011. Observations with the more sensitive, second-generation Advanced Virgo detector started in 2017. Advanced Virgo is part of a global network of GW interferometers together with the Advanced Laser Interferometer Gravitational-Wave Observatory detector (LIGO, USA) and Kamioka Gravitational Wave Detector (KAGRA, Japan) that carry out coordinated observing runs. The scientific responsibility of Virgo is assumed by the Virgo Collaboration in which researchers, engineers and students from more than 120 institutes in 16 countries participate. Dutch institutes in the Collaboration include Nikhef and physics institutes at Nikhef partner universities, the GRAPPA institute at UvA and the Department of astrophysics at RU.

USERS PERSPECTIVE

Relevance for the user community

The Netherlands has a strong track record in GW research, which requires global collaboration and coordination. Members of the Virgo Collaboration participate and share data in the Global LIGO-Virgo-KAGRA (LVK) Collaboration estimated to have close to 4000 members. The network also collaborates on the production of scientific results. The data produced are proprietary for 18 months after their collection, after which they become publicly available. Signal validation, constraining polarisation information and source localisation on the sky by triangulation completely depend on the detection of an event by independent, widely separated GW detectors with similar sensitivity. This makes Virgo an essential element in the global GW detector network. Nikhef has been and remains heavily involved in the technical efforts required to improve the performance of the Virgo detector – from Virgo to Advanced Virgo, and next to Advanced Virgo Plus at which point the detector will reach full capability. These planned upgrades of Virgo and the other detectors in the network will increase the volume of the universe that can be probed and thereby the rate of detections. Both are required to achieve the key science goals of the GW community. Other Dutch

contributions to the Collaboration cover development of data analysis techniques, astrophysical interpretations of GW detections and combining GW information with data from traditional telescopes. The computing power needed for GW research is provided by facilities such as the Dutch National e-Infrastructure that is coordinated by SURF and is partly accommodated at Nikhef. Due to the Dutch contributions to EGO and the Virgo detector upgrades, Dutch GW researchers have free access to LVK data.

In 2015, the LIGO Scientific Collaboration and Virgo Collaboration directly detected gravitational waves for the first time. This revolutionary achievement opened a new window on the universe. The signal, which originated from a coalescing binary black hole, was discovered in data taken by Advanced LIGO. Dutch physicists and astronomers made important contributions to the validation of the detection, the data analysis and the astrophysical interpretation. In 2017, soon after Advanced Virgo became operational and joined observations with Advanced LIGO, the network detected the signal of a merger of a neutron-star binary. The electromagnetic signature of this event was also detected with space- and ground-based telescopes, heralding the start of an era of multi-messenger GW astronomy. Dutch researchers were directly involved in this discovery and the follow-up efforts.

GW research lies at the intersection of physics and astronomy, bringing the respective Dutch research communities closer together. Observations of gravitational waves and multi-messenger approaches enable tests of the theory of general relativity, investigations of spacetime, studies of the astrophysical properties of GW sources and new ways to do cosmology. The Committee for Astroparticle Physics in the Netherlands (CAN) represents the Dutch scientific community interested in astro-particle physics, including GW research.

STRATEGIC PERSPECTIVE

Alignment with national research/strategic agendas

GW research, including its multi-messenger connections, is high on the agendas of the Dutch and international (astro)particle physics and astronomy communities. It is prominently featured in the CAN Strategic Plan for Astroparticle Physics in the Netherlands 2014–2024, the Nikhef Strategy 2017–2022 as well as the Nikhef Strategy 2023–2028, the 2020 Strategy Document of the Particle and Astroparticle Physics working group of the Dutch physics research communities, and the Strategic plan 2021–2030 for Astronomy in the Netherlands. It is among the high-priority research themes of the European communities, as reflected in the Astroparticle Physics European Consortium (APPEC) strategic plan 2017–2026 and ASTRONET Science Vision and Infrastructure Roadmap 2022–2035. The National Roadmap for Large-scale Research Infrastructure 2021 and the European ESFRI Roadmap 2021 focus on the future facilities Einstein Telescope (ET) and LISA, but acknowledge the impact of the second-generation facilities Advanced LIGO and Advanced Virgo.

Relation to other (similar) Research Infrastructures

In Europe, there is no other large GW observatory besides EGO/Virgo. Virgo, LIGO and KAGRA participate in coordinated observing runs and align their detector upgrades. In the future, LIGO-India might be added to the network. Advanced LIGO and Advanced Virgo are the most sensitive detectors, with the sensitivity of Advanced LIGO superseding that of Advanced Virgo. The ESA-led Laser Interferometer Space Antenna (LISA) mission, planned for launch in the late 2030s, will be the first GW observatory in space. LISA will be sensitive to lower frequencies than ground-based GW observatories, thereby expanding the discovery space to different types of astrophysical sources such as compact binaries in our galaxy or binary supermassive black holes.

To overcome intrinsic limitations of the current generation of GW interferometers, the design and R&D process for the next-generation of ground-based detectors has already started – notably at the ETpathfinder R&D laboratory located in Maastricht. Two future detectors, the underground Einstein Telescope in Europe and Cosmic Explorer in the USA, are currently in the planning phase. Their completion is foreseen for the late 2030s. As of 2023, the selection of their sites is ongoing. There is government-level support for a possible future ET site in the Netherlands. Funds have been allocated to prepare a joint bid with Belgium and Germany to host the ET at the border region of the three countries.

Impact & outreach

Measuring gravitational waves is an extremely challenging effort that requires extensive R&D programmes. Nikhef collaborates with Dutch (high-tech) industry to develop technology and instrumentation for Advanced Virgo. The results of these efforts have spun off to other applications e.g. for seismic sensors. The first direct detection of gravitational waves, which resulted in the award of the Nobel Prize in Physics in 2017, generated an enormous interest from the public. EGO has a visitors programme (10,000 visitors/year before COVID), an internship programme (10–15 students/year) and also provides (virtual) visits and courses to high-school students and senior citizens. EGO coordinates the Citizen Science programme REINFORCE funded by EU.

Time period

Until LISA, ET and Cosmic Explorer come online, EGO/Virgo will remain relevant for gravitational wave research.

CONCLUSION

The Virgo detector hosted by EGO is an **important** infrastructure for gravitational-wave research in the Netherlands and Europe. Research themes that depend on participation in the Virgo Collaboration are of the highest priority for the Dutch (astro)particle physics and astrophysics communities. Through Nikhef, the Netherlands is deeply involved in planned upgrades of Virgo that are required to attain full capability. The Dutch community can build on a strong and widely recognised expertise in gravitational-wave research and related engineering activities to prepare for next-generation gravitational wave detectors.

EMFL – European Magnetic Field Laboratory

EMFL is an **important** research infrastructure for a large user community in condensed matter physics, materials science, and technology and instrumentation physics in the Netherlands. Dutch participation in EMFL through HFML-FELIX is crucial to ensure that Dutch scientists can make a major contribution to the field, and to enable European and global research.

SYNOPSIS

EMFL is a research infrastructure that develops and operates three world-class high magnetic field facilities: the High Magnetic Field Laboratory (HLD; Dresden, Germany), the Laboratoire National des Champs Magnétiques Intenses (LNCMI; with sites in Grenoble and Toulouse, France) and the High Field Magnetic Laboratory (HFML-FELIX; Nijmegen, the Netherlands). It is the mission of EMFL to act as a European user facility for the scientists of participating countries and for other scientists, and to act as the European centre of excellence for different magnetic-field based material characterisation techniques in very high fields. High magnetic fields are among the most powerful tools available to scientists for the study, modification and control of states of matter. Access to the state-of-the-art EMFL facilities, which provide the highest possible fields (both continuous and pulsed), is of crucial importance for a broad range of research in condensed matter physics, technology and instrumentation physics, and materials research. HFML-FELIX is the only facility worldwide where continuous high magnetic fields are linked with an infrared/THz free electron laser facility. This combination offers unique possibilities to investigate a wide range of physical and chemical properties and processes.

EMFL is a distributed facility. It was founded in 2015 with the aim to unite, coordinate and reinforce the existing European high magnetic field laboratories in a single body as a world-leading infrastructure. The UK community, represented by the University of Nottingham, joined EMFL at the end of 2015 followed by University of Warsaw (Poland) and CEA-IRFU (France) in 2019.

USERS PERSPECTIVE

Relevance for the user community

EMFL is responsible for the management of users' access to the EMFL facilities via a user proposal selection procedure. The EMFL facilities are available for excellent research by in-house and external users. External scientists come to visit the facility on-site to perform their experiments. In its coordinating role, EMFL represents the European high magnetic field facilities at the national/European/global level, explores new technical developments, and stimulates synergy and cooperation in science and technology policies of each of its members. EMFL also facilitates networking and fund raising for scientific research and infrastructure development at EU and international level. A wide range of techniques are available at EMFL facilities at a state-of-the-art standard with highly expert local technical and scientific support. The main areas of EMFL research are quantum information technology, quantum matter, metals and superconductors, magnetic materials, semiconductors, photovoltaic materials, 2D materials and soft condensed matter. EMFL activities also cover the areas of magnet technology, advanced light sources, medical technology, microscopy and nano-electronics. Dutch scientists play a world-leading role in these areas, and make important contributions to instrument development for the Dutch node HFML-FELIX. In the recent past,

HFML-FELIX has developed a research programme on the magnetic manipulation of nanomaterials, as well as molecular and biological matter, making it more relevant for the large national physical-chemistry community. Dutch researchers who require high magnetic fields for their experiments are completely dependent on the EMFL facilities. In the last 5 years, more than 20 research groups from Dutch universities have made use of the EMFL facilities, mostly but not solely at HFML-FELIX. Dutch participation in the EMFL through HFML-FELIX is crucial to ensure that Dutch scientists can make a major contribution to the field through convenient and supported access, and to enable the broader European and global research output. HFML-FELIX also plays a key role in the organisation and strategy of EMFL, as well as in its User Programme. Started in 2021, the ongoing EU-funded SuperEMFL project aims to develop a design report concerning the feasibility as well as the maturity of a major upgrade of the EMFL facilities based on the development of the high-temperature superconductor technology.

Education & Training

EMFL sponsors and organises conferences, (hands-on) workshops and schools. In addition, EMFL issues calls for exchange visits to stimulate research in high magnetic fields and to improve further collaborations between the EMFL facilities, the regional partner institutions and the high-field user community.

STRATEGIC PERSPECTIVE

Alignment with national research/strategic agendas

EMFL constitutes a forum where strategic scientific and technical plans of the members are discussed and where possible common strategies are developed. An important strategic target of EMFL is to combine high field magnets with the instruments of other European large-scale research infrastructures, resulting in powerful experimental platforms to help address the many challenges confronting society. EMFL was awarded Landmark status in the ESFRI Roadmap in 2016. The Dutch node HFML-FELIX leads a National Roadmap for Large-scale Research Infrastructure project to develop new instrumentation that will open new research directions that are key to the Dutch research community. EMFL also contributes to realising the Dutch materials agenda, and the Advanced Materials 2030 Initiative 'A strong European Materials ecosystem driving the green and digital transition' of the EC.

EMFL receives (relative modest) membership fees and in-kind contributions (<1 fte in total) from the founding members. The (much larger) investments in the individual facilities and operational costs are paid at the national level. Therefore, long term stable funding for HFML-FELIX is key for the Dutch user community.

Relation to other (similar) Research Infrastructures

Synergy between the participating facilities is engrained in the mission of EMFL. Collaborations exist with other international facilities. The EMFL facilities, the National High Magnetic Field Laboratory (USA), the Wuhan National High Magnetic Field Center and the High Magnetic Field Laboratory of the Chinese Academy of Sciences (China), the High Field Laboratory for Superconducting Materials and the International MegaGauss Science Laboratory (Japan) together form the Global High Magnetic Field Forum. The goal of this consortium is to promote, improve and expand top-level science through the use of high magnetic fields by enhancing communication, coordination and collaboration. EMFL, with important Dutch participation through the lead role of HFML-FELIX, has supported and advised developing high field laboratories in China and South Korea.

Impact

EMFL and the EMFL facilities work with industrial partners to share knowledge and develop new techniques. There have been many instances where Dutch companies have participated in addressing the technological challenges set by the instrumentation of the EMFL facilities and, thereby, have benefited significantly in acquiring new knowledge and securing orders at the EMFL facilities and elsewhere. As the development of new and advanced materials is a driver of innovation, EMFL also contributes to tackling societal challenges in areas such as green energy, data storage, the design of materials with biomedical applications and health care. There are many examples of visitors to the EMFL facility at HFML-FELIX who later take up positions as PhD students, postdocs or senior researchers in the Netherlands. This is an important channel of knowledge exchange and dynamism of the national research community.

Time period

Given the continuous innovation, and taking into account that condensed matter physics and materials science are major research fields in the Netherlands, EMFL will remain relevant for at least the coming 20 years. The goal of the EU-funded ISABEL project, started in 2020, is to strengthen the long-term sustainability of EMFL.

CONCLUSION

EMFL is an **important** research infrastructure for a large user community in condensed matter physics, materials science, and technology and instrumentation physics in the Netherlands. Dutch participation in EMFL through the national infrastructure HFML-FELIX is crucial, not only to ensure that Dutch scientists can make a major contribution to the field, but also to enable the broader European and global research output.

EPOS – European Plate Observing System

EPOS is an important infrastructure for solid Earth science to understand planet Earth dynamics for a safe and sustainable society.

SYNOPSIS

EPOS is the European Plate Observatory System and facilitates access to European data, products and facilities for solid Earth science to study the deep subsurface, geohazard and georesources based on open source and open access policies. EPOS is an ERIC with 17 member countries. Key services become available in 2023 via the central data portal. The Dutch consortium, EPOS-NL, consists of Utrecht University, TU Delft, VU Amsterdam, University of Groningen, KNMI and TNO. EPOS-NL research focuses on geohazards, geo-energy, subsurface storage, seismology, and sedimentary basin structure, dynamics and evolution. These are international research themes that benefit from harmonised, central and transnational access. The themes fit well in the Dutch research agendas given their relevance for energy and the energy transition, and safe use of the subsurface. EPOS-NL contributes to the international infrastructure by providing transnational access to research facilities and by linking several distributed data portals to the central portal.

USERS PERSPECTIVE

Relevance for the user community

EPOS enters the operational phase in 2023, focussing on making data, products and facilities available for research within Earth science. This is most relevant for research in seismology, geophysics, rock physics, geochemistry, hydrology, microscopy, tomography, petrology, geology, satellite remote sensing, volcanology and analogue modelling of geological processes, but could also link to the fields of physical geography, environmental sciences, material sciences, engineering, defence, medical sciences, cultural heritage and computer sciences.

Dutch solid Earth research is generally oriented on international research themes. EPOS will integrate various Earth scientific datasets and facilities that were previously largely decentralised over various institutes and countries into a single data portal. Within the portal, several discipline-specific clusters exist called Thematic Core Services (TCS). The Netherlands contributes the KNMI's ORFEUS data centre to the Seismology TCS, various laboratories at TU Delft and Utrecht University to the Multi-Scale Laboratories TCS, the DAP geothermal well at TU Delft to the Geo-Energy Test Beds For Low Carbon Energy TCS, and geological data of the Dutch subsurface at TNO to the Geological Information and Modeling TCS.

Currently, EPOS facilitates the interaction and harmonisation between the national and European EPOS community, but research activities conducted using EPOS data and services are still limited; Dutch research activities are therefore partly dependent on access to EPOS. Use of the infrastructure's data and facilities is expected to increase once EPOS central data portal becomes fully operational. EPOS-NL mainly focuses on the following research areas:

1. **Geohazards** (UU, TUD, RUG, TU/e, UT, TNO, KNMI, Deltares and public and private partners)
Hazards such as earthquakes, landslides and volcanic activity. The main focus in the Netherlands is on human-induced earthquakes by gas extraction (e.g. Groningen), or potentially by geothermal energy production, storage of CO₂, heat or hydrogen. In addition, Dutch researchers study natural earthquakes, volcanic activity, and landslides.

2. **Geo-energy** (TNO, TUD, UU, Deltares and public and private partners)
Exploration and exploitation of new, low carbon geo-energy resources, including geothermal energy. The Delft Geothermal Project (DAP) geothermal well, within the TU Delft Urban Energy Lab is now being prepared to be one of the main research centres on geothermal energy in Europe. The TNO Rijswijk Centre for Sustainable Geo-energy is a unique laboratory for well technology testing and large-scale rock physics and fluid flow experiments which will be linked to EPOS.
3. **Subsurface storage** (TNO, TUD, UU, TU/e, VU, UT, Deltares and public and private partners)
Subsurface storage of e.g. CO₂, hydrogen, heat, and radioactive waste. Subsurface storage projects are being executed in the Netherlands, e.g. in the Porthos CO₂ storage site (operational >2024), and in other locations in Europe and beyond. EPOS provides a key platform to share data and experience between sites and has a dedicated discipline group (“Geo-energy test beds”) for data dissemination of field-scale applications.
4. **Regional/global seismology** (UU, TUD, UT and KNMI)
Tomographic imaging of crust and mantle requires seismic data and theoretical developments in order to study a.o. the crust in the Netherlands, regional upper mantle models in Europe and Africa, as well as global models of the lower mantle. European countries have facilitated access to a seismic data portal, which was initially developed by ORFEUS and is now an integral part of EPOS.
5. **Sedimentary basin structure, dynamics and evolution** (UU, TUD, RUG, VU and TNO)
Understanding the structure, kinematic and dynamic evolution of sedimentary basins is key for understanding the subsurface and the four research areas mentioned above. Research topics include the dynamics of sedimentary systems from human to tectonic time-scales, understanding of basin deformation, and quantification of land use and exploitation of the subsurface to vertical motions of the surface.

Training and education

Current EPOS training and outreach activities focus on outreach and dissemination of EPOS contents and usage to stakeholders and users. EPOS organises workshops about the capacity and capabilities of EPOS services.

STRATEGIC PERSPECTIVE

Alignment with national research/strategic agendas

EPOS is on the National Roadmap (eNLarge) and a landmark on the ESFRI roadmap. Geohazards, geo-energy and subsurface storage research align well with the NWO DeepNL programme and the Knowledge Programme on Effects of Mining (KEM) initiated by the Ministry of Economic Affairs and Climate Policy. Safe and sustainable use of the subsurface also relates to energy and the energy transition, and as such relates to national and international plans to reduce greenhouse gas emissions (e.g. the Dutch National Climate Agreement). Renewable energy is a current theme in NWA (route Energy Transition) and KIC (KIA Climate and Energy), and is mentioned as one of the main research topics in the Sector Portrait for Earth and Environmental Sciences. Subsurface storage also relates to large-scale research programmes like CATO, GroenvermogenNL, IFAHydrogen en DOCS.

The Netherlands has paid a reduced EPOS membership fee until 2023, but now that EPOS-eNLarge is funded through a National Roadmap grant, the Netherlands will contribute the full fee for the period of 2024–2029.

Relation to other (similar) Research Infrastructures

The research infrastructure most similar to EPOS is AuScope in Australia. AuScope is a not-for-profit company established in 2007 to develop a national research infrastructure for geosciences in Australia. In 2022 EPOS and Auscope have signed a Memorandum of Understanding to fully cooperate. Other initiatives connected to EPOS are ECCSEL, a pan-European research infrastructure dedicated to carbon capture and storage (CCS), ENVRI-FAIR, Research Data Alliance (RDA), EuroGeographics, Copernicus, EUREF, EUMETNET, EuroGeoSurveys, ESA, JERICO, EOSC.

Impact & outreach

EPOS research in the Netherlands is societally relevant as it centres around safe use of the subsurface for energy and waste storage and energy production. The build environment also benefits from EPOS data accessibility by reducing uncertainties of subsurface heterogeneity and response dynamics in engineering projects.

Time period

EPOS is entering its operational phase. EPOS services are expected to be relevant for decades.

CONCLUSION

EPOS is an **important** infrastructure for research on the deep subsurface. Dutch research in the EPOS domain focuses on geohazards, geo-energy, subsurface storage, seismology, and sedimentary basin structure, dynamics and evolution. These topics relate to societal challenges concerning safe use of the subsurface for georesources and energy and waste storage and fit well with national and international research agendas. Once operational, EPOS will provide harmonised central access to European solid Earth science data, products and facilities.

ESA – European Space Agency

ESA is an **important** infrastructure for astronomy, Earth observation and planetary science in the Netherlands.

SYNOPSIS

The European Space Agency (ESA) is Europe's gateway to space. Its mission is to shape the development of Europe's space capability and ensure that investment in space continues to deliver benefits to the citizens of Europe and the world. ESA is an international organisation with 22 member states. ESA's mission is much broader than science. In the Netherlands, the responsible ministry is the Ministry of Economic Affairs and Climate Policy. The Dutch contribution to the ESA science programme is funded through the Ministry of Education, Culture and Science.

The ESA science programme that covers astronomy, the solar system and fundamental science is a mandatory programme for all ESA member states. The long-term planning structure to select scientific satellite missions is a bottom-up process that allows the scientific community in the member states to control the direction of the programme through advisory bodies. In addition to the science programme, the optional Earth observation programmes are very relevant for the Dutch scientific community.

USERS PERSPECTIVE

ESA designs different space programmes / satellite missions to find out more about Earth, its immediate space environment, our Solar System and the Universe. Scientists participate in the design and instrumentation development of these satellites, and once the mission is operational, they make use of the data (and other products) for their science.

Relevance for the user community

There are multiple satellite missions, each with its own specific user community and science case. The overall ESA user community is very broad, and includes astronomy and astrophysics, Earth observation and planetary science. In 2020, the Ministry of Economic Affairs commissioned a report on the added value of space-related activities for the Netherlands. This study confirmed the added value of space missions for scientific research and concluded that hundreds of scientists in the Netherlands make extensive use of space infrastructure. Examples with strong interest from the Dutch astronomy community include the operational Gaia and JWST missions, the Euclid mission launched in 2023, and the flagship future ESA large missions Athena and LISA. The Dutch planetary science community participates in e.g. the recently launched JUICE mission (Dutch PI experiment), PLATO, ARIEL, EnVision and more future missions are currently being discussed. The Earth Observation community recently published its first 'Earth Observation Research in the Netherlands, Strategic Plan 2020–2025' focusing on five broad areas: atmosphere, land, ocean, cryosphere, and solid Earth. The Netherlands has a long history and strong track record in atmospheric research from space, the most recent example being the TROPOMI instrument on board the Copernicus Sentinel-5 mission, with new missions under development including the SPeXone instrument onboard the NASA PACE mission and the upcoming ESA TANGO mission.

Although different universities and research institutes are participating in a diversity of space related activities, it is important to highlight the role of SRON, the Netherlands Institute for Space Research. The institute develops pioneering technology and advanced space instruments, and uses

them to pursue fundamental astrophysical research, Earth science and exoplanetary research. As national expertise institute SRON gives counsel to the Dutch government and coordinates – from a science standpoint – national contributions to international space missions.

STRATEGIC PERSPECTIVE

Alignment with national research/strategic agendas

At the national level the Netherlands Space Office (NSO), the space agency of the government of the Netherlands, prepares an advice on the national space policy every three years. The most recent one covering 2023–2025 mentions that access to space is essential for scientific research in areas like climate research, atmospheric research, and astronomy. Specifically for the astronomy community, both the ‘Strategic Plan 2021–2030 for Astronomy in the Netherlands’ and the European ‘ASTRONET Science Vision and Infrastructure Roadmap 2022–2035’ confirm the need for satellite missions. ESA has its own bottom-up process for defining a long-term planning strategy, resulting in the ‘Cosmic Vision’ that is currently being implemented, and the recently defined ‘Voyage 2050’ programme for the coming decades. Scientists from the Netherlands actively participated in this process. The Earth Observation community has launched its own strategy supported by >100 scientists. The importance of Earth observation is also recognized in the recent Sector Portrait for Earth and Environmental Sciences.

In addition, space research contributes to the Dutch innovation policy, and in particular the key technologies agenda, and to different routes of the Dutch Science Agenda (NWA).

In 2023, the Dutch government will introduce for the first time a national long-term agenda for space, with prominent positions for both Earth observation and climate research, and breakthrough science.

Impact & outreach

In terms of impact, the geographical return, or ‘GeoReturn’ policy is a fundamental pillar of ESA’s structure. ESA member states pay a membership fee to ESA and get equivalently valued high-tech space contracts back to their industry. The Netherlands hosts the European Space Research and Technology Centre (ESTEC), the technological heart of ESA, resulting in economic activities in the Noordwijk area.

In terms of outreach ESA has a strong programme, as space appeals to everyone’s imagination. In the Netherlands, the former ESA astronaut André Kuipers is an ambassador of science and space research. At the ESTEC location there is the Space Expo – the space museum of the Netherlands.

Relation to other (similar) Research Infrastructures

ESA works closely with space organisations around the world. Some of the satellite missions are joint missions or have multiple contributing agencies.

Time period

Space missions require long term planning and have long lead times, as reflected in the recent ESA long-term science plan ‘Voyage 2050’.

CONCLUSION

ESA is an **important** infrastructure for astronomy, Earth observation, and planetary science in the Netherlands. ESA’s mission is broader than science, and the Dutch participation in ESA is organised at the level of the national government.

ESO – European Southern Observatory

ESO is an **important** infrastructure for astronomy in the Netherlands. Data obtained through observations with ESO telescopes are critical for all research themes in Dutch astronomy.

SYNOPSIS

The European Southern Observatory (ESO) designs, builds and operates world-class observatories on the ground affording scientists worldwide facilities to study the Universe in optical and near-infrared wavelengths. Together with North-American and South-East Asian partners, ESO also operates the Atacama Large Millimeter/submillimeter Array (ALMA). ESO headquarters are located in Garching, Germany, while the ESO telescopes are in Chile where ESO operates three observatories in the Atacama Desert region. ESO will also participate in CTA and host the CTA Observatory in the south. Part of the open CTA time will be available to ESO members.

ESO is an intergovernmental organisation created in 1962 and is currently supported by 16 member states, host state Chile and strategic partner Australia. The Dutch membership fee is funded by the Ministry of Education, Culture and Science. Dutch astronomers and engineers have a long history of using ESO telescopes to make scientific discoveries and contributing to the development of ESO telescopes and instrumentation. Construction of the ESO Extremely Large Telescope (ELT) is ongoing with first light expected in 2027. With its 39-metre primary mirror, the ESO ELT will be the largest of the upcoming ELTs. Combined with a cutting-edge suite of instruments, including Dutch-led METIS, the ESO ELT will be transformational. Membership of ESO will remain essential for Dutch astronomy in decades to come.

USERS PERSPECTIVE

Observing time on ESO telescopes is allocated based on scientific excellence via calls for proposals that are open to scientists worldwide (additional criteria apply for proposals from non-member states). Typically, the proprietary period for data obtained through ESO observations is 12 months, after which the data become publicly available through the ESO Science Archive Facility.

Relevance for the user community

Astronomy research in the Netherlands is organised around three themes as described in the Strategic Plan 2021–2030 for Astronomy in the Netherlands: Evolution of our Universe and origin of the Milky Way, Origin of stars and planets and our place in the Universe, and Space and matter under extreme conditions – the Universe as a laboratory. In each of these themes, extensive research activities are carried out at all Dutch astronomy institutes that are completely dependent on ESO data. The most versatile astronomical observations are performed in the optical and infrared wavelength range, and this is in fact the range covered by the ESO facilities. ESO's Very Large Telescope (VLT) and the future ESO ELT are/will be the flagship optical/infrared ground-based facilities of European astronomy. ALMA is the world's largest ground-based submillimeter astronomy facility. Through the ESO membership, ALMA provides astronomers in the Netherlands (and other member states) access to a (sub)millimeter observatory that is unrivalled in terms of sensitivity, spatial resolution and wavelength coverage. ESO has delegated ALMA user support to ALMA Regional Center (ARC) nodes. Allegro, the ARC node in the Netherlands, offers essential

support to Dutch ALMA users during the preparation and analysis of observations thereby facilitating and enhancing their access to ALMA.

The development of innovative instrumentation and telescope systems for ESO facilities is done through collaborations between ESO and (institutes in) the ESO member states. In the Netherlands, the NOVA Instrumentation Groups in Dwingeloo and Groningen have a strong track record of developing hardware components for ESO and ALMA facilities, which continues with Dutch involvement in four future ELT instruments: METIS (Dutch PI), MICADO, MOSAIC and EPICS. These R&D activities bring a benefit for Dutch users: guaranteed-time (early) data access and in-depth understanding of the instruments give them a lead in the exploitation of the data.

Education & training

ESO organises several science workshops each year that bring the community together. The annual ESO Summer Research Programme provides university students who are not yet enrolled in a PhD programme the opportunity to obtain research experience. The ESO Fellowship programme for early-career astronomy PhDs is aimed at training and preparing the next generation of astronomers. ESO also started a programme offering engineering students the opportunity to participate in the ESO R&D projects.

STRATEGIC PERSPECTIVE

Alignment with national research/strategic agendas

The Dutch astronomy community has identified ESO's VLT and future ELT, as well as ALMA, among the key facilities to answer the big questions in astronomy for the next decade such as 'What happened during the dawn of the Universe?', 'How do planetary systems form around new-born stars?', 'What is the origin of the elements?'. Participation in the instrumentation development for the ESO ELT is one of the top priorities for Dutch astronomy as stated in the Strategic Plan 2021–2030 for Astronomy in the Netherlands. Funding for instrumentation for the ESO ELT is also listed as one of the priorities of the Group 'Astronomy and Particle Physics' in the National Roadmap for Large-scale Research Infrastructures 2021. The ESO ELT received Landmark status in the ESFRI Roadmap in 2016. ELT instruments are among the key priorities in the European 'ASTRONET Science Vision and Infrastructure Roadmap 2022–2035'.

Relation to other (similar) Research Infrastructures

ESO telescopes are the only ground-based optical/infrared facilities in the southern hemisphere to which Dutch astronomers have access, apart from various other facilities (e.g. Gemini Observatory, the Subaru Telescope) in which the Netherlands does not participate as a partner and that offer only a very small amount of international time. Astronomy is an observationally driven science, and new discoveries often involve a multi-wavelength/multi-messenger approach. ESO facilities (including ALMA) will continue to complement observations obtained with current and future observing facilities in the radio (JIVE/EVN, ILT, SKA), (near)infrared (JWST, Euclid), X-ray (XMM, Chandra, Athena), and gravitational waves (LISA) to name but a few. ESO telescopes provide the southern coverage needed to follow-up on targets identified in surveys by e.g. the Gaia and Euclid satellites, unlocking a scientifically critically important part of the sky.

Impact & outreach

The NOVA Instrumentation Group specialises in the development of astronomical scientific instrumentation, often with the involvement of industry partners (e.g. VDL-ETG). The existence of such a group with very specific expertise depends on a continuous demand for R&D activities to develop and build cutting-edge hardware. This is provided by ESO's ambitious programme that uses some of the most advanced technologies and techniques to enable scientific discovery. Astronomy

enjoys broad interest by the general public as an exponent of humanity's innate curiosity about the origin of the Universe, and our place within it. ESO operates a wide range of educational and outreach activities aimed at the general public, schoolteachers and students at all levels. In each member country, communication experts target their national audience. For the Netherlands this is the NOVA Information Center. Images, videos and animations produced by ESO are freely available to science journalists and broadcasters. In 2019, 60.000 people engaged with the ESO Supernova Planetarium & Visitor Centre in Garching.

Time period

The ESO ELT is currently under construction with anticipated first light in 2027. As regular updates of the ELT suite of instruments are already foreseen, ESO will remain highly relevant for at least the next 20–30 years. The same is true for ALMA, which is still actively expanding its capabilities (ALMA2030: increased sensitivity through larger bandwidths; receiver and correlator upgrades), and Allegro.

CONCLUSION

ESO is an **important** infrastructure for astronomy in the Netherlands. Data obtained through observations with ESO telescopes are critical for all research themes in Dutch astronomy, and the development of instrumentation for ESO's upcoming Extremely Large Telescope (ELT) is a top priority of the Dutch astronomy community. The capabilities of the ESO ELT and the (upgraded) ALMA are unparalleled by other ground-based optical/infrared and (sub)millimeter facilities, making membership of ESO highly relevant for decades to come. In the future, part of the open time of the CTA Observatory will become available through ESO membership, which is of relevance to the Dutch astroparticle physics community.

ESRF – European Synchrotron Radiation Facility

The ESRF is an **important** research infrastructure for a wide user community in the Netherlands including researchers in soft matter physics, chemistry, materials science, geosciences, astrophysics, cultural heritage and life sciences. The ESRF offers unique synchrotron facilities for which there are no alternatives in the Netherlands.

SYNOPSIS

ESRF is the world's brightest X-ray source and a centre of excellence for fundamental and innovation-driven research in condensed and living matter science. The ESRF generates X-ray beams 10 trillion times brighter than medical X-rays. The ESRF synchrotron ring is run at an energy of 6.0 GeV, making the hard X-ray range its area of strength. The ESRF-EBS (Extremely Brilliant Source) is a recent upgrade of the ESRF that resulted in the world's first fourth-generation high-energy synchrotron light source opening new vistas for X-ray science. ESRF provides unrivalled opportunities for scientists in the fields of chemistry, material physics, archaeology and cultural heritage, structural biology and medical applications, environmental sciences, information science and nanotechnologies.

ESRF is located in Grenoble, France. The Netherlands was one of its founding members in 1988. Currently, a total of 21 partner countries cooperate in ESRF, including 13 member states and 8 scientific associates. The Netherlands participates in ESRF together with Belgium through the Benesync consortium. The ESRF provides synchrotron radiation to a wide user community in the Netherlands.

USERS PERSPECTIVE

Relevance for the user community

The ESRF facility allows to obtain detailed information on the structure and behaviour of matter at the molecular and atomic level. As there is no synchrotron facility available within the Netherlands, access to the ESRF is of utmost importance to the Dutch research community at large. With the discontinuation after 2021 of Dutch funding for the Dutch-Belgian Beamline project (DUBBLE) located at the ESRF, the amount of available beamtime for Dutch scientists has roughly halved. It is very important that access to the ESRF as a whole remains possible.

The scope of the research activities of Dutch users of ESRF is very wide. General areas of Dutch research for which the ESRF is important include chemistry, materials science, Earth and environmental sciences, planetary sciences, astrophysics, cultural heritage and life sciences. The Dutch materials community is particularly strong in soft matter science and thin film research. Overall, ESRF provides access to high-end instrumentation, hereby supporting high-quality research and expediting knowledge exchange within many fields. Access to synchrotron radiation is important to study the structure of soft (hierarchical) materials in the 0.1–10000 nm range and therefore important for many 'soft matter' researchers and industrial users. The ESRF offers a variety of techniques ranging from high resolution and time-resolved X-ray diffraction to X-ray scattering at medium and low angles to X-ray spectroscopy and microscopy. These allow powerful characterization of soft matter and nanocomposites, which are complementary to lab-based spectroscopic and microscopic techniques. For research concerned with the physics of technology

and instrumentation, ESRF is important as it enables studies of the properties of thin layers/multilayers, which is relevant for the understanding of the fundamental physics and development of sensors and actuators. For Earth and environmental sciences, the ESRF enables studies characterizing minerals and other materials in Earth environments (atmospheric dust, rocks, soils, sediments, lakes, rivers, seawater) and in biological materials. It is also critical for experiments on mineral dissolution and precipitation and for studies on planetary interiors. For Dutch research in the life sciences, the ESRF is very relevant for structural biology approaches to study the structure and dynamics of molecules.

New access modes based on large European consortia have just started at the ESRF. These consortia are envisaged to push many more scientific breakthroughs rather than a single group activity in fields such as biophysics, cultural heritage and energy storage. Some Dutch groups are already involved in some of these large X-ray based consortia. The Netherlands also contributes in terms of collaborations for the development of instruments for use by the ESRF scientific community at large.

Recently, a user organization has been started (DUALIS = Dutch User Organisation for Accelerator-based Light Sources) that aims to strengthen the Dutch user community and its competitiveness for experiment time at international accelerator-based light sources including synchrotrons and free electron lasers.

Education & Training

ESRF hosts and supports many young scientists and engineers, post-doctoral fellows, PhD students, and trainees who participate in training programmes, topical workshops and conferences, and who interact with experts in world-class methods in experimental science. Most of them return to the European science scene, in particular to national facilities. The excellence of ESRF staff and managers is continuously enhanced by professional training and exchange programmes with similar institutions.

STRATEGIC PERSPECTIVE

Alignment with national research/strategic agendas

No facility like ESRF exists in the Netherlands. Continued investment in ESRF allows Dutch researchers to get more and sufficient access to advanced equipment to study materials and living matter and to keep up with new technological developments. National membership of ESRF also aligns well with the goals in the Dutch National Agenda Materials and the new initiative for a research agenda to attain strategic autonomy in materials research. The methods and techniques available at ESRF are essential for Dutch research (e.g. in soft matter studies). Lab X-ray experiments are complementary but no alternative for all experiments. Participation in ESRF is relevant to realise a diversity of research agendas, the Dutch materials agenda being one example. ESRF participates in the strategic consortium League of European Accelerator based-Photon Sources (LEAPS), whose primary goal is to actively and constructively promote and ensure the quality and impact of fundamental, applied and industrial research carried out at their facilities. As stated in the LEAPS strategy 2030, the new ESRF-EBS is a revolutionary facility, setting the agenda world-wide. The ESRF-EBS has landmark status in the ESFRI Roadmap. The Netherlands currently provides the vice-chair to the Council (the highest governing body of the ESRF), and from 2023 also the chair.

Relation to other (similar) Research Infrastructures

ESRF-EBS is the best performing synchrotron in the world at energies above 5 keV. Low and medium energy rings as MAX-IV complement ESRF-EBS in the infrared, VUV and soft-X-ray range. For many research activities in the Netherlands there are no alternatives for the ESRF. Synergies

exist with the EMBL high magnetic field lab (soft matter), Instruct, DESY, Swiss Light Source, Diamond Light Source (life sciences).

Impact & outreach

ESRF promotes the use of ESRF technologies to benefit society through licensing to companies who turn them into successful commercial products. ESRF develops partnerships with local and international industrial networks. The ESRF supports many initiatives and public events aimed at making sophisticated science understandable to a range of audiences, from public, high-school students, to young children. Synchrotron@School is geared for high-school students and consists of a one-day programme of experimental workshops and ESRF site visits. The annual joint ESRF/ILL International Summer Student Programme on X-Ray and Neutron Science is a 4-week immersion programme designed around an experimental project. It includes introductory lectures, specialised courses and hands-on research.

Time period

The ESRF has just completed an upgrade to the EBS and therefore remains the state-of-the-art facility for the use of high-intensity X-ray beams for a wide range of applications. Because of the recent upgrade, the ESRF will remain highly relevant for (at least) the coming ten years.

CONCLUSION

The ESRF is an **important** research infrastructure for a wide user community in the Netherlands including researchers in soft matter physics, chemistry, materials science, geosciences, astrophysics, cultural heritage and life sciences. The ESRF offers unique synchrotron facilities for which there are no alternatives in the Netherlands. Due to the recent upgrade, the ESRF-EBS remain highly relevant for (at least) a decade.

ESS – European Spallation Source

The ESS is a multi-disciplinary research infrastructure under construction based on the world's most powerful neutron source. The ESS is set to revolutionise science in many fields, in particular materials research and its applications. The ESS is a potentially **important** infrastructure for materials science in the Netherlands. As efforts to gather sufficient support to realise full membership were unsuccessful, the observer status expired in 2020. In 2022 a renewed observer status was offered by the ESS and the acceptance is still pending.

SYNOPSIS

The European Spallation Source ERIC (ESS) aims to build and operate the world's most powerful neutron source, enabling scientific breakthroughs in research related to materials, energy, health and the environment, and addressing some of the most important societal challenges of our time. The ESS is a Big Science facility that will include unprecedented state-of-the-art instrumentation, a suite of laboratories, and a supercomputing data management and software development centre.

The ESS facility is currently under construction in Lund, Sweden, while the ESS Data Management and Software Centre will be based in Copenhagen, Denmark. Start of the user programme is foreseen for 2027. At present, thirteen European countries are member of ESS. The Netherlands had observer status since the founding of the ESS ERIC in 2015, however this status expired in 2020. Renewal of the observer status was paused due to the lack of funding in the Netherlands to become full member. Nevertheless, interest in ESS from the relevant national communities remains high as the ESS facilities are regarded as of high value to the user community and a good fit to the research strategies. In November 2022 the ESS offered the Netherlands a renewed observer status and acceptance of this offer is still pending.

USERS PERSPECTIVE

Relevance for the user community

The unprecedentedly bright neutron beams of the ESS will revolutionise science in materials research, physics, health, environment, climate, energy, transport sciences and cultural heritage by looking faster and with higher sensitivity, orders of magnitude better than at any existing facility. The ESS will be surrounded by extensive ESS Science Support Systems that include sample environment equipment, scientific laboratories and a future user office. One such support facility is the Deuteration and Macromolecular Crystallisation (DEMAX) platform, which supports life science and soft matter research users. DEMAX entered initial operations in 2019 with the first of a series of pilot calls meant to establish procedures, complete fit-out of the lab, develop the proposal system, and practice serving users to be ready for first science at ESS.

The academic quality of materials science in the Netherlands is among the highest in the world. The Dutch materials research community is determined to keep this world-leading position. Participation in ESS is important to achieve this ambition. The ESS will open up research opportunities in the fields of energy (hydrogen storage, Li batteries, magnetocaloric effect), soft matter or magnetism. For biophysics and biochemistry research, the ESS will establish neutrons as an important probe as well. For the Dutch Physics for Technology and Instrumentation (PTI) community, the ESS is important by itself as well as in synergy with the European Synchrotron

Radiation Facility (ESRF): both facilities enable the study of the properties of thin/multi-layers that are used in sensors and actuators, which is part of the PTI remit. As Dutch researchers in all these fields have been successful in obtaining beam time at the existing European neutron facilities, it is expected that the ESS will be the seed for excellent scientific research and new collaborations. The TU Delft Reactor Institute (RID) constitutes the Dutch centre of expertise for scientific research and education in the fields of reactor physics, neutron radiation, positron emissions, radiation detection and radiochemistry. The research focuses on medical applications, the development of new materials for sustainable energy such as solar cells and batteries, and development of the nuclear reactors of the future. At the heart of this centre is the 2 MW Hoger Onderwijs Reactor (HOR), which is becoming the link between Dutch scientists and international neutron research facilities. Under the OYSTER project, the HOR is being modernised and upgraded to increase its experimental capabilities. The international standing of the RID in the field of nuclear technology has been acknowledged by the International Atomic Energy Agency, which (re)designated RID as one of the world's thirteen Collaborating Centers multiple times. Despite a large interest from the research community in national participation, the Netherlands never attained ESS member status. The Netherlands was observer from 2015. The national expertise in the development of neutron scattering techniques and their applications led to Dutch participation in the ESS Design Update phase. The RID contributed work packages on feasibility studies of add-on spin-echo components on several instruments. However, efforts to gather sufficient financial support to realise full membership were not successful. The ESS was again brought forward in the Materials Group of the 2021 National Roadmap for Large-scale Research Infrastructure. However, in the cluster for material science the first priority was given to the Dutch Materials Fabrication and Characterisation Platform (DMFCP).

Education & Training

The two European neutron facilities – Institut Laue Langevin (ILL) and ESS – organise joint user meetings and topical workshops, and jointly participate in European and international conferences on neutron scattering. In addition, ESS supports the organisation of science symposia and conferences to strengthen the science related to the capabilities provided by its instrumentation. ESS collaborates with university groups in PhD projects related to the building of the facility as well as to the preparation for its usage. ESS hosts the “pan-learning.org” website, which is an e-learning infrastructure that provides training for neutron scattering methods. In 2022 the RID also hosted the Swedish neutron school to train the next generation of neutron scientists.

STRATEGIC PERSPECTIVE

Alignment with national research/strategic agendas

The ESS fits very well in the strategic agenda of the Dutch materials research community: by 2030 to 2040, they aim to be the world leader in technologies for the design of materials with a high level of added value from sustainable sources. Participating in ESS is important to maintain their high academic quality and improve their international position. In 2016, ESS was included in the National Roadmap for Large-scale research infrastructure but no Roadmap funding was allocated. In the 2021 edition, coordination between RID and ESS is recommended. The ESS has landmark status in the ESFRI Roadmap.

Relation to other (similar) Research Infrastructures

There are several neutron research facilities in Europe, ranging from large-scale facilities (in France, Germany, Switzerland and the UK) that have user bases of hundreds to 1000+ unique users, to medium- and small-scale facilities (such as the RID) with up to 50 users. Once operational, ESS will be a large-scale facility. European neutron research facilities work together in the League of

advanced European Neutron Sources (LENS) in order to support and strengthen the ecosystem of neutron facilities in Europe. There is a large synergy between the ESS and the ESRF. Neutron facilities could provide important insights that are complementary to information obtainable by using synchrotron and in-house X-ray facilities.

Impact

Construction of the ESS depends to a large extent on in-kind contributions from the partners. This model ensures that key technologies are cultivated and enhanced in member states supporting national institutes and industry. The ESS will serve not only curiosity-driven research, but will also contribute to finding solutions to the major societal challenges. Research enabled by the ESS will lead to the targeted development of new, smart materials that are used, among others, in medical technology or energy storage systems that are key to achieve (inter)national sustainable energy goals.

Time period

Given that ESS-enabled research is important to tackle grand societal challenges, it is expected that the ESS will remain relevant for the long term (>10 years).

CONCLUSION

The ESS is a multi-disciplinary research infrastructure under construction based on the world's most powerful neutron source. The ESS is set to revolutionise science in many fields, in particular materials research and its applications. ESS-enabled research is relevant for answering the grand societal challenges of our time. The ESS is a potentially important infrastructure for materials science in the Netherlands. The TU Delft Reactor Institute connects Dutch scientists to international neutron research facilities including ESS. The Netherlands was observer in the ESS from 2015 and made in-kind contributions to the ESS pre-constructions phase. As efforts to gather sufficient (financial) support to realise full membership were unsuccessful, the Dutch observer status expired in 2020 and was offered to be renewed in 2022. Acceptance is pending until there is clarity about future membership.

ICDP – International Continental Scientific Drilling Program

ICDP is an **important** infrastructure for world-wide collaborations in continental scientific drilling programmes to study key questions on geodynamic processes, geohazards, georesources and environmental change.

SYNOPSIS

The International Continental Scientific Drilling Program, ICDP, is a collaboration between 22 countries and UNESCO with the aim to coordinate and facilitate continental drilling projects worldwide. Scientific drilling projects of ICDP allow Dutch researchers to access valuable records of Earth's history and explore, analyse, theorise, and test models that address how our planet works on local-to-global spatial scales and on decadal-to-millennial time scales. The collaboration agreement is outlined in an MoU and research focuses on three themes: Climate & Ecosystems, Sustainable Resources, and Natural Hazards. ICDP feeds into extensive research activities for Earth sciences in the Netherlands, and into some research activities in geotechnics, energy sciences and geomicrobiology. ICDP, and for the oceans IODP, are unique global international collaborations to facilitate expensive scientific drilling campaigns that would not be possible at the national level.

USERS PERSPECTIVE

Relevance for the user community

ICDP and IODP (International Ocean Discovery Program) are thematically similar collaborations that (co-)fund deep drill cores on the continents and in the deep sea to international scientific consortia. ICDP provides integrated, large-scale missions in key localities that individual scientists or groups cannot fund. This allows scientists to obtain data and samples from those parts of the Earth that are not accessible otherwise. Science team members have exclusive access to the core material following the drilling until the moratorium passes (usually two years). After the moratorium other scientists can apply for sample material as long as they have a PI-approved plan of investigation. Membership is furthermore important for access to legacy material from older projects, which can still produce important new insights.

ICDP evaluates, funds and provides operational support for drilling proposals within three themes: Climate & Ecosystems, Sustainable Resources, and Natural Hazards. ICDP feeds into extensive research activities for Earth Sciences in the Netherlands, and into some research activities in geotechnics, energy sciences and geomicrobiology. In the Earth sciences, ICDP research in the Netherlands has targeted the traces of early life in deep time, natural climate and vegetation dynamics, and improvements in dating of the geological record. In terms of research on geohazards and energy sciences, Netherlands-led initiatives have been developed on induced seismicity related to hydrocarbon production, and plans are in preparation for a project on a deep geothermal well in the Netherlands, which would involve research in the field of energy sciences and geotechnics, and provides opportunities for research on bacterial or archaeal life in extreme habitats deep in the wells.

Dutch participants in ICDP research are: TNO, UU, TUD, UvA, VU, NIOZ, WUR, COVRA, LU, UM and Naturalis. Since Dutch membership in 2011, several Dutch PIs have secured workshop funding, aimed for science team formation and full proposal writing. Three Dutch PI's have so far completed a drilling project and 98 Dutch scientists have actively participated in drilling initiatives, training courses and workshops.

ICDP drilling projects are typically multi-million dollar projects. Especially for smaller countries such as the Netherlands, ICDP projects provide an opportunity to target the best-preserved stratigraphic sections worldwide that would otherwise be too expensive to fund individually. The research communities that investigate long continuous records of climate and ecosystem change are nearly fully dependent on the ICDP material. The 'early life' communities require fresh rock material for optimal geochemical and petrological analysis for which the ICDP coring is highly important. Since ICDP projects are supported by many different international groups and laboratories, the multitude of analytical techniques applied lead to comprehensive and high-quality results.

Training and education

Both ICDP and IODP build on intellectual capacity through the promotion of international collaboration, education, and training. Scientists from member countries can participate in trainings (drilling techniques, proposal writing), can apply to workshops and become PIs on drilling initiatives. The ICDP workshops are a key route into project participation since application to them with relevant expertise is the route for becoming a science team member, other than being a proponent of a new project.

STRATEGIC PERSPECTIVE

Alignment with national research/strategic agendas

ICDP is a global collaboration. The ICDP theme "Hidden biosphere" connects to the (NWA) Origins Center Research Agenda themes 'The emergence of molecules relevant to life' (which chemical processes occurred where on the prebiotic Earth are investigated as well as the chemical and physical composition of the prebiotic Earth, and its atmosphere and oceans), and 'The interaction between life and its environment' (how does life influence planetary evolution and how is life influenced by geological events and gradual changes in the environment). ICDP partly relates to research agendas on renewable energy, given proposals on geothermal energy. Renewable energy is a current theme in NWA (route Energy Transition) and KIC (KIA Climate and Energy), and is mentioned as one of the main research topics in the Sector Portrait for Earth and Environmental Sciences.

Relation to other (similar) Research Infrastructures

ICDP is the terrestrial counterpart of the sea-going IODP in which the Netherlands also participates. The IODP targets climate change, deep life, planetary dynamics, and geohazards. The environments, logistics and research questions of continental and ocean drilling programmes are different and as such are organised by different organisations. In near-shore drilling projects the two programmes join efforts and co-organise these so-called land-to-sea projects.

Impact & outreach

Key questions in the ICDP research plan address fundamental science, but many also link to wider societal challenges encompassed in the United Nations Sustainable Development Goals (UN-SDGs). In particular, ICDP projects can provide important information to underpin the UN-SDGs related to clean water and sanitation, affordable and clean energy, sustainable cities and communities, and climate action.

Time period

The most recent ICDP Science Plan deals with the time period 2020–2030. After 2030, a renewed science plan will determine what type of new initiatives are evaluated, and how this lines up with Dutch research groups. The Dutch community is involved in developing these Science Plans. Therefore, the expectation is that ICDP will remain relevant for the Dutch community at least until 2030, and most likely longer.

CONCLUSION

ICDP is an **important** infrastructure for Earth sciences in the Netherlands. International collaboration and collaborative funding are the only means to access those parts of the Earth that are not accessible otherwise. ICDP enables fundamental research in the Earth sciences on the themes Climate & Ecosystems, Sustainable Resources and Natural Hazards, with potential application towards (sustainable) energy science and Sustainable Development Goals.

ICOS – Integrated Carbon Observation System

ICOS is an important infrastructure for CO₂ monitoring and associated research in the Netherlands and internationally.

SYNOPSIS

The Integrated Carbon Observation System, ICOS, is a European-wide greenhouse gas (GHG) research infrastructure with ERIC status since 2015. ICOS is a distributed multi-site infrastructure that produces standardised data on greenhouse gas concentrations in the atmosphere, as well as on carbon fluxes between the atmosphere, the Earth and oceans. The high-quality and open ICOS data are made available through the Carbon Portal and are based on the measurements from over 140 stations across 14 European countries. The Netherlands plays an active role in the Carbon Portal and contributes to ICOS with observations from several sites, embedded in the Ruisdael Observatory. The international ICOS network plays a crucial role in measuring and modelling carbon emissions and fluxes, and facilitates research in anthropogenic GHG emissions, climate change, and ecosystem resilience.

USERS PERSPECTIVE

Relevance for the user community

Three Dutch measurement stations (Cabauw, Loobos, Lutjewad) contribute to ICOS. Data of these stations can be standardised and effectively made available to the international community through ICOS. ICOS labelling of stations forms a standardised quality assurance for measurement data, which enhances uptake of measurements. ICOS data is used by the Dutch community and internationally for monitoring, ground-based verification of satellite measurements, and feeds into carbon flux models. In addition to creating a European ground-based measurement network, ICOS membership facilitates the interaction of Dutch researchers with the international community. The Dutch research community focuses on four main research areas:

1. Monitoring and verification of CO₂ emissions and sequestration

Measured CO₂ changes in the atmosphere come from the distributed ICOS network across Europe, and increasingly also from satellite platforms that are carefully calibrated to the long-term and high precision CO₂ data gathered at the surface. Measurements at the Dutch ICOS sites support this independent monitoring and verification for the Netherlands. There is no viable alternative for local Dutch measurements. Access of the ICOS-NL community to the measurements, but also data services, provided by ICOS-RI is crucial to its position in European carbon cycle research.

2. Urban anthropogenic GHG emissions

Urban areas form large and concentrated hotspots of anthropogenic emissions. This includes greenhouse gases such as CO₂ and N₂O, but also CH₄ and hydrofluorocarbons, aerosols, and air pollutants released during combustion. ICOS-RI therefore facilitates an expansion of the research infrastructure into urban metropolitan environments. Local observations and models, and therefore monitoring facilities, are necessary for understanding the Dutch urban greenhouse gas exchange. Urban research in the Netherlands does not fully depend on

ICOS-RI, but it is expected that ICOS-RI and ACTRIS will form the backbone of upcoming pan-European research programmes on urban greenhouse gas exchange and air quality.

3. Ecosystem resilience to climate change

ICOS data provide a harmonised approach to ecosystem carbon flux measurements, data treatment, data storage and access, from which ICOS-NL benefits and to which it contributes. In a European context, the CO₂ exchange of many distinct types of ecosystems are observed, allowing comparison of Dutch results to international ones. Participation in ICOS guarantees access to international collaboration, data platforms, as well as data and model comparison studies. It ensures that ICOS-NL's data will be used in an international setting, and it allows ICOS-NL to engage in international progress.

4. Carbon-climate interactions across scales

Frequent measurements of short-term processes are important also for studying climate time scales. A cascade of interactions makes the climate system highly coupled across scales. This is an important research area for the ICOS-NL community, and extends to meteorology, hydrology, ecology, and biology. Observations enable this research, with ICOS-NL infrastructure in the field and laboratory as indispensable platforms. Numerical modelling by ICOS-NL partners forms the backbone to understand actions across scales. Research in this field has reached the top in the world due to the infrastructure now covered under ICOS-NL. Multiple decades of high precision measurements at Cabauw, Loobos, and Luttjehad form unique records in Europe, with no viable alternative within Europe for the community. The numerical modelling does not strictly depend on the ICOS-RI and could in principle use other international observation sets, but close collaboration between experimentalists and numerical modellers is facilitated by ICOS research.

The ICOS-NL consortium consists of ten universities and knowledge institutes: the VU University Amsterdam, the University of Groningen, the Energy Research Centre of the Netherlands (ECN), Wageningen University, Wageningen Environmental Research, Utrecht University, the Royal Netherlands Meteorological Institute (KNMI), SRON Netherlands Institute for Space Research, the Royal Netherlands Institute of Sea Research (NIOZ), and TNO Research.

Training an education

ICOS offers a summer school and an ICOS conference.

STRATEGIC PERSPECTIVE

Alignment with national research/strategic agendas

ICOS has been on the ESFRI Roadmap since 2006 and was established as an ERIC in 2015. Dutch participation in ICOS is part of the Ruisdael Observatory, which is on the National Roadmap for Large-scale Research Infrastructure. Measuring, monitoring and modelling efforts conducted in the ICOS context align with strategies in the Sector Portrait for Earth and Environmental Sciences. ICOS activities contribute to the agendas of the NWA Routes Energy transition, Measuring and detecting: anything, anytime, anywhere, and Quality of the living environment, and link to the EU Mission Climate.

Relation to other (similar) Research Infrastructures

The Ruisdael Observatory is the Dutch national measurement network for atmospheric science. Through ICOS, the national measurement network is connected to the European scale. Similarly, ACTRIS (Aerosols, Clouds and Trace Gases Research Infrastructure) is embedded in Ruisdael. Outside of Europe, many other countries have one or several research infrastructures in the fields that ICOS operates in. The Japanese NIES is the research infrastructure most similar to ICOS as it also integrates atmosphere, ecosystems and oceans. ICOS cooperates with fellow research infrastructures.

Impact & outreach

The international component of the ICOS network increases the network's coverage, efficiency, and its relevancy for monitoring greenhouse gas emissions and for informing European policy on emissions and climate change. ICOS-NL supports the National Emission Registration (NER), as well as the United Nations Framework Convention on Climate Change (UNFCCC), to monitor the changing emission landscape and to verify reported reductions in CO₂ emissions.

Time period

Given the need for ground-based monitoring of CO₂ for monitoring emissions, and research associated with climate change and ecosystem resilience, ICOS is expected to remain relevant for research conducted in the Netherlands for at least the next 10 years and potentially much longer.

CONCLUSION

ICOS is an **important** infrastructure for the Netherlands. Scientifically, ICOS aligns with Dutch and European research agendas. The network is crucial for reliably measuring carbon fluxes in the Netherlands and Europe, and ICOS provides the international context to make high quality data accessible.

ILT – International Low-Frequency Array (LOFAR) Telescope

ILT is an **important** infrastructure for astronomy in the Netherlands. LOFAR is a unique instrument and many lines of Dutch research depend on it. ILT contributes to the Dutch positioning at the forefront of radio astronomy.

SYNOPSIS

LOFAR is the world's premier low-frequency radio-interferometric telescope. It allows astronomers to engage in multiple lines of research at once: they can look back billions of years to a time before the first stars and galaxies were formed, they can survey vast areas of the low-frequency radio sky, and they can be constantly on the lookout for radio transients originating from some of the most energetic explosions in the Universe. In addition to the sensor network, LOFAR has an innovative computer and network infrastructure that can handle extremely large data volumes.

LOFAR was designed and built as a national project by ASTRON. In 2010, an MoU was signed to establish the International LOFAR Telescope (ILT). LOFAR consists of a network of sensors in the ten participating countries: The Netherlands (38), Germany (6), Poland (3), France (1), Ireland (1), Latvia (1), Sweden (1), the UK (1), Italy (in development), and Bulgaria (in development). The partnership is now entering a next level with the establishment of the LOFAR ERIC (foreseen in 2023, hosted in the Netherlands) and a major upgrade of the telescope to LOFAR2.0 (online in 2024).

ILT is available to scientists from the worldwide community through competitive calls for proposals. Data are centrally processed and become public after a one-year proprietary period.

USERS PERSPECTIVE

Relevance for the user community

LOFAR is one of the most scientifically impactful radio telescopes in the world – and the harvest of LOFAR science is still far from complete. It is without question a Dutch science success story, one that is still growing. LOFAR is unmatched in terms of sensitivity, field-of-view, and resolution. All three of these factors are critical for detecting faint radio sources, mapping the sky efficiently, and accurately imaging the morphology of these sources. LOFAR is being used to perform the deepest and highest-resolution surveys ever conducted at such low radio frequencies. LOFAR is used for astronomical studies in the Solar System (e.g., solar and planetary emission), within our Milky Way galaxy (e.g., pulsars, flare stars, exoplanets), in extragalactic space (e.g., galaxy clusters, star-forming galaxies, active galactic nuclei), and out to the earliest periods in the Universe's evolution (e.g., high-redshift galaxies, the Epoch of Reionization, Cosmic Dawn). LOFAR is also relevant for several non-astronomical studies, including space weather (studying the heliosphere and solar wind), ionospheric studies, tracing lightning strikes, and measuring meteor showers.

LOFAR2.0 will provide an order-of-magnitude greater computational power at the LOFAR antenna fields, and this will make it possible to use all the low- and high-band antennas simultaneously and/or over a larger field-of view. The LOFAR2.0 upgrade is funded in a significant way through NWO medium and large investment grants. LOFAR2.0 offers many new possibilities and the community has outlined the various science cases for LOFAR2.0 in the second half of the 2020s.

Astronomers at ASTRON cover a broad range of science topics, often in collaboration with the Dutch universities. The four NOVA university institutes have the following leading roles in LOFAR:

Amsterdam: radio transients: including pulsars; magnetars; fast radio bursts; gamma-ray bursts; flare stars.

Leiden: radio surveys: including high-redshift galaxies; exoplanets; stellar radio sources; galaxy clusters; cosmic web.

Nijmegen: cosmic rays and cosmic magnetism.

Groningen: Epoch of Reionization and Cosmic Dawn; exoplanets; stellar radio sources.

STRATEGIC PERSPECTIVE

Alignment with national research/strategic agendas

LOFAR has a high priority position in the 'Strategic Plan 2021–2030 for Astronomy in the Netherlands', both in terms of the science perspective and in delivering and developing future radio astronomy technologies. LOFAR has also a prominent position in the European 'ASTRONET Science Vision and Infrastructure Roadmap 2022–2035', and the '2021 National Roadmap for Large-scale Research Infrastructure'. There are links with the Dutch innovation policy (e.g. key enabling technologies, data science) and the Dutch Science Agenda (NWA).

The Netherlands has played a unique role in low-frequency radio astronomy, true to its historical position as a radio astronomy powerhouse. This has led to a significant investment in expertise and human capital. At the same time, radio astronomy is entering a phase of huge international projects at the scale of a billion euros of which the Netherlands can only be a small part, due to natural funding limitations. In this era, a niche research infrastructure such as LOFAR in the Netherlands allows to (1) inspire and train the next generation of radio astronomers and (2) challenge our engineers to devise new technological breakthroughs that can best be achieved with nimble smaller-scale experiments.

Impact & outreach

The Netherlands leads LOFAR, a European wide facility that is soon to become an ERIC – a major milestone that will secure its long-term operation. Together with the broader LOFAR community, the Operations team at ASTRON are at the forefront of developing automated calibration and imaging strategies for LOFAR. The experience gained in processing LOFAR will be invaluable going forward in the SKA era. In a broader sense, LOFAR continues to pioneer the use of distributed clocks, high-speed networks, and (near-)real-time processing of large data volumes. These technologies and techniques are relevant to a wide range of 'sensor networks' both in other areas of science as well as in industry. ASTRON works closely with SURF and other (industrial) partners (e.g. Neways). LOFAR's design and signal processing are cutting edge, and this has trained several generations of advanced problem solvers who can apply their knowledge in other sectors of science and industry. LOFAR is more than just an astronomical research facility, it is a multi-disciplinary distributed sensor network that also provides unique capabilities for ionospheric, space weather and lightning studies. These domains are of direct societal and economic relevance because satellite technology is prone to damage from solar eruptions (coronal mass ejections) that can be tracked and better understood to avoid catastrophic failures.

Relation to other (similar) Research Infrastructures

LOFAR is a unique facility. The GMRT, that has a far lower survey speed, is sometimes used for the follow-up of LOFAR discoveries, as are other radio telescopes that provide complementary information such as EVN/JIVE and JVLA. LOFAR data are often complemented with optical, X-ray, and gamma-ray data to diagnose the physical properties of these radio sources.

A key LOFAR synergy is with SKA. SKA will provide data on a scale similar to / larger than that of LOFAR, meaning the lessons from LOFAR can be directly applied. For example, the design and development of the ASTRON Science Data Centre, currently focusing on LOFAR, will lead directly into the SKA Regional Centres. LOFAR will continue to be unique even in the era of the SKA-Low telescope. Whereas SKA-Low offers much higher collecting area and access to higher frequencies, LOFAR will provide 10 times higher angular resolution and access to the novel 10–50 MHz window that is inaccessible to SKA-Low. LOFAR will be observing the northern hemisphere and SKA-low the southern hemisphere, so together they can observe the full sky.

Time period

With the LOFAR2.0 upgrade LOFAR's lifetime and scientific capabilities will be extended well into the 2030s.

CONCLUSION

ILT is an **important** infrastructure for astronomy in the Netherlands. LOFAR is a unique instrument given its frequency coverage, sensitivity and angular resolution and many lines of Dutch research are explicitly tied to this niche. ILT is now entering a next level with the upgrade to LOFAR 2.0 and the establishment of the LOFAR ERIC that will provide funding stability. LOFAR contributes to maintaining the Dutch position at the forefront of radio astronomy and allows to fully exploit the synergies with SKA.

ING – Isaac Newton Group of Telescopes

ING is an important infrastructure for astronomy in the Netherlands. It is a priority to scientifically harvest from the Dutch investments in WEAVE and exploit synergies with Gaia, Euclid and LOFAR.

SYNOPSIS

The Isaac Newton Group of Telescopes (ING) consists of the 4.2-m William Herschel Telescope (WHT) and the 2.5-m Isaac Newton Telescope (INT), operating on the island of La Palma, Spain. The ING is operated on behalf of the UK Science and Technology Facilities Council (STFC), the Dutch Research Council (NWO), and the Instituto de Astrofísica de Canarias (IAC). STFC, NWO, and IAC have entered into collaborative agreements for the operation of and the sharing of observing time on the ING telescopes. The ING is the only optical facility that the Dutch community has access to in the northern hemisphere.

The ING is undergoing a strategic transformation: at the WHT the new multi-fiber spectrograph WEAVE, built by an international consortium with strong Dutch involvement, is currently (2023) being commissioned. WEAVE will soon start observing eight surveys, in which many scientists in the Netherlands will participate. The INT telescope will be refurbished with a new instrument, HARPS3, designed to find Earth-like exoplanets, arriving in 2024. HARPS3 is built by an international consortium with significant Dutch involvement.

USERS PERSPECTIVE

Observing time on the ING telescopes is distributed via an open call for proposals. Circa 40% of the observing time on both the WHT and INT goes to the Dutch community (corresponding to the Dutch share in ING). As soon as WEAVE and HARPS3 are operational, the majority of the observing time will be devoted to the WEAVE and HARPS3 surveys with strong Dutch participation. The remaining open time will be distributed via an open call.

Relevance for the user community

At each of the four Dutch university (NOVA) institutes, there are extensive research activities that either completely or partly depend on access to ING. The focus in the upcoming years will be the scientific exploitation of the WEAVE instrument, realised with a budget of about M€ 25 and strong Dutch involvement (the WEAVE co-PI and project scientist is from RUG). Once WEAVE is operational, about 63% of the telescope time will be devoted to the WEAVE surveys. Most of the rest of the time is PI time that can be applied for. The main reason for building WEAVE has been to follow up spectroscopically all interesting sources that have been and will be discovered using Gaia, a satellite that is currently determining positions of nearly two billion stars in our Milky Way. By taking a spectrum with WEAVE it is possible to understand the composition and radial velocity of the stars. Furthermore, millions of objects discovered with the LOFAR instrument need identification. In the near future (from 2023 or 2024) the Euclid satellite will produce many interesting objects that need to be followed up. Since Gaia and Euclid cover the whole sky, telescopes in both the northern and southern hemisphere are needed; also LOFAR is in the northern hemisphere, with its core in the Netherlands. For many areas of optical astronomy (studies of the Milky Way, some galaxies in the northern hemisphere like the Andromeda group and the Coma cluster), having access to the ING is fundamental.

At the INT, about 70% of the time will be used for the decade-long HARPS3 survey, which has considerable Dutch involvement. The rest of the time will be PI time. There is interest in the Netherlands to use this open time from the groups in Leiden, Amsterdam and Groningen working on exoplanets, and from the general community needing spectra for small experiments.

Training and education

The ING Student Programme allows six students per year to come to La Palma for a one-year training period in observational astronomy. In addition, the INT is ideal for master and PhD students to learn how to observe, with observing trips for master students being organised annually by several Dutch universities.

STRATEGIC PERSPECTIVE

Alignment with national research/strategic agendas

The most relevant strategic agendas for astronomy are the 'Strategic Plan 2021–2030 for Astronomy in the Netherlands', and the European 'ASTRONET Science Vision and Infrastructure Roadmap 2022–2035'. The importance of the ING is confirmed in the national strategic plan with particular emphasis on the combination of the WEAVE surveys with Gaia and Euclid. The ASTRONET Science Vision and Roadmap has provided instrumental support for the development of WEAVE. ING is included in the Dutch landscape of Large-scale Research Infrastructure. It is not part of the 2021 National Roadmap for Large-scale Research Infrastructure, because the observatory, operational since the 1980's, requires no new investments at the investment level of the National Roadmap. Science harvesting of the Dutch investments in the WEAVE instrument has high priority. To this end, both the WEAVE and HARPS3 surveys are well prepared, with ample opportunities for other science cases in the open time.

ING is preparing for the future with the recent (2021) advice of an external Science Advisory Committee.

Relation to other (similar) Research Infrastructures

Many countries have national, publicly-funded optical-near-infrared national observatories, yet few attain the category of 'world-class observatory'. In the southern hemisphere, Dutch astronomers have access to the European Southern Observatory (ESO), which has a whole range of telescopes. ESO and ING cooperate in several areas. In particular, European leadership in the exploitation of ESA's Gaia satellite rests on massive spectroscopy from mid-size telescopes on the ground: ING covers the northern hemisphere, and ESO the southern hemisphere. Only from ING in the northern hemisphere can Dutch astronomers exploit findings from their radio facilities. In terms of synergies, ING is extremely relevant for the follow-up of objects from high priority research facilities, such as the Gaia and Euclid satellite missions and LOFAR.

Impact & outreach

The ING telescopes produce images of superior quality, which are used all over the world, in many public outreach materials. Its location in La Palma is relatively easily reachable, and recently, a visitor's center has been opened next to the site. Each year, the winner of the 'Nederlandse Sterrenkunde Olympiade' for high school students gets an observation trip to La Palma.

Time period

ING will remain relevant until at least 2035. In 2021 an international Scientific Advisory Committee (SAC) was asked to report about the future (2026–2035) of the ING. The SAC envisions compelling reasons to continue operating the WEAVE spectrograph at the WHT until at least 2035, if not beyond. There will be a continuing need to follow-up sources from Gaia, LOFAR and Euclid. The HARPS3 “Terra Hunting Experiment” survey at INT is designed to last at least a decade. The current ING exploitation agreement between STFC, NWO and IAC runs from 2017–2027, meaning that a decision on continuing the agreement is needed in the coming years. The mid-term review that is foreseen to take place in 2023/2024 will provide input for the decision making process.

CONCLUSION

ING is an **important** infrastructure for astronomy in the Netherlands. It is a priority to scientifically harvest from the Dutch investments in WEAVE. Research activities are aligned with the scientific priorities in the community, and include strong synergies with Gaia, Euclid, and LOFAR. ING provides Dutch astronomers with access to the northern hemisphere.

The ING is in a transformation phase, and therefore monitoring of the progress is recommended.

(1) The commissioning of WEAVE is currently ongoing: the importance of ING goes hand in hand with successful operations of WEAVE. (2) The current ING exploitation agreement will end in 2027 and therefore a decision on its continuation is required soon. A mid-term review is being prepared.

JIVE – Joint Institute for Very Long Baseline Interferometry (VLBI) ERIC

JIVE is an **important** infrastructure for astronomy in the Netherlands, as it provides unique capabilities that are essential to address a number of high-priority and widely supported science cases.

SYNOPSIS

The Joint Institute for VLBI ERIC (JIVE) is a research infrastructure providing central support to the European VLBI Network (EVN). JIVE's mission is to promote and implement the use of Very Long Baseline Interferometry (VLBI) and other radio astronomical techniques. JIVE develops and implements the core data processing and user services that turn the EVN network of distributed telescopes around the world into a single observatory to study the radio sky at the highest-possible angular resolution.

JIVE was founded in 1993, and is since 2015 a European Research Infrastructure Consortium (ERIC). There are seven member countries: France, Italy, Latvia, the Netherlands, United Kingdom, Spain and Sweden, and additional partner institutes in China, Germany and South Africa. JIVE is hosted in the Netherlands at ASTRON, the Netherlands Institute for Radio Astronomy.

USERS PERSPECTIVE

The EVN issues calls for proposals that are open to all astronomers (Open-Sky policy). JIVE processes the EVN data and provides expert user support during each step of the process, from the first idea to a successful observation and science-ready data products. JIVE maintains an open and searchable online archive of EVN data that have passed their 12-month proprietary period.

Relevance for the user community

The EVN has produced a scientific roadmap ([arXiv:2007.02347](https://arxiv.org/abs/2007.02347)) describing the key science goals for the next decade (2020–2030) in six broad areas within astronomy and astrophysics, cosmology, and space science. Within the Netherlands, there are extensive research activities related to each of these topics – at ASTRON, JIVE, all four NOVA university astronomy institutes, TU Delft and SRON. The most recent and prominent ones include outflows and AGN feedback (RUG/ASTRON/JIVE), fast radio bursts (UvA/ASTRON/JIVE), gravitational lensing (RUG/ASTRON), galaxy structure and stellar evolution (Leiden/JIVE) and near-field VLBI/planetary science (Delft/JIVE). These research activities are completely dependent on JIVE/EVN. JIVE/EVN is also being increasingly used by Dutch researchers to followup sources discovered in the deep Low-Frequency Array (LOFAR) surveys of the sky. These two world-leading radio telescopes strongly complement each other. JIVE is also an important partner to Dutch universities in the Event Horizon Telescope (EHT) project, where JIVE is leading VLBI data processing developments.

Training

JIVE plays an important role in training the next generation of radio astronomers working in the field of interferometry through organising local training sessions and international schools (e.g., recently on the broadly used CASA software). The ASTRON/JIVE summer student programmes is recognised worldwide as one of the best opportunities for students to get started with research in interferometry.

STRATEGIC PERSPECTIVE

Alignment with national research/strategic agendas

The most relevant strategic agendas for astronomy are the 'Strategic Plan 2021–2030 for Astronomy in the Netherlands', the European 'ASTRONET Science Vision and Infrastructure Roadmap 2022–2035', and the '2021 National Roadmap for Large-scale Research Infrastructure'. All three recognise the importance of JIVE (and EVN) for addressing key science questions, and also for developing future key technologies. The ASTRONET document states "Radio VLBI provides the highest angular resolution imaging and among all the VLBI networks EVN/JIVE is the most sensitive. It delivers a wide range of excellent science and will remain the premier VLBI instrument during the SKA1 era."

The scientific and technology priorities for JIVE and EVN have been formulated in the EVN Science Vision 'VLBI20-30: a scientific roadmap for the next decade – The future of the European VLBI Network' ([arXiv:2007.02347](https://arxiv.org/abs/2007.02347)) and the associated technological roadmap for its implementation. The hosting of JIVE at ASTRON in the Netherlands comes with a relatively high membership contribution (host premium). Having JIVE at ASTRON is very valuable as it contributes to the positioning of the Netherlands at the forefront of radio astronomy worldwide. VLBI is one of the most difficult astronomy topics to take data and produce science-ready products, and having JIVE in the Netherlands ensures the embedding of expertise in the Dutch community. There are strong science and technology synergies between the activities at ASTRON and JIVE.

Relation to other (similar) Research Infrastructures

There are similar infrastructures available, especially the Very Long Baseline Array in the US (VLBA), the Korean and Chinese VLBI networks in East Asia (KVN/CVN/EAVN), and the Long Baseline Array in Australia (LBA). However, the EVN remains unmatched in its sensitivity and flexible correlator modes, including real-time correlation and ground-breaking interferometric observations of fast radio bursts on millisecond timescales.

There are synergies with two other research infrastructures that are highly relevant for the Netherlands: the International LOFAR Telescope (ILT) and the Square Kilometre Array (SKA). ILT and JIVE/EVN strongly complement each other since LOFAR can scan the full northern sky to unprecedented depths while EVN can provide 100–1000x higher angular resolution for studying the most interesting discoveries in detail. In the framework of SKA, JIVE is leading the development of SKA-VLBI capabilities which will provide fantastic new science, notably in very high precision astrometry of weak radio targets. Other synergies relate to the data expertise at JIVE and the SKA data science centres that are being developed. The Netherlands has world-leading experience thanks to LOFAR/JIVE/EVN. JIVE is also key to the EHT project: JIVE is leading CASA-VLBI data processing developments and is the home base of the current EHT Director.

Impact & outreach

JIVE is hosted by ASTRON. JIVE staff, including 18 PhD scientists, are *de facto* members of the Dutch astronomical community. Nearly 30-yr-long close interaction between the Dutch (national) and JIVE/EVN (international) collaboration is mutually beneficial.

JIVE is an R&D intensive organisation. The technologies (clock distribution, high-speed networks, high-performance real-time computing, smart systems) that go into building radio interferometric arrays also have many applications in other sensor networks used in other areas of science and in industry (e.g., weather detection, financial transaction systems, etc.). There are economic opportunities in engaging people in a part of the Netherlands that typically has limited highly skilled technical jobs. This impacts local economics and has a positive influence on the small (shrinking) villages in the region.

In terms of outreach, JIVE does most of the outreach for the EVN, such as the Newsletter, press releases, social networks. JIVE also participates in outreach events in the Netherlands. A major educational effort is the contribution to build human capacity in Africa by providing training and experience opportunities in radio astronomy (with EC support).

Time period

JIVE/EVN will remain a unique and significant research infrastructure for at least 10/20 years. Long term future (new global VLBI) developments will depend on when and how SKA is deployed and the emergence of other VLBI networks.

CONCLUSION

JIVE is an **important** infrastructure for astronomy in the Netherlands, as it provides unique capabilities that are essential to address a number of high-priority and widely supported science cases. The importance of the infrastructure for Dutch and European science is recognised in both the Dutch and European strategic plan for astronomy for the next decade, and there are users at all Dutch astronomical institutes in the Netherlands. In addition, the participation in JIVE is well aligned with other priorities such as the International LOFAR Telescope and the Square Kilometre Array, and allows for exploiting synergies. The hosting of JIVE at ASTRON in the Netherlands contributes to positioning the Netherlands at the forefront of radio astronomy worldwide.

KM3NeT – Cubic Kilometre Neutrino Telescope

KM3NeT is an important research infrastructure for Dutch neutrino physics and neutrino astroparticle physics and astronomy. The Netherlands has a major involvement in KM3NeT. The completion of the KM3NeT infrastructure and its science exploitation are key priorities of the Dutch (astro)physics communities.

SYNOPSIS

The Cubic Kilometre Neutrino Telescope (KM3NeT) is a research infrastructure under construction in the waters of the Mediterranean Sea that hosts two next-generation neutrino telescopes. The Astroparticle Research with Cosmics in the Abyss (ARCA) telescope will be used to search for and study astrophysical sources of high-energy cosmic neutrinos. The Oscillation Research with Cosmics in the Abyss (ORCA) telescope was designed to measure the properties of neutrinos generated in the Earth's atmosphere. KM3NeT will also house instrumentation for Earth and Sea sciences for long-term and on-line monitoring of the deep sea environment.

KM3NeT was co-founded by the Netherlands. The KM3NeT Collaboration is a consortium of more than 50 institutes in more than 15 countries. ARCA is being built off the coast of Sicily, while ORCA lies off the French coast. The construction of KM3NeT is realised in phases, adjusting to the amount of available funding. The first phase started in 2015 and included partial construction of the facility and a validation programme. The project is currently in its second phase (KM3NeT2.0), which covers the completion of ARCA and ORCA within this decade. A third site, near the coast of the Greek island Pylos, could be added in a future expansion.

USERS PERSPECTIVE

Relevance for the user community

The KM3NeT telescopes are formed by three-dimensional arrays of sensors distributed over large volumes of water and suspended at depths of several kilometres. Nikhef, in collaboration with other Dutch institutes, contributed significantly to the conceptual and technical design of the sensors: the Digital Optical Modules (DOMs). The ARCA and ORCA telescopes are similar in layout and detection principle, but the different arrangement of the DOMs allows KM3NeT to address a range of science questions. The main scientific objectives of KM3NeT are twofold. ARCA is designed to study the characteristics of the cosmic high-energy neutrino flux and, due to its high angular resolution, identify the associated astrophysical sources such as supernovae, gamma-ray bursts, active galactic nuclei or colliding stars. ORCA will be used to study atmospheric neutrinos for neutrino oscillation patterns with the goal to establish the neutrino mass ordering. ARCA and ORCA both also allow indirect dark matter searches by looking for the signs of dark matter annihilation into neutrinos. ARCA and ORCA are currently operational with a small number of detectors and already with these allow first physics studies.

The KM3NeT collaboration includes about 250 people worldwide. Besides Nikhef, Dutch members of the KM3NeT Collaboration include the University of Amsterdam, Leiden University, TNO and the Dutch Institute for Sea Research NIOZ. The Dutch partners play an important part in the science exploitation, and the development of technology, software and data analysis. NIOZ has provided the mechanism to deploy the sensors and performs oceanographic research at one of the KM3NeT

sites. The Committee for Astroparticle Physics in the Netherlands (CAN) represents the Dutch scientific community interested in astroparticle physics, including neutrino astronomy. The transfer and processing of the measurements collected by the telescopes involve large data streams that require an extensive e-infrastructure. The Dutch facility FuSE (Fundamental Sciences E-infrastructure) will be used by the Dutch community to analyse the data and extract the scientific results for KM3NeT and two other National Roadmap facilities, experiments at CERN's Large Hadron Collider and the Square Kilometre Array. KM3NeT will follow an open-data access policy. After a short period of proprietary access to collaboration members, the data will be made publicly available.

Education & Training

The KM3NeT education platform aims to provide basic information and skills to understand the principles of the research infrastructure to the public and educate fellow scientists about the use of KM3NeT research results. For KM3NeT collaboration members, the platform provides documentation about KM3NeT data taking and analysis.

STRATEGIC PERSPECTIVE

Alignment with national research/strategic agendas

Continued strong involvement in the construction and science exploitation of KM3NeT has high priority in the CAN Strategic Plan for Astroparticle Physics in the Netherlands 2014–2024 (an update that includes KM3NeT is underway), the Nikhef Strategy 2017–2022 (the updated 2023–2028 strategy that is underway also includes KM3NeT) and the 2020 Strategy Document of the Particle and Astroparticle Physics working group of the Dutch physics research communities. KM3NeT is also mentioned in the Strategic plan 2021–2030 for Astronomy in the Netherlands and the ASTRONET Science Vision and Infrastructure Roadmap 2022–2035 for European astronomy: it is a key facility needed to address the main science questions in the area of Extreme astrophysics. KM3NeT is on the National Roadmap for Large-scale Research Infrastructure since 2016. As stated in the National Roadmap 2021, active participation in the construction and operation of KM3NeT as well as other facilities for high-energy cosmic messengers (GRAND, GCOS, CTA), gives the expertise needed to position the Dutch astroparticle physics research community prominently in the international cosmic multi-messenger research community. KM3NeT2.0 is on the ESFRI 2016 and 2021 Roadmaps, and is included in the Astroparticle Physics European Consortium (APPEC) strategic plan 2017–2026, whereby the endorsement was again explicitly emphasised in the APPEC Midterm Review report (2023).

Relation to other (similar) Research Infrastructures

The ANTARES neutrino telescope in the Mediterranean Sea, close to the French KM3NeT site, was a precursor to KM3NeT. The US-led IceCube telescope on the South Pole is the largest cosmic neutrino observatory currently in operation. The Global Neutrino Network (GNN) aims for a closer collaboration and a coherent strategy among the neutrino telescope projects. At present, it consists of the ANTARES, Baikal-GVD (under construction), IceCube and KM3NeT Collaborations. When completed, KM3NeT's sensitivity and angular resolution will be superior to those of existing neutrino telescopes. The KM3NeT field of view, which includes the Galactic Center, is complementary to that of IceCube. Together, IceCube in the southern hemisphere and KM3NeT in the northern hemisphere will view the full sky and form a global neutrino observatory. The Astronomy ESFRI and Research Infrastructure Cluster, ASTERICS, was a funded European Research Infrastructure that aimed to address the cross-cutting synergies and common challenges shared by the various Astronomy and Astroparticle Physics ESFRI facilities (SKA, CTA, KM3NeT & ELT) in order to support and accelerate their implementation. In 2019 it was followed by the ESCAPE

project (European Science Cluster of Astronomy & Particle physics ESFRI research infrastructures). There are also scientific synergies with other astroparticle physics experiments such as Pierre Auger Observatory (cosmic rays), Virgo (gravitational waves) and XENON (direct dark matter searches).

Impact & outreach

The successful design, construction and operation of the KM3NeT detector requires the development of new solutions in several key technology areas. KM3NeT relies on advanced technology to operate in the deep sea, with high reliability, low power, and high-bandwidth-communication. This makes KM3NeT interesting for high-tech industrial partners. KM3NeT technology is developed by Nikhef in collaboration with partners in Dutch industry. The science addressed by KM3NeT comprises subjects that appeal to the imagination and are of great interest to the general public. KM3NeT will develop and implement an outreach and communication policy.

Time period

KM3NeT will, after completion, continue to operate for at least ten more years.

CONCLUSION

KM3NeT is an **important** research infrastructure for Dutch neutrino physics and neutrino astroparticle physics and astronomy. The Netherlands has a major involvement in KM3NeT. Many leading roles (construction, computing, physics) are held by Nikhef members and Nikhef is a key contributor in the construction of the detector. The completion of the KM3NeT infrastructure and its science exploitation are key priorities of the Dutch (astro)physics communities. The under-sea location of KM3NeT, offering ports for experiments for Earth and sea sciences, facilitates interdisciplinary connections.

PRACE – Partnership for Advanced Computing in Europe

PRACE is an important research infrastructure that supports a broad range of Dutch research activities with high demand for intensive computational modelling and data driven approaches.

SYNOPSIS

PRACE is a research infrastructure that provides access to Europe's world class High Performance Computing (HPC) facilities. The mission of PRACE is to enable high-impact scientific discovery and engineering research and development across all disciplines to enhance European competitiveness for the benefit of society. PRACE offers computing and data management resources and services to scientists and researchers from academia and industry. The PRACE facilities are relevant for all research activities that require access to HPC infrastructure, including chemical sciences and materials, biochemistry/bioinformatics/life sciences, fundamental constituents of matter, engineering, universe sciences, Earth system sciences, and mathematical and computer sciences.

PRACE is a distributed research infrastructure with headquarters in Brussels, Belgium. It was established in 2010 by a group of founding member countries including the Netherlands. PRACE currently has 25 members and 2 observers. The hosting members, which currently are France, Germany, Italy, Spain and Switzerland, have committed to fund and operate PRACE's computing and data management resources.

USERS PERSPECTIVE

Relevance for the user community

PRACE provides access to seven leading-edge HPC systems in the five hosting countries (Tier-0 systems) through a peer review process. Access to PRACE HPC systems is free of charge. PRACE members pay an annual fee and many of them provide national HPC resources (Tier-1 systems) as additional in-kind contributions. In the current phase of the project (PRACE 2) researchers in non-member countries cannot lead PRACE projects, but can be collaborators. Users from industry with head offices or substantial R&D activity in Europe are also eligible to apply for PRACE projects. PRACE supports users and user communities in porting, scaling and optimising their applications to fully exploit the capabilities of the PRACE systems. These activities facilitate the establishment of an EU-integrated HPC ecosystem for large-scale scientific computing and data infrastructure. Proposals for access to PRACE facilities are assessed on scientific excellence. They come from a broad range of research areas as high-performance computing and advanced digital technologies such as big data analysis and artificial intelligence are taking up key roles across all sciences and engineering. Demand for PRACE resources is high and all PRACE calls are oversubscribed. The Tier-1 facilities introduce a scaling level without having to face greater restrictions at the start of the optimisation work.

The Netherlands contributes to the PRACE Tier-1 infrastructure through the Dutch supercomputer Snellius. The computational facilities that PRACE offers to researchers in the Netherlands allow them to maintain their key positions in fields with strong international competition from USA, China and Japan. PRACE is also relevant for Dutch research via collaborations with other research infrastructure with strong Dutch participation. For example, CERN, SKAO, GÉANT and PRACE work together to help realise the full potential of the coming new generation of HPC technology. Coupled with the growing use of machine learning, the power of HPC will be vital in ensuring the success of upcoming big science projects such as SKAO and CERN's High-Luminosity Large Hadron Collider.

Similarly, the European Brain ReseArch INfrastructureS (EBRAINS) not only provides access to the most comprehensive set of brain data but also makes PRACE HPC resources available to brain research.

Through SURF, the cooperative association of Dutch educational and research institutions in the area of IT facilities, the Netherlands has contributed financially to the PRACE offices and since 2017 to the support organisation. This has enabled researchers in the Netherlands to put in proposals for access to large HPC systems independently from others. The Netherlands is a member of PRACE Council and, as such, is involved in the decision making process of the infrastructure, including setting the strategic objectives and multiannual strategic plan of PRACE. Additionally, the Dutch representative was elected Chair of PRACE Council in 2016, and under this role had the task to lead the renovation of the infrastructure for the period 2017–2022.

Education & Training

PRACE operates 14 PRACE Training Centres (PTCs) and they have established a state-of-the-art curriculum for training in HPC and scientific computing. The PTC activities enable both European academic researchers and European industry to utilise the infrastructure available through PRACE. PRACE seasonal schools complement the PTC training program. In addition, PRACE offers online training material, and (co-)organises the International HPC Summer School, as well as workshops and seminars throughout Europe. All training activities are free of charge to eligible participants. Access to these programmes is important for the Dutch research community in view of the increasing use of computational and data-driven approaches.

STRATEGIC PERSPECTIVE

Alignment with national research/strategic agendas

The research agendas of a broad range of disciplines depend on the availability of state-of-the-art, large-scale high-performance computing infrastructure for data processing, advanced modelling and data-driven approaches. PRACE puts special emphasis on extreme-scale simulations, big data analysis and artificial intelligence, which are critical to realise the ambitions of e.g. the physics, astronomy, theoretical chemistry and material science, climate research, and the engineering communities. PRACE was awarded Landmark status in the ESFRI Roadmap in 2016.

The EuroHPC Joint Undertaking (EuroHPC-JU) will advance the European supercomputer landscape by completing the computing infrastructure with pre-exascale and petascale supercomputers that will be located at and operated by supercomputing centres (Hosting Entities) in the European Union. The missions of PRACE and EuroHPC are complementary. While EuroHPC-JU operates from top to bottom with high-level funding instruments, PRACE is a science-driven infrastructure developed as a bottom-up activity. The goal is to bring the two together in a strong partnership that will create optimal synergies for the benefit of the European scientific and industrial communities. PRACE facilities are gradually taken over by EuroHPC facilities, which provide the same advantages to researchers on top of national facilities.

Relation to other (similar) Research Infrastructures

Programmes very similar to PRACE exist in the USA with INCITE and XSEDE. The PRACE Tier-0 program is meant for innovative and challenging scientific problems that requires large amounts of resources (like INCITE), while the PRACE Tier-1 program is helping scientists in their line of research where resources are needed that are still not available on local/national clusters (like XSEDE). A strong collaboration exists between PRACE and XSEDE with a joint call. PRACE also actively interfaces with RIKEN (Japan), Compute Canada, the European data network for the research and

education community (GÉANT), the European Grid Infrastructure (EGI), the European Data Infrastructure (EUDAT), and the Human Brain Project (HBP).

Impact & outreach

PRACE seeks to strengthen the European users of HPC in industry through various initiatives, and aims to strengthen the connection with many European (ESFRI) research infrastructures to maximise their impact. During COVID-19 times, PRACE has made computing time available at short notice throughout Europe for projects in connection with the pandemic. PRACE has a strong interest in improving energy efficiency of computing systems and reducing their environmental impact. Having access to the PRACE computing facilities from the Netherlands attracts students and researchers, and adds to a competitive academic environment. This in turn is beneficial for the national industry and economy.

Time period

Systems deployed by PRACE are continuously updated and upgraded to be at the apex of HPC technology to meet the needs of the scientific communities and keep up with technical developments.

CONCLUSION

PRACE is an **important** research infrastructure that supports a broad range of Dutch research activities with high demand for intensive computational modelling and data driven approaches. The mission of PRACE is complementary to that of EuroHPC-JU. A future strong partnership will create optimal synergies for the benefit of the European scientific and industrial communities. The positioning of PRACE will depend on the development of this partnership.

SKAO – Square Kilometre Array Observatory

SKA Observatory is an **important** infrastructure for astronomy in the Netherlands. It is a top priority of the Dutch astronomy community.

SYNOPSIS

The SKA Observatory is the next-generation radio astronomy big data facility currently under construction. The SKA Observatory will operate two radio telescopes: the SKA-Low Telescope in Western Australia and the SKA Mid-Telescope in South Africa. Its headquarters are based at Jodrell Bank Observatory in the United Kingdom.

SKAO is a global intergovernmental organisation and the Netherlands is one of the founding members (2019). The Netherlands participated in the SKA project from the beginning – 30 years ago, and contributed to the design and prototyping of parts of the SKA telescope through participation in the design consortia. ASTRON led two of these and was involved in three further design consortia. SKAO just entered the construction phase that will take about 8 years, and is expected to be operational in 2029.

USERS PERSPECTIVE

Once operational, access to SKA can be obtained via calls for proposals that will be largely restricted to scientists from SKA member countries. All SKA data will become public after a proprietary period.

Relevance for the user community

SKAO is not operational yet, but the Netherlands is very much involved in the preparatory activities. Dutch astronomers have leading positions on many of the SKA Science Working Groups (e.g. Cosmic Dawn/Epoch of Reionization, HI, pulsars) and are in prime position with their experience with LOFAR and the Westerbork telescope (WSRT) to reap the rewards from SKA in the coming decade. Research activities with LOFAR, Apertif and MeerKAT (all SKA precursor or pathfinder instruments) are preparing for the science and research that will be done with SKA.

Interests of the Dutch scientific community include:

- studying the formation and evolution of black holes, galaxies and clusters of galaxies;
- detecting the 21-cm signal of neutral hydrogen and characterising it;
- stellar/exoplanet radio emission and Active Galactic Nuclei evolution;
- detecting transients using dedicated pipelines;
- using SKA-Mid to perform ultra-precise localisations of fast radio transients like fast radio bursts (FRBs), pulsars, kilo-novae and tidal disruption events;
- making real-time detections of high-redshift FRBs;
- studying the evolution of the neutral hydrogen gas content of the universe over cosmic time;
- studying galaxy evolution with ultra-high resolution and ultra-sensitive observations of nearby galaxies.

In the future, this research will be very heavily dependent on the SKA, as SKA represents the next big leap forwards and comparable facilities will not be available on similar timescales. SKA-Low and -Mid are felt to be the key instruments to advance Dutch (radio) astronomy, heavily building on the legacy of both science with and leadership in the WSRT and LOFAR.

STRATEGIC PERSPECTIVE

Alignment with national research/strategic agendas

SKA is one of the flagship projects of Dutch astronomy, both in the current 'Strategic Plan 2021–2030 for Astronomy in the Netherlands' and in the previous one. This is also true for European astronomy with a prominent position on the 'ASTRONET Science Vision and Infrastructure Roadmap 2022–2035'. SKA is included on the '2021 National Roadmap for Large-scale Research Infrastructure', and has Landmark status on the ESFRI roadmap. There are links with the Dutch innovation policy (e.g. key enabling technologies, data science) and the Dutch Science Agenda (NWA). The SKA is very much a global endeavor and it is a flagship of radio astronomy. Given the rich Dutch heritage and ambitious plans for the coming decades, participating in SKA is a key priority. The Netherlands (represented by the Ministry of Education, Culture and Science) has joined SKAO, with a financial contribution of M€ 30 from the Ministry and M€ 9.1M from ASTRON.

Impact & outreach

The Netherlands is actively involved in setting up one of the SKA Science Regional Centres at ASTRON. As opposed to SKAO, which is a centralised facility, the network of SKA Regional Centres is a distributed facility. This will require work in smart handling of large data sets, transporting and storing these data sets, and facilitating access to these such that these data sets can also be easily used by non-radio astronomers. This will have an impact beyond just astronomy, as it will require expertise in IT, computing hardware, and software development. The presence of an SKA Regional Science Centre in the Netherlands as a "smart hub" is also felt to have a positive impact beyond astronomy alone in terms of a knowledge and information driven society.

Regarding return on investment: construction activities come with the reward of contracts. Today, ASTRON is already participating in two contracts together with Dutch industry.

Another societal impact is through outreach. SKA pathfinders and precursors are already involved in citizen science projects such as Radio Galaxy Zoo. The SKAO commissioned the Shared Sky exhibition which presents works by Aboriginal Australian and South African artists.

Relation to other (similar) Research Infrastructures

There are other radio telescopes in operation (e.g. LOFAR, EVLA, GMRT, ASKAP, MeerKAT) but the SKA telescopes will be the most sensitive on Earth. Existing telescopes will continue to provide unique and complementary capabilities to SKA-Low and SKA-Mid when operational, in terms of frequency coverage, angular resolution or sky coverage (northern versus southern sky).

Both SKA telescopes will also form part of a global VLBI network which provides the highest resolution to study black holes and distant radio galaxies.

There are synergies with multiple facilities, including:

- **LOFAR** – LOFAR will remain highly competitive in the SKA era as it will have higher angular resolution (international baselines) and will cover lower frequencies. It is also going to be monitoring the northern sky whereas SKA-Low will cover the southern sky.
- **MeerLICHT/BlackGEM** – coordinated observations/follow-up for transient and imaging astronomy

- **ELT** – to obtain deep optical follow-up of key transient events
- **Current ESO facilities** (including ALMA) – multi-wavelength research in all areas discussed.
- **WEAVE** (ING, La Palma) – optical spectroscopy of many of the faint galaxies SKA-Mid will observe

Also for non-radio-astronomers SKA will be of importance, providing synergy with other (upcoming) facilities such as JWST, Euclid, and the Einstein Telescope (SKA can do coordinated follow-up of gravitational wave events).

The Dutch facility FuSE (Fundamental Sciences E-infrastructure) will be the key enabler for the Dutch community to analyse the data and extract the scientific results for the SKA and two other National Roadmap facilities, KM3NeT and experiments at CERN's Large Hadron Collider .

Time period

SKA will remain relevant for at least the next couple of decades, the lifetime of the instrument is 50+ years.

CONCLUSION

SKA Observatory is an **important** infrastructure for astronomy in the Netherlands. It is a top priority of the Dutch astronomy community and the global flagship of radio astronomy. The Netherlands has invested heavily in SKA, and is well positioned to participate both in technical developments and science harvesting.

SLICES – Scientific Large-Scale Infrastructure for Computing/Communication Experimental Studies

SLICES-RI is a research infrastructure under development that supports research in the domain of the design, deployment and operation of digital infrastructures and future internet technologies. SLICES-RI is set to become an **important** infrastructure for Dutch computer science and for experimenting with multi-scale, cross-domain, federated infrastructure solutions. It has the potential to become **important** for data-driven and AI powered scientific applications once the infrastructure transitions to the operational phase.

SYNOPSIS

SLICES-RI (SLICES hereafter) aims to become the first European-wide platform designed to support large-scale experimental research focused on networking protocols, radio technologies, services, data collection, parallel and distributed computing and in particular cloud and edge-based computing architectures and services. SLICES is currently in its Preparatory Phase (SLICES-PP). SLICES-PP strives to position SLICES as an impactful instrument to support European advanced research, industrial competitiveness and societal impact in the digital era.

SLICES is a distributed digital infrastructure with its headquarters at the French National Institute for Research in Digital Science and Technology (INRIA) France. The project has received support from European governments, key stakeholders including industry, and global initiatives. At present 25 partners from 15 countries are involved in the EC-funded SLICES-PP, including the University of Amsterdam (UvA). Following the design phase, SLICES-PP started in September 2022 and will run until the end of 2025. SLICES is included in the ESFRI Roadmap 2021 as a new digital research infrastructure, and has the intention to propose an ERIC.

USERS PERSPECTIVE

Relevance for the user community

SLICES strives to make a fundamental contribution to research and innovation in Digital Sciences and Infrastructures, future Internet technologies, future smart networks and services (e.g. Internet-of-Things, 5G & beyond, cloud/edge). To this end, SLICES will design, deploy and operate advanced testbed infrastructure and tools, including compute, storage and network components required for “on-demand” services, interconnected by dedicated high-speed links between resources made available by diverse universities and research centres (European and internationally). SLICES will also offer services that can be easily integrated into domain specific applications. It is too costly and complex to operate these facilities at the local level. In addition, the set up as a European but internationally operating infrastructure assures scientific interaction and more easy standardisation.

The coordination group of the Dutch node of SLICES (SLICES-NL) includes representatives from UvA, VU, TU Delft, TU Eindhoven, SURF, Nikhef, CWI, TNO, KPMG, NLeSC, DAS6, and ASCI.

SLICES-NL has identified several relevant research areas:

- core technology areas that include infrastructure technologies that will have a continuous long-term evolution: hyper-converged digital infrastructures and high performance networking, data infrastructure and data spaces, new security and compliance models for Complex Cyber Infrastructure;
- application domain areas, which may change depending on advancement of the core infrastructure technologies: trustable/explainable internet-based open networking technologies, federated data analytics and deep learning focused on domain-specific use, support of education on key technologies of the future data centric and cloud enabled infrastructures;
- common infrastructure and services for researchers to support experimental research reproducibility, covering experiment automation and full lifecycle management and including FAIR metadata and data management infrastructure that will be interoperable and federated with the EOSC data management infrastructure. SLICES intends to provide services and support to other non-ICT research infrastructures.

The Dutch community is particularly active in the core technology areas and in the education-related efforts. Currently, research in the abovementioned areas is being conducted at the organisations' own facilities in the framework of projects or grants. As these are limited in size, functionality, and typically project lifetime, the research scope, potential results and possible impact are limited accordingly. SLICES with centralised user access will improve this. The Dutch contribution to SLICES concerns: experimental research reproducibility, covering experiment automation and full lifecycle management, experimental data management infrastructure, ensuring interoperability and federation with the EOSC data management infrastructure. In addition, the UvA will also facilitate creating a SLICES-NL community involving Dutch research organisations and universities. The goal is to define the research agenda for SLICES-NL and coordinate efforts to obtain national funding.

Education & Training

SLICES aims to build capacity by strongly contributing to the education of both students and engineers. The SLICES infrastructure will be used to design e-labs and MOOCs supplied on demand where students can remotely learn, programme, and practice with the technologies that they do not have *in situ*.

STRATEGIC PERSPECTIVE

Alignment with national research/strategic agendas

The Netherlands maintains a leadership position in networking and digital technologies with a strong focus on complex cyber infrastructure, data driven technologies and Artificial Intelligence. Active participation in SLICES will help consolidate and advance digital technologies research in the country. Being part of an active cross-European cooperative network including EOSC, GÉANT and EGI, as well the expected growing international user communities, brings strong and mutual benefits to SLICES-NL.

Among others, SURF is involved in SLICES-NL. Many academics in the Netherlands make use of their services and therefore it is deemed of strategic importance to be involved on an international level. A digital infrastructure such as SLICES can become very relevant for tackling the issues the research community at large will encounter when handling and analysing increasingly large and complex data sets. SLICES also targets to increase research efficiency, sustainability and reducing environmental impact by creating a usable experimental research reproducibility framework and FAIR data management infrastructure. SLICES entered the ESFRI Roadmap in 2021.

Relation to other (similar) Research Infrastructures

National infrastructures for digital research include DAS5/DAS6, SURF testbed facilities, and SURFsara computing facilities. Dutch universities benefit from participation in existing and related US, South-Korean and Japanese research infrastructure projects and testbeds. Internationally the Dutch community collaborates with GÉANT, PRACE, EuroHPC (Europe), projects FABRIC and Bridges, and with ESnet (USA).

Impact

SLICES aims to develop activities that will benefit Europe at a broad range of levels: economic, industrial, research, societal, education. Moreover, SLICES will create an attractive research environment in the Netherlands with a European dimension by supporting and facilitating experimental research reproducibility and FAIR data. This potentially will draw more talent to the country.

Time period

Infrastructure research for digital technologies will follow the typical technology evolution: from lab testing to experimental deployment to production, operation, and services maintenance. This approach will ensure the relevance of SLICES for the core technology area up to 10–15 years. Application domain areas are estimated to remain relevant for 3–5 years as technology and research domains mature.

CONCLUSION

SLICES-RI is a research infrastructure under development that supports research in the domain of the design, deployment and operation of digital infrastructures and future internet technologies. It provides services and tools for experimental research automation and reproducibility and targeting for the environmental sustainability of infrastructures and reducing environmental impact. SLICES-RI is currently in its preparatory phase, with significant involvement from the Netherlands as one of the prospective members. SLICES-RI is set to become an **important** infrastructure for Dutch computer science and digital infrastructure researchers and has the potential to become **important** for data-driven and AI powered scientific applications by the Dutch research community once the infrastructure transitions to the operational phase. SLICES-NL is seeking funding for the national node to be able to influence the consistent and sustainable development of SLICES-RI and to benefit from SLICES-RI.

5.2 Life and Medical Sciences

The characteristics of the Life and Medical Science Research Infrastructures

The sixteen large scale research infrastructures (RIs) in the Life and Medical Sciences domain included in this analysis serve a very large number of researchers (Sector Portrait Biology and Pharmaceutical Sciences 2020, Vision for Chemistry 2040²). They drive frontier research in a wide range of disciplines: from ecology to infectious diseases and structural biology, contributing to advance the scientific knowledge within this wide domain. Moreover, the RIs enable and stimulate multi- and inter-disciplinary research, ranging from the ecosystem to molecular level (figure 1). The **diversity** in disciplines and the scientific development in the research areas served by the RIs is mirrored by the number of RIs and by the difference in their maturity level (design, preparation, construction and operational phases). A common denominator for the RIs is the need for **instrumentation, research facilities and specialised laboratories** coupled to **data platforms** and resources, which in turn require harmonisation and standardisation policies. Importantly, the RIs in the Life and Medical Sciences domain are predominantly **distributed**, with exception of EMBL that is considered multi-site (figure 1).

The Life and Medical Sciences RIs landscape

The ESFRI established in 2002 has greatly influenced the current shape of the RI landscape in the Life and Medical Sciences domain. The aim of supporting the development of “a *coherent and strategy-led approach to policy-making on RIs in Europe, and to facilitate multilateral initiatives leading to the better use and development of RIs*” has nourished a rapid evolution leading to a **dense RI landscape** in this domain and simultaneously has been a major contributor to the development of the European Research Area. All the Life and Medical Sciences RIs within the ESFRI scope are included in its most recent roadmap update (2021). These RIs hold either the *project* or *landmark* status, depending on their maturity level. With the exception of EBRAINS, ELIXIR, ERINHA and EMBL³, the RIs have opted for, or are in the process of establishing an European Research Infrastructure Consortium (ERIC) as legal entity. The Netherlands currently hosts one RI, EATRIS-ERIC in the area of translational medicine, and has the ambition to host DiSSCo(-ERIC), an RI that aims at digitally unifying the European natural sciences collections to enable bio- and geodiversity studies.

² https://www.universiteitenvannederland.nl/files/documenten/Nieuwsberichten/Voor_een_sterker_fundament_sectorbeelden.pdf ;
https://www.nwo.nl/sites/nwo/files/media-files/vision-for-chemistry-2040_0.pdf

³ EMBL was founded as an intergovernmental organization in 1974, which precedes the existence of the ERIC as a legal entity ([2009], Regulation (EC) No 723/2009).

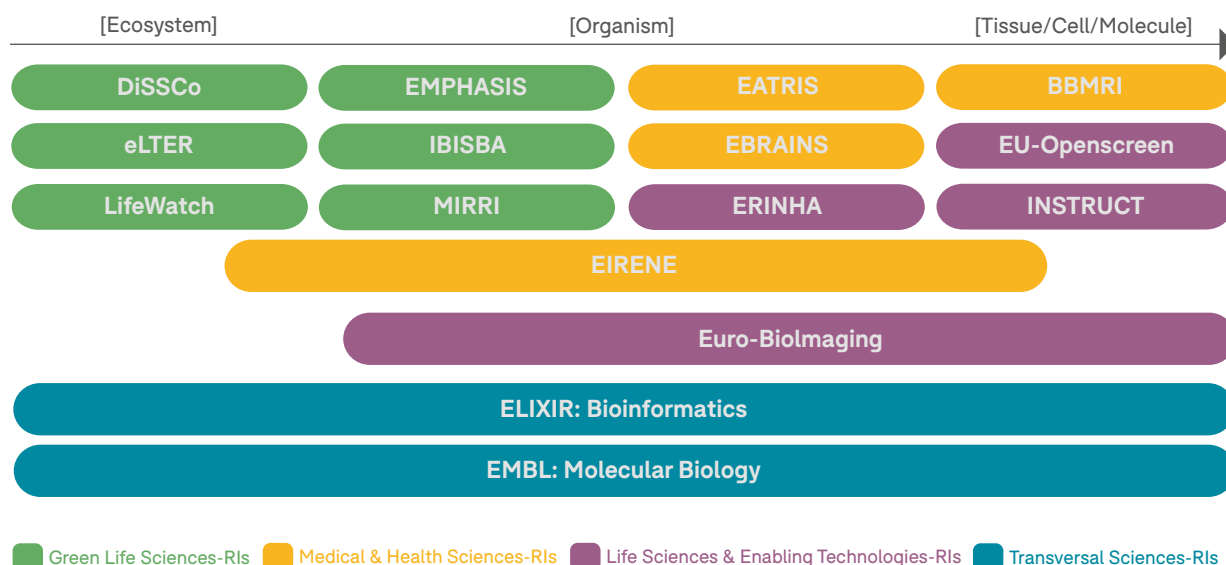


Figure 1: Landscape and interrelation of the sixteen individual large- scale RIs in the Life and Medical Sciences domain. The figure provides an overview of the Life and Medical Sciences RIs domain only. While complementarities and synergies with RIs from other domains exist, *i.e.* the Technical and Natural Sciences domain [Geosciences and Material groups] and the Social Sciences and Humanities domain, they are not herein depicted.

The pivotal role of RIs in advancing scientific research has been acknowledged by the research community in their Sector Portraits. Furthermore, the recognition that highly specialised personnel supporting RI activities is essential, has been alluded to and accounted for in their Sector Plans. Nonetheless and up to now, the Dutch participation in EU RIs remains mostly driven by the participation at research group level (or consortia between research groups), by means of participation in European Framework programmes. As a consequence, the visibility of a Dutch node of an international RI within and beyond a faculty or even an university remains confined.

The link between European and the National Roadmap Large-scale Research Infrastructure

The consortia and initiatives that form the Dutch nodes of European RIs are often included in the National Roadmap for Large-scale Research Infrastructure 2021 and are currently distributed over the four Groups within this domain: Green Life Sciences; Life Sciences and Enabling Technologies; Medical Sciences and Health Sciences.

Conclusions and suggested actions

The Dutch participation in the sixteen European RIs is of fundamental **importance** to the Life and Medical Science domain, as it brings **volume** and **scale** to the research activities at an extent that cannot be achieved by any single European country. Furthermore, it enables the scientific community to take and maintain an internationally leading role at the forefront of science. The potential for **joint research activities, technological co-development** and participation in **training and educations** programmes adds further value to the Dutch research activities. Finally, participation in European RIs increases the **visibility** of the Dutch resources and facilities, translating to a direct benefit for the Dutch research community.

The Life and Medical Sciences domain is **highly dynamic, complex and multidisciplinary** as it represents a sizeable research community with a wide spectrum of interacting disciplines, served by the variety of RIs with diverse stakeholders. To keep up with unprecedented scientific and technological innovation developments at such a fast evolving pace, it is evident that a long-term strategy is needed, both in terms of decision making, as well as in long-term financing and planning. **Coordination and positioning** of the RIs in the domain, is now opportune and needed. Refraining to steer for a concerted and coordinated approach may pose a **risk of fragmentation of activities** and may lead to resource duplication and service redundancy.

In addition to thematic and disciplinary focused RIs, and to enable a meaningful positioning of each RI, there is a clear need for 'backbone' RIs that transversally serve the entire domain (EMBL: Molecular Biology and ELIXIR: Bioinformatics). Moreover further coordination and improved collaboration among RIs at (inter)national levels needs to be continuously stimulated and its outcomes periodically monitored. Examples of such efforts in this domain can already be highlighted. At European level, in 2021, an alliance between BBMRI, EATRIS, ECRIN was rooted in EU-AMRI. In 2022, a memorandum of understanding formalised the collaboration between INSTRUCT, EU-OPENSOURCE and Euro-Biolmaging. More recently the formal collaboration between ELIXIR and BBMRI was realised (2023).

At national level, coordination efforts are also ongoing in the context of the National Roadmap for Large-scale Research Infrastructure within the Group process. LifeWatch, eLTER, DiSSCo, IBISBA, EMPHASIS and MIRRI join forces within the Group Green Life Sciences by means of joint project applications. Similar collaboration is observed between the national nodes of INSTRUCT, EU-OPENSOURCE, Euro-Biolmaging within the Life Science and Enabling Technologies Group as well as between EATRIS, BBMRI and ELIXIR (integrated in Health-RI) in the Health Sciences Group. These concerted actions should be further supported, developed and implemented.

The RIs in the preparatory and implementation phases (DiSSCo, eLTER, EMPHASIS, EIRENE, IBISBA) can benefit from **raising awareness** to their services, resources and training activities. This will ultimately lead to wider support, higher user numbers and increased development of joint research activities. The Netherlands is not yet a member in MIRRI, EU-OPENSOURCE (operation phase).

For all RIs, whether in the preparatory or operational phases, and while considering future participation of the Netherlands as (founding) member, it should be clear that (financial) commitment needs to be considered for a minimal period of five years, and ideally for a longer period.

The analysis provided in this report on the value of the Dutch participation in international RIs can be interpreted as a starting point, *i.e.* a '*baseline measurement*' and should be followed up with a **periodic monitoring** of the (r)evolution in the domain in order to facilitate decision making, positioning and as basis for future financing.

List of memberships

Green Life Sciences

DISSCo

The Distributed System of Scientific Collections is a Research Infrastructure for Natural Science Collections

<https://www.dissco.eu/>

Countries: NL, BE, BG, DK, EE, FR, GR, IT, PT, SK, UK

Legal entity: ERIC (application stage)

EMPHASIS

The European Infrastructure for Multi-scale Plant Phenomics and Simulation for Food Security in a Changing Climate aiming at enabling researchers to use facilities, resources and services for plant phenotyping across Europe

<https://emphasis.plant-phenotyping.eu/>

Countries: DE, BE, CH, CY, EE, FR, IE, IL, IT, NL, RS, UK

Legal entity: ERIC (application stage)

eLTER

Integrated European LongTerm Ecosystem, Critical Zone & Socio-ecological RI aiming at facilitating the understanding of the complex interactions between people and nature over the long term

<https://www.elter-ri.eu/>

Countries: DE, AT, BG, CH, CZ, ES, FI, FR, GR, IL, IT, LV, PT, RO, SI, SK, UK, (NL)

Legal entity: ERIC (application stage)

IBISBA

European Research Infrastructure for Industrial Biotechnology aiming at provide a single access point to researchers from academia and industry across the globe to integrated services for end-to-end bioprocess development

<https://www.ibisba.eu/>

Countries: FR, BE, ES, FI, GR, IT, NL

Legal entity: ERIC (application stage)

LifeWatch

e-Science Research Infrastructure for biodiversity & ecosystem research providing e-Science research facilities to scientists investigating biodiversity and ecosystem functions and services in order to support society in addressing key planetary challenges

<https://www.lifewatch.eu/>

Countries: ES, BE, GR, IT, NL, PT, SI

Legal entity: ERIC

MIRRI

Microbial Resource Research Infrastructure distributed Research Infrastructure for the preservation, systematic investigation, provision and valorisation of microbial resources and biodiversity

<https://www.mirri.org/>

Countries: PT, BE, ES, FR, LV, (NL, RO)

Legal entity: ERIC

Life Sciences & Enabling Technologies

ERINHA

European Research Infrastructure on Highly Pathogenic Agents, a distributed Research Infrastructure dedicated to the study of high-consequence emerging and re-emerging pathogens

<https://erinha.eu/>

Countries: FR, HU, PT, NL

Legal entity: AISBL

EU-OPENSREEN

European high capacity screening network for chemical biology and early drug discovery

<https://www.eu-openscreen.eu/>

Countries: CZ, DK, ES, FI, LV, NO, PL, (NL)

Legal entity: ERIC

EuroBioImaging

European Research Infrastructure for Imaging in Biological & Biomedical Sciences providing open access to imaging technologies, training and data services in biological and biomedical imaging

<https://www.eurobioimaging.eu/>

Countries: FI, AT, BG, CZ, DK, FR, HU, IL, IT, NL, NO, PL, PT, SE, SI, UK, EMBL, (BE)

Legal entity: ERIC

INSTRUCT

pan-European Research Infrastructure in structural biology providing open access to high-end structural biology services and techniques

<https://instruct-eric.org/>

Countries: UK, BE, CZ, DK, ES, FI, FR, IL, IT, LT, LV, NL, PT, SK, EMBL, (GR)

Legal entity: ERIC

Medical & Health Sciences

BBMRI

The Biobanking and Biomolecular Research Infrastructure offers access to biosamples, images and data, to tools to capture, integrate and analyse data, and support on ethical, legal and societal implications

<https://www.bbmri-eric.eu/>

Countries: AT, BE, BG, CZ, DE, EE, FI, GR, HU, IT, LV, MT, NL, NO, PL, SE, (CH, CY, TR, IARC/WHO)

Legal entity: ERIC

EATRIS

The EU Infrastructure for Translational Medicine provides access to a vast array of pre-clinical and clinical expertise and facilities

<https://eatris.eu/>

Countries: NL, BG, CZ, ES, FI, FR, IT, LU, NO, PT, SE, SI, HR, LV

Legal entity: ERIC

EBRAINS

Digital research infrastructure for brain research, an open research infrastructure that gathers data, tools and computing facilities for brain-related research, built with interoperability at the core

<https://www.ebrains.eu/>

Countries: FR, BG, CH, DK, ES, GR, IT, NL, NO, SE

Legal entity: AISBL

EIRENE

Environmental Exposure Assessment Research Infrastructure, aiming at fill the gap in the European infrastructural landscape on human exposome

<https://www.eirene-ri.eu/>

Countries: CZ, AT, BE, DE, ES, GR, IS, IT, NL, SK

Legal entity: ERIC (application stage)

Transversal Sciences

ELIXIR

Distributed infrastructure for life-science information, bringing together life science resources from across Europe, including databases, software tools, training materials, cloud storage and supercomputers

<https://elixir-europe.org/>

Countries: EMBL, BE, CH, CZ, DE, DK, EE, ES, FI, FR, GR, HU, IE, IL, IT, LU, NL, NO, PT, SE, SI, UK, (AT)

Legal entity: Consortium Agreement

EMBL

European Molecular Biology Laboratory is the European Life Sciences Laboratory covering the spectrum of molecular biology research

<https://www.embl.org/>

Countries: DE, AT, BE, CH, CZ, DK, EE, ES, FI, FR, GR, HR, HU, IE, IL, IS, IT, LT, LU, ME, MT, NL, NO, PO, PT, SE, SK, UK

Legal entity: Intergovernmental Organisation

BBMRI — Biobanks and Biomolecular Resource Infrastructure

BBMRI is an **important** research infrastructure providing coordinated, transnational access to a wide collection of biomaterials, data & images and IT tools. The extent of resources provided and the opportunities for joint research, covering a wide spectrum of diseases, is only possible by pooling European resources together.

SYNOPSIS

BBMRI is a **distributed** research infrastructure providing coordinated access to European biobanking collections and services (quality management, ELSI (Ethical, Legal and Societal Implications) expertise, open and accessible research IT software and tools to support biomedical research. This in turn, contributes to a better understanding of disease aetiologies, ultimately leading to new treatments in the personalised medicine era. Currently in the **operational phase**, BBMRI is an established European Research Infrastructure Consortium (**ERIC**) since 2013, with the *landmark* status in the ESFRI roadmap (2021). Organised as a **Hubs & Nodes** model, BBMRI-ERIC is hosted by Austria and counts 24 European member states: 18 full members and 6 observers, including the International Agency for Research on Cancer (IARC/WHO). **Access** to BBMRI facilities, resources and services is coordinated by the central hub but access to the national facilities is arranged via the national nodes.

The Netherlands is one of BBMRI's founding members, with the Dutch node BBMRI-NL one of the largest contributors. BBMRI-NL resources represent 43% of the total collections and bring together 115 national organisations/biobanks. BBMRI-NL has been leading BBMRI central IT services (directory) as well as initiating the discussion on ELSI. Recognition of the importance of collaborative research is illustrated by its integration both at national level in Health-RI, together with EATRIS-NL and ELIXIR-NL, as the national infrastructure for health research, and at EU level via Alliance of Medical Research Infrastructures (EU-AMRI), with EATRIS (translational medicine) and ECRIN (clinical trials).

USERS PERSPECTIVE

By providing coordinated, transnational access to biobanking resources, collections, findable, accessible and interoperable data & IT tools, research on the areas of genomics and metabolomics, pathology, cohorts & registers and imaging genetics, extensive support is provided to the biomedical research community. Access to BBMRI services benefits research activities on a wide spectrum of diseases: oncology, cardiovascular, neurodegenerative, infectious and rare diseases; the COVID-19 pandemics is a pertinent example.

Relevance for the user community

Dutch biomedical researchers rely and are dependent on state-of-art biobanking resources and services, which are in compliance with ethical, legal and privacy demands. The services provided by BBMRI enable the findability, exchange and use of collections of biomedical data, biomaterials and images. The latter is illustrated by the dependence on the XNAT platform (imaging platform) which enables the sharing of images, (meta-)data and analysis among international researchers. Other concrete examples are the [BBMRI.nl](https://bbmri.nl) Catalogue and the request management tool PODIUM, which

are completely integrated. This specifically means that a researcher can benefit from a single system beyond the Dutch borders to request data, samples and images. Furthermore the support on ELSI provided via the ELSI service desk and development of biobanking quality management standards and procedures, is equally defined as crucial for the Dutch research community.

Education & training

BBMRI offers an extensive training catalogue in three main pillars: i) quality management in biobanking (international standards, procedures and certification), ii) Ethical, Legal, Societal Implications (ELSI) and iii) General Data Protection Regulation (GDPR).

STRATEGIC PERSPECTIVE

Alignment with national research/strategic agendas

BBMRI is prioritised in the National Roadmap for Large-scale Research Infrastructure (2021): Group Health Sciences, in which emphasis is given to the establishment of a Federated Dutch Cohort Infrastructure (NCC). BBMRI is prioritised in the strategic NWO-Round Table Life Sciences Research Communities 'Biology of molecules, cells and tissues', 'Advance methods, analyses and data to understand the living system' and in line with the priorities described in the Sector Portrait Biology (2020) 'Building blocks of life' pillar. The research activities enabled by BBMRI fit well with the ZonMw Policy Plan 2020–2024, in which the need for collaborative projects supported by knowledge infrastructures as learning networks is highlighted. BBMRI resources support the research prioritised in the Top Sector Life Sciences & Health, several Dutch Research Agenda lines and Knowledge and Innovation Agenda missions. Internationally, BBMRI resources support the prioritised research in the EU missions (Mission Cancer and more broadly EOSC). Research enabled by BBMRI resources and services is thus well aligned with different national and international strategic agendas.

National & International dimensions

Participation of Dutch researchers in BBMRI is of importance to biomedical researchers as it provides coordinated access to a wide catalogue of European biobank resources. Dutch biobank resources (collections) and expertise (IT tools and ELSI) benefit from the beyond border exposure, as it increases its usage, as evidenced by the increased number of user requests. Consequently, opportunities are created for joint research activities, advancing the understanding of diseases aetiologies. Also population (cohort) studies benefit at an extent that is not possible in a single country. Conversely, BBMRI-ERIC largely benefits from the Dutch contribution in two distinct ways: i) by the inclusion of a large network of Dutch biobanks, bioresources, collections and derived expertise. Noteworthy that Dutch collections currently represent 43% from the total BBMRI catalogue; ii) by making use of the Dutch expertise on IT solutions, in which the most prominent example is the Dutch contribution to the BBMRI-ERIC directory (main interface/database), based on the open source software MolGenis, developed by the BBMRI-NL (UMCG team).

Relation to other (similar) Research Infrastructures

Synergies were identified and collaboration activities developed and formalised at European level by means of the establishment of the Alliance of Medical Research Infrastructures, with EATRIS (translational medicine) and ECRIN (clinical trials). Collaboration with ELIXIR, as the backbone transversal data infrastructure for biomedical research, has been recently formalised (2023).

Impact & outreach

The wider societal impact of BBMRI can be best described by the unprecedented level of sharing biomaterials and data from large population (cohort) studies, clinical registries and methodologies, among the European biomedical community via conferences, workshops and symposia. The knowledge herein generated contributes to address several challenges and contributes to advance personalised medicine. This is not easy to quantify and its impact may be only visible in the next generations of Europeans, for instance on the development of prevention strategies based on long-term population (cohort) studies. Worth mentioning is the yearly EU Biobank Week organised by BBMRI and Europe's largest biobanking conference. It attracts researchers, technical staff (academy and private sectors), patients representatives and policy makers and the Dutch community actively participates therein.

Time period

BBMRI is expected to remain relevant for longer than ten years, provided that the upgrade of its facilities and IT tools is accounted for.

CONCLUSION

BBMRI enables the biomedical research community to have coordinated access to findable biomaterial, interoperable datasets and images and specific expertise (biobanking quality management, certification and ELSI areas). Access to an European biobanking infrastructure is of importance to better understand disease aetiology and consequently, to support the development of new treatments in a wide spectrum of diseases.

The Netherlands has a leading role and has been a key member in BBMRI-ERIC since its foundation. It provides strong expertise, contributes to essential elements of BBMRI (*i.e.* Catalogue) and makes its collections available at a pan-European level. The fact that the research community recognises and acts on the need to intensify the collaboration among the research infrastructures in the Health domain nationally (through Health-RI) and internationally (through EU-AMRI) is considered an important development. BBMRI counts with a significant number of members and observer countries, however the consequences of recent withdrawal of the UK and France from BBMRI-ERIC and its consequences for the Dutch researchers should be carefully monitored.

DISSCO – DISTRIBUTED SYSTEM OF SCIENTIFIC COLLECTIONS

DiSSCo is very well positioned to be an **important** infrastructure for research in geo- and biodiversity areas as it will enable physical and virtual access, via a single entry point, to European digitised natural sciences collections.

SYNOPSIS

DiSSCo aims to be the virtual, **distributed** research infrastructure, linking the major European Natural Sciences collections, by means of digitised natural specimens information to build an **open access** infrastructure of FAIR Digital Objects. Research on geo- and biodiversity, global change as well as on data science and digitisation will be enabled by DiSSCo resources. Currently concluding the **preparatory phase**, DiSSCo counts with 23 countries and CETAF (Consortium of European Taxonomic Facilities) and is progressing well to establish an European Research Infrastructure Consortium (**ERIC**) as legal entity by the end of 2024. DiSSCo has the *project* status in the ESFRI roadmap (2021). DiSSCo will follow a central **Hub & Nodes** governance model. Access to DiSSCo resources has mostly been enabled by transnational access calls (TNA), in DiSSCo related projects. At national level, Naturalis hosts the coordination and support office and has been coordinating DiSSCo during the preparatory phase (2019–2022); by means of projects as SYNTHESIS, dealing with access to digital collections and joint research activities, and MOBILISE concerning staff training and research networking activities. By working towards mass digitisation of Natural Science Collections (NSC), striving for a digital unification of its assets under common curation and **open access data policies**, in a harmonised manner across Europe, DiSSCo is an unique infrastructure for geo- and biodiversity, global change and environmental monitoring research areas. Given the role that Naturalis has been playing thus far, Naturalis and thereby the Netherlands, will be well positioned to host the statutory seat of DiSSCo-ERIC.

USERS PERSPECTIVE

DiSSCo will provide e-services, digitisation and physical access to collections as well as training and consulting services. This will be supported by a back office sustaining the IT infrastructure, data curation and preservation as well as provision of users support. Given that DiSSCo is transitioning between the preparatory (2019–2022) and the construction phases (2024–2026), considerations on the support and relevance for its user community are based on the progress achieved and on the assumption of its current potential to serve the needs of the geo- and biodiversity research community.

Relevance for the user community

DiSSCo has no direct users yet. Within the DiSSCo-SYNTHESIS four subsequent projects (2004–2023), user needs have been surveyed and (transnational and virtual) access to Natural Science Collections (NSC) has been provided. Transnational access calls constitute a suitable indicator to estimate the user numbers as well as to anticipate the community needs. In that period, a total of >10.000 requests have been received, of which 4.000 have been approved, leading to >1.500 scientific outputs i.e., papers, monographs and theses. DiSSCo has the potential to extensively support geo- and biodiversity research activities. These will strongly benefit from the aggregation

and coordination level that DiSSCo will bring above the current local NSC management systems. Naturalis is one of the partners of the ARISE project (National Roadmap call 2021), which aims at constructing an infrastructure to identify and monitor every eukaryotic species in the Netherlands. Knowledge derived from ARISE, as reference datasets for instance, is expected to feed in the international context.

Education & training

During its preparatory phase and within MOBILISE project (COST Action: 2018–2023), DiSSCo provided four annual courses on data mobilisation and digitisation of small and medium collections, facilitated staff exchange missions (19 exchange missions, 2019) and published 9 papers (2018–2019). When in the operational phase, it is foreseeable that DiSSCo will further focus on transfer of knowledge, capacity building and user support as (one of the) core services provided by DiSSCo-RI.

STRATEGIC PERSPECTIVE

Alignment with national research/strategic agendas

Research on 'Adaptation & Evolution' and 'Monitoring of Geo- & Biodiversity' in the context of 'Global Change' is prioritised in several strategic research agendas such as the Sector Portrait Biology (2020), the NWO Round Table Life Sciences (2020) research community on 'Advanced methods, data and analysis from a better understanding of living systems' and the research community on 'Life and planet'. Naturalis is included in the National Roadmap for Large-scale Research Infrastructure (2021): Group Green Life Sciences. More broadly, initiatives as BiodiversityXL and Deltaplan *Biodiversiteit* have been put forward, and funding lines are available within the Dutch Research Agenda and Knowledge and Innovation Covenant. At European level, several EU missions (*ie.* EU-Green Deal, EU Biodiversity strategy 2030) and different partnerships (Biodiversa*), demonstrate the strategic importance given to geo- and biodiversity research. The services and resources provided by DiSSCo are well aligned with the (inter)national priorities.

National & International dimensions

DiSSCo-NL is a consortium of 14 members and 3 additional partners (natural history museums, research institutes and national nodes of Global Biodiversity Information Facility (GBIF). The value of the Dutch participation in DiSSCo pertains to the physical access (archive function), which is complemented by the digital access to NSC, and thereby, of crucial relevance to the Dutch researchers. For each NSC specimen, DiSSCo infrastructure will create its digital specimen, including persistent identifier and machine-actionable metadata, acting as a 'digital twin'. This will enable the (re-)use of validated (taxonomic) data that can be enriched by other researchers data (morphological, chemical, genetics, etc). The contribution of DiSSCo to the development and implementation of an open-source FAIR Digital Objects is thus evident. DiSSCo is partner in ENVRI-FAIR as a cluster of Environmental & Earths Systems research infrastructures with a close linkage to EOSC.

Relation to other (similar) Research Infrastructures

Complementarities were identified with eLTER, in which the information provided by DiSSCo at species level is complemented with information at community level provided by eLTER; LifeWatch offers the e-services to access data, which is provided among others by DiSSCo; ELIXIR, by linking the NSC specimens information to the nucleotide sequence information (DNA & RNA databases). In the context of networks of collections, such as Global Biodiversity Information Facility (GBIF), Catalogue of Life (CoL) information services, Biodiversity Heritage Library and International Barcode of Life (iBOL), the common factor is the link needed to the digital specimens available and provided by DiSSCo.

Impact & outreach

Given its contribution to the digitisation of NSC, DiSSCo's impact will be visible in the training and innovation areas by, for instance, the development of new training curricula and capacity building on digital skills for collection managers, RI staff and researchers.

Time period

The DiSSCo resources once available will be of permanent nature, as they deal with the preservation and the digitisation of existent NSC. In line with the fast evolving area of data science, it can be anticipated that continuous development of DiSSCo digital resources will be required.

CONCLUSION

DiSSCo will provide coordinated access to NSC via a single entry point and thereby, is well positioned to advance scientific research in geo- and biodiversity areas. These areas were defined as (inter)national research priorities and significant national investments have been made. Research on geo- and biodiversity can only be addressed at a global scale. Therefore policy development and investments are counterparted at European level. DiSSCo is currently in the transition phase, with operations expected to start in 2026. Naturalis, as coordinator of DiSSCo during the preparatory phase, plays a leading role in coordinating and advancing the (digital) access to the European NSC. DiSSCo is well positioned to foster the needed collaboration with other (inter)national infrastructures and networks.

EATRIS – European Advanced Translational Research Infrastructure in Medicine

EATRIS is a research infrastructure that enables the translation from fundamental and applied medical knowledge to clinical implementation and practice. It is an **important** infrastructure for the Dutch (bio-)medical sciences researchers.

SYNOPSIS

EATRIS is a **distributed** research infrastructure providing pre-clinical and clinical services, platforms and expertise focusing on optimising preclinical and early clinical development of drugs, vaccines and diagnostics. Currently in the **operational phase**, EATRIS is an established European Research Infrastructure Consortium (**ERIC**) since 2013, with the *landmark* status in the ESFRI roadmap (2021). Following a **Hubs & Nodes** model, EATRIS counts 14 European member states, representing more than 140 academic centres. **Access** to EATRIS services and platforms is subjected to pre-defined EATRIS criteria (applicable to academy and industry). **Open access** to FAIR data is encouraged by EATRIS, although under the responsibility of the individual institutions and under contract. The Netherlands is the host country and coordinates the activities of EATRIS-ERIC. The Dutch researchers co-lead three from the five EATRIS platforms: i) Vaccines, Inflammation & Immunomonitoring; ii) Biomarkers iii) Imaging & tracing. Recognition of the importance for collaborative health research is illustrated by its integration at the national level in Health-RI, as the national data infrastructure for health research. In addition, the need to create a collaborative R&D infrastructure environment to support the Dutch pharma & biotech research community has been strengthened by two National Growth Fund initiatives: PharmaNL and Onco-PACT, as well by the establishment of the Centre for Future Affordable Technologies and Sustainable Therapy Developments (FAST).

USERS PERSPECTIVE

EATRIS focuses on preclinical and early clinical development of drugs, vaccines and diagnostics. The service ranges from consultation service on Health Technology Assessment (HTA), COVID-19, rare disease, regulatory affairs, funding opportunities, industry-academia collaboration, to translational feasibility assessment which have been organised in five platforms: i) advanced therapy medicinal products, ii) imaging and tracing, iii) small molecules, iv) vaccines and v) biomarkers. EATRIS offers support on regulatory services as well as mentoring services. These are targeted at both academic and industry users. Specifically, within the EATRIS biomarkers platform synergies with the X-Omics Initiative (National Roadmap for Large-scale Research Infrastructure, 2018) were identified, in which data integration techniques developed for multi-omics approaches can be applied in EATRIS. Similarly, the EATRIS imaging and tracing platform enables technological developments and generates additional research projects. Taken together, it can be concluded that research activities are **supported** by the access to EATRIS.

Relevance for the user community

EATRIS, as the research infrastructure supporting the translation of fundamental knowledge into the clinical implementation, provides access to a vast array of pre-clinical and clinical expertise and facilities. As illustration, the research community working on a wide range of diseases, from oncology to rare diseases, are to some extent dependent on the knowledge aggregated in the different EATRIS platforms as imaging and biomarkers.

Education & training

EATRIS offers an extensive training catalogue on translation medicine related topics from gene therapy to regulatory affairs and Good Manufacturing Practices guidelines. The EATRIS educational activities are open to academic institutions, to private partners (pharma, biotech) and to regulatory organisations.

STRATEGIC PERSPECTIVE

Alignment with national research/strategic agendas

EATRIS is prioritised in the National Roadmap for Large-scale Research Infrastructure (2021): Group Health Sciences. EATRIS activities support the priorities described in the Sector Portrait Biology (2020) 'Building blocks of life' pillar as well as in the ambitions described in the Sector Portrait Pharmaceutical Sciences (2020). EATRIS is equally included in the strategic NWO-Round Table Life Sciences- Research Communities 'Biology of molecules, cells and tissues', 'From genes to organisms' and 'Advanced methods, analyses and data to understand the living system'. Likewise, the research activities enabled by EATRIS fit well with the ZonMw Policy Plan 2020–2024, in which the need for collaborative projects supported by knowledge infrastructures as learning networks, is highlighted. EATRIS supports the ambitions of FAST. In a broader context, EATRIS platforms support the research prioritised in the Top Sectors Life Sciences & Health and High Tech Systems and Materials, several Dutch Research Agenda lines and in the Knowledge and Innovation Agenda: Health & Care; Key Enabling Technologies missions. Internationally, EATRIS platforms support the prioritised research in the EU missions (Mission Cancer and more broadly EOSC) and several UN-SDGs. It can be concluded that research enabled by EATRIS resources and platforms is thus well aligned with diverse (inter)national strategic agendas.

National & International dimensions

Participation of Dutch researchers in EATRIS is of importance as it provides access to a wide range of platforms and services, creating opportunities for joint R&D activities, which otherwise would not be possible in a single country. A suitable example is the research on rare cancers and rare diseases that largely benefit from access to expertise and data in a wide, cross border context. Another example is the research on infectious diseases and consequently also the preparedness to pandemics (evidenced during the COVID-19 pandemic), which benefits from a concerted, European approach. Participation in EATRIS brings equally visibility to Dutch R&D activities. Conversely, EATRIS-ERIC largely benefits from the Dutch contribution as it enables other European researchers to have access to the expertise areas in which the Netherlands is particularly strong: Imaging, biomarkers and pre-clinical development. Moreover, the level of funding recently awarded to national initiatives, Health-RI (data infrastructure), Pharma-NL (new therapies and [academic] drug development & repurposing), Oncode-PACT (pre-clinical development in oncology) positions the Netherlands as a knowledge & innovation hub and thereby, a demonstrator to other European countries.

Relation to other (similar) Research Infrastructures

In the European context, complementarities can be identified with Euro-Biolmaging and with EU-OPENSOURCE, in terms of imaging and compound screening platforms, respectively. Both research infrastructures focus on collecting fundamental knowledge, whereas EATRIS focuses on the translation of fundamental knowledge to application in clinical practice and thereby collaboration is needed. Moreover, collaboration activities were recently formalised at European level within the context of the Alliance of Medical Research Infrastructures (EU-AMRI), with BBMRI (biobanking and biomolecular resources) and ECRIN (clinical trials). Collaboration with ELIXIR, as evidenced in the context of European initiatives as EOSC-Life, BY-COVID and EOSC4Cancer should be further strengthened.

Impact & outreach

The impact of EATRIS can be described in two ways: i) the societal impact of a translational medicine infrastructure, in which the translation of findings from the scientific context to its implementation in the clinical setting has a direct benefit for the (ageing) European population, and as such contributing to address several societal challenges in the areas of Health & Care; and ii) economic impact by generation of knowledge, opportunities for co-development with the Biotech and Biopharma industry, and thus generating and maintaining jobs and attracting further (private and public) investment.

Time period

EATRIS is expected to remain relevant to its research community for a period longer than ten years.

CONCLUSION

EATRIS serves the European biomedical research community by providing coordinated access and expertise to pre-clinical and early clinical development of drugs, vaccines and diagnostics. The Netherlands, with strong expertise and leading several EATRIS platforms (*i.e.* imaging, biomarkers, vaccines), benefits and strongly contributes to EATRIS. In view of recent investment by the National Growth Fund, the establishment of FAST and by formalised collaborations both at national (BBMRI-NL, ELIXIR-NL through Health-RI) and at European level (ECRIN, BBMRI), EATRIS activities will most likely be strengthened and therefore of added value to the Dutch research community.

EBRAINS – European Brain ReseArch INfrastructures

EBRAINS is a research infrastructure serving the neurosciences research community by providing coordinated access to a wide catalogue of digital services and tools to advance the study of the brain, and consequently **important** for the Dutch research community.

SYNOPSIS

EBRAINS is a **distributed** digital research infrastructure aiming at accelerating the understanding of human brain function and disease, by providing digital tools for brain research and brain-inspired technology development. The tools assist researchers to collect, analyse, share, and integrate brain data as well as to perform modelling, simulation and emulation of brain function, aided by neuromorphic computing and robotics. EBRAINS builds upon the efforts from the Human Brain Project (HBP: 2013–2023), being also one of its co-founders.

EBRAINS is an International non-profit Association under Belgian Law (**AISBL**, 2019), with the *project* status in the ESFRI roadmap (2021). EBRAINS counts with participation of nine institutions as full members from nine European member states, and each full member represents other, associated members. In view of the extensive number of organisations listed as prospective members, an expansion in the number of (full) member organisations can be anticipated. EBRAINS is centrally coordinated by Belgium. **Access** to EBRAINS digital services and tools, is laid down in the EBRAINS access policy and structured in two levels: i) open access, and ii) registered/controlled access to specific data sets. Human datasets made available through EBRAINS services comply with the General Data Protection Regulation (GDPR) provisions. Dutch political support has been provided to the EBRAINS initiative (ESFRI context). The University of Amsterdam has led the Dutch node of EBRAINS, EBRAINS–NL (2015–2022) while, Radboud University (Nijmegen), is the full member and represents the Dutch interests at the level of the board. EBRAINS–NL has been included in the National Roadmap for Large-scale Research Infrastructure (2021): Group Health Sciences and investment for a different but related initiative has been provided to the DYNAMIC consortium (NWO Large-Scale Research Infrastructure call 2021).

USERS PERSPECTIVE

EBRAINS provides an extensive catalogue of digital services and tools, structured in six categories: i) Data & knowledge: enabling the finding and sharing of data tools and software, ii) Brain atlases: providing reference systems for neuroscience, and thereby enabling the navigation, characterisation and information analyses on the basis of anatomical location in different organisms, iii) Simulations: as an instrument to allow the interchange between experiments and theory, iv) Brain inspired technologies, including robotics and neuromorphic computing, allowing better understanding of neural networks, v) Medical data analysis: a platform providing analytics for diagnosis and research in clinical neuroscience, and vi) Community: offering a collaborative workspace, computing and storage resources. As such, EBRAINS supports the Dutch neurosciences/neurobiology community, by making its platforms and resources available and accessible.

Relevance for the user community

The Dutch research community is dependent on the EBRAINS data and e-tools and benefits from access to a wide range of services, tools and expertise that otherwise would not be available at a single country level. As illustration, individual Dutch researchers (groups) benefit from the opportunity to share their data so that it can be re-used and re-integrated by other researchers performing integrative analyses and as such, of added value. Dutch researchers in turn provide knowledge, tools and services for worldwide brain research and contribute with data from fundamental, clinical and neurotechnological research, which is curated in the EBRAINS Knowledge Graph according to FAIR data principles.

Education & training

Given the academic institutions that are members of EBRAINS–AISBL, training and education activities occur under the umbrella of those organisations. European coordination of training has been provided by HBP and is now being continued by EBRAINS members. It can also be anticipated that a central training catalogue will be developed, during the current preparatory phase, under the EBRAINS remit of activity.

STRATEGIC PERSPECTIVE

Alignment with national research/strategic agendas

EBRAINS-NL is prioritised in the National Roadmap for Large-Scale Research Infrastructure (2021): Group Health Sciences. It is also included in the Sector Portrait Biology (2020)– ‘Building Blocks of Life’ pillar particularly aligned with the priorities from the neurobiology research community. In a broader national context, EBRAINS supports the research prioritised in the Top Sectors Life Sciences & Health, High Tech Systems & Materials, Dutch Digital Delta (Team ICT), as well as several Dutch Research Agenda routes and in Knowledge and Innovation Agenda: Health & Care; Key Enabling Technologies missions. At European level, building upon the HBP FET Flagship initiative and by contributing to EOSC, there is a clear alignment with the EU Strategic Research Agendas. It can be concluded that research enabled by EBRAINS facilities is aligned with specific national and international strategic agendas.

National & International dimensions

Participation of Dutch researchers in EBRAINS is important as it provides coordinated access to a digital network of data services and e-tools. Particularly, EBRAINS provides access to curated and findable data (*i.e.* knowledge graphs) as well as the simulation services that enable large scale computer modelling and analysis. Access to such broad catalogue of services and experimental techniques is not possible by a single national consortium (either by the lack of specific expertise or by the lack of human (FTE) capacity). In addition, by having Dutch research(ers) contribute to the EBRAINS network by providing their own unique tools and services, opportunities for joint research activities are created and the visibility for the Dutch specific areas of expertise within the neurosciences is enhanced. Conversely, EBRAINS benefits from the Dutch contribution, as it provides specific expertise in the areas of theoretical and computational neurosciences, digital brain health and neuroprosthetics, unique expertise that has been consolidated, through the Dutch Neurotechnology Consortium (Neurotech-NL) and related initiatives *ie.* EBRAINS-NL consortium formation (National Roadmap for Large-scale Research Infrastructure), the Dutch NanoLabNL consortium for research on intelligent nanomaterials and consortia engaging in brain-inspired neuromorphic computing.

Relation to other (similar) Research Infrastructures

Currently there is no other European knowledge network/research infrastructure that compares with EBRAINS given its specific research area on one side and on the other side by the fact that EBRAINS builds upon the collaborative work already developed during the HBP. At mid-long term, it is possible to anticipate synergies with other research infrastructures in the area of biomedical sciences and resources like BBMRI (biobanking & biomolecular resources), EATRIS (translational medicine), EIRENE (environmental exposure assessment on human health), ELIXIR (Bioinformatics & computational biology) and Euro-BioImaging (biomedical imaging).

Impact & outreach

The wider impact of EBRAINS has both an economic and a social component, by the creation of knowledge, jobs and technological innovations as well as by addressing a relevant topic with social effect (ageing European population and neurodegenerative diseases).

Time period

EBRAINS is expected to remain relevant to its research community for a period longer than ten years.

CONCLUSION

EBRAINS serves the neurosciences research community by providing coordinated access and expertise, via one single entry point, to an extensive catalogue of digital services and tools to advance the study of the human brain and its applications in neurotechnology. The foundations of EBRAINS were laid by the HBP as one of the EU FET Flagship Initiatives. EBRAINS builds upon an existing network at European level. The Dutch researchers extensively benefit from participation in EBRAINS in several ways most notably by the opportunities for joint research activities and technological developments, as well as by an increase in visibility of Dutch expertise and resources. Having the HBP as starting point, Dutch neuroscientists will keep on providing unique tools and services to EBRAINS, particularly in the areas of theoretical neuroscience, neurotechnology, digital brain health, neuroprosthetics and neurocognition.

EIRENE – Environmental Exposure Assessment Research Infrastructure

EIRENE is an interdisciplinary research infrastructure aiming at bridging environment & health research areas. Being in the early stages it can be anticipated that EIRENE will be in position to become an **important** infrastructure for the Dutch health research community active in exposome research.

SYNOPSIS

EIRENE is a **distributed** research infrastructure aiming at addressing the effects of exposure to environmental factors in the human population health (exposome research), by developing technical and scientific services & resources supporting research on the lifelong health effects of environmental factors.

Currently in the early beginning of its **preparatory phase**, EIRENE has *project* status in the ESFRI roadmap (2021), whereas discussions on its legal form are ongoing and thereby legal entity is still pending.

EIRENE-RI (preparatory phase project) is coordinated by the Czech Republic and counts with the participation of 14 European member states, and Norway, the UK and the USA. The expectation, based on the organisation and governance of the preparatory phase project is that a **Hub & Nodes** model will be followed. **Access** to EIRENE services, resources and data is currently under development but it can be expected that where possible, an **open access** policy will be implemented.

At Dutch level, EIRENE-NL (formerly NIFER) builds on the expertise collected in Exposome-NL, a scientific network coordinated by University of Utrecht and counting with the participation of LEI, VU, UMCU, UMCG and the RIVM. Moreover, Exposome-NL has been prioritised in the National Roadmap for Large-scale Research Infrastructure (2021): Group Health Sciences. Investment on Exposome research has been provided among others, by the NWO Gravitation grant (2020).

USERS PERSPECTIVE

EIRENE aims at supporting interdisciplinary human exposome research in the area of environment and health, bringing together expertise in environmental & analytical chemistry, biology, toxicology, environmental and human exposure and risk assessment, epidemiology, biostatistics, bioinformatics, pharmacokinetics, and geospatial modelling. However, EIRENE services, resources and tools are currently under development, thus it is not currently possible to fully and concretely describe to what extent EIRENE will support the current exposome research activities in the Netherlands.

Relevance for the user community

At the current stage, it is not possible to completely ascertain to which extent the Dutch research community will be **dependent** on access to EIRENE resources, services and tools. Nonetheless it is possible to anticipate that some research activities in particular in terms of FAIR data points integration, *i.e.* secure link between health datasets and environmental exposure information will be (largely) dependent on this infrastructure, and thus would benefit from access to EIRENE-RI. Moreover, and in the context of an NWO–Research Infrastructure: national consortia grant in which a structure/tool has been developed, Exposome Scan, linking population health services, would greatly benefit from its integration in EIRENE, as the overarching pan European RI.

Education & training

At the current stage, it is not possible to describe which education and training activities will be included in EIRENE service portfolio given that EIRENE is still in its early preparatory phase.

STRATEGIC PERSPECTIVE

Alignment with national research/strategic agendas

EIRENE is prioritised in the National Roadmap for Large-Scale Research Infrastructure (2021): Group Health Sciences and aligned with the priorities described in the Sector Portrait Biology (2020) 'Building Blocks of Life', 'Adaptation & evolution' and 'Innovative technologies: data analyses and advanced methods' pillars. Furthermore the research activities enabled by EIRENE fit well with the ZonMw Policy Plan 2020–2024, particularly the topic 'Contributions to societal and public (health) issues'.

In a broader national context, EIRENE supports the research prioritised in the Top Sectors Life Sciences & Health, as well as in several Dutch Research Agenda routes and in the Knowledge and Innovation Agenda: Health & Care mission. At European level, there is a clear alignment with the EU Cancer Mission, the Green Deal, and several UN-SDGs. It can be concluded that research enabled by EIRENE is aligned national and international strategic agendas.

National & International dimensions

Considerations on the national and international dimensions of EIRENE are premature given the phase in which EIRENE is. Nonetheless, it can be anticipated that Dutch exposome researchers benefit from access to services, resources and data collected in the context of EIRENE, as the breadth of data and resources cannot be provided by a single country. As illustrative example, EIRENE has developed a strategic partnership with Health and Environment Alliance (HEAL), representing a wide range of stakeholders from researchers to health professionals, patients groups, non-governmental organization and public health institutes. Such endeavour is naturally facilitated in the context of an European RI.

Conversely, EIRENE would benefit from the Dutch contribution, as it would provide unique and specific expertise, such as the one included in the Exposome gravitation grant (cardiometabolic health).

Relation to other (similar) Research Infrastructures

At national level, it can be expected that EIRENE will seek collaboration and synergies in the context of Health-RI (Data infrastructure for health research), particularly with BBMRI (biobanking and biomolecular resources), EATRIS (translation Medicine) and ELIXIR (data infrastructure for Life Sciences and Health). In the ESFRI roadmap (2021), and in addition to those research infrastructures above mentioned, further opportunities for collaboration have been highlighted with ECRIN (clinical

trials), INFRAFRONTIER & EBRAINS (Models for environmental research), with AnaEE (Environment research) and ACTRIS (Atmospheric constituents data). At the longer term, synergies with specific research infrastructures from the ESFRI Social & Cultural Innovation domain are expected, particularly those collecting data on social aspects such as social capital and networks, cultural capital and norms as well as psychological and mental stress.

Impact & outreach

The wider socio-economic impact analyses of EIRENE is been currently developed. Nevertheless it is expected that the impact analysis will be performed both by the national nodes (Smart Specialisation Strategies) and at a central level (Hub) from a pan-European strategic perspective.

Time period

Being in the beginning of the preparatory phase, it is expected that EIRENE remains relevant to its research community for longer than a decade.

CONCLUSION

EIRENE is a multidisciplinary research infrastructure that serves the health and environmental research communities, by bringing them together in the context of exposome research. Being in the early stages of its preparatory phase, most considerations made are based on the potential that such research infrastructure would bring to the Dutch research community.

The Dutch researchers would benefit from participation in EIRENE in several ways; most notably by the opportunities for joint research initiatives and linkages of data sets both in the health as well as environment domains. As such, to reach its goals and achieve its potential, EIRENE (and Exposome-NL), will benefit from strong links with other existent research infrastructures both at national and at European level.

ELIXIR – EUROPEAN INFRASTRUCTURE FOR LIFE SCIENCES DATA

ELIXIR is an **important** infrastructure for the broad Life Sciences and Health research community, as it provides free-of-charge, open access to crucial data services, resources and tools, at an extent that is not possible by any single country.

SYNOPSIS

ELIXIR is the **distributed** data infrastructure for the Life Sciences. ELIXIR coordinates, integrates and sustains bioinformatics resources across 22 European countries and the European Molecular Biology Laboratory-European Bioinformatics Institute (EMBL-EBI), comprising more than 250 institutions. Virtual, transnational, **free-of-charge, open access** to ELIXIR resources and services is enabled by institutional login. Established as an **intergovernmental organisation** (EMBL special project, 2013), ELIXIR governance structure follows the **Hub & Nodes** model. Conditions for engagement are defined in the ELIXIR Collaboration Agreement and ELIXIR holds the *landmark* status in the ESFRI roadmap (2021). ELIXIR resources are structured in five platforms (Data, Compute, Tools, Interoperability and Training), in thirteen disciplinary communities (from marine biology to human data) and ten focus groups (from FAIR data to AI). The Netherlands is full member since 2014, the Dutch node (ELIXIR-NL) is coordinated by the Dutch Techcentre for Life Sciences (DTL)/Health-RI. Participation in ELIXIR enables the Dutch research community to steer the design of the current and future platforms, resources and standards adoption to fit their needs and priorities. Access to ELIXIR data, resources and tools from publically funded research, which are widely used by the Dutch research community, leads to the realisation of (new) research projects, using biological data and standards from any living organism.

USERS PERSPECTIVE

ELIXIR serves the wide Life Sciences and Health Domain, specifically the Health; Agri-Food; Microbial Biotechnology; Biodiversity and Bioinformatics & Computational Structural Biology areas. ELIXIR extensively supports the research activities in these areas. In the Health research area, ELIXIR has facilitated and co-developed Health-RI, the health data research infrastructure, providing access to a wide range of data (genetic, omics, environmental factors), images and biosamples, via a single entry point. ELIXIR resources have been foundational in the development of the Genomics Initiatives: 1+ Million Genomes leading ultimately to the Genomics Data Infrastructure (GDI). For the Life Sciences, virtually any research project involving molecular and cellular biology requires access to the ELIXIR infrastructure and services; specifically: data collections (genes, proteins/enzymes, metabolites), tools (bioinformatics software applications and validated workflows to support bioinformatics analyses) and computing facilities. In a wider context, ELIXIR has developed an Authentication and Authorisation Infrastructure (ELIXIR AAI) as a general service allowing institutional login, with application and usage across Life Sciences research infrastructures and projects (now Life Sciences AAI).

Relevance for the user community

The unique value of ELIXIR lays on coordinating the access to public data resources and tools, leading to long-term access and preservation of biological data. These are the Deposition Databases (DD), the Core Data Resources (CDR) and the Recommended Interoperability Resources (RIR). To name a few: Ensembl, Genome Database, Uniprot as the database of protein sequence and functional information (proteomics), the Human Protein Atlas (HPA), ChEMBL, the database of bioactive molecules with drug-like properties (chemistry), European Genome Phenome Archive (EGA). Another very relevant benefit from participating in ELIXIR is the access to the training component via the TeSS portal. The user community is completely dependent on ELIXIR services.

Education & training

ELIXIR provides extensive education and supports services (TeSS portal) with more than 170 training courses [2023], ranging from data mining to genome sequencing and targeted at researchers, students and technical personnel. ELIXIR events as conferences, workshops, bio-hackathons and industry forum are planned yearly.

STRATEGIC PERSPECTIVE

Alignment with Research & Strategic Agendas

(Bio)informatics & computational skills are marked as the common denominator/priorities in the Sector Portrait Exact and Natural Sciences (2020) for the four disciplines (Pillar Data Science/AI/ Big data & research facilities/ instrumentation / infrastructure). ELIXIR is mentioned in all the strategic papers of the NWO Round Table-Life Sciences, as the research infrastructure to be supported. In the Health domain, alignment is visible with the mission of Centre for Future Affordable Sustainable Therapy Development, and with the goals described in the KNAW report on academic drug development. In a wider context, ELIXIR resources serve well the goals of the Top Sectors Agri & Food; Life Sciences & Health; Horticulture & Starting Materials; several routes from the Dutch Research Agenda and National Growth Fund projects, most notably Health-RI. ELIXIR tools and resources largely contribute to the Open Science policy and EOSC. Thus research activities enabled by ELIXIR are well aligned with (inter)national strategic agendas.

National & International dimensions

ELIXIR is included in the National Roadmap for Large-scale Research Infrastructure: Health Sciences (2021). ELIXIR-NL was foundational to the development of Health-RI and provides the backbone bioinformatics resources to large-scale RI projects as X-Omics (2018) and the Dutch Research Agenda-Virtual Human Platform for Safety Assessment (2020). Collaborations with other research infrastructures, namely ARISE, IBISBA-NL, NPEC and Exosome-NL are ongoing. The Dutch research community has developed several resources with RIR label: Molgenis, a molecular genetics open source data platform with broad applications in biobanking, rare disease research and patient registries; and BridgeDB, a framework to map different biological databases providing information from genes to diseases. In this context ELIXIR greatly benefits from the Dutch node. Conversely, ELIXIR puts forward community endorsed standards to facilitate data sharing and interoperability, contributing to the implementation of the FAIR data principles, the sharing of best practices in data management and stewardship. The contribution that the Dutch researchers deliver to and receive from ELIXIR is considered as important, due to the knowledge brought to the Interoperability, Training & Compute platforms.

Relation to other (similar) Research Infrastructures

Existent synergies between ELIXIR and other ESFRIs landmarks in the Health & Food domain are BBMRI (biobanking resources) and EATRIS (translational medicine). Collaboration with research infrastructures in the preparatory phase, DiSSCo (geo- and biodiversity), EMPHASIS (agri-food), EIRENE (exposome), IBISBA (industrial Biotech) is being established. Given the phase in which these research infrastructures are, the interaction level and collaboration with the ELIXIR communities is mostly at EU level (Horizon Europe project funding). To capitalise on the synergies between ELIXIR and the future Dutch nodes of EMPHASIS, IBISBA, EIRENE, and DiSSCo, cooperation at national level and within the framework of the NWO TDCC programme, should be further encouraged and developed.

Impact & outreach

ELIXIR has socio economic impact by contributing to the implementation of FAIR guidelines, the data stewards professionalisation and strengthening of the digital competencies beyond the Life Sciences and thereby, the generation of knowledge, research opportunities and jobs in bioinformatics area with wider application.

Time period

ELIXIR resources remain relevant for longer than ten years due to its bottom-up, community-driven and flexible approach. To keep up with the evolving needs of its users continuous investment should be anticipated.

CONCLUSION

ELIXIR, as the backbone RI for the wide Life and Medical Science domain, is important for the Dutch researchers. It enables that data produced by several European institutions remains accessible, findable and interoperable, and thereby ensures that it can be reused by any researcher from any Life Sciences discipline. This generates new scientific knowledge, resources, data and analytic tools. Dutch researchers actively participate in and benefit from ELIXIR services. While ELIXIR services play a pivotal role in supporting the Dutch (bioinformatics) community, its visibility can be better acknowledged and further improved by means of more active branding of ELIXIR resources, services and tools.

eLTER – integrated European Long Term Ecosystem, critical zone and socio ecological Research

eLTER is an **important** infrastructure for the Dutch ecological and environment research community, as it provides access to specific Dutch and European study sites, enabling long-term ecosystem monitoring and coupling it to socio-economic data.

SYNOPSIS

eLTER is the **distributed** European research infrastructure dealing with long-term ecosystems monitoring. eLTER is the European regional node of the ILTER (International Long Term Ecological Research network) and aims at advancing the understanding of interaction humans-nature, by facilitating research on climate change, biodiversity loss, soil degradation and unsustainable resource use. Currently in the **preparatory phase** and with expected operational start by 2025, eLTER builds up on 26 formal LTER networks in Europe and counts with 25 participating Members States. eLTER is working towards the establishment of an European Research Infrastructure Consortium (**ERIC**) as legal entity, and holds the *project* status in the ESFRI roadmap (2021). Access conditions to eLTER-RI sites and services are currently being developed, under the **free-of-charge, open access** assumption. eLTER provides access to more than 500 research sites and more than 50 platforms across Europe, representing diverse biogeographical regions. In addition, eLTER aims at offering harmonised and standardised data as well as training activities. At national level, the Dutch node of eLTER, LTER–NL is coordinated by Netherlands Institute of Ecology (NIOO-KNAW). It can be expected that the transition from a research network to a research infrastructure and a future Dutch membership in eLTER-ERIC will further accelerate the organisation of its research community. eLTER-NL is complementary and has synergies with other national nodes of large scale research infrastructures (National Roadmap for Large-scale Research Infrastructure: Group Green Life Sciences), as also demonstrated with LTER-LIFE, a joint initiative that brings together LTER-NL, LifeWatch-NL and NEMNET.

USERS PERSPECTIVE

eLTER **supports some** research activities in the ecosystems research area, by combining long-term monitoring environmental assessment data (ecological, environmental and evolutionary biology data) with socio-economic data. The combination of data from different scientific domains enables the study of human-environment interactions and thus, of wider societal interest. For instance, studies on spatial planning and on the different functions of the landscape (socio-economic impact, agriculture, tourism and nature use) lead to a better understanding and improvement of landscape sustainability.

Relevance for the user community

The Netherlands contributes to eLTER by providing three platforms: the LTSE Dutch Wadden Sea Area, the LTSE Veluwe and the Schelde estuary. Research activities pertaining the long-term monitoring of ecosystems data are partially dependent on the eLTER study sites both in the Netherlands and across Europe.

Research activities focus mostly on the long-term ecosystem monitoring (plants, animals, environmental variables and socio-economic parameters). The combination of long-term monitoring data on both biotic and abiotic parameters leads to further understanding of the evolutionary processes at population level (heritability, selection on traits) on a global scale (climate change, nitrogen deposition, biodiversity loss).

The development of the ICT facilities and digital infrastructure is needed to integrate spatial and temporal (meta-) FAIR data, to ensure its quality and availability to the research community. In the framework of eLTER PLUS preparatory phase project and its TransNational Activities (TNA), a total of 26 requests to use eLTER sites have been received, 6 requests for remote access and 235 datasets were requested (2020–2021). To note that under the TNA scheme, only 20% of the capacity can be made available.

Education & training

Due to the fact that most eLTER sites are owned by research organisations and universities, training and education activities are available to the students (BSc, MSc and PhDs) and academic staff. Training includes workshops, seminars, summer schools as well as training on operating the equipment for measurements. Nonetheless it is expected that once eLTER enters in the operational phase, and being capacity building one of its core activities, its training offer will be further coordinated and made available via eLTER-ERIC. Training activities will cover the areas of data management & integration, data analytics & modelling as well as training on analytical laboratory skills and technology development (sensors, instrumentation, etc).

STRATEGIC PERSPECTIVE

Alignment with national research/strategic agendas

The activities of eLTER are aligned with the priorities described in the Sector Portrait Biology (2020) “From ecosystem process to biodiversity” pillar as well as prioritised in the strategic research agendas from the NWO Round Table Life Sciences (2020) – Research communities ‘From genes to Organisms’ and ‘Organisms in their environment’. The Dutch node of eLTER, LTER-NL, is included in the National Roadmap for Large-scale Research Infrastructure (2021). More recently LTER-LIFE has been awarded funding within the National Large-scale Research Infrastructure call (2023). eLTER research activities address specific questions as defined in several Dutch Research Agenda routes, Knowledge and Innovation Agenda missions, EU missions (Green Deal, Ocean and Soil) and UN-SDGs, and thus are the research activities enabled by eLTER well aligned with the (inter) national agendas.

National & International dimensions

Participation of Dutch researchers in eLTER is considered as important, as it enables the access from the Dutch researchers to very ecologically diverse European study sites, its associated data and technical expertise, established within the eLTER network. Conversely, European researchers have access to unique Dutch study sites, as for instance the Dutch Waddenzee, a protected UNESCO world heritage site. It can be expected that, once eLTER-RI reaches its operational phase, further development of its ICT capabilities and access to high-quality and interoperable datasets are in place, these will add value to eLTER-RI. It can be anticipated that enlarging the number of eLTER study sites will allow a better positioning, lead to an increased visibility and user numbers of eLTER resources by (inter)national environmental researchers.

Relation to other (similar) Research Infrastructures

eLTER collaborates with the Global Ecosystems Research Infrastructure (GERI), in which other initiatives take part such as ICOS, CERN, SAEON, TERN and NEON. However, either these initiatives (CERN, SAEON, TERN & NEON) differ in terms of geographic coverage (eLTER focus on the European continent, whereas the other initiatives in Asia, South-Africa, North-America and Australia (sub-) continents respectively) or, in terms of scope. ICOS focusses on greenhouse gases and their fluxes and eLTER in integrating these measurements for long term monitoring. Within the ESFRI-Environment domain, synergies with LifeWatch as the e-infrastructure supporting biodiversity and ecosystems research (*i.e.* ICT facilities, e-services, digitisation), should be further encouraged at EU level, and in line with the objectives of LTER-LIFE initiative at national level.

Impact & outreach

The wider societal impact of eLTER is evident when considering the current societal challenges on topics as climate change, adaptation and biodiversity. As such, research activities enabled by eLTER study sites support the provision of scientific evidence and knowledge, leading to the proposition of site-specific interventions.

Time period

Given that the main asset of eLTER is to provide long-term ecosystems monitoring data and its associated socio-economic impact, it can be estimated that this RI remains relevant for permanent time period.

CONCLUSION

eLTER aims at providing the research community with resources and services that enable long-term ecosystem monitoring, combining data from different scientific domains (ecology, environmental and socio-economic).

While being in the preparatory phase and simultaneously undergoing a transition from an European regional node of an international research network to an European RI; eLTER is currently undergoing a re-positioning and development of its service portfolio. Access to integrated and interoperable data sets of high quality and the development of ICT capabilities are a matter of attention. Its importance to the Dutch researchers is clear. At national level, LTER-NL was identified as one of the priorities by the National Roadmap-Large scale Research Infrastructure (2021). The successful re-organisation, collaboration and prioritisation of research infrastructures within the Green Life Sciences Group may further support its development at European level.

EMBL – European Molecular Biology Laboratory

Dutch membership of EMBL is **important** to the Dutch research community since no other European organisation offers such a comprehensive combination of research and training programmes, access to core facilities and support services, cutting edge technologies as well as access to scientific data and analytical tools.

SYNOPSIS

The European Molecular Biology Laboratory (EMBL) is the only European organisation dedicated to molecular biology research serving the life and medical sciences research community. Since its establishment in 1974, EMBL aims at advancing molecular biology research by enabling fundamental discoveries in Life Sciences, by training researchers and by developing innovative technologies. Set up as an **intergovernmental organisation**, EMBL counts with currently 28 member states, one associate member (Australia) and two prospective members (Latvia and Serbia). With its headquarters in Heidelberg (research units on cell biology & biophysics, developmental biology, genome biology, structural and computational biology); EMBL operates five additional European research sites (core facilities), i) Barcelona (focusing on tissue biology and diseases modelling); ii) Hamburg (focusing on structural and infection biology); iii) Hinxton, European Bioinformatics Institute [EBI] (focusing on bioinformatics and data resources); iv) Grenoble (focusing on structural biology) and v) Rome (focusing on epigenetics and neurobiology). Its **core facilities** are **open** to EMBL member states and user fees are solely applicable to specific experimental services, following a cost recovery model and thus not bringing any additional income to EMBL. Access to **data** follows an **open access** policy. The Netherlands is one of its 10 founding members and the membership fee to EMBL is provided by the Ministry of Education, Culture and Science. The Dutch researchers are particularly active in the areas of structural biology (NeCEN), bioimaging (NEMI, NL-Biolmaging), developmental biology (Hubrecht Institute) and bioinformatics (ELIXIR-NL).

USERS PERSPECTIVE

Virtually any life sciences researcher using molecular biology for fundamental or applied research benefits from EMBL comprehensive research programmes, core facilities and support services. EMBL extensively supports life science research in a variety of research fields such as advanced imaging, cryo-electron microscopy, genomics, bioinformatics and computational biology. More recently, EMBL largely contributed to advance fundamental and applied knowledge in biomedical sciences by developing and hosting the COVID-19 Data Portal as well as by fostering the collaboration with BioNTech (mRNA vaccine development) during the COVID-19 pandemics.

Relevance for the user community

Research activities in the molecular biology are completely dependent on EMBL membership, as EMBL greatly facilitates and contributes to advance molecular biology research in the Netherlands. Specifically considering the structural biology and (bio-)imaging areas, in which access to core facilities as synchrotron X-ray beamlines, crystallisation facilities and cryo-EM facilities as well as

access to work flows and expertise is crucial. Another example is the immense bioinformatics expertise available within EMBL-EBI in terms of biomolecular databases, repositories and access to bioinformatics tools. It would be unthinkable to foresee the effect on the lack of access to certain databases and functionalities of specific resources like UniProt and Ensembl, which are solely available via EMBL-EBI (ELIXIR Recommended Core Data Resources), which is probably daily consulted by any Dutch molecular biologists.

Education & training

Being education & training one of its key missions, EMBL offers an extensive training programme consisting of Fellowship targeted at PhD candidates (International PhD program), postdocs (EMBL Postdoctoral & Interdisciplinary Postdoctoral Programme, EIPOD) and at engineers and technology developers (ARISE technology programme). EMBL offers a Scientific Visitors Programme in which visiting scientists and students benefit from access to new technologies and state-of-art equipment at the EMBL different sites (600 visitor/year). EMBL offers an extensive educational programme consisting of conferences, courses, summer schools on molecular biology as well as specific EMBL-EBI bioinformatics training courses and on-demand webinars.

STRATEGIC PERSPECTIVE

Alignment with Research & Strategic Agendas

In view of the current EMBL scientific programme 2022–2026 ‘Molecules to ecosystems’, it can be inferred that there is a strong alignment with the priorities defined in the Sector Portrait Biology (2020), as well as in the NWO Round Table – Life Sciences and in the NWO Round Table-Chemistry (‘Vision for Chemistry 2040’). In addition, by facilitating technology transfer and collaboration with industrial partners there is further alignment with the Dutch top sectors namely Agri-Food, Chemistry and Life Sciences and Health. The strategic priorities of EMBL fit very well with the strategic ambitions of the Dutch Life Sciences research agendas.

National & International dimensions

The Dutch Life Sciences research community benefit from the EMBL membership on several levels: i) by having access to a critical infrastructure and wide extent of core facilities/EMBL sites; ii) by having access to a broad range of scientific and technical services from data resources, omics facilities and imaging facilities iii) by having access to a comprehensive fellowship programme (PhDs, Postdocs and visiting scientists), and iv) by having access to an ample catalogue of conferences, workshop and courses. By training Dutch scientists, who are consistently in the top 10 position in terms of participation, knowledge and expertise transference to the Dutch research community is enabled. Conversely, the Dutch research community is well positioned in the fields of developmental biology, structural biology and imaging, and as overarching expertise computational biology and bioinformatics. It contributes to EMBL by generating fundamental knowledge and expertise, technology developments which ultimately lead to further joint grant applications and truly European collaborative, interdisciplinary research. Membership of EMBL remains important to virtually any Dutch life sciences researcher.

Relation to other (similar) Research Infrastructures

In the European/ESFRI context, EMBL collaborates with several European research infrastructures like EuroBioImaging-ERIC (EMBL is one of its three Hubs), INSTRUCT-ERIC (EMBL Heidelberg, Hamburg and Grenoble sites) and ELIXIR (EMBL-EBI being an ELIXIR node). At national level and since 2016, EMBL is one of the partners of the Hubrecht Institute-Developmental Biology and Stem Cell Research (KNAW-Institute), via an institutional collaboration.

Impact & outreach

The broader impact of EMBL can be subdivided in: i) societal impact, in which molecular biology discoveries play a role in addressing urgent societal challenges as described in several EU-Missions (i.e. Green deal, Mission Soil, Mission Cancer and European Open Science Cloud) and on several UN-SDGs in the areas of health and well-being, industrial biotechnology, food security, environment and climate; ii) economic impact by technology transfer through licensing, by the establishment of spin-off companies and by supporting industry by making data resources accessible and (re-)usable and thus contributing to increased efficiency; and on iii) human capital, to which the extensive fellowships programme and training events are illustrative.

Time period

EMBL will remain relevant for the Dutch researchers for a period longer than 20 years (permanent). This is justified by the role that the life sciences research will have on addressing the current societal challenges, due to the increased complexity to address them and to which a combination of technologies and life sciences (sub-)disciplines and complex datasets is needed.

CONCLUSION

EMBL is an unique organisation serving a wide research community to advance molecular biology research. By expanding the remit of molecular biology in the context of changing environments (scientific programme 2022–2026) EMBL seeks new links with other disciplines (i.e. ecology, epidemiology, toxicology, engineering, and mathematical theory) to address current societal challenges and to remain relevant on the long term. The Dutch research community largely benefits from its membership to EMBL by having access to unique core research facilities, cutting edge technologies and support services, opportunities for joint research collaborations via EMBL partnerships and extensive training and education programmes. This is not possible to achieve at a single, member state level. The level of collaborative, cross-border research enabled by EMBL is not comparable to any other organisation.

EMPHASIS – European Infrastructure for Multi-scale Plant Phenomics and Simulation for Food Security in a Changing Climate

EMPHASIS is well positioned to become an **important** infrastructure in the Plant Sciences research field as it generates fundamental knowledge and contributes to technological developments on plant phenotyping for sustainable food production.

SYNOPSIS

EMPHASIS is a **distributed** European research infrastructure that provides access to facilities, field sites, and technologies to advance the knowledge on the interaction between the environment and plants (genotype and phenotype). By providing state-of-art, non-invasive, high-throughput plant phenotyping, EMPHASIS will largely contribute to advance plant science research. Currently in the **implementation phase** EMPHASIS is working towards the establishment of an European Research Infrastructure Consortium (**ERIC**) as legal entity [end 2024]. EMPHASIS is included as *project* status in the ESFRI roadmap (2021). Organised as **Hub, Nodes** and Thematic Functional Units (FU), EMPHASIS counts currently with the participation of 11 countries. Access modalities to the different FUs and services therein is currently under development, in which both **open access** and **service level agreement (SLAs)** under the ERIC legal form are being considered.

At national level, the Netherlands Plant Eco-phenotyping Center (NPEC) has been (co-) funded by a NWO Large-scale Research Infrastructure grant and the NPEC Consortium (2017–2018). Hosted at two sites Wageningen University Research and Utrecht University, NPEC is one integrated national facility.

NPEC consists of 6 modules: 1) Ecotron 2) Plant-microbe interactions phenotyping 3) Multi-environment climate chamber 4) High-throughput phenotyping climate chamber 5) Open field phenotyping and 6) Data. In short NPEC, provides automatisisation, specialised imaging systems and specific climate-controlled environments to facilitate research on plant performance (genotype-phenotype associations) on a variety of conditions.

USERS PERSPECTIVE

EMPHASIS serves the wide plant sciences research field. Particularly research activities in: 1) plant-microbe interaction; 2) plant genetics & breeding; 3) photosynthesis efficiency; 4) plant exposure to biotic and abiotic stress and 5) terrestrial and microbial ecology will be extensively supported by access to the different EMPHASIS FUs and services.

Relevance for the user community

Research on plants genetics, photosynthesis efficiency, adaptation to climate change and plant-microbe interaction is completely dependent on access to EMPHASIS. For instance, access to efficient high-throughput phenotyping allows the simultaneous screening of a large number of plants (phenotypes), which has been a bottleneck in plant genetics for decades. Another example refers to the need of combining cutting-edge molecular biology and imaging experiments to study plant-microbe interactions as well as plant shoot and root development. Such tools used to quantify root/shoot development are now available within different facilities in EMPHASIS. Moreover, Dutch researchers are actively involved in studying the interaction between abiotic factors (light, drought,

temperature extremes, salinity, floods) and biotics stress (microbiome, pathogens, pests). The access to such scale, accuracy and integration of services as envisaged in EMPHASIS will be of high relevance to the Dutch community. EMPHASIS builds upon the effort of the European Plant Phenotyping Network (EPPN), in which the user requirements and services needs have been thoroughly surveyed. EMPHASIS has been successful in attracting third party European funding (H2020, Horizon Europe: preparation and implementation phases). At national level, considerable investment has been awarded by the National Growth Fund (CROP-XR) as well as in the NWO Gravitation programme (MiCrop).

Education & training

During EMPHASIS Preparatory phase courses/ summer schools and joint research activities have been provided. Attention is given to deepen the knowledge in plant phenotyping techniques, image capture, experimental design and statistical analysis. As overarching theme: data capture, data management and machine learning is included. The establishment of a consistent information system across the different nodes has been accounted for. The targeted audience comprises academic and private industry (R&D) researchers. Moreover, 'Training & Education' & 'Advance phenotyping practices' will be two FUs in EMPHASIS.

STRATEGIC PERSPECTIVE

Alignment with national research/strategic agendas

The research activities supported by EMPHASIS are well aligned with priorities described in the Sector Portrait Biology (2020). EMPHASIS is prioritised in the NWO Round Tables – Life Sciences 'Genes to Organisms' and 'Organisms in their environments' strategy papers. NPEC (EMPHASIS-NL) is included in the National Roadmap for Large-scale Research Infrastructure: Green Life Sciences (2021). Research activities carried out in the context of EMPHASIS generate knowledge supporting policy development, and are aligned with the priorities in the Dutch Top Sectors 'Health & Food', 'Horticulture & Starting materials'; with the Dutch Research Agenda: Sustainable production of safe and healthy food line and the National Knowledge and Innovation Agenda: Agriculture, Water and Food mission. At International level, alignment with the EU-Green Deal and EOSC and with several UN-SDGs is evident.

National & International dimensions

Participation of Dutch researchers in EMPHASIS is of importance, as it enables Dutch researchers to participate in multi-site experiments, simulating a variety of experimental conditions. Participation of the Dutch research community in EMPHASIS enables the access to facilities and (coordinated infrastructure) services as well as access to data, modelling and computational services. Conversely, access to NPEC by international researchers will contribute to a broader exposure and profiling of the NPEC facilities. A wider dissemination of plant phenotyping technologies, sharing of best practices and training activities will lead to the intensification of collaborative international research. These will strengthen the international position of the Dutch plant sciences within the academic setting and within the industry/private sectors (*i.e.* plant breeding, agronomy).

Relation to other (similar) Research Infrastructures

In the context of European Research Infrastructures synergies were identified with AnaEE (exchange of methodologies and protocols on open field monitoring); ELIXIR (alignment of methodologies regarding (meta-) data analysis and standardisation); Euro-Biolmaging (exchange of protocols and sharing of imaging technologies expertise). Synergies were equally identified

between NPEC and complementary facilities available in other European countries: ECOTRON (France), an experimental instrument enabling the simulation of different experimental conditions, in which an upgraded version is available in NPEC module 1; and GROWTHSCREEN Rhizo (Germany) enabling the study of root architecture, complementary to NPEC module 4.

Impact & outreach

By bridging the fundamental and applied knowledge, the wide (socio economic) impact of EMPHASIS can be quantified in terms of i) knowledge generation and ii) (inter)national investment on technological innovative solutions. While the first deals with the creation of positions within academia, the second relates to opportunities for co-development with private parties within the R&D agri & food sector (plant breeding, food technology, instrumentation & sensors, automatisisation & robotics).

Time period

EMPHASIS will be relevant for its research community for at least ten years. In view of rapid technological developments on instrumentation and equipment, and provided that the upgrade of its facilities has been accounted for, EMPHASIS has the potential to remain relevant for an indefinite period of time.

CONCLUSION

EMPHASIS provides the research community with coordinated access to automated, high-throughput plant phenotyping to study plant development both above and below ground, under different (a)biotic conditions, on multi-site locations. The RI is crucial for addressing fundamental research questions pertaining topics as sustainable food production and plant adaption to climate change and will stimulate technological developments on imaging, sensors and instrumentation as well as on data analyses and AI/Machine Learning. EMPHASIS is expected to reach its operational phase on a short term. Provided that the Netherlands will be a (founding) member, the Dutch node NPEC, and its associate research community will benefit from wider exposure in the international setting and additional joint research and training activities on a scale that is not possible by any single country.

ERINHA – European Research Infrastructure on Highly Pathogenic Agents

ERINHA is a research infrastructure dedicated to the study of highly pathogenic infectious agents, providing coordinated access and expertise to specialised European facilities. It is an **important** infrastructure for the Dutch researchers since, in addition to access, it enables the development of advanced laboratory research models and collaborative projects of (re)emerging diseases of epidemic/pandemic significance.

SYNOPSIS

ERINHA is a **distributed** research infrastructure providing access to high specialised facilities (Bio-Safety Level 4 [BSL4] and complementary Bio-Safety Level 3 [BSL3] facilities), services and expertise advancing the current knowledge of highly pathogenic agents. Currently in the **operational phase**, ERINHA is an International non-profit Association under Belgian Law (**AISBL**, 2017), with the *landmark* status in the ESFRI roadmap (2021). ERINHA counts with participation of institutions from 11 European member states, having its central coordination unit located in France. **Access** to ERINHA member facilities and expertise, in person or remotely, is open to any researcher, the service provision being settled via contracts. Access costs are defined individually by the ERINHA nodes and free-of-charge access is a possibility arranged under transnational access calls (TNA), currently funded by the ERINHA-coordinated pan-European ISIDORE emergency response project, involving 17 European infrastructures/networks and their eligible members, totaling >150 partners. A reference and allocation process to accede ISIDORE services is applicable. In the Netherlands, Erasmus MC is a full member of ERINHA, integrating the multimodal high biocontainment laboratory (BSL3) in the European network. The BSL3 research facility – unique in the Netherlands – operates according to the highest international biosafety and biosecurity standards, to facilitate research by multiple teams simultaneously, and thereby creating opportunities for collaborative research using a variety of research modalities, high end instruments for experiments and analyses, *in vivo* (animals) and *in vitro* systems.

USERS PERSPECTIVE

In organising research infrastructures on highly pathogenic agents, ERINHA features scientific expertise and instrumentation, with state-of-art biocontainment provisions suitable for *in vivo*, *ex vivo*, and/or diagnostic and molecular research activities. The relevant research areas cover incidental (e.g. imported) and re-emerging infections, public health, animal health & monitoring as well as biomedicine in the context of infectious diseases. These research areas are rather wide in scope because high containment facilities form the upper end of a continuum (wide base, narrow peak); lower levels of containment (BSL1 & BSL2) are commonplace in clinical and public health diagnostic laboratories and so classified facilities for dedicated research applications are of lesser complexity regarding biosafety and biosecurity requirements; ERINHA focusses on high biocontainment research facilities (BSL3 & BSL4) and thereby extensively supports advanced research into, e.g., novel infectious entities, agent-host interaction and host responses.

Relevance for the user community

The Dutch research community benefits and is partly dependent on access to ERINHA nodes, which can be justified by i) the joint research activities in the context of H2020/Horizon Europe projects that go beyond single country borders; ii) the level of specialised scientific and technical expertise on research with highly infectious pathogens; iii) economic efficiency, given the costs and vision needed to conceive, design, construct and operate high biocontainment facilities by a single country, and, iv) the strategic investment for preparedness to deal with epidemic-prone pathogenic agents by positioning European research infrastructures for international collaboration.

Education & training

ERINHA offers training in three main areas: i) safe working practices in high containment laboratories, ii) on general biosecurity and iii) on biosafety operations. ERINHA training opportunities are applicable to operating and maintaining BSL3 and BSL4 laboratories. These are targeted at oversight and technical staff as well as specialised engineers. Access opportunities serve to train and qualify researchers in different career levels (technicians, graduates, PhDs and postdocs). Capacity building includes other experts such as policy makers.

STRATEGIC PERSPECTIVE

Alignment with national research/strategic agendas

BSL3, and by proxy ERINHA, is prioritised in the National Roadmap for Large-Scale Research Infrastructure (2021): Group Life Sciences & Enabling Technology and included in the strategic NWO-Round Table Life Sciences- Research Community 'From genes to organisms'. ERINHA activities support the priorities described in the Sector Portrait Pharmaceutical Sciences (2020), and likewise, the research activities enabled by ERINHA fit well with the ZonMw Policy Plan 2020–2024, particularly in the topic 'Contributions to societal and public (health) issues'. In a broader national context, ERINHA supports the research prioritised in the Top Sectors Life Sciences & Health and High Tech Systems and Materials, several Dutch Research Agenda lines and in the Knowledge and Innovation Agenda: Health & Care; Key Enabling Technologies missions. At International level, ERINHA supports the prioritised research in several UN-SDGs. It can be concluded that research enabled by ERINHA facilities is aligned with specific (inter)national strategic agendas.

National & International dimensions

Participation of Dutch researchers in ERINHA is of importance as it provides coordinated access to high specialised facilities as well as expertise and training in operating high specialised facilities as BSL3 & BSL4 laboratories. Conversely, ERINHA benefits from the Dutch contribution by having an additional site/facility, embedded in a country with extensive research in animal health industry and hosting the European Medicines Agency (EMA). Taken together the Netherlands has developed a rich research ecosystem in this topic.

Relation to other (similar) Research Infrastructures

In the European context, and concerning the ISIDORE project 'Integrated Services for Infectious Disease Outbreak Research' complementarities with other European research infrastructures were identified and collaboration stimulated: BBMRI (human clinical samples), EATRIS (immuno-monitoring profiling, regulatory access and access to clinical trials expertise areas), ELIXIR (bioinformatics), EuroBioImaging (analytical imaging services and immuno-monitoring profiling areas), InfraVec (arthropod vectors transmitting pathogens), INSTRUCT (vaccine development), MIRRI (biodiversity, microbial collections), Transvac (vaccine development), VetBioNet (zoonoses and animal infectious diseases) and EVAg (global virus archive) in which the Netherlands

participates. It cannot be excluded that further synergies with the ESFRI Social and Cultural Innovation domain particularly with ESS (European Social Survey) could be sought.

Impact & outreach

The wider impact of ERINHA can be distinguished in: i) societal by training the next generation of researchers to better understand the origin, emergence and approaches for detection and control of infectious diseases as well as evidence based diagnostics, treatment and prophylaxis. As witnessed during the COVID-19 pandemic, it presented itself not only as a world societal challenge but also as an opportunity for outreach activities, albeit via WHO and via the RIVM ; ii) economic impact: investment in such highly specialised facilities and equipment (and its operation) benefits from pooling resources and streamlining services.

Time period

ERINHA is expected to remain relevant for a period longer than ten years, provided that upgrade of its technologies is accounted for.

CONCLUSION

ERINHA serves a specific research community by providing coordinated access and expertise in the area of highly infectious diseases. Its contribution to public (and animal) health can translate into major impact on society as a whole. ERINHA resources enable addressing challenges such as the Covid-19 pandemic, influenza and zika epidemics; by pooling resources, capacity and expertise beyond national borders. The Dutch research community can be extensively supported by ERINHA. The Erasmus University Medical Center, as ERINHA participating organisation and as host of the BLS3 facility in the Netherlands, equally benefits from the visibility and opportunities for joint research activities, functioning as a knowledge hub. As evidenced by the ISIDORE project, collaboration and synergies with other research infrastructures in the Health & Food Domain are also stimulated. Further synergies with specific research infrastructures in the environment area, in the context of One Health as well as in the area of Social Sciences can be sought.

EU-OPENSOURCE – European Infrastructure of Open Screening Platforms for Chemical Biology

EU-OPENSOURCE is a research infrastructure for chemical biology and early drug discovery providing access to high-throughput screening facilities, expertise and data, ultimately facilitating the discovery of novel therapeutics. EU-OPENSOURCE is an **important** infrastructure to the Dutch chemical biology researchers.

SYNOPSIS

EU-OPENSOURCE is a **distributed** research infrastructure for bridging the gap between the biology community (assay providers) and the chemistry community (compounds providers), and thereby facilitates the collaborative development of novel molecular tools, among which, vaccines and new therapeutics.

Currently in the beginning of its **operational phase**, EU-OPENSOURCE is an established European Research Infrastructure Consortium (**ERIC**) since 2018, with the *landmark* status in the ESFRI roadmap (2021). Organised as an **Hubs & Nodes** model, EU-OPENSOURCE-ERIC is hosted by Germany and counts with the participation of 10 European member states, with over 20 affiliated high-throughput screening and chemistry facilities, coordinated by its own national nodes.

Access to EU-OPENSOURCE is distinguished in five categories: i) biologists (assay providers); ii) chemists (compound providers); iii) industry; iv) data, v) training. In addition, general access to EU-OPENSOURCE is on project-by-project basis, and regulated by service agreements and material transfer agreements (MTAs) between EU-OPENSOURCE and the partner sites. **Open access to data** is accounted for.

The Netherlands is not a member of EU-OPENSOURCE, but Dutch researchers do have access to the facilities available at the European Lead Factory and ESCulab, as alternative screening centres. Chemical Probe Consortium (CPC), as potential EU OPENSOURCE Dutch node, has been prioritised in the National Roadmap for Large-Scale Research Infrastructure (2021): Group Life Sciences & Enabling Technologies.

USERS PERSPECTIVE

EU-OPENSOURCE supports all stages of a chemical tool development project, including assay adaptation, high-throughput screening, and chemical optimisation of the ‘hit’ compounds. It operates an open-access database and a unique, common compound collection, which is hosted by the European Chemical Biology Library (ECBL), consisting of over 100.000 compounds. The EU-OPENSOURCE national nodes provide researchers with access to cutting-edge technologies to develop their own tools and compounds. In addition, EU-OPENSOURCE provides a collaborative environment for the participation of academic researchers, Biotech SME’s and industry. It can be stated that the Dutch research activities could be (extensively) supported by membership and access to EU-OPENSOURCE.

Relevance for the user community

At the current stage, it is not possible to completely ascertain to which extent the Dutch research community will be dependent on access to EU-OPENSOURCE resources, services and tools.

Education & training

Training is one of the core services of EU-OPENSOURCE, and as such (technical) staff exchange and training activities are targeted at Master and PhD students, postdoctoral scientists and independent principal investigators so that the transfer of knowledge as well as optimal use of the EU-OPENSOURCE infrastructure is ensured. Examples of relevant training topics are assay development, assay technologies, instrumentation and automation, compound management, and informatics.

STRATEGIC PERSPECTIVE

Alignment with national research/strategic agendas

EU-OPENSOURCE potential future Dutch node, the Chemical Probe Consortium, is prioritised in the National Roadmap for Large-scale Research Infrastructure (2021): Group Life Sciences and Enabling Technologies and is aligned with the priorities described in the Sector Portrait Biology (2020)- 'Building Blocks of Life' but most importantly in the context of interdisciplinary with Pharmaceutical Sciences ambitions as described in its Sector Portrait (2020). In addition, it is also mentioned in the strategic paper of the NWO Research Community 'From cells to organisms' as well as in the Strategic Paper from the NWO Research Community Chemistry 'Vision for Chemistry 2040'. In a broader national context, EU-OPENSOURCE supports the research prioritised in the Top Sectors Life Sciences & Health, High Tech Systems & Materials, several Dutch Research Agenda routes and in the Knowledge and Innovation Agenda: Health & Care; Key Enabling Technologies missions.

At European level, there is a clear alignment with the EU Cancer Mission and several UN-SDGs. It can be concluded that research enabled by EU-OPENSOURCE is aligned with specific (inter) national strategic agendas.

National & International dimensions

The Dutch chemical and biological community could largely benefit from access to services, resources and data collected by EU-OPENSOURCE, as the same breadth of data and resources cannot be provided by a single country. Conversely, EU-OPENSOURCE could benefit from the Dutch contribution as it enables other European members to have access to the facilities in the Netherlands: the European Lead Factory and ESCulab. Moreover, funding recently awarded under National Growth Fund Programme, to a national initiatives as PharmaNL (new therapies and academic drug development & repurposing) and Oncode-PACT (pre-clinical development in oncology) positions the Netherlands as a knowledge and innovation hub and therefore, as demonstrator to other European countries members of EU-OPENSOURCE.

Relation to other (similar) Research Infrastructures

Even though EU-OPENSOURCE is a unique research infrastructure in its essence, at national level synergies could be sought with other research infrastructures identified in the National Roadmap for Large-scale Research Infrastructure: Group Life Sciences & Enabling Technologies, like Models to Combat Ageing and Cancer (MCCA2.0)/ ESFRI INFRAFRONTIER. At European level, it is noteworthy that in spite of the differences in scope, technologies and research communities served, the need for more coordination and collaboration to support molecular life sciences research(ers) in a broader sense has been recognised and formalised in a Memorandum of Understanding (2022) between EU-OPENSOURCE, Euro-BioImaging, and INSTRUMENT.

Impact & outreach

The impact of EU-OPENSSCREEN can be described in two layers: i) the societal impact in which the conversion of findings from the scientific context to its implementation in the clinical setting has a direct benefit for the (aging) European population and consequently contributes to address several societal challenges in the areas of Health & Care; and ii) economic impact by generation of knowledge, opportunities for co-development with the Biotech and Biopharma industry, thereby generating and maintaining jobs and attracting (further private and public) investment.

Time period

EU-OPENSSCREEN is expected to remain relevant to its research community for a period longer than ten years provided that the upgrade of its facilities is accounted for.

CONCLUSION

EU-OPENSSCREEN offers the research community compound screening methods to validate novel therapeutic targets and support for basic mechanistic studies addressing fundamental questions in cellular physiology. Dutch researchers can benefit from participation in EU-OPENSSCREEN in several ways: i) by access to the wide library of compounds hosted by EU-OPENSSCREEN, ii) by access to high-throughput facilities and expertise, and most importantly, iii) through opportunities for European joint research activities. On a mid-term a Dutch membership in EU-OPENSSCREEN could be considered for the benefit of the wider Biological and Chemical research community.

Euro-Biolmaging – European RI for Imaging Technologies in Biological and Biomedical Sciences

Euro-Biolmaging is an **important** infrastructure for the life sciences and biomedical researchers using microscopy, as it provides coordinated access to an European network of facilities, services and expertise with a scope and scale that is not possible at national level.

SYNOPSIS

Euro-Biolmaging is a **distributed** research infrastructure providing the biological and biomedical research community with coordinated access to imaging facilities and services. Currently in the **operational phase**, Euro-Biolmaging is an established European Research Infrastructure Consortium (**ERIC**) since 2019 and has the landmark status in the ESFRI roadmap (2021). Euro-Biolmaging counts with sixteen European members states and the European Molecular Biology Laboratory (EMBL). Organised as an **Hub & Nodes** model, Euro-Biolmaging counts with three hubs: Finland hosting the headquarters, EMBL hosting the biological imaging hub and Italy hosting the biomedical imaging hub. Currently, 35 imaging facilities constitute the Euro-Biolmaging nodes. **Access** to the different Euro-Biolmaging nodes and services is based on assessment of the user application (scientific merit and technical feasibility); whereas access to **data** follows the **open access** policy.

The major contributors to Euro-Biolmaging research infrastructure include the Dutch node Biolmaging-NL, the Dutch High Field Imaging Hub and Population Imaging Flagship Node Rotterdam that bring together 8 + 5 + 1 nodes serving both research communities: 1) Facility of Multimodal Imaging (AMMI Maastricht), 2) Challenges Framework Flagship Node, 3) Correlative Light Microscopy Dutch Flagship Node, 4) Erasmus MC-Advanced Light Microscopy Rotterdam Node, 5) High Throughput Microscopy (HTM) Dutch flagship node, 6) The van Leeuwenhoek Centre for Advanced Microscopy (LCAM)-Functional Imaging Flagship node, 7) Preclinical Imaging Center (PRIME)-Molecular Imaging Dutch Node, 8) The Wageningen Imaging and Spectroscopy Node (WISH) & Molecular Imaging Node-Wageningen, 9) Highfield Imaging node UMC Utrecht, 10) Gorter center LUMC, 11) Spinoza Centre for Neuroimaging, 12) Scannexus Maastricht, 13) Donders Institute for Brain Research, 14) Population Imaging Flagship Node Rotterdam. These nodes cover a wide spectrum of imaging techniques and therefore support research from molecular to population levels in different areas of life and biomedical sciences.

USERS PERSPECTIVE

Euro-Biolmaging facilities and services support a wide spectrum of research areas from clinical pathology to multimodal plant imaging, applicable to single cell, organs, organisms (animal and human) and population imaging to answer specific biological and biomedical research question. Euro-Biolmaging extensively supports research activities in both life sciences and biomedical research areas, by providing access to a wide range of imaging instrumentation (and resolution scales), techniques (from MRI, to optical microscopy X-ray crystallography to cryo-electron microscopy), image analysis tools and training activities.

Relevance for the user community

The microscopy research community is dependent on Euro-Biolmaging services, by allowing access to comprehensive set of facilities, instrumentation techniques and training activities. The coordination role of Euro-Biolmaging as well as the scale in which the services and expertise are accessible and opportunities for joint research activities contribute to its dependency. In addition and in terms of (cost) efficiency access to Euro-Biolmaging facilities as opposed to establish and maintain new ones counts as an additional factor. Regarding the number of users an oscillation between 4700–1900 users per year is observed (2018–2019).

Education & training

Being training and support one of the core activities of Euro-Biolmaging, an extensive catalogue of training activities is available and geographically distributed over its nodes. It ranges from biological and medical imaging courses targeted at both researchers with different seniority levels (master and PhD students, post graduates and senior scientists), facility staff support and industrial partners. Mobility of students is also taken into account and included in the MSc degree programmes and internships. The courses offered include both a theoretical and practical (“hands on”) components.

STRATEGIC PERSPECTIVE

Alignment with national research/strategic agendas

Euro-Biolmaging is included in the National Roadmap for Large-scale Research Infrastructure: Group Life Sciences & Enabling Technologies (2021). Furthermore is prioritised in the Strategic Research Agenda of several Life Sciences disciplines such as Biology (Sector Portrait 2020) and Chemistry (Vision for Chemistry 2040). It is marked as essential research infrastructure by the NWO-Round tables for Life Sciences and Chemistry. This is justified by the broad application that imaging technologies have in several research areas from ecology to medicine, by enabling the visualisation and study of molecules, cells, organs and organisms. Euro-Biolmaging is well aligned with the national strategic priorities.

National & International dimensions

Participation of Dutch researchers in Euro-Biolmaging is important for the life and biomedical sciences researchers. The benefit for the Dutch researchers goes beyond the access to advanced imaging facilities, which otherwise would not be possible on a smaller scale. The costs to acquire and maintain such cutting-edge facilities would not be manageable within a single country. The Dutch researchers also benefit for specialised technical support, in sample preparation and handling, high quality microscopy services and access to standardised data. By being part of such extensive RI and being exposed to the latest technological developments, opportunities for collaborative and joint research activities arise. These ultimately boost the transfer of knowledge among European researchers and contribute to excellent science. Euro-Biolmaging benefits from the available high density of facilities in a single country and longstanding expertise in advanced microscopic, molecular and medical imaging brought by the Dutch nodes.

Relation to other (similar) Research Infrastructures

In the national context, the most direct collaborations are with the X-Omics initiative (Large-scale Research Infrastructure, call 2018) by enabling the combination of omics and imaging technologies as well as with Health-RI (biomedical imaging). At European level, collaborations are ongoing with INSTRUCT (structural biology), particularly iNEXT project (imaging techniques ranging from X-ray

imaging and crystallography, NMR and Cryo-EM) and with EU-OPENSOURCE (high-throughput facilities for biochemical compound screening), collaboration which has been formalised by a Memorandum of Understanding (2022). Further synergies were identified with BBMRI (imaging sharing platforms for population screening and cohort studies), EMBRC (support microscopy for marine biology research) and ELIXIR (bioinformatics, FAIR data and workflows, data management & stewardship).

Impact & outreach

The impact of Euro-Biolmaging can be divided in i) training the next generation of life sciences and biomedical researchers in advanced microscopy and instrumentation in topics as diverse as samples acquisition and handling to AI in imaging; ii) contributing to joint technological developments between private partners/industry and the academy, in which several Dutch nodes are actively participating: PRIME [pre-clinical research area in the development and production of tracers]; AMMI Maastricht and HTM [drug development, pharmaceutical and imaging companies] and WISH [food technology] to name a few. The recent funding of NL-Biolmaging (Large-scale Research Infrastructure, 2023) enables further alignment among the Dutch nodes, combined efforts towards an united access policy, and shared outreach activities with Euro-Biolmaging as demonstrated at ELMI 2023.

Time period

Euro-Biolmaging remains relevant for longer than ten years, provided that the upgrade of its facilities and technologies is accounted for.

CONCLUSION

Euro-Biolmaging provides coordinated access to a set of cutting-edge imaging facilities and advanced microscopy instrumentation as well as access to highly skilled personnel, harmonised data and work flows. Such a wide scale of services and expertise is not available within a single country. Imaging facilities, associated instrumentation and technologies are pivotal for, and form the core of, multiple research areas from agri-food to biomedical sciences. Euro-Biolmaging serves a wide research community that extends beyond the Life and Medical Science domain, including the Technical and Natural Sciences domain. It is anticipated that its user numbers and services will significantly increase in the near future, and consequently the visibility and the added value of Euro-Biolmaging (and the Dutch Biolmaging nodes) services to the research community.

IBISBA – European Research Infrastructure for Industrial Biotechnology

IBISBA is well positioned to become an **important** infrastructure in the industrial biotechnology area, as it provides services to advance the fundamental and applied knowledge on biobased processes and biomanufacturing.

SYNOPSIS

IBISBA is a **distributed** European research infrastructure, which provides access to translational Research & Development & Innovation services on industrial biotechnology, serving the international community of stakeholders, including academia, SMEs and industry (Pharma, Materials & Textiles, Energy, Food Ingredients, Biomedical and Biological). The scientific case of IBISBA lays on advancing the (functional) understanding of biological processes and thereby its applications.

Currently, in the beginning of the **preparatory phase**, IBISBA is working towards the establishment of an European Research Infrastructure Consortium (**ERIC**) as legal entity [end 2026], and has the *project* status in the ESFRI roadmap (2021). IBISBA counts with eight European members states and the UK. IBISBA aims to the follow **Hubs & Nodes** governance model, in which national facilities are organised at member state level as National Nodes, complemented by an IT & data management Node and the Coordination Hub. **Access** to the different IBISBA nodes and services therein is currently under development, but a combination of both **Service Level Agreements (SLAs)** and **open access** is being considered.

The Dutch node IBISBA, IBISBA-NL, is hosted at Wageningen University Research (WUR). It includes high-throughput strain-construction, bioprospecting and phenotyping facilities and automated laboratory. In addition, two facilities in the Netherlands, the Dutch Bioprocess Pilot Facility (TU Delft) and the Algaeparc (WUR), would benefit from its inclusion in and access to IBISBA(-ERIC).

USERS PERSPECTIVE

IBISBA technologies platforms will cover enzyme screening, omics facilities, automated microbial strain construction and genetic circuit assembly, bioprospecting workflows and high-throughput analytics. These biocatalyst facilities will be completed by micro- and mini-fermentation systems, larger bioreactors as well as downstream separation and purification equipment for bioprocess development. Hardware ICT infrastructure, including a ScienceCloud, will offer the database, hosting capacity and supply the means to implement business process management strategies for the operation of complex multi-stage industrial biotechnology projects. IBISBA will **extensively support** research activities in the areas of microbiology, systems & synthetics biology, industrial biotechnology & bio-manufacturing.

Relevance for the user community

IBISBA-NL focuses on the infrastructure development for the systematic deployment of the engineering approach Design-Build-Test-Learn for tailored biocatalyst development in a range of bio-industries. Given that IBISBA is in the early stage of its preparatory phase, research activities in the industrial biotechnology area are **partly dependent** on the access to the IBISBA service portfolio. Nonetheless, by aiming at understanding how biological processes function (enzymatic and microbial functions) and how they can be modified to produce applications in diverse sectors (food and feed, new medicines discovery, fine, bulk chemicals and new materials generation, environmental pollution and reduced carbon footprint), it can be anticipated that the relevance of IBISBA for industrial biotechnology community will increase at short term.

Education & training

Education and training activities provided by IBISBA are in its early stage (from 2019 on) and consist primarily of workshops and webinars. Workshops are targeted at the IBISBA operators (R&D researchers, technical staff) whereas webinars mostly deal with scientific aspects like bioprocesses development, omics tools for biotechnology, protein engineering and biocatalysts as well as systems and synthetic biology.

STRATEGIC PERSPECTIVE

Alignment with national research/strategic agendas

IBISBA is included in the National Roadmap for Large-scale Research Infrastructure: Group Green Life Sciences (2021). There is also alignment between the research activities enabled by IBISBA and the priorities defined in the Top Sectors 'Agri & Food', 'Chemistry NL', and 'Life Sciences & Health', in the Knowledge and Innovation Agenda: Missions 'Agriculture, Water & Food', 'Health and Care', 'Key enabling technologies', and several Dutch Research Agenda routes. At European level, IBISBA is aligned with the ambitions in the EU Green Deal, EU Mission Soil and the EOSC. At international level, alignment with infrastructures for Biomanufacturing such as Global Biofoundries Alliance, Agile Biofoundry and Biomade is present. It can be thus considered that research activities enabled by IBISBA are well aligned with the strategic priorities from (inter-)national agendas.

National & International dimensions

Participation of Dutch researchers in IBISBA is important, given that it will enable the access to IBISBA harmonised services on industrial biotechnologies and digital tools, at a European scale via a single entry point. Specifically, access to resources and services in engineering of bioparts (*i.e.* automated protein expression, enzyme screening, enzyme protein discovery, functional characterisation of proteins, etc); in strain development (*i.e.* automated strain construction, high throughput phenotyping screening, exploratory cultivation in bioreactors, etc) and in bioprocess development (*i.e.* development of enzyme – catalyse of bioprocess, scale up process with a variety of microorganisms and plant cells, etc) will provide the Dutch research community with an opportunity to benefit from a transnational, multidisciplinary environment. In the context of the transnational access (TNA) activities and as of 2021, five calls have been launched leading to 59 applications to access IBISBA resources, of which 5% were from Dutch researchers. In total 28 projects have been funded. Even though, under the TNA scheme only 20% of the actual capacity can be made available, the TNA constitutes a good indicator on the needs and requirements of the user community. Conversely, international researchers will benefit from access to the Dutch node of IBISBA by having access to bioprocess facilities with a Technology Readiness Levels (TRL) 4–6; in which the opportunities for process and prototype validation, testing and implementation are available.

Furthermore, and building upon the position of the Dutch Biotechnology and longstanding collaboration between academia and Industry/SMEs, IBISBA-NL adds an unique asset in terms of translation to the different market sectors. Noteworthy, the recently approved National Growth Fund projects: 'Biotech Booster' and 'Cellular Agriculture' and 'BioBased Circular' would constitute suitable examples on how research & innovation projects benefit and feed into a research infrastructure like IBISBA.

Relation to other (similar) Research Infrastructures

In the national context opportunities for further collaboration should be explored with Nanolabs (nanofabrication technologies) and with X-Omics (omics technologies and data analysis). At European level, synergies can be identified with MIRRI ((micro)Biological Resources Centers), with INSTRUCT (structural biology) and ELIXIR (FAIR, data management & stewardship).

Impact & outreach

The impact of IBISBA will be visible in the transition to a biobased economy by contributing to novel business opportunities, by increasing and consolidating industrial portfolios, but mostly by generating new knowledge, increasing skilled human capacity and thereby generating employment in the industrial biotechnology area. This lays on the fact that biological conversions and biotechnology processes are at the core of (R&D) processes in a wide range of industries (Chemistry, Materials, Fuel, Agri-food and Health).

Time period

IBISBA is expected to remain relevant to its research community for a period longer than ten years provided that the upgrade of its facilities and technologies is accounted for.

CONCLUSION

IBISBA will provide the research community with access via a single access point to distributed industrial biotechnology facilities and digital tools. Acting in an emergent field and anticipating on opportunities that will arise from the transition to a biobased economy, the potential of IBISBA is extensive. Being at the start of its preparatory phase, it is expected that awareness and visibility of IBISBA services and resources will grow and consequently be of increasing value to Dutch research community. Participation in IBISBA will further create opportunities for research collaborations (academic and public-private) and thereby contribute to the generation of knowledge and applications in bioprocesses and industrial biotechnology.

INSTRUCT – Integrated Structural Biology Infrastructure

INSTRUCT is an **important** research infrastructure providing access to European state-of-art facilities, high specialised technologies and expertise in structural biology. The opportunities for joint collaborative research and technological co-developments at this scale are only possible by pooling resources to the benefit of the European biological and medical community.

SYNOPSIS

INSTRUCT is a **distributed** research infrastructure providing access to structural biology technologies and methods to enable structural and functional studies at cellular, molecular and atomic levels.

Currently in the **operational phase**, INSTRUCT is an established European Research Infrastructure Consortium (**ERIC**) since 2017, with the *landmark* status in the ESFRI roadmap (2021). Organised as an **Hubs & Nodes** model, INSTRUCT-ERIC is hosted by the UK and counts with 27 facilities in 16 European member countries, offering technological infrastructures services, training and internships. INSTRUCT is composed of fifteen European member states and the EMBL, being active beyond the European borders by international partnerships with countries in South America, Asia and with South Africa. External **user access** to INSTRUCT facilities is at least in part free-of-charge for its members; whereas non-members can accede the different services upon a user fee determined by the individual nodes or via individual collaboration agreements.

The Dutch node, INSTRUCT-NL, brings together 3 research organisations: The Bijvoet Centre (UU) with focus on NMR spectroscopy, proteomics and computational structural biology; the Netherlands Cancer Institute – Protein Facility (NKI) with focus on protein production and the biophysical characterisation of macromolecules and their interactions and the Netherlands Centre for Electron Nanoscopy (LEI) with focus on cryo-electron microscopy (cryo-EM).

USERS PERSPECTIVE

By providing access to state-of-art structural biology research facilities and resources, participation in INSTRUCT contributes to advance the knowledge in structural biology and thereby, to advance fundamental knowledge in the fields of biochemistry and biophysics, immunology, oncology, genetics, omics as well as biotechnology and biomaterials. By supporting the 3D visualisation at molecular level, structural and functional studies are made possible, in turn further advancing the knowledge on molecular dynamics. Specifically, fundamental structural biology research activities and the technological and methodological developments therein derived are extensively supported by access to INSTRUCT.

Relevance for the user community

INSTRUCT provides coordinated access to high end facilities, training and a technology catalogue (sample preparation; biomolecular analysis; 3D structural analysis and computational analysis) of which the Dutch research community is largely dependent. There has been considerable infrastructural public investment (OCW, NWO) over the last decade (2012–2022): uNMR-NL, Proteins@Work,

NEMI, X-Omics), in structural biology technology development which has contributed to position the Netherlands at the European forefront. In turn, additional funding at the European level (*i.e.* EU-NMR, PRIME-XS, iNEXT, iNEXT-Discovery) has been generated, which the Dutch research community largely benefits from. INSTRUMENT membership is also beneficial for e-Science activities in relation with EOSC and EuroHPC-JU (*e.g.* EGI-ACE, BioExcel center of excellence). The Netherlands is currently self-sufficient in fast developing areas such as mass spectrometry, NMR technologies and access to biophysics tools. Nonetheless, in areas like cryo-EM and several X-ray methods it is highly advantageous to have access to the INSTRUMENT facilities, whereas for other technologies like nanobody generation or X-ray imaging, there is no suitable nor affordable option available beyond access via INSTRUMENT.

Education & training

The training catalogue comprises theoretical courses (basic structural biology) and hands-on training on crystallography, cryo-EM and cryo-electron tomography; as well as training in computational skills and data analysis. The target audience of these activities ranges from early career researchers to technical personnel. Noteworthy is the INSTRUMENT Internship Programme in which applicants can benefit from access to techniques and knowledge existent in INSTRUMENT facilities, which is otherwise not obtainable in their own facilities. Several workshops and the biennial Structural Biology conference have been organised throughout the years (the Netherlands, 2022), bringing together the structural biology and molecular biology international communities.

STRATEGIC PERSPECTIVE

Alignment with national research/strategic agendas

The INSTRUMENT facilities at NeCEN (Cryo-EM) and the Bijvoet Centre (NMR) are directly connected to Netherlands Electron Microscopy Infrastructure (NEMI) and Ultra High Field NMR facility for the Netherlands (uNMR-NL), respectively, both included in the National Roadmap for Large-scale Research Infrastructure (2021): Group Life Sciences and Enabling Technologies. INSTRUMENT is mentioned in the strategic papers from NWO-Life Sciences 'Biology of molecules, cells and tissues' and 'Advanced methods, data and analyses to understand Living systems' research communities and equally in the NWO Round Table Chemistry Strategic Agenda – 'Vision for Chemistry 2040'. The priorities defined in the Sector Portrait Biology (2021), priority area 'Innovative technology, data analysis and advanced methods' benefit from the facilities, technologies and expertise present in INSTRUMENT centers. It can be concluded that the research activities enabled by INSTRUMENT are well aligned with different national agendas.

National & International dimensions

Participation of Dutch researchers in INSTRUMENT is of importance as it allows access to state-of-art equipment, which in some cases is not present in the Netherlands or not present with the same technical level (*i.e.* resolution, sensitivity, automation) and at higher costs. Access to a network of experts, technologies and training activities, not only expands the opportunities for research and development for Dutch researchers, but it also brings visibility to the Dutch research community within and beyond the European borders. Vice versa, INSTRUMENT benefits from the Dutch participation as it adds specific expertise and additional sites.

Relation to other (similar) Research Infrastructures

At European level, (technological) synergies can be identified with ELIXIR (3D-BioInformatics community) and more broadly with the EOSC. Noteworthy is that in spite of the differences in scope, technologies and research communities served, the need for more coordination and collaboration to support molecular life science research(ers) in a broader sense has been recognised and formalised in a Memorandum of Understanding (2022) between Euro-BioImaging, EU-OPENSOURCE and INSTRUMENT. At national level, synergy and collaborations should be further explored with other research infrastructures prioritised on the National Roadmap within the Life Sciences and Enabling Technology and Medical Sciences groups.

Impact & outreach

The broader impact of INSTRUMENT can be summarised as of i) societal impact by its contribution to the development of new therapeutics and biologics, being a pertinent example the effect on controlling transmissible disease outbreaks (*i.e.* COVID-19 pandemic). In addition, structural biology technologies have direct application in the agri-food (improving crop resistance to pathogens) & biotechnology (bioremediation, production of biomaterials) sectors; ii) economic impact by providing training in a specific skill set and thus contributing to job creation and generation of R&D&I activities (*i.e.* drug development). The latter has been recognised recently by the awarding of two National Growth Fund projects (Pharma-NL and Oncode-PACT), which make use of INSTRUMENT (and INSTRUMENT-NL nodes).

Time period

INSTRUMENT is expected to remain relevant for a period longer than ten years provided that the upgrade of its facilities and instrumentation is accounted for.

CONCLUSION

INSTRUMENT directly serves a specific life sciences research community, structural biology, but services reach out to the wider biochemistry, cell biology, virology, and medicinal chemistry communities. Scientific knowledge on structural and functional molecular studies contribute to advance the fundamental and applied knowledge in several disciplines from biophysics to genetics, and as such, structural biology is also prioritised in several national research agendas. Being part of INSTRUMENT enables the Dutch research community to benefit from wide access to highest-end and inevitably expensive equipment and technologies, with an investment rate that is hardly affordable by any individual country. More importantly, by being member of INSTRUMENT-ERIC, Dutch researchers benefit from the opportunity to participate in joint research and methodological co-developments activities, not seldom funded by the EC, in a scientific field with a fast-evolving pace.

LIFEWATCH – e-Infrastructure for Biodiversity and Ecosystem Research

LifeWatch is an **important** infrastructure providing an overarching layer of e-services for building Virtual Laboratories, enabling data analyses and modelling in biodiversity and ecosystem research.

SYNOPSIS

LifeWatch is a **distributed** research infrastructure, which provides e-science research facilities for the study of biodiversity and ecosystem functions. LifeWatch research facilities are organised in i) Thematic Services; ii) Catalogues of Virtual Labs; iii) Eco portal and iv) LifeWatch metadata portal. In short, LifeWatch deals mostly with providing access to data, workflows and pipelines and its deployment in a cloud platform environment.

Currently in **operational phase**, and set up as an European Research Infrastructure Consortium (**ERIC**) since 2017, LifeWatch counts with eight member states as partners. LifeWatch has the *landmark* status in the ESFRI roadmap. Organised as an **Hubs** (Common Facilities) & **Nodes** model (Distributed Centers), the Common Facilities are based in Spain, Italy and the Netherlands. **Access** to LifeWatch services and resources follows a registration procedure whereas access to data is mostly open access, unless otherwise agreed with the data owner.

At national level, the Dutch node is coordinated by the University of Amsterdam (UvA), which hosts one of the Common Facilities, the Virtual Laboratory and Innovation Centre (VLIC). VLIC contributes to the technology development by providing prototypes on Virtual Research Environments (VREs); done in collaboration with SURF (ICT, computing and storage) and the e-Science Center (research software). The contribution of the Dutch node to LifeWatch is mostly via project/technology development at the UvA (in kind).

USERS PERSPECTIVE

The e-services provided by LifeWatch form the technical backbone of LifeWatch RI, that support several research activities of its user community. As examples: within NaaVRE (Notebook as-a-VRE) infrastructure, several prototypes were developed to meet the requirements of its users and are now available. These prototypes are EBVs (generating Essential Biodiversity Variables) and LiDAR (Ecological application of Light Detection And Ranging). At present, LifeWatch counts with 6 workflows, 12 VREs and over 1500 datasets and related catalogues for data, services and training resources. Currently, LifeWatch supports several research activities, and further development of LifeWatch VRE technology points to a potential increase in the support that LifeWatch e-services can provide to its community.

Relevance for the user community

Currently, the activities in the biodiversity and ecosystems research areas are partially dependent on the e-services offered by LifeWatch. Definition of user numbers and its quantification is scarce, but in the period of 2018–2019 an average of 360 data requests were placed by the Dutch researchers (corresponding to an average of 3% of the total users for the same period). This might relate to the fact that most of the LifeWatch activities to date, address an important bottleneck in accessing data (or accessing a combination of datasets) from different sources and the constraints

therein derived in terms of accessibility, interoperability and efficiency. By providing a structured VRE according to the FAIR data principles and by training its users, it can be expected the relevance and the usage of the LifeWatch e-services and technical solutions will increase, and thus also contributing to the visibility, scalability and sustainability of the LifeWatch e-services and facilities.

Education & training

LifeWatch offers training events (workshops, conferences, international summer schools) on biodiversity and ecosystem research topics, as well as courses on how to use LifeWatch tools, services and VREs. These events are aimed at young researchers and data/ICT specialists. Currently LifeWatch-ERIC counts with 35 resources listed in the training catalogue.

STRATEGIC PERSPECTIVE

Alignment with national research/strategic agendas

The research activities supported by LifeWatch are well aligned with the priorities described in the Sector Portrait Biology (2020) namely in the pillars: 'Adaptation & evolution'; 'From ecosystems process to biodiversity' and 'Innovative technology: data analyses and advanced methods'. LifeWatch is prioritised in the NWO Round Table – Life Sciences from 'Genes to Organisms' as well as 'Organisms in their environments' strategy papers. LifeWatch is included in the National Roadmap for Large-scale Research Infrastructure (2021): Group Green Life Sciences. Furthermore within the current National Roadmap Group there is clear prioritisation to develop an integrated set of measuring tools and instrumentation to monitor biodiversity, ecology and living environment. This will be addressed in close collaboration with eLTER(-NL).

National & International dimensions

At national level the contribution of the Dutch node to LifeWatch consists of *in-kind* contribution via the participation in seven EU-H2020 projects, as well as collaborative projects between UvA, SURF and eScience Center. The prototypes herein developed as well as hosting the LifeWatch-ERIC VLIC contribute to the further development of LifeWatch. As LifeWatch is an e-infrastructure rather than a physical infrastructure, transnational access (TNAs) is limited to deployment of e-services that are developed by the LifeWatch-ERIC.

Relation to other (similar) Research Infrastructures

LifeWatch has synergies with other research infrastructures both at national and international level. Recently, the LTER-LIFE project was funded as a Large-scale Research Infrastructure, in which LifeWatch, eLTER-NL and NEMNET (hosted by RIVM) are the main contributing research infrastructures. The focus is on developing site-specific digital twins, which has a huge potential to foster new collaborations (inter)nationally. At national level, collaboration within the ARISE project (Large-scale Research Infrastructure 2021) in the context of e-services provision regarding the digitisation of collections and digital twins of individual specimens is ongoing.

At international level GBIF (Global Biodiversity Information Facility), the e-services provided by LifeWatch may offer an additional layer of services enabling analysis and modelling of data available via the GBIF infrastructure. In the context of the European research infrastructures (ESFRI and its national nodes), further opportunities for collaboration between LifeWatch and eLTER (by enabling the virtual access and data analyses from eLTER sites data), DiSSCo (by co-development in the data digitisation and access to collections) and ELIXIR (by co-development of FAIR data tools and training) may be foreseen. Taken together, further exploration of these opportunities may lead to an increase in the outreach and visibility of LifeWatch e-services and facilities.

Impact & outreach

As the research infrastructure providing e-services and facilities to study the biodiversity and ecosystems functions, the impact of LifeWatch comprises the generation of knowledge in the areas of climate change and sustainable development, resource efficiency and energy, food security and agriculture and health. As such contribution to several UN-SDGs, EU missions (Green Deal, Oceans and Soil missions), as well as at Dutch Research Agenda lines and Knowledge and Innovation Agenda missions is noticeable. It can be anticipated that LifeWatch e-services, technical expertise and knowledge generated can be fed in to further development of EOSC and thereby, contribute to the development of Open Science policy.

Time period

Access to LifeWatch e-Services (data, workflows and platforms) will remain relevant for longer than ten years, provided that the evolving needs of its users, the re-organisation/re-positioning of the RIs within the Green Life Sciences/Environment landscape, and continuous development of its service portfolio are accounted for.

CONCLUSION

LifeWatch provides the research community with unique e-services and virtual facilities for the study of biodiversity and ecosystem research. In this context, the access to extensive data analyses and modelling services is of paramount importance. In its first strategic period LifeWatch has been focusing on developing its vision and operational framework. LifeWatch is expected to further develop its services in the second strategic period (2022–2026), increasing its visibility and outreach, with direct consequences to its user numbers. LifeWatch's potential will further increase with continued investment at both national (through LTER-LIFE) and EU level. In addition, closer collaboration between LifeWatch and other e-research infrastructures is being sought and facilitated in order to meet the e-needs of its user community.

MIRRI – Microbial Resource Research Infrastructure

MIRRI is an **important** infrastructure for microbiology research by providing access to microbial resources centres and expertise, via a single and coordinated access point.

SYNOPSIS

MIRRI is a **distributed** research infrastructure for the preservation, systematic investigation, provision and valorisation of microbial resources. It brings together 50 microbial domain Biological Resources Centres (mBRC) culture collections and research institutes from ten European countries. Currently in the **operational phase** and set up as an European Research Infrastructure Consortium (**ERIC**, 2022), MIRRI-ERIC has its headquarters in Portugal and counts with Spain, France, Belgium and Latvia as founding members. MIRRI has the *landmark* status in the ESFRI roadmap (2021). MIRRI aims at providing free-of-charge, **open access** to its members and observers. Access to MIRRI resources by other non-members is expected to be arranged either via European transnational access calls (TNA), or via a market driven access model (cost recovery). MIRRI catalogue has available more than 400.000 microbial strains that can be used as reference and testing material for taxonomic and phylogenetic basic research, health and agri-food research, biodiversity, environment and energy research; which taken together show the wide breath of application of the MIRRI resources.

At national level, the Westerdijk Institute (WI-KNAW) has been participating in MIRRI-related projects since 2010, via EU funding-Research Infrastructures pillar. WI-KNAW would be in position to function as the Dutch node (MIRRI-NL) of MIRRI-ERIC. WI-KNAW hosts a collection of the 100.000 strains of fungi (including yeasts) bacteria, as well as plasmids and phages.

USERS PERSPECTIVE

MIRRI-ERIC serves the bioscience and the bio-industry research communities by facilitating the access to a broad range of microorganisms, their derivatives, associated data and services, with focus on biodiversity, health & agri-food and environment & energy research areas.

Relevance for the user community

MIRRI is not yet a fully operational RI but data from 2019 (preparatory phase projects) shows a total number of 6.200 unique users. Data from the two transnational access (TNA) calls showed a total of 26 application received of which 11 were granted. Dutch users have placed around 1.000 requests concerning around 5.800 strains (2014–2021). Requests to use these strains are mainly from researchers in the biotech, pharmaceuticals and agri-food areas. Biodiversity research(ers) can be extensively supported by having access to the 400.000 strains in the MIRRI microbial Biological Resources Centres (mBRCs), of which 9.000 strains are originated for natural and non-natural locations in the Netherlands, 500 of these being reference strains. Preserving and keeping available these strains remains crucial to study biodiversity and its evolution. Further enrichment of the strain information with DNA sequence data will enable the (correct) identification of new species. This is also aligned with the goal of the ARISE project (Large Scale Research Infrastructure call, 2020), which aims at the construction of an infrastructure to identify and monitor every eukaryotic species in the Netherlands. WI-KNAW is one of partners of the ARISE project. For the environment and energy research, research activities support by MIRRI comprise the biological management of soil and crops, bioremediation of pollutants and plastics in soil and water, as well as the development of

renewable biobased materials. Health researchers equally rely on access to well identified, well preserved reference strains in order to develop new diagnostic tools for pathogen microorganisms, to study human/human animal infectious diseases and to contribute to advance the discovery of anti-microbial drugs. In the context of One Health, the research community depends on mBRC that MIRRI offers for the development of new vaccines, phages therapies and microbiome therapeutics. For agri-food research, the possibility of screening and using fungi and yeast collections contributes to the development of pre- and pro-biotic research and ultimately to new feed and food products.

Education & training

MIRRI has developed an educational component having available 25 training courses in its service catalogue, ranging from technical courses on microbial preservation to quality and management of microbial collections. In addition MIRRI organises 'European Specialisation course on Microbial Resources Centres' and several workshops on Biorisk (Access and Benefit Sharing and on the General Requirements for Biobanking).

STRATEGIC PERSPECTIVE

Alignment with national research/strategic agendas

Microbiome research as enabled by the MIRRI resources is well aligned with the priorities described in the Sector Portrait Biology (2020, specifically 'Building blocks of life', 'Adaptation and evolution' and 'From ecosystems processes to biodiversity'). MIRRI and the WI-KNAW are equally mentioned in the strategic paper of the NWO Round table-Life Sciences- research community on 'Advanced methods, data and analysis a better understanding of living systems' (2020); as well as included in the National Roadmap for Large-scale Research Infrastructure: Group Green Life Sciences (2021). Investment in microbiome research areas has been highlighted within the Knowledge and Innovation Covenant (2020–2023) in three of six topics: Energy Transition & Sustainability; Agriculture, Water & Food and Health & Care. WI-KNAW is partner in initiatives as BiodiversityXL and *Deltaplan Biodiversiteit*.

National & International dimensions

The WI-KNAW, is the only Dutch institution that hosts all the public microbial culture collections (CBS and NCCB) fulfilling simultaneously the role of archive and distributor of these collections. In addition, WI-KNAW functions as an expertise centre by ensuring that quality standards and compliance procedures for culture collection management are met according to international standards (OECD, ISO). MIRRI offers access to 300.000 additional strains and associated datasets to its members as free-of-charge, via single portal. Equally important, MIRRI membership supports researchers to comply with the legislation and regulatory requirements in sharing microbial resources and will further update and expand the set of tools for compliance to biosafety and biosecurity of microbial resources. Currently Dutch mBRCs (WI-KNAW) are available through the MIRRI catalogue, via European project funding. It cannot be excluded that once the current project(s) are concluded, and in absence of Dutch membership in MIRRI, these collections will be absent from the MIRRI catalogue. This might affect the visibility and the international use of the Dutch collections.

Relation to other (similar) Research Infrastructures

Within the context of European research infrastructures, MIRRI has identified synergies with: BBMRI with focus on biobanking of human cell lines/tissues for microbiome research; IBISBA in the context of industrial biotechnology; EMBRC as the Resource Center on Marine Biology. Within the biodiversity research area, complementarities with both DiSSCo and LifeWatch have been identified, and with ELIXIR as the overarching research infrastructure for Life Sciences research data.

Impact & outreach

As an example of the broader societal impact of MIRRI, WI-KNAW activities in the area of Citizen Science are mentioned, particularly the national campaign 'World fame: fungus with your name' targeted a young population and aimed at increasing the general interest in biodiversity and bio-discovery. This campaign led to the identification of 29 new microbial species. MIRRI is in addition developing training programs for scientists, culture managers and biotech entrepreneurs; and educational programs aimed at the general public.

Time period

Given that MIRRI resources deal with the long term preservation and assurance of microbial strains supply, it can be anticipated that it remains relevant for longer than ten years.

CONCLUSION

MIRRI deals with a specific area in the Life and Medical Sciences domain: microbiology. It provides access to collections, data and services, with application in diverse research areas from health, biodiversity to energy, and thus to a wide range of potential users. Being at the start of its operational phase (2022), it is expected that MIRRI will further expand its microbial collections, services and activities by the inclusion of additional member states as MIRRI-ERIC members. To improve its position among the Dutch research community, MIRRI can benefit from raising awareness activities, increase the visibility and prioritisation of its resources and services to serve the wide Life and Medical Sciences community.

5.3 Social Sciences and Humanities

The characteristics of the Social Sciences and Humanities RIs

The Social Sciences and Humanities (SSH) landscape covers a wide range of academic disciplines which focus on human behaviour and help us understand ourselves, others and the human world around us. It includes the study of (foreign) languages, history, philosophy, literature, heritage studies, (performing) arts, law, religion, anthropology, archaeology, geography, linguistics, logic, sociology, pedagogics, psychology, economics, finance, public administration, political science, demography, environment. Many of these research areas are taking a digital turn: methods, data and tools are in transition. (See also SSH Sector Portrait 2019 and the SSH sector plan 2021; <https://www.sectorplan-ssh.nl/>). The research infrastructures in this domain serve **a large number of often multidisciplinary scholars and scientists** for an increasing number of aspects of research workflows.

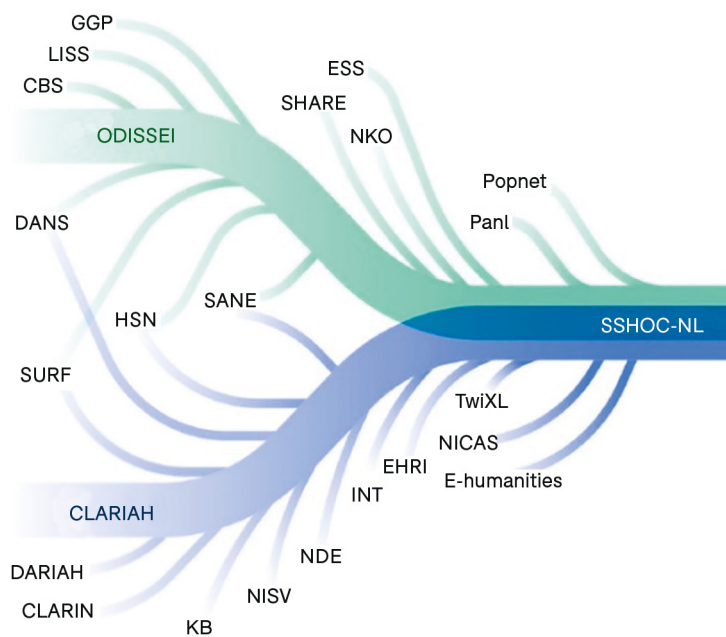
Social Sciences and Humanities researchers address the constant challenges faced by societies in the forms of transformations, crises and divides. Human behaviour and its consequences are extremely complex, yet have far-reaching impacts for the way in which culture is generated and shared, how society is structured and organised and how technology and policies should be developed and implemented. Understanding the mechanisms underpinning these processes requires integrated research infrastructures that allow for the **simultaneous cross-disciplinary study of their development over time, interlinkages and contemporary manifestations**. It requires facilities for 'big data': data types that are not only large in volume, but also complex because of the multi-layered nature and the need for proper contextualisation. This holds for the situation in the Netherlands as well as for the European Research Area.

Many SSH infrastructures are of a **distributed** nature, most are providing access to large volumes of complementary **digital data** and offer **federated services**. Their datasets are not generated by instruments or machines, but have been collected or curated by surveys and/or human legwork and expertise in many countries worldwide. The international coordination offices ensure the complementarity of data collected, supports the development of standards, implements shared platforms to make data and federated services available and coordinates training and support for the users. Heritage sciences also require instruments and techniques to study **tangible heritage objects**. Some RIs, e.g. EHRI, RESILIENCE and E-RIHS, deploy instruments for transnational access (TNA) that facilitate **physical access** to their resources.

The Social Sciences and Humanities RIs landscape and its stakeholders

In preparing for the 2016 Roadmap for Large-scale Research Infrastructure, the humanities RIs CLARIN-NL and DARIAH-NL started collaborating in **CLARIAH** (Common Lab Research Infrastructure for the Arts and Humanities). The main founding partners are Huygens ING, Dutch Language Institute (INT), International Institute for Social History, the National Library of the Netherlands, Meertens Institute, Max Planck Institute for Psycholinguistics, Data Archiving and Networked Services (DANS) and Netherlands Institute for Sound and Vision. Additional partners are the relevant academic departments in Amsterdam, Groningen, Leeuwarden, Leiden, Maastricht, Nijmegen, Utrecht and NIOD, National Archive and Netherlands eScience Center. Presently there are 22 partners in the CLARIAH consortium.

The RIs in the social sciences joined forces in **ODISSEI** (Open Data Infrastructure for Social Science and Economic Innovations), and created a consortium in which all the relevant RIs participate, as well as all social sciences faculties and institutes and relevant public organisations, such as CBS, DNB, CPB, SCP, PBL and RIVM. All consortium members pay an annual membership fee. A total of 45 partners contribute to ODISSEI.



Cross-disciplinary collaboration between social sciences and humanities RIs has intensified further in the context of the [Roadmap for Large-scale Research Infrastructures 2021](#). Within the SSH Domain, all SSH RIs on the Landscape formed a single Roadmap Group and formulated a joint SSH narrative describing the main challenges in the field and the RI investments needed to do breakthrough academic research. All existing RI-plans for the social sciences and humanities domain were included within the overarching concept of the Macroscopic: an imaginary machine to study the extremely complex. The Macroscopic can zoom out to the level of populations and cultural systems and can zoom in, down to the level of individual constituents. Analyses can chart long-term change and trends, and trace societal developments from different types of data ranging from the built environment and physical artefacts to the digital breadcrumbs left behind today. They can also track the state of events in real time and make predictions, using models to extrapolate observed trends, detect early warning signals, and develop interventions that help researchers and policy makers shape the society of tomorrow. The next step for the SSH RIs was to join forces (together with institutions, specific collections and other networks) in the [SSHOC-NL](#) project. This grant will stimulate further collaboration between the SSH RIs and lay the foundation for the realisation of the Macroscopic vision. In the future, SSHOC-NL will enable researchers to securely and ethically connect and analyse any large amount of data, such as historical data, text data, speech, images, survey data and social media data. This will help them address some of the most pressing social issues, such as polarisation, social inequalities, and the changing environment.

Link between European and the national Roadmap for Large-scale Research Infrastructures

All Dutch SSH RIs in this report are on the [ESFRI Roadmap](#), some of them already since 2006 and others have entered more recently. SHARE, ESS, CESSDA, CLARIN and DARIAH have already reached ESFRI Landmark status. EHRI, E-RIHS, RESILIENCE, GGP and OPERAS are on the ESFRI Roadmap and in a Preparatory Project phase. The research community in the Netherlands has a leading role in constructing and running these RIs as the Netherlands is the **host** country of CLARIN, GGP and EHRI and is an essential partner in many others.

The Netherlands has expressed political support to all 10 ESFRI RIs, which have already been collaborating at the European level in the [SSH Open Cluster](#) that is building on the results of the [SSHOC project \(H2020; 2019-2022\)](#). The national Roadmap and ESFRI Roadmap are consequently very well linked.

The membership fees to the ESFRI RIs cover the costs of a coordination office in the host country of the ERIC and sometimes also some subsidiary offices in other member countries. They deliver standards and generic tools for data collection, data coding and enrichment, data curation, data linkage, data storage, archiving and publishing, and data analysis, and in addition provide support and training for communities of users and, in some instances, transnational physical access to facilities. Member states often make additional resources available for **large in-kind contributions**. These resources facilitate the collection of national data, the alignment with FAIR data principles and open-up national research infrastructures for trans-national access. The latter contributes to the interoperability of data and access services across countries.

Conclusions and suggested actions

The Dutch participation in the 10 European RIs is of key **importance** for the scientific development of the social sciences and humanities. In view of the cultural and linguistic diversity of the relevant data sets and the need to facilitate comparative research across regions and languages, it is essential that data are being collected and made accessible in a FAIR way in as many countries as possible. These data cannot be simply collected by instruments or machines, but **require human input and/or legwork and expertise from researchers in communities and countries worldwide**. The bottom-up ESFRI Roadmap has now resulted in a series of international SSH RI initiatives that benefit from a **long-term strategy** of collaboration both in terms of decision making and long-term planning and financing. CLARIAH, ODISSEI and SSHOC-NL are **excellent and trailblazing examples** of coordination within SSH.

The breadth and complexity of the SSH RI collaborations both in The Netherlands and at European level is commendable and engages the SSH community as a whole. It requires careful **monitoring and support**, especially since not all SSH disciplines are currently fully served by the existing RIs. Periodic monitoring of the evolution in the domain is needed to facilitate decision making, positioning and future planning. All SSH RIs need to continue activities regarding the formulation and monitoring of **KPIs** that emphasize both their **national** and **international added value**.

As additional international RIs emerge that fill white areas in the SSH RI landscape (e.g. [MEDem](#) and the e-infrastructure [SoBigData](#)), continued actions are needed to promote shared solutions for shared challenges, and to prevent fragmentation and inefficient use of limited funding.

All SSH RIs are in a continuous process of increasing (the volume and quality of) their data, linking them and improving the services they offer to their users. This requires **long-term (financial) commitments** from the relevant stakeholders to ensure the sustainability of these investments.

List of memberships

Humanities – Language, Speech, Images. Video, Data, Material Heritage

CLARIN

Common Language Resources and Technology Infrastructure: a digital research infrastructure offering data, tools and services to support research based on language resources

<https://www.clarin.eu/>

Countries: NL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, GR, HR, HU, IS, IT, LT, LV, NO, PL, PT, SE, SI (UK, ZA)

Legal entity: ERIC

DARIAH

Digital Research Infrastructure for the Arts and Humanities: a digital research infrastructure in support of ICT-based research practices in the arts and humanities that sustains researchers in building, analysing and interpreting digital resources

<https://www.dariah.eu/>

Countries: FR, AT, BA, BE, BG, CH, CY, CZ, DE, DK, ES, GR, HR, IE, IT, LU, MT, NL, PL, PT, RS, SI

Legal entity: ERIC

EHRI

European Holocaust Research Infrastructure: EHRI enables online and physical access to Holocaust sources and expertise dispersed across many institutions in Europe and beyond. EHRI provides innovative tools and training that advance the digital transformation of Holocaust research

<https://www.ehri-project.eu/>

Countries: NL, AT, BE, CZ, DE, HR, RO, SK, UK (IP, PL)

Legal entity: ERIC (application stage)

E-RIHS

European Research Infrastructure for Heritage Science: E-RIHS supports research on heritage interpretation, preservation, documentation and management by providing integrated access to expertise, data and technologies through a standardized approach

<https://www.e-rihs.eu/>

Countries: IT, BE, CY, DE, DK, ES, FR, GR, HU, MT, NL, PL, PT, RO, SE, SI, UK

Legal entity: ERIC (application stage)

RESILIENCE

REligious Studies Infrastructure: tooLs, Innovation, Experts, conNections and Centres in Europe: an interdisciplinary and invigorating research infrastructure for Religious Studies, building a high-performance platform, supplying evolving tools and big data to scholars from all the scientific disciplines crossing religions in their diachronical and synchronical variety

<https://www.resilience-ri.eu/>

Prospective partner countries: IT, AL, BA, BG, GR, IL, NL

Legal entity: MoU between research institutes

Social Sciences – Surveys, Cohorts, Registry Data

CESSDA

Consortium of European Social Science Data Archives: CESSDA provides large-scale, integrated and sustainable data services to the social sciences. It brings together social science data archives across Europe, with the aim of promoting the results of social science research and supporting national and international research and cooperation

<https://www.cessda.eu/>

Countries: UK, AT, BE, CH, CY, CZ, DE, DK, FI, FR, GR, HR, HU, IS, IT, MK, NL, NO, PT, RS, SE, SI, SK

Legal entity: ERIC

ESS

European Social Survey: an academically driven cross-biannual national survey that has been conducted across Europe since 2001 which measures the attitudes, beliefs and behaviour patterns of diverse populations in more than thirty nations

<https://www.europeansocialsurvey.org/>

Countries: UK, AT, BE, BG, CH, CY, CZ, DE, EE, ES, FI, FR, HR, HU, IE, IL, IS, IT, LT, LV, ME, NL, NO, PL, PT, RS, SE, SI, SK

Legal entity: ERIC

GGP

Generations & Gender Programme: a research infrastructure started in 2000 that provides scientists and policy makers with high quality and timely data about population and family dynamics to enable researchers to contribute insights and answers to current demographic societal and public policy challenges

<https://www.ggp-i.org/>

Countries: NL, AT, DE, EE, FR, HR, HU, IT, LT, NO, PL, SE

Legal entity: Consortium Agreement (ERIC application stage)

SHARE

The Survey of Health, Ageing and Retirement in Europe: a research infrastructure for studying the effects of health, social, economic and environmental policies over the life-course of European citizens and beyond

<https://share-eric.eu/>

Countries: DE, AT, BE, BG, HR, CH, CY, CZ, FR, GR, HU, IL, IT, NL, PL, SE, SI

Legal entity: ERIC

Humanities and Social Sciences – Open Science

OPERAS

Open Scholarly Communication in the European Research Area for Social Sciences and Humanities: OPERAS is the Research Infrastructure supporting open scholarly communication in the social sciences and humanities (SSH) in the European Research Area. Its mission is to coordinate and federate resources in Europe to efficiently address the scholarly communication needs of European researchers in the field of SSH.

<https://operas-eu.org/>

Prospective partner countries: FR, BE, CH, DE, ES, GR, HR, IT, LU, NL, NO, PL, PT, RS, SE, SI, UK (BR, CA)

Legal entity: AISBL

CESSDA – Consortium of Social Science Data Archives

CESSDA is an important international research infrastructure that coordinates large-scale, integrated and sustainable data services to the social sciences.

SYNOPSIS

CESSDA is the Consortium of European Social Science Data Archives. It focuses on bringing together a series of national data archives that operate in the social science domain providing services and exchange for this scientific community. A large focus lies on survey data within the social sciences, but CESSDA also addresses social science researchers working with qualitative data and new types of data including social media data and computational social sciences. The CESSDA Consortium is currently composed of 22 member countries and one observer. It became part of the ESFRI Roadmap in 2010 and was awarded ERIC status in 2017. The Dutch partner is the KNAW/NWO institute DANS.

USERS PERSPECTIVE

Support provided to the user community

CESSDA supports Dutch researchers in the social sciences domain across all stages of the Research Data Life Cycle. CESSDA operates the CESSDA Data Catalogue (CDC) where more than 35.000 datasets can be found across a wide domain of social sciences including datasets archived at DANS. CESSDA provides trainings and information for researchers on how to process and document data, as well as giving tips on how to establish a research data management plan to ensure data is FAIR and as open as possible. A well-used resource developed by CESSDA is the Data Management Expert Guide (cessda.eu/dmeg).

CESSDA develops standards for metadata and data documentation (e.g., DDI and ELSST thesaurus) that are used by Dutch researchers to document data which increases the findability and interoperability of the Dutch social science research data.

Relevance for the user community

CESSDA provides a research infrastructure to support research in the social science domain, in particular making data available for re-use and supporting data archiving, FAIR data and Open Science.

STRATEGIC PERSPECTIVE

Alignment with national research/strategic agendas

CESSDA's activities are in line with the Dutch Open Science strategy which promotes more open and collaborative research practices in which publications, data, software and other types of academic output are shared at the earliest possible stage and made available for reuse. CESSDA support for FAIR data practices and reuse of trusted data are fundamental to Open Science.

National & International dimensions

CESSDA facilitates technical developments to improve the data archiving and data management tools and technology available to Dutch and other European social science researchers. DANS and several other Service Providers use the Dataverse software for their repositories. Within the H2020 SSHOC project (led by CESSDA), various new technical developments have been realised. DANS has been involved in the establishment of a community of CESSDA archives using Dataverse where partners can align work and connect to collaborate. Through this collaboration, new features in Dataverse are available to the Dutch social science community, for instance through the archiving services of DANS that make use of Dataverse.

The coordinating role that CESSDA has for social science data archives allowed DANS to participate in European projects as a linked third party in CESSDA. The most recent project was SSHOC (Social Sciences and Humanities Open Cloud) which next to the technical developments mentioned above also contributed to the development of training materials and registries for re-use. The development of Dutch national infrastructure for the social sciences – ODISSEI – has taken standards and guidelines established by CESSDA as a basis for the metadata portal that is being developed.

The Netherlands had a major role in the establishment of certification guidelines for digital repositories including the development of CoreTrustSeal (CTS). Within CESSDA, DANS has been part of the Trust working group providing support and guidance for other archives and promoting the importance of CTS and trust in the wider scientific community (financed by internal CESSDA projects). Through CESSDA DANS was able to participate in the Trust activities performed in the SSHOC project which provide guidance and support that Dutch repositories can make use of to provide sustainable archiving services for the social science researchers in the Netherlands.

Governance and national field organisation

CESSDA ERIC is managed by the General Assembly, the Director, the Scientific Advisory Board and the Service Providers' Forum. Its main office is in Bergen, Norway. Each member is represented by a national institution, a Service Provider, which is responsible for providing relevant services. The Dutch service provider is DANS, the national centre of expertise and repository for research data. The Service Providers constitute the CESSDA main resource, and CESSDA integrates the work of the Service Providers by establishing a one-stop shop for data location, access, analysis and delivery.

Impact & outreach

CESSDA is a distributed infrastructure that supports data archiving infrastructure for the social sciences across Europe. An important role of CESSDA is the coordination of the landscape and connecting the social science data archives that operate across Europe.

CESSDA's impact is often indirect as CESSDA influences the work performed at the national service providers. The impact CESSDA has is therefore hard to measure when compared to other ERICs which provide services to researchers directly.

For DANS in the Netherlands, CESSDA has created a lot of opportunities to collaborate and align with other data archives, combining efforts to develop training materials and technology used by the Dutch social science research community. DANS has been able to join EC-funded projects through CESSDA which have led to new developments in all the domains CESSDA covers (trust, technology, training and tools).

For countries where the scientific infrastructure for the social sciences is not that well developed yet, CESSDA has a large impact to improve the services provided to the national communities. The widening programme that CESSDA operates allows knowledge distribution across Europe and supports smaller archives to provide services to their communities.

Relation with other (similar) Research Infrastructures

CESSDA is currently participating in EOSC Future (2021–2023), TRIPLE (2019–2023), eRImote (2022–2024) and FAIR-IMPACT (2022–2025). In addition, CESSDA is a key partner in the [Social Sciences and Humanities Open Cluster \(SSHOC\)](#) which has proven an important vehicle for the collaboration between the Social Sciences and Humanities (SSH) research infrastructures. The ERICs involved act as a science cluster (aka thematic cluster) in the context of the emerging EOSC ecosystem.

Time period

A coordinating body like CESSDA will always remain relevant. Research is an international endeavor and coordinating the infrastructure developed across Europe as well as harmonising controlled vocabulary services, services around metadata standards, technology and tools will remain an important task.

CONCLUSION

CESSDA is an **important** and widely respected research infrastructure linking national service providers providing access to trusted social science data. It also provides vital services and tools for social science research. CESSDA is actively participating in the collaboration of SSH research infrastructures (SSHOC) as well as in the EOSC ecosystem.

CLARIN – Common Language Resources and Technology Infrastructure: a digital research infrastructure offering data, tools and services to support research based on language resources

CLARIN is an **important** international infrastructure that provides essential services and tools to researchers in (computational) linguistics and to all disciplines in humanities, social sciences and beyond, studying language-based resources. In the Netherlands CLARIN and DARIAH have joined forces in CLARIAH.

SYNOPSIS

The Common Language Resources and Technology Infrastructure (CLARIN) is a distributed Research Infrastructure that provides easy and sustainable access for scholars in humanities, social sciences and beyond to FAIR digital language data – in written, spoken or multimodal form – and advanced tools to discover, explore, exploit, annotate, analyse or combine them, independent of their location. CLARIN provides a networked federation of language data repositories, service centres and centres of expertise, with single sign-on access for all members of the academic community in all participating countries. Tools and data from different centres are interoperable, so that data collections can be combined and tools from different sources can be chained to perform complex operations to support researchers in their work.

The CLARIN infrastructure entered the ESFRI Roadmap in 2006 and became an ERIC in 2012. The Netherlands is hosting the coordinating office of the CLARIN ERIC at Utrecht University. At the moment 24 countries participate in CLARIN as full member, 2 countries are observers and CMU in the USA is third party member.

USERS PERSPECTIVE

Support provided to the user community

CLARIN – the research infrastructure for language as social and cultural data – is a digital infrastructure offering data, tools and services to support research based on language resources. CLARIN enables users to deposit language resources in a sustainable repository at a CLARIN centre; to discover distributed language resources using a faceted browser; to access the available resources with their institutional username and password; to explore and analyse language data with a wide variety of tools; to create virtual collections of data by applying digital bookmarks that enable easy citation of datasets; and to search different corpora with a single search engine. A range of materials and formats are available to train the various communities of use.

Relevance for the user community

CLARIN tools and resources provide essential support for a variety of disciplines in the humanities, the social sciences and beyond. These include linguistics and a range of disciplines that work with language material as a data type.

Linguistics is a very broad field unifying multiple methodologies, including quantitative tools for large data sets, but also qualitative analyses of language in use. The quantitative turn is clearly discernible across the field, also in the more traditional subdisciplines. This means that future research activities in linguistics will heavily depend on the infrastructure even more strongly. For other scholars using language data, e.g. in (social-economic) history, literature, philosophy, (social) media, the tools and services provided by CLARIN have become essential for carrying out their research as well.

CLARIN and DARIAH are collaborating in the Netherlands – and several other countries – in CLARIAH, and as a result the relevance and focus on serving a diverse academic community have increased. CLARIAH aims to play a key role in informing scholars on how to ensure that their data can be shared and their observations are verifiable by others and provides access to copyrighted and/or sensitive material in a controlled environment, thereby enabling researchers to make use of large volumes of digital contemporary material that would otherwise not be available for computational research because of licensing issues.

To study aspects of Dutch culture and history, access is needed to large corpora in Dutch, Netherlandish dialects, Afrikaans, Frysian and early modern Dutch, which are wholly dependent on an infrastructure that provides tools tailored for this specific language family.

Finally, CLARIN tools are also very useful for a large number of other disciplines that need the option of searching textual resources such as articles and books describing past research efforts or laboratory notebooks.

STRATEGIC PERSPECTIVE

Alignment with national research/strategic agendas

The Netherlands has been the main advocate of collaboration between humanities and social sciences research infrastructures. It started out by the collaboration within the humanities in CLARIAH. Within CLARIAH, CLARIN has been the stimulator of defining standards for annotating, enriching and linking text data. The collaboration in CLARIAH, and the submission of joint proposals for both the implementation of CLARIN-NL and DARIAH-NL have been beneficial in securing the NWO funding needed to ensure that the resources are FAIR and as open as possible.

National & International dimensions

The Netherlands – host of the CLARIN research infrastructure – has been a founding member of CLARIN. The Netherlands has been at the forefront of developments in computational linguistics and the creating of language resources, tools and services since the 1980s. The main partners in the Netherlands are Utrecht University, Radboud University Nijmegen, University of Amsterdam, Vrije Universiteit, Leiden University, Tilburg University, Groningen University, Erasmus University, Twente University, Delft University, the Digital Infrastructure group at the Humanities Cluster of the KNAW, the KNAW/NWO institute DANS, the Dutch Language Institute (INT), TLA-Max Planck Institute, the Fryske Akademy, the Netherlands Institute for Sound & Vision and the National Library of the Netherlands (KB).

In CLARIN ERIC 25 national nodes coordinate the CLARIN activities in their respective countries. All international activities are in turn coordinated by the coordinating office in Utrecht.

Impact & outreach

CLARIN organises a number of activities stimulating the use of its resources and impact thereof. [Tour the CLARIN](#) highlights prominent user involvement activities of different CLARIN national consortia, and spotlights individual Knowledge Centres (K-centres) and Service Providing Centres (B-centres). Contributions include case studies, relevant user involvement activities, recently developed tools, and interviews with prominent researchers who are using a national consortium's infrastructure.

CLARIN also presents a series of [impact stories](#) that showcase high-quality and innovative research that uses CLARIN tools and resources. These impact stories illustrate the huge variety of disciplines that use the CLARIN infrastructure, highlight the excellent research linked to it, and demonstrate the wider impact that CLARIN and the social sciences and humanities have on broader societal issues. An [SSH Training Discovery Toolkit](#) has been set up to improve the discoverability of training resources developed in the Social Sciences and Humanities.

Furthermore, in collaboration with DARIAH-EU, the [Digital Humanities Course Registry](#) was set up to provide up-to-date information of the Digital Humanities teaching and training opportunities worldwide and help students find suitable programmes for their needs.

Relation with other (similar) Research Infrastructures

In June 2017, CLARIN ERIC signed the EOSC Declaration, as member of a coalition of ‘doers’. CLARIN ERIC is also a member of the EOSC Association (EOSC-A) that was established in 2020. Several CLARIN representatives are involved in EOSC Task Forces and active in H2020/Horizon Europe projects aimed at the further development of EOSC e.g. by integrating the Virtual Language Observatory in EOSC. CLARIN is currently participating in EOSC Future (2021–2023), EOSC Focus (2022–2025) and FAIRCORE4EOSC (2022–2025). In addition CLARIN is a key partner in the project ‘Social Sciences and Humanities Open Cloud (SSHOC) which has proven an important vehicle for the collaboration between the Social Sciences and Humanities (SSH) research infrastructures, including the ones that recently entered the ESFRI Roadmap, under the name of SSH Open Cluster. The ERICs involved act as a science cluster (aka thematic cluster) in the context of the emerging EOSC ecosystem.

Time period

CLARIN has already made a large number of resources available. Once available, CLARIN resources are of permanent nature and their volume will continue to grow as national nodes will continue adding resources.

CONCLUSION

CLARIN is an **important** distributed research infrastructure for sharing, using and sustainability of language data and tools supporting research in the humanities and social sciences. It aims at making language resources and tools from all over the world accessible through a single sign-on online environment. CLARIN has been playing a pivotal role in the collaboration of SSH research infrastructures (SSHOC) and in setting up the EOSC ecosystem.

DARIAH – Digital Research Infrastructure for the Arts and Humanities

DARIAH is an **important** international distributed research infrastructure in support of ICT-based research practices in the arts and humanities that sustains researchers in building, analysing and interpreting digital resources. CLARIN and DARIAH have joined forces in CLARIAH.

SYNOPSIS

The Digital Research Infrastructure for the Arts and Humanities (DARIAH) aims to enhance and support digitally-enabled research and teaching across the arts and humanities. DARIAH is a research infrastructure providing expertise, information, knowledge, content, methods, tools and technologies from its member countries. It develops, maintains and operates an infrastructure in support of ICT-based research practices and sustains researchers in using them to build, analyse and interpret digital resources. By working with communities of practice, DARIAH brings together individual state-of-the-art digital arts and humanities activities and scales their results to a European level. It preserves, provides access to and disseminates research that stems from these collaborations and ensures that best practices, methodological and technical standards are followed.

DARIAH entered the ESFRI Roadmap in 2006 and was established as a European Research Infrastructure Consortium (ERIC) in 2014, awarded Landmark Status in the 2016 ESFRI Roadmap as a Research Infrastructure that reached its implementation phase and was considered a pan-European hub of scientific excellence. Currently, DARIAH has 20 Members, 1 Observer and several Cooperating Partners in six non-member countries. The KNAW/NWO institute DANS is providing the Chief Integration Officer function as part of the DARIAH overall Coordination Office.

USERS PERSPECTIVE

Support provided to the user community

DARIAH integrates digital arts and humanities research and activities from across Europe, enabling transnational and transdisciplinary approaches. In particular, it provides value to its members and stakeholders through the validation and sharing of data, services and tools; by providing training and education opportunities; by enabling ‘bottom-up’ organisation around emerging research needs; and through the exercise of foresight and policy engagement. Through these activities, DARIAH promotes the further development of research methods in the arts and humanities, documenting the state-of-the-art, supporting the preservation and curation of research data with a focus on particular challenges including diversity, provenance, multimedia collections and granularity, and acting as a coordinator and integrator for a diverse community of practice.

Relevance for the user community

Digital tools are nowadays indispensable in various research fields. Researchers in the arts and humanities are also increasingly making use of digital tools and computational methods. Not only is their material digital, such as digitised collections of books and databases, the methods are becoming increasingly digital, too. Think of software to analyse languages and texts, applications for organising historical data or digital cartography.

STRATEGIC PERSPECTIVE

Alignment with national research/strategic agendas

The Netherlands has been the main advocate of collaboration between humanities and social sciences research infrastructures. It started out by collaboration within the humanities in CLARIAH.NL. Within CLARIAH.NL, DARIAH provides support and training for those researchers using computational methods in doing research in the arts and humanities. Dutch researcher and infrastructure staff is active in the DARIAH Working groups. The collaboration in CLARIAH, and the submission of joint proposals for both the implementation of CLARIN-NL and DARIAH-NL have been beneficial in securing NWO funding needed to create fair access to their resources.

National & International dimensions

The Netherlands have been pioneering in the innovation of digital methods in the humanities and arts. Currently, DANS hosts one of the four international central offices of DARIAH and the Chief Integration Officer position. For the humanities one has to mention the large Dutch investment in digitisation, resulting in Delpher (Royal Library), and more recently, in tools such as the MediaSuite (Sound and Vision). Based on a network of larger and smaller digitised collections a rich landscape of innovative research projects has emerged which represent the national core of the Dutch DARIAH connected activities. The pioneering role of both CLARIN and DARIAH (if it comes to humanities) led to a concerted, combined infrastructural action under the name of CLARIAH.NL.

Governance and national field organisation

DARIAH-EU is constituted by its Executive Bodies (General Assembly and Board of Directors), Advisory Bodies (Scientific Board), Coordinating Bodies (National Coordinators Committee, Senior Management Team), Implementation Bodies (Joint Research Committee, Virtual Competence Centres and Working Groups) and Administrative Bodies (DARIAH Coordination Office).

Impact & outreach

DARIAH has impact on four interconnected domains: research, education, culture and economy. The consortium supports the sustainable development of digitally-enabled research in the arts and humanities by building services for researchers working with ICT-based methods. It helps them to further advance their research and ensures the long-term accessibility of their work, thus directly contributing to the understanding of the cultural, economic, social and political life in Europe and beyond. In addition, it offers teaching material as well as teaching opportunities to develop digital research skills. DARIAH also demonstrates how traditional humanities research skills play a prominent role in the digital age, and how such skills can be deployed in other settings. Training and education are central to DARIAH's mission. Research in a fast-changing environment requires sustained access to new perspectives and methods. DARIAH aims to enhance the highest quality arts and humanities research. DARIAH promotes skills awareness and development outside of formal qualifications, complementing the formal education provided by our university partners. DARIAH-Campus provides a discovery framework and hosting platform for arts and humanities learning resources. DARIAH Teach offers free community-driven and multilingual learning and teaching materials.

Relation with other (similar) Research Infrastructures

As long as there is humanities research, the existence of humanities centred European Research Infrastructures remains an essential driver for international, collaborative research. As the Digital turn penetrates more and more subdisciplines and specialties in the Humanities and Arts, there are emerging more specific (tailored towards certain specialties) research infrastructures, e.g. EHRI and RESILIENCE. What makes DARIAH unique is that it provides a platform for cross-domain exchange in the humanities and arts.

DARIAH closely works together with CLARIN (and in some countries has merged into CLARIAH). DARIAH provides its expertise to co-design EOSC thematic services that are relevant for research communities as well as to promote the use of [EOSC Core](#) services in its community. Several DARIAH representatives are in H2020/Horizon Europe projects aimed at the further development of EOSC e.g. by integrating the DARIAH campus in EOSC. DARIAH is currently participating EOSC Future (2021–2023), TRIPLE (2019–2023), Policy Alignment of Open access Monographs in the European Research Area (Palomera) (2023–2024), On the road to sustainability: paving the way for OPERAS as an efficient open Social Sciences and Humanities scholarly communication Research Infrastructure (OPERAS-PLUS) (2022–2025), Deployment of a common European data space for cultural heritage (DS4CH) (2022–2024), and Computational Literary Studies Infrastructure (CLS INFRA) (2021–2025). DARIAH also participated in the project ‘Social Sciences and Humanities Open Cluster (SSHOC) which has proven an important vehicle for the collaboration between the Social Sciences and Humanities (SSH) research infrastructures. The ERICs involved acted as a science cluster (aka thematic cluster) in the context of the emerging EOSC ecosystem

Time period

DARIAH has already made a large number of resources available. Once available, DARIAH resources are of permanent nature and will continue to grow as national nodes will continue adding resources.

CONCLUSION

DARIAH is an **important** distributed research infrastructure supporting arts and humanities scholars using digital methods. DARIAH is also playing a pivotal role in the collaboration of SSH research infrastructures (SSHOC) and in setting up the SSH Open Marketplace in the EOSC ecosystem.

EHRI – European Holocaust Research Infrastructure

EHRI is well positioned to become an **important** infrastructure for trans-national Holocaust studies by providing access via a single entry point to the distributed archives and expertise.

SYNOPSIS

EHRI's mission is to overcome the geographical fragmentation of sources and expertise and set standards for excellence in transnational Holocaust research, documentation, education and remembrance. As such, EHRI continually develops and maintains a distributed, digital and human infrastructure that provides access to archival resources and services to a diverse community. EHRI is hosted and coordinated by the Dutch NIOD (Institute for War, Holocaust and Genocide Studies).

The EHRI consortium currently comprises 27 partners in 17 countries from across Europe, Israel and the United States. The Scientific Advisory Board consist of 11 members from 9 different countries from Europe, the USA and Israel. EHRI also has a Board of Governmental Representatives (BGR). The BGR is an important body in EHRI's transformation from a series of projects into a permanent organisation in the form of an ERIC. The BGR is composed of ministerial representatives from eleven countries that have already indicated strong support for the EHRI-ERIC. In June 2023, the BGR replaced by the interim General Assembly (iGA) of EHRI, and the 1st step of the ERIC application was submitted by the Dutch Ministry of Education, Culture and Science mid 2023.

The original EHRI initiative started already in 2010. It is foreseen that EHRI has become ERIC in January 2025, the 80th anniversary of the liberation of the German Nazi concentration and extermination camp Auschwitz. and is fully operational in 2025. Its current H2020-funded preparatory phase project ran until May 2023, while a H2020 integrating activity, called EHRI-3, runs until September 2024.

USERS PERSPECTIVE

Relevance for the user community

EHRI provides physical and virtual access services to a wide user community consisting of Holocaust researchers; to scholars working in a wide range of thematically adjacent fields including research on non-Jewish victims of Nazi crimes, antisemitism research, war and conflict studies, genocide studies, memory studies, refugee and migration studies, and research on transitional justice and human rights; and to digital humanists as well as other professional users, particularly archivists, librarians, curators and other information professionals. Currently EHRI is in the process of a substantial increase in the coverage of the EHRI Portal, particularly with regards to the holdings of micro-archives, and is developing new digital tools that connect dispersed Holocaust sources.

Education and training

EHRI has an extensive state-of-the-art training and education programme for researchers and archivists, that includes the Conny Kristel Fellowship Programme which gives researchers access to the resources of the world's twenty leading Holocaust archives. In addition, EHRI's extensive programme of networking and training brings people together via a series of seminars and workshops, an online course in Holocaust Studies, and a MOOC.

STRATEGIC PERSPECTIVE

Alignment with national research/strategic agendas

EHRI was added as a project to the ESFRI Roadmap 2018. The Netherlands has since reaffirmed its long-term commitment to EHRI by offering to host the Central Hub of the evolving EHRI-ERIC and by making significant funding available. All other countries that have indicated their intention to become founding members of EHRI-ERIC have agreed to the Netherlands hosting the head-quarters.

The two Dutch institutes involved in EHRI so far, NIOD-KNAW and DANS-KNAW, are providing essential strategic and managerial expertise and significant scientific input: in the areas of Holocaust research and documentation (NIOD), and FAIR data management and digital infrastructure development (DANS). Two further Dutch institutions – the University of Amsterdam and the Jewish Cultural Quarter, Amsterdam – have signed a Memorandum of Understanding (MoU) to participate in the Dutch National Node of the future EHRI-ERIC. EHRI is providing an essential resource for Holocaust researchers all over the world. The wider Dutch Holocaust research and documentation community constitutes a significant proportion of the EHRI user base.

Impact & outreach

Trans-national Holocaust research, commemoration and education is the mission of the European Holocaust Research Infrastructure (EHRI), and its main challenge is the wide dispersal of sources and expertise across many institutions. EHRI overcomes such fragmentation by connecting sources, institutions and people, and by offering integrated online and physical access to Holocaust-relevant resources and expertise no matter where they are located. By combining access and training provisions with the development and promotion of innovative digital tools and methods, EHRI significantly advances the digital transformation of Holocaust research and archiving and enables the study of the Holocaust from truly inter-disciplinary and trans-national perspectives. Although EHRI's primary impact is scientific, it also advances a wider social and political agenda. The recent rise of antisemitism, xenophobia, aggressive nationalisms and the return of war to Europe demonstrate that Holocaust research is never a purely academic concern, but a prerequisite for open and non-discriminatory societies across Europe and beyond. By collaborating closely with other relevant initiatives, including the International Holocaust Remembrance Alliance (IHRA), and the EC's Coordinator on Combatting Antisemitism, and by undertaking extensive outreach and impact activities, EHRI makes a vital contribution to tackling public policy priorities such as combatting Holocaust denial and distortion; conspiracy theories; antisemitism and racism; protecting human rights; compensation and restitution; and promoting Holocaust education and remembrance.

National & International dimensions

EHRI will integrate a large number of distributed national RIs. Many European countries have a national RI for Holocaust research and documentation with similar services: i.e. access to archives, access to expertise, research facilitation. Examples include NIOD Institute for War, Holocaust and Genocide Studies (NL), Mémorial de la Shoah (FR), Institut für Zeitgeschichte (DE), Elie Wiesel National Institute for the Study of the Holocaust in Romania (RO), etc. The two largest (national) Holocaust RIs are located outside of Europe: Yad Vashem in Israel and the United States Holocaust Memorial Museum in Washington DC.

Relation with other (similar) Research Infrastructures

With regards to the digital transformation of Holocaust research, other international RIs, particularly DARIAH-ERIC and CLARIN-ERIC – offer some relevant tools and services. Their tools and services will be adapted to the requirements of the specific research domain of Holocaust studies.

Time period

EHRI was added to the European Strategy Forum for Research Infrastructures (ESFRI) Roadmap in 2018 and is currently transforming itself from a project into a permanent organisation that will help secure the future of trans-national Holocaust research, commemoration and education. EHRI will undertake all the necessary legal, financial and strategic work to have this permanent organisation fully operational by January 2025. In line with the fast evolving area of data science and its policies, it can be anticipated that continuous development of the EHRI resources will be required.

CONCLUSION

EHRI is an **important** and leading research infrastructure for Holocaust research in the Netherlands and beyond. This research requires a global approach as resources and expertise are spread across many different countries. EHRI will play a pivotal role in connecting and providing user-friendly access to distributed archives and expertise.

In 2021, the Dutch government officially offered to co-fund the establishment of the national node of EHRI-ERIC at NIOD in Amsterdam, thus supporting to safeguard continuing international research into the Holocaust that informs excellence in commemoration and education about the Holocaust. Furthermore, EHRI has been included in the European Commission's Strategy on combating antisemitism and fostering Jewish life (2021).

E-RIHS – European Research Infrastructure for Heritage Science

E-RIHS is an **important** distributed research infrastructure supporting research on heritage interpretation, preservation, documentation and management by providing integrated access to expertise, data and technologies through a standardised approach.

SYNOPSIS

E-RIHS is the European Research Infrastructure for Heritage Science that supports research on heritage interpretation, preservation, documentation and management. Heritage science is a cross-cutting domain embracing a wide range of research disciplines, supporting the various aspects of tangible and intangible heritage conservation, interpretation and management. The mission of E-RIHS is to deliver integrated access to expertise, data and technologies through a standardised approach, and to integrate world-leading European facilities into an organisation with a clear identity and a strong cohesive role within the global heritage science community. The E-RIHS partnership is led by Italy and comprises 17 EU Member States plus Israel. The Dutch partner is the Cultural Heritage Agency of the Netherlands (RCE). E-RIHS entered the ESFRI Roadmap in 2016 and is working toward becoming an ERIC in 2023.

USERS PERSPECTIVE

Support provided to the user community

Through interdisciplinary access to the four platforms (E-RIHS ARCHLAB, E-RIHS DIGILAB, E-RIHS FIXLAB, E-RIHS MOLAB), E-RIHS will support a wide variety of research, from smaller object-focused case studies, to large-scale and longer-term collaborative projects. Proposals for access are handled through a common entry point, their evaluation is based on excellence, following assessment by independent international peer review panels.

E-RIHS is in a preparatory phase but can build on a series of related international projects such as the FP7 project ARIADNE (Advanced Research Infrastructure for Archaeological Dataset Networking in Europe) and the H2020 project IPERION HS (Integrating Platform for the European Research Infrastructure on Heritage Science) that are already providing many types of support to heritage scientists. In the Netherlands it can build on the existing partnership Netherlands Institute for Conservation, Arts and Science (NICAS) led by the Rijksmuseum.

Relevance for the user community

Heritage science is the interdisciplinary domain of scientific study of cultural heritage objects drawing on diverse humanities, sciences and engineering disciplines. Research activities aim at the understanding, care and sustainable use of cultural heritage and can be subdivided into the following categories: a) Diagnosis and understanding of the material dynamics of cultural heritage objects, b) Conservation and restoration treatment of moveable heritage (museums, libraries and other collections) and built heritage, c) Technical art history, d) Archaeology. E-RIHS mission is to deliver integrated access to expertise, data and technologies through a standardised approach, and to integrate world-leading European facilities into an organisation with a strong cohesive role within

the global heritage science community. New instruments, new protocols and new techniques have a decisive impact on heritage science research, enabling improved understanding of heritage objects and sites. E-RIHS ERIC will stimulate innovation in large-scale and medium-scale instrumentation, portable technologies and data science. Through interdisciplinary access to the four platforms (E-RIHS ARCHLAB, E-RIHS DIGILAB, E-RIHS FIXLAB, E-RIHS MOLAB), E-RIHS ERIC will support a wide variety of research, from smaller object-focused case studies, to large-scale and longer-term collaborative projects. Proposals for access are handled through a common entry point, their evaluation is based on excellence, following assessment by independent international peer review panels.

STRATEGIC PERSPECTIVE

Alignment with national research/strategic agendas

Universities and research labs of cultural heritage institutes, like for instance in the Netherlands the RCE and Rijksmuseum, already provide access through their laboratories and expertise to researchers in the cultural heritage field (conservation scientists, conservators, curators, art historians and technical art historians, monument managers and archaeologists). For example, KNAW DANS, SURF and eScience Center contribute to the field with innovative data management and visualization technologies. The Netherlands Institute for Art History, the National Library of the Netherlands, the Institute for Sound & Vision, and the Institute for Architecture, Design and Digital Culture provide access to their archives and expertise. Museums, public monuments, and archaeological sites provide access to the public appreciation of cultural heritage and they often collaborate in research activities. All these actors have now joined the national E-RIHS-NL node.

National & International dimensions

Research activities in the Netherlands will profit richly from E-RIHS in the future, given the excellent facilities and expertise offered by e.g. Consiglio Nazionale delle Ricerche (IT), Institute for Nuclear Research, Hungarian Academy of Sciences (MTA-Atomki) (H), Institute of the Protection of Cultural Heritage of Slovenia (IPCHS) (SLO), Koninklijk Instituut voor het Kunstpatrimonium (KIK-IRPA) (B), National Laboratory of Civil Engineering (NLEC) (P), National Scientific Research Centre (CNRS) (F), The Foundation for Research and Technology-Hellas (FORTH) (GR), University College of London (GB), University of Malta, Faculty of Built Heritage (MT).

Impact & outreach

Considering its partnership of research institutes, heritage institutes and industry, E-RIHS is inherently framed to enable excellent impact and outreach. As expected for any research infrastructure, the main field of impact is related to science production. The entire cultural heritage field also benefits from the network (human capital formation) and the effects of dissemination and outreach of the E-RIHS consortium.

Heritage science research has direct socio-economic impact through increasing knowledge and interpretation of heritage, enhancing public engagement and access, particularly in public-facing institutions such as museums and galleries, publicly accessible monuments, and archaeological sites. It strongly benefits the economy through cultural tourism. It contributes to cultural heritage education and supports European cohesion through intercultural dialogue and science diplomacy.

Relation with other (similar) Research Infrastructures

E-RIHS closely collaborates with the related ERICs DARIAH and CERIC. E-RIHS is also a partner in the European Social Sciences & Humanities Open Cloud (SSHOC), a project funded by the EU framework programme Horizon 2020. SSHOC partners include both developing and fully established European Research Infrastructures from the social sciences and humanities, and the association of European research libraries (LIBER). Between them, they have expertise across the entire data cycle from creation and curation to optimal re-use, training and advocacy.

Governance and national field organisation

E-RIHS is on its way to become a pan-European distributed research infrastructure with the legal form of an European Research Infrastructure Consortium (ERIC). E-RIHS will have a star design, with a Central Hub in Italy and National Hubs in all participating countries. National Hubs could possibly be organised in Regional Hubs.

Time period

E-RIHS ERIC shall exist for an indefinite period of time. Collected data will remain important and will continue to grow over time.

CONCLUSION

E-RIHS is an **important** research infrastructure supporting the highly interdisciplinary field of heritage science. It prevents fragmentation and duplication of efforts and brings together diverse humanities, sciences and engineering disciplines. Implementation activities of E-RIHS-NL are being supported by the Ministry of Education, Culture and Science.

ESS – European Social Survey

ESS is an **important** academically driven cross-national survey that has been conducted across Europe since in 2001. ESS measures change (and stability) over time within and between European countries in their living conditions, social structure, public opinion and attitudes.

SYNOPSIS

The ESS survey measures the attitudes, beliefs and behaviour patterns of diverse populations in more than thirty nations. The main aims of the ESS are to provide high quality data measuring change (and stability) over time within and between European countries in their living conditions, social structure, public opinion and attitudes; to practise and promote the highest scientific standards in cross-national comparative research in the social sciences; to continue the development of ESS infrastructure through ongoing methodological research and innovation; to facilitate training in the effective use of ESS data; to ensure the visibility, accessibility and reach of ESS data among researchers in the social sciences and beyond, policy makers and the wider public, at both the national and international level. The ESS data is available free of charge for non-commercial use and can be downloaded from the ESS Data Portal. In 2013 the ESS ERIC was established.

USERS PERSPECTIVE

Support provided to the user community

ESS offers the ESS Data Portal to search and download European Social Survey data for 18,000 questions and variables contained in 60 downloadable data files. The data are available without restrictions, for not-for-profit purposes. The ESS Data Wizard allows users to create and download a subset dataset by choosing a selection of rounds, variables and/or countries. A new tool for data visualisation and analysis is under development.

Relevance for the user community

The ESS provides data that are relevant for the following research areas: Comparative Sociology, Comparative Political Science, Comparative Health Studies, Comparative Demography/ Geography, Comparative Economics and Comparative Social Science Methodology.

The adjective 'comparative' to all of the areas was added, as the ESS is a data infrastructure that particularly allows comparative research on attitudes and behaviours. Data are collected every two years in over 30 European countries, allowing for the analysis of long time-series of attitudes in a comparative European perspective. Within each of the listed areas, a very diverse set of specific topics is studied (political attitudes, social attitudes, migration, social exclusion, integration, well-being, human values). Most of this research has a comparative dimension, as the ESS is the best available data source for comparative research on these topics.

For each of these areas, extensive research activities with this infrastructure are conducted. To give an indication of this, more than 500 peer-reviewed research articles with at least one author being affiliated with a Dutch university have been published with the ESS, making it the most widely used survey data set in the Dutch social sciences.

STRATEGIC PERSPECTIVE

Alignment with national research/strategic agendas

The Netherlands has been the main advocate of collaboration between humanities and social sciences research infrastructures. In the social sciences ODISSEI is maintaining the national data collection for ESS, SHARE, GGP and EVS. The collaboration in ODISSEI, and submitting joint proposals for the implementation of the Dutch parts of the international surveys has been very beneficial in securing NWO funding needed to carry out these surveys and create the ODISSEI Portal which combines metadata from a wide variety of research data repositories into a single interface, allowing for advanced queries to support findability, and facilitates data access to social science datasets in the Netherlands.

National & International dimensions

One of the main aims of the ESS is “to chart stability and change in social structure, conditions and attitudes in Europe”. To make meaningful comparisons of survey estimates of attitudes across countries, ESS data was collected in as many countries as possible. The data collection was accomplished by local doing people face-to-face interviews. In pursuit of maximum data comparability, essential survey conditions are implemented as similarly as possible across ESS participating countries.

In the Netherlands, social science research infrastructures are successfully collaborating in ODISSEI (Open Data Infrastructure for Social Science and Economic Innovations). ODISSEI brings together researchers with the necessary data, expertise and resources to conduct ground-breaking research and embrace the computational turn in social enquiry. Through ODISSEI, researchers have access to large-scale, longitudinal data collections as well as innovative and diverse new forms of data. These can be linked to administrative data at Statistics Netherlands (CBS). Combining data from a wide range of sources enables researchers to answer new, exciting, interdisciplinary research questions and to investigate existing questions in original, new ways. In the ODISSEI Secure supercomputer (OSSC), researchers can analyse data from CBS in a secure way on SURF's Snellius high-performance computing environment.

Impact & outreach

The data from ESS have a broader impact in both economic and societal terms. A recent [impact study](#) showcased a number of non-academic impacts. In the Dutch situation, ESS results are disseminated to a broader interested public via websites like [socialevraagstukken.nl](#), and through reports – for instance by the Netherlands Institute for Social Research (SCP). Generally, the ESS enables to benchmark views of the Dutch population vis-à-vis those of other relevant European countries.

ESS also is innovative in terms of developing new tools that can be used by the marketing industry. In particular tools developed for ESS via the Dutch organisation Centerdata have been used by fieldwork agencies to monitor fieldwork progress.

Relation with other (similar) Research Infrastructures

In comparative sociology, the European Values Study (EVS) and the International Social Survey Programme (ISSP) are alternative data sources. However, the EVS only collects data once per 9 years, and the ISSP has a more limited set of questions and less coverage of Europe. In demography and family sociology, the Generations and Gender Programme (GGP) is an alternative source, particularly to understand family-related behaviours. In social gerontology, the Survey of Health,

Ageing and Retirement (SHARE) is an important alternative data source, with a particular focus on those aged 50 and over. However, the kind of comparative research questions that can be answered by these alternative sources can be viewed as complementary to the ones central to the ESS, rather than as overlapping with them.

Governance and national field organisation

The ESS ERIC is governed by a General Assembly. The General Assembly has three standing committees: a Scientific Advisory Board, a Methods Advisory Board advising on technical and methodological aspects of the survey and a Finance Committee. Central to ESS's operations are the National Coordinators coordinating the activities of the ESS ERIC at a national level and assuring its compliance with the specifications issued by ESS.

ESS headquarters are located at City University London. The Netherlands Institute for Social Research (SCP) is one of the seven institutes comprising the ESS Core Scientific Team responsible for the design and implementation of the ESS ERIC Work Programme.

Time period

The ESS started collecting data in 2002, has been repeating the data collection biannually in face-to-face interviews. ESS resources, once available are of permanent nature and will continue to grow as national nodes will continue adding survey data. An important activity is to transition the ESS data collection from face-to-face interviews to a 'web first self-completion' design.

CONCLUSION

The European Social Survey is an **important** and widely-used distributed research infrastructure providing access to comparative data vital for comparative social science research. It provides vital information to academics, policy makers and others on patterns of social attitude formation, stability and change across Europe. ESS is actively participating in the collaboration of SSH research infrastructures (SSHOC) and also in the EOSC ecosystem.

GGP – Generations and Gender Programme

GGP is an important social science research infrastructure on population and family dynamics.

SYNOPSIS

The GGP is a distributed research infrastructure which provides scientists and policy makers with high quality and timely data about families and life course trajectories of individuals to enable researchers to contribute insights and answers to current societal and public policy challenges. The GGP provides users with an open-access data source of cross-nationally comparative surveys (like the Generations and Gender Survey – GGS) and contextual data. The GGP was launched in 2000 by the Population Unit of the United Nations Economic Commission for Europe (UNECE) and has been coordinated and hosted by the Netherlands Interdisciplinary Demographic Institute (NIDI) since 2009. Its central hub is in the Netherlands (hosted by NIDI).

USERS PERSPECTIVE

Support provided to the user community

The GGP collects data on population and family dynamics via its main instrument, the Generations and Gender Survey (GGS). This survey has been carried out in more than 25 countries so far and has provided very rich and detailed information on the life and demographic events of more than 275,000 individuals. These data have been used in two main areas of research in the Netherlands: 1) Family demography and sociology, and 2) survey methodology, social statistics, and computational demography.

Relevance for the user community

The GGS data are unique in their focus on young adults and the childrearing years, in their longitudinal and cross-national dimensions, and in view of their large samples that allow analyses for specific subgroups of the population.

In the area of family sociology and demography, the GGS data provide unique insights into changes in patterns of family formation and dissolution, their underlying inequalities, and their complex life-course trajectories. Other rich sociology and demography Dutch data are available and have led to important work, but none of them combines both a longitudinal and a cross-national dimension.

STRATEGIC PERSPECTIVE

Alignment with national research/strategic agendas

The GGP occupies a specific position in the landscape of social sciences RIs through its focus on population and family dynamics. It is thus complementary to social sciences infrastructures GUIDE, SHARE-ERIC, and ESS-ERIC. These RIs are collaborating together with some of the humanities RIs as part of EU-funded cluster projects, namely SERISS and SSHOC. In the Netherlands they all are collaborating in SSHOC-NL.

National & International dimensions

The GGP entered the ESFRI roadmap in 2021 as a sustainable, world-class research infrastructure. Previously, the GGP-EPI project, funded by the European Commission, provided GGP with the means to institutionalise and further formalise key internal processes.

In the methodological field of survey research, GGP is leading as a research infrastructure in being the first one to have transitioned to a web-based survey. The other two research infrastructures in Europe – the ESS-ERIC and the Survey of Health and Retirement (SHARE-ERIC) have indicated that they will engage in a similar transition in the next years. This means that the experience of the GGP is providing much needed insights regarding such a transition, especially across countries with very different survey conditions (sampling frame and internet penetration).

The headquarters (Central Hub) of the GGP being based in the Netherlands means that the Netherlands has positioned itself as a leading center for demographic research, adding to the already well established position of its institutional host: the KNAW Netherlands Interdisciplinary Demographic research institute.

The GGP as a research infrastructure has a broader scientific and economic impact in all participating countries. Not only is there a substantial investment in each country for collecting the GGP survey data, but it also involves groups of scientists and stakeholders (national teams) in raising money for overseeing the data collection and its quality, properly storing and analysing the data and disseminating the findings based on these data.

Impact & outreach

The GGP has a large impact in providing empirical evidence to address important societal challenges internationally. According to the EU Strategic Foresight Report, demographic shifts are one of the mega-trends affecting the future and sustainability of our societies. The GGP therefore responds to large needs for solid data on individuals' demographic biographies, on families, gender roles, and relationships between generations. This includes data responding to the Horizon Europe global challenges of health and inclusive societies, but also allowing measurement of two Sustainable Developmental Goals (UN-SDGs): on contraceptive use and on gender autonomy.

GGP data are used for teaching in universities, especially in social statistics courses, and the data are suitable for both introductory and advanced courses. The GGP is involved in various outreach activities. GGP distributes a newsletter and conducts monthly webinars for partners and users.

Governance and national field organisation

GGP has a well-established organisational structure at three levels: governance, advisory and organisational ones. The governance level of GGP encompasses the Director, the Consortium Board, and the Steering Committee. It is currently governed through a Consortium Agreement with partners from eleven countries (AT, DE, FR, EE, IT, HR, HU, LT, NL, PL, SE). In addition, GGP serves a large community of users and is governed by a Council, comprised by national partners and observers from over forty-seven countries.

CONCLUSION

The Generations and Gender Programme provides **important** high quality cross-national, longitudinal data for the study of population change. The data provided by the GGP have been used by more than 3,000 researchers worldwide and have led to over 500 peer-reviewed journal articles. The data provides insights into some of the most pressing societal challenges such as care for older persons, female employment, inequality, social exclusion, social mobility, migration and urban development. Moreover, there is a large impact of the GGP in supporting capacity building in countries where the expertise in survey methodology and demographic research is limited.

OPERAS – OPen scholarly communication in the European Research Area for Social Sciences and Humanities

OPERAS is well positioned to become an **important** research infrastructure to enable Open Science and upgrade scholarly communication practices in the Social Sciences and Humanities

SYNOPSIS

OPERAS is the Research Infrastructure supporting open scholarly communication in the social sciences and humanities (SSH) in the European Research Area. Its mission is to coordinate and federate resources in Europe to efficiently address the scholarly communication needs of European researchers in the field of SSH.

OPERAS aims to provide the research community with the missing brick it needs to find, access, create, edit, disseminate and easily and efficiently validate SSH outputs across Europe. OPERAS aims to unlock scholarly communication resources that are very diverse in nature. SSH output is challenged by a diversity in publication languages, the entrenchment in diverse cultural backgrounds and the need for specific forms of scholarly communication (monographs, critical editions, and edited bibliographies, amongst others).

OPERAS is a research infrastructure, established in 2019 as an international non-profit association (AISBL) which is based in Brussels, Belgium. OPERAS entered the ESFRI Roadmap in 2021.

USERS PERSPECTIVE

Support provided to the user community

OPERAS pools resources and offers services to enable all SSH stakeholders to streamline their activities and maximise the societal impact, in an interdisciplinary, mission-driven approach.

OPERAS fosters the co-creation and adoption of scholarly communication services addressing research needs in terms of discovery, content creation, quality assurance, dissemination, outreach, and evaluation of outputs.

Relevance for the user community

OPERAS' aim is to make Open Science a reality for research in the SSH and achieve a scholarly communication system where knowledge produced in the SSH benefits researchers, academics, students and more generally the whole society across Europe and worldwide, without barriers.

OPERAS started its Preparatory Phase in 2019 by developing the business plan and governance model and promoting services creation and alignment with European Open Science Cloud (EOSC) and transnational access. OPERAS is striving to efficiently guarantee an efficient move to the Operation Phase with a coherent approach to technical, administrative, and financial issues and the establishment of OPERAS ERIC. The recently launched EU funded project 'Operas-Plus', is intended to further develop OPERAS towards its transition to an ERIC.

Education & training

OPERAS delivers training webinars as a part of some of its projects – i.e. the Triple Open Science Training Series, and the Skills4EOSC ‘Skills for the European Open Science commons: creating a training ecosystem for Open and FAIR science’. It is expected that these services will further intensify in the process of transition to ERIC.

STRATEGIC PERSPECTIVE

Alignment with national research/strategic agendas

OPERAS closely collaborates with OAPEN (Open Access Publishing in European Networks) which works with publishers to build a quality controlled collection of open access books, and provides services for publishers, libraries and research funders in the areas of deposit, quality assurance, dissemination, and digital preservation. OAPEN was developed as a targeted project co-funded by the EU in its eContentplus-programme (2008–2010). The goal of the project was to achieve a sustainable publication model for academic books in humanities and social sciences and to improve the visibility and usability of high quality academic research in Europe. After the close of the project, OAPEN continued its activities as a foundation.

OAPEN Foundation was established by the University of Amsterdam (UvA), the University of Leiden (LEI), the University library of Utrecht University (UU), the Royal Netherlands Academy of Arts and Sciences (KNAW), the National Library of the Netherlands (KB) and Amsterdam University Press (AUP). Other Dutch members are: the Directory of Open Access Books (DOAB), Hypothesis, Linguistics in Open Access (LingOA), and SPARC Europe.

National & International dimensions

OPERAS gathers 54 organisations from 18 countries in Europe and beyond and is governed by an Executive Assembly of 10 members. The OPERAS Scientific Advisory Committee (SAC) is an independent body, composed by 14 experts, providing advice and recommendations to the Executive Assembly on the ethical, scientific and technical area for current and future projects as well as OPERAS activities. OPERAS also has a coordination team for the management tasks.

Impact & outreach

OPERAS pools resources and offers services to enable all SSH stakeholders to streamline their activities and maximise the societal impact, in an interdisciplinary, mission-driven approach. OPERAS fosters the co-creation and adoption of scholarly communication services addressing research needs in terms of discovery, content creation, quality assurance, dissemination, outreach, and evaluation of outputs. It catalyses knowledge and know-how sharing, practices adoption, and increases return on socio-economic investments.

Relation with other (similar) Research Infrastructures

OPERAS is collaborating very closely with DARIAH, CESSDA, CLARIN, SHARE as their services are complementary to each other. These ERICs are focused on data in specific disciplines as OPERAS is dedicated to publications and scholarly communications in the whole of the SSH domain. OPERAS provides complementary service to the other RIs, while strengthening relations between data and publications. This collaboration allows the researchers to have interoperable services for the whole research process.

Time period

Launched as a EU-funded project in 2018, it entered the ESFRI Roadmap 2021. OPERAS is currently striving to guarantee an efficient move to the operation phase with a coherent approach to technical, administrative, and financial issues and the transition OPERAS ERIC in 2028.

CONCLUSION

OPERAS fills a gap in the European landscape, between generic e-Infrastructures and RIs dedicated to research data in specific disciplines or topics. OPERAS deals with a neglected part of the research lifecycle, regarding the production and access to research outputs specific to SSH such as monographs, critical editions, and edited bibliographies, and supports multilingual scholarly communication cultures in SSH.

The European landscape of SSH scholarly communication is currently progressing to efficiently transition to Open Science. By fulfilling its mission, OPERAS provides the research community with the missing brick it needs to find to access, create, edit, disseminate and easily and efficiently validate SSH outputs across Europe.

As there are currently no other RI's worldwide providing similar services in the area of SSH, OPERAS is considered an **important** RI.

RESILIENCE – RELigious Studies Infrastructure: tools, Innovation, Experts, conNections and Centres in Europe

RESILIENCE well positioned to become an **important** research infrastructure which will innovate Religious Studies, supplying tools and big data to study religions in their different forms both in their diachronic and synchronic variety.

SYNOPSIS

RESILIENCE is a distributed RI in the preparatory phase. It is an interdisciplinary RI for Religious Studies, combining physical and digital knowledge, building a high-performance platform, supplying tools and services for researchers, collection managers/librarians, decision makers and workers in religious communities.

The concept and design of RESILIENCE have been built on several steps, both on national and European level, being supported by thirteen European partners which have proven to be able to actively collaborate. The Theological University Apeldoorn (TUA) is the Dutch member of the RI consortium. The leading partner is FSCIRE, Italy. Other partners are based in Albania, Belgium, Bosnia and Herzegovina, Bulgaria, France, Germany, Greece, Israel, Poland.

RESILIENCE was recognised in 2018 by ESFRI as an RI project addressing a strategic area for research and societal impact in SSH and entered the ESFRI Roadmap in 2021. For the preparatory phase it has received funding from the European Commission (2022–2026). In this preparatory phase the legal, financial and technical frameworks are set up, and the RESILIENCE service catalogue will be completed.

USERS PERSPECTIVE

Relevance for the user community

RESILIENCE responds to the need of researchers in Religious Studies for easy access to digital and physical data on religion and to advanced tools to annotate, link, analyse and interpret these data, and thus facilitate high-quality research concerning religion in Europe and beyond. To create the infrastructure, active involvement of excellent researchers is needed. For the Dutch community of scholars and institutions working in Religious Studies RESILIENCE strengthens the possibilities of internationally sharing resources and expertise and offers a unique environment for more effective and innovative research.

Support provided to the user community

RESILIENCE provides TNA Fellowships: scholars and researchers from across Europe are invited to apply for a research fellowship to visit the special collections, archives, and libraries of the actual 13 TNA hosts (FSCIRE, Italy; VOLOS Academy, Greece; Sofia University, Bulgaria; KU Leuven, Belgium; Theological University of Apeldoorn; Bar-Ilan University, Ramat Gan; Bektashi World Center, Tirana; University of Sarajevo, Bosnia and Herzegovina; University of Ljubljana, Faculty of Theology, Ljubljana; WWU Münster; Mikado Library, Aachen; New Georgian University, Poti; CIRCSE, Milan), in order to obtain direct, fast, and effective access to research objects, which are located in different countries. The first call ended in 2022 and resulted in 13 fellowships in four host institutions, while the second call opened in May 2023 (<https://www.resilience-ri.eu/cfa-tna/>).

Another service already available is the discovery platform RelReSearch.

The RESILIENCE governance structure is still in a preparatory phase, but the interim governance and organisational model were put in place in June 2022 (see <https://www.resilience-ri.eu/news/resiliences-governance-set-up-proceedings-now-available/>).

STRATEGIC PERSPECTIVE

Alignment with national research/strategic agendas

The domain area of cultural heritage and languages is represented by 4 ESFRI RIs (DARIAH, CLARIN, E-RIHS, ERIH). RESILIENCE is actively interacting with existing RIs relevant for research in Religious Studies, filling their gaps, making them more visible within its own community and benefitting from the experience and results achieved so far by the operational RIs. Within the Netherlands, all SSH RIs collaborate within the SSH Group of the National Roadmap 2021 and many of them are receiving some financial support via de SSHOC-NL project.

The Theological University of Apeldoorn (TUA) is an active partner in the RESILIENCE consortium and is represented in the Board of directors of RESILIENCE.

RESILIENCE is listed in the ESFRI Roadmap 2021 and has received funding from the European Commission for its Preparatory Phase (2022–2026). Full Operations are expected to start in 2034 (see <https://roadmap2021.esfri.eu/projects-and-landmarks/browse-the-catalogue/resilience>).

National & International dimensions

RESILIENCE positions itself in the European research landscape where it challenges and fosters national and international academic approaches to the role of Religious Studies in research, policy-making, and public management.

RESILIENCE responds to the challenges of the European societal landscape and of dialogue with neighbouring countries, and also fills the gap in the RI landscape by giving physical and digital access to major relevant data archives for Religious Studies – which are not yet part of ERA, mostly for historical or geographical reasons; fostering the digitisation of collections of esp. dead and rare languages both handwritten and in print; providing domain-specific ontologies as well as build the necessary bridges between analogue and digital data and providing sophisticated communication platforms among researchers, social actors and decision makers.

Relation with other (similar) Research Infrastructures

DARIAH, CLARIN (in the Netherlands collaborating in CLARIAH) are targeting respectively language studies and humanities research, but neither one offers targeted in depth services for the Religious Studies community required by the typology of high-quality research conducted by the RS community. RESILIENCE will be able to create a thematic platform for (Digital) Religious Studies that is still lacking in SSHOC (SSH Open Cloud) and therefore also in EOSC.

CONCLUSION

RESILIENCE will provide an **important** research infrastructure for supporting the digital turn in Religious Studies. It will link and provide access to essential digital and physical data, by supplying tools and services for researchers, collection managers/librarians, decision makers and workers in religious communities. Where needed, collaborations with related SSH RIs have been initiated. At the moment, the RESILIENCE project is still in a preparatory phase that is supported by a grant from the European Commission.

SHARE – the Survey of Health, Ageing and Retirement in Europe

SHARE is an **important** research infrastructure for studying the effects of health, social, economic and environmental policies over the life-course of European citizens and beyond.

SYNOPSIS

The Survey of Health Ageing and Retirement in Europe (SHARE) is a survey among the 50+ population and their partners. Information on, e.g., demographics, health & health care, social networks, work & retirement, income & welfare, and educational attainment and cognition is elicited biennially. In addition, wave 2 gathered information on individuals' life history and waves 9 and 10 also gathered information on behaviour and outcomes in relation to the COVID-19 pandemic. SHARE started in 2004, entered the ESFRI Roadmap in 2006 and in 2011 became the first European Research Infrastructure Consortium (ERIC). SHARE is led by Germany and has 27 European countries and Israel organising the survey in their countries. In the Netherlands the survey is coordinated by the Utrecht University. Continuous effort is needed to secure funding for the biannual survey waves that involve face-to-face interviews. Experiments are being carried out to transition to a mixed (online/telephone) mode of data collection.

USERS PERSPECTIVE

Support provided to the user community

Access to the data, collected and generated in the SHARE projects is provided free of charge for scientific use globally, subject to European Union and national data protection laws. Access services are rendered through two public data archives in cooperation with the Central SHARE Coordination Team: the CentERdata Archive located at Tilburg University in the Netherlands and the Data Archive for the Social Sciences, a public data archive run by GESIS Leibniz-Institute for Social Sciences in Cologne.

An aspect of SHARE-data gathering that is highly relevant for the Netherlands, and Dutch users, is that SHARE-NL data has been made available in the secure data environment of Statistics Netherlands (CBS). This means that SHARE-NL data can be linked with the administrative records held by CBS, which is an enormous enrichment of the data that will further push the frontier on doing research, and answering policy-relevant questions, for the years to come.

Relevance for the user community

The longitudinal individual-level data of SHARE are used to gain insights into the life circumstances of individuals aged 50 and over (e.g., their health, finances, and wellbeing) and how, and why, their life circumstances have changed over time. In particular, SHARE aims to help understanding how (public) policies can improve the life circumstances of the elderly. SHARE allows to understand the process of ageing from multiple angles and over periods of time.

Academic research topics are in the areas of, e.g., (public) health, economics, finance, sociology, and psychology. The most interesting work made possible by SHARE data is multidisciplinary research that advances knowledge in several of these topic areas. These include cross-country comparisons,

and often exploit differences across European countries to answer a research question and for policy evaluation. For instance, on the effects of an increase in the state pension age on retirement and health, or on how social networks benefit the elderly, on informal health care from friend and family and how it effects formal health care, or on health, health care needs and economic and health inequality among the elderly. SHARE data is therefore also used regularly by the Ministry of Social Affairs and Employment, the National Institute for Public Health and the Environment (RIVM) and the Netherlands Institute for Social Research (SCP).

STRATEGIC PERSPECTIVE

Alignment with national research/strategic agendas

The Netherlands has been the main advocate of collaboration between humanities and social sciences research infrastructures. In the social sciences ODISSEI is maintaining the national data collection for ESS, SHARE, GGP and EVS. The collaboration in ODISSEI, and submitting joint proposals for the implementation of the Dutch parts of the international surveys has been very beneficial in securing NWO-funding needed to carry out these surveys and create the ODISSEI Portal which combines metadata from a wide variety of research data repositories into a single interface, allowing for advanced queries to support findability, and facilitate data access to social science datasets in the Netherlands.

National & International dimensions

The Dutch participation in SHARE has been consistent across the waves. As a major contributor to the data, it is important to keep this participation ongoing as it provides a stable, reliable source. For comparability, the Dutch data is important to maintain in the dataset. Given that the Netherlands has participated in all 9 waves, it is among the 12 countries that has participated in all waves. The Netherlands is moreover a rather interesting case when it comes to ageing. A combination of multiple contextual factors, such as a relative high GDP, well developed welfare state and high trust and participation makes the country an ideal case to look at and compare with. The Dutch context has been shown to cluster together with the Nordic countries despite its geographical distance. The nuances that are brought through including the Netherlands in international comparisons are of a paramount importance if we are to better understand the role of context on the ageing process.

Governance and national field organisation

In March 2011, the Survey of Health, Ageing and Retirement in Europe (SHARE) became the first European Research Infrastructure Consortium (ERIC). This status also provides a firm governance structure and permits tax exemptions (e.g. VAT) and lean procurement procedures for subcontracts, two important advantages for running a large-scale survey such as SHARE. All member countries are represented in the Council and there is a central Management Board, an Assembly of Country Team Leaders and a Scientific Monitoring Board carrying out and overseeing the national data collections.

Impact & outreach

SHARE is a large social science panel study that has set new standards in research and scientific data collection. It has global impact since it not only covers all EU member countries in a strictly harmonised way. SHARE data enable researchers all over the world to practice in-depth and topical multidisciplinary comparative research in a variety of research fields, from biology to demography, economics, epidemiology, gerontology, medicine, psychology, public health, sociology, and more.

Additionally, SHARE is a unique observatory for policy effects over the life course and for people's reactions to policies and events like reforms and crises. SHARE's aim is to improve people's quality of life with high-quality research on their health and socioeconomic living situations and to help making policy reforms more targeted to the needs of people.

Relation with other (similar) Research Infrastructures

SHARE is embedded in a network of sister studies all over the world, from the Americas to Eastern Asia.

It collaborates with related surveys like ESS, GGP and EVS on improving survey methodology. In the Netherlands SHARE takes part in the ODISSEI en SSHOC initiatives.

Time period

According to its statutes, SHARE was initially set up for a period up to 31 December 2024, and discussions on how to continue beyond 2024 ("SHARE ERIC 2.0") have started within SHARE ERIC HQ and the SHARE ERIC GA.

CONCLUSION

The Survey of Health, Ageing and Retirement in Europe is an **important** and widely used distributed research infrastructure providing access to comparative data vital for comparative social science research. It provides vital information to academics, policy makers and others on the effects of health, social, economic and environmental policies over the life-course of European citizens and beyond. SHARE is actively participating in the collaboration of SSH research infrastructures (SSHOC) and also in the EOSC ecosystem.

Annex 1 – List of memberships

Although the majority of the Dutch memberships of large international research facilities has been included, the selected set does not provide a complete overview. The intention is not to exclude memberships and to add other memberships that meet the criteria.

Technical and Natural Sciences

ACTRIS	Aerosol, Clouds and Trace Gases Research Infrastructure
CERN	European Organization for Nuclear Research
CTAO	Cherenkov Telescope Array Observatory
DANUBIUS	International Centre Advanced Studies on River-Sea Systems
ECORD/IODP	European Consortium for Ocean Research Drilling / International Ocean Discovery Program
EGO	European Gravitational Observatory
EMFL	European Magnetic Field Laboratory
EPOS	European Plate Observing System
ESA	European Space Agency
ESO	European Southern Observatory
ESRF	European Synchrotron Radiation Facility
ESS	European Spallation Source
ICDP	International Continental Scientific Drilling Program
ICOS	Integrated Carbon Observation System
ILT	International LOFAR Telescope
ING	Isaac Newton Group of Telescopes
JIVE	Joint Institute for VLBI ERIC
KM3NeT	Cubic Kilometre Neutrino Telescope
PRACE	Partnership for Advanced Computing in Europe
SKAO	Square Kilometre Array Observatory
SLICES	Scientific LargeScale Infrastructure for Computing/ Communication Experimental Studies

Life and Medical Sciences

BBMRI	European research infrastructure for biobanking
DISSCo	Distributed System of Scientific Collections
EATRIS	European infrastructure for translational medicine
EBRAINS	Digital research infrastructure for brain research
EIRENE	Environmental Exposure Assessment Research Infrastructure
ELIXIR	Distributed infrastructure for life-science information
EMBL	European Molecular Biology Center
EMPHASIS	The European Infrastructure for Multi-scale Plant Phenomics and Simulation for Food Security in a Changing Climate
eLTER	Integrated European LongTerm Ecosystem, Critical Zone and Socio-ecological RI
ERINHA	European Research Infrastructure on Highly Pathogenic Agents
EU-OPENSOURCE	European high capacity screening network

EuroBioImaging	European Research Infrastructure for Imaging in Biological & Biomedical Sciences
IBISBA	European Research Infrastructure for Industrial Biotechnology
INSTRUCT	pan-European Research Infrastructure in structural biology
LifeWatch	e-Science Research Infrastructure for biodiversity and ecosystem research
MIRRI	Microbial Resource Research Infrastructure

Social Sciences and Humanities

CESSDA	Consortium of European Social Science Data Archives
CLARIN	Common Language Resources and Technology INfrastructure
DARIAH	Digital Research Infrastructure for the Arts and Humanities
EHRI	European Holocaust Research Infrastructure
E-RIHS	European Research Infrastructure Heritage Science
ESS	European Social Survey
GGP	Generations & Gender Programme
OPERAS	Open scholarly communication in social sciences and humanities
RESILIENCE	Religious Studies Research Infrastructure
SHARE	Survey of Health, Ageing and Retirement in Europe

Annex 2 – Templates of Questionnaires

Questionnaire – User Groups Consultation

Name Research Infrastructure/International Membership:

Your name:

Your email address:

Your telephone number:

** For infrastructures that are still under construction, are not (fully) operational yet or have only just started operations: please indicate potential / future research activities.*

1a. Please indicate for which research activities in the Netherlands this infrastructure* is relevant

1b. Please state which researchers / research groups (and their affiliations) have been consulted.

2a. For each research area mentioned in 1a, state one of the following:

In the Netherlands,

- ☐ Extensive research activities with this infrastructure* are conducted.
- ☐ Some research activities with this infrastructure* are conducted.

2b. Describe the research activities in the Netherlands in each area mentioned in 1a. (max 400 words per area)

3a. For each research area mentioned in 1a, state one of the following:

In the Netherlands,

- ☐ the research activities in the relevant areas are completely dependent on access to the specific infrastructure*.
- ☐ the research activities in the relevant areas are partly dependent on access to the specific infrastructure* and alternative solutions can adversely affect the research activities.
- ☐ the research in the relevant areas is only to a small extent dependent on access to the specific infrastructure and / or alternative solutions are available.

3b. For each research area mentioned in 1a, describe the extent to which researchers / research groups are dependent on access to the specific infrastructure*. Describe opportunities to use other similar infrastructures, both nationally and internationally. (max 400 words)

4. For each research area mentioned in 1a, provide your estimation of the time period over which the infrastructure* will remain relevant for the research conducted in the Netherlands.

5. What is the broader (e.g. economic, societal) impact of the research infrastructure*? (max 400 words)

6. Is there anything in the infrastructure's* response to the survey that should be commented on from a Dutch user perspective? (max 400 words)

Questionnaire – Strategic Consultation (Advisory Bodies)

Name Scientific Domain/Discipline:

Name Research Infrastructure:

Your name:

Your email address:

Your telephone number:

** For infrastructures that are still under construction, are not (fully) operational yet or have only just started operations: please indicate potential / future research activities.*

1a. Please state the discipline or research area whose interests you are representing.

1b. If you have consulted other parties to answer this questionnaire, please indicate whom you have consulted.

2a. State one of the following:

- ☐ Research that the infrastructure* supports **fits well** into the current strategic plan.
 - ☐ Research that the infrastructure* supports **partly fits** into the current strategic plan.
 - ☐ The area **is not included** in the current strategic plan.
-

2b. How does the research that the infrastructure* supports fit your strategic plan? (max 400 words)

3a. State one of the following:

- ☐ The infrastructure* is **crucial** for Dutch research in the field.
 - ☐ The infrastructure* is **important** for Dutch research in the field.
 - ☐ The infrastructure* is **less important** for Dutch research in the field.
-

3b. Describe the value of the infrastructure for Dutch research. (max 400 words)

4a. State one of the following:

- ☐ Dutch participation in the infrastructure* is **crucial** for international research in the field.
 - ☐ Dutch participation in the infrastructure* is **important** for international research in the field.
 - ☐ Dutch participation in the infrastructure* is **less important** for international research in the field.
-

4b. How does Dutch participation in the infrastructure* contribute to international research in the field? (max 400 words)

4c. What is the most important aspect (i.e., activity, service, access to facility /equipment) that Dutch membership brings to the international infrastructure*? (max 400 words)

5. What is your estimate of the time period over which the infrastructure* will remain relevant for Dutch research in this field?

6. Are there similarities or synergies with other facilities¹ that the Netherlands participates in? If so, what would be the added value if these were to coordinate (more)?

¹ = other facilities can also include research infrastructures that are not included in this national consultation.

7. Is there anything in the infrastructure's* response to the survey that should be commented on from a Dutch user perspective? (max 400 words)

Annex 3 – List of Acronyms & Glossary

AAI	Authentication and Authorisation Infrastructure
AI	Artificial Intelligence
AISBL	Association Internationale Sans But Lucratif
AKA	Academy of Finland
ALICE	A Large Ion Collider Experiment at the Large Hadron Collider (LHC) at CERN
ALMA	Atacama Large Millimeter/submillimeter Array
AMMI	Advanced Microscopy and Molecular Imaging facility
AnaEE	Analysis and Experimentation on Ecosystems
ANTARES	Astronomy with a Neutrino Telescope and Abyss environmental RESearch (KM3NeT precursor)
Apertif	APERture Tile In Focus, observing system using focal plane array technology on the WSRT
APPEC	Astroparticle Physics European Consortium
ARCA	Astroparticle Research with Cosmics in the Abyss telescope
ARIADNE	Advanced Research Infrastructure for Archaeological Dataset Networking in Europe
ARISE	Authorative and Rapid Identification System for Essential biodiversity information
ARM	Atmospheric Radiation Measurement
ASCI	Advanced School for Computing and Imaging
ASKAP	Australian Square Kilometre Array Pathfinder
ASTERICS	Astronomy ESFRI & Research Infrastructure Cluster
ASTRON	Netherlands Institute for Radio Astronomy
ASTRONET	Network of European funding organisations dedicated to the coordination of European astronomy
ATLAS	A Toroidal LHC Apparatus general-purpose particle physics experiment at the Large Hadron Collider (LHC) at CERN
Baikal-GVD	Baikal Deep Underwater Neutrino Telescope
BIC	Business Innovation Centre
Biodiversa+	European Biodiversity Partnership
BiodiversityXL	Centre of Excellence for Netherlands Biodiversity Research
BlackGEM	Wide-field array of optical telescopes at ESO's La Silla Observatory
BRIDGES	Binding Research Infrastructures for the Deployment of Global Experimental Science
BSL	Bio-Safety Level
CAN	Committee for Astroparticle Physics in the Netherlands
CATO	Dutch Carbon Capture and Storage research programme
CBS	Statistics Netherlands
CBS	Collection of yeasts and filamentous fungi
CDC	CESSDA Data Catalogue
CDR	Core Data Resources

CEA-IRFU	Institute of research into the fundamental laws of the Universe, France
CERIC	Central European Research Infrastructure Consortium
CERN	European Organization for Nuclear Research
CERN	Chinese Ecosystem Research Network
CETAF	Consortium of European Taxonomic Facilities
ChEMBL	Manually curated chemical database of bioactive molecules with drug-like properties
CLARIAH	Common Lab Research Infrastructure for the Arts and Humanities
CLS INFRA	Computational Literary Studies Infrastructure
CMU	Carnegie Mellon University
CNRS	French National Centre for Scientific Research
Copernicus	Earth observation component of the European Union's Space programme
COST	European Cooperation in Science and Technology
COVRA	Centrale Organisatie Voor Radioactief Afval
CPB	Netherlands Bureau for Economic Policy Analysis
CPC	Chemical Probe Consortium
Cryo-EM	Cryogenic electron microscopy
CTV	CoreTrustSeal
CVN	Chinese VLBI Network
CWI	National research institute for mathematics and computer science in the Netherlands (Centrum Wiskunde & Informatica)
DANS	Data Archiving and Networked Services
DAP	Delft Aardwarmte Project
DAS	Distributed ASCI Supercomputer
DD	Deposition Databases
DDI	Data Documentation Initiative
DeepNL	Research programme to improve the fundamental understanding of the dynamics of the deep subsurface under the influence of human interventions
Deltaplan Biodiversiteitsherstel	Initiative to restore Dutch biodiversity
DEMAX	Deuteration and Macromolecular Crystallisation platform
DESY	Deutsches Elektronen-Synchrotron
DMFCP	Dutch Materials Fabrication and Characterisation Platform
DNB	Dutch National Bank
DOAB	Directory of Open Access Books
DOM	Digital Optical Module
DS4CH	European data space for cultural heritage
DTL	Dutch Techcentre for Life Sciences
DUALIS	Dutch User organisation for Accelerator-based Light Sources
DUBBLE	Dual Belgian Beamlines (until 2021 Dutch-Belgian Beamline project)
DUNE	Deep Underground Neutrino Experiment
DYNAMIC	Dutch National 14 Tesla Initiative in MRI and Cognition

EAVN	East Asia VLBI Network
EBI	European Bioinformatics Institute
EBV	Essential Biodiversity Variable
EC	European Commission
ECBL	European Chemical Biology Library
ECCSEL	European Research Infrastructure for CO ₂ Capture, Utilisation, Transport and Storage
ECN	Energy Research Centre
Ecotron	Research infrastructure of Ecolabs devoted to the analysis of the ecosystems, organisms and biodiversity responses to environmental changes
ECRIN	European Clinical Research Infrastructure Network
EGA	European Genome Phenome Archive
EGI	European Grid Infrastructure
EGI-ACE	Advanced Computing for EOSC
EHT	Event Horizon Telescope
EIROforum	European Intergovernmental Research Organisation forum
ELMI	European Light Microscopy Initiative
ELSI	Ethical, Legal and Societal Implications
ELSST	European Language Social Science Thesaurus
ELT	Extremely Large Telescope, ESO
EMA	European Medicines Agency
EMBRC	European Marine Biological Resource Center
EMSO	European Multidisciplinary Seafloor and water column Observatory
ENVRI-FAIR	Environmental research infrastructures building FAIR services for research, innovation and society
EOSC	European Open Science Cloud
EOSC-A	EOSC Association
EPICS	Exoplanet Imaging Camera and Spectrograph for the ESO ELT
EPOS-eNLarge	National Roadmap project aimed at physics-based understanding of the subsurface
EPPN	European Plant Phenotyping Network
Erasmus MC	Erasmus University Medical Center
ERIC	European Research Infrastructure Consortium
ESCAPE	European Science Cluster of Astronomy & Particle physics ESFRI research infrastructures
ESCulab	European screening centre; unique library for attractive biology
ESFRI	European Strategic Forum on Research Infrastructures
ESRF-EBS	Extremely Brilliant Source
ESnet	Energy Sciences Network, US
ESTEC	European Space Research and Technology Centre, ESA
ET	Einstein Telescope
EU	European Union
EU-AMRI	European Alliance of Medical Research Infrastructures
Euclid	Space telescope designed to explore the composition and evolution of the dark Universe
EUDAT	European Data infrastructure

EUMETNET	Network European National Meteorological Services
EUREF	Reference Frame Sub-Commission of the International Association of Geodesy
EuroGeographics	Independent international not-for-profit organisation representing Europe's National Mapping, Cadastral and Land Registration Authorities
EuroGeoSurveys	Not-for-profit organisation representing the Geological Surveys of Europe
EuroHPC-JU	European High-Performance Computing – Joint Undertaking
EuroNanoLab	Distributed research infrastructure of nanofabrication centers across Europe
European Lead Factory	Open-innovation platform for drug discovery
EVAg	European Virus Archive Global
EVLA	Expanded Very Large Array
EVN	European VLBI Network
EVS	European Values Study
Exposome-NL	Dutch research program of multiple Dutch universities in the field of exposome research
EZK	Ministry of Economic Affairs and Climate Policy
FABRIC	FABRIC is Adaptive Programmable Research Infrastructure for Computer Science and Science Applications
FAIR	Findable, Accessible, Interoperable, Re-usable
FAST	Centre for Future Affordable Sustainable Therapy Development
Fermilab	America's particle physics and accelerator laboratory
Fermi satellite	NASA's Fermi Gamma-ray Space Telescope
FET Flagship	Future and Emerging Technologies Flagship
FU	Functional Unit
FuSE	Fundamental Sciences E-infastructure
GA	General Assembly
Gaia	Global Astrometric Interferometer for Astrophysics, ESA
GANIL	National Large Heavy Ion Accelerator, France
GBIF	Global Biodiversity Information Facility
GCOS	Global Cosmic Ray Observatory
GDI	Genomics Data infrastructure
GDPR	General Data Protection Regulation
GÉANT	Collaboration of European National Research and Education Networks
GeoReturn	ESA's Industrial Policy relating to geographical distribution or fair return
GERI	Global Ecosystems Research Infrastructure
GGS	Generations and Gender Survey
GHG	Greenhouse gas
GMRT	Giant Metrewave Radio Telescope, India
GNN	Global Neutrino Network
GRAND	Giant Radio Array for Neutrino Detection
GRAPPA	Gravitation Astroparticle Physics Amsterdam
Gravitation programme	Programme for scientific consortia that have the potential to rank among the world's best in their field

GroenvermogenNL GW	Accelerating and realising the green hydrogen and green chemistry economy Gravitational-wave
H.E.S.S.	High Energy Stereoscopic System
H2020	8 th EU Framework Programme
Horizon Europe	9 th EU Framework Programme
HARPS3	Fibre-fed, high resolution, high stability, echelle spectrograph to be installed on the Isaac Newton Telescope in La Palma
HBP	Human Brain Project
HEAL	Health and Environment Alliance
Health-RI	Health Research Infrastructure initiative
HFML-FELIX	High Field Magnet Laboratory (HFML) and Free-Electron Lasers for Infrared eXperiment (FELIX)
HLD	Dresden High Magnetic Field Laboratory
HOR	Hoger Onderwijs Reactor
HPA	Human Protein Atlas
HPC	High Performance Computing
HQ	Headquarters
HTA	Health Technology Assessment
HTM	High Throughput Microscopy
Huygens ING	Huygens Institute
I&W	Ministry of Infrastructure and Water Management
IARC	International Agency for Research on Cancer
IceCube	IceCube Neutrino Observatory on the South Pole
IGO	Intergovernmental Organisation
IHE	Institute for Water Education
IHRA	International Holocaust Remembrance Alliance
ILL	Institut Laue-Langevin
ILTER	International Long Term Ecological Research Network
INCITE	Innovative and Novel Computational Impact on Theory and Experiment program
INEXT	Infrastructures for NMR, Electron Microscopy and X-rays for Translational research
INFN	National Institute for Nuclear Physics, Italy
INFRAFRONTIER	European Research Infrastructure for Modelling Human Diseases
Infravec	Research infrastructures for the control of insect vector-borne diseases
INRIA	National Institute for Research in Digital Science and Technology, France
INT	Isaac Newton Telescope
INT	Dutch Language Institute
IPERION-HS	Integrating Platform for the European Research Infrastructure on Heritage Science
ISIDORe	Integrated services for infectious disease outbreak research
ISO	International Organization for Standardization
ISOLDE	Isotope mass Separator On-Line facility at CERN
ISSP	International Social Survey Programme

JAMSTEC	Japan Agency for Marine-Earth Science and Technology
JERICO	Joint European Research Infrastructure for Coastal Observations
JVLA	Jansky Very Large Array
JWST	James Webb Space Telescope
KAGRA	Kamioka large-scale Cryogenic Gravitational Wave Telescope
KB	National Library of the Netherlands
KEM	Knowledge Programme on Effects of Mining
KIC	Knowledge and Innovation Covenant
KIA	Knowledge and Innovation Agenda
KNAW	Royal Netherlands Academy of Arts and Sciences
KNMI	Royal Netherlands Meteorological Institute
KPMG	Global network of professional firms providing Audit, Tax and Advisory services
KVN	Korean VLBI Network
LBA	Long Baseline Array, Australia
LCAM	Van Leeuwenhoek Centre for Advanced Microscopy
LEI	Leiden University
LENS	League of advanced European Neutron Sources
LHAASO	China's Large High Altitude Air Shower Observatory
LHC	Large Hadron Collider at CERN
LIBER	Association of European research libraries
LiDAR	Light Detection and Ranging
LIGO	Laser Interferometer Gravitational-wave Observatory, US
LingOA	Linguistics in Open Access
LISA	Laser Interferometer Space Antenna
LNCMI	Laboratoire National des Champs Magnétiques Intenses
LNv	Ministry of Agriculture, Nature and Food Quality
LOFAR	Low-Frequency Array
LTER-LIFE	e-infrastructure for Digital Twins of ecosystems
LTSER	Long-Term Socio-Ecological Research Platforms
LUMC	Leiden University Medical Center
LVK	Global LIGO-Virgo-KAGRA collaboration
MAGIC	Major Atmospheric Gamma Imaging Cherenkov Telescope
MAX IV	Next-generation synchrotron radiation facility in Lund
MarE3	Institute for Marine-Earth Exploration and Engineering, JAMSTEC
mBRC	Microbial domain biological resource centre
MCCA2.0	Models to Combat Cancer and Ageing consortium
MEDem	Monitoring Electoral Democracy
MeerKAT	South African MeerKAT radio telescope

MeerLICHT	Optical telescope that simultaneously scans the Southern Skies together with MeerKAT
METIS	Mid-Infrared ELT Imager and Spectrograph
MICADO	Multi-Adaptive Optics Imaging Camera for Deep Observations
MOOC	Massive Open Online Course
MOSAIC	Multi-Object Spectrograph for the ESO ELT
MRI	Magnetic Resonance Imaging
MSP	Mission Specific Platform
MTA	Material Transfer Agreement
NaaVRE	Notebook-as-a-VRE
NanoLabNL	Dutch national facility for nanotechnology research.
Naturalis	National research institute for biodiversity
NCC	Netherlands Cohorts Consortium
NCCB	Netherlands Culture Collection of Bacteria
NCK	Netherlands Centre for Coastal Research
NCR	Netherlands Centre for River Studies
NeCEN	Netherlands Centre for Electron Nanoscopy
NEMI	Netherlands Electron Microscopy Infrastructure
NEMNET	National Environmental Monitoring Network
NEON	National Ecological Observatory Network, US
NER	National Emission Registration
NESSC	Netherlands Earth Science Systems Centre
NeuroTech-NL	Network of leading neurotechnology experts based in the Netherlands
NGF	National Growth Fund
NICAS	Netherlands Institute for Conservation, Arts and Science
NIDI	Netherlands Interdisciplinary Demographic Institute
Nikhef	Dutch National Institute for Subatomic Physics
NIOD	Institute for War, Holocaust and Genocide Studies
NIOO	Netherlands Institute of Ecology
NIOZ	Royal Netherlands Institute for Sea Research
NKI	Netherlands Cancer Institute
NLeSC	Netherlands eScience Center
NMR	Nuclear magnetic resonance
NOVA	Netherlands Research School for Astronomy
NPEC	Netherlands Plant Eco-phenotyping Centre
NSC	Natural Science Collections
NSF	National Science Foundation, US
NSO	Netherlands Space Office
NWA	Dutch Research Agenda
NWO	Dutch Research Council
NWO-I	Foundation for Dutch Scientific Research Institutes

OAPEN	Online Library and Publication Platform
OCW	Ministry of Education, Culture and Science
ODISSEI	Open Data Infrastructure for Social Science and Economic Innovations
OECD	Organisation for Economic Co-operation and Development
Oncode-PACT	Preclinical Accelerator for Cancer Treatment
One Health	Integrated, unifying approach to balance and optimize the health of people, animals and the environment
ORCA	Oscillation Research with Cosmics in the Abyss telescope
OSSC	ODISSEI secure supercomputer
Palomera	Policy Alignment of Open access Monographs in the European Research Area
PBL	Netherlands Environmental Assessment Agency
PharmaNL	Infrastructure and human capital for development and availability of essential medicines
PI	Principal Investigator
Pierre Auger Observatory	International cosmic ray observatory in Argentina
PRIME	Preclinical Imaging Centre
PTC	PRACE Training Centre
PTI	Dutch Physics for Technology and Instrumentation research community
R&D&I	Research & Development & Innovation
RCE	Cultural Heritage Agency
RDA	Research Data Alliance
RHIC	The Relativistic Heavy Ion Collider
RI	Research Infrastructure
RID	TU Delft Reactor Institute
RIR	Recommended Interoperability Resources
RIVM	Dutch National Institute for Public Health and the Environment
RU	Radboud University
RUG	University of Groningen
Ruisdael Observatory	Nationwide observatory for measurements of the atmosphere
SAC	Scientific Advisory Committee
SAEON	South African Environmental Observation Network
SCP	Netherlands Institute for Social Research
SERISS	Synergies for Europe's Research Infrastructures in the Social Sciences
SLA	Service Level Agreement
SMEs	Small and Medium-sized Enterprises
SoBigData	Ecosystem of human and digital resources
SPARC Europe	Open Science and Open Access policy-making and advocacy resources
SRON	Netherlands Institute for Space Research
SSH	Social Sciences and Humanities
SSHOC	SSH Open Cluster

SURF	Collaborative organisation for IT in Dutch education and research
SURFsara	National HPC and e-Science support center
SWGO	Southern Wide-field Gamma-ray Observatory
TCS	Thematic Core Services
TDCC	Thematic Digital Competence Centres
TERN	Terrestrial Ecosystem Research Network, Australia
TeSS	Training eSupport System
TLA	The Language Archive
TNA	Transnational Access
TNO	Netherlands Organisation for Applied Scientific Research
Transvac	European Network of Vaccine Research and Development
TRIUMF	Canada's particle accelerator centre
TRL	Technology Readiness Level
TUA	Theological University Apeldoorn
TUD	Delft University of Technology
TU/e	Eindhoven University of Technology
UN-SDGs	United Nations-Sustainable Developmental Goals
UU	Utrecht University
UM	Maastricht University
UMCG	University Medical Center Groningen
UMCU	University Medical Center Utrecht
UN	United Nations
UNECE	United Nations Economic Commission for Europe
UNFCCC	United Nations Framework Convention on Climate Change
uNMR-NL	Ultrahigh-field NMR facility for the Netherlands
UvA	University of Amsterdam
VAT	Value-Added Tax
VDL-ETG	VDL Enabling Technologies Group
VERITAS	Very Energetic Radiation Imaging Telescope Array System
VetBioNet	Veterinary Biocontained research facility Network
Virgo	Gravitational-wave detector, hosted by the European Gravitational Observatory (EGO)
VLBA	Very Long Baseline Array, US
VLBI	Very Long Baseline Interferometry
VLIC	Virtual Laboratory and Innovation Centre
VLT	Very Large Telescope, ESO
VR	Swedish Research Council
VRE	Virtual Research Environment
VWS	Ministry of Health, Welfare and Sport
VU	Vrije Universiteit Amsterdam

WEAVE	WHT Enhanced Area Velocity Explorer, a new multi-object survey spectrograph for the 4.2-m William Herschel Telescope
WHO	World Health Organization
WHT	William Herschel Telescope
WI	Westerdijk Institute
WISH	Wageningen Imaging and Spectroscopy Hub
WSRT	Westerbork Synthesis Radio Telescope
WUR	Wageningen University & Research
XENON	Deep underground detector facility for direct dark matter searches
XNAT	Open source imaging informatics platform
X-OMICS	National Roadmap project to establish a X-omics research infrastructure across the Netherlands
XSEDE	Extreme Science and Engineering Discovery Environment
ZonMw	Netherlands Organisation for Health Research and Development

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