Project information

Project full title	European Research Infrastructures - Pathway to Improved Resilience and Digital and Remote Access
Project acronym	eRImote
Project number	101057557
Type of action	HORIZON Coordination and Support Actions
Duration	01/06/2022 – 30/11/2024
Website	erimote.eu

Deliverable information

Deliverable no.	4.2
Deliverable title	Remote access use case report
Deliverable responsible	EMSO ERIC
Related Work-Package/Task	WP4 – T4.2
Type (e.g. Report; other)	report
Author(s)	Marco Galeotti, Valentina Tegas
Dissemination level	public
Document Version	1.0
Date	25/11/2024
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Document information

Version no.	Date	Author(s)	Comment
1.0	25/11/2024	Marco Galeotti, Valentina Tegas	

Funded by the European Union
DOI: 10.5281/zenodo.14235482

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DOI: 10.5281/zenodo.14235482
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Introduction

European Research Infrastructures (RIs) are crucial for scientific and technological advancement across the continent, serving as strategic hubs that drive innovation, support high-impact research, and foster collaboration across disciplines. These infrastructures provide researchers with access to cutting-edge tools, facilities, and resources that go far beyond what individual institutions or countries can offer. EU RIs are fundamental not only for advancing European science but also for enhancing global research networks, sharing expertise, and maintaining a high standard of scientific integrity and reproducibility.

During the COVID-19 pandemic, the importance of remote access to these facilities became particularly evident. Restrictions on travel and physical presence accelerated the need for innovative digital solutions, allowing researchers to continue their work despite global disruptions. Remote access facilitated by EU RIs has shown that, with the right infrastructure and support, high-quality research can be conducted without the need for physical proximity. This adaptation not only preserved scientific progress during a time of crisis but also set a new precedent for how research infrastructure can operate, reducing the dependency on physical presence. This evidence accelerated the adoption and enhancement of remote and virtual access models.

Moving forward, remote access to EU RIs is set to play a transformative role in increasing the inclusivity, efficiency, and environmental sustainability of research. By reducing the need for travel, remote access significantly decreases the carbon footprint of research activities, aligning with the European Union's commitment to sustainability and green growth. This approach also opens doors for researchers from the Global South, who may face financial or logistical barriers to physical access. Providing digital and remote access levels the playing field, enabling a broader and more diverse group of scientists to contribute to and benefit from these world-class facilities.

Initiatives such as the RICH project and insights from the ESFRI (European Strategy Forum on Research Infrastructures) working groups have underscored the potential of remote access models. These models ensure that EU RIs not only support European researchers but also contribute to global scientific equity by offering resources to underserved regions. They also highlight the importance of developing robust digital infrastructure and standardized protocols to support remote access, ensuring security, reliability, and scalability. As the scientific community embraces these new models, EU RIs will continue to lead in fostering an inclusive, sustainable, and highly efficient research ecosystem, ultimately enhancing Europe's role as a global leader in research and innovation.

The eRImote project (European Research Infrastructures - Pathway to Improved Resilience through Digital and Remote Access) was established in response to the COVID-19 pandemic and the need for innovative approaches to access Research Infrastructures. The eRImote consortium unites twelve partners from a range of scientific fields, including environmental, life, physical, and social sciences, to explore methods for enabling digital and remote RI access. By conducting targeted surveys, hosting stakeholder workshops, expert group discussions, and analyzing specific use cases, eRImote seeks to uncover the benefits, challenges, and limitations of remote and digital RI access.

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Executive summary

This report is part of the work done in Task 4.2 that aimed at driving the analysis of remote access use cases across different types of research infrastructures. This task focused on examining various management, technological, and IT processes involved in enabling remote access, specifically assessing drivers and barriers in the development of the projects associated with the use case in order to contribute to the eRImote Green Paper.

The task evaluated technological and management aspects through practical use cases in domains like environmental, life sciences, physics and interdisciplinary RIs, aiming to establish best practices and identify challenges.

This associated deliverable compiles the insights and evaluations of these use cases, the lessons learnt, best practices and the impact of the use cases.

During the document, we will present the results of the steps taken to develop a full picture of the use cases, their evolution along the project and the final results.

Overview of use cases

This section includes a detailed description of each use case from the RIs involved in the project, notably EMSO, Euro-BioImaging, LEAPS, INTERACT and INSTRUCT. We will present the description, the objectives of each use case, their contributions to the advancement of remote and virtual access solutions, and the technological and operational strategies employed. In addition, we are going to present also the impact of the use cases and the next steps in the exploitation of the new features.

INSTRUCT - Instruct-ERIC: Improving Remote Access Project Tracking in ARIA

Instruct-ERIC's use case explored how its ARIA software can improve remote access project management through new and improved features.

This use case focused on two aspects of remote access provision: enhancing the display of remote service offerings to users and improving the tracking of remote project progress.

To achieve this, service availability (whether physical, remote, or both) is now automatically displayed on the service pages to support users in service selection. Additionally, the project status and workflow progress are now automatically displayed to users in their ARIA dashboard. This greatly decreases the administrative work for service providers in keeping users up to date and keeps users engaged and informed, in particular during long, remote access projects. Going forward, INSTRUCT will continue to

work with its service providers to expand the use of workflows to make the best use of the developed user dashboard updates.

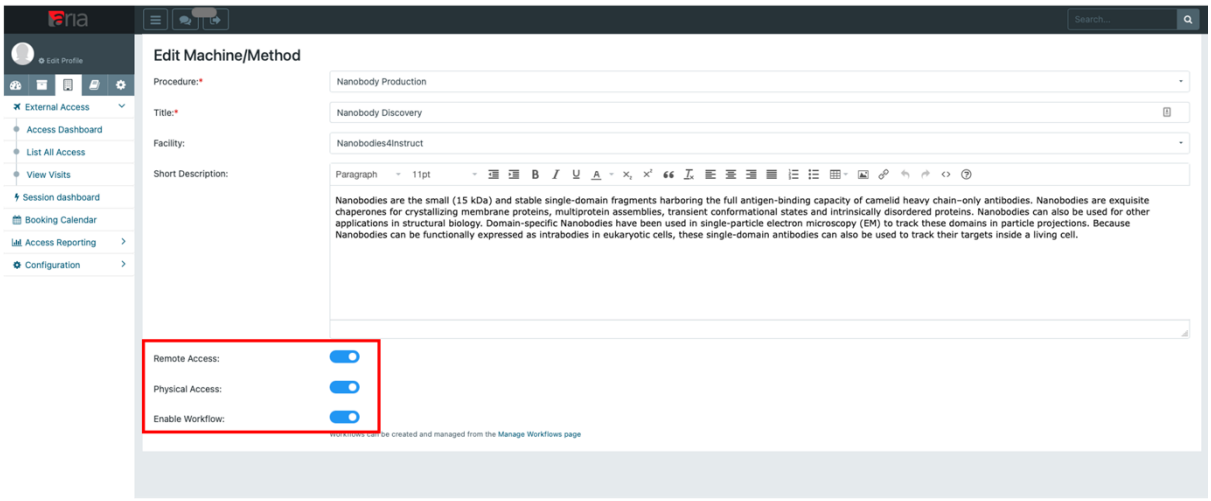

Figure 1 - Machine availability selection in ARIA.

Technical and operational details

ARIA[1] is a cloud software platform developed and maintained by Instruct-ERIC, which provides an integrated suite of tools for research infrastructure management. The acronym "ARIA" is an abbreviation of "Access to Research Infrastructure Administration" and the functionality covers a range of access management functions: access catalogue, proposal submission, scientific peer review, technical evaluation, access delivery, feedback collection and access reporting. In addition, ARIA provides software tools for facility management such as instrument booking; website management, document management, events/news/job postings, survey tools, and APIs for data integration. These tools are supported by context-dependent integrated internal messaging and automated notifications and reminders.

ARIA was initially developed to service Instruct's own needs due to a lack of suitable commercial software; however, it has since grown to support projects and infrastructures throughout the life sciences, and beyond.

[1] https://aria.services

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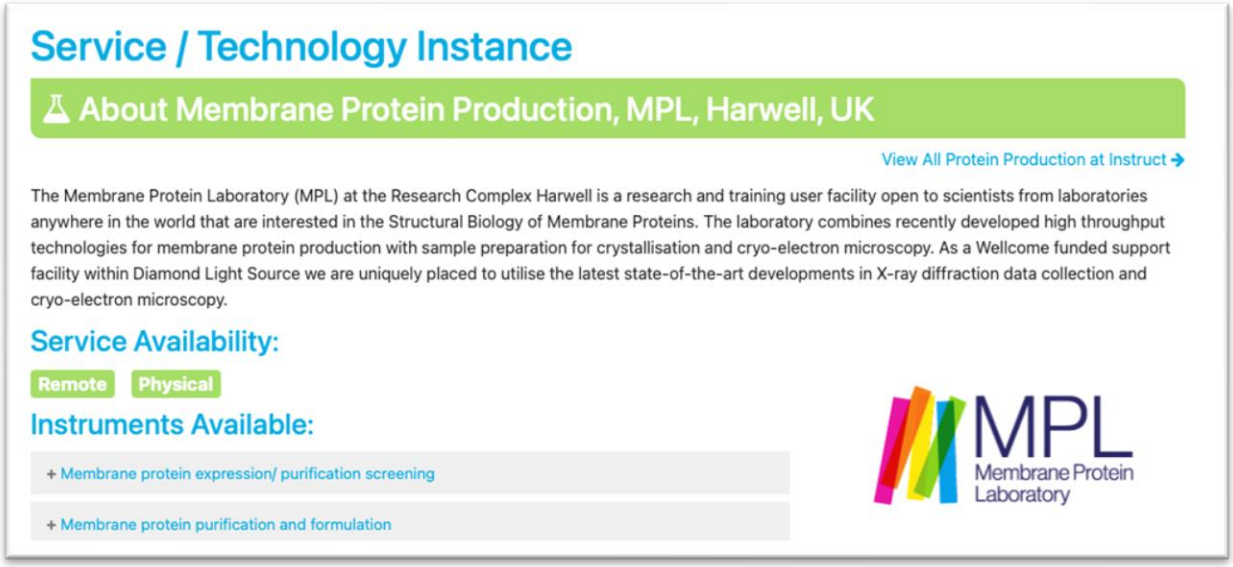

Figure 2 - Service availability display

Outcomes and impact

Improvement of the remote service offer display

(i) For each service, machine, facility administrators can specify if the use equipment (machine) is available to users for physical access, remote access or both (**Fehler! Verweisquelle konnte nicht gefunden werden.**). However, before the eRImote project, this information was not displayed on the machine's corresponding service page but manually collated for users to view on a Service Status page[2] which was introduced due to an urgent need at the start of the COVID-19 pandemic. This disconnect made the information hard for users to access and prone to delays and errors due to the manual collation of the data.

As part of this use case, INSTRUCT developed an API that updates each service page in the catalogue to automatically display the machine availability settings specified in ARIA (**Fehler! Verweisquelle konnte nicht gefunden werden.** and example Membrane Protein Production service[3]). Additionally, it was ensured that the information is available for all Instruct services by collaboration with the service-providing facilities.

Now it is clearly visible to users if a service is available for physical access, remote access or both. This makes the information readily available to users when selecting services and reduces the administrative burden of informing prospective users by email.

[2] https://instruct-eric.org/service-status
[3] https://instruct-eric.org/platform/membrane-protein-production-mpl-harwell-uk/)

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DOI: 10.5281/zenodo.14235482

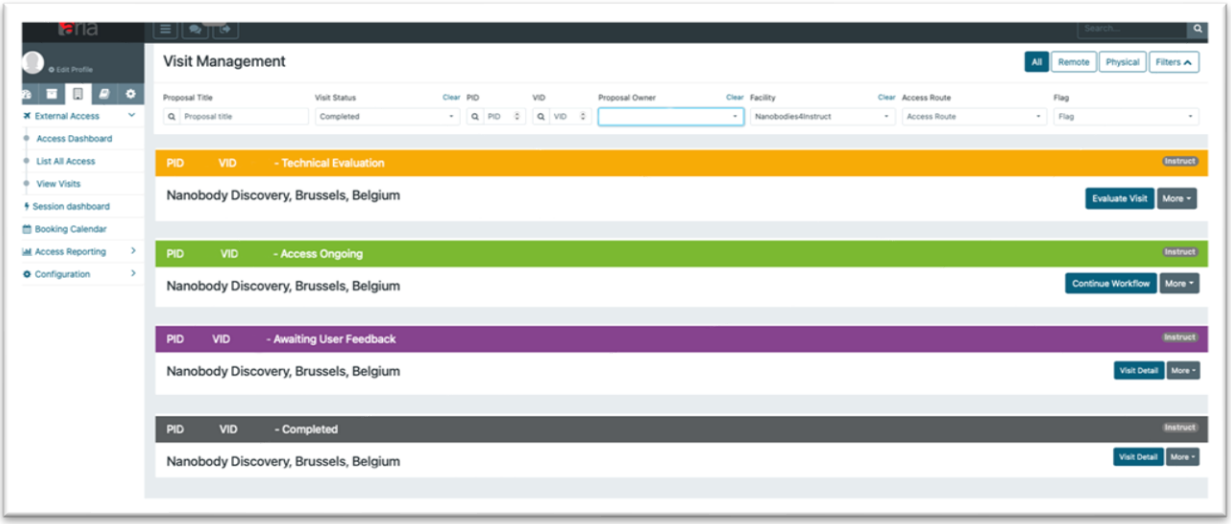

Figure 3 - Visits status display for facility managers in ARIA.

Remote project tracking for users and access managers

(ii) In Instruct-ERIC, each access project goes through distinct major phases: scientific review, technical review, project in-progress, feedback, and completion. This information is displayed to facility administrators in ARIA (**Fehler! Verweisquelle konnte nicht gefunden werden.**) to easily track projects' status. However, this information was only available to access administrators in the ARIA admin panel, not users on their dashboard. It is important to keep users informed of the project's status, especially during remote access projects, as users can feel disconnected from the project's progress. Updating the users via email can be a burden for access administrators and facility staff and automation of the process would greatly improve this communicating.

To this end, it was decided to improve the user dashboard to display the project's status to the user as part of this use case. Now, users can easily follow their remote project's progress (**Fehler! Verweisquelle konnte nicht gefunden werden.**). This is particularly crucial for remote access – physical visits are easier to keep track of as the user is on-site, but remote users may wish to keep up to date with their project without needing to send frequent emails or contacts with lab teams.

The update of the dashboard is a core ARIA feature which has an impact beyond Instruct-ERIC as it is also helping communication of other ARIA utilising research infrastructures with their users.

(iii) Additionally, visits undergo distinct progress steps once in progress. These can be specified by service administrators in ARIA via machine workflows. Workflows can help facility staff to track project progress, especially for projects that run several weeks to a month. An example of this is the Nanobody Discovery service – it can take up to a year and is only available remotely to users (**Fehler! Verweisquelle konnte nicht gefunden werden.**). Keeping users informed beyond project in-progress for such long, remote projects is important to ensure they remain engaged and informed.

To support this, the progress steps are now displayed to the user in the user dashboard while the project is in-progress (**Fehler! Verweisquelle konnte nicht gefunden werden.**). This greatly improved user engagement and information, especially for remote access projects.

The use of machine workflows to improve project progress tracking is a core ARIA feature. This means that not just Instruct but other ARIA-using research infrastructures can utilise this feature and keep their users informed about their (remote) project's status in detail via the user dashboard.

(iv) An additional gap identified during the use case was the availability of statistics on remote service usage. ARIA does collect various statistics that are available to access managers in the *visits statistics report*. However, statistics on physical vs remote access use of services are currently not available to access managers through ARIA. To this end, a table will be added to the access report to provide statistics on the physical and remote use of services. This feature has been developed and is currently being tested before release. It is expected to be available for access managers from Instruct-ERIC and all other ARIA-using organisations by the end of the eRImote project.

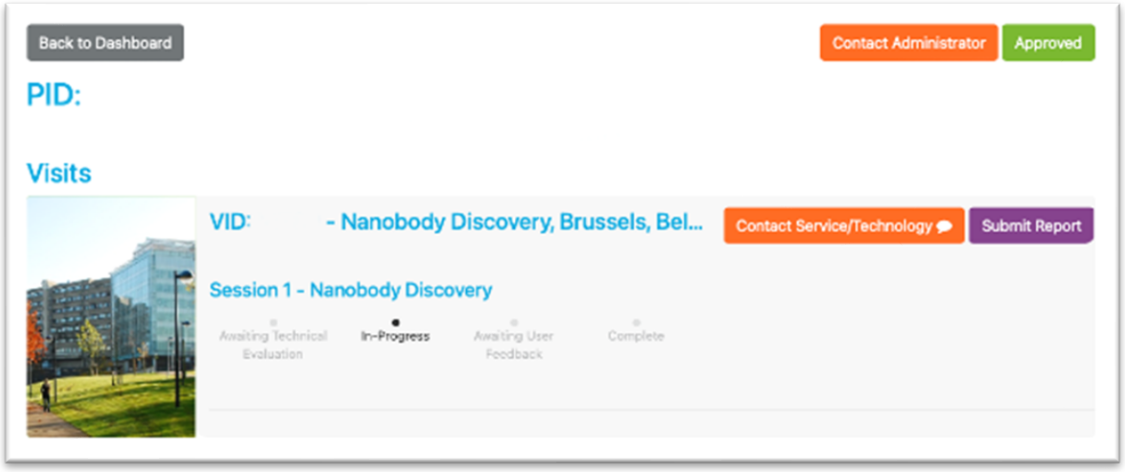

Figure 4 - Visits status display in the ARIA user dashboard. Example: Service Nanobody Discovery.

Future developments and next steps

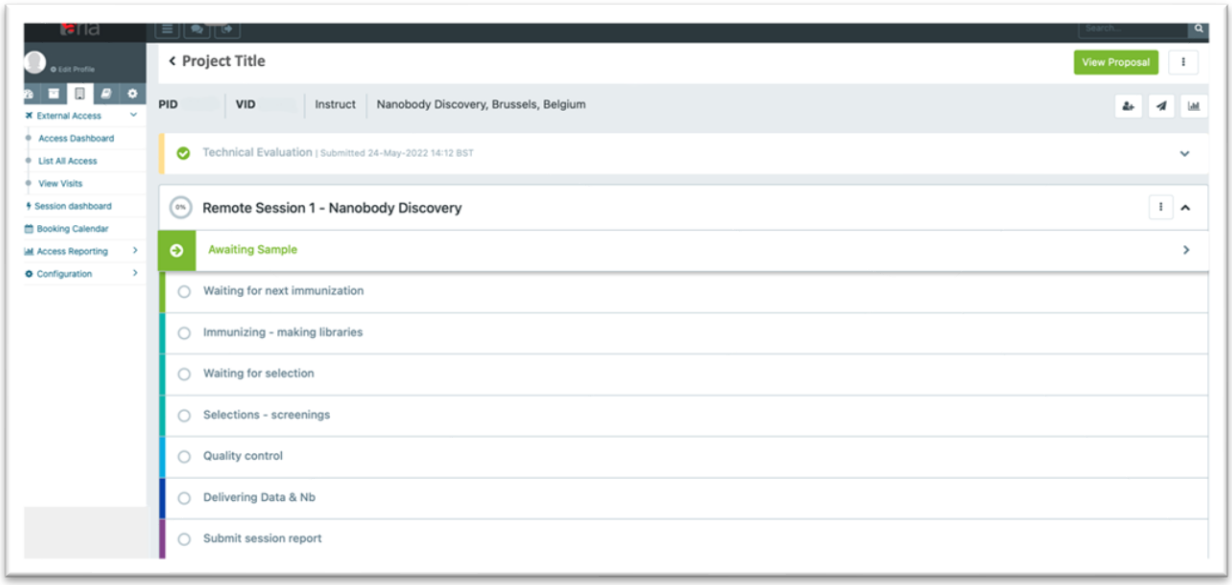

Figure 5 - Machine workflow display for service administrators in ARIA. Example: Service Nanobody Discovery.

During this use case, Instruct has made great strides in improving the user dashboard to keep users informed about the status and progress of their research project.

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However, not all Instruct facilities make use of the machine workflow opportunities in ARIA. Going forward the ERIC will continue to work with facility staff by supporting them in implementing machine workflows for remote access services to ensure users receive detailed progress information about their project in an automated fashion for all services provided.

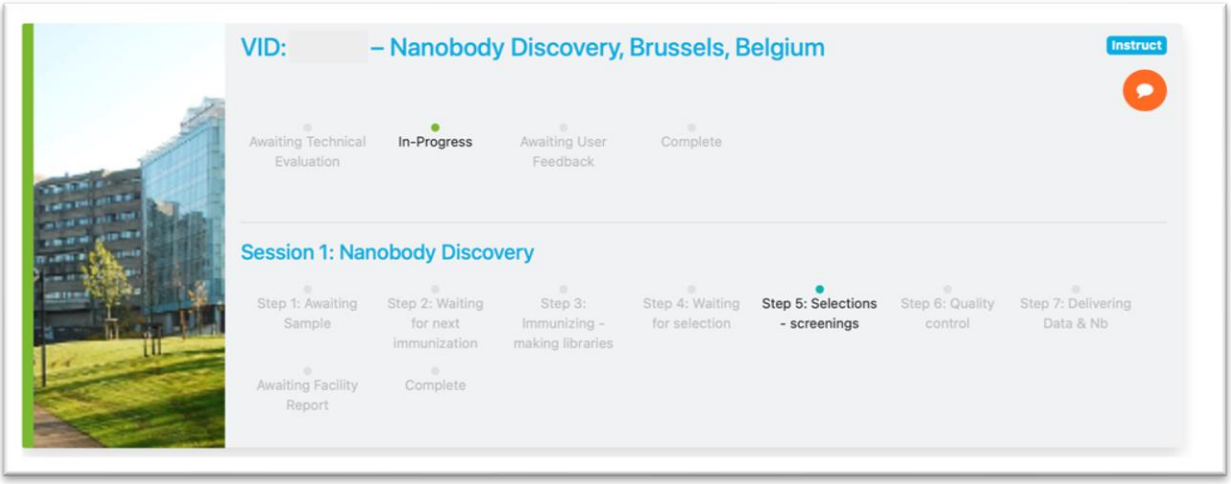

Figure 6 - Machine workflow status display in the ARIA user dashboard. Example: Service Nanobody Discovery.

Euro-bioimaging - Advancing remote access and hybrid training models in imaging core facilities

The Euro-BioImaging use case aims to develop best practices for offering full remote access to imaging technologies and services traditionally accessed in person. It also explores a hybrid training model that combines remote and physical training modalities for sustainable and impactful training delivery in distributed Research Infrastructures.

Indeed, traditionally, the large majority of access to imaging core facilities and training in imaging has been in-person, but during the pandemic, many core facilities switched to remote access and set up remote training courses.

In some imaging technology areas remote access to imaging instruments has proven to be a long-term attractive solution, but for a sustained delivery and to enable new imaging core facilities to adopt remote access, guidelines, exchanges with experienced remote access service providers and training for RI staff, including with support from instrument manufacturers, are still needed. This formed the first pillar of the use case.

When it comes to user training in imaging, there is now a growing interest in the community in hybrid training formats that creatively combine the advantages of in-person with the benefits of remote training formats developed during the pandemic. The use case provided an opportunity for developing and testing one of the experimental hybrid formats, which are unfamiliar to trainers and organisers and assessing the impact on student experience. This formed the second pillar of the use case.

As part of the eRImote use case, Euro-BioImaging pursued two activities to address the needs of the imaging community in terms of access and training:

1) Through the eRImote Expert Group on Remote Instrument Control and a dedicated series of three virtual training workshops for RI staff focussed on remote access for Electron Microscopy, expertise transfer and RI staff development were achieved. The participating Euro-BioImaging facilities received the best practice guide from experienced remote access service providers and industry experts and were subsequently better able to provide remote access services for their users.
2) To address the need in the RI community for the development of innovative training formats, for the first time a distributed training course was organised among three Euro-BioImaging Nodes in different countries. While originally the development of fully remote training was foreseen, the changing reality and expectations of users for training post-pandemic, led to a focus on a distributed hybrid training format. In this course, three local teaching sites were connected online, with the teachers rotating throughout the course and providing the training remotely, but with local support for the students. The practical component of the course was delivered remotely through a jointly accessible remote desktop system for image analysis which all students, irrespective of their training site, used.

Technical and operational details

Increasing remote access expertise for RI staff

While some imaging facilities have adopted remote access post-pandemic as one part of their regular operations to facilitate user access, work processes can still be optimised and facility staff can gather new skills to improve service delivery. At the same time, facilities that do not implement remote access regularly yet, are interested in gaining an understanding of the technical, practical, and operational requirements of the provision of remote access. To facilitate the expertise transfer and RI staff development, the expert group on remote instrument operation and the workshop series on remote access to Electron Microscopes were organised and many staff members from Euro-BioImaging Nodes attended the events. As this aspect of the use case was delivered via online workshops and exchanges of best practices, there were no specific technical or operational aspects.

Distributed hybrid training course

The organisation of the distributed hybrid training course across three Euro-BioImaging Nodes in different countries and time zones raised a range of interesting technical and operational aspects.

The organisation of a distributed hybrid training requires a significantly higher investment in alignment, planning, and central organising than the organisation of a single-sited in-person or remote training course. The trainers of the three sites had to co-develop the program, align their training content and practises, develop practical modules that dovetailed with each other and jointly decide on participant selection to have comparable levels of student starting knowledge and expectations at the different sites. Time zone offsets and different local expectations and habits on training course timings required some compromise but were able to be resolved very positively. The offset in timing

between course sites in different timezones was used to offer catch-up sessions and individual consultations for the local students either in the hour before or after the main course days.

From a central organisational standpoint, distributed hybrid training courses also require more investment as there are multiple parallel levels of communication with the course participants to share both central and divergent local information. Outreach for training mostly targeted at a regional and national audience in three different countries also requires particular focus, messaging, and support from local partners.

The actual course delivery was also followed centrally to ensure any technical and organisational aspects could be addressed as they arose and to support the local trainers.

A specific technical aspect of this distributed hybrid training course was the requirement for a joint online platform for the practical course component, easily accessible to students at all sites, and meeting computational requirements for the taught image analysis.

The remote desktop BAND[4] was used for this purpose. BAND was developed as part of the Euro-BioImaging participation within the EOSC-Life project (GA# 824087) by Jean-Karim Heriche and Yi Sun for exactly this kind of shared online image analysis in a training or service provision context. However, BAND had to be deployed on a suitable computational resource to be accessible for this course, as the combined number of students across the three course sites and the planned image analysis practicals within the course required a computing platform able to provide access to a significant number of CPUs.

The deployment of BAND for this use case was made possible by the **EGI Training Infrastructure service**[5] supported by national resource providers in the EGI Federation. In particular, **CESNET**[6] provided the computational resources and support here. This resource was kindly provided without costs to the use case through the training infrastructure program of EGI. Otherwise, the cost of computing resources would have provided a potential limiting factor for the implementation of this course.

To increase the accessibility of the training course, several travel grants were provided for researchers joining the course at different sites. This made the training accessible to some participants from other regions of the host country and a few international participants. The grants, similarly to the general participation, were selected competitively and based on the excellence of the application and the impact of the participation for the applicant. These travel grants were also enabled by the funding of the eRImote use case.

[4] https://forum.image.sc/t/anouncing-the-band-a-virtual-desktop-for-bioimage-analysis-in-the-cloud/63078
[5] https://www.egi.eu/service/training-infrastructure/
[6] https://www.egi.eu/partner/cesnet/

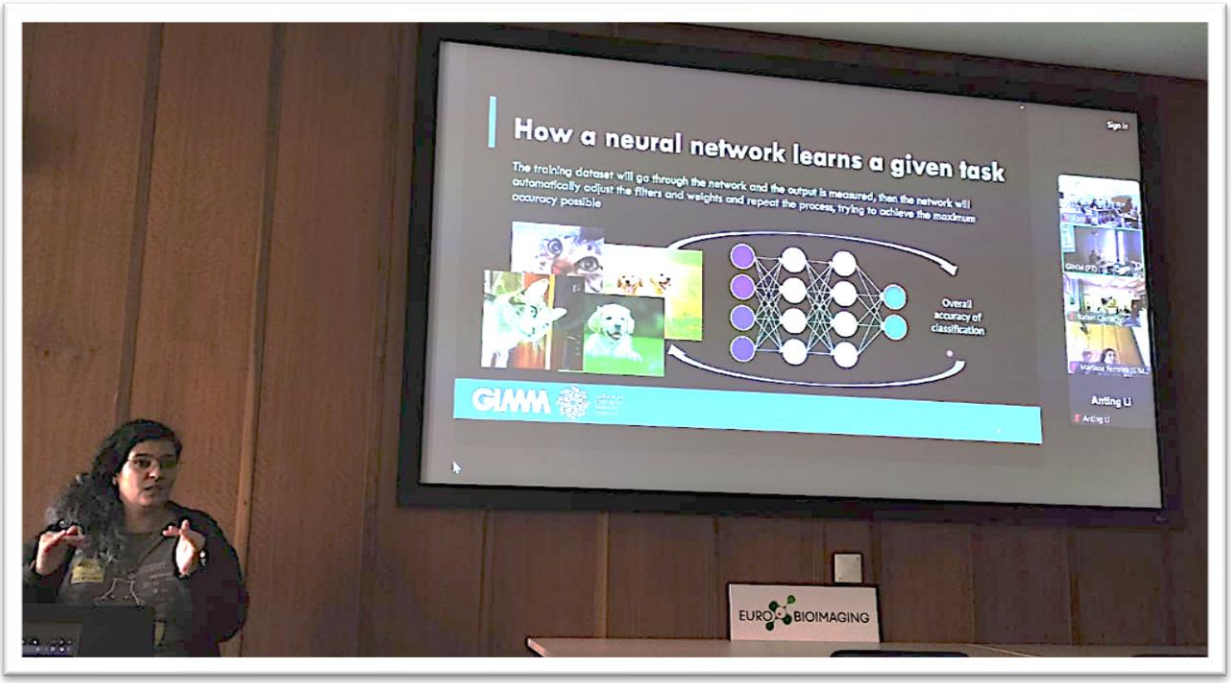

Figure 7 - Mariana Ferreira, GIMM, delivering a lecture to both the local group and the two virtually connected training sites on the use of neural networks in image analysis.

Outcomes and impact

Increasing remote access expertise for RI staff

The feedback from RI staff attending the exchanges and workshops was very positive, indicating that they learned useful new tips and tricks and if they had not yet been implementing remote access as a regular access modality, they reported being interested in piloting remote access in their facility in the next six months. This will increase the availability of remote access as a service option within Euro-BioImaging. The sharing of expertise sparked by this use case will continue in the framework of the EVOLVE project (GA# 101057557) within Euro-BioImaging ERIC. They will also work with the global imaging community as part of Global BioImaging to translate the gathered information into a set of international recommendations on remote access service provision. These recommendations will be targetted at imaging facilities, but as has been already seen in the series of workshops on remote access to EM, which was jointly organised by Euro-BioImaging and INSTRUCT ERIC, many of the tools and processes will be translatable and relevant also to other RIs and core facilities where the provided service is access to a specific piece of equipment for sample characterisation or data gathering that is remotely controllable.

The workshop material is already available on Euro-BioImaging YouTube channel[7], allowing other RI and core facility staff to benefit from the knowledge shared.

[7] https://www.youtube.com/@EuroBioImagingCommunication

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Distributed hybrid training course

The delivery of the course[8] was a success with very positive feedback from both the students and trainers.

It highlighted the opportunity of this training modality to deliver the advantages of in-person training – direct support, facilitating exchange, adaptability to student needs, and building of community – with the advantages of remote training – increased accessibility, reduced travel needs and resulting environmental impact, access to a wider range of trainers and teachers who are experts in different aspects of a topic. It also highlighted that this model is indeed scalable across a distributed RI and delivered valuable lessons learned for a larger-scale deployment of this training model across even more nodes of a distributed infrastructure.

85% of the students reported being satisfied or very satisfied with the course and 100% said that the course will certainly or likely support their future research/work. As a significant number, of course, participants were image analysts within imaging core facilities, partially within Euro-BioImaging but also others not associated with the RI, the delivered training impact will be multiplied as it will support the service delivery and future teaching of these RI and core facility experts towards their own users.

From the perspective of the Research Infrastructure this hybrid distributed training course also provided an opportunity for alignment of training methods and levels across the participating centres, which is something very difficult to achieve under other circumstances across a large consortium of facilities. Each hosting site was led by an experienced trainer and topic expert, but in all cases supported by a number of junior trainers who provided hands-on support for the students and delivered some parts of the teaching. All the junior trainers were early career core facility staff and for some, this was their first experience teaching to an online audience at different sites and working with other experts to develop a training course. Therefore this course also increased pedagogical skills across the RI and upskilled new staff members who gained confidence and experience in a new teaching modality.

The deployment of the digital infrastructure for the course on the EGI resource was also a useful outcome of this course, as it provided a test case for a larger scale and longer-lasting deployment of the BAND remote desktop.

The information on the course outcomes will be broadly disseminated, highlighting this model of training also to other Ris. The Euro-BioImaging team is available to provide more detailed insights into organisational and operational aspects for other Ris who are interested in developing similar training models.

[8] See the full report at the following link https://www.eurobioimaging.eu/news/euro-bioimaging-runs-a-highly-successful-distributed-image-analysis-training-course/

Euro-BioImaging facility sites highlighted with black pins. The red dots mark the three sites involved in the delivery of the distributed hybrid training course.

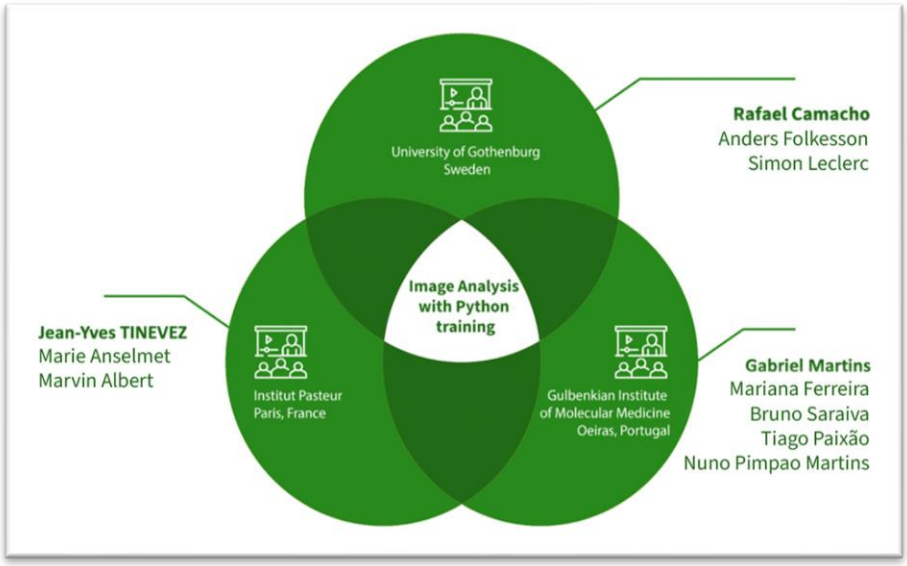

Figure 8 - Scheme highlighting the unified distribution of the "Image Analysis with Python" training program across the three hosting sites and the local involved experts and trainers.

Future developments and next steps

Increasing remote access expertise for RI staff

As already indicated above, the experiences gathered within the eRImote use case and wider eRImote activities for remote access to imaging facilities will be combined with experiences from global partners on the topic to develop a set of international recommendations on remote access.

The work on sharing experiences and building skills across the RI staff within Euro-BioImaging on remote access will continue as part of the Euro-BioImaging EVOLVE project. The project includes a specific focus on advancing the uptake and visibility of remote access within Euro-BioImaging as part of efforts to increase Green RI practices and increase accessibility.

Euro-BioImaging will build on the success of the training course and, based on the lessons learned with the three hosting sites in this round, next year will organise the next iteration of this course across a larger number of Euro-BioImaging Nodes in more countries. This further expansion and delivery of this innovative training course model will be done as part of the Euro-BioImaging EVOLVE project.

LEAPS - Virtual Femtosecond X-Ray experiments with VLab

LEAPS has funded a functional Virtual Lab (VLab), but the software needed some serious decluttering on the source code level to allow for further upgrades. This step is vital to allow the addition of new beamlines and functionalities.

The LEAPS use case thus aimed to carry out the software decluttering to support these additional improvements. The development process progressed and has allowed several improvements to be added, though it's still in the process of overcoming technical challenges related to the previous software code structure.

Within LEAPS a large part of the code has been successfully decluttered, and it resulted in a fully functional VLab, both for training and teaching purposes. The system's stability has improved significantly, shifting the focus from merely fixing bugs to enhancing the experiment experience. Within LEAPS the possibility of turning VLab into a versatile scientific instrument has been explored, allowing more advanced experiments and extending this software architecture to be able to model other beamlines more efficiently.

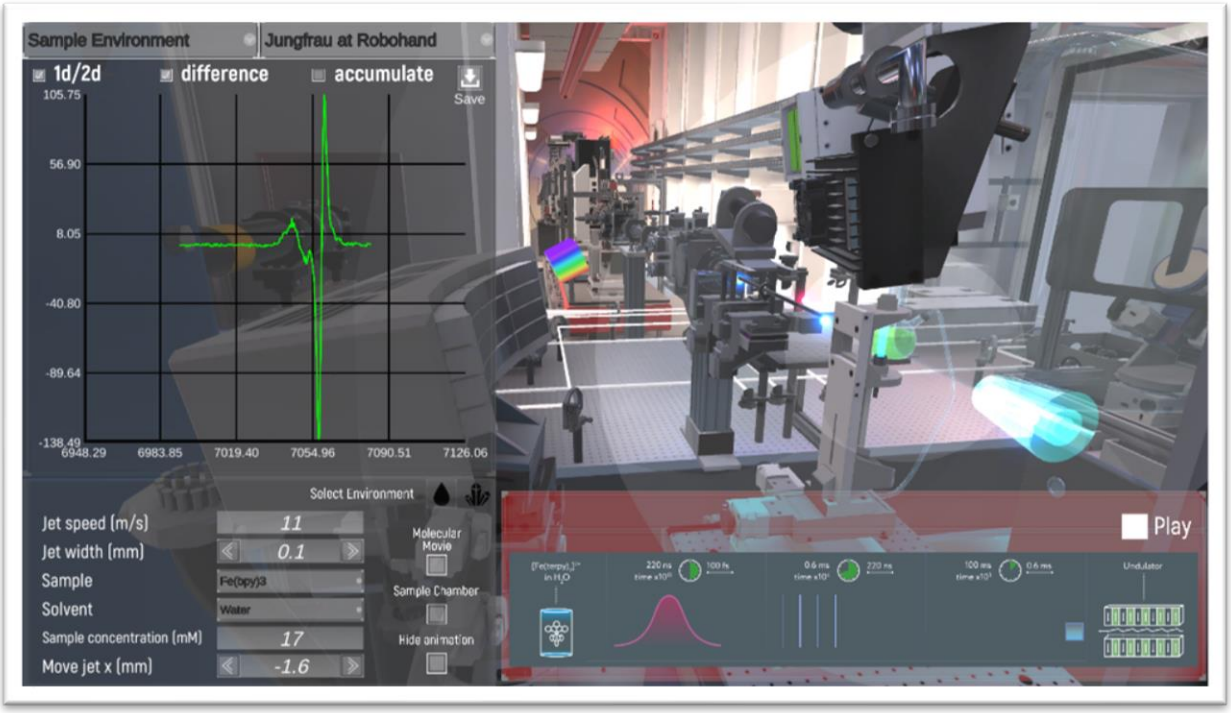

Figure 9 - A Screenshot of the VLAB in action.

In the Fig.9 there is the VLab in action, left showing live detector data and right the ongoing experiment with the 3D view of the sample environment with moving light blue spheres demonstrating the incident X-ray pulses and moving red spheres for the pump laser pulses. The chosen view looks upstream into the tunnel. The truncated moving cyan cones reflect scattered X-ray pulses from the sample and the rainbow-coloured shape illustrates the dispersive X-ray emission spectrum moving from the von Hamos spectrometer to the detector. The left front data monitor displays the current detector reading, below are some interactive controls. The right bottom level shows a simplified sketch of a moving X-ray beam pulse train travelling from the undulator up to the sample. Once a user has succeeded in working all the way through VLab, the signal of a real measured experiment will appear on the detector with a noise level reflecting the prior beamline adjustments. This data can then be downloaded and analysed for interpretation.

Technical and operational details

VLab is a fully functional virtual laboratory of a real experimental end station dedicated to ultrafast X-ray experiments at an X-ray Free-Electron Laser facility (Fig. 9). Unity 3D is used to embed the CAD drawings of the real beamline and the further functionalities into VLab. The software contains two layers, an "Overview Mode" and an "Experiment Mode" (Fig. 10). The "Overview Mode" allows users to freely navigate through the control room and the experimental hutch to observe the overall setup and all its beamline components from the outside. This is the standard virtualisation of real environments in virtual reality and helps more with just observing the original components in 3D rather than gaining any deeper understanding of how the beamline works and even less about the underlying physical processes within. For this, LEAPS staff have designed an entirely new "Experiment Mode", which is accessed by "opening" any beamline component. They now enter a completely different

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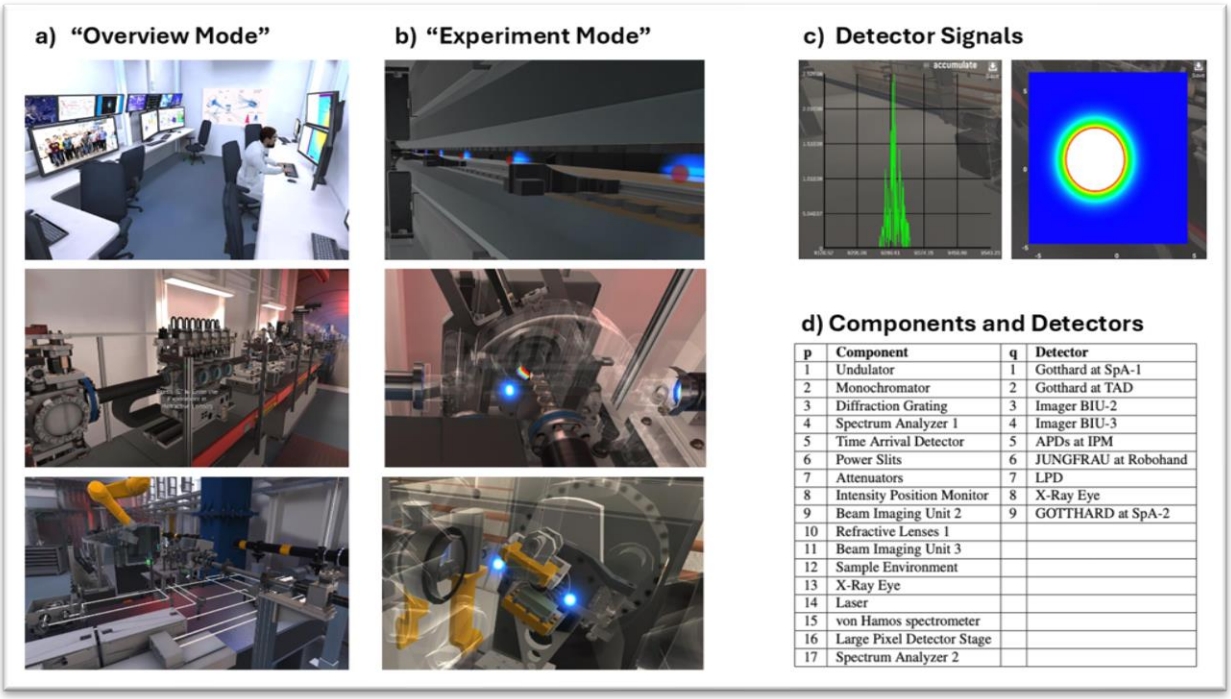
world: the user observes the entire setup in action and the operational details of each component in the long beamline. Starting with the X-ray pulse generation in the upstream undulators, these pulses enter the beamline and interact with each different component delivering signals for several virtualized detectors. The beam eventually impinges on the sample under investigation and creates a sample response reflecting all prior adjustments in the upstream beamline components. This data is displayed on the live data screen and can be downloaded and analysed offline via conventional plot programs and with scientific programming software, e.g., Matlab or Python.

In order to have a logical program, every change in a component needs to influence the manipulation results for all downstream components. This was not the case in the original software version, which led to several bugs in the beamline operation. These issues, next to more precise calculations of the outcome of each manipulation, were the main task.



p	Component	q	Detector
1	Undulator	1	Gotthard at SpA-1
2	Monochromator	2	Gotthard at TAD
3	Diffraction Grating	3	Imager BIU-2
4	Spectrum Analyzer 1	4	Imager BIU-3
5	Time Arrival Detector	5	APDs at IPM
6	Power Slits	6	JUNGFRAU at Robohand
7	Attenuators	7	LPD
8	Intensity Position Monitor	8	X-Ray Eye
9	Beam Imaging Unit 2	9	GOTTHARD at SpA-2
10	Refractive Lenses 1		
11	Beam Imaging Unit 3		
12	Sample Environment		
13	X-Ray Eye		
14	Laser		
15	von Hamos spectrometer		
16	Large Pixel Detector Stage		
17	Spectrum Analyzer 2		

Figure 10 - In the picture, some views from the user interface of VLAB.

In Figure 10, the user starts VLab. The software opens in "Overview Mode", which resembles the reality view of the laboratory (a). The user can walk through the control room and X-ray experimentation room. In the latter, the user can switch to "Experiment Mode" by entering one of the components (b). Here, the detector signals can be observed (c) and the distinct components (d) can be adjusted to settings in which the experiment can be performed.

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Outcomes and impact

VLab was presented in a Summer school dedicated to teaching and training the next generation of Master's and PhD students with the opportunities available at X-ray free electron laser sources. This 2.5-week long summer school, organized by UHH/EuXFEL, Aarhus and Lund Universities featured a thorough introduction to femtosecond X-ray experiments at XFEL facilities (Aarhus) next to a focused femtosecond X-ray beamline introduction (FXE at EuXFEL). Participants spent the next full week in Hamburg performing two different fs X-ray experiments with our virtual software VLab, which replicates the actual FXE instrument in action. They aligned the X-ray and laser beams on two different samples and recorded transient X-ray emission data from laser-excited liquid solution samples and femtosecond X-ray diffraction data from laser-shocked solid-state materials.

This interaction with VLab in week 2 prepared them for week 3, where they learned about femtosecond optical experiments before performing a real fs XRD experiment at FemtoMAX at the MAX IV synchrotron. The participants felt that they had accumulated enough valuable insight information about such RI experiments to consider a future career at one of these facilities. They completed the summer school by writing a paper-style report about their experiments. The overall appreciation was overwhelming, in Annex 3 we present the outcome of the feedback forms for these 2.5 weeks.

The participants were thrilled to receive such detailed on-site information about actual experiments performed at EuXFEL, and the initiative underlines the success in drawing in new users and staff scientists for such RIs. Although limited to X-ray studies at an XFEL source, VLab has demonstrated its potential to expand towards different RIs with completely different science objectives. An expansion of VLab to embrace these is an attractive next step.

Future developments and steps

The achieved precision in VLab status allows LEAPS to envision even more sophisticated tools to be implemented, which may allow users to fully simulate a hitherto unknown sample and experiment. Moreover, the VLab architecture can now attempt to scientifically virtualize a larger number of very different complex experiments, starting with Synchrotron Radiation beamlines and other XFEL-related instruments. This new idea can also be transferred into completely different scientific domains outside of the photon sciences.

EMSO – Scalability and cybersecurity for a resilient infrastructure

The EMSO use case initially focused on improving remote access for the command and control of marine observatories, to enhance autonomous and teleoperated sensors. The intention was to strengthen the observatories' scientific capabilities and increase their accessibility for global researchers.

Later, the increasing concerns about cybersecurity due to the geopolitical situation pushed EMSO to implement a robust Authentication and Authorization Infrastructure (AAI) system using Keycloak and

an API. The primary difficulties were keeping the system updated, training the users, and managing user roles and permissions effectively.

During the process, the RI's managers deemed it necessary to further expand the scope of the use case, focusing more on migrating the whole EMSO IT Infrastructure to a dedicated Data Center developed by INGV, one of the organisations participating in EMSO ERIC as member, to secure the ERDDAP for virtual access to data and to build more personalised services for the scientific community and external users. The new Data Center called NEREIDE, located in Porto Palo, Sicily, will enable EMSO to develop a Virtual Tour of the facilities for remote and virtual access, to the sensors and more suitable data products thanks to the possibility of storing the visualisation tools and the snapshot of all the EMSO data in the same place.

Although the AAI system isn't yet activated, the focus remains on creating seamless remote access and improving the resilience of EMSO's IT infrastructure.

Technical and operational details

EMSO goal was to achieve a seamless and secure remote access framework across different European Research Infrastructure Consortia (ERICs), improving user management, enhancing security protocols, and ensuring that all members have the necessary training and access for efficient collaboration.

EMSO pursued similar goals but without AAI at the moment. The migration process of the EMSO IT infrastructure ended in September 2024. Now EMSO has a more secure IT Infrastructure able to sustain reliable remote and virtual access to its infrastructure using a VPN service, and EMSO started thinking about how to enable seamless access from other organizations. From the technical point of view, the data center uses OpenManage Enterprise, a Server MAAS, a Server Juju, and Cloud IAAS with Openstack. For the storage management, EMSO employed Cluster Ceph because it is open source as Open Stack and vendor independent and easily scalable.

Outcomes and impact

The main means to assess the impact in the future will be the definition of a set of KPIs related to access to the infrastructure, cybersecurity, business continuity, disaster recovery, and redundancy of the tools and resources behind the services. The point here is to evaluate not only the quantitative parameters that could help assess the situation but also the qualitative aspects of the service provision to the final users. EMSO wants to have users who are satisfied with its Services, preserving at the same time the security of the infrastructure and the traceability of the access provision in compliance with the GDPR. In order to have the whole picture, EMSO is planning to launch surveys and make focus groups of users and frontal interviews to have a clear view of the level of success of the improvements.

Funded by the European Union
DOI: 10.5281/zenodo.14235482
25/11/2024

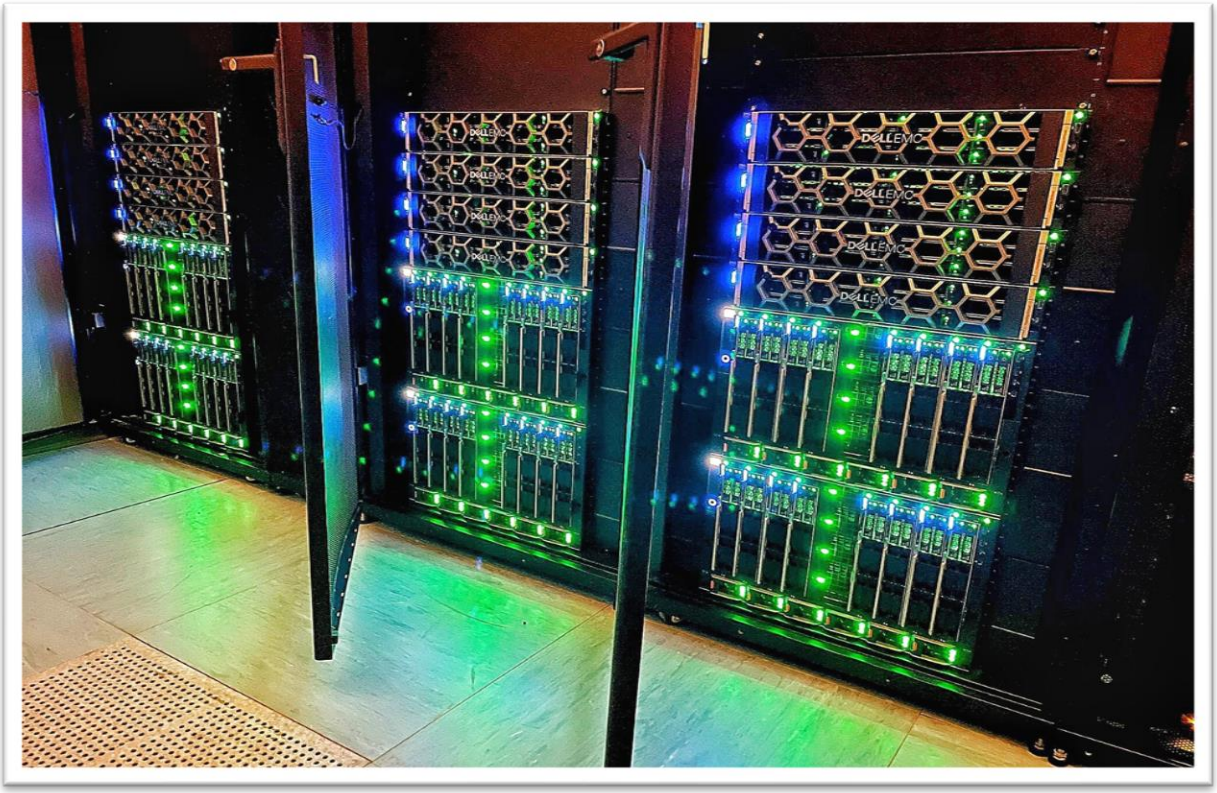

Figure 11 - EMSO new Data Center NEREIDE located in Porto Palo, Sicily, Italy. The data center is equipped with 48 nodes (~2600 CPU cores), 36 TB RAM, 8x NVidia A100 and in terms of storage, 12 nodes with 240 HDD, 60 SSD hosting a total of 3.6 PB raw disk.

Future developments and steps

EMSO would like to propose to the members to have an annual cybersecurity audit to assess and improve the infrastructure on a continuous basis. So there will be a committee that visits the facility and does the assessment, does the overall checking of KPIs, makes tests and provides recommendations for improving the security and usability. Typically, external companies are in charge of it, producing reports on how the users are using the system and gathering information through interviews every year on aspects like cybersecurity, and usability, accompanied by statistics that could be used to produce an annual report.

In addition, the new data center is able to provide HPC capabilities for improving the user experience in using EMSO Data products and the Virtual Research Environments (VRE) that are going to be developed in the next two years. Having scalable computational resources to analyze large volumes of data is the next challenge in the climate change research community and EMSO with NERIEDE will be at the forefront, providing its community with a one-of-a-kind powerful tool to cover the whole data analysis chain, from the raw data to the final product. EMSO, in this way, is positioning itself as a one-stop shop for climate change analysis related to the oceans' role in the Earth's climate bio-physical dynamics.

Funded by the European Union
DOI: 10.5281/zenodo.14235482

INTERACT - Roadmap for the transition to enhanced remote and virtual access services

In this use case, INTERACT aimed to learn from over a decade of experience in providing in-person, remote, and virtual access to Arctic research stations, and to develop a roadmap to enhance future remote and virtual access services. The use case also explored how collaboration with local Arctic communities can be improved using remotely operated equipment.

Remote Access in INTERACT has been limited, constituting only around 10% of all access provided since 2016, and Virtual Access via the INTERACT Data Portal since 2021 has grown but faced challenges e.g. due to the lack of IT and data management skills in smaller infrastructures.

The use case focuses on developing a roadmap to increase both remote and virtual access use, with particular emphasis on remotely operated instrumentation and collaboration with local communities. The lack of data management skills at small infrastructures has been a challenge, but the potential to scale up remote and virtual access services is envisioned as significant. The roadmap development has been crucial for the development of future access services in INTERACT, with a focus on enhancing remote use of instrumentation and ensuring better collaboration with local communities.

Technical and operational details

INTERACT uses several tools and software for access provision and management. For the aim of the use case, the software involved was INTERACCESS, which is the Access Management Platform developed by INTERACT, and the INTERACT Data Portal, which is an online platform based on metadata harvesting of datasets offered for virtual access by the INTERACT research infrastructures.

Technical development is essential for the improvement of remote and virtual access services. The roadmap aims to improve both INTERACCESS and INTERACT Data Portal to allow comprehensive, streamlined and efficient provision and management of Remote and Virtual Access.

As envisioned in the roadmap, INTERACCESS can be further customised for Remote Access, as it is currently mainly tailored for in-person access. On the other hand, INTERACT Data Portal can advance towards even better compliance with FAIR guidelines, in addition to advocating and advising the partners of the distributed research infrastructure on adhering to the standards.

Research infrastructures across the Arctic and in different countries and continents are implementing various protocols and standards for data management, making it difficult for the infrastructures to comply with the metadata standards used in the INTERACT Data Portal to harvest the metadata. In the future, INTERACT will focus on harmonisation of the standards used, and on providing training and support to INTERACT RIs, which will help further populating the data portal.

INTERACCESS has already undertaken major developments in 2024. The new Access Management Platform, called “Transnational Access Platform” (TAP), is an advanced version of the previous

INTERACCESS. This new access management system will enable better management of Remote Access provision e.g. in the form of a document library containing guidelines and protocol template for Remote Access.

Outcomes and impact

The Roadmap for future development of Remote and Virtual Access envisions the improvement and enhancement of Remote and Virtual Access provision for the next five years from 2024 to 2029.
Expected outcomes from the use case implementation are:

- Guidelines for a Feasible Remote Access and work on a Project Experiment Protocol template.
- Harvesting of datasets resulting from in-person and Remote Access projects.
- Increased Virtual Access, with INTERACT Data Portal populated with new datasets by new data providers, implying increasing data harmonisation, training and support to RIs to adhere to the INTERACT metadata guidelines.
- Development of an INTERACT Non-Profit Association Quality Assurance Program, identifying tangible KPIs for both Remote and Virtual Access provision.
- Promotion of acknowledgement practices and tracking of the VA data use.
- Enhanced cooperation on Remote Access with other industries, such as remote sensing community and space agencies, to explore new ways to employ Remote Access in research, while also seeking the provision of near or real-time remotely collected data.
- Enhanced cooperation in data rescue and sharing efforts for Virtual Access.
- Networking practices between stations and communities, also by supporting community monitoring and citizen science projects for access.
- Access provision in new areas, such as calibration and validation services.
- Acquiring a Quality Assurance Certification.

The new Transnational Access Platform will open for commercial use, with the possibility for other RI operators and networks to utilize it to enhance their access provision and management.

Guidelines for Remote Access will be available in the Document Library of Transnational Access Platform (TAP), open to all registered users at https://polarin-tap.eu.inkode.org/ ; registering as a user to TAP is free.

INTERACT Data Portal[9] will continue to provide free and open access to datasets from INTERACT RIs, including e.g. valuable time-series and monitoring data. The expansion of data provision and enhancement of the portal functionalities will provide added value to its users, fostering open science efforts.

[9] https://dataportal.eu-interact.org

Future developments and steps

The roadmap for improved remote and virtual access services converges with multiple initiatives that the INTERACT Non-Profit Association (INTERACT NPA) is undertaking to advance its access provision, one of them being the Transnational Access Platform (TAP) development.

TAP is already in use in POLARIN and AQUARIUS, EU-funded sister projects of INTERACT. Both projects opened their first TA call in the autumn of 2024 and are utilising TAP in their access management. TAP will be employed in all steps of access provision, from application and evaluation to access decisions and reporting.

To conclude, the roadmap for improved remote and virtual access services has been developed as part of an overall strategy for the development and enhancement of access provision of INTERACT. INTERACT NPA, as the legal entity of the INTERACT network of Ris, aims to establish a new Access Program, based on the success and experience of the EU-funded INTERACT Transnational Access Program. The improvements in remote and virtual access services are therefore interlinked with the overall development of INTERACT NPA access provision, paving the way for its future success.

Outcomes of the survey and of the interviews

The methodology followed for the implementation of task T4.2 foresaw the submission of a survey and interviews, aiming at understanding the practices, challenges, and outlooks of Research Infrastructure managers in implementing the activities foreseen in their use cases.

The following paragraphs, based on the survey and interview findings, provide valuable insights into the current state and future potential of remote access in research infrastructures, contributing significantly to the Green Paper titled “Facilitating remote and virtual access provision by European research infrastructures – requirements, issues, and recommendations”[10] on best practices in this domain developed within WP4.

Survey overview

The respondents represented RIs in various ESFRI thematic areas, including Environment (2 responses), Health and Food (2 responses), and Physical Sciences and Engineering (1 response). Most RIs were distributed (4 out of 5), indicating a broad geographic reach. This diversity highlights the range of sectors engaged in the research infrastructure activities involved in the survey. The predominance of distributed RIs (4 out of 5) suggests that the outcomes of the survey are more easily applicable to distributed RIs and take into consideration the challenges connected to a geographically distributed organization.

[10] https://open-research-europe.ec.europa.eu/articles/4-152/v1

Funded by the European Union
DOI: 10.5281/zenodo.14235482

Key Findings

The most relevant findings have been grouped below into key areas that were useful to extract contributions to the first draft of the Green Paper covering the most relevant aspects of the use cases presented by the RIs involved in the task.

1. **Technological support and responsibility**:
   - Almost all the surveyed use cases employ technological tools for remote access.
   - The responsibility for technological support varies, including shared responsibility between central administration and single facilities, or central administration alone. Also, thematic centers play a key role in some distributed RIs in terms of responsibility for supporting the users.
2. **Management and feedback mechanisms**:
   - Management of these tools requires significant personnel resources, varying from 3 to 61.2 person-months (PM) per year.
   - Feedback mechanisms for technological tools are implemented in most cases, ensuring continuous improvement.
3. **Access provision and software characteristics**:
   - Remote access is predominantly provided through online platforms/software.
   - The majority of these platforms are custom-developed, often utilizing open-source software or similar solutions.
4. **Access Request and User Management**:
   - Remote access requests undergo a rigorous process, including scientific and logistical evaluations.
   - User management involves multiple tiers, including authentication and role-based access, primarily for internal users and affiliated organizations.
5. **Training and user engagement**:
   - Training for remote access is a feature present in half of the use cases, with a focus on hybrid modalities post-pandemic, on the use of data standards. The development of guidebooks is also a practice in place.
   - The involvement of end-users is a significant aspect, underlining the importance of user-centric approaches.
   - In three out of five organizations, there is personnel dedicated to users' training. An average of 1.5 PMs are devoted on an annual base to the users' training.
6. **Cybersecurity and Data Management**:
   - Strong cybersecurity measures are in place, with emphasis on encryption (SSL certificates), VPNs, real-time monitoring systems (e.g. network intrusion and logs monitoring) and regular vulnerability assessments.
   - Data management practices are diverse, trying to adhere to FAIR principles, and often managed at individual RI sites. Data integrity check practices are also adopted.
   - Risk management practices are also in place in the majority of the RIs interviewed. Risk management plans include regular security audits, real-time monitoring systems, and incident response protocols. Proactivity is perceived as key in cybersecurity activities.
7. **Implementation and challenges**:
   - Implementation strategies involve central administration with facilities' involvement.
   - Challenges include managing the diversity of data management practices and keeping up with evolving digital landscapes. Also, the provision of services tailored to the different groups of users is a perceived complex challenge.
8. **Expected results from use cases**:
   - Development of a roadmap for future remote and digital access services.
   - Testing new and creative hybrid training modalities.

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DOI: 10.5281/zenodo.14235482

- Improvement of remote service offerings, including API development for service page updates, enhanced user dashboards, optimization of workflows, and improved user engagement for remote access projects.
- Aiming to achieve a seamless and secure remote access framework.
- Creation of a new virtual beamline with simulated experimental results.

To outline the most relevant conclusions, it was decided to group them into the three following key areas. The following bullet points give an immediate and clear vision of the main outcomes that could or should be taken into consideration in pursuing similar objectives in future projects.

1. **Common aspects in Remote Access Management**:
   - A strong emphasis on custom technological solutions tailored to specific RI needs.
   - Robust user management systems, with a focus on security and efficient access control.
   - Significant training and user support investment indicates a shift towards more user-centric remote access models. In the majority of the use cases, the users will be involved in the implementation phase.
2. **Contributions to Green Paper on best practices**:
   - Insights from diverse RIs can provide guidelines on effective remote access management, particularly in the areas of technological support, user engagement, and cybersecurity.
   - The shared experiences underscore the importance of flexibility and adaptability in remote access provision and the evolution of the already existing systems and procedures.
   - Recommendations from the survey can inform the development of a comprehensive and sustainable approach to remote access in research infrastructures, contributing to the broader objectives of the eRImote project.
   - From the experiences gained in planning and running the use cases activities emerged that the success heavily relies on the collaboration between central administration and end users. Regular feedback loops, training sessions, and user-focused support mechanisms are essential to ensure the system meets the needs of all stakeholders and adapts to the evolving digital landscape in research infrastructures.
3. **Recommendations for future practices**:
   - Emphasize the development of hybrid and flexible remote access models that cater to varied user needs and RI contexts.
   - Strengthen collaboration and sharing of best practices among RIs to enhance the efficiency and effectiveness of remote access provision.
   - Continue to evolve and adapt digital infrastructures in response to changing user needs and technological advancements.

Summing up, the survey indicates a strong focus on digital transformation and remote access within RIs, with efforts directed towards enhancing user engagement and streamlining workflows. The involvement of a majority of distributed RIs allows for underlining the importance of well organized collaboration and networked activities in reaching the goals set in the use cases. The expected outcomes reflect a commitment to advancing research infrastructure capabilities, particularly in remote operations and digital access with a strong focus on the users' needs.

The trend towards digital transformation and remote access improvement within RIs is likely to continue, with increasing emphasis on security, user experience, and inter-RI collaboration.

The development of new training modalities and improved workflow management suggests a move towards more efficient and user-friendly research environments to open up and optimize access as much as possible to broaden the impact of EU RIs in the European and International research and innovation ecosystem.

As RIs evolve, ongoing dialogue with stakeholders and regular assessments will be essential to adapt to fast-changing needs and technological advancements. The use of AI tools will be a key point in the future to support the user in accessing remotely the RIs facilities and further improve the overall experience and outcomes.

Interviews' responses overview

In this section, the outcomes of the interviews conducted with the five EU research infrastructures involved with the use cases, namely EMSO, Euro-BioImaging, LEAPS, INTERACT, and INSTRUCT are summarised. These interviews, performed in 2024, aimed to gather more detailed insights on use cases related to improving directly or indirectly remote access to facilities. The findings are organized by aggregating responses to specific interview questions, followed by additional recommendations for the Green paper.

In the next section, the final outcomes of the interviews grouped around the main topics are presented. At the end of the section, the second iteration of recommendations for the Green paper developed from the responses is showcased as well.

Aggregated responses

Goals and challenges

1. **EMSO**: initial challenge of implementing a robust AAI system using Keycloak and API. Switched to ERDDAP, resulting in the need for a complete overhaul of previous efforts. Migration to a new data center for improved resilience and cybersecurity is the final aim.
2. **Euro-BioImaging**: implemented hybrid distributed training courses across national communities and scaled up to the ERIC level. Identified best practices for remote access and training setups.
3. **LEAPS**: improved existing VLab software by decluttering and restructuring code. Achieved a functional and user-friendly software state despite initial bugs and complexities.
4. **INTERACT**: increased remote access during COVID-19 but struggled to sustain this post-pandemic. Developed a roadmap for remote and virtual access provision to optimize the provision of remote and virtual access services in the future.
5. **INSTRUCT**: implemented remote service availability within the submission system but faced challenges in getting facility managers to engage with the system consistently.

Unplanned Issues

1. **EMSO**: shift in focus due to human resource challenges, geo-political situation and IT infrastructure failures. Prioritized building a resilient and secure IT infrastructure.
2. **Euro-BioImaging**: adapted to changes in training demands post-pandemic. Shifted from fully remote to hybrid distributed training models. Availability of large-scale parallel usable compute infrastructure.
3. **LEAPS**: selection of personnel with appropriate expertise proved crucial. Encountered complexities in software improvements.
4. **INTERACT**: realized the extensive work required for developing a comprehensive roadmap for remote access. Involved more stakeholders than initially planned.
5. **INSTRUCT**: overestimated the extent to which facilities would utilize new remote access tools.

Professionals involved

1. **EMSO**: managed migration internally without additional professionals.
2. **Euro-BioImaging**: utilized expertise from facility staff, IT, and training experts as planned, collaboration initiated with EGI to address the compute infrastructure challenge
3. **LEAPS**: no additional professional figures involved. Utilized internal expertise and collaboration with an IT company at first and then with a software engineer.
4. **INTERACT**: engaged a wider range of research infrastructure operators and access providers than initially planned.
5. **INSTRUCT**: strong development team managed the implementation without needing additional professionals.

Expected Results Achieved

1. **EMSO**: achieved a more secure IT infrastructure and reliable remote access framework. Plans for future cybersecurity audits.
2. **Euro-BioImaging**: planning a distributed training course. Confident in success based on initial pilot of the course across two sites.
3. **LEAPS**: successful improvements in software leading to functional virtual labs. Planning further development in synchrotron beamlines.
4. **INTERACT**: developed a strategic roadmap for remote and virtual access. Received positive feedback from the General Assembly.
5. **INSTRUCT**: achieved main objectives including an API for service updates and user dashboards. Aiming for broader implementation.

Exploiting Use Case Results

1. **EMSO**: annual cybersecurity audits proposed for continuous improvement.
2. **Euro-BioImaging**: building on training programme experiences to develop and deploy this mode of distributed hybrid training across the infrastructure and expand to different modalities and models.

3. **LEAPS**: pending LEAPS proposal for expanding virtual labs. Exploring further development in synchrotron radiation.
4. **INTERACT**: roadmap as a foundation for future access programme and quality assurance activities.
5. **INSTRUCT**: increasing facility engagement and user awareness to fully exploit remote access functionalities.

Assessing Impact

1. **EMSO**: KPIs related to access, cybersecurity, business continuity, and user satisfaction.
2. **Euro-BioImaging**: participants' feedback and local trainer experiences for training courses. Tracking international recommendations.
3. **LEAPS**: user questionnaires and monitoring usage through counters in local versions of virtual labs.
4. **INTERACT**: quality assurance programme for remote and virtual access provision. Tracking outcomes through KPIs, user feedback and virtual access assessment.
5. **INSTRUCT**: statistics and qualitative data through surveys.

Recommendations for the Green Paper

Starting from the responses received to the survey, here below is the second set of ten recommendations for the Green Paper listed below:

1. **Establish robust IT Infrastructure**: ensure resilient and secure IT systems to support seamless remote access.
2. **Hybrid training models**: develop hybrid training programmes to accommodate varying demands and improve accessibility.
3. **Personnel selection**: engage personnel with the appropriate expertise in both scientific and technical domains.
4. **Stakeholder engagement**: involve a broad range of stakeholders in planning and implementing remote access initiatives.
5. **Continuous improvement**: implement regular cybersecurity audits and quality assurance programmes.
6. **User feedback**: collect and utilize user feedback to continuously improve remote access services.
7. **Clear communication protocols**: develop standardized communication protocols to set clear expectations for remote access.
8. **Scalable solutions**: design remote access solutions that can be scaled and adapted to different research infrastructures.

Funded by the European Union
DOI: 10.5281/zenodo.14235482

9. **Documentation and transparency**: maintain detailed documentation of remote access protocols, challenges, and solutions.
10. **Collaboration and knowledge sharing**: promote collaboration and knowledge sharing among research infrastructures to leverage best practices and innovative solutions.

As a conclusive remark, it is valuable to say that the interviews revealed the significant benefits of the improvements realized during the use cases projects. Common challenges include the selection of a suitable project team, data security, flexibility and adaptability in project management in case of change in the technical solutions, and engaging facility managers. Successful implementation of remote access technology advancements has enhanced research efficiency, broadened access, and improved data collection. Future developments will focus on advancing technological integration, improving user support, and expanding remote access functionalities to meet the evolving needs of the research community.

Final ecommendations to the Green Paper

Due to the fact that the first version of the Green Paper was published before the drafting of this deliverable, it was possible to complement the recommendations included in the Green Paper which have been collected during the life span of the project, with the ones that emerged as best practices and lesson learned after a complete and in-depth analysis of the use cases data acquired in the survey and in the interviews for the final version of the Green Paper.

The main conclusive recommendations that emerged from the use cases analysis and that were not already present in the Green Paper are the following:

Establish robust IT Infrastructure

To ensure the long-term success of remote and virtual access models, a robust and secure IT infrastructure is paramount. RIs must prioritize the development of resilient network connections, secure data transfer protocols, and scalable systems to support high-quality remote and virtual access. By ensuring sufficient bandwidth, data storage capabilities, and cybersecurity measures, research institutions can facilitate seamless and secure remote interactions for users. Such an investment in IT infrastructure will also support the broader sustainability goals of reducing travel and democratizing access to RIs.

Personnel selection

In order to have effective operations in the provision of remote and virtual access services, it is critical to engage personnel with expertise in both scientific and technical domains in the long term. These professionals must be capable of managing complex remote interactions and troubleshooting issues in real time. However, the recruitment of these professionals could be a long process and the RIs could incur additional expenses. Nonetheless, by recruiting individuals with the necessary technical and scientific expertise, research infrastructures can guarantee smooth operations, minimizing disruptions and ensuring a high standard of service in the long run.

Stakeholder engagement

Engaging a diverse range of stakeholders is crucial to the successful implementation of remote access initiatives. With the involvement of academic institutions, industry partners, and policymakers from the planning stage, RIs can ensure that remote and virtual access services are designed to meet the needs of all relevant parties from the very beginning. In addition, regular feedback from stakeholders will help refine these services, fostering collaboration and optimizing their impact.

User feedback

Collecting and utilizing user feedback is essential for the continuous improvement of remote access services. Establishing a structured feedback mechanism will enable research infrastructures to identify pain points, gather insights into user experiences, and make informed adjustments to their services. This iterative process of evaluation and improvement ensures that remote access remains user-centered and responsive to evolving needs.

Continuous improvement

The security and efficiency of remote and virtual access models must be regularly reviewed through continuous cybersecurity audits and quality assurance programs. In this sense, with regular assessments, RIs can stay ahead of emerging threats and ensure that systems are operating at optimal levels. Proactive measures will also help maintain user trust and ensure that RIs remain resilient and secure in an increasingly dynamic digital landscape.

Clear communication protocols

Standardized communication protocols are key to ensuring that users have clear expectations for their remote access experience. These protocols should include guidelines for requesting access (including a flowchart of the process[11]) using RI instruments remotely, and resolving technical issues. Clear communication will foster smoother interactions between users and RI staff, reducing misunderstandings and enhancing the overall efficiency of remote services.

Scalable solutions

Remote access solutions must be designed to be scalable and adapt to different scenarios. Flexibility in scaling services based on user demand will ensure that the system remains efficient, even if the number of users grows. By investing in scalable technologies, RIs can better accommodate both small-scale and large-scale research projects, enhancing accessibility for a broader research community. In this regard, the COVID-19 pandemic has taught us that it is necessary to develop systems that can remain efficient even during a sudden change of scenario, in order to enhance the resilience of research infrastructures in the provision of the services to the stakeholders.

Documentation and transparency

Maintaining detailed documentation of remote access protocols, challenges, and solutions is critical for ensuring transparency and promoting continuous learning within the research community. Comprehensive records allow institutions to track the evolution of their remote services, share insights

[11] The flowchart developed by EMSO ERIC for the Physical Access procedure, is a good example: https://emso.eu/physical-access/

with other RIs, and provide users with clear and updated guidelines for accessing resources. Such transparency fosters trust and enables continuous improvements.

Conclusions

The eRImote project has made significant strides in advancing remote and digital access for European Research Infrastructures. By exploring diverse use cases across various scientific domains, this deliverable has highlighted the potential of innovative technologies, administrative practices, and user-centered approaches to transform access provision. The collaborative efforts of the participating RIs have led to the development of new tools, workflows, and training models that address critical challenges and pave the way for more inclusive, efficient, and sustainable research practices.

While technical achievements and operational improvements have been successfully implemented, the importance of stakeholder engagement and user adoption remains central to ensuring the long-term success of these initiatives. The findings and recommendations presented herein provide a solid foundation for the continued evolution of remote access capabilities, fostering stronger collaborations and broader accessibility within the research community.

Looking ahead, the project emphasizes the need for ongoing dialogue, robust IT infrastructure, and scalable solutions to meet the dynamic needs of researchers and facilities alike. By leveraging the lessons learned and embracing the opportunities presented by digital transformation, European RIs are well-positioned to lead in fostering a resilient and equitable research ecosystem on a global scale.

Funded by the European Union
DOI: 10.5281/zenodo.14235482

Annex 1 – Questions included in the Survey

GENERAL INFORMATION

This section aims at collecting general information on the access provision in your RI

1. What is your job role in the RI?

2.How is the access (physical, remote, virtual) program scheduled in your RI?

- periodic calls
- always open/available
- periodic calls plus open opportunities

3.If your access program is scheduled on the basis of periodic calls, how often do you publish the calls? If this is not your case, please skip this question.

4.Who is responsible for handling user remote access requests? Please, specify the office/department and the job role of the person accountable for it

5.If the access requests are managed jointly from the central hub with the local facilities, how the responsibilities are shared?

6.Do you have any particular procedure to collect users' report/feedback after remote access has been provided?

- yes
- no

12. If you responded yes to the previous question, please briefly explain the procedure otherwise skip the question

ADMINISTRATIVE ASPECTS

This section aims at gathering information about the administrative aspects of the management of remote access provision in your RI

13. Do you organize the shipping of samples?

- Yes
- No

14. If yes, please describe which quality check procedure you have in place. If No, please skip this question

15. Do you have any specific rules for shipping the samples?

- Yes
- No

16. If yes, please describe the rules. If No, please skip this question

17. Do you have a quality check procedure for remote access provision?.

- Yes
- No

18. If yes, please describe which quality check procedure you have in place. If No, please skip this question

19. Do you have any environmental management standards that could be applicable also to remote access activities (e.g. ISO 14000)?

- yes
- No

20. If yes, please describe which environmental management procedure you have in place. If No, please skip this question

21. How many PMs are devoted to access management in your RI?

22. How many PMs are devoted to REMOTE access management in your RI?

23. How do you estimate the costs for access (e.g. access unit cost)?

24. Do you foresee any financial support for the facilities that are providing access?

- Yes
- No

25. If yes, please provide more information on it. If No, please skip this question

26. Do you foresee any financial support for users?

- Yes
- No

27. If yes, how do you plan this support and which requirements do you set? If No, please skip this question

28. In the case of distributed RI, do you report/check/analyze the costs incurred by facilities for giving access?

- Yes
- No

29. If yes, please provide some information. If No, please skip this question

30. How are the IPR issues managed in the case of public users? Please explain.

31. How are the IPR issues managed in the case of private users? Please explain.

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DOI: 10.5281/zenodo.14235482

32. How are the IPR issues managed in the case of publication? Please explain.

33. How are the IPR issues managed in the case of patents? Please explain.

34. Where do you state how the IPRs are managed after the access has been provided?

- in the calls
- in the access agreement
- in a specific agreement established on the basis of the access results in the data management plan
- Other

35. Does your Research Infrastructure have an access policy?

- Yes
- No

36. If yes, could you please share the main outlines (e.g. web link)? If No, please skip this question

TRAINING

This section aims at collecting information about training activities related to the remote access provision.

37. Has your RI any training courses in place on Remote Access Practices? *Mark only one oval.*

- Yes
- No

38. Do you have any specific user training programmes to facilitate remote access?

- Yes
- No

39. If yes, is the programme organized on a yearly basis?

- Yes
- No
- we have no user training programmes

40. How many users did you train last year in order to facilitate remote access to your RIs?

41. Do you have personnel staff dedicated to users' training programme?

- Yes
- No

42. If yes, how many PMs are devoted to users' training programme per year? If No, please skip this question

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43. Is the training programme organized as a remote or face-to-face class or hybrid?

- remote
- face-to-face
- hybrid
- Other

44. Do you have any specific activity in place to collect training users' needs and feedback?

- Yes
- No

45. If yes, could you please provide some information on that? If No, please skip the question

46. Do you have any specific marketing/communication strategy for promoting the users' training courses?

- Yes
- No

47. If yes, could you please provide some information on that? If No, please skip the question

48. Do you organize any specific training programme for your RI staff?

- Yes
- No

49. If yes, is the training programme developed internally, externally or partially internally and partially externally? If No, please skip the question

50. Is your staff training program mainly organized remotely or face-to-face or in a hybrid mode?

- remote
- face-to-face
- hybrid
- Other

51. Do you participate in any European programmes for doctoral education, postdoctoral training of researchers, mobility of researchers, and excellent frontier research (e.g. Marie Curie, ERC, etc.)?

- Yes
- No

52. If yes, could you please provide some information on that? If No, please skip this question

53.Do you have or do you participate in any staff exchange programme?

- Yes
- No

54. If yes, could you please provide some information on that? If No, please skip this question

REMOTE/DIGITAL ACCESS PROCEDURES

This section aims at collecting information about procedures related to the remote access provision.

55. How do you provide remote access to your facilities? (If Other, please specify the solutions your RI adopted)

- Online platforms/software for remote control of instrumentation
- Other:

56. If you use online platforms/software for remote control of instrumentation, could you please specify the characteristics of the software? (If Other, please specify the solutions your RI adopted)

- Proprietary
- Open source
- Other

57. If you use online platforms/software for remote control of instrumentation, please provide the names of the platforms/software. Otherwise please skip this question

58. Do you have any particular procedure/criteria to assess the remote access requests? If yes, please elaborate

59. In your RI, which job role does the manager/s of the platform for access have, and to which organization he belongs (e.g. to the RI or to a representing entity or to an external company)?

60. Do you provide user interfaces for live data capture during remote access sessions?

- Yes
- No

61. If yes, please briefly describe the user interfaces used for live data capture. If No, please skip this question

62. What digital tools and services do you offer to facilitate remote access?

63. Which Authentication and Authorisation Infrastructure (AAI) are you using, if any, to enable seamless, authenticated access to services and research data? (If Other, please specify the solutions your RI adopted)

- B2ACCESS
- EGI Check-in
- eduTEAMS
- INDIGO-IAM
- Perun

- WaTTS
- MasterPortal
- RCauth.eu
- we don't use an AAI
- Other

64. What types of Remote Access you are providing looking at the three different levels of remoteness in the following list?

- Combination of TA/RA: part of the group is remote, and few users are on-site
- Mailing in: RI staff does the work on site (sampling, lab work) and sends samples/results to the user group
- Fully remote: Researchers are fully autonomous (Access to remote instruments, software, databases)

65. Do the scientists at the local facilities in your RI have a scientific background to assure they can review and assess the quality of sample collection, in case your RI collect samples?

- Yes
- No
- we do not collect samples

66. Are there any legal requirements for remote access users that you need to check before the provision of access?

- Yes
- No
- Other

DATA MANAGEMENT

This section aims at collecting information about data management activities related to the remote access provision.

67. Do you provide APIs for data transfer?

- Yes
- No
- Other

68. If yes, please briefly describe the APIs used for data transfer (e.g. web API or remote API, synchronous or asynchronous, solutions in place for threats like SQL injection, Denial-of-service attack (DoS), broken authentication, or exposing sensitive data, etc.). if you have not API, please skip this question

69. What type of data storage solutions do you employ? (If Other, please specify the solutions your RI adopted)

- POSIX-like
- Object stores
- Block storage
- Other:

70. How do you curate data according to FAIR principles? (If Other, please specify the solutions your RI adopted)

- Standardized data repositories
- Certification of the processes
- Other

71. What kind of tools do you provide for data analysis? (If Other, please specify the solutions your RI adopted)

- In-situ analysis tools
- Post-acquisition analysis tools
- we do not provide tools
- Other

72. What computing infrastructure options do you offer? (If Other, please specify the solutions your RI adopted)

- Local computing infrastructure
- Regional computing infrastructure
- Cloud services
- EU landscape services (e.g., EGI, EUDAT)
- Other

73. Do you have developed an internal data centre for storage and computing resources or you are paying for external services (e.g. AWS, EGI, etc.)? Please explain how it works in your RI

74. Do you provide support for open access to data generated from remote access sessions?

- Yes
- No

75. Are your data "FAIR by design" or do they need some kind of post-production activity using a middle-ware to become FAIR?

- FAIR by design
- post-production activity
- Other

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CYBER-SECURITY

This section aims at collecting information about cyber-Security activities related to the remote access provision.

76. What cyber-security measures do you have in place for remote access sessions? (If Other, please specify the solutions your RI adopted)

- Encryption technologies
- VPN technologies
- Authentication and authorization infrastructure
- Data integrity checks
- Other

77.Are there any specific challenges you face in ensuring cyber-security during remote access sessions?

78. Does your RI have any Risk Management Plan to face malicious infiltrations in instrumentations or software that happened during the provision of remote access?

- Yes
- No
- Other

79. If yes, please briefly describe how it works (insert the link if it is a public document), otherwise please skip this question

ADDITIONAL INFORMATION

This last section is to collect any other comments you want to add to this survey. Thank you for your participation! Your input is highly appreciated.

80. Please provide any additional information or comments related to the provision of remote access to the facilities in your RI you want to add.

Annex 2 – Questions included in the interviews

1. Did you overcome the challenges identified at the beginning of the use case, as stated in the survey?

2. Did you experience issues not initially identified in the planning phase of the project associated with your use case?
3. Did you need to involve professional figures not initially planned for implementing your use cases? If yes, please specify.
4. Have you achieved the expected results, as stated in the survey?
5. Can you share any relevant documents on the results of the use cases?
6. How do you plan to exploit the results of your use case? Is there any other plan to further build upon the results of the use case project?
7. How do you plan to assess the impact of the improvements linked to your use case?
8. Do you have any other comments to add or relevant information about your use case to share?

Annex 3 - VLab evaluation outcomes

Summer school evaluation questionnaire I+II

X-ray Free Electron Lasers: A combined Virtual Lab and real-lab experience of European XFEL

Part I: 7 – 11 August 2024, Aarhus, Denmark

Part II: 12 – 18 August 2024, Hamburg, Germany

How would you evaluate the program?	(very good) 1.0	2.0	3.0	4.0	(very poor) 5.0
Quality of contents	**9**	5	1		
Quality of presentation	**9**	4	2		
Opportunities for interaction	**13**	1	1		
Practicality of exercises and handouts (if applicable)	**8**	5	1	1	
Was the trainer competent?	**11**	2	1		
Did the trainer produce a productive working atmosphere?	**10**	4		1	
Did the trainer respond to your questions?	**15**				

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Practicality for your work	4	**8**	2	1	
Tour(s)/talks of EuXFEL Instruments	4	**7**	3	1	
Tour/Talk of PETRA III	3	**8**	2	1	
Tour/talk of FLASH	6	**7**	1	1	
Overall assessment	**8**	5	1	1	

Summer school evaluation questionnaire III

X-ray Free Electron Lasers: A combined Virtual Lab and real-lab experience of European XFEL

Part III: 19 -23 August 2024, Lund, Sweden

How would you evaluate the program?	(very good) 1.0	2.0	3.0	4.0	(very poor) 5.0
Quality of contents	**5**	1	1		
Quality of presentation	**5**	2			
Opportunities for interaction	**7**				
Practicality of exercises and handouts (if applicable)	2	**5**			
Was the trainer competent?	**7**				
Did the trainer produce a productive working atmosphere?	**4**	3			
Did the trainer respond to your questions?	**7**				
Practicality for your work	3	**4**			
Tour of MAX IV/III	**6**	1			
Overall assessment	**5**	2			

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