Remote work and remotization of infrastructure case study

European University of the Seas
Remote work and remotization of infrastructure for research and innovation (Task 2.3)

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This document includes a survey of research fields, groups, and situations where remote work is already practised, as well as examples of successful remotization and possible remotization case studies. It also includes feedback and discussions from the human-centred design (HCD) exercise, held on March 17th 2022 in a hybrid model with Task Team members and invited experts and researchers sharing their experience and insights into remote work and remotization.	

Versions and contributions history

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0	08/04/2022	N/A	Presentation of the deliverable to the RDIS.
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Contents

Introduction

One of the specific objectives of the reSEArch-EU project is to provide a systematic approach and transformation of the SEA-EU Alliance towards building and increasing the capacities to not only resist but to thrive in extraordinary situations and under unforeseen shocks.

Because of the pandemic's global and broad impact, the support of the entire economic and social system, and the infiltration of digitalization into our daily lives, some activities (administration, management, lectures, etc.) were unaffected, allowing for a smooth transition to a virtual working environment. However, activities requiring field and lab work were essentially halted [1].

Through an exploratory survey of research fields, groups, and situations where remote work is already practised, 2.3 Task Team members explored the variations in resilience and anti-fragility across universities and their activities in times of crisis. The survey is presented in the first part of this case study. It includes an explanation of the process of qualitative data analysis, analysis and interpretation of the qualitative data findings.

The second part of the case study presents the European Organization for Nuclear Research (CERN) as an example of how remote work can be successfully implemented. We describe how and where remote work is accomplished at CERN, including examples from the CMS experiment. Additionally, a hypothetical research setting without remotization is presented, and how remotization can be introduced in this specific case. We conclude this part with several questions that researchers need to think about when applying remotization to their research area.

The report ends with an overview of the Human-Centered Design Workshop, which took place on March 17th 2022 among task team members and additional invited experts and researchers with experience in remote work and remotization. Researchers' expectations and opportunities for intervention were discussed throughout this session in order to reveal new insights and examples from a variety of fields.

The aim of this report is to provide an in-depth look and examples into remote work and opportunities for remotization of the infrastructure. This output will be used in the upcoming SEA-EU Academy Workshop, during which participants will speculate about various technological, economic, political, and social futures (both desired and undesirable). During the workshop, future remote research will be contextualized, giving participants the opportunity to construct prototypes and answer identified remotization challenges.

Exploratory survey

An exploratory survey was conducted to get insights and direct inputs from researchers related to remote work. The "Survey of research fields, groups and situations where remote work is already practised" aimed to identify related good practices and critical issues across different research fields and groups. It was distributed from December 2021 to March 2022 via LimeSurvey (https://ls.sea-eu.org/limesurvey/index.php/835781) within the SEA-EU network targeting principal investigators and research group leaders. Among other questions, the participants were asked to critically review and describe their research groups' remote work practices and recent positive and negative experiences.

A total of 41 completed questionnaires were collected, not as much as necessary for quantitative and cross-disciplinary comparison, yet a sound basis for qualitative analysis. First, the general overview is given of the participants' background, followed by the methodology and results of the qualitative analysis performed in ATLAS.ti. Data analysis and interpretation was done by Maja Čukušić and Jasenko Ljubica.

In terms of the distribution across research domains (Table 1), the largest number of participants are from Physical sciences and engineering (43,90%), followed by participants from Life sciences (24,39%) and Social sciences and humanities (31,71%).

Table 1 Research domain of the participants

Research domain*	Count	Percentage
PE1 Mathematics	1	2,44%
PE2 Fundamental Constituents of Matter	4	9,76%
PE3 Condensed Matter Physics	0	0,00%
PE4 Physical and Analytical Chemical Sciences	0	0,00%
PE5 Synthetic Chemistry and Materials	0	0,00%
PE6 Computer Science and Informatics	4	9,76%
PE7 Systems and Communication Engineering	2	4,88%
PE8 Products and Processes Engineering	2	4,88%
PE9 Universe Sciences	0	0,00%
PE10 Earth System Science	3	7,32%
PE11 Materials Engineering	2	4,88%
Total PE	**18**	**43,90%**
LS1 Molecules of Life: Biological Mechanisms, Structures and Functions	2	4,88%
LS2 Integrative Biology: from Genes and Genomes to Systems	1	2,44%
LS3 Cellular, Developmental and Regenerative Biology	0	0,00%
LS4 Physiology in Health, Disease and Ageing	1	2,44%
LS5 Neuroscience and Disorders of the Nervous System	0	0,00%
LS6 Immunity, Infection and Immunotherapy	1	2,44%
LS7 Prevention, Diagnosis and Treatment of Human Diseases	3	7,32%
LS8 Environmental Biology, Ecology and Evolution	2	4,88%
LS9 Biotechnology and Biosystems Engineering	0	0,00%
Total LS	**10**	**24,39%**
SH1 Individuals, Markets and Organisations	1	2,44%
SH2 Institutions, Governance and Legal Systems	1	2,44%
SH3 The Social World and Its Diversity	3	7,32%
SH4 The Human Mind and Its Complexity	2	4,88%
SH5 Cultures and Cultural Production	2	4,88%
SH6 The Study of the Human Past	2	4,88%
SH7 Human Mobility, Environment, and Space	2	4,88%
Total SH	**13**	**31,71%**
Total	41	100,00%

* Based on https://erc.europa.eu/sites/default/files/document/file/ERC_Panel_structure_2021_2022.pdf

PE - Physical sciences and engineering

LS - Life sciences

SH - Social sciences and humanities

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To follow up on the selection of the research domain in more specific terms, the participants were asked to list several keywords that are most relevant to their research focus. The keywords are illustrated in the Word Cloud (Figure 1).

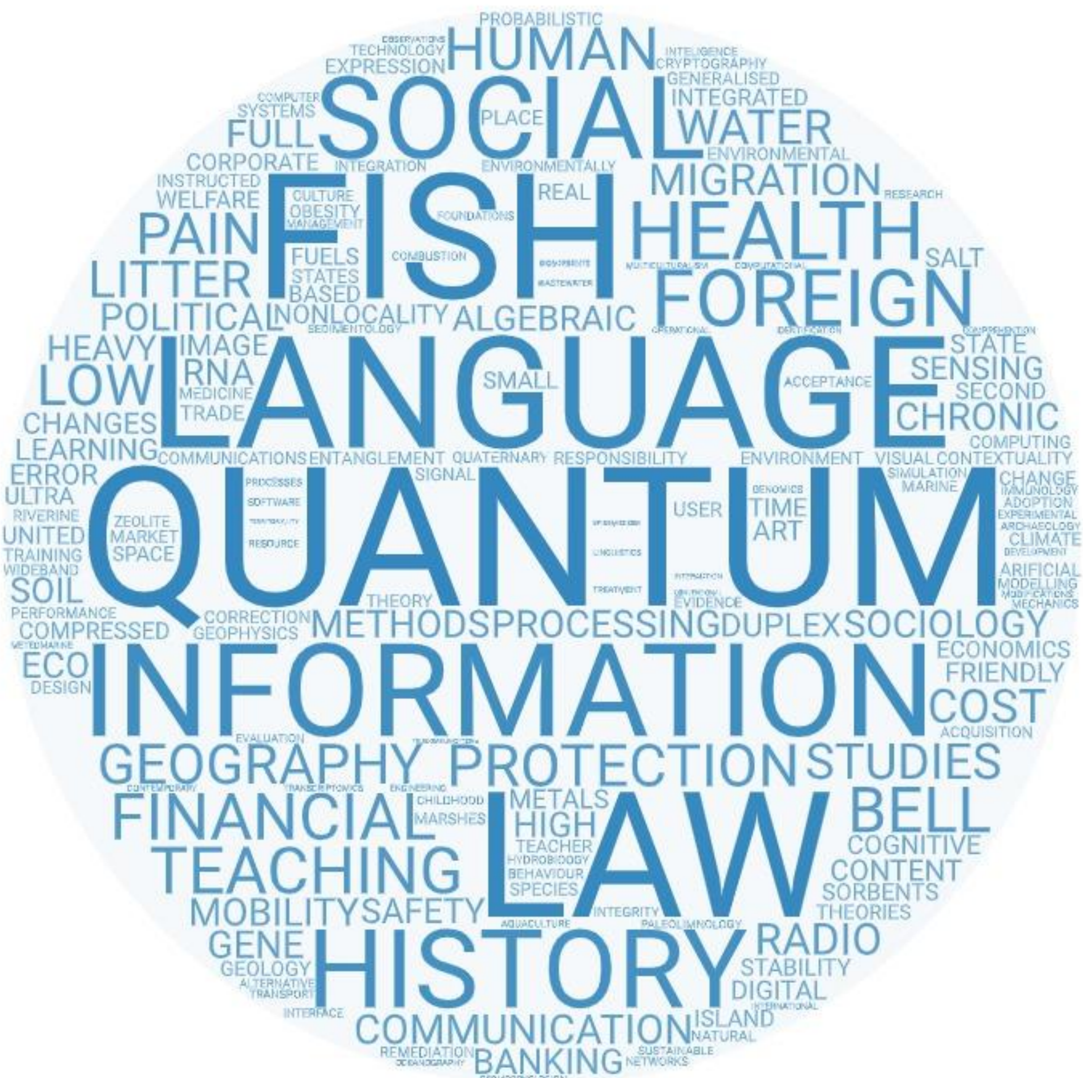

Figure 1 Word Cloud based on current research focus keywords (wordart.com)

Over 73% of participants are employed either as Assistant professors/lecturers, Associate professors/senior lecturers or Full professors (Table 2). Equitably, over 73% got their PhD more than 7 years ago (Table 3). As principal investigators and research group leaders were targeted, this fits the sought profile. Regarding the size of their research groups, there are, on average,

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seven members in the group (MEAN=6,74, STDEV=3,23, MIN=3, MAX=15, MEDIAN=6, MODE=4).

Table 2 Academic position of the participants

Academic position	Count	Percentage
Full professor	14	34,15%
Associate professor, senior lecturer	10	24,39%
Assistant professor, lecturer	6	14,63%
Postdoctoral researcher	7	17,07%
PhD student	2	4,88%
Other: independent senior research without teaching obligation; university research associate	2	4,88%

Table 3 Years from PhD for the participants

Years from PhD	Count	Percentage
More than 12 years since PhD	23	56,10%
7-12 years after PhD	7	17,07%
2-7 years after PhD	8	19,51%
Not applicable	3	7,32%

The participants have a solid preference for hybrid work arrangements (68,29%, Table 4), and some of the reasons are discussed in this report. This percentage is in line with recent studies within academia (e.g. Powell, 2022) [2] and beyond (IPSOS, 2021) [3].

Table 4 Preferred working arrangements

Which of the following work arrangements do you prefer?	Count	Percentage
Hybrid	28	68,29%
Fully remote	1	2,44%
Fully at the office	11	26,83%
Other: "Mostly at home; but with one or two days physically at the office"	1	2,44%

In terms of the individual productivity in the remote work, the participants are relatively neutral (Table 5), whereas the average score for the group productivity is slightly lower (2,78, Table 6).

Table 5 Remote work productivity (individual)

I am more productive working remotely compared to working in the office.	Count	Percentage	Sum
(1) Strongly disagree	5	12,20%	29,27%
(2) Disagree	7	17,07%	
(3) Neither agree nor disagree	18	43,90%	43,90%
(4) Agree	2	4,88%	
(5) Strongly agree	9	21,95%	26,83%
Sum (Answers)	41	100,00%	100,00%
Arithmetic mean	**3,1**		
Standard deviation	1,3		

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Table 6 Remote work productivity (team)

My team is more productive working remotely compared to working in the office.	**Count**	**Percentage**	**Sum**
(1) Strongly disagree	6	**14,63%**	**34,15%**
(2) Disagree	8	**19,51%**	
(3) Neither agree nor disagree	20	48,78%	48,78%
(4) Agree	3	7,32%	
(5) Strongly agree	4	9,76%	17,07%
Sum (Answers)	41	100,00%	100,00%
Arithmetic mean	**2,8**		
Standard deviation	1,1		

On the other hand, most of the participants (87,80%) agree that their group is flexible in arranging their on-site and remote duties (Table 7) and that they have the tools and resources needed to support remote work (73,17%, Table 8).

Table 7 Team flexibility in organising on-site and remote work

My team is flexible in the arrangement of on-site and remote duties.	**Count**	**Percentage**	**Sum**
(1) Strongly disagree	0	0,00%	2,44%
(2) Disagree	1	2,44%	
(3) Neither agree nor disagree	4	9,76%	9,76%
(4) Agree	19	**46,34%**	
(5) Strongly agree	17	**41,46%**	**87,80%**
Sum (Answers)	41	100,00%	100,00%
Arithmetic mean	**4,3**		
Standard deviation	0,7		

Table 7 Availability of tools and resources for remote work

My team has the tools and resources needed to support remote work.	**Count**	**Percentage**	**Sum**
(1) Strongly disagree	1	2,44%	7,32%
(2) Disagree	2	4,88%	
(3) Neither agree nor disagree	8	19,51%	19,51%
(4) Agree	20	**48,78%**	
(5) Strongly agree	10	**24,39%**	**73,17%**
Sum (Answers)	41	100,00%	100,00%
Arithmetic mean	**3,9**		
Standard deviation	0,9		

Several open-ended questions were also used to elucidate and complement the ratings with qualitative data:

- Please consider a situation where you would be required to switch to fully remote work arrangements. What is your top challenge in working remotely?
- During times when fully remote work arrangements were imposed, were there any good practices you could highlight? Differentiate between organisational, team- and individual-level practices.
- Is there anything that has been especially helpful in the transition to remote work?
- Please explain your remote work environment: do you have access to all the necessary materials, training, or equipment for remote work?
- Have you had difficulties in organising fieldwork or lab work during a lockdown? Do you use sophisticated machinery, or are you bound to some space in your teaching and research that could not be carried out during that time?
- Is it easier or harder to set up remote work arrangements considering your research focus, and why is that so?

The process of qualitative data analysis

Two researchers engaged in the data analyses. One researcher coded the data while both researchers met regularly (every 2-3 days) to discuss the coding process, codes and the overall methodological application. Due to the clarity and straightforwardness of the data and the findings, as well as the high degree of agreement between the researchers at every stage of the analytical application, additional coders were not included. Thus, further analytic actions (inter-coder reliability calculations and similar) were unnecessary. The design and focus of the questions and the mentioned clarity, as well as conciseness of the participants' responses, facilitated the analyses of the data, rendering it smooth and unencumbered.

Amendments to the methodological selection for future research on the topic are recommended - conducting in-depth or semi-structured interviews instead of administering brief and explanatory power-limited questions. Furthermore, amendments in the analytical process for future research on the topic are also suggested – here, a variety of options are available (e.g. different types of coding techniques), the selection of which is research design (research instrument, data) dependent.

An overview of the analytical process

- Atlas.ti (version 8) analytical software and three types of coding techniques were used inductively to analyse the data across three stages.
- In the first stage, the data was open-coded. When incidents (data chunks evaluated as having a meaning relevant to the goal of the analyses) converged in meaning with pre-established codes, these were assigned to the relevant code, and when not, a new code was created. Using the stated technique, 29 open or lower-order codes were developed.
- In the second stage, focused coding was used whereby the most significant and frequent codes were identified, and those that the coders believed held the most analytical sense and value to categorise the data incisively and completely. During this phase, an increased level of abstractness was maintained and the coders strived to integrate the preceding round, data-driven, lower-order codes into more conceptual higher-order focused codes, thus, condensing and reducing the data. In this way, the open-codes were collapsed into 8 higher-order focused codes.
- In the final stage, thematic coding was used, whereby the abstraction level was increased to integrate the focused codes into more abstract theoretical constructs or themes. Using this technique, the higher-order codes were collapsed into 2 major themes.
- The data and code structure illustrating this process are presented in Figure 2.

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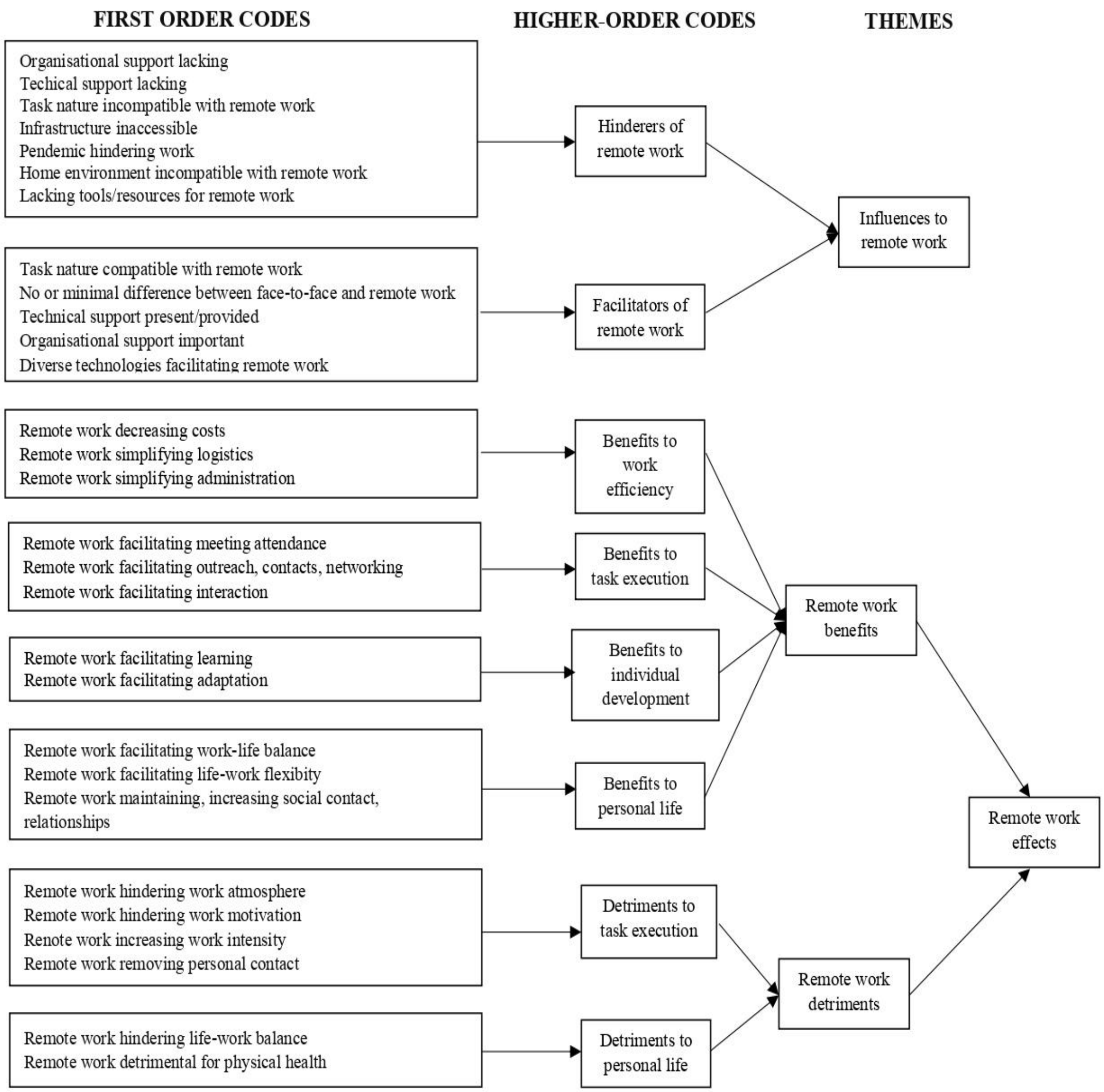

Figure 2 Data structure

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Analyses and interpretation of the findings of the qualitative data

- Two major themes emerged out of the analyses relating to the influences to remote work and the effects of remote work (Table 8). Facilitating and hindering influences to remote work and, similarly, benefits and detriments of the remote work have been identified.
- Benefits of the remote work entail those relating to the efficiency of work, task execution, individual development and personal life.
- Detriments of the remote work entail those relating to task execution and personal life.
- The dataset was stratified across the available demographic specifics and differences in terms of the scientific branch and age of the participants were identified while the majority of the concepts converged across these specifics.

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Table 8 Major themes emerging out of the analyses of qualitative data

		Influences to remote work		Remote work effects					
				Benefits of remote work				Detriments of remote work	
		Facilitating	Hindering	Efficiency	Task execution	Individual development	Personal life	Task execution	Personal life
Convergent		Technical support present/provided Organisational support Diverse technologies	Pandemic hindering work Home environment incompatible with remote work Lacking tools/resources for remote work Organisational support lacking	Remote work decreasing costs Remote work simplifying logistics Remote work simplifying administration	Remote work facilitating meeting attendance Remote work facilitating outreach, contacts, networking Remote work facilitating interaction	Developing leadership skills	Remote work facilitating work-life balance Remote work facilitating life-work flexibity Remote work maintaining, increasing social contact, relationships	Remote work hindering work atmosphere Remote work hindering work motivation Remote work increasing work intensity Remote work removing personal contact	Remote work hindering life-work balance Remote work detrimental for physical health
Branch of science	**Computer-depended / intensive sciences**	Task nature compatible with remote work No or minimal difference between face-to-face and remote work							
	Physical equipment-dependent / intensive sciences		Task nature incompatible with remote work Infrastructure unaccesable						
Age (seniority)						Remote work facilitating learning Remote work facilitating adaptation			

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Influences to remote work

- The converging facilitators of the remote work mostly entail organisational support and technological features, that is, the IT tools used for remote work.
- Organisational support connotes provision of the administrative (development, adaptation and implementation of the policies and procedures facilitating the transition to and execution of the remote work) and technical (provision and maintenance of the software, hardware necessary for remote work at home).
- Technological features entail diverse technologies (apps, various specialised online tools) enabling and facilitating remote work.
- Scientific branch-specific facilitators of the remote work relate to sciences which are compute-intensive or dependent (e.g. theoretical physics), which, therefore, connote no or minimal differences in remote work in comparison to office work priory.
- The converging hinderers of remote work include the lack of organisational support, lack of technological tools needed for the execution of tasks from home and the incompatibility of the home environment for remote work (intrusions of the personal life into work-life - e.g. noise, children).
- Scientific branch-specific hinderers of the remote work related to the infrastructure and equipment-dependent or intensive sciences (e.g. experimental physics, medicine) where tasks cannot be executed remotely.

Effects of the remote work

- Benefits of the remote work are in majority convergent across the demographics, with one exception in the benefits for individual development, which vary by age.
- The convergent benefits of remote work for work efficiency imply that remote work decreases costs (e.g. commuting to work), simplifies logistics (easier to manage work, assign tasks, supervise colleagues/students, coordinate work) and administration (less paperwork involved, more electronic handling of documentation, procedures adapted to remote work).
- The convergent benefits of remote work to task execution include improved (i.e. more intense and more frequent) interactions, hence, improved networking activities, meeting attendance and similar.
- The convergent benefits of remote work for individual development relate to learning leadership skills (all participants have academic leadership positions) in a virtual environment.
- Age-specific benefits of remote work for individual development include learning from remote work experiences and adapting to the remote work on the basis of

this learning. More precisely, this connotes learning to manage diverse technologies, their features and utilising them in their work, which leads to the acquisition of new, previously unattained skills and competencies. This, in the majority, relates to more senior researchers.

- The convergent benefits of remote work for personal life relate to the betterment of the work-life balance, whereby participants report being able to better coordinate personal and professional life, being able to amend their nutrition and being better able to protect their mental and physical health by having more time to engage in activities that enabled them to do so (more frequent exercising, yoga etc.).
- Detriments of the remote work all converge across the demographics and entail detriments for task execution and personal life.
- Detriments of the remote work for task execution include the removal of personal contact, which prevents social bonding and hinders collaboration, hampering the work motivation in comparison with office/lab work environment; removal of work atmosphere that develops in on-site work and an increase in work intensity during remote work.
- Detriments of the remote work for personal life entail the worsening of the life-work balance, e.g. work intensification that decreases the time for private life, and the fact that the home environment facilitates "friction" between professional and personal activities. In addition, remote work is also reported to worsen the physical health of the participants as in wrist, hand and back pain due to prolonged usage of an inadequate furnishing at home (sofa, benches) and worsened eyesight or screen fatigue due to intense usage of the hardware (computers).

Selected quotations for each of the 8 higher-order focused codes are provided in Table 9.

Table 9 Selected participant quotations

	Code	Participant quotation
Influences to remote work	Hinderers of remote work	*Part of our work is lab work which cannot be done at home or remotely.* *Fieldwork had to wait and labwork postponed* *The biggest limitation is that the University itself has bureaucracies resisting and limiting the adoption of remote work*
	Facilitators of remote work	*…the "remote" aspect of not being in the office is less relevant and mostly applies to our online teaching…* *…provision by the University of good computer equipment and tools for distance communication* *Our university prepared and shared very quickly a comprehensive set of rules to guide the staff personnel and students for the teaching and research activities.*
Remote work effects	Benefits to work efficiency	*…remote work forced online meetings of various committees, which allowed to save a lot of time and resources as there was no need to travel.* *It is easier to arrange to do work remotely*
	Benefits to task execution	*It would allow me to take the lab global in an official sense, which is now easier than ever in the pandemic setting* *flexibility in timings helped me work better with less external distraction* *Remote work facilitated the collective mobilisation and high degree of interaction between all the members of our organisation.*
	Benefits to individual development	*Remote work forced as to review and readjust principles of our teaching work, so that aims and procedures were optimised.* *Working remotely made us learn more about remote working techniques and acquire new technical skills, in order to become as efficient as for face-to-face work.*
	Benefits to personal life	*Remote work provided me with the possibility to make tea and coffee conveniently and easily. Also, the possibility to have healthy and tasty food options that I couldn't take to the office otherwise.* *…I can take many short breaks to do yoga and stretches*
	Detriments to task execution	*…we had problems with lab work as we use lab equipment which needs special infrastructure.* *…some of our research objectives, especially in terms of data acquisition and publication, had to be postponed.* *It is difficult to keep being motivated, as the work I can develop in remote is quite monotonous and with no so many interactions with other people, so keep focus and motivated is sometimes hard for me.*
	Detriments to personal life	*I've developed health problems in my wrists, arms, back, and legs* *Having many online meetings is tiring: I have screen fatigue and my eyesight has worsened.* *…having an appropriate home office space (size, noise, temperature regulation, desktop, chair, PC monitor).*

Example of a successful remotization

What a better example of a successful application of remote work than the European Organization for Nuclear Research [4] (French: Organisation européenne pour la recherche nucléaire), known as CERN. We will use CERN to showcase how remote work can be introduced at each of the steps of scientific research. This can provide valuable guidance on the needed preparation to achieve such a level of remotization that leads to very high resilience and anti-fragility of the research setup.

A short overview of CERN

It is easy to understand why CERN was designed with optimal remotization infrastructure. It operates the largest particle physics laboratory in the World and requires the constant collaboration of more than 12.000 users from more than 70 countries to produce scientific results.

CERN is the site of the Large Hadron Collider [5] (CERN), the world's largest and highest-energy particle collider that hosts seven large experiments. These experiments were designed to try to unravel the biggest mysteries of the Universe. Scientific results are already fruitful and include the discovery of W and Z bosons [6], the first creation of antihydrogen atoms [7], the discovery of Quark Gluon Plasma [8], and the most recent discovery of the Higgs boson [9,10] that resulted in 2013 Nobel prize in physics to Francois Englert and Peter Higgs [11]. In addition to scientific discoveries, CERN is also the birthplace of the World Wide Web [12], PET scanners [13], and touchscreen technology [14].

The LHC's goal is to allow physicists to test the predictions of different theories of particle physics. In order to allow for such a huge collaboration from all over the world, CERN was carefully planned to introduce remote access in all segments where this was possible.

While scientific research at CERN is impossible without remotization in this section we will try to showcase all the benefits of remote work that could easily be exploited in other scientific research areas. This also includes advanced planning of remotization infrastructure which is sometimes a key to achieving resilience and anti-fragility of the research setup.

How and where remote work is achieved at CERN

Scientific research can be divided into several steps:

- Theoretical prediction (eg. Standard model predicts the existence of a new particle called the Higgs boson)
- Experimental measurement (eg. LHC collides protons and collisions are recorded with different experiments)
- Data analysis (eg. CERN scientists analyze collision data)
- Scientific results (eg. Higgs boson particle is discovered)

We will now focus on the examples of how the core of scientific research has been adapted for remote work in the case of CERN.

We will start with the experimental setup. At CERN, experiments can be thought of as large scale electronic devices that are built with the idea of being able to have full control of them remotely. To successfully achieve this one has to plan in advance. It usually requires special or additional infrastructure in terms of either hardware or software. Being such a large scale laboratory, CERN can afford advanced technologies but also often develop new technologies to achieve this. The benefits of remote infrastructure at CERN are obvious, but an important question arises. How does the benefit of remote work infrastructure depend on the number of scientists involved in the experiment? This is not a trivial question and is something to be considered case by case.

It goes without saying that the pandemic of COVID-19 showed the importance of having at least a basic infrastructure for remote work incorporated in all projects that include scientific research. In many cases, in-person work is more beneficial and productive but having no infrastructure to support any kind of remote work can be detrimental. This was best experienced in the pandemic outburst when many experiments were stopped. During the pandemic, CERN benefited from the strong resilience and anti-fragility of the research setup. They were able to easily adjust to pandemics by simply increasing the amount of work done remotely since the infrastructure was already available. This is why we believe that in the future every experimental setup should include a basic remotization infrastructure to allow remote work at least in special situations.

To better understand the infrastructure available to achieve remote work we will focus on the specific examples from the Compact Muon Solenoid (CMS) experiment at CERN.

Specific examples from the CMS experiment

The CMS experiment records 40 million high energy proton-proton collisions happening every second and producing 1 petabyte of data. All of the electronics can be monitored remotely using computers to manipulate hardware. For example, hardware is used to make extremely fast decisions every 25 ns whether the collision was interesting enough to record it or not. These decisions can be altered remotely.

While the CMS experiment is running it is critical to understand if all of the electronics are working as expected as any malfunction would result in useless data for scientific research. In order to assure the quality of the collected data, CMS Control Room is located at the location of the CMS detector. The CMS detector is 100 meters below the ground in the LHC tunnel and the CMS Control Room is at ground level. Usually, there are 5 experts present in the CMS Control Room at all times to monitor data quality. To adapt for the pandemic this number was reduced to two experts present in person, while three experts were monitoring data remotely from their personal computers located anywhere in the world. This is a perfect example of remote infrastructure that is available but only used at specific times.

In addition, to live monitoring of data, more thorough studies are made later where hundreds of experts study recorded data in much more detail to ensure no detector problems were present. For sociological reasons, this work requires you to be present at the CERN site (Meryin, Switzerland). The work is done on personal computers that although present at the CERN site, access the recorded data remotely using the internet connection. Thus, it was very simple to switch this work to be fully done remotely during the time of the pandemic and it will be equivalently easy to switch back to in-person work once the conditions allow for it.

Another example includes around 20 on-call experts that have specific knowledge about a particular part of the CMS detector. They are available 24 hours a day, 7 days a week and have to be present at the CERN site and have to carry special CERN phones so that they could be easily reached in case of problems. During the pandemic, most of the on-call experts were switched from having to be present in person at the CERN site to performing their duties fully remotely from their home country. To achieve this, CERN developed a custom Android and iOS application that emulates CERN phones. This is a perfect example where CERN had to develop specific technology that was not available in order to achieve remote work.

Another critical aspect of research work at CERN and CMS is of course the statistical analysis of the recorded data. All of the data is held at the CERN Data Centre which also includes additional services like the email and videoconferencing equipment. There are several key aspects to be considered for productive remote data analysis:

- Remote data access
- Remote data analysis infrastructure (in particular software)
- Remote collaboration tools (eg. email, video conference tools, chat, …).

Experiments at CERN were all designed with the idea of thousands of scientists from all around the world analyzing the collected data. This is trivial to achieve thanks to planning that achieved that 100% of CERN data is analyzed remotely. Even when you are physically present at the CERN site you still have to remotely access the data using an internet connection. This of course requires additional infrastructure, for example, one has to be careful not to allow non-users to remotely access data. CERN also provides all the necessary scientific software for data analysis available to be accessed remotely. Since data analysis is often too advanced for the personal computers of the users, CERN has supercomputers that can also be accessed remotely by its users. This allows CERN users to share computational resources that are often very demanding.

To have a successful remote scientific collaboration, regular meetings between the scientists are of utmost importance. At CERN, all of the meetings are always done in the so-called hybrid mode where around half of the participants are connected remotely with a video conference tool. Having a video conference setup in place it was trivial to switch to fully remote meetings during the pandemic.

Not to paint the picture that absolutely everything at CERN can be done remotely, we will just point to a couple of examples that did suffer from the pandemic. For example, CERN scientists are currently working on developing new detector technology for the future upgrades of the experiments. While the work continues remotely even during the pandemic it is severely slowed down because manufacturing and testing of new electronics and hardware can never become a fully remote work.

Finally, CERN has performed a survey [15] to estimate how productive is fully remote work when compared to a combination of in-person and remote work. The first results show that remote work is not as productive as the combination and CERN is planning to increase the amount of in-person work to the same level it was at before the pandemic occurred.

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Key takeaways from the CERN example

To summarize, we would like to highlight some key takeaways from the above discussed example of the CERN scientific research that would be helpful when planning for remotization of other research projects.

First place where remotization can and should be incorporated is the experimental setup. While CERN represents the largest scientific collaboration in the world that is impossible without remote work even small research projects benefit from basic remotization infrastructure. Planning is the key to incorporating this kind of anti-fragility into your research as very often these things include additional technology.

Another important aspect of every research is data analysis. This part is done fully remotely at CERN and this is achieved mainly thanks to the huge computing resources available. This aspect is very often present in other research areas and in very small collaborations. This is probably because it is fairly easy to achieve. Usually, it is enough to ensure some kind of a computer where the data will be stored and enable all of the users to access this data remotely with an internet connection. This can be further beneficial if the remote connection also allows users to access the needed scientific software and run it on shared computing resources.

To conclude, we strongly believe that remote scientific collaboration and having at least a basic remotization infrastructure is the future of scientific research.

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An example of a possible case study for remotization

In this section, we will present a hypothetical research setup that has no remotization implemented. We will then discuss how resilience and anti-fragility can be introduced through the means of remote work infrastructure. We will conclude with some guidelines on how to incorporate remotization for a generic research setup.

A hypothetical research setup with no remotization

While in the survey performed and discussed in this document we focused on cases of research setup that already had at least some level of remote work implemented we will now switch our focus to an extreme. We will design a hypothetical research setup that has no remote work implemented. We will use it to demonstrate how it is very easy to introduce remotization infrastructure in some places, while in other places it is sometimes impossible without planning it in advance.

Let's consider a taught-of research setup in medicine that has the goal of studying a new bacteria. Without going into any detail we will outline the four key steps matching the example of CERN:

- Theoretical prediction: The antibiotic we are testing is successful against a new bacteria.
- Experimental measurement: Cultivate bacterial cultures and study how the interaction with the antibiotic influences the number of bacteria.
- Data analysis: Analyze the data collected on the number of bacteria and doses of the antibiotic.
- Scientific results: The antibiotic is effective against the new bacteria.

As we already discussed in the example of CERN, the two main points where remote work can be introduced are experimental measurement and data analysis. Before we discuss how this can be achieved we first have to give more details on the setup before any remotization is introduced.

For example, a basic experimental setup can be designed as follows:

- Bacterial cultures are cultivated in Petri dishes.
- Antibiotic dose is measured with pipettes and scales.
- Number of bacteria is studied with a microscope.

- Data (antibiotic dose and number of bacteria in time) is noted on a paper or in a document on a personal computer.

Here, we have to stress that while this is a completely hypothetical experimental setup designed only to present a case where no remote work is introduced at first, one can easily adjust the example to a more realistic case and other research areas.

In addition to the experimental setup another important step is the data analysis. In this case, data analysis would be represented by the researcher using software installed on their personal computer together with the collected data to perform statistical analysis that would lead to scientific results.

One can think of this research as being performed by a small collaboration of 5-10 researchers. Some of the researchers could be involved in all steps while others could be specialized only for one of the steps. However, it is easy to see that in the case of a pandemic the work would stop for those that don't have physical access to the experimental area. Also, if someone wants to join the collaboration they would have to be physically present there to have use of the experimental setup.

Introducing remotization

We will start with the easiest place to introduce remotization with a lot of potential benefits and that is the last step of the data analysis. Instead of writing down data on a personal computer one could invest in a basic setup that allows remote access to data. Without going into details, this can be achieved fairly easily and with minimal IT support as long as the data produced and the number of people needing to access it remotely are not too large. In addition, remotely-accessed computers can also include scientific software needed for data analysis. There are several immediate benefits:

- During the times when access to the experimental setup is not available all of the scientists from the collaboration can easily access and analyze previously obtained data.
- Collaboration can benefit from having researchers analyzing data from all around the world.
- Researchers that don't have the resources to obtain all the needed software and computing power for data analysis can still contribute by connecting to the collaboration resources and analyzing the data.

We believe that remote data analysis these days is introduced in many research areas and experimental setups and this was also visible in many examples of the survey that was conducted as part of this research. Depending on the scale of the research this step can become a bit complicated but we strongly believe that it will always be beneficial.

Discussing remotization of the experimental setup is very case-dependent but the general idea can always be followed. The general idea is to try and understand if experimental measurements can be performed fully with digitized devices that can be controlled remotely. Sometimes this can be achieved in every single step of the experiment like it is in the case of CERN, but sometimes this can only be introduced at some of the steps while human in-person interaction is needed in other steps. Our goal is not to convince all of the research areas that every step should be remotized, but to showcase the benefits of remotization where it is possible.

We will break the discussion down step by step. First, let's discuss the part where the bacteria is grown in Petri dishes and antibiotics are applied. Oversimplifying the process, let's imagine it by having to simply transfer a sample of bacteria to a Petri dish filled with a medium. This can of course be done by a researcher and requires you to be present in person. After some time a certain amount of antibiotics is also applied to the Petri dish. The only obvious way to remotize this process would be to introduce a robotic arm. This arm could be controlled remotely and if the bacteria sample and antibiotics are available, one could start the process remotely. Of course, this step has to be planned in advance and requires special technology that increases the needed budget.

In the next phase, the number of bacteria is studied with the microscope as a function of time. Again, to remotize this step one needs to plan in advance. If no remotization is planned, the microscope used would be the one that requires researchers looking at the sample. One could introduce a microscope that can be controlled remotely and that produces images of the sample in some defined time intervals and stores them to a remotely accessible computer. Of course, this also requires advanced planning of specific technology. In this case maybe the technology is not even available or too expensive. In the case of a small collaboration it is impossible to develop the technology themselves like CERN can do, but stressing the need for such devices could motivate companies to invest in the idea for the future.

To summarize, a fully remotized setup of our hypothetical research in medicine would allow researchers from the collaboration to operate the experiment without being present in person. Of course, just like at CERN, maintenance and repairment of the setup would always be performed in person. This kind of setup would yield many benefits:

- At the time of pandemic experimental measurements and new data can be obtained remotely.
- Researchers from all over the world can benefit from the experimental setup and perform measurements remotely.

- Larger collaborations can be built sharing different remotely accessible experimental setups.

How to apply remotization to my research area

We would like to finish this hypothetical example by stressing that the benefits of ensuring resilience and anti-fragility are twofold. While ensuring high productivity in challenging times of pandemic it also opens broad collaboration options during the normal times. In order to apply the discussed to your own research area here are some important questions you will need to consider:

- Can you pinpoint four main steps in your scientific research?
- What are the biggest differences between your research and the examples of CERN and a hypothetical case study in medicine?
- Do you already have experience with remote work in your field? How often is it present and in what steps?
- What do you see as the biggest challenge to including remote work in your research?
- Is the remotization of your experimental setup possible without planning in advance?
- Do technologies needed for the remotization of the experimental setup in your field already exist? Are they easily accessible?
- If you had to choose only one key component for remotization which one would it be and why?
- Are there parts of your research that can never be performed remotely?

Workshop on remotely accessible infrastructure: Expectations of researchers and opportunities for intervention

What is human-centred design?

Human-centred design is defined by ISO [16] as an "approach to systems design and development that aims to make interactive systems more usable by focusing on the use of the system and applying human factors/ergonomics and usability knowledge and techniques".

Today's human-centred design is based on the use of techniques that communicate, interact, empathise and stimulate the people involved, obtaining an understanding of their needs, desires and experiences which often transcends that which the people themselves actually realised. Human-centred design is thus distinct from many traditional design practices because the natural focus of the questions, insights and activities lies with the people for whom the product, system or service is intended, rather than in the designer's personal creative process or within the material and technological substrates of the artefact [17].

Workshop discussion and HCD phases

The 2.3 Task was designed as a two-step process: the survey was developed to capture experiences and examples of remote work and remotization, while the HCD workshop was designed to outline those experiences and explore expectations and opportunities for intervention. The results of the survey of research fields, groups, and situations where remote work is already practised were presented during the workshop. The goal of the presentation was to steer the conversation and provide a landscape of best practices and challenges as an introduction. The presentation of the survey was followed by case studies presentations on remote work experience at CERN and on the remote control and the maintance of observing stations and computing infrastructure.

The Miro board was used to collect all of the feedback and categorize it according to the HCD phases.

<u>Inspiration Phase</u>

Understanding the individuals who are experiencing a problem is the initial phase (Inspiration) of any human-centred design methodology. This section is referred to as empathy mapping and participants explained and shared their experiences with remotization in their research work.

In this context, Aldo Drago presented remote control and maintenance of observing stations and computing infrastructure in operational oceanography. The purpose of this presentation was to show how technology is assisting us in being able to remotely control complex systems. He used an example of the Internet of Things (IoT), which refers to a rapidly growing network of connected objects that can collect and exchange data in real-time using embedded sensors. And recently, we can see how IoT is used in many applications of remote work and remote control, as well as how it opens up important new possibilities for us to explore. As a result, technology is an important component in the remotization of infrastructure for research and innovation, and it should be highlighted not only in the case study but also in our reSEArch-EU project's future work. Aldo also described to the participants how WhatsApp enabled the Physical Oceanography Research Group at the University of Malta to communicate effectively remotely. During the COVID-19 lockdown, many research activities on the field became very difficult to perform, especially with regard to operational activities such as those related to the routine maintenance of remote observation stations at sea or on the coast. These data collection stations often require intervention on the spot by specialised technical staff to repair, check or control the various components of such systems including sensors, data loggers and communication hardware. Their effort and practice were revised to adapt as much as possible to the circumstances imposed by COVID that restrained the physical presence of more than one person at the same site. Social media and smartphones became very handy for many situations and to improvise solutions. In the case of the Physical Oceanography Research Group at the University of Malta, they used WhatsApp extensively as a means of virtually connecting people in real-time to act together on an observation site without the need of being all present on site. The person on site could thus consult with other specialists through WhatsApp by describing the status and functioning of the system, exchanging pics to identify problems and deciding collectively on the best interventions. The team could thus work together remotely, and at times this included even the involvement of team members from abroad, making interventions quick and efficient.

The next step for participants in this phase was to identify unique aspects of remote work and remotization in research and innovation. As an introduction, Katarzyna Świerk from the University of Gdańsk presented previous research [2,18,19,20] that engaged further discussion and comparisons with survey findings. The experiences described in these articles were very similar to those gathered by the task survey. Remote data analysis, for example, was mentioned several times in the survey as a need and a challenge, and it was also mentioned in the Springer Nature article by Ru Gunawardane of the Allen Institute for Cell Science's Stem Cells and Gene Editing [20]. In the article she describes how she and her research team redeployed everyone to freeze and label hundreds of different cell lines, allowing them to analyze collected data remotely. Senior people in the group trained the junior people over Slack and Zoom on how to analyse the genetic data and they are building the infrastructure to store, track and search within their genetic data.

The Springer Nature article [20] illustrates other unique aspects of remote work, such as a lack of teamwork, contacts, and idea exchange, or better organization and improved focus on work, resulting in a healthier and better life/work balance. In this regard, the work completed in the scope of the SEA-EU Erasmus+ project and Task 5.4 *Pan-European joint research and innovation management* was presented to the participants. This activity is an Alliance's first step toward establishing remote and virtual management and collaboration among the six universities. Through the established SEA-EU Community Channel on the Discord Platform, SEA-EU virtual offices are now able to share their best practices and tackle challenges, communicate on upcoming deadlines and project activities, and also explore new collaboration opportunities. This activity exemplifies the task survey's findings that facilitation of interaction, networking, and adaptation are critical elements and benefits of task execution and remote work.

The discussion and debate allowed the team to identify the following unique aspects of remote work and remotization in research and innovation:

- It is not possible or is limited to doing lab work remotely.
- There is a lack of practice in laboratory activities.
- Sometimes fieldwork is delayed or cancelled.
- Some people see remote work and remotization as time-consuming, while others say it saves them time.
- There is a lack of teamwork, contacts and idea exchange.
- There is a conflict between remote work and personal responsibilities and obligations.
- Because of its flexibility, remote work allows for better organization and focus at work, resulting in a healthier and better life/work balance.
- Remote work provides a long-term environmental benefit in terms of a lower carbon footprint.Remote work enabled the introduction of new IT tools, expanded access to training and courses, and the digitization of administrative processes.

Based on these identified unique aspects, the team was able to create an overview of the needs for remote work and remotization in research and innovation as the next step. The intention of the workshop was to collect feedback from various fields of research, so the following needs were introduced while keeping this variety of aspects in mind:

- There is a need for infrastructure operation reliability, as well as experts servicing systems/equipment and IT support in general.
- In the future every single experimental setup should include a basic remotization infrastructure. This is why remotization could be a key in future research projects and therefore there is a need for a tool that could help researchers for including remotization in their projects.
- There is a need for specific calls for the remotization of research centers and for specific projects including remotization in contingency plans.
- There is a need for a policy (a set of rules or guidelines) for the research infrastructure access – this need is outlined based on the experience from the EU-CONEXUS in developing a common policy and strategy access to joint infrastructures and services which is described in the appendix of this section.

Ideation Phase

The second phase of human-centred design is Ideation, and a critical part of this stage is to create insights statements that provide context for what was outlined during the Inspiration part of the workshop. These statements reveal people's true motivations behind what they say and do.

After the discussion, the following insights statements were developed:

- Researcher wants to integrate remotization setup in the research because it will make it more resilient but lacks the necessary IT support.
- Researcher wants to include remotization to research because it allows for a better work-life balance and more flexibility but there is a problem with large data sharing among the research groups members.
- Researcher wants to incorporate remotization setup into the research because it will improve the competitiveness of the project but lacks the necessary support and tools.
- Researcher wants to develop a remote working culture because it allows to establish co-supervised student and postdoctoral relationships globally but the university has bureaucracies resisting and limiting the adoption of remote work and recognition of remote co-supervision.
- Researcher wants to include more remote work as a part of the research because it enables better organization and time management but there is a problem with conducting experiments and analyses in the remote work environment.

The task team's next step was to turn these insights into opportunities by asking "how might we?" questions:

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- **HOW MIGHT WE** enable large data sharing among the researcher group so that their work can be remotized and their collaboration and resilience increased?
- **HOW MIGHT WE** develop a tool for incorporating remotization into research so that researchers can improve their project proposals and increase the number of successful project applications?
- **HOW MIGHT WE** formally recognize international remote researcher groups in order to promote remote working culture and established globally co-supervised student and postdoctoral relationships?
- **HOW MIGHT WE** ensure the efficient use of research equipment by implementing remote working?

By rephrasing the challenge as a question, the team was able to explore deeper into the possibilities for intervention and lay the groundwork for potential solutions. The next step in the research-EU project will be an exploration of some of these possibilities for intervention during the upcoming Task 2.4 SEA-EU Academy Workshop.

The workshop approach will be multidisciplinary, using Critical and Speculative Desing as a cohesive vehicle connecting different research fields and backgrounds with the design perspective. The outcome of the workshop will be a series of possible preferable and less preferable future scenarios of remote research dealing also with the implications of these scenarios, presented using different communications methods, tools and approaches (adapted to the group needs).

APPENDIX:

Experience from the EU-CONEXUS – Task 4.3 "Developing a common policy and strategy for access to joint infrastructures and services"

The present text includes, firstly a brief description of the EU-CONEXUS RFS project task for the development of the Access Policy access to research infrastructures of EU-CONEXUS, and secondly provides some contribution to the findings of the "On-line SEA-EU Workshop: Remotely accessible infrastructure" presentations and discussion during the workshop organised by the SEA-EU Alliance on the 17th March 2022. During the workshop, the EU-CONEXUS participated with a representative (co-observer Dr. C. Chasos, Frederick University, Cyprus).

The alliance of the European University for Smart Urban Coastal Sustainability EU-CONEXUS aims to the development of joint research infrastructures for the partners of EU-CONEXUS, as well as external users and this is envisaged to be facilitated by the establishment of a common policy and strategy among the partners of EU-CONEXUS. In particular, the Working Group (WG) "Research Infrastructures and Resources" within the WP4 of the EU-CONEXUS RFS project coordinated by the Agricultural University of Athens (AUA) (Prf. E. Miliou & Mrs V. Charitou) accomplishes the Task 4.3 "Developing a common policy and strategy for access to joint infrastructures and services", in order to finalize the Access Policy to joint infrastructures and services of EU-CONEXUS. The access policy covers the types and modes for access, aspects of health, safety security and environment, the regulatory framework, transparency and data management, as well as the assurance of quality through key performance indicators (KPIs) for research infrastructures.

The Online SEA-EU Workshop provided the opportunity for pertinent and informative presentations on the remote access to research infrastructures for a wide spectrum of research fields and was complemented with discussions on issues related to the remotely executed research activities. During the discussion, the present author identified the need for a self-assessment for productivity evaluation for remote work, as well as conveyed the current practice of EU-CONEXUS and the possibility for the accomplishment of Strength, Weaknesses, Opportunities and Threats (SWOT) for remote work to accompany the survey of SEA-EU. Additional points from the present author that were identified during the presentations and discussion, and may require further evaluation in order to establish and sustain remote research work, include first the operation reliability of remotely accessible infrastructures, second the expertise and training of the personnel servicing the relevant infrastructures and third the identification of the remote research work interdependence on other systems/services for instance data storage and management.

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