WHITE PAPER

Recommendations towards cooperation between African and European research infrastructures

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Executive summary

International cooperation in science and technology is an important part of addressing major global issues like climate change, infectious disease, food security and natural disasters. Research infrastructures (RIs) are organizations that enable scientists to use specific facilities, resources and services in order to accelerate scientific achievements, break boundaries and promote sustainable research. Fostering RI partnerships across borders has the potential to improve the efficiency and quality of research to tackle the many challenges faced by society today.

The RI-VIS project is a Horizon 2020-funded project to increase the visibility and raise awareness of European RIs to new communities beyond Europe. This report, as part of RI-VIS, focuses on ways to increase collaboration between African and European RIs. It collates the insights of experts from African RIs, European RIs and policymakers into sections that cover examples of successful collaboration, lessons learned and possible challenges/bottlenecks.

The following key recommendations from experts to facilitate African-European RI partnerships are categorized into actionable items for RI representatives, policy makers and funders:

Key recommendations for RI representatives

RATIONALE/GLOBAL CHALLENGES

- RIs are often involved with global issues and need to include Africa in its research, both in terms of data and solutions.

FRAMEWORK

- Offer different approaches, concepts and other means of participation to countries outside of the continent.
- Provide a formal framework for partnership between countries, such as a memorandum of understanding or a joint grant including expectations and standards for the RI collaboration.
- Recognize that the RI collaboration should have mutual benefit to both parties.

CO-CREATION BASED ON NEEDS

- Patience and tolerance for other cultures as well as different levels of technical competencies.
- Learn new approaches: working in different parts of the world requires simpler and different solutions, based around mobile technology and scarcity of research infrastructure.

- Engagement with the people and institutions on the ground.

ACCESS

- Access for outside researchers to have RI access to specialized equipment or facilities that may not be available in their own country or continent.

OUTREACH

- Organization of outreach activities such as workshops and summer schools for international students.

BEST PRACTICE

- Learn from existing success stories of African-European RI collaborations.

Key recommendations for policy makers & funders

FUNDING

- Assess the value of potential RI projects through the lens of critical mass, affordability and alignment with national priorities.
- Join forces to contribute funding from both the European and African side, with each supporting their own country's researchers to focus on collaborative projects.
- Promote synergies between funding agencies working towards shared objectives.
- Lobbying with key decision-making entities such the African Union for more funding for research.
- Continue to develop and promote European funding programmes that are open to the world or emphasize non-EU partners.

FRAMEWORK

- Co-develop RI roadmap, if the country doesn't already have one.
- Consider signing a low-commitment letter of intent for a year with another country to test the waters of collaboration.

CO-CREATION BASED ON NEEDS

- Listen to the local research community and assist its members in forming proposals that are relevant to local communities, tackling local impact of global issues and devising appropriate solutions
- Listen to the local research community and assist its members in forming proposals that show their project's socioeconomic benefit.
- Support capacity building initiatives on both continents to enable wider use of RIs, including establishing local hubs and sample collections to avoid loss of precious samples and create a resource of international importance.

Contents

Background

In 2015, the United Nations General Assembly outlined a set of 17 Sustainable Development Goals to achieve a better and more sustainable future for all (Sustainable Development Goals, 2015). They aim to address major societal challenges faced by humankind related to disease, climate change, food security, environmental degradation and poverty. Scientific research is an essential part of tackling these issues. The process of gathering information and expanding our knowledge of the world has the power to improve overall health, safety and standard of living.

Research infrastructures (RIs) are crucial to the advancement of science in many fields. The availability of well-maintained RIs facilitates cutting-edge research and training of highly skilled specialists. They include major scientific equipment and infrastructures, cyber- or e-infrastructures, scientific collections, archives and structured information and entities of a unique nature that are used for research (European Strategy Forum on Research Infrastructures, 2018).

A key motivation of RIs is the sharing of knowledge and resources across institutions, countries and continents. Large-scale research facilities are incredibly expensive and challenging to build and maintain by one single nation on its own. Other RIs require data collection from different parts of the world. Thus, a more effective and productive way to conduct research is to pool together resources and share costs.

The RI-VIS project is a Horizon 2020-funded project to increase the visibility and raise awareness of European RIs to new communities beyond Europe. Part of RI-VIS involves identifying routes to maximize the exchange of information and bases for new partnerships, in particular with RIs or communities outside of Europe. Mutually beneficial RI partnerships across borders can harness collective knowledge, assist in meeting global challenges and enhance global science capacity.

This report assembles the insights of several experts from both Europe and Africa who have previous experience with such collaboration. Interviews were conducted from February to April 2020 with five representatives from RIs in Europe and Africa, as well as two individuals from the policy side (see Appendix A). They highlighted examples of African-European RI collaboration, best practices for successful collaboration, challenges/bottlenecks and recommendations to policy makers and funders. The preceding sections will outline the definition of an RI, the importance of RIs to society and the benefits of international research collaboration.

What is a research infrastructure?

The term “research infrastructure” comes with a certain degree of flexibility, since it lacks an established formal definition in scientific and policy literature. The European Commission defines research infrastructures (RIs) as “facilities that provide resources and services for research communities to conduct research and foster innovation” (European Research Infrastructures, 2020). The RI-VIS Communication Toolkit for European Research Infrastructures states that an RI is “an organization that enables the research community to use specific facilities, resources and services in order to accelerate scientific achievements and promote sustainable research” (Abecasis & Pintar, 2020). According to South Africa’s Department of Science and Technology, the concept of RI includes “facilities, resources and services used by the scientific community across all disciplines for conducting cutting-edge research for the generation, exchange and preservation of knowledge” (South African Research Infrastructure Roadmap, 2016).

Despite it being used in different contexts both internationally and even within Europe, the term maintains some common threads across definitions (International Research Infrastructure Landscape 2019: A European Perspective, 2019; Florio, Forte, Pancotti, Sirtori, & Vignetti, 2016):

- RIs are motivated first and foremost by **scientific goals**. The main purpose of RIs is to acquire new knowledge in a scientific field, allow research and innovation to break barriers, and push the frontiers of science. They may be purely **curiosity-driven** without any direct, obvious practical application, or they could have a more application driven, practical **benefit to humanity.**
- All RIs at their heart contain **valuable and unique assets**, whether they be major facilities, instrumentation, knowledge-based collections or collaborative networks.
- RIs often require **substantial capital investment** that typically goes beyond the capacity of an individual faculty, institution or funding programme.
- Access to RIs expands **beyond an institutional level** to a national or international reach. The uniqueness and steep cost of the assets means that the RI's capabilities will be in demand by external researchers in the field.

High-profile examples of RIs include CERN's Large Hadron Collider, the world's largest and most powerful particle accelerator; INSTRUCT, a collection of distributed facilities that promote structural biology research; and the Square Kilometre Array, a radio telescope project partly based in South Africa. Further examples from Europe and Africa are provided in Table 1.

RIs are often placed into three broad categories: single-sited, distributed or virtual. Single-sited RIs are centralized facilities at a single physical location. These include large telescopes, particle accelerators, synchrotrons, nuclear reactor sources or extreme laser sources. Distributed RIs usually have a central hub and interlinked nodes scattered in different regions. They consist of a network of distributed instruments or collections that, taken as a whole, constitute a large-scale facility. An interferometrically linked array of radio telescopes and large genome sequencing projects are two types of distributed RI. Lastly, virtual RIs (also referred to as e-infrastructures) are internet-based systems for scientific research, such as an archive of historical texts or virtual research environments (virtual labs) for data processing and analysis. RIs often offer a mixed category that combines physical and virtual aspects.

Societal impact of research infrastructures

The development, operation and maintenance of RIs require large investments from countries, sometimes encompassing tens or hundreds of millions of Euro per year. Decisions about investment in RIs at a national level often include an assessment of any direct societal benefits in addition to their future scientific impact (Horlings, Gurney, Somers, & van den Besselaar, 2013). However, such benefits tend to be difficult to predict, particularly for curiosity-driven projects.

For example, the overarching goal of CERN's Large Hadron Collider (LHC) was to better understand the fundamental structure of matter. The total cost of the accelerator, detectors and computing was 4.332 billion Swiss francs, making it one of the most complex and most expensive scientific research facility ever constructed. Beyond its obvious contributions to physics, CERN has been responsible for innovations that have improved medical and biomedical technology, space missions, art restoration and energy efficiency (Our Contribution to Society, 2020). The building of LHC has resulted in highly advanced superconducting magnets, exceedingly accurate measurement equipment and breakthroughs in data communication and storage. CERN also sparked the invention of the World Wide Web in 1989 (The birth of the Web, 2020) and the capacitative touch screen in 1972 (Stumpe & Sutton, 2010).

Other RIs have a more direct impact with their observations. For instance, the European Plate Observing System (EPOS) and the European Multidisciplinary Seafloor and water-column Observatory (EMSO) are both distributed RIs that inform society about environmental hazards and allow for more advanced preparation.

On the economic side, jobs are created throughout the RI development process, and revenue is created for businesses contracted to build the facility (Low, 2013). The Square Kilometre Array (SKA) – to be constructed in South Africa and Australia with the help of several partner countries – will be the world's largest radio telescope. Thousands of dishes and up to a million antennas will allow astronomers to monitor the sky in greater detail than ever before, with the hope of answering questions about the origins of the universe. The SKA has already rendered substantial economic benefits to South African communities, including ZAR136 million spent through local suppliers and the creation of 7,284 employment opportunities as of 2016 (Gastrow & Oppelt, 2018). The local hospitality industry has also benefitted, since visitors to the SKA must lately stay off-site. The project is also predicted to have a positive socio-economic impact for the many partner countries that are helping with the development and operation of the telescope.

Aside from such spillover technologies, RIs impact the economy and society in several other ways. RIs serve as key learning environments and hubs where knowledge is exchanged (Horlings, Gurney, Somers, & van den Besselaar, 2013). Researchers, students, industry and government all interact throughout the RI's development, construction and use. In addition, many RIs participate in public outreach to stimulate interest in students and other members of the community. The aim is to inspire curiosity and encourage a new generation of scientists to enter the field.

Taking all of the above points into consideration, the general consensus tends to be that RIs provide a positive return on investment and a substantial net benefit to society, economic development and scientific progress.

Scientific collaboration across borders

The collaborative nature of scientific research is inherent to its success. By sharing skills and data, researchers improve the efficiency and quality of their work while supporting the process of scientific production, knowledge creation and breakthroughs. The whole of a scientific collaboration is undoubtedly greater than the sum of its parts. But what are the benefits of collaborating with researchers based in other countries?

Different motivations exist, depending on the scientific field and country at hand. However, one thing is clear: The number of scientists participating in international collaborations is growing. An analysis of scientific publications and co-authorships found that international scientific collaboration is increasing in volume in all research fields over time (Coccia & Wang, 2016). Research is more global, cross-national, and cross-cultural than ever before.

A metaphor used to describe the importance of international collaborations is a frog deep inside a well, who has an excellent view of a small patch of sky (National Research Council, 2008). If most of the research in a field is done predominantly stuck in one well, such as North America or Europe, it can prove detrimental to scientific discovery. Getting out of the well can provide new research topics and collaborators, which help question underlying assumptions and spark fresh insights.

Many research opportunities can only be found in a specific region of the world. For instance, a study on scientific collaboration between Germany and South Africa found that many publications resulted from uniquely "South-African" topics: observations of the Southern Sky, as well as local geology, ecology and plant science (Schubert & Sooryamoorthy, 2010). Other projects require an international pool in order to attain a research population of sufficient size. Studies on rare diseases or other unusual phenomena require going beyond what a single country can provide.

In addition, international collaborations have the power to mobilize a global network to consider and refine important ideas that affect humanity as a whole. Global issues include environmental protection, energy security, natural disaster mitigation, preventing/curing infectious diseases and food security. RIs bring experts together to form a network where they can openly share knowledge and technology. In the area of food security, for example, researchers from academia and industry across the globe often have similar goals, such an increase in crop productivity and resilience, and RIs are pivotal in this respect (Pieruschka & Schurr, 2019).

Beyond the scientific benefits, international collaboration in large science projects can also save money and support foreign policy (U.S. Congress, Office of Technology Assessment, 1995). The cost of "big science" has gone up, which makes it more difficult for a single nation to undertake such projects alone. Of course, reducing net costs for individual countries also motivates the creation of RIs. Collaboration makes it possible to share both the financial and technical risks of ambitious projects.

Lastly, research can also be a form of diplomacy, leading to alliances and memoranda that support foreign policy objectives. Joint scientific research can strengthen bonds with other countries and establish levels of trust.

African-European research infrastructure collaboration

Bringing together RIs from Europe and Africa with the common goal of scientific advancement and innovation has the potential to breath fresh life into research topics, bring new perspectives and spur on novel developments. In fact, because RIs are already focal points of collaboration within themselves, the mutual advantages of African-European RI partnership are expected to be even greater.

The European Union-funded PAERIP (Promoting African-European Research Infrastructure Partnerships) project was a 2013 initiative aimed at promoting research collaboration between the two continents. PAERIP defined an RI partnership as "an agreement between governments, research societies, research institutions, higher education institutions or individual researchers or groups of researchers to jointly plan, invest, develop, construct, manage, use, and phase out RI that holds mutual benefit in terms of advancing the frontiers of knowledge, enables research on intercontinental or global challenges, provides access to science that holds geographic or regional knowledge advantage, and contributes directly or indirectly to national competitiveness" (PAERIP, 2012).

Broadly, RI partnerships at a global or intercontinental scale are worth developing for the following reasons:

- To harness collective global knowledge and experience
- To support leveraging of new international funding for RIs
- To promote access to and exchanges between RIs
- To facilitate the mobility of researchers
- To assist in meeting global challenges
- To compensate each other's shortcomings with regard to available infrastructures

African-European RI collaboration can take many forms, and the examples that follow represent only a small sampling of partnerships. However, our objective is to learn from these real-world cases for the benefit of future collaborations and to better recognize opportunities for the two continents to work together.

Examples

CHPC & CERN

More than a decade ago, scientists at South African universities had to use facilities based in the United Kingdom and other countries in order to perform large computational analyses. The science community petitioned the Department of Science and Technology (DST) for the creation of a supercomputing RI based in South Africa. The Centre for High Performance Computing (CHPC) was established with funding from the DST in 2007. Today, the CHPC provides much-needed local supercomputing resources for projects on climate change, energy storage, astrophysics, bioinformatics and other disciplines.

In 2015, the CHPC signed a memorandum of understanding with the European Organisation for Nuclear Research (CERN) for provision of a Tier 2 processing facility. The Worldwide LHC Computing Grid is composed of four tiers, with each level being made up of several computing centres that process, store and analyse data from the LHC. As part of Tier 2, made up of 155 sites around the world, the CHPC provides computing power for specific analysis tasks.

"African scientists in general have been participating in experiments at CERN for a very long time. But when I looked at who was contributing computing resources to the LHC, Africa was not contributing at all," said Happy Sithole, Director of the CHPC. "This is why we thought it is important to provide some of our resources, and we pledged them to the overall resource allocation at the LHC."

The CHPC gave its support for two years on a trial basis before becoming an official Tier 2 facility. Understandably, CERN requires that any new partner into the Worldwide LHC Computing Grid demonstrate its capabilities first.

"CERN has got a really high standard and stringent requirements that they need for any facility to be accepted," said Sithole. "You have to really build up your operations and test them. It's not just a walk in the park."

Sithole worked closely with people at the LHC during the trial period, and they helped the CHPC to meet all the necessary requirements. Throughout the process, the CHPC's engineers have learned new skills and become part of the larger computing community at the LHC. The partnership also gives the local high-performance computing community access to CERN, making it easier to attend workshops, schools, and training facilities. He also believes that South Africa's involvement in such a large global project shows the world that African countries have the ability to contribute to international science experiments.

"It's important for African countries to not be just sitting and looking for donations. Collaboration is about putting something on the table," Sithole said. "We might not be able to put an equal contribution as other European countries, but the little contribution that we can put is very significant. That is one thing I would say is very critical for the success of collaboration between Europe and Africa."

ESS & SASAS

The European Social Survey (ESS) is a cross-national survey established in 2001 that measures the attitudes, beliefs, and behaviour patterns of diverse populations in more than thirty countries. Face-to-face interviews are conducted every two years, with the data available online free of charge for non-commercial use. The ESS has completed over 425,000 interviews within a 20-year period.

Sir Roger Jowell, originally born in South Africa, co-founded the ESS to produce a standardized social survey whose results could be reliably compared across countries (The history of the ESS ERIC, 2020). He maintained an interest in his place of birth and became a special advisor to the South African Social Attitudes Survey (SASAS) funded by the Human Sciences Research Council (HSRC). The SASAS has been conducted annually since 2003 with heavy influence from the ESS.

"The methods of survey data collected that Jowell implemented here through the European Social Survey, he enacted on the South African Social Attitudes Survey as well," said Stefan Swift, Media and Communications Officer at the ESS. "So there was always a relationship there."

Beginning in 2010, the two RIs began testing the waters of a formal collaboration when the SASAS fielded identical questions to ones the ESS had already done. The partnership between the ESS and the SASAS became formalized in 2014 with a grant from the UK's Newton Fund, formed to build research and innovation partnerships with 17 partner countries to support their economic development and social welfare (Data from South African survey now available, 2017). This meant that, for the first time, attitudes in South Africa on topics like democracy, health, justice, and trust in the police could be scientifically compared with those in European countries.

To further strengthen ties, the ESS signed a memorandum of understanding with the South African HSRC in 2019, which lasts for four years (Global partnerships revealed, 2019). ESS survey questions will be once again fielded in the SASAS, which will promote the exchange of knowledge and allow for methodological improvements to all three surveys.

"I think we're very lucky with the South African team in that they have a very good survey methods background, and they have the capacity to implement them," said Swift. "You have this opposition of lowering your standards to allow more countries in, and this is the case even within Europe. But the South African team is very experienced in this field, so in many senses, the challenges I would normally expect from cross-national partnerships doesn't exist."

The partnership with South Africa is a first step towards a global social attitudes survey. The ESS also signed a memorandum of understanding with Australia and hopes to expand their global reach further in the next decade. The ability of researchers to compare social science data between countries all over the world will undoubtedly help to advance scientific progress in the field.

IITA within the CASS project

Headquartered in Nigeria, the International Institute of Tropical Agriculture (IITA) offers leading research partnership to facilitate agricultural solutions to hunger, poverty, and natural resource degradation throughout sub-Saharan Africa. This region is home to some of the world's poorest people, and IITA works to improve their livelihoods through the implementation of agricultural research and technology.

"We are involved in translational work – so, taking more basic sciences in Europe and the U.S. and translating that into solutions that benefit people in Africa," said Michael Abberton, Head of the IITA's Genetic Resources Center.

One example is a study on genetically modified cassava within the CASS (Cassava Source-Sink) international project (Sonnewald et al 2020) (IITA commences confined field trials of transgenic cassava, 2017). Cassava's starch-rich roots deteriorate quickly after harvest, which leads to a 40 percent reduction in the postharvest value of the crop and thus has a large negative impact on the income of farmers. Scientists within CASS produced genetically modified cassava plants to try and hinder the process of deterioration.

After testing the plants under controlled condition in greenhouses, the project consortium wanted to take the next step and grow the plants in an African tropical climate. IITA carried out a confined field trial with the highest biosafety standards, which included the protection of test plants to prevent insect access and cross-pollination (Confined field trial of transgenic cassava is completely safe, says IITA scientist, 2018). It also used drone technology in the field to observe cassava growth through the seasons.

"Cassava is an African crop, so it doesn't really make much sense to put it out on the field in Europe. But they have the technology to better understand the genetics of cassava plants," said Abberton. "So the genetically modified plants are coming from Europe, and we have the capacity to run field trials here in Nigeria."

The collaboration produced a scientific publication in 2020 (Obata, et al., 2020), which found the possible basis for the cassava's high rate of photosynthesis and areas to target for genetic improvement of the crop. IITA also has a partnership with the University of Helsinki in Finland, where they send DNA samples for next-generation sequencing. For instance, IITA is involved in a project that uses next-generation sequencing in the diagnosis of viruses in cassava and yam.

SAMRC & Forte

For over fifty years, the South African Medical Research Council (SAMRC) has funded and conducted medical research with a mandate to improve the health of the country's population. It consists of intramural research units, based at the SAMRC campuses, and extramural research units, which are funded by the SAMRC but based at tertiary institutions. The scope of the projects includes tuberculosis, HIV/AIDS, cardiovascular and non-communicable diseases, gender and health, as well as alcohol and other drug abuse.

In 2015, the SAMRC entered into a memorandum of understanding with the Swedish Research Council for Health, Working Life and Welfare (FORTE) to expand collaboration between South African and Swedish scientists. The funding, which comes from both organizations, went to eleven collaborative projects that focused on inequalities of health and health system policies.

“The memorandum of understanding really underpins the relationship in terms of how we fund projects, how we operationalize projects, and so forth,” said Niresh Bhagwandin, Executive Manager of Strategic Research Initiatives at SAMRC. “That has worked very well for us.”

Under the agreement, the two organizations put out a joint call for proposals in South Africa and Sweden. The proposals went through a peer review process in both countries, and the successful projects just completed phase one consisting of a three-year funding period. The SAMRC and Forte are now looking at jointly funding phase two.

They had one co-primary investigator in each country, and the funding from each country went to its respective researchers. One project, for instance, studied the feasibility of the introduction of a Swedish human papillomavirus test (HPV) for the management of cervical disease in the Eastern Cape. Another looked at how to promote institutional collaboration between Sweden and South Africa to improve the accessibility and uptake of sexual health services among men.

The SAMRC believes that these projects will synergize and complement the expertise of scientists from both countries.

“By collaborating with our counterparts in Europe and elsewhere, we build our capacity and skills, which then can be transferred to others in our country,” said Bhagwandin.

INSTRUCT & South Africa

INSTRUCT is a distributed RI that makes high-end technologies and methods in structural biology available to researchers around Europe and increasingly outside of Europe. (Daenke & Owens, 2017)

“In the field of structural biology, we’ve been involved in collaboration with South Africa for some years,” said Susan Daenke, Coordinator of INSTRUCT. “In Cape Town, scientists were interested in using structural techniques for their work on local pathogens, specific to the South African region, and other areas of research as well.”

The researchers had very little technology in South Africa for this purpose, so they began a collaboration with partner sites in the UK to gain access to instrumentation there. When INSTRUCT was formed, they were able to broaden that relationship to include the other sites across Europe.

“That was a way that we were able to increase the value to South Africa, of bringing in more technologies and more access, pathways, training, and support for the structural work they wanted to do but were unable to service themselves with their own national facilities,” said Daenke.

INSTRUCT has also acted as a service provider for further collaborations, including a 2019 project called START (Synchrotron Techniques for African Research and Technology) funded by the UK Science and Technology Facilities Council (Project launched with Africa to develop new energy and healthcare research, 2019). The START grant aims to develop relationships between the UK and Africa in the domain of structural biology. The project is led by the Diamond Light Source synchrotron research facility, which is part of INSTRUCT. The African countries involved include South Africa, Lesotho, Ethiopia, and Egypt.

START held its first workshop at the University of Cape Town in January 2019, followed by a virtual symposium in March 2020 due to the COVID-19 pandemic. The project has already led to a publication on a pathogen found in South Africa (Ebrecht, et al., 2019), and some of the techniques used have become very important for research on the virus that causes COVID-19.

Recommendations & best practices

Many experts noted that a formalized partnership between countries – such as a memorandum of understanding, a joint grant, or RI membership – begins with individual researchers from Africa and Europe working together. Collaboration across regions must start with the science itself as motivation to move forward towards a larger commitment.

For African researchers, working with European partners often stems from a need to access specialized equipment or facilities not available in their own country or continent. According to Abberton, Nigeria lacks the infrastructure for the latest tools in agricultural research, like next-generation DNA sequencing. To gain access to such technology, IITA must work with partners outside of Africa.

"It's about being able to capitalize on those strengths of Europe and the U.S. They can maintain themselves up-to-date in areas like sequencing, where technologies are changing all the time," he said. "But we can apply those tools to our own objectives and needs here in Africa."

"The tried and tested pathway to membership always starts with a scientific collaboration," Daenke said. "So we engage with the scientists first and then rely on them to sort of act as a champion locally to engage the other key stakeholders."

The local scientists are the ones who know who in the ministry they should be talking to, who the local organizers are, and which individuals are the decision-makers. So she recommends relying on the scientists to make the initial broader contacts within their own country, and then representatives from the RI can develop those further.

Several experts mentioned that mutual benefit is a key part of successfully working together. During his Ph.D. work, Sithole realized that African scientists have the ability to bring new research topics to the table. In the field of materials science, Sithole worked on difficult questions related to the mining industry in South Africa. He collaborated with UK universities that had the materials analysis tools he needed to complete his research.

"They had these tools, but they never applied them to the problems that we were presenting," said Sithole. "It made for a very good collaboration in the sense that we were coming up with specific problems for these tools that had never been tested beyond what the people in Europe understand."

Daenke agrees, noting that structural biology research in Africa tends to revolve around local pathogens and diseases in both humans and animals that European scientists don't have any experience with. The unique geographical context of such research brings new and uncharted topics to the table.

When it comes to formalizing African-European RI collaboration, experts stress the importance of laying out expectations and standards in writing. As an example, Bhagwandin brought up a key point about intellectual property. There have been past instances where researchers come from Europe or elsewhere, "parachuted" into an African country, performed the study, and published their findings. But any benefits from the study failed to get back to the local researchers who worked on the project.

"We have had experiences where IP has been taken from the country, and we haven't been compensated adequately," he said. "So there is a certain amount of suspicion by researchers here."

Both parties need to be protected when it comes to intellectual property, and Bhagwandin adds that sound material transfer agreements must be in place. He wants African researchers to avoid the situation of having their unique samples taken by industrialized countries and exploited for their own purposes, such as drug development, with very little credit or monetary return coming back.

Abberton also recommends that European researchers need to engage with people and institutions on the ground in Africa instead of just shipping equipment over and expecting experiments to happen. They need to have boots on the ground, so to speak. In the past, he has seen several instances of equipment sent from Europe or the U.S. either stuck in the port or gathering dust in a building somewhere. Perhaps it broke and no one knows how to fix it, or it requires a reliable source of electricity, which doesn't always exist in Africa.

"These are projects that have been funded to increase infrastructure in national programmes and have not at all been effectively utilized," said Abberton. "So I would say very strongly that all those details have to be carefully thought through."

Even IITA has had issues with procurement in the past. Sometimes chemicals with a finite expiration date, like biological reagents, will get stuck in the port for years. The electricity also fails very regularly, but IITA thankfully has four or five generators in place to rely on as backup.

"European scientists should think about the actual needs of research in Africa. Otherwise, there is a big danger of repeating the research pitfalls of the past," he said. "Some of it requires things that scientists would not traditionally do, like figuring out supply chain issues or regulations. How will you get the equipment from A to B? Is it going to be something that functions in this heat, dust, etc.? And the training of people and capacity development is very important."

Lastly, Sithole suggests that patience and tolerance for other cultures, as well as different levels of technical competencies, is critical to a successful international collaboration. The standards put in place by the LHC in order to join its computing grid presented a high bar for the CHPC, but open communication between the two RIs helped it be an enjoyable and fruitful experience. Ultimately, the success of becoming a Tier 2 facility depended on perseverance and enthusiasm from both parties.

Challenges and bottlenecks

When asked about challenges to effective RI collaboration, many experts mentioned the lack of funding for research in Africa. While bi-regional partnerships involve a pooling of resources and sharing of expertise, the majority of funding originates on the EU side (Cherry, Haselip, Ralphs, & Wagner, 2018).

"If you look at the statistics, I think we get more money from external sources outside of South Africa for research rather than from internal sources like the private sector and government," said Bhagwandin. "Funding is always a major challenge."

He believes not enough money is allocated to scientific research in South Africa because of problems with translating findings for policy makers. Researchers have trouble publishing their results in a way that people can understand, while those in government don't have the sufficient expertise to look at research outputs and translate them to policy.

In addition, Bhagwandin feels that the low research capacity in Africa is a bottleneck to RI collaboration with Europe. A very small portion of researchers are medically qualified in South Africa because they spend years training to become a doctor and need to earn money afterwards to pay off their student loans. Research doesn't pay very well, so not many choose to go that route.

As a result, differences in capacity and skill level could create an initial rift between African and European researchers. Sithole mentioned that CERN engineers had to help the CHPC meet its standards for becoming a part of the Worldwide LHC Computing Grid. This bottleneck, however, is not exclusive to collaborations with African countries. Swift stated that even some European countries joining the ESS had a lack of quantitative data analysis expertise.

"We have had to put a lot of work into getting the national teams up to our high standard," said Swift. "I suspect the lesson here is that there needs to be a lot of focus on capacity building, but you are still at the behest of local conditions and funding structures."

On a related note, Daenke states that navigating the labyrinth of government and politics in an unfamiliar country can be a barrier to entry. INSTRUCT has tried to broaden its reach into African countries such as Mali, Cameroon, Nigeria and Kenya. But it has proven challenging to wade through the politics and funding capabilities of the different countries.

"In Africa, we have dealt mostly with South Africa, but that's not to say that we aren't aware that there are plenty of other African countries where there is some structural biology. But it's very difficult sometimes to understand the local political scene, which can be very complicated," she said. "We have found it quite difficult to engage with those countries, partly because they tend to have small projects that are rather independently run, and so we haven't so far been able to bring everybody together under a single umbrella."

Typically, it takes five years of work for a non-European country to go from a scientific collaboration to achieving INSTRUCT membership due to all these factors.

Abberton also brings up the point that some Europeans may have a negative perception of traveling to Nigeria and other countries in Africa. He notices that institutions in Europe and the U.S. will organize workshops mostly in places like Nairobi, Kenya or Accra, Ghana.

"I think once people come here, it's fine, but there is that perception, which means there may be a reluctance to collaborate," said Abberton. "There are some countries which just naturally people are more comfortable visiting in Africa compared to others."

Advice for policy makers and funders

Policy makers should start with co-creating an RI roadmap with local partners, if the country doesn't already have one. Such a framework prioritizes the development of national RI needs and provides guidance to government bodies on RIs as necessary tools for research, development, and innovation.

The South African Research Infrastructure Roadmap, for instance, was developed through a joint agreement between South Africa and the EU (South African Research Infrastructure Roadmap, 2016).

“Research infrastructures are very much an important priority for South Africa,” said Pillay. “We should never look at a research infrastructure as just a research infrastructure. It’s about the benefits that accrue from that research infrastructure being in a specific place.”

To convince policy makers to fund a collaborative RI project, the larger socioeconomic benefits must be emphasized. Pillay mentions the SKA as a global RI project that has already had positive effects on the neighbouring community that go beyond the science.

“We’ve set up a new university focused on the skills needed for the SKA like data analytics and computing, which is important for the community because they didn’t have access to a university before,” she said. “It’s about using the research infrastructure to leverage off on some of the socioeconomic development associated with it.”

Adams describes three criteria that influence whether an RI-related project will receive funding from the DST or not: critical mass, affordability, and alignment with national priorities. First, he asks whether there is a critical mass of researchers in the country who need access to the facility. If there are only two or three of them, then the project is unlikely to be funded. Second, the project needs to be affordable – especially given that European RIs require payment in Euro or Swiss francs.

“Lastly, we need to know the objectives of the collaboration, and how they align with the priorities of the country,” said Adams. “There are always competing priorities, because providing money for researchers to go to CERN means less money for building hospitals or HIV/AIDS research. An emerging requirement for our researchers is to demonstrate translation of the research in terms of societal impact.”

He also suggests that countries interested in collaborative research could start with signing a low-commitment letter of intent for a year to test the waters. The letter of intent allows researchers to visit the facilities, attend workshops, and start conversations around potential projects.

“After a year, you learn what that facility is about and what you can offer, if you like what you see and hear, you can go into a formal agreement,” he said.

While research funding is an issue for African countries, European programs that are open to the world or emphasize non-EU partners have worked well to foster collaboration between the two continents. Horizon 2020 is the biggest EU Research and Innovation program to date, with nearly 80 billion Euro worth of funding available over 7 years (2014 to 2020). It is “Open to the World,” meaning that participants from anywhere can apply for most of the calls. In addition, several topics strongly encourage or require cooperation with non-EU partners. The successor to Horizon 2020, Horizon Europe, will cover the period of 2021 to 2027.

As of 2019, the EU has invested a total of 123 million Euro in African Union partners and funded 310 African projects through Horizon 2020 (Horizon 2020: Africa and the EU strengthen their cooperation in research and innovation, 2019). South Africa had 126 projects funded by the program, followed by Morocco with 50 projects and Kenya with 47 projects. The main thematic areas are environment, food, information and communication technology, and health. Horizon Europe, the successor program to Horizon 2020, should provide similar opportunities.

On a smaller scale, the ESS and SASAS tapped into the UK's Newton Fund for their project, which supports research and innovation partnerships with 17 countries including South Africa and wider Africa. Or two nations could work together to contribute funding, such as in the case of the SAMRC and Sweden's Forte. The two organizations each funded their own country's researchers to focus on collaborative projects.

Future opportunities and areas of growth

All experts believed that the opportunities for African-European RI collaboration would only increase in the future. One reason is the growth of e-infrastructures, which involve networked systems in which technologies and social institutions are intertwined. Today, almost all large-scale research activities include or are supported by several e-infrastructure components (e-IRG secretariat, 2017). Resources are shared and used remotely, which allows researchers from Africa and Europe to collaborate without incurring the costs of travel and accommodation.

As an example, some of the structural biology instrumentation at INSTRUCT can be accessed remotely. Researchers ship their samples to the site where the instrument is based and can even watch in real-time as the data are collected live. Some work has to be done to ensure that sample quality is maintained during shipping and handling, but it is a much cheaper option for African scientists who need those particular tools.

In addition, Pillay sees e-infrastructure as an important resource that can benefit a wide range of scientific projects. The CHPC provides computing power for calculations and simulations that cover physics, infectious disease, bioinformatics, energy storage, astronomy, and environmental science to name a few.

"I think digital skills, high-performance computing, and data analytics are things that can be used from a research infrastructure perspective across different domains," she said. "It isn't necessarily confined to one field like ocean research or agriculture. These resources are cross-cutting."

Both Pillay and Adams stress the geographical advantages of South Africa for research, which can be extrapolated to the continent as a whole. When it comes to identifying research priorities, the DST has focused on South Africa's unparalleled access to the southern oceans, the Southern Sky, and the Antarctic. For instance, South Africa signed a joint Statement on Atlantic Ocean Research and Innovation Cooperation with the EU and Brazil in 2017 to better understand the ecosystems and climate of the South Atlantic (EU expands its research cooperation with Brazil and South Africa, 2017). The statement specifically describes the sharing of RIs within the partnership in order to increase operational efficiencies.

In medical research, Bhagwandin mentions that South Africa has good expertise – and a plethora of patients – in areas like HIV/AIDS, tuberculosis, and diabetes. Daenke mentions that research conducted with South Africa on local infectious disease pathogens has become very important in light of the COVID-19 pandemic.

Lastly, the experts mentioned outreach activities by RIs as being crucial to increasing the amount of African-European RI collaboration. Summer schools, workshops, and internships based at RIs are all excellent ways to get young people involved at an early stage to build skills and training. INSTRUCT provides internship grants twice a year for students and young researchers to travel to one of its centres to work for three months.

"For scientists from a country where structural biology is perhaps less mature, they really thrive in those conditions because they see first-hand how a busy collaborative laboratory in Europe works," Daenke said. "They get exposed to all the collateral benefits of being in a place like that. The grants are competitive, but if you get one, it could really kickstart your career."

In general, part of INSTRUCT's outreach programme focuses on regions in Africa, Australia and Latin America where structural biology is less established.

Conclusion

African-European RI collaboration has the potential to advance scientific progress in several areas, including astronomy, agriculture, environmental science and medicine. Challenges and bottlenecks do exist – for instance, a lack of funding, low research capacity and political barriers – but the case studies outlined in this report demonstrate that these can be successfully overcome.

Key recommendations from experts to facilitate African-European RI partnerships can be categorized into actionable items for RI representatives, policy makers and funders.

Key recommendations for RI representatives

RATIONALE/GLOBAL CHALLENGES

- RIs are often involved with global issues and need to include Africa in its research, both in terms of data and solutions.

FRAMEWORK

- Offer different approaches, concepts and other means of participation to countries outside of the continent.
- Provide a formal framework for partnership between countries, such as a memorandum of understanding or a joint grant including expectations and standards for the RI collaboration.
- Recognize that the RI collaboration should have mutual benefit to both parties.

CO-CREATION BASED ON NEEDS

- Patience and tolerance for other cultures, as well as different levels of technical competencies.
- Learn new approaches: working in different parts of the world requires simpler and different solutions, based around mobile technology and scarcity of research infrastructure.
- Engagement with the people and institutions on the ground.

ACCESS

- Access for outside researchers to have RI access for specialized equipment or facilities that may not be available in their own country or continent.

OUTREACH

- Organization of outreach activities such as workshops and summer schools for international students.

BEST PRACTICE

- Learn from existing success stories of African-European RI collaborations.

Key recommendations for policy makers & funders

FUNDING

- Assess the value of potential RI projects through the lens of critical mass, affordability, and alignment with national priorities.
- Join forces to contribute funding from both the European and African side, with each supporting their own country's researchers to focus on collaborative projects.
- Promote synergies between funding agencies working towards shared objectives.
- Lobbying with key decision-making entities such the African Union for more funding for research
- Continue to develop and promote European funding programs that are open to the world or emphasize non-EU partners.

FRAMEWORK

- Co-develop RI roadmap, if the country doesn't already have one.
- Consider signing a low-commitment letter of intent for a year with another country to test the waters of collaboration.

CO-CREATION BASED ON NEEDS

- Listen to the local research community and assist its members in forming proposals that are relevant to local communities, tackling local impact of global issues, and devising appropriate solutions.
- Listen to the local research community and assist its members in forming proposals that show their project's socioeconomic benefit.
- Support capacity building initiatives on both continents to enable wider use of RIs, including establishing local hubs and sample collections to avoid loss of precious samples and create a resource of international importance.

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Table 1: Examples of research infrastructures in Europe and Africa

Energy	• European Carbon Dioxide Capture and Storage Laboratory Infrastructure (ECCSEL) • South African National Energy Development Institute (SANEDI)
Environment	• European Multidisciplinary Seafloor and water column Observatory (EMSO) • BIOdiversity Monitoring Transect Analysis in Africa (BIOTA Africa)
Biomedical Sciences	• European Clinical Research Infrastructure Network (ECRIN) • African Network for Drugs and Diagnostics Innovation (ANDI)
Physics & Engineering	• European X-Ray Free-Electron Laser Facility (European XFEL) • Southern African Large Telescope (SALT)
Social Sciences & Culture	• Survey of Health, Ageing and Retirement in Europe (SHARE) • South African Social Attitudes Survey (SASAS)
Big Data & Computing	• European High-Performance Computing Joint Undertaking (EuroHPC JU) • National Integrated Cyber Infrastructure System (NICIS)

Many more examples of research infrastructures can be found in the RISCAPE International Research Infrastructure Landscape 2019, which can be found online at https://riscape.eu/riscape-report/.

APPENDIX A: List of experts interviewed

Dr. Michael Abberton
Head of the Genetic Resources Center at the International Institute of Tropical Agriculture (IITA)

Abberton is Head of the Genetic Resources Center at the International Institute of Tropical Agriculture (IITA) based in Ibadan, Nigeria. He obtained his B.Sc. in Botany and Ph.D. in plant cytogenetics from the University of Manchester and subsequently undertook postdoctoral research in molecular biology at the University of St. Andrews. Following two years working on coffee germplasm improvement in Malawi, Abberton joined the Institute of Grassland and Environmental Research (IGER) in Aberystwyth, UK. in 1993. For a number of years, he carried out research and breeding in forage legumes and became Head of the Plant Genetics and Breeding Department at IGER. Following merger with Aberystwyth University in 2008, which created the Institute of Biological, Environmental and Rural Sciences (IBERS), he became Professor of Public Good Plant Breeding and Director of International Development.

Dr. Daniel Adams
Chief Director for Basic Sciences and Infrastructure at the Department of Science & Technology (DST) in South Africa

Adams is the Chief Director for Basic Sciences and Infrastructure at the Department of Science and Technology (DST), the South African government department responsible for scientific research. His responsibilities include the development and support of basic science research in fields like mathematics, physics, and chemistry. His portfolio also includes the oversight and management of research infrastructures, both lab-based physical infrastructure as well as e-infrastructure. Adams received his Ph.D. in materials science from Arizona State University in the U.S. He spent almost three decades in the higher education sector as a professor at the University of the Western Cape before joining the DST in 2007.

Dr. Niresh Bhagwandin
Executive Manager of Strategic Research Initiatives at the South African Medical Research Council (SAMRC)

Bhagwandin is the Executive Manager of Strategic Research Initiatives at the South African Medical Research Council (SAMRC), an organization that conducts and funds health research and medical innovation. His portfolio includes collaboration with a number of funding institutions across the world such as the National Institutes of Health (NIH) and the Centers for Disease Control and Prevention (CDC) in the U.S., as well as Forte in Sweden. Bhagwandin received a Ph.D. in biomedical engineering from the University of Cape Town and an M.B.A from Keele University. He has held his position with the SAMRC for almost 23 years.

Dr. Susan Daenke
Coordinator of the Instruct-ERIC Hub

Daenke is the Coordinator of the Instruct-ERIC Hub, a pan-European distributed research infrastructure making high-end technologies and methods in structural biology available to users. She is responsible for the delivery of all access, training, internship, and networking offered through Instruct. She has more than ten years of experience in managing and coordinating large European projects in structural biology. Daenke is a former scientist and group leader who oversaw the implementation of the first European

Commission access program to be run at the structural biology facilities through the I3 project P-CUBE and subsequently through the Biostruct-X project.

Vinny Pillay
Senior Science & Technology Representative at the South African Embassy

Pillay is the Senior Science & Technology Representative to the EU, of South Africa's Department of Science & Innovation. She is currently based at the South African Embassy in Brussels. She holds a Master's Degree in Science, and a Master's Degree in Business Leadership, with experience in international relations, the science and technology sector as well as the environmental sector. In her previous role as Chief Director-Bilateral Cooperation, Pillay managed the science, technology and innovation cooperation between South Africa and strategic partners in Europe, Americas, Asia and the Gulf. In engaging with bilateral partners, she negotiated value addition to the South Africa science system, promoting research, exchanges, human capital development as well as policy dialogues in key science, technology and innovation priority areas.

Dr. Happy Sithole
Director of the Centre for High Performance Computing (CHPC) in South Africa

Sithole is the director of the Centre for High Performance Computing (CHPC) at the Council for Scientific and Industrial Research (CSIR), South Africa's central and premier scientific research and development organization. The CHPC is one of three primary pillars of the national cyber-infrastructure intervention supported by the Department of Science and Technology (DST). The South African National Research Network (SANReN) and the Data Intensive Research Infrastructure of South Africa (DIRISA) complement the CHPC through the provision of high-speed, high-bandwidth connectivity, and the effective curation of a variety of notably large and critical databases. Sithole completed his Ph.D. in materials science, focusing on electronic and atomistic simulation of iron sulphides, at the University of Limpopo. He has led South African participation in the international student cluster competition, hosted by the International Supercomputing Conference – twice walking away with the first prize.

Stefan Swift
Media and Communications Officer at the European Social Survey (ESS)

Swift is the Media and Communications Officer at the European Social Survey (ESS), an academically driven cross-national survey that has been conducted across Europe since its establishment in 2001. Following an application to the European Commission, the ESS was awarded European Research Infrastructure Consortium (ERIC) status in 2013. In the role, he has created -- and is now delivering -- a comprehensive Media, Communications and Public Affairs Strategy to assist the dissemination of results to the European Community in Brussels, European civil society and policy-makers, and the general public in Europe. Swift has developed news material using contemporary and historical survey data accrued and deciphers what can be complicated academic research into more understandable language for the general public. He previously worked for Tower Hamlets Council and London Communications Agency.

APPENDIX B: Further Reading

ESFRI Roadmap 2018: Strategy Report on Research Infrastructures: http://roadmap2018.esfri.eu/media/1066/esfri-roadmap-2018.pdf

RISCAPE International Research Infrastructure Landscape 2019: https://riscape.eu/wp-content/uploads/2019/12/Riscape_report_digi_19122019.pdf

South African Research Infrastructure Roadmap 2016: https://www.gov.za/sites/default/files/gcis_document/201610/sa-research-infrastructure-road-mapa.pdf

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Joint Communication to the European Parliament and the Council - Towards a comprehensive Strategy with Africa: https://ec.europa.eu/international-partnerships/system/files/communication-eu-africa-strategy-join-2020-4-final_en.pdf

Towards an African Light Source by Simon H. Connell, Sekazi K. Mtingwa, Tabbetha Dobbins, Nkem Khumbah, Brian Masara, Edward P. Mitchell, Lawrence Norris, Prosper Ngabonziza, Tshepo Ntsoane, and Herman Winick: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6682199/