SOUTH AFRICAN | RESEARCH INFRASTRUCTURE ROADMAP

FIRST EDITION

science
& technology

Department:
Science and Technology
REPUBLIC OF SOUTH AFRICA

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MINISTER'S FOREWORD

There is a realisation that access to adequate and relevant research infrastructure is essential to promote the outcomes and quality of research. In order to maximise the return from investment in research, scientists and researchers must have access to modern and appropriate infrastructure. To underpin this, adequate levels of funding for such infrastructure should form a key component of any national research system.

Through a joint agreement between South Africa and the European Union, the South African Research Infrastructure Roadmap (SARIR) framework was developed as the basis for prioritising the development of national research infrastructure needs. SARIR is a high-level strategic and systemic intervention to provide research infrastructure across the entire public research system, building on existing capabilities and strengths, and drawing on future needs. This roadmap will provide guidance to the Department of Science and Technology (DST) on the strategic development, acquisition and deployment of research infrastructure as a necessary enabler for research, development and innovation.

A sector-based bottom-up approach was used to develop SARIR. Six scientific domains were identified in which research infrastructure needs to be developed, namely, humans and society; health, biological and food security; Earth and environment; materials and manufacturing; energy; and physical sciences and engineering. Originally 17 research infrastructures (RIs) across the six scientific domains were recommended for inclusion in SARIR, with their scope ranging from medium to large. Following a rigorous review and evaluation process, 13 RIs were selected from five of the domains to constitute the SARIR.

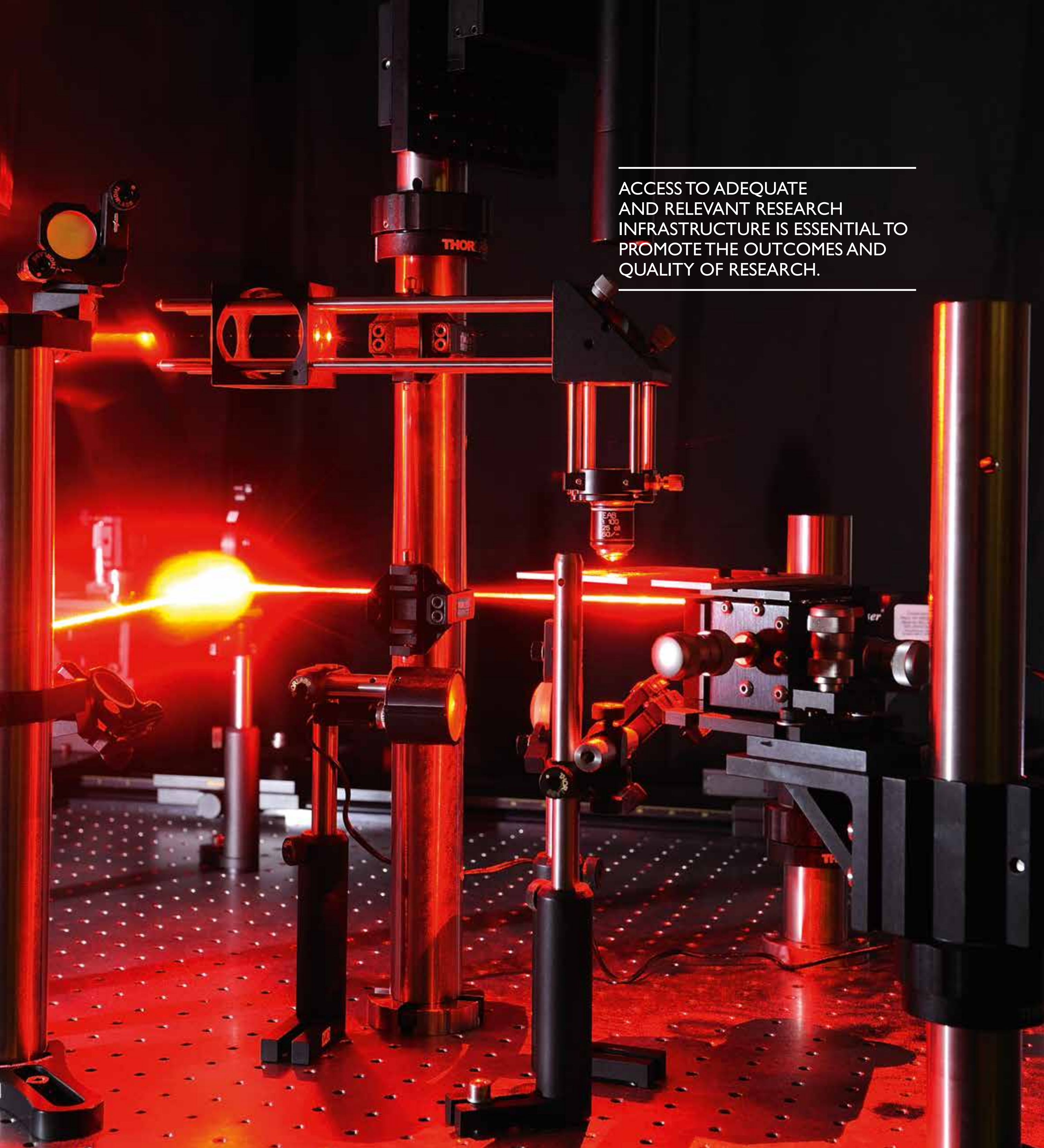
Given the scope and nature of the selected RIs, some of them will be implemented by entities under the auspices of departments other than the DST, making SARIR a truly intergovernmental initiative. The expected long and short-term outcomes of SARIR will undoubtedly contribute to the high-level goals of the Department, thereby benefiting not only the country, but also responding to continental and global challenges.

SARIR will be evaluated and reviewed every three years in order to monitor the implementation of the selected RIs and update the roadmap.

I am proud to present the first SARIR to the entire science community in South Africa and all relevant stakeholders.

MRS GNM PANDOR, MP
MINISTER OF SCIENCE
AND TECHNOLOGY

Right: Cutting-edge digital laser with liquid crystal display at the CSIR National Laser Centre.



ACCESS TO ADEQUATE AND RELEVANT RESEARCH INFRASTRUCTURE IS ESSENTIAL TO PROMOTE THE OUTCOMES AND QUALITY OF RESEARCH.

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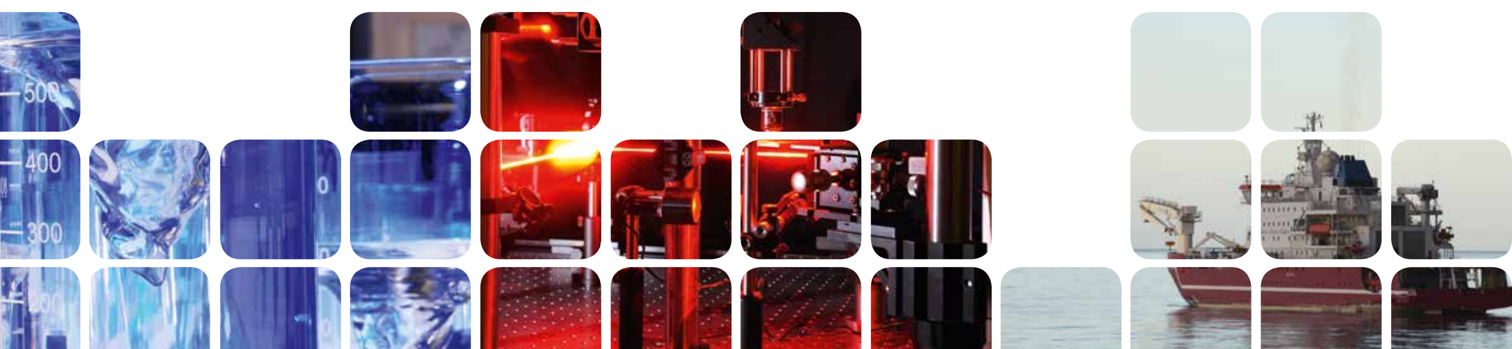

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EXECUTIVE SUMMARY

South Africa has considerably strengthened its association with global projects such as the Square Kilometre Array (SKA) and the Larger Hadron Collider at CERN, the European Organisation for Nuclear Research. Investment in astronomy has been significant and the country has successfully attracted a major part of the SKA. Likewise, substantial investment in the Southern African Large Telescope as a global facility shows the importance South Africa places on research infrastructure to engage global science.

To complement the focus on global infrastructure in South Africa, a South African Research Infrastructure Roadmap (SARIR) has been developed to facilitate a research infrastructure investment programme. SARIR is intended to provide a strategic, rational, medium to long term framework for planning, implementing, monitoring and evaluating the provision of research infrastructures (RIs) necessary for a competitive and sustainable national system of innovation. SARIR also provides a basis for discussion concerning financing future infrastructure for research in South Africa, and for participating in joint international RIs.

The roadmap was developed through a bottom-up process driven from within the national research community, moderated at a technical level by an expert Steering Committee and aligned with national research priorities through strategic moderation by the Department of Science and Technology (DST).

The list of 17 RIs initially emerging from the consultative process ranged from medium to large and were clustered around six scientific domains, namely, (i) humans and society, (ii) health, biological and food security, (iii) Earth and environment, (iv) materials and manufacturing, (v) energy and (vi) physical sciences and engineering. Through two iterations of detailed business plans prepared by dedicated champions for each of the 17 RIs, coupled with dual expert reviews by a Steering Committee comprising 15 experts from a wide array of sectors, 13 RIs from five scientific domains eventually emerged as concrete and sufficiently conceptualised proposals for inclusion in SARIR.

13 RIs FROM FIVE SCIENTIFIC DOMAINS EMERGED AS CONCRETE PROPOSALS FOR INCLUSION IN SARIR.

The RIs that are included in the first iteration of SARIR are listed per scientific domain in the accompanying table.

Scientific domain	Identified RI
Humans and society	South African network of health and demographic surveillance sites
	National centre for digital language resources
Health, biological and food security	Distributed platform for "omics" Research
	Biobanks
	Nuclear medicine research facility
Earth and environment	South African marine and Antarctic research facility
	Biogeochemistry research infrastructure platform
	Expanded national terrestrial and freshwater environmental observation network
	Shallow marine and coastal research infrastructure
	Natural sciences collection facility
Materials and manufacturing	Materials characterisation facility
	Nano-micro manufacturing facility
Energy	Solar research facility

Several of the RIs in the table above are closely related to or extend existing RIs, which consequently present themselves as obvious hosts for the new RIs; this is especially true in relation to the national facilities of the National Research Foundation (NRF). However, the scientific domains, nature and scope of others place them outside the current mix of national facilities, making research institutions such as universities and science councils would be more suitable hosts for the identified RIs.

On the basis of a comprehensive and robust assessment process, the following seven RIs were approved for establishment in the 2016/17 financial year:

- An expanded terrestrial and freshwater environmental observation network.
- A nuclear medicine research facility.
- A South African network of health and demographic surveillance sites.
- A national centre for digital language resources.

Above: High resolution transmission electron microscope at CHRTEM, Nelson Mandela Metropolitan University.

- A Natural science collections facility.
- Shallow marine and coastal research infrastructure.
- Distributed platform for "omics" research.

The DST has budgeted for the medium-term costs for the above RIs, but additional funds will need to be secured from a combination of sources, including the public fiscus, other government departments, the host institutions themselves, the private sector and international sources, as relevant. Further conceptual work will be done on the six RIs not included for immediate establishment, while the Department seeks additional funding for the longer-term implementation of the roadmap, in consultation with relevant stakeholders.

SARIR PROVIDES AN EXCITING OPPORTUNITY FOR SOUTH AFRICA TO BECOME PROMINENT IN INTERNATIONAL RESEARCH.

The DST will monitor the implementation of SARIR with the support of a national SARIR Advisory Committee, and the roadmap itself will be reviewed every three years, with the intervals increasing over time. The Department will also endeavour to remain part of global discussions and communities of practice on the role of RIs in research development and innovation, in order to ensure that SARIR remains an example of best practice in this regard.

This roadmap provides an exciting opportunity for South Africa to become more prominent in international research, making the country more attractive to international stakeholders.

1 INTRODUCTION

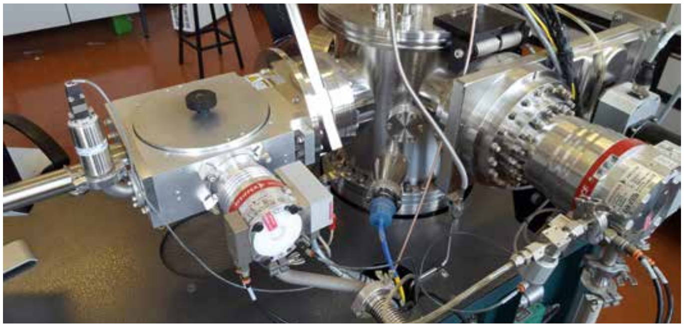
The importance of developing and establishing research infrastructure (RI) to support national research and innovation systems is self-evident, and given the cost involved in most cases, such initiatives always involve planning. Until comparatively recently, though, planning for the development of individual facilities was generally approached in an ad hoc fashion, with little regard for the collective infrastructure landscape of the country or region, and seldom in the context of a comprehensive, system-wide, long-term plan.

SCIENCE PLANNERS AND POLICY MAKERS HAVE INCREASINGLY BEGUN SYSTEMATIC PLANNING AROUND RESEARCH INFRASTRUCTURE.

However, in the past two decades, science planners and policy makers have increasingly begun to systematise planning around research infrastructure. For instance, in 2008 the G8+5 group of countries established an informal Group of Senior Officials on Global Research Infrastructures (GSO), which began meeting regularly from 2011 onwards, and is advancing an analytical and systematic approach to understanding and promoting the role of RIs in research ecosystems. Such interests and endeavours have also given rise to the European Strategy Forum for Research Infrastructures. This spawned the International Conference on Research Infrastructures, which is becoming the premier global forum for academic and practical exchange of knowledge on RIs. It is in this context that the concept of research infrastructure roadmaps has emerged and been promoted.

The idea of producing RI roadmaps started just over a decade ago for both national and international RIs, and they are now becoming an increasingly common feature of the research landscape. The first, and most obvious reason, is that they allow funders to budget knowing what can be expected. Secondly, and most importantly, roadmaps force researchers to come together to share their ideas and work together for the national good. Thirdly, roadmaps make it possible for researchers to plan their own research in the reasonable knowledge of what will be supported. Roadmaps also inform institutions and other countries what is envisaged in the way of RIs and to plan their investments in human and support services accordingly.

Left: Deployment of a current meter as part of the Agulhas System Climate Array.
Below: Physical vapour deposition system.



[1]*European Strategy Forum on Research Infrastructures Roadmap, 2016.*

The SARIR initiative is a high-level strategic and systemic intervention to provide research infrastructure across the entire public research system, building on existing capabilities and strengths, and drawing on future needs. The roadmap is a long-term research infrastructure investment plan complementing existing research equipment programmes (such as the National Equipment Programme and the national Strategic Research Equipment Programme), conceptualised and developed at a higher level. The overall objective of SARIR is to provide a strategic, rational, medium to long-term framework for planning, implementing, monitoring and evaluating the provision of research infrastructures necessary for a competitive and sustainable national system of innovation (NSI).

RIs INCLUDE FACILITIES, RESOURCES AND SERVICES.

The production of SARIR was supported by the European Commission, and informed by the experience gained in Europe in both the Union and in the member states.

In the above context, the concept of "research infrastructure" 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. It includes major facilities, equipment or sets of instruments, collaborative networks and knowledge-containing resources such as collections, archives, databanks and biobanks. Research infrastructure may be single-sited, distributed, or virtual (the service being provided electronically).

Right: Southern African Large Telescope.

National research infrastructure should–
- award free, open access to users selected through a world-class peer-review competition;
- ask the users to publish/share their research results in the public domain;
- manage access for proprietary and/or training activities;
- have, as a mission and goal, a clear national scientific priority, e.g. to attract at least 30% of the selected users coming from non-host (non-owner) countries.

The definition of RI used by the European Strategy Forum for Research Infrastructures[1] introduces the basic guiding principles for an RI. It should be built, managed, operated and funded to serve external researchers, chosen independently of the ownership (or the capability of the users to pay for the service) and only on the basis of the quality of their proposals, which should be evaluated on the basis of independent and international peer review. In return for being admitted free of charge, users must share their research results in the public domain, and/or with the RI.

The concept of results encompasses both the specific results of the research performed with the use of the RI facilities and the possible results of developments performed to increase the technical capabilities while working at the RI. The former are normally shared in the public domain, while the latter are not, in most cases, and may lead to new technologies or ways of working that can be further exploited.

The general result for local stakeholders, in addition to undertaking their own research, is a continuous improvement of instruments, technologies and training of technical and scientific personnel, as well as in the quality of science produced. These are the effective results (or returns on investment) for the national and local funders, which justifies the free open access.

NATIONAL RIs SHOULD BE OPEN TO ALL BASED ON QUALITY AND EXCELLENCE.

The advantages of opening national RIs to international use have become clearer only in the last 10 to 15 years. This is now an established method to improve national investments and both the national and international quality of research, while increasing domestic capability. This is not a new concept and has been employed by the astronomy community for some time, where telescopes and observatories have for many decades been established and operated on a multinational basis.

The good governance of RIs is important for the following reasons:

- RIs are needed in all fields of science, and no single institution can provide them all.
- No nation can afford to have national facilities that are not open to all on the basis of quality alone; and ensuring that the operation of the RIs adheres to the principles of good governance will make them attractive to researchers and funders from other countries.

2 CATEGORISING RESEARCH INFRASTRUCTURE

2.1 Different types of research infrastructure

This chapter focuses on the various types of research infrastructure. However, the development of complex RI also implies the development or optimisation of complex technologies. At the very least, information and communication technologies and data management services will be a fundamental part of every type of research infrastructure, but the construction phase of a new RI could also require the development and testing of new materials, the robotic manipulation of scientific instruments in hazard environments, or the deployment of a distributed network of specialised sensors in a wide range of RIs.

It is necessary to distinguish between the RIs included in SARIR and smaller equipment used at a research group level. Any RI roadmap focuses attention on RIs where complexity, added value and cost require specific policy measures for the interest of the whole national community.

Figure 1 depicts the range of scientific equipment and infrastructure considered for the research infrastructure roadmap. SARIR focuses on RIs used for the whole scientific community in South Africa or, in some cases, with the participation of South Africa in other international RI. Some equipment in education or research institution departments may be included when it constitutes a component of a distributed RI and is coordinated with other infrastructures available in other nodes of the network to offer a global service to the scientific community. For reasons of comparison, Figure 1 also depicts the span of infrastructures

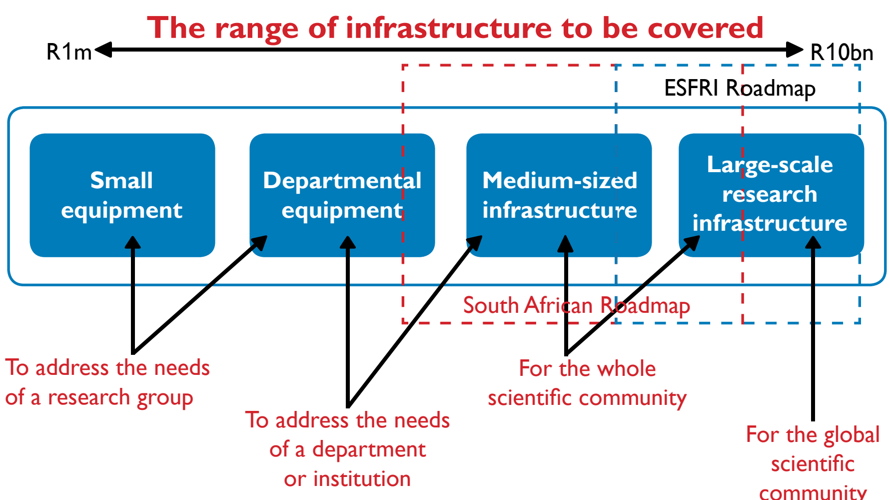


Figure 1: Range of research infrastructures for SARIR

covered by the European Strategy Forum for Research Infrastructures (ESFRI) Roadmap.

Owing to the large variety of research infrastructures and the lack of a common terminology, the GSO[2] adopted three broad categories of RIs of global relevance to be used in its discussions.

- **Single-sited global facilities** are unique, geographically localised facilities where governance is fundamentally international in character. The Large Hadron Collider at CERN and the International Thermonuclear Experimental Reactor are current examples. Future projects of global interest and relevance need to be identified. The Atacama Large Millimeter/sub-millimeter Array and the SKA are two of these; the International Linear Collider (location to be finalised) might be another. The possibility of future opportunities offered by similar projects developed in different countries needs to be kept in mind in order to ensure that there is scope for building a local facility. In this context, the Cherenkov Telescope Array could be an example.

- **Globally distributed research infrastructures** constitute national or institutional nodes, which are part of a global network, and where governance is fundamentally international in character. For example, LifeWatch, the e-Science European Infrastructure for Biodiversity and Ecosystem Research, can only function through a globally coordinated set of nodes; Argo, a system for observing temperature, salinity, and currents in the Earth's oceans, and the Global Earth Observation System of Systems (GEOSS) are two other examples. In Africa, the African Very Long Baseline Interferometry Network will be very similar to the European Very Long Baseline Interferometry Network (of radio telescopes) and would potentially benefit the global very long baseline interferometry system. Earth, ocean and sea-floor observatories belong in this category, including oceanography fleets of research vessels and polar research facilities (for both the Arctic and the Antarctic). Ad hoc distributed facilities, linked with observation campaigns of limited duration, might also be considered for inclusion in this category. Scientific information exchange, data preservation and distributed computing infrastructures relying on open high-speed connectivity may provide new opportunities in terms of virtualisation of resources, advanced simulation environments and improved and wide access to research infrastructures.

- **National facilities of global interest** are national facilities with unique capabilities that attract wide interest from researchers outside of the host nation. Antarctic or ocean drilling facilities are typical examples. The MeerKAT radio telescope in South Africa could be another example, since it will remain a globally important South African research instrument for several years prior to its amalgamation with the SKA. Existing RIs with the potential for wide international utilisation (for instance, facilities that leverage geographical advantages or exhibit unique opportunities for advanced research) may fall in this category. Countries may

[2] *Group of Senior Officials on Global Research Infrastructures Framework, 2012.*

propose national facilities that have the potential to be opened for global participation, taking care to balance national and international interests, and carefully considering which national facilities have the potential to be opened up at global level.

2.2 Single-sited versus distributed research infrastructures

Several research infrastructures incorporated in the SARIR are distributed RIs. This approach is very relevant in domains where there is no need for a single centralised RI, but where researchers should have access to a range of specialised equipment located in several sites in a coordinated way. Typically, the concept of a distributed RI evolves from situations found in many science and technology domains where relevant equipment items are dispersed and resources used suboptimally.

SEVERAL RESEARCH INFRASTRUCTURES IN THE SARIR ARE DISTRIBUTED RIs.

A distributed RI should do the following, as illustrated in Figure 2:

- Offer researchers a single entry point to a set of related equipment located in different sites and institutions across the country.
- Serve as a tool to reinforce cooperative multidisciplinary research by creating synergies in complementary services by avoiding the duplication of efforts and opening possibilities to address more complex research activities.
- Give policy makers a tool to define country-based or region-based policies in relation to the distributed RI within the domain, to obtain longitudinal data, to facilitate public-private partnerships and to support the internationalisation of the South African innovation system.
- Allocate future resources to the centralised coordination structure and give it the responsibility to distribute resources to different nodes according to strategic plans and quality of service.

The initial situation is represented as a set of non-coordinated research equipment of different sizes and locations (some of them could be duplicated and not necessarily well maintained because the responsibilities for this depends on individual institutions). The final situation implies a centralised coordination structure which provides a single window for researchers and the possibility of coordinating the allocation of resources for upgrading, for the purchasing and placement of new equipment, and its integration with pre-existing equipment in order to optimise the available resources and, if necessary, to dispose of obsolete equipment.

The transition process is not necessarily easy to implement because the creation of a national distributed research infrastructure implies the commitment of resources and the acceptance of responsibility on behalf of the whole scientific community. Any distributed research facility should be based on a contract-based commitment with the scientific community through the South African government.

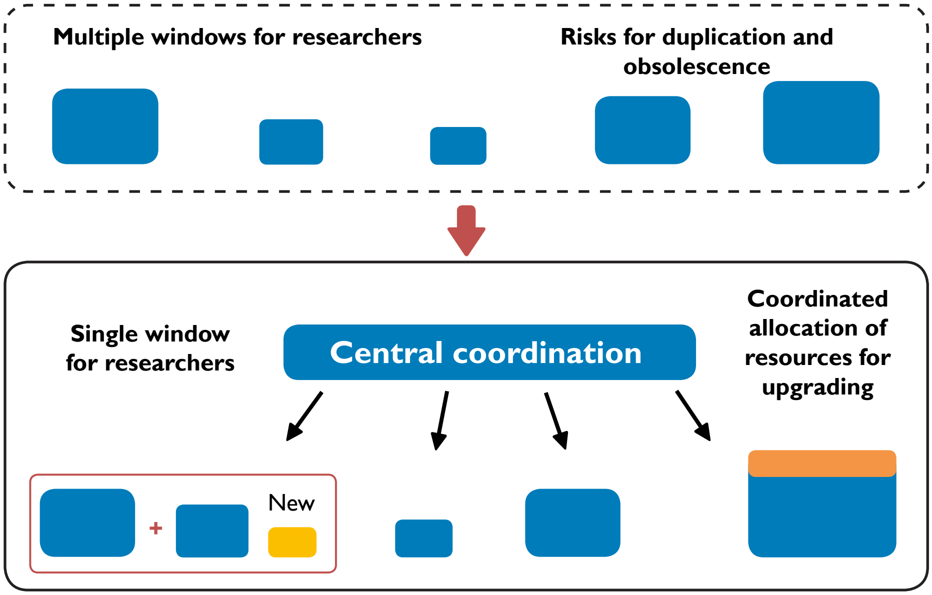
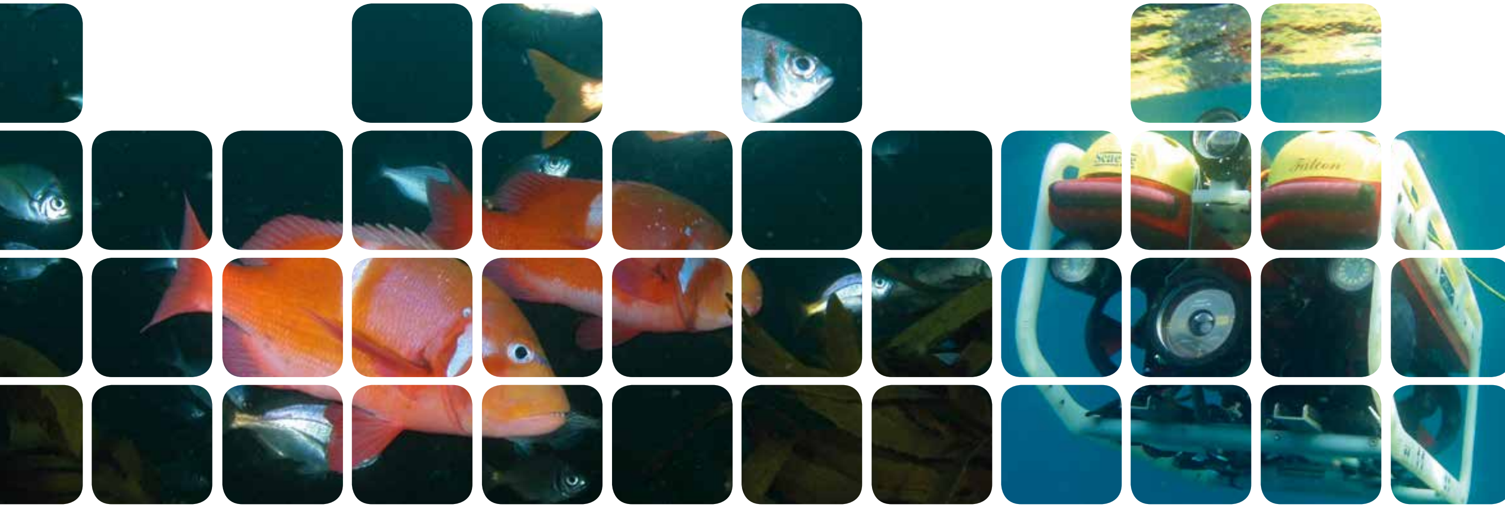


Figure 2: Transition from a dispersed set of equipment items to a coordinated structure as a distributed RI

Figure 3 indicates the main elements of such a process, which should include the following:

- Agreement between all government departments involved where appropriate. These departments should create an interdepartmental structure for funding allocations and high-level coordination.
- Contract-based commitments between the participating entities. These long-term contracts should be monitored through key performance indicators and agreed delivery plans to trace the evolution of the distributed facility and the possible reaction against deviations, the legal approach for liabilities, intellectual property issues, the management of public funds, and support for professional management.
- Memoranda of understanding (MoUs) between individual nodes and the coordination structure. These should all have similar elements, as well as specific details related to the type of equipment or services offered. All nodes will therefore be subject to the governance requirements of both the host institution to which they belong (university, research centre, etc.) and the distributed RI network, as they accept the external interface of the coordinator and the common rules as a member of the distributed RI.
- The creation of a coordination structure to serve as the interface with public administrations, to facilitate international cooperation, monitor the quality of the services offered to the scientific community, give visibility and centralised information, and distribute users' requests for access to specific nodes.



- Easy and equitable access, as in the case of site-specific RIs, the preferred mode of operation should be free at the point of access so that all researchers have a right to use the facility depending on the quality of their application. This avoids unnecessary bureaucracy and complex trading between universities, but will require the availability of funds to support the activity.

A final point is the possible participation of private entities in the distributed RI. The governance model could also attract the interest of private entities which could be interested in sharing the use of sophisticated equipment for research and commercial uses (this approach is conceptually not very far from the dual use of medical imaging systems for research and clinical use). Specific conditions should be addressed in the preparation of specific MoUs. For non-public bodies there would be an agreed system for charges.

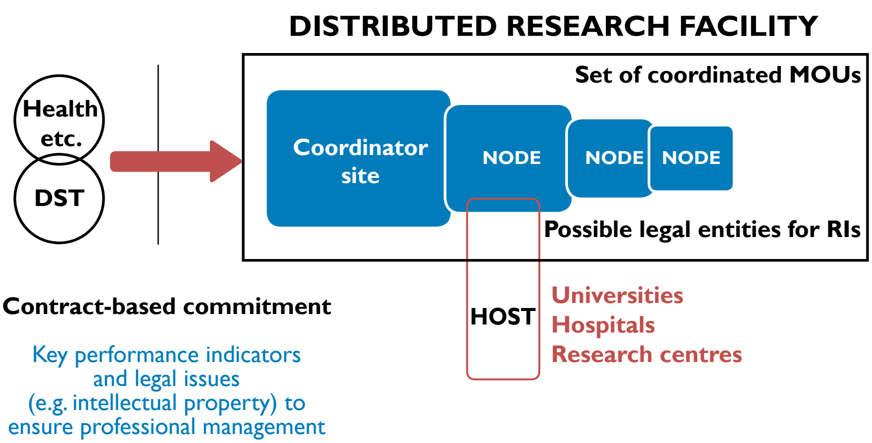


Figure 3: Structure of a national distributed research infrastructure

3 RELEVANCE OF RESEARCH INFRASTRUCTURES TO SOUTH AFRICAN RESEARCH PRIORITIES

This chapter summarises the more important government policies and strategies that define the national priorities for research and against which inclusion of the RIs in the roadmap was considered. It gives an outline of the policy developments that guide and affect research development and research infrastructure provision.

3.1 The White Paper on Science and Technology

The 1996 White Paper on Science and Technology introduced the term "science and technology infrastructure" to refer collectively to national research facilities (including universities, science councils and what are now called the national facilities), libraries, regulatory frameworks, and extended physical structures such as telecommunications networks. Particular attention was afforded the national facilities for the provision of highly specialised infrastructural platforms to undertake cutting-edge scientific research. The national facilities were therefore deemed multi-user facilities, which were to play a vital role in sustaining a vibrant NSI.

In addition, the White Paper made provision for the purchase and maintenance of expensive research equipment provided that the following principles were met:

- The equipment was accessible to the wider research community, in particular researchers from historically disadvantaged institutions.
- The equipment was placed at an institution where there was a significant concentration of researchers from the relevant scientific discipline.
- The institution contributed financially towards the procurement or development of the research equipment.

3.2 The National Research and Development Strategy

The 2002 National Research and Development Strategy (NRDS) articulates the priorities for the country under technology missions and science missions. The technology missions are intended to meet key national and social objectives, such as poverty reduction, and to promote advanced manufacturing, resource-based industries, new and emerging technologies, and innovation.

THE NRDS ARTICULATES THE PRIORITIES FOR THE COUNTRY UNDER TECHNOLOGY MISSIONS AND SCIENCE MISSIONS.

The science missions, on the other hand, emphasise the importance of making an impact on the global stage in specific areas where the country could contribute to leading-edge global knowledge. These include areas in which South Africa has an obvious geographic advantage, such as astronomy, palaeoanthropology, biodiversity, Antarctic research, and unique geological features, as well as areas in which South Africa has acquired a knowledge advantage, such as indigenous knowledge, biodiversity, deep mining technology, technologies for diseases of poverty, an integrated approach to HIV/Aids vaccine development and fluorine technology.

The NRDS operates in the context of the White Paper policy framework, with the intention of strengthening key elements of the NSI identified as requiring particular attention and focus. The main focus of the strategy is to give expression to the national goals of economic development and improvement of quality of life for all citizens.

The NRDS is indicator-based and rests on the following three pillars:

- Innovation.
- Science, engineering and technology, human resources and transformation.
- An effective government science and technology system.

Innovation

The NRDS identifies the following technology missions:

- Poverty reduction, which includes the demonstration and diffusion of technologies to improve quality of life and enhance service delivery.
- Key technology platforms, which include knowledge-intensive new industries such as biotechnology and information and communication technology.
- Advanced manufacturing.
- Leveraging resource-based industries and developing new knowledge-based industries.

The realisation of the technology missions' objectives requires a strong infrastructural foundation comprising the following:

- Reliable, low-cost and high-speed communication networks.
- Data storage and management systems.
- High-performance computing for advanced simulations, including the fast-tracking of therapeutic prototypes.
- Scientific equipment for training scientists, engineers and technologists, as well as research associated with the development of therapeutics, drug regimens and diagnostic tools.
- Accredited drug development, clinical and manufacturing facilities and biosafety laboratories. These facilities need to comply with Good Laboratory Practice and Good Manufacturing Practice standards.

THE REALISATION OF THE TECHNOLOGY MISSIONS' OBJECTIVES REQUIRES A STRONG INFRASTRUCTURAL FOUNDATION.

Advanced manufacturing is cited by the NRDS as a sector that largely comprises the automotive, chemical and pharmaceutical industries. These industries have been identified as key contributors to economic development and growth for the country. Fundamental to the advancement of these industries is the need for a transition from a resource-based to a knowledge-based sector. Underpinning this paradigm shift is the need for infrastructure to facilitate the design and development of deep mining machinery, automobile production and a new generation of biopharmaceuticals. A critical factor to make this shift successful is the need for highly trained human resources, continuous improvement, technological innovation, and the acquisition of know-how. Both infrastructure and skilled human resources are necessary for other resource-based industries such as agriculture, fishing and forestry, mining and minerals, and energy production. The economy's dependence on raw materials, cheap labour, propriety production technology and privileged access to markets is not sustainable in its current form.

Finally, the NRDS highlights the existence of the "innovation chasm" in South Africa. The proposition for closing the gap is to adequately resource the technology development process, which is the stage at which most firms are unwilling to assume such a high risk with potentially minimal returns. Resourcing this stage of the value chain would include an investment in infrastructure such as pilot plants, technology demonstrators and incubators for scale-up, product introduction, process engineering and new plant trials. These later stages of innovation are expensive and remain risky for private investors.

Science, engineering and technology, human resources and transformation

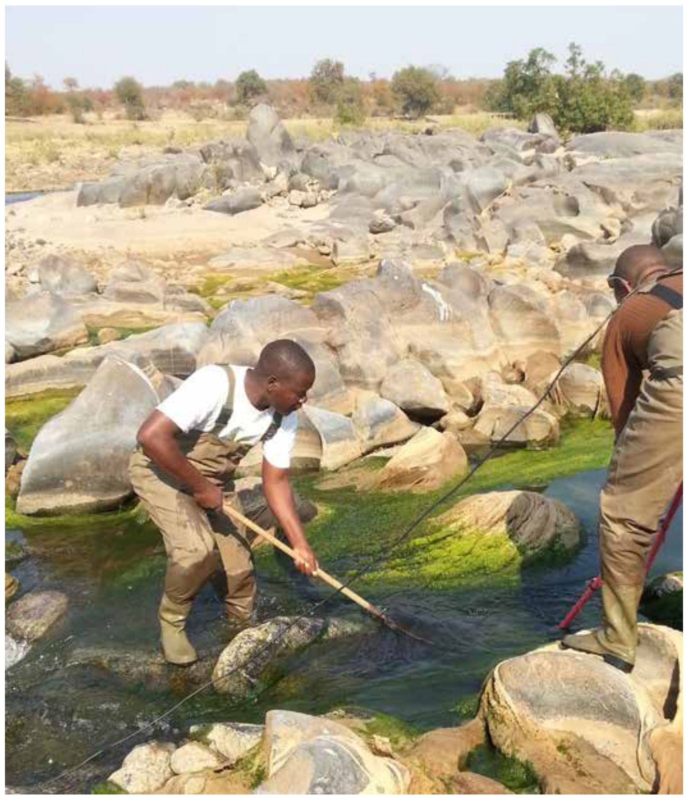
Skilled human resources are critically linked to the innovation pillar and are essential for science, engineering and technology advancement.

The NRDS encourages knowledge generation in scientific areas where South Africa has an obvious geographical advantage, including astronomy, human palaeontology and biodiversity, as well as in scientific areas where there is an obvious knowledge advantage, such as indigenous knowledge, technology for deep mining, and microsatellite engineering.

In order to grow the human capital base, scientific equipment is needed to train students and to provide an enabling environment for scientists and researchers to conduct credible, high-quality research. There is a positive correlation between human capacity and the availability of research infrastructure; the more researchers there are in a specific discipline, the greater the demand for research infrastructure, and vice versa.

Given that science is highly globalised, it is necessary to establish and strengthen international science and technology networks and connections, particularly on the African continent, thereby attracting

Below: Freshwater sampling.



[3] Department of Science and Technology Innovation Towards a Knowledge-based Economy, Ten-Year Innovation Plan for South Africa (2008-2018), 2008.

skilled human resources to South Africa. Such endeavours are to be encouraged, given that highly specialised and large infrastructure cannot be duplicated at a regional or national level. Access to such infrastructure, either in or outside South Africa, is therefore essential for researchers to be competitive.

3.3 The Ten-Year Innovation Plan

A major policy intervention that builds on the NRDS is the DST's Ten-Year Innovation Plan (TYIP)[3], which is designed to "drive South Africa's transformation towards a knowledge-based economy, in which the production and dissemination of knowledge leads to economic benefits and enriches all fields of human endeavour".

THE TYIP IS DESIGNED TO DRIVE SOUTH AFRICA'S TRANSFORMATION TOWARDS A KNOWLEDGE-BASED ECONOMY.

It identifies five areas, the so-called "grand challenges" of strategic importance for innovation. These are "Farmer to Pharma" (now generally referred to as Bioeconomy), "Space Science and Technology", "Energy Security", "Global Change" science with a focus on climate change, and "Human and Social Dynamics". Four cross-cutting drivers are recognised as key in assessing progress in these multidisciplinary priority areas, namely, human capital development; knowledge generation and exploitation; knowledge infrastructure; and enablers to address the "innovation chasm" between research results and socio-economic outcomes.

The plan emphasises that the country's economic growth will accelerate with the right mix of investment in knowledge stocks and knowledge infrastructure, and concludes that state-of-the-art infrastructure, modern laboratories and research institutions, and an NSI that is linked to the rest of the global scientific community are among the prerequisites for the successful implementation of the TYIP.

Regarding RI, the TYIP highlights the need for life-cycle planning for research and development (R&D) infrastructure (including depreciation, skills needs and running costs) and strengthening South Africa's infrastructure development through appropriate international connections to make the country a preferred destination for science and technology investment, with the location of major international research hubs across the grand challenge domains.

This policy document does not spell out the type of research infrastructure required in any detail, and only brief reference is made to RIs under the grand challenges, for example the following:

- Bioeconomy – The establishment of appropriate technology platforms, and R&D and innovation infrastructure (including for structural biology, functional genomics, etc.) that facilitate diagnostic and medical solutions and bridge the gap between research and commercial implementation.
- Space Science – Observation satellites as RI and other RIs required for Earth observation.
- Energy Security – Pilot-scale plants for the production of hydrogen by water splitting, using either nuclear or solar power as the primary heat source.

- Global Change – global monitoring capabilities on Marion Island, in Antarctica and in the Southern Ocean in partnership with other nations.

The reliance on research infrastructure has since been set out in considerably more detail in grand challenge-specific strategic and policy documents, and through actions planned and carried out following the publication of the TYIP.

3.4 The National Development Plan

The National Development Plan (NDP)[4] by the National Planning Commission outlines in sober tones the immense challenges facing South Africa, but provides a vision of what needs to be done to address these in order to place the country on a firm trajectory of growth, eliminate poverty and reduce inequality. The country's higher education system is seen as having a critical contribution to make in achieving the desired outcomes, and the NDP emphasises the need to address the capacity and quality of staff to grow knowledge production and innovation in order for universities to become world-class centres of excellence, capable of contributing to innovative answers and solutions to the challenges the country is faced with.

The NDP acknowledges the need for more investment in R&D, to improve the link between innovation and the needs of business and society, and to build the research infrastructure required by South Africa's development strategy.

While South Africa needs to spend more on R&D in general, the institutional set-up also needs to improve the link between innovation and business requirements. Government should partner with the private sector to raise the level of R&D, with resources targeted towards building the research infrastructure required by a modern economy.

It furthermore calls for greater efficiency in terms of knowledge productivity, throughput, graduation rates and participation, with particular emphasis on the growth in PhD graduates, as these are the dominant drivers of new knowledge production in the NSI. It also recognises the need for a differentiated higher education system that takes cognisance of the need for universities to build on existing strengths and allows them to respond to needs they identify.

Above: Research and Development Strategy, Ten-Year Innovation Plan and the Bio-economy Strategy – DST policy publications.

[4]National Planning Commission National Development Plan 2030, 2011.

4 RESEARCH INFRASTRUCTURES IN THE CONTEXT OF SCIENTIFIC DOMAINS

The RIs included in SARIR were selected through a bottom-up process in close consultation with the South African research community. The initial ideas were clustered around six thematic domains, and for reasons of convenience the subsequent SARIR process was taken forward within the framework of these six domains, which are depicted in Figure 4. The grouping is empirical and somewhat coincidental. The identified domains are not totally independent and it is expected that interdisciplinary RIs will eventually become more common, cutting across these domains.

During the SARIR development process, the sixth domain (physical sciences and engineering) was eliminated because the RI proposed under it was not accepted for the final SARIR blueprint. This means that the RIs chosen for implementation over the medium-term span only the first five of the domains depicted above.

RIs WERE SELECTED THROUGH A BOTTOM-UP PROCESS IN CLOSE CONSULTATION WITH THE SOUTH AFRICAN RESEARCH COMMUNITY.

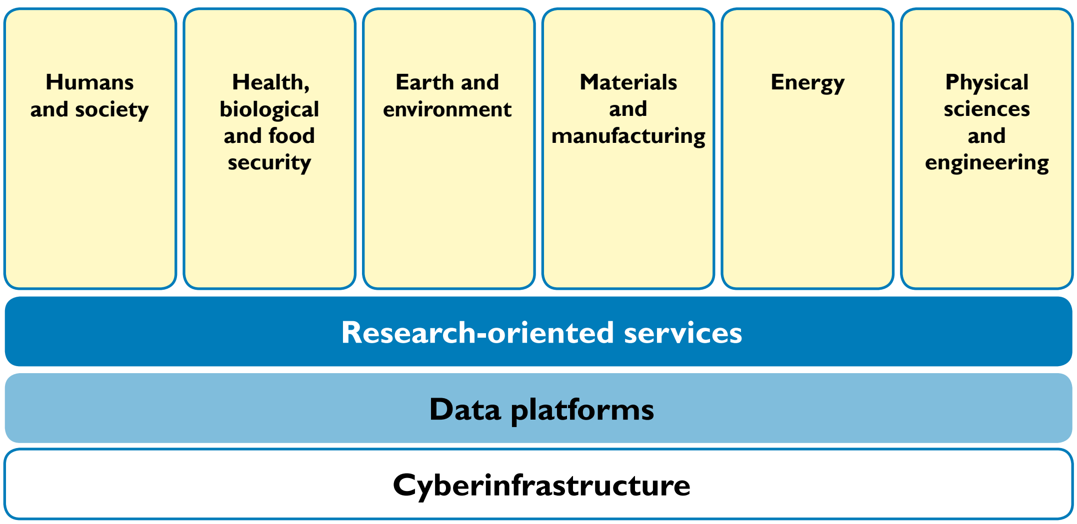


Figure 4: Scientific domains of SARIR

In addition to the vertical thematic domains, three cross-cutting horizontal support platforms were identified, whose purpose is to provide a common set of services to the scientific community in order to facilitate their work on the range of RIs. This entails the following:

- **Cyberinfrastructure:** Essential infrastructure to support data exchange, cooperative work and remote access. The very fast evolution of broadband connectivity based on fibre optics but also in the broadband mobile networks can provide unlimited access from anywhere.
- **Data platforms:** The trend towards data-driven science implies that many of the research teams will base their scientific activity on the processing of collected data and remote access. Data management services are therefore essential to ensure the competitiveness of research groups.
- **Research-oriented services:** A specific set of services linked to the RI to support not only data management, but also the development of scientific instruments, capabilities for product development (moving from laboratory prototypes to industrial prototypes) and other general-purpose infrastructures. In all these cases, data services and broadband networks are needed to facilitate the remote use of those facilities.

The South African context for the five identified scientific domains that form the basis of SARIR are described in detail in the remainder of this chapter.

4.1 Humans and society

Research in the human and social sciences is essential for social, economic and cultural development and transformation in South Africa. Yet a number of recent studies, such as the Consensus Study on the State of Humanities in South Africa: Status, prospects and strategies[5] and the Charter for Humanities and Social Sciences[6] have highlighted the diminishing role of these disciplines in academia, and emphasised that they should be enabled to play a stronger role in the development of society, the economy and intellectual life in South Africa. The need for an elevated role of the human and social sciences in the country's development has also been recognised by the DST in its TYIP[7], which highlights human and social dynamics as one of the grand challenges. The objective of this grand challenge is to increase and deepen research to improve scientific understanding and practice in a range of fields, while contributing to the development of evidence-based public policy that improves human well-being. The science plan developed for this grand challenge[8] specifically mentions the need for research infrastructure and longitudinal studies to achieve this objective.

An important issue raised during the consultations on human and social sciences is that many academics in the human and social sciences do not think in terms of national research infrastructure or of the need for a culture of sharing and cooperation on a national and even international level.

[5] *Academy of Science of South Africa Consensus Study on the State of Humanities in South Africa, 2011.*
[6] *Department of Higher Education and Training Charter for Humanities and Social Sciences Report, 2011.*
[7] *Department of Science and Technology Innovation Towards a Knowledge-based Economy, Ten-Year Innovation Plan for South Africa (2008-2018), 2008.*
[8] *Department of Science and Technology Human and Social Dynamic in Development Grand Challenge Science Plan, 2010.*

Types of research infrastructure needed to advance scientific knowledge

- Digital libraries with every historical or artistic document of research interest in museums or public and private collections, including provenance and other data for identification.
- While also being an object of study, language contributes to internalising, understanding and imparting knowledge within and across scientific domains. In a multilingual and multicultural society, it is necessary to have access to large-scale digital testing and speech resources, not only for language and communication-related studies, but also for the development of language technology applications for public good.
- Population platforms for health and socio-economic research that provide timely, up-to-date information and support intervention research and policy evaluation to guide policies and programmes.
- Satellite monitoring of urban evolution, migration, remote sensing, etc., and the continuous updating of data.
- Other common services like dating facilities or the preservation of cultural heritage.

Research infrastructure identified in South Africa

These are distributed across the country in several universities, research centres and entities.

- Health and demographic surveillance sites as a distributed platform of observation sites are primarily linked to the South African Medical Research Council (MRC), but with significant potential for the social sciences. Existing sites are Agincourt, Mpumalanga (Wits); Africa Centre for Population Health, KwaZulu-Natal (University of KwaZulu-Natal); and Dikgale, Limpopo (University of Limpopo).
- A few data repositories such as those managed by the Human Sciences Research Council (HSRC), the South African Data Archive at the National Research Foundation, Statistics South Africa, and others.
- A centralised repository for the archiving and reuse of digital language resources, the Resource Management Agency, was recently established at North-West University (NWU).
- The HSRC currently conducts social surveys from time to time for various clients, primarily in government.

Relevant research infrastructure in other countries

Most countries have RIs in this field and research cooperation between countries should be encouraged. South African scientists have strong links with the European Common Language Resources and Technology Infrastructure (CLARIN) initiative. An African/Asian example is the International Network for the Demographic Evaluation of Populations and their Health (INDEPTH)[9], which comprises over 40 demographic surveillance centres, and promotes multi-centre research, in which there are also strong links with South African scientists.

Constraints

These include difficulties in accessing digital information disseminated at many sites where data interoperability is a basic requirement, e.g. for standardised surveillance methodology and data. Digitisation takes time and is costly.

[9]International Network for the Demographic Evaluation of Populations and their Health, the Importance of Core Support, 2010.

Above: Novel pharmaceutical dosage form for liquid based medicines.

4.2 Health, biological and food security

This domain groups three main areas related to living organisms: health, biology and food security. Five subdomains have been identified, namely, the agricultural production of food (crops production, food security, genetically modified organisms, fight against plagues, biobanks, etc.), the identification and processing of living organisms (genomics, proteomics and metabolomics), health systems (medical imaging, health services including telemedicine, micro-robotic surgery, brain simulation, nuclear medicine, etc.), biodiversity (identification and preservation of endangered species) and structural biology (use of synchrotrons and neutron sources for the analysis and synthesis of living organisms or parts of organisms such as proteins).

These subdomains are not isolated, and research and innovation activities are rapidly moving towards multidisciplinary support through a combination of centralised and distributed RIs. A common characteristic of potential RIs related to this field is that it is not necessary for the key equipment to be centralised. Owing to the need for multidisciplinary cooperation, links to research facilities in other domains are very relevant. Specific examples could be found with energy (e.g. biomass), humans and society (e.g. with the development of epidemiological studies), physics and engineering (e.g. with microscopy or synchrotron facilities), and Earth and environment (e.g. biodiversity and climate/global change studies).

Types of research infrastructure needed to advance scientific knowledge

In this domain, the wide range of activities is also reflected in the vast array of RIs that could be used in aid of innovation in science and technology. RIs from other domains could also be integrated (e.g. synchrotrons are also used in life sciences):

- Facilities for the controlled growth of genetically modified organisms (greenhouses, growth chambers, etc.).
- Secure laboratories (P3, P4 levels) for animal experimentation.
- Genomics/proteomics/metabolomics platforms.
- Biobanks (plants, animals, seeds, genomes).
- Nuclear medicine and medical imaging.

IN THIS DOMAIN, THE WIDE RANGE OF ACTIVITIES IS REFLECTED IN THE VAST ARRAY OF RIs THAT COULD BE USED IN AID OF INNOVATION.

Research infrastructure identified in South Africa

Although many South African universities and research centres have modern facilities in this domain, they are not necessarily open to the whole community, or may not operate as a national RI should.

- In the health subdomain a distinction between the medical use and the research use of some facilities needs to be considered as part of the roadmap. In many cases, large imaging machinery (e.g. magnetic resonance imaging, positron emission tomography-computed tomography, etc.) is used for routine medical diagnostics and is not readily accessible for research.
- Cyclotrons that produce short-lived radioisotopes are more closely linked to clinical research and practice in hospitals. For example, at the iThemba Laboratory for Accelerator-Based Sciences (LABS) the dual use of a cyclotron to accommodate research is not well established.
- Advanced research in population health, socio-economic well-being and food security can be conducted in the longitudinal population platforms listed in the "humans and society" domain.

Relevant research infrastructure in other countries

- The RIs above are common in many countries. Furthermore, access to international facilities and programmes in the field is relevant (e.g. European Molecular Biology Laboratory, the European and Developing Countries Clinical Trials Partnership, and the European Synchrotron Radiation Facility). Bilateral programmes help address the need by supporting South African research groups and training new generations of scientists in close contact with other international teams. The skills development derived from these collaborations contributes to building the scarce skills required for improving South Africa's global competitiveness. It is therefore essential to increase the interaction with other facilities by strengthening the participation of South Africa in international networks.
- Nanotechnology facilities for medical purposes, e.g. in connection with international efforts like the Interuniversity Microelectronics Centre (IMEC) in the European Union.
- Facilities for structural biology in the European Molecular Biology Laboratory.
- Beam lines in synchrotrons.

Constraints

- The lack of coordinated structures at national level constitutes the most important constraint (these facilities usually adopt the form of service platforms for specific uses or distributed networks). Equipment is not substantial and becomes obsolete relatively quickly. Furthermore, the cost of upgrades or replacements is exorbitant.
- With the growing importance of bioinformatics, the increasing demand for resources and for training in exploiting these techniques cannot be met.
- The dual (research and medical) use of advanced equipment like medical imaging systems, cyclotrons or robotic systems available in hospitals to support translational research is inadequate in South Africa.

4.3 Earth and environment

In a time of global change South Africa faces significant but as yet uncertain challenges in respect of its climate and its resources. Being located in the ocean-dominated Southern Hemisphere, South Africa has a recognised comparative geographical advantage on which to build a strong Earth systems infrastructure for long-term observations and models that support risk assessment in the 21st century. Its unique biodiversity and its exceptional geological record and associated ore deposits, as well as its extensive palaeontological and palaeoanthropological heritage, are globally acknowledged, and make it an ideal laboratory to study important geological and evolutionary events in the Earth's history from the origin of life on Earth to present-day Earth systems processes.

Types of research infrastructure needed to advance scientific knowledge

Owing to the large variety of fields in this domain, diverse RIs are required.

- Oceanographic research vessels and autonomous oceanographic data-gathering submersibles.
- Polar bases, especially in the Antarctic.
- A distributed network of sensors for climate change and the monitoring of natural hazards (both on the sea and on land).
- Balloons, instrumented aircraft, etc. for atmospheric and remote-sensing studies.
- Global and regional networks of robotics-based *in situ* observations.
- Earth observation satellites.
- Drilling probes in the ocean and on land.

Research infrastructure identified in South Africa

- A platform for marine and Antarctic research, incorporating state-of-the-art research vessels and research bases in Antarctica and on Marion and Gough Islands.

Below: SAEON automatic weather station in the Drakensberg.

- There are limited facilities for shallow marine and coastal research at the South African Environmental Observation Network (SAEON), the South African Institute for Aquatic Biodiversity (NRF) and the Marine Unit of the Council for Geoscience.
- Deep ocean research infrastructure for ship-based and robotics observations available at the Council for Scientific and Industrial Research and at the Oceans and Coasts unit of the Department of Environmental Affairs.
- SAEON, established in the past decade as a national facility of the NRF, consists of several key sentinel sites spread across the country for long-term ecological and environmental research.
- Instrumentation for geochemistry, dating and the chemical characterisation of biological material is scattered across the country and is not well coordinated. The recently completed accelerator mass spectrometer facility at iThemba LABS in Gauteng will add an important dimension to the country's capabilities in this domain.

Below: Remote underwater video system capturing diversity of sea life on SA reefs.

- The South African National Space Agency has Earth observation receiving, archiving and processing capacity which has been accessing remotely sensed data almost since the beginning of the satellite era, and the CSIR and several universities have processing capacity.
- South Africa has a world-renowned biodiversity data system, partly through the South African National Biodiversity Institute (SANBI), but also based in museums and herbaria, and with the help of an extremely active citizen science sector, for instance at the Avian Demography Unit at the University of the Western Cape.
- South Africa has a long-established weather station network run by the South African Weather Service and others, and a hydrological recording system run by the Department of Water and Sanitation, both exceptional in Africa, along with a climate and hydrological modelling capability at the CSIR and several universities.
- The custodian of the geological record is the Council for Geoscience, which has an archive of surface and underground samples, drill cores, seismic and aeromagnetic surveys, and seismographic arrays. The AfricaArray is coordinated from South Africa.
- The palaeontological and palaeoanthropological research collections are based at universities (notably the Bernard Price Institute at Wits) and in museums, along with active excavation sites in several renowned locations, such as the Cradle of Humankind.

Relevant research infrastructure in other countries

- Access to oceanographic research vessels owned by other countries is negotiated by scientists on an individual basis but dictated by the research interests of that country and very infrequently negotiated in support of the South African priority to explore the continental platform.
- Many international facilities and platforms exist for Earth observation and South Africa already has close linkages with several of them, e.g. International Long-Term Ecological Research, GEOSS, the Global Biodiversity Information Facility, the Global Ocean Observing System, and the Group on Earth Observations Biodiversity Observation Network and FluxNet.

Constraints

As in many other domains, there is a general need to archive and access data generated in scientific campaigns, and to exchange them with similar information available in other countries. Furthermore, research on atmospheric, ocean-air interactions, climate change models, etc. requires access to very advanced high-performance computing facilities.

4.4 Materials and manufacturing

Materials science is a very versatile domain which serves many others domains; the domain evolution is currently driven by two main forces, namely, nanoscience and nanotechnology to characterise or develop new materials, and better instruments to observe the matter interactions on a nanoscale. For example, the interface between biomedicine and nanostructures is currently a very vibrant area for research. Of particular importance to South Africa is the materials science contribution to mineral and metals beneficiation and new manufacturing technologies such as additive manufacturing.

MATERIALS SCIENCE IS A VERY VERSATILE DOMAIN WHICH SERVES MANY OTHERS DOMAINS.

Materials RIs are focused on understanding, developing, measuring, modifying and application improvement of materials from nanoscale to macro-scale. Manufacturing RIs support the design, development, processing, testing, integration and packaging of structural or functional materials from demonstration and pilot phase to full commercialisation.

Types of research infrastructure needed to advance scientific knowledge

- New generation of synchrotrons.
- Neutron sources.
- Nuclear microscopy systems.
- Hybrid electron microscopy systems (focused ion beam scanning electron microscopy, etc.).
- Surface science or nanotechnology facilities.
- Molecular spectroscopies.

Research infrastructure identified in South Africa

South Africa has many components which could evolve towards national distributed facilities:

- Advanced electron microscopy facilities, including high resolution transmission electron microscopy and aberration-corrected high resolution transmission electron microscopy, scanning electron microscopy, and electron and X-ray analytical facilities to analyse materials at the atomic level.
- State-of-the-art surface science facilities, including secondary ion mass spectroscopy, X-ray diffraction, X-ray photo-electron spectroscopy, scanning Auger microprobe, atomic force microscopy, low-energy electron diffraction spectroscopy.
- The National Centre for Nanostructured Materials, including electron microscopes, scanning probe microscopy, X-ray diffraction, X-ray scattering, optical characterisation, electrical characterisation and surface analysers.
- The Centre of Excellence in Strong Materials, including electron microscopy, micro-analysis, materials strength analysis, optical spectroscopy, materials preparation facilities, and thermal analysis.

Relevant research infrastructure in other countries

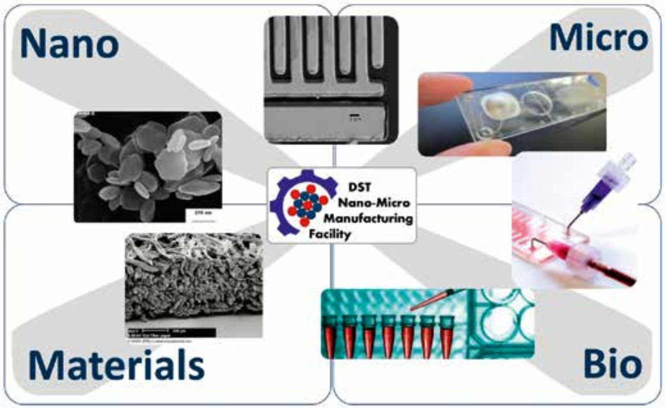
- XFEL, the X-ray free electron laser facility under construction at DESY in Hamburg.
- Synchrotrons (e.g. the European Synchrotron Radiation Facility, Grenoble, France).
- European Spallation Source (under construction in Lund, Sweden).
- Nanotechnology facilities for research on materials design and characterisation are available in many countries (e.g. IMEC facilities in the European Union).

Constraints

The development of a new physical RI would be very expensive (the user community is not large enough to compensate for the costs) and a distributed system coordinated through a hub has therefore been proposed, to make the best use of available facilities. However, South Africa is constrained by a lack of experience in the construction of large RIs such as synchrotrons. It seems more feasible to enter as a partner in RIs under development allowing experience in construction, usage and management. In this way, the internal community will be built up until such time as a decision to build a dedicated facility in South Africa is reached. Many future RIs will be located abroad and remote use becomes a relevant approach to facilitate their use by the South African scientific community.

4.5 Energy

Energy RIs are focused at understanding, developing, measuring and applying improvements to conventional, renewable and other energy systems. In this sector, many of the potential RIs could adopt the form of a pilot plant. The following subdomains are identified from the RI perspective: Nuclear energy (fusion and fission) research facilities; techniques for fossil energy (shale gas extraction, biodiesel, carbon dioxide sequestration, etc.); renewable energy (photovoltaic, concentrated solar power, wind, biomass, tide energy, fuel cells); energy efficiency



Above: Nano-micro manufacturing overview.

(in housing, factories, etc.), and energy distribution (smart grids, distributed generation, etc.).

Types of research infrastructure needed to advance scientific knowledge

- Solar cells development capabilities.
- Pilot plans for thermo-solar (concentrated solar power) or photovoltaic systems, with or without solar concentration (concentrated photovoltaics).
- Pilot plants for wind turbine testing.
- Smart grid testing facilities.
- Nuclear reactors for fission energy research and for materials testing.
- Participation in fusion RIs.

Research infrastructure identified in South Africa

- SAFARI-1. A fission research reactor that serves mainly as a source of neutrons. A research reactor is essential for any country with an active nuclear power industry to support research at the front and back ends of the nuclear fuel cycle. The reactor is also applied in medical isotope production.
- Distributed energy research laboratories focusing on generation, transmission and distribution, as well as energy efficiency and smart grids.

Relevant research infrastructure in other countries

- Plataforma Solar de Almeria (for research, development and testing of concentrating solar technologies) in Spain.
- Institute Laue Langevin in France.
- Fusion research reactors (Joint European Torus, International Thermonuclear Experimental Reactor, the National Ignition Facility at Lawrence Livermore National Laboratory in the USA, etc.).
- Experimental fission reactors and nuclear waste treatment plants in several countries.

Constraints

Fission research is mainly linked to the evolution of nuclear plants while South Africa is not active in fusion research.

5 SELECTION OF RESEARCH INFRASTRUCTURES FOR INCLUSION IN THE SOUTH AFRICAN RESEARCH INFRASTRUCTURE ROADMAP

5.1 Initial selection of research infrastructures for inclusion in the roadmap

In 2013, a jointly funded project was launched between the European Commission (under the Trade, Development and Cooperation Agreement) and the DST for the development of a national research infrastructure roadmap. The process was led by a team of four experts (two from South Africa and two from Europe). A key deliverable of the team was a framework for a national research infrastructure roadmap for South Africa and the development of guidelines, a policy framework and the scope of the roadmap. The framework provided a comprehensive set of principles and a basis for the development of a national research infrastructure roadmap. Details on the consultation process and outcomes are given in the final SARIR Framework Report of 2013[10], which can be downloaded from the DST website.

Through a bottom-up approach, including several multidisciplinary workshops, survey questionnaires and interviews with researchers and research managers from both the public and the private sectors, the expert group produced a SARIR framework identifying 17 medium to large research infrastructures across six scientific domains: (i) humans and society; (ii) health, biological and food security; (iii) Earth and environment; (iv) energy; (v) materials and manufacturing; and (vi) physical sciences and engineering (Table 1).

[10] *A South African Research Infrastructure Roadmap Framework, 2013.*

5.2 Final selection of research infrastructures for inclusion in the roadmap

The final selection of RIs took place in two steps. The first step involved the development of high-level proposals or concept documents for each of the 17 RIs identified during the initial bottom-up phase. These proposals were assessed to see whether the relevant infrastructures should progress through to the final stage of developing SARIR, for which detailed and comprehensive conceptual design reports (the science cases) and technical design reports (the business cases) would be required for each identified infrastructure. The development of such reports is costly and lengthy, and would be undertaken with a considerable risk that the specific infrastructure might never be developed. For example, due to the conceptualisation and planning being insufficient, there may be insufficient interest by the research community in the infrastructure, or it may be too expensive.

THE SARIR FRAMEWORK IDENTIFIED 17 MEDIUM TO LARGE RIs.

Hence, instead of commissioning comprehensive and costly reports/proposals for each of the initial 17 RIs identified, it was decided to commission less comprehensive analyses of the conceptual purpose and financial implications of each infrastructure to enable a first-order ranking. These high-level analyses were referred to as meta-design reports. Following a rigorous process, 17 researchers were appointed to act as champions for each RI, and trained by the appointed experts (Prof. John Wood from the Association of Commonwealth Universities and Prof. Anne Grobler, Director: DST/NWU Preclinical Drug Development Platform) on how to produce the meta-design reports for the 17 RIs. The champions were selected on the basis of their involvement during the bottom-up development of the framework and/or expertise in the particular field. Their role was not to develop the proposals by themselves but to act as facilitators and coordinators to assist all relevant stakeholders and role players.

Table 1: Scientific domains and research infrastructures constituting the SARIR framework

Scientific domain	Identified research infrastructure	
Humans and society	1.	South African network of health and demographic surveillance Sites
	2.	South African human and social science data archive
	3.	National centre for digital language resources
Health, biological and food security	4.	Animal biosecurity laboratory P4 level (ABL-4)
	5.	Distributed platform for "omics" research
	6.	Biobanks
	7.	Nuclear medicine research facility
Earth and environment	8.	South African marine and Antarctic research facility
	9.	Biogeochemistry research infrastructure platform
	10.	Expanded national terrestrial environmental observation network
	11.	Shallow marine and coastal research Infrastructure
	12.	Natural sciences collection facility
Materials and manufacturing	13.	Materials characterisation facility
	14.	Nano-micro manufacturing facility
Energy	15.	SAFARI-2 materials research reactor
	16.	Solar research facility
Physical sciences and engineering	17.	National support centre for science

The champions produced 17 reports which were subjected to an evaluation and selection process by the Steering Committee appointed by the DST. From the 17 meta-design reports submitted, 13 RIs were identified for incorporation into the final SARIR. The selected 13 RIs are listed in Table 2.

Table 2: Selected SARIR RIs based on meta-design reports

Scientific domain	Identified research infrastructure
Humans and society	South African network of health and demographic surveillance sites
	National centre for digital language resources
Health, biological and food security	Distributed platform for "omics" research
	Biobanks
	Nuclear medicine research facility
Earth and environment	South African marine and Antarctic research facility
	Biogeochemistry research infrastructure platform
	Expanded national terrestrial environmental observation network
	Shallow marine and coastal research infrastructure
	Natural sciences collection facility
Materials and manufacturing	Nano-micro manufacturing facility
	Materials characterisation facility
Energy	Solar research facility

The following criteria were used to select the 13 RIs (from the original 17) to constitute the SARIR:

- Strategic importance for South Africa.
- Local and global impact.
- Maturity and state of readiness, including the governance model and financial projections.
- Scope and range of science – relevance, technology transfer and intellectual property.
- Potential for success – current level of competence.
- Policy and policy makers.

Right: Proprietary vacuum system.

Following the selection of the 13 RIs to be included in principle in the roadmap on the basis of the evaluation of the meta-design reports, the next step was to develop full proposals (including addressing the gaps identified in the meta-design reports, such as proposed governance structures and budget, consultation levels with key

stakeholders, and the state of readiness and time frame required to establish the infrastructure). With only one exception, the champions who had developed the meta-design reports were retained to develop detailed proposals incorporating the contents of both conceptual design reports and technical design reports. This was done under the guidance of a specialist who assisted in developing a standard template for these reports, as well as the oversight of the Steering Committee and the Department.

RI PROPOSALS WERE EVALUATED FOR OVERALL FEASIBILITY AND STATE OF READINESS.

The 13 final, detailed proposals were reviewed and evaluated by the Steering Committee for rigour, adherence to the template for the proposals, and overall feasibility and state of readiness. The committee issued its final report to the Department in this regard in 2016. The report – constituting the committee's recommendations on how to establish the 13 RIs – served as the seminal input to the Department for the last stage of the SARIR's development, namely a plan on how to implement it. This last step is outlined in Chapter 7. Chapter 6 outlines the 13 RIs selected for inclusion in the SARIR.

Above: CHPC: SA's first petascale hpc system.

6 DESCRIPTIONS OF SELECTED RESEARCH INFRASTRUCTURES ACROSS THE FIVE SCIENTIFIC DOMAINS

6.1 Expanded terrestrial and freshwater environment observation network

Project description

In the current era, the era of the Anthropocene, the key drivers of Earth system processes include human actions. To meet the practical challenges of environmental management in the 21st century, and to remain at the cutting edge of ecological science, it is necessary to start by taking a systems view, integrating previously disparate fields such as biodiversity, biogeochemistry, hydrology and land use sociology, and then to develop ways of studying the coupled social-ecological systems at the scale at which they operate and must be managed. This requires a new and innovative research approach and accompanying infrastructure, building on elements that have already been developed, and focusing on ecosystems that are both important and best studied in South Africa.

INTEGRATED TERRESTRIAL AND FRESHWATER ECOSYSTEM PROCESS MEASUREMENT PLATFORMS WILL BE ESTABLISHED,

A system of integrated terrestrial and freshwater ecosystem process measurement platforms will be established in six selected landscapes around South Africa. Within these areas, each measuring hundreds of square kilometres, coordinated measurements of land-atmosphere and land-water, ocean fluxes of water, carbon and other elements will take place on an ongoing basis, collocated with measurements of key biodiversity variables and social variables related to ecosystem use and benefits. Scaling the data streams in space and time will make use of dedicated collections of remotely sensed data to create a highly detailed, integrated public-domain data set for studying the dynamics of coupled social-ecological systems, including highly modified systems such as agricultural and urban landscapes. The investigated landscapes will contain long-term experimental modifications.

The infrastructure will be distributed over six important landscapes, accompanied by a centralised service and information technology hub.

Impact

Land and freshwater ecosystems in South Africa, as elsewhere, are under multiple stresses from increasingly intensive use, climate change, biodiversity loss and alien invasion. At the same time the dependence of a growing and better-off population, increasingly urbanised, is growing the demand for services from those ecosystems. This research infrastructure will enable the determination of the limits of sustainable use, the strategies for optimal use, and the trade-offs between various management approaches.

6.2 Nuclear medicine research facility

Project description

The nuclear medicine research infrastructure will be a medical imaging facility dedicated to drug development and clinical research. It will be a not-for-profit company, providing a framework to consolidate expertise and implement new strategic initiatives relating to R&D in nuclear technologies in medicine and the biosciences, adding significant research, development and innovation capacity in South Africa. The research infrastructure will be rolled out in phases, with the establishment of an interim preclinical imaging facility at the South African Nuclear Energy Corporation (Necsa), Pelindaba, to allow for immediate operations during the construction of the main site. The completed infrastructure will be a distributed network comprising the intensity modulated neutron therapy centre at iThemba LABS in Cape Town, the Positron Emission Tomography Centre for Infection Imaging at Tygerberg Hospital in Cape Town, and the main facility at a suitable academic hospital. The RI will boast a wide range of preclinical and clinical imaging modalities. A variety of radioisotopes and tracers are readily accessible within South Africa, which is the key ingredient for the studies performed at a facility of this nature. Furthermore, South Africa's biodiversity gives researchers access to a diverse pool of patients for clinical trials. The nuclear medicine research laboratories will host a team of seasoned radiochemists, veterinarians, pharmacists, medical physicists and nuclear medicine physicians to facilitate the studies generated by the nuclear medicine community. The research infrastructure will provide enabling support for healthcare R&D for academia as well as commercially driven healthcare (pharmaceutical and biotechnology) companies. The effectiveness of the RI will be measured in terms of research, innovation and value generation in areas of country and region-specific health challenges.

The RI will be a sought-after destination for preclinical and clinical screening of new drug entities that can be performed under one roof giving drug developers (local and international) a one-stop shop. It will create a viable pipeline of radiopharmaceutical compounds that will be exploited on the world market by the already established and successful South African companies operating in this space.

Drug development will not be limited to radiopharmaceuticals (diagnostic and therapeutic), but also to the evaluation of conventional drug candidates such as new antibiotics, tuberculosis (TB) or oncology drug formulations. The break-through value lies in the ability to rapidly reach drug development go/no-go decisions early on during the translational phase, as well as fast-tracking the development of locus-specific therapies, needed for many cancers, for instance. The outputs generated through the RI will enhance the quality of life of the general population, through better and safer pharmaceuticals, more accurate diagnosis and more effective treatment planning. The clinical research platform also has an important role to play in addressing South Africa's priority diseases, such as TB. Many of the applications described have a wider reach, with significance beyond our borders. For example, TB is gaining new momentum worldwide, including India. This research infrastructure complements the European and Developing Countries Clinical Trials Partnership (EDCTP2) launched in December 2014. The nuclear medicine research infrastructure will participate in bilateral programmes as articulated in the DST SAccess Report[11], and collaborate with European researchers to build South Africa's research capacity.

The nuclear medicine RI is aligned with the TYIP's Bioeconomy Grand Challenge, and will contribute to South Africa's target of being "one of the top three emerging economies in the global pharmaceutical industry". The RI will demonstrate its impact in respect of pharmaceutical solutions to attack the disease burden that is further worsened by poverty.

[11] *Department of Science and Technology SAccess ACCESS4EU – South Africa, Supporting the EU Access to South Africa's Research and Innovation Programmes: Report on South African Research and Innovation Capacity, issue 243851.*

Impact

The socio-economic relevance of establishing the national facility and the preclinical competence is multidimensional. This will not only create jobs, but also increase South Africa's global competitiveness in science, technology and innovation. The expertise that will develop through the national preclinical facility will elevate South Africa's already high standard in the sciences, giving budding young scientists access to quality education and opening new career opportunities that will grow the pool of critical skills within the country, hence making South Africa globally competitive in the field of science and innovation.

THE NETWORK WILL BE EXPANDED TO INCLUDE FOUR NEW NODES.

In addition to the socio-economic impact of addressing "top national health priorities, linked to the growth of the local pharmaceutical industry", the RI will demonstrate economic benefit by attracting foreign direct investment from the international pharmaceutical industry, which in turn will contribute towards reducing the national deficit. Furthermore, indirect jobs will be created through spin-off companies/start-ups that will provide services and consumables needed for the RI operations.

6.3 South African network of health and demographic surveillance sites

Project description

South Africa is striving to emerge from a legacy of gross social injustice and consequent health and socio-economic inequality to become a country where all citizens can access ever-broadening opportunities to build productive lives. But stewardship of the country faces several challenges, including high levels of inequality. South Africa has a Gini coefficient of 0.65, an unemployment rate of 25% (substantially higher in rural areas and among young people), a poverty headcount ratio of 57%, as well as colliding epidemics of HIV/TB and non-communicable diseases.

Health and demographic surveillance national research infrastructure would address the critical need for an improved, science-based information system, and related research platform, to direct development-oriented decision-making, investments and interventions.

The health and demographic surveillance national research infrastructure will be a distributed platform of health and demographic surveillance system (HDSS) nodes. An HDSS system is a standardised, field-based information system and research platform, with data routinely collected from entire populations at both individual and household level, in impoverished and developmentally constrained communities, both rural and urban. Unbiased individual and household indicators that will be routinely and continuously collected and assessed include vital events, e.g. births and deaths (by cause), residence status and migration, household dynamics, socio-economic status, disease monitoring, labour and employment status, education status and social protection. The individual and household registration systems will be complemented by public sector records on health system utilisation, school attendance and social grant receipt, to enable population-level research on access to, and failure to access, public services. Communities in which HDSS nodes are embedded are crucial partners. Care is taken to interface with community structures in multiple ways, including routine feedback on research findings, supporting the use of research data, and active engagement with community advisory boards.

THE PROJECT WILL FIRST INTEGRATE AND STANDARDISE THE THREE EXISTING HDSS NODES IN SOUTH AFRICA.

In terms of geographic scope, the project will first integrate and standardise the three existing HDSS nodes in South Africa (namely, the MRC/Wits Agincourt HDSS in Bushbuckridge, Mpumalanga, established in 1992 with a current population of 120 000; the University of Limpopo Dikgale HDSS in Dikgale, Limpopo, established in 1996, with a current population of 35 000; and the Africa Health Research Institute's Population Intervention Platform in uMkhanyakude, KwaZulu-Natal, established in 2000, with a population of 100 000). Then, the network of optimised HDSS nodes will be expanded to include new nodes in Gauteng (urban), eThekwini (urban), Eastern Cape (rural) and Western Cape (urban). This expanded platform, representing over 1% of the national population (55,6 million), will cover a more inclusive spectrum of impoverished yet dynamically developing subpopulations, and enable a new and unprecedented understanding of the dynamic bidirectional migration flows that link poor, rural communities with urban centres.

Impact

- Ongoing, up-to-date, longitudinal data representative of South Africa's fast-changing poorer communities for research and policy evaluation, interpretation and calibration of national data (the outcome will be accessible, dynamic, representative, timely data).
- Access to the extensive, versatile and interdisciplinary research platform for researchers from universities, science councils, regional and international collaborations (the outcome will be enhanced research outputs).
- A scientific evidence-base for cost evaluation, policy making and targeting of intervention programmes, thereby improving the accuracy, efficiency and effectiveness of pro-poor, health and well-being interventions (the outcome will be making poorer South Africans healthier and better-off while reducing costs to government).
- Expanded human capacity for conducting advanced research that is effectively linked with national, regional and international networks (the outcome will be an elevated capacity for conducting science in South Africa).

The health and demographic surveillance national research infrastructure will contribute to the Human and Social Dynamics Grand Challenge identified in the TYIP, through which South Africa will contribute to a greater global understanding of shifting social dynamics, and the role of science in stimulating growth and development.

6.4 National centre for digital language resources

Project description

A South African centre for digital language resources will create and manage digital resources and software applicable to all South Africa's official languages in order to stimulate and support R&D in the humanities and social sciences.

THE CENTRE WILL ACQUIRE, SYSTEMATICALLY DEVELOP AND MANAGE DIGITAL TEXT AND SPEECH RESOURCES OF THE OFFICIAL LANGUAGES.

The centre will acquire, systematically develop and manage digital text and speech resources of the official languages of South Africa, creating representative and sustainable resources for R&D. It will also facilitate research capacity building by promoting and supporting the use of digital data, relevant software, and innovative methodological approaches in the humanities and social sciences.

A digital humanities approach to research entails, among other things, access to large corpora of digital data (text, speech or multimodal), and software tools that allow researchers to ask previously unanswerable questions. Fields of research include language and literary studies, heritage studies, history, music, sociology, journalism, philosophy, psychology, media studies, and visual and graphic art. In turn, the availability of large data sets facilitates the development of a variety of language technology applications for public good.

The multi-partner distributed research infrastructure, comprising the Council for Scientific and Industrial Research, the University of South Africa, the University of Pretoria, and the Inter-institutional Centre for Language Development and Assessment, will be hosted by NWU. The RI will provide a single point of entry for access to a web-based platform, making digital language resources and software tools freely available for research and educational use (they will be licensed for use in commercial applications).

The centre for digital language resources is a response to the Constitution of the Republic of South Africa, 1996, and the Use of Official Languages Act, 2012, pertaining to the equal development and use of the 11 official languages of the country.

The centre, the first of its kind in Africa, will promote existing links with similar entities globally, especially with a major counterpart in Europe, e.g. CLARIN, which is also part of the European Strategic Framework for Research Infrastructures Roadmap.

Impact

- Opening new opportunities for research in the humanities and social sciences in general.
- Documenting the nature and use of local African languages, including cultural heritage practices as part of a living archive.
- Providing digital resources and tools for the development of a wide range of language technology applications in the fields of, for instance, health services, education, social services and business. The availability of interactive telephone or Internet-based information systems in a language of choice will contribute to the language rights of all South Africans.

Above: Weevil from the Drakensberg. Image provided by H. Robertson (Iziko Museums) and SANBI.

6.5 Natural science collections facility

Project description

In terms of biodiversity, South Africa is considered a megadiverse country, and its extremely wide variety of plant and animal species is an asset that sustains life and presents economic and scientific opportunities. Natural science collections can be considered reference libraries for the country's more than 100 000 species, with over 30 million preserved plant, animal and fossil specimens and living microbial cultures kept in more than 40 museums, science councils and universities in the country. These collections have been built up over almost 200 years and they continue to be expanded with new exploration and research. The collections

Right: Collecting a skin sample from an African elephant's ear.

provide materials and data that will have relevance in increasingly broad ways as new questions about sustaining life arise and as new technologies emerge. Globally such collections are becoming recognised as essential research infrastructure.

COLLECTIONS ARE BECOMING RECOGNISED AS ESSENTIAL RESEARCH INFRASTRUCTURE.

An assessment of natural science collections in South Africa in 2010 highlighted the need for an integrated and cohesive approach to ensuring that the full potential of collections is realised through strategic research that addresses questions of global and national significance. In order to achieve this aim, the collections and their associated data need to be secured and accessible, and appropriate capacity needs to be developed. A national natural science collections facility would comprise a central coordinating hub, with a network of existing collection institutions collaborating and contributing to achieving the objectives and associated targets.

Impact

Collection-based research is often considered foundational because it provides knowledge that is critical for most other research fields involving biological materials. The specimens in the collections are used by local and international scientists for documenting and describing biological diversity and exploring its origins and evolutionary relationships, as well as for investigating various facets of global change. The collections are essential as a reference for accurately identifying materials for bioprospecting, agriculture and health.

They can be used to track pathways of disease and pest spread, and to analyse past diets and movements of animal species, which is especially relevant for sustaining industries such as fishing. Data associated with the specimens are used for modelling climate change impacts on the distribution of economically important species, and on the timing of ecologically important events such as pollination. They are also important for spatial planning that informs decision-making for sustainable development. The natural science collections facility will therefore contribute to two of the TYIP's Grand Challenges – the Bioeconomy ("Farmer to Pharma") and Global Change. The above uses of the collections and data illustrate the socio-economic benefits of the infrastructure.

6.6 Shallow marine and coastal research infrastructure

Project description

The three oceans around South Africa play a vital role in determining southern Africa's climate and weather patterns. They also have a strong influence on the global climate. Understanding how climate and global change will alter coastal environments and influence coastal livelihoods requires research and long-term observational data at appropriate spatial and temporal scales and across a broad spectrum of coastal ecosystems. The shallow marine and coastal research infrastructure (SMCRI) will establish an array of instruments and physical research platforms around the coast of South Africa (and its sub-Antarctic Islands) to collect long-term reliable data for scientific research to help decision-makers formulate appropriate environmental policies to lessen the risk and vulnerability of the coastal zone to climate and global change. The SMCRI will build on the suite of observatories, sentinel sites and research platforms already established and maintained by the South African Environmental Observation Network, the South African Institute for Aquatic Biodiversity, and the Oceans and Coasts unit of the Department of Environmental Affairs. Key research infrastructure will include underwater wave and current sensors to observe the increase in magnitude and frequency of storm surges, partial carbon dioxide and pH sensors to quantify the risk of ocean acidification on marine ecosystems, water level gauges to determine the rate of sea-level rise, state-of-the-art coastal research vessels and a suite of other sensors to better understand the physical and chemical drivers of and the ecosystem response to the changes taking place.

Impact

The response to global change is one of the key grand challenges identified by the DST's TYIP. South Africa is well positioned to lead research on the continent in terms of understanding and projecting changes to the marine environment, the impact of these changes, and mitigation to limit their long-term effects. Mitigating climate change also provides an economic opportunity for South Africa in the "blue economy". In the development of the blue economy, the exploitation of living (fisheries, aquaculture and tourism) and non-living marine resources (oil and gas, minerals, and energy) should be on a scale that is socially and economically justifiable and ecologically sustainable. The SMCRI will be one of the largest arrays of coastal observatories in the world and the long-term data sets will be of global significance. It is anticipated that the SMCRI will make a significant contribution to the knowledge economy (through the graduation of postgraduate students, the publication of peer-reviewed manuscripts and the mentoring of interns), the data-driven economy (through the publication of thousands of unique data sets that will be made freely available) and the blue economy (through improved understanding of our ocean space, its resources, the threats it faces and the opportunities it can provide).

THE SMCRI WILL BUILD ON THE SUITE OF OBSERVATORIES, SENTINEL SITES AND RESEARCH PLATFORMS ALREADY ESTABLISHED.

6.7 Distributed platform for "omics" research

Project description

In early 2014, the DST released a national Bioeconomy Strategy[12], an update of the Biotechnology Strategy released in 2001, which included a commitment to enhancing South Africa's research infrastructure through SARIR. Genomics, proteomics, metabolomics and bioinformatics, high-technology-based research areas often referred to as "omics", were identified as likely to benefit from advanced RI.

A distributed platform for "omics" will use a network-based, distributed organisational model to bring together existing infrastructure into a whole that enhances availability, accessibility and affordability of "omics" technologies in South Africa, enhancing South Africa's research and innovation capacity in the biological, biotechnological and biomedical research.

THE "OMICS" RI WILL INFORM INITIATIVES AND ACTIVITIES IN AREAS AS DIVERSE AS HEALTH, AGRICULTURE AND PHARMACEUTICAL MANUFACTURING.

The "omics" RI will inform and support initiatives and activities in areas as diverse as health, agriculture and pharmaceutical manufacturing, through the development of new medical solutions, enhanced crops and more efficient processes, respectively.

Impact

"Omics" technologies are essential to a vast array of biological, biomedical and biotechnological research activities. In addition to fuelling discovery-oriented research through the production of data on an unprecedented scale, practical applications are emerging in medical diagnostics (precision medicine), food testing, infectious disease management, drug development, crop improvement and biofuels design.

To give an idea of the economic value of these technologies, the genomics sector (to date the most prominent of the "omics" technology areas) contributed US$30 billion to the United States gross domestic product in 2012, approximately 0,2% of the total of US$15 trillion. This contribution comes through public research spending, venture capital funding for start-ups, industry investments in R&D, and sales of genomics products and services.

The RI will contribute positively to better disease management and prevention, population health and job creation, and have a positive impact on innovation.

6.8 Biobanks

Project description

The biobanks RI will consist of two parts, namely a national coordinating facility (knowledge-hub) and a state-of-the-art biobank storage facility. The biobank will house biomaterial collections of strategic value to South Africa, serve as a back-up facility for tissue collections of high value, serve as a technology transfer and training centre, and conduct research on the science-of-collections. The national coordinating facility, with a centralised database, will support the network of biobanks found throughout South Africa, and support the biomaterial source and

[12] Department of Science and Technology Bio-Economy Strategy, 2013.

user stakeholder communities in the country, as well as regionally and globally.

The biobank will support the organised securing and sustainable utilisation of South Africa's biological resources, through a distributed network of partners and stakeholders. The acquisition, processing, banking and distribution of biomaterials is a complex series of events that requires state-of-the-art facilities and expert input representing multiple disciplines and stakeholders, including legal and regulatory agencies, research institutions, national and provincial conservation authorities, higher education institutions, and the private sector, including citizen scientists.

Impact

The biomaterial collections (cells, tissue, DNA, RNA, etc.) held in biobanks represent a geographically unique resource that will be managed as a national asset for the benefit of biodiversity conservation and biotechnology development. The biobank service to partner biobanks and user communities will enhance productivity and efficiency in the acquisition, banking and distribution of sub-samples for increased multi-institutional research outputs. The biobank collection facility will serve as national training and research centre for human capacity development in biobank management and science-of-collections research programmes. Research productivity per sample (from the distributed biobank network and the national facility) is enhanced through the provision of good quality sub-samples for multi and transdisciplinary research programmes, multiplying the research output and publications per set of samples. The emerging national and

Above: The acquisition, processing, banking and distribution of biomaterials is a complex series of events that requires state-of-the-art facilities.

global market for components of South Africa's genetic resources (biomaterials) will stimulate growth in research output, including in the further development of appropriate biotechnologies to support the conservation of genetic resources, and will further stimulate South Africa's green economy. The biobank will also play a supportive role, where necessary, in some of the other identified RIs, so further saving costs, including the natural sciences collection facilities (museums), the distributed platform for "omics" research (Centre for Proteomic and Genomic Research), the SMCRI, the South African marine and Antarctic research facility, and the expanded national terrestrial and freshwater environmental observatory network, many of which will at times also deal with biomaterials or samples from sediments or ice cores, for example, which may contain biomaterials.

6.9 South African marine and Antarctic research facility

Project description

The polar and marine national facility will improve efficiency in the use of current infrastructure to support science in the Antarctic region and enhance the capacity of this infrastructure to realise South Africa's national development goals and honour its commitments to contribute to the scientific understanding and conservation of services rendered by the Antarctic region.

South Africa's comparative regional geographic advantage has been identified, through the Global Change Grand Challenge and the Marine and Antarctic Research Strategy, as a basis for strategic investment in science to support development goals. This region provides massive scope to expand South Africa's contribution in Earth systems science, and is an attractive basis for international collaboration. There is scope for generating long-term observations of scientifically agreed and defined Antarctic region phenomena and building on networks, e.g. SAObs21. Linked to the need for observations are opportunities for technological and economic innovation in observation platforms, sensors and systems. Research in this region can accelerate human capital development, especially the advanced skills in science and engineering required for a 21st century economy.

THERE ARE OPPORTUNITIES FOR TECHNOLOGICAL AND ECONOMIC INNOVATION IN OBSERVATION PLATFORMS.

The Oceans and Coasts unit of the Department of Environmental Affairs already has substantial South African social investment in the infrastructure already in the Antarctic region to support research.

Impact

- Providing a premier platform for advanced human capital development in scientific and engineering fields.
- Supplying information and projections about ecosystems and climate needed to assist all sectors to respond to global change.
- Complementing and reinforcing the proposed comprehensive marine and Antarctic research strategy and the Antarctic regional strategy.
- Contributing to ocean sector GDP and job creation through an expanded Operation Phakisa, and through projects to support South Africa's presence in the Antarctic region.

6.10 Nano-micro manufacturing facility

Project description

A nano-micro manufacturing facility will be established at a number of sites across South Africa. Nano-micro manufacturing enables the mass production of new types of devices such as flexible electronics, advanced sensors and low-cost diagnostic devices, as well as highly sensitive nanosensors, light emitters and memory devices, which will all benefit South African society and industry.

The technology concerns the use of sophisticated equipment to produce and integrate nanomaterials (such as functional nanoparticles and nanotubes, atomic layers, graphene sheets, microfluidics, biomarkers and micro-electro mechanical systems) in processes such as printing, embossing, nano-lithography, layer deposition and fabrication.

While many research groups in South Africa are already active in this field, they lack facilities and equipment to advance the R&D of products to a higher technology readiness level in order to compete internationally in a market that is expected to exceed US$10 billion by 2018.

In response to the international growth in nanotechnology research, the DST has already established two nanotechnology innovation centres, the Centre for High Resolution Transmission Electron Microscopy and a number of university chairs, as well as a Nanotechnology Equipment Programme, flagship projects and postgraduate programmes. The nano-micro manufacturing facility will be an appropriate continuation of these activities, towards achieving a greater impact from these investments.

The RI will operate through technology and activity nodes or tiers, which will be chosen in line with already established critical research activities in a region, as well as available complimentary equipment.

While the focus of the facility will be finalised in the first phase of implementation, stakeholders have indicated that the following areas have potential:

- Fabrication of flexible and low-cost nano-micro devices using advanced printing and including lateral flow devices.
- Fabrication of nano-micro devices using high-end fabrication techniques such as silicon fabrication, nanodeposition, nanomanipulation and micro-device assembly.
- Fabrication of thin films for solar cells and energy applications using film deposition techniques.

NANO-MICRO MANUFACTURING ENABLES THE MASS PRODUCTION OF NEW DEVICES.

The nano-micro manufacturing facility will thus assist the South African research community in higher education, research councils and industry in efforts to research and commercialise nano-micro manufactured products. Through its key focus on human capital development, the RI will also allow postgraduates and interns to advance their career in science and technology, and as young professionals accelerate the growth of a nano-micro manufacturing industry, which will create jobs and benefit society through numerous products.

Impact

The aim of nano-micro manufacturing is the production of low-cost, high-volume novel devices and sensors. Owing to the nature of the techniques used, such devices can be complex and versatile. They can be used to benefit ordinary citizens in matters such as the provision of affordable diagnostics for better access to health services and clean water. Many other devices and applications will emerge, also incorporating printed electronics, photovoltaics, sensors and displays. In addition, nano-micro sensors produced in fabrication facilities will find their way into advanced applications such as astronomic observation, satellites and electronic equipment. With South Africa's knowledge in areas such as health care, water and the environment, as well as through the SKA project, the country is in a position to use nano-micro manufacturing technologies to create local products that solve many challenges.

Below: Nanocomposite extruder.

6.11 Solar research facility

Project description

Owing to the billions of rands needed for the building of commodity-scale power plants, power plant business owners and banks are technology risk averse and will only consider new technology if it has been demonstrated on a commercial scale or at least at a large enough demonstration plant to significantly reduce the risk of scaling-up.

A single-sited national solar research facility for both photovoltaic and concentrated solar power technologies is needed to demonstrate newly developed technologies at a megawatt scale. The RI will be used to develop, test and demonstrate solar energy systems and subsystems to support the solar energy economy of South Africa. The facility will stimulate local R&D and assist in the training of operational and maintenance staff for the new power and equipment production plants.

It is envisaged that the proposed facility will consist of the following:

- A solar tower (about 60 m high) rated up to 5 MW_{th}, with several test platforms for different receiver types, e.g. liquid salt, air or other heat transfer fluids.
- A heliostat field of approximately 6 000 m^2 aperture area to provide solar flux on the tower.
- Space for testing other heliostat designs and concepts with optical and thermal targets on the tower.

- Parabolic trough test loops with oil and molten salt as heat transfer fluids.
- Thermal energy storage test facilities.
- Space for the dedicated testing of concentrated solar power components, in order to establish suitability for local conditions.
- Demonstration systems of various photovoltaic device types and configurations.
- Accelerated photovoltaic lifetime testing equipment (environmental chamber and other stress testing equipment).
- Advance photovoltaic material and device characterisation.
- Offices, workshops, laboratories and lecture/meeting facilities for staff and visitors.

Impact

- Supply of skilled operations and maintenance personnel to support the solar power industry. The full implementation of the Renewable Energy Independent Power Producer Procurement Programme (REIPPPP) will require about 1 300 permanent personnel and an additional 4 000 operations and maintenance personnel per 5 GW installed capacity. This is over and above the REIPPPP targets.
- The research done at the national solar research facility should see about 30 MSc and 15 PhD students graduate annually.
- The research findings from the expected number of postgraduate students will result in about 50 conference papers and 30 peer-reviewed journal articles a year.
- The RI will facilitate the development of novel solar technologies that can be commercialised in South Africa for local and export products.
- The successful commercialisation of technology development programmes is expected to reduce the total installed cost of a concentrated solar power plant to US$3/W. It is estimated that such a reduction in cost will make a positive contribution to the South African economy in the order of billions of rands.
- South Africa could also become a major world-wide technology supplier and supplier of proprietary equipment, which in turn could have a positive effect on South Africa's technology balance of payments, also in the range of billions of rands.

6.12 Material characterisation facility

Project description

For R&D in materials to be relevant, sophisticated modern characterisation infrastructure is needed. Beneficiation and competitive manufacturing then require process and compliance testing from reputable facilities. If South Africa is to beneficiate its resources, increase metal and other materials fabrication, and be generally competitive, it needs comprehensive, state-of-the-art materials characterisation and testing infrastructure.

Materials characterisation to serve the needs of both R&D and manufacturing can be sourced from a number of local university-based facilities, science councils, national facilities, commercial testing facilities and international facilities, but to serve the community effectively and efficiently, a new dispensation that will foster multidisciplinary research and advance manufacturing is required. This could be provided by RI in the form of a hub and spoke model that will harness and strengthen existing infrastructure and create new infrastructure. The hub will fulfil a coordination role, provide assistance with funding for the maintenance and renewal of instrumentation, provide information on available services and capabilities, assist with access, connect the local system to internationally based facilities, assist with the training of experts and operators, provide assistance with quality systems, traceability and accreditation, and host specialised meta-infrastructure not available elsewhere in South Africa.

IT IS ANTICIPATED THAT THE HUB AND THE NODES WILL PROVIDE A STATE-OF-THE-ART MATERIALS CHARACTERISATION FACILITY.

The spokes will connect nodes at national facilities, centres of excellence, institutional instrumentation and other characterisation infrastructure, forming an extensive network that can meet local needs. High-end and feeder infrastructure will be maintained at the nodes, although some feeder instrumentation may be placed at the hub to enable industry access to screening before the specialist research facilities are accessed. An equipment maintenance budget pool, administered by the hub, is envisaged to support instrumentation at participating nodes. An increase of funding for meta-infrastructure is envisaged, which could be administered within the existing National Nanotechnology Equipment Programme and National Nanotechnology Equipment Programme.

Impact

The anticipated outcome is that the hub and the nodes will provide a state-of-the-art materials characterisation facility with a sub-Saharan footprint, with special benefits to the Southern African Customs Union, followed by the Southern African Development Community and other African countries with collaborative research interests. It will be linked to global RIs, a function specifically requested by large industrial users as well as by most of the R&D community consulted. It will also be able to assist the Africa Network for Education in Nuclear Science and Technology with future research on materials used in nuclear reactors, fuel and waste management. Energy-saving and emerging technologies such as nanotechnologies, additive manufacturing and advanced materials for aerospace will benefit. Human capital development will be integral to the overall strategy and postgraduate students will be trained in advanced materials characterisation to a level of international expertise. This will provide a much needed pipeline of material characterisation researchers to the national system. Other outputs will include publications, services to industry, innovation and technology development, measuring instrument development, and the training of analysts and technologists.

The RI will impact on the science and technology missions of manufacturing technology, frontier science and technology, high-value industry and cross-cutting sectors.

6.13 Biogeochemistry research infrastructure platform

Project description

The main objective of the biogeochemistry research infrastructure platform is to gain further insight into the interactions of human activity and the environment over the past several hundred millennia and to determine how the environmental impact of anthropogenic activity has contributed to the change in Earth system dynamics (chemical, physical and biological). This includes the search for an understanding of the behaviour of well characterised and emerging pollutants and their current impact on the environment.

The use of multidisciplinary teams to continue characterisation of the Earth's natural resources will also contribute to future sustainability models, including the recycling of resources, and even develop technologies for remediation. Recent advances in science and technology have contributed significantly to the understanding of environmental processes and extended knowledge of maintaining better ecological balances to sustain. As a result, in the past decade, many countries have assigned resources to establish centres of excellence to conduct cutting-edge biogeochemical research with the aim of attracting, retaining and developing talented researchers from both local and international scientific communities. The RI will be a research centre with four essential pillars, namely, interdisciplinary research, innovation development with partners, an education development centre and value-added services for all stakeholders. Accelerating the interplay between academia, industry and society will advance internationally competitive

Below: The governance model could attract the interest of private entities which could be interested in sharing the use of sophisticated equipment for research and commercial uses.

scientific excellence and extensive characterisation of the environment.

THIS RI WILL BE ACCESSIBLE TO BIOLOGISTS, GEOLOGISTS, CHEMISTS AND PALAEONTOLOGISTS.

This RI will comprise a single-sited platform facility (at the University of the Free State/Bloemfontein, as this would be centrally accessible to all stakeholders) that will cover a broad spectrum of state-of-the-art analytical techniques for high quality nutrients, trace elements, heavy metals, stable, radiogenic isotopes and biological diversity analyses, with abilities for dating for the geological, biological and environmental sciences. This strategy is intended to provide a holistic framework for the development of the research line in biogeochemistry.

Impact

The DST has identified the deeper understanding of the Earth and environmental science challenges as a national research priority. With the increasing energy demands of an ever growing South African population, as well as the increased consumption of natural resources, including water, and issues like global climate change, a better understanding of the environment and the impact of human activities is essential, as is orienting ourselves with knowledge of the origin and sustainability of resources. The activity of the biogeochemistry facility will provide a mechanism for testing a wide range of hypotheses about the origins, balances and impacts of anthropogenic activities on the environment in the past, as well as the present. The data and models generated from the activities of the biogeochemistry RI will be accessible to various biologists, geologists, chemists and palaeontologists. They will also be used for skills development and graduate training while hypotheses are verified. The RI will facilitate knowledge generation and skills development while contributing to the development of technologies to recover and recycle resources, thus joining the interests of the private and public sectors, and promoting scientific, technological and economic development in South Africa directly and indirectly.

7 IMPLEMENTATION OF THE SOUTH AFRICAN RESEARCH INFRASTRUCTURE ROADMAP

With 13 RIs identified under SARIR, a plan was developed for their establishment. Clearly, not all individual proposals and plans for the implementation of the research infrastructures are at the same stage of readiness and, even if they were, it would hardly be feasible to begin establishing all of them at the same time, if only because of financial constraints.

THE DST HAD TO DETERMINE THE CHRONOLOGY IN WHICH THE ROADMAP SHOULD BE IMPLEMENTED.

The Department therefore had to determine the chronology in which the roadmap should be implemented. Among many other considerations, it was necessary to balance available budgets with expected costs and projected cash flows, ensure that any gaps identified in the detailed proposals were addressed, confirm the availability of sufficient capacity to implement the project, and secure the required institutional arrangements.

7.1 Ordering of research infrastructures for roll-out

The final Steering Committee report reviewed the detailed proposals, identified gaps, made several relevant observations and suggestions, and scored the proposals in terms of their intrinsic scientific merit and the rigour of the respective business cases. Specifically, the following criteria were considered for this purpose:

- Impact.
- Scientific excellence, novelty and innovation.
- Management plan.
- Implementation.
- Governance structure.
- Financials.
- Capacity development and transformation.
- Monitoring and evaluation.

Using the Steering Committee's inputs and scores, the DST next needed to assess the readiness for implementation of the 13 RIs, taking into account DST-internal financial and strategic considerations. The following criteria were applied to prioritise and order the 13 RIs for implementation:

- Affordability, considering the full cost of establishing the RI.
- Cost to implement the RI over the initial three years, especially in the 2016 Medium Term Expenditure Framework (MTEF).
- Alignment with DST priorities, strategies and the TYIP grand challenges.
- Spread across different scientific domains, including the humanities and social sciences.
- Alignment with national priorities (the NDP, the Medium Term Strategic Framework, addressing the triple challenge of poverty, inequity and unemployment, and the Nine-Point Plan).
- Extent of return on investment over the short term.

Above: Transforming written text to electronic format.

- Interface with other government departments.

From the above review, it became evident that the implementation of some of the RIs will require underwriting (at least in principle) by other government departments, and that agreement will have to be sought from these departments before the establishment can begin.

On the basis of the Steering Committee assessment, internal DST assessment, and informed by the seven additional strategic considerations outlined above, the Minister of Science and Technology approved the Department's recommendation to roll out the roadmap as set out in Table 3, beginning in 2016/17. As can be seen, the establishment of seven of the RIs will begin in 2016/17, with the remainder being phased in over a five-year period.

As outlined in Table 3, the establishment of the biobanks and biogeochemistry RIs will be initiated in 2017/18; the South African marine and Antarctic research facility in 2018/19; and the materials characterisation facility in 2019/20. Given the complexity and costs associated with the solar research facility and the nano-micro manufacturing facility, their implementation will only be initiated in 2020/21. RIs not initiated in 2016/17 will be given limited financial support for the further development of proposals and, in the case of larger facilities such as the solar and nano-micro RIs, to conduct detailed feasibility studies.

IT BECAME EVIDENT THAT THE IMPLEMENTATION OF SOME OF THE RIS WILL REQUIRE UNDERWRITING BY OTHER GOVERNMENT DEPARTMENTS.

The decision on the host and implementing agency for the RIs for which establishment will begin in 2016/17 (as per Table 3) was informed by broad national consultation among all relevant role players and stakeholders, including the Technology Innovation Agency, the National Research Foundation and relevant government departments, and as suggestions emerged in the process of developing the respective proposals. This approach will also be adopted for the final determination of the appropriate governance structures and host institutions for the RIs for which establishment will be initiated later.

Table 3: Chronology of SARIR implementation

Research infrastructure	Proposed host	Financial year for start of implementation				
		2016/17	2017/18	2018/19	2019/20	2020/21
Expanded terrestrial and freshwater environment observation network	SAEON/NRF	✓				
Nuclear medicine research facility	Phase 1: Necsa; Phase 2: at a hospital	✓				
South African network of health and demographics surveillance sites	MRC	✓				
National centre for digital language resources	NWU	✓				
National science collections	SANBI	✓				
Shallow marine and coastal research infrastructure	SAEON/NRF	✓				
Distributed platform for "omics" research	Centre for Proteomics and Genomics Research	✓				
Biobanks	To be determined		✓			
South African marine and Antarctic research facility	To be determined			✓		
Nano-micro manufacturing facility	To be determined					✓
Solar research facility	To be determined					✓
Material characterisation facility	To be determined				✓	
Biogeochemistry Research Infrastructure Platform	To be determined		✓			

7.2 Funding requirements

The projected budget requirements of the RIs over the first five years of an initial life cycle of 15 years are shown in Table 4. Over the 2016 MTEF period (that is, 2016/17 to 2018/19), R180m, R200m and R220m, respectively, are budgeted for the establishment of the RIs indicated in Table 3 above. It is therefore evident that, as early as 2018/19, additional funding over the existing baseline of the R&D Infrastructure budget will be required for the RIs.

Table 4: Projected budget requirements for the RIs over the first five years

Research infrastructure		Budget (in Rand million)				
		2016/17	2017/18	2018/19	2019/20	2020/21
1.	Expanded terrestrial and freshwater environment observation network	18,40	12,60	23,40	15,80	25,30
2.	Nuclear medicine research facility	56,90	46,10	46,10	125,00	169,00
3.	South African network of health and demographics surveillance sites	27,00	32,00	40,00	78,00	87,00
4.	National centre for digital language resources	7,50	28,87	30,72	36,50	37,82
5.	Natural science collections facility	15,00	17,80	18,70	26,30	26,30
6.	Shallow marine and coastal research infrastructure	29,70	32,40	35,60	35,60	39,22
7.	Distributed platform for "omics" research	10,00	12,00	15,00	78,00	101,00
8.	Biobanks	0,00	3,70	4,40	3,70	3,30
9.	South African marine and Antarctic research facility	0,00	1,00	40,00	60,00	150,00
10.	Nano-micro manufacturing facility	0,00	1,00	1,40	2,40	68,00
11.	Solar research facility	0,00	0,70	1,00	1,10	92,00
12.	Materials characterisation facility	0,00	0,50	0,60	15,00	22,30
13.	Biogeochemistry research infrastructure platform	0,00	15,00	18,00	24,00	6,27
Total investment		**164,50**	**203,67**	**274,92**	**501,40**	**827,51**

Caution is required when dealing with the estimated costs in Table 4 above. The amounts for the first three years are more certain and represent the best estimate available at the time of writing, whereas those in the outer two years are indicative amounts.

The initial implementation of the SARIR will be funded through the DST's existing allocations.

The current 2016 MTEF allocations to the DST for the R&D Infrastructure Budget will not allow roll-out of the 13 RIs over the five-year implementation phase without additional new funds being provided by Treasury. This is where the SARIR initiative comes in. It was conceptualised as a strategic intervention, not only to map out a rational, long-term plan to guide national-level research infrastructure investment, but also to serve as a basis for securing long-term financial commitment from Treasury for this plan. In other words, the Department will embark on a process to secure Treasury commitment in conjunction with relevant stakeholders, especially other government departments. It is envisaged that the final outcome of this engagement with National Treasury should be the establishment of a long-term infrastructure fund for the sustainable implementation of SARIR.

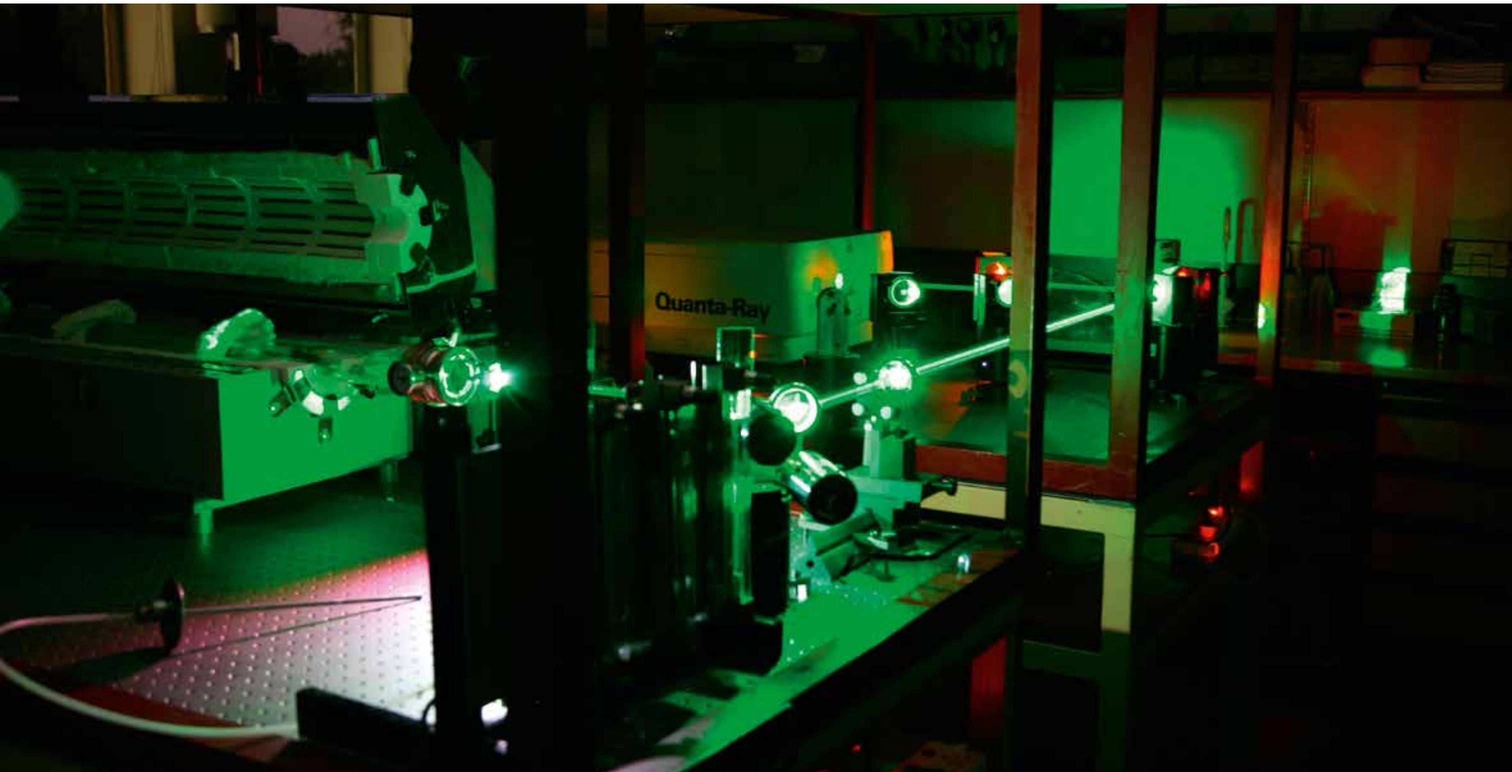
7.3 Cyberinfrastructure requirements

Cyberinfrastructure is critical to all RIs, whether virtual or physical. This includes virtual access to physical sites, data sharing, curation, provenance, protection, and developing interoperability and metadata standards. E-science and cyberinfrastructure need to be planned from the start of any RI programme allowing virtual access and open access to national and international data. The roll-out and ongoing development of the National Integrated Cyberinfrastructure System in the form of the Centre of High Performance Computing, the South African National Research Network and the Data Intensive Research Initiative of South Africa will provide the necessary cyberinfrastructure capabilities for the successful operation of all the RIs on a generic basis. Where specific cyberinfrastructure requirements are identified around an RI, the Department will consider these requirements.

7.4 Consultations

Implementation of the RIs will include further, formal consultation with all relevant government departments to contract them on their level of involvement in and support for the establishment of relevant RIs, as either funding partners or non-funding, strategic partners whose commitment to the RI constitutes a necessary condition for implementation. There will also be discussions with the institutions that will host the RIs, with a view to finalising contractual agreements between the institutions and the DST. Lastly, the SARIR plan will also form the basis of engagement with Treasury on its long-term financial implications.

Below: Nanoparticle laser ablation system.



8 REVIEW, MONITORING AND EVALUATION

Periodic review, monitoring and evaluation throughout the full life cycle of each RI are key requirements for successful realisation of the set objectives, delivery of the anticipated outcomes and impact, ensuring that public funds are used effectively, and highlighting the value generated by the research infrastructure and the resulting research over the medium to long term. The DST and the nominated implementing agency will have to ensure that all RIs are committed in a formal and structural manner to contribute to and report on the DST's key performance indicators, such as scientific publications, patents, human capital and research capacity development, and socio-economic impact.

For SARIR, monitoring and evaluation will be conducted at two levels, namely the institutional level by the hosting and implementing entity; and (ii) the departmental (DST) level. With regard to external evaluation and review of the SARIR implementation, the establishment of a steering committee (key members being scientific domain experts and government departments, with as many members of the original steering committee as possible) and an advisory committee (domain specialists, government departments, private sector individuals, implementing agency executives and international experts) is proposed. This review, monitoring and evaluation structure is depicted in Figure 5. The terms of reference for the individual components of this structure will be developed in consultation with all relevant stakeholders.

SARIR will be reviewed substantively on a three-yearly basis, with attention paid to all life-cycle issues, from planning, development, establishment and operation to phase-out, termination or reuse of research infrastructures. However, for at least the first three years, more regular review will be necessary at various levels, from RI to sectoral and departmental.

Figure 5: SARIR implementation and oversight structure

9 CONCLUSION

SARIR represents the first iteration of a national plan that describes the long-term research infrastructure needed to enhance current research and enable the introduction of new research of the highest quality. Its development has enabled a fresh way of thinking about research infrastructure provision in South Africa, and considerably expanded the scope of planning by introducing an approach that breaks the mould of the two that normally prevail, namely, traditional bottom-up competitive research equipment processes, and top-down strategic investment programmes.

In addition, the approach taken to formulating the roadmap expanded the scope of scientific domains for research infrastructure investment, bringing in the humanities and social sciences in a way that, for South Africa, at least, is novel. Lastly, the approach has allowed a diversification of the institutional arrangements that are established around RI projects, and has integrated a multi-institutional angle throughout the initiative.

One possible aspect of a roadmapping process that was, however, not realised in this first iteration in South Africa, is the detailed consideration of the role of global RIs on South African science. The cost and effort involved in accessing such infrastructure can rival the cost and effort associated with the domestic establishment of RIs, and decisions around such investments should therefore be embedded in the broader RI roadmap. The DST and the national research community should give some consideration to this matter.

The roadmap was prepared through a combination of extensive bottom-up and top-down consultation involving the national facilities, science councils, universities, private sector, government departments, and the research community. The outcome of this consultative process was an agreement on the relevant scientific domains and RIs to constitute SARIR.

The implementation of SARIR for the 13 selected RIs across the five scientific domains will be undertaken in a parallel process. An immediate start will be made with the infrastructure proposals that have demonstrated a sufficiently high level of scientific and technical readiness, while the further development of proposals in which critical gaps were identified will take place simultaneously. All RIs will be phased in over a five-year period as part of an initial projected life cycle of 15 years.

A robust review and monitoring and evaluation system will be put in place to ensure the sustainable establishment and operation of the 13 selected RIs and to review their progress, as well as considering proposals for introduction of new RIs.

10 ACKNOWLEDGEMENTS

The Department acknowledges with thanks the contributions to the development of SARIR made by the the expert group, steering committee, champions and scientific community.

Below: Small-scale CSIR solar photovoltaic plant.

APPENDIX 1: LIST OF ABBREVIATIONS

CHPC	Centre for High Performance Computing
CHRTEM	Centre for High Resolution Transmission Electron Microscope
CLARIN	Common Language Resources and Technology Infrastructure
CSIR	Council for Scientific and Industrial Research
DST	Department of Science and Technology
ESFRI	European Strategy Forum for Research Infrastructures
GEOSS	Global Earth Observation System of Systems
GSO	Group of Senior Officials on Global Research Infrastructures
HDSS	health and demographic surveillance systems
hpc	high performance computing
HSRC	Human Sciences Research Council
IMEC	Interuniversity Microelectronics Centre
INDEPTH	International Network for the Demographic Evaluation of Populations and their Health
KPI	key performance indicator
MoU	memorandum of understanding
MRC	Medical Research Council
MTEF	Medium Term Expenditure Framework
NDP	National Development Plan
Necsa	South African Nuclear Energy Corporation
NRDS	National Research and Development Strategy
NRF	National Research Foundation
NSI	national system of innovation
NWU	North-West University
R&D	research and development
REIPPPP	Renewable Energy Independent Power Producer Procurement Programme
RI	research infrastructure
SAEON	South African Environmental Observation Network
SANBI	South African National Biodiversity Institute
SARIR	South African Research Infrastructure Roadmap
SKA	Square Kilometre Array
SMCRI	shallow marine and coastal research infrastructure
SOC	state-owned company
TYIP	Ten-Year Innovation Plan for South Africa
Wits	University of the Witwatersrand

APPENDIX 2: EXPERT GROUP, CHAMPIONS AND STEERING COMMITTEE MEMBERS

Expert group

Responsible for developing the framework for SARIR

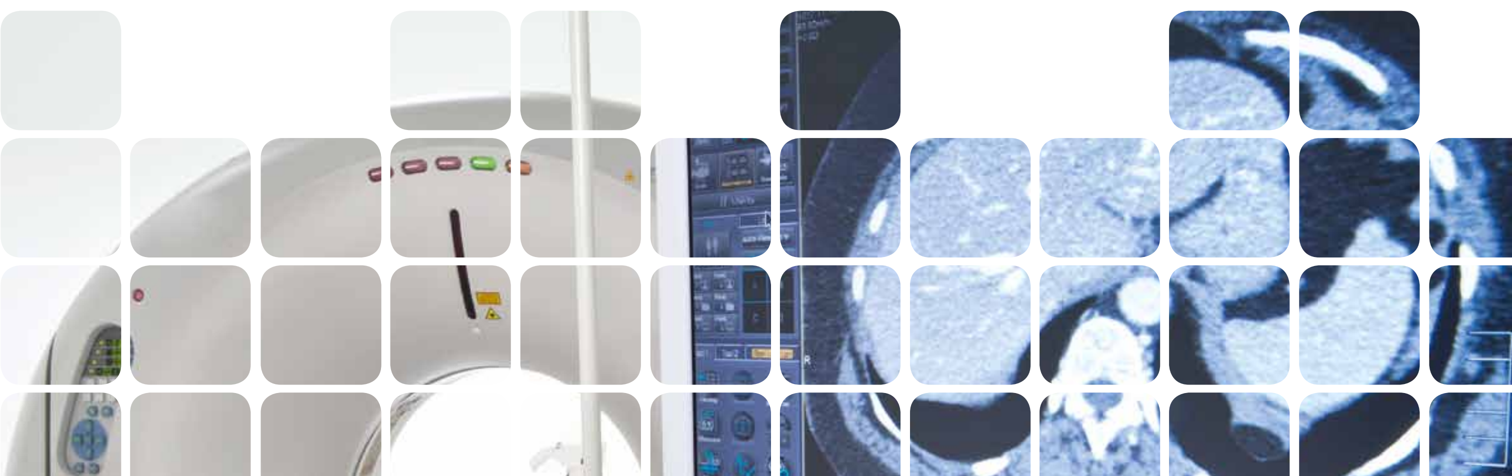
Name	Designation and affiliation
Dr Anthon Botha	Managing Director, TechnoScene, South Africa
Prof. Gonzalo León	Vice President for Research at the Universidad Politécnica de Madrid
Prof. Gerhard von Gruenewaldt	Independent consultant, South Africa
Prof. John Wood	Secretary General of the Association of Commonwealth Universities

SARIR champions

Responsible for coordinating the development of RI proposals

Name	Designation and affiliation
Dr Paul Bartels	Veterinarian and lecturer at the Department Nature Conservation, Tshwane University of Technology
Dr Tommy Bornman	Manager: Elwandle Coastal Node, SAEON, NRF
Dr Mark Collinson	Senior Researcher at the MRC/Wits Rural Public Health and Health Transitions Research Unit (Agincourt), School of Public Health, Wits Principal investigator, Migration, Urbanisation and Health Working Group, INDEPTH Network
Dr Simon Connell	Professor at the Department of Physics, Faculty of Science, University of Johannesburg
Prof. Michelle Hamer	South African National Biodiversity Institute
Dr Jacobus Herbst	Deputy Director and Head of Research Operations at the Africa Centre for Population Health
Dr Reinhart Hiller	Managing Director: Centre for Proteomic and Genomic Research
Prof. Stephen Hosking	Head of Business School, Cape Peninsula University of Technology
Dr David Jansen	Researcher: Radiochemistry, Necsa Nuclear Technologies in Medicine and the Biosciences Initiative Project Assistant
Dr Kevin Land	Materials Science and Manufacturing, CSIR
Dr Phiyane Lebea	Research Group Leader: Molecular Diagnostics, CSIR
Dr Wynand Louw	Director: Research and Technology Development, National Metrology Institute of South Africa
Dr Thato Mtshali	Polar Research: CSIR Southern Ocean Carbon and Climate Observatory
Dr Pedro Monteiro	Head: Ocean Systems and Climate, CSIR Centre for High Performance Computing

Ms Anza Murovhi, Necsa	Programme Manager, Necsa
Prof. Justus Roux	Director: Language Centre, NWU, Mercator Fellow Institute for Computational Linguistics University of Stuttgart, Germany Retired professor
Dr Bob Scholes	Head: Global Change and Sustainability Research Institute, Wits
Dr Manfred Scriba	Principal Technologist and Researcher at the DST-CSIR Nanotechnology Innovation Centre. Manager: DST-CSIR Nanomaterials Industry Development Facility
Prof. Esta van Heerden	Professor of Microbial Biochemical and Food Biotechnology, University of the Free State
Dr Anton Vosloo	Seconded professor, Stellenbosch University
Dr Jan Rijn Zeevaart	Scientific Head: Radiochemistry, Necsa



SARIR Steering Committee

Responsible for evaluating RI proposals

Name	Designation and affiliation
Prof. Neville Comins	Consultant: Innovation Systems and Science Park Development (Retired professor)
Prof. Anne Grobler	Director: DST/NWU Preclinical Drug Development Platform
Prof. Albert Helberg	Director: Research Unit for Energy Systems at NWU
Prof. Dirk Knoesen	Researcher/academic at the University of the Western Cape
Prof. Robert Lindsay	Head of Department: Physics at the University of the Western Cape
Dr Musa Mhlanga	Senior researcher at the CSIR
Dr Monde Ntwasa	Molecular biologist, genomics at Wits
Dr Antonel Olckers	CEO of DNAbiotec Pty Ltd
Dr Angus Paterson	Managing Director: South African Institute for Aquatic Biodiversity
Dr David Phaho	Functional Manager: Refinery Technologies Group, Sasol Technology R&D
Prof. Gerhardus Prinsloo	Durban University of Technology and National Advisory Council on Innovation Technology Specialist
Dr Dirk Swanevelder	Agricultural Research Council Biotechnology Platform
Dr Christa van Zyl	Research Coordination, Longitudinal and cross-sectional survey initiative, HSRC
Prof. Colin Wright	Cyberinfrastructure expert, CSIR

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