National Research Foundation

25

Celebrating 25 Years of Research, Innovation, Impact and Partnerships



National Facilities

National Research Foundation

25

Celebrating 25 Years of Research, Innovation, Impact and Partnerships

NATIONAL FACILITIES

science & innovation

Department:
Science and Innovation
REPUBLIC OF SOUTH AFRICA

Copyright © National Research Foundation (NRF).
Published by the National Research Foundation, NRF Building, South Gate, CSIR Complex, Meiring Naudé Road, Brummeria, Pretoria, South Africa.
P.O Box 2600, Pretoria, 0001, South Africa

The National Research Foundation ("the NRF") is a statutory body established in terms of the National Research Foundation Act No 23 of 1998.

First edition 2024

Print ISBN: 978-0-7961-8530-3
Electronic (PDF) ISBN: 978-0-7961-8531-0

Copyright in the text is vested in the NRF and its National Facilities. All rights reserved. No part of this publication may be reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopying, recording, or any such information storage or retrieval system, without prior permission in writing from the publisher. The authors and publisher have made every effort to obtain permission for and to acknowledge the use of any copyrighted material. Should any infringement of copyright have occurred, please contact the publisher, and every effort will be made to rectify omissions or errors in the event of a reprint or future edition.

The publisher gratefully acknowledges the funding from the South African Department of Science and Innovation (DSI) towards the publication of this work.

Editor: Penny Haworth
Proofreaders: Liz Gowans, National Facilities' content coordinators, Patrick Saunders
NRF National Facilities' content coordinators: Gillian Arendse, Daniel Cunnama, Lucky Dlamini, Londiwe Mabuza, Teboho Monareng
Design and layout: Liz Gowans, Susan Abrahams
NRF Vision 2030 infographic: Georgiet Hammond

Front cover photograph: A portion of the MeerKAT Radio Telescope's Array, with clear night skies, outside of the town of Carnarvon, in the Northern Cape province of South Africa. This image is the property of NRF-SARAO.
Back cover photographs: Photo collage of NRF National Research Facilities – clockwise from top left: NRF-SAIAB; NRF-iThemba LABS; NRF-SAAO; NRF-SAEON.
Photographs on p. 66 provided courtesy of The Southern African Foundation for the Conservation of Coastal Birds (SANCCOB).

Printed by Rand Data Forms, c/o Remata Building, International Business Gateway Park, CNR 6th and New Road, Midrand. Tel: 011 626 1330; 012 329 0181

National Research Foundation 25

CONTENTS

FOREWORD 1
INTRODUCTION 2
OVERVIEW: NRF-SAIAB 9
OVERVIEW: NRF-SAEON 13
OVERVIEW: NRF-iThemba LABS 17
OVERVIEW: NRF-SARAO 21
OVERVIEW: NRF-SAAO 25

TRANSFORMATION

Collaborative programmes transforming marine science at South African HDIs 31
Women in water: NRF-SAIAB's Professional Development Programme 33
NRF-SAEON Graduate Student Network: Overview of transformation and linking the next generation of researchers 35
NASSP: Building a legacy of astronomers and data scientists 37
SAINTS: Advancing transformation 39
Establishing a fit-for-purpose Human Capital Development Programme 41
NRF-SAIAB's science engagement legacy 43
Empowering educators, inspiring learners, and nurturing future astronomers 45
Learning for a sustainable future: NRF-SAEON Environmental Science Education Programmes (ESEP) 47

IMPACT

Isotopes and health 51
Investment in radio astronomy maximises opportunities for societal benefit 53
SALT Collateral Benefits Programme: Linking science to society, transforming a community 55
Tilapia mapping to support decision making for aquaculture development 57
Deep impact: ACEP projects support improved ocean protection 59
Managing aquatic invasions in South Africa 61
Inland fisheries management research informs new national policy 63
Understanding rangelands informs decision making and improves food security 65
Sustainable Ocean Modelling Initiative: A South African Approach (SOMISANA) 67
BioEnergy Atlas of South Africa: Ensuring energy security through sustainable energy systems 69
Advancing water and income security in the unique Maputaland coastal plain 71
Essential marine and coastal platforms for sustainable resource management and driving the Blue Economy 73

INNOVATION

TIPping point: Advanced AI enhancing health outcomes in the Global South 77
Particle therapy as a treatment for cancer 79
NRF-SARAO's innovation and commercialisation value chain 81

NRF-SARAO and the National Ventilator Project: Resilience, flexibility and leadership in times of crisis....83
Illuminating pathways: Optical innovations transforming agriculture, medicine, and beyond....85
Revolutionising astronomy with AI and robotics....87
Enhancing astronomical research through in-house CCD detector integration....89
Combating antimicrobial resistance through harnessing South Africa's marine biodiversity....91
Coastal harmony: Weaving indigenous and scientific solutions for resilient shores....93

EXCELLENCE (Knowledge)

MeerKAT's unique capabilities enable ground-breaking findings....97
The Southern African Large Telescope (SALT): A powerful tool for discovery....99
Expanding taxonomic frontiers: *Coastal Fishes of the Western Indian Ocean*....101
Understanding climate and global change in Southern Africa....103
Advances in subatomic physics....105
Gamma-ray spectroscopy....107
Research excellence developing an African footprint through U2ACN2....109

EXCELLENCE (Infrastructure)

MeerKAT: A pioneering scientific instrument in its own right....111
SALT: A beacon of world-class astronomy infrastructure in Africa....113
South African Isotope Facility expands particle accelerator portfolio....115
NRF-SAEON's National Long Term Ecological Research infrastructure (LTER)....117
Equipping researchers with research equipment: End to end integrated aquatic infrastructure....119

SUSTAINABILITY

National Research Infrastructure Platforms (NRIPs): Portfolio of innovation....123
Ensuring a social licence to operate: NRF-SARAO case study....125
Science diplomacy: SA and the SKA project – facilitating scientific cooperation....127
Astronomy for a better world....129
Pioneering sustainable astro-tourism in South Africa....131
Diversification of income....133

LOOKING FORWARD....134

CONTRIBUTORS....136

ACRONYMS and TERMINOLOGY....138

FOREWORD



The National Research Foundation (NRF) celebrates its 25th anniversary, which coincides with 30 years of democracy in South Africa. As we look back, we reflect on the NRF's achievements and challenges, while we remain excited and encouraged by the new opportunities for impact that lie before us. The NRF Act (23 of 1998), led to the formation of the NRF in 1999 to promote and enhance inclusive South African research and knowledge transfer. The NRF combined the focus of the Foundation for Research Development (FRD) on the natural, physical and engineering sciences and that of the Centre for Science Development (CSD) on the human and social sciences, to ensure that one research foundation covered all fields and disciplines, including indigenous knowledge. While the CSD and the FRD were the main predecessor organisations, other entities also joined the NRF, either in 1999 or later, bringing into the NRF fold a focus on science engagement and engaged research, as well as leading to the development of NRF National Research Facilities.

The NRF's mandate has been amended to ensure its contribution to national development, through:

a) Supporting, promoting and advancing research and human capacity development, through funding and the provision of the necessary research infrastructure to facilitate the creation of knowledge, innovation and development in all fields of science and technology;
b) Developing, supporting and maintaining national research facilities;
c) Supporting and promoting public awareness of, and engagement with, science;
d) Promoting the development and maintenance of the national science system and support of government priorities.

The mandate thus highlights the need for research and knowledge advancement to respond to the needs and challenges of society. The NRF adopted Vision 2030, centred on the key concepts of Transformation, Innovation and Impact, Excellence and Sustainability. Our Vision is to see science and research in service of society through contribution to national development, response to economic priorities, and investigation of sustainable solutions to persistent challenges. The National Research Facilities are key in responding to this Vision, as they continue to deliver transformative human capacity development, societal benefits, innovative solutions and excellent research. These National Research Facilities are available for use across the national science system, and they enhance the sustainability of science though technology products and income generation which is then reinvested into the science system. Their contribution over the last 25 years has been phenomenal. While we celebrate their past achievements, we also look forward to seeing further developments as they move from strength to strength. This book looks at the contribution of the NRF through the National Facilities. A separate book will look at the impact from granting perspectives.

Fulufhelo Nelwamondo, PhD
Chief Executive Officer

Celebrating 25 years of research, innovation, impact and partnerships

Angus Paterson

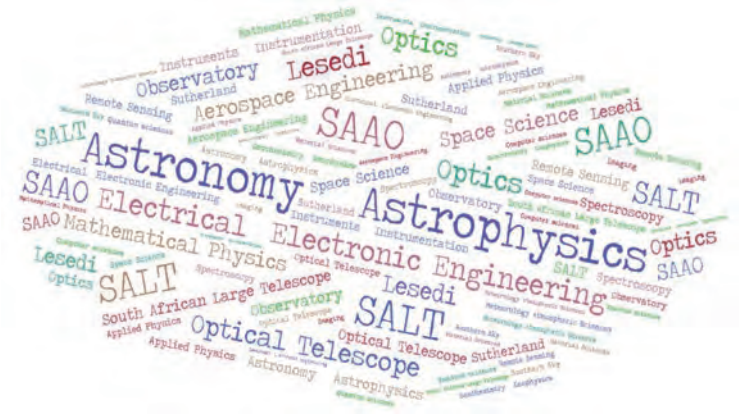
As the NRF celebrates the 25th anniversary, it is opportune to reflect on the organisation's achievements and impact. One area in which the NRF has made a significant contribution to the National System of Innovation (NSI) and broader society, is through the NRF National Facilities. Their key role is the provision of cutting-edge large (single or distributed) research infrastructure for use by the national and global research community. Along with this, the National Facilities carry out research and innovation, and assist in developing the next generation of researchers in their research area through various human capacity development programmes. The promotion and advancement of science with impact is a cross-cutting priority in all activities.

National Facilities do not work in isolation and are deeply imbedded within South Africa's NSI and work collaboratively with universities, science councils, Government departments, museums, industry, NGOs, civil and community entities, and international institutions, among others.

Over the past 25 years, the suite of NRF National Facilities has adapted. For instance, the Hermanus Magnetic Observatory (HMO), which joined the NRF in 2001, moved to join the South African National Space Agency (SANSA). The National Zoological Gardens joined the NRF in 2004 and was transferred to the South African National Biodiversity Institute in 2018. The NRF currently has four National Facilities, with their origins discussed below, all of which joined the NRF as research infrastructures after it came into existence through the National Research Foundation Act, 1998, and the merger between the Foundation for Research Development (FRD) and Centre for Scientific Development (CSD) in 1999.

South African Astronomical Observatory (NRF-SAAO): The Royal Observatory at the Cape of Good Hope was founded in 1820 and is the oldest scientific institution in the country. It was initially controlled by the British Admiralty for the improvement of navigation. The present observatory was formed in 1972 by combining the Royal Observatory at the Cape with the Republic Observatory in Johannesburg which were amalgamated into the South African Astronomical Observatory (SAAO), with its headquarters in the old Royal Observatory buildings in Cape Town. However, dark, unpolluted skies are a distinct advantage for observing the stars and a site away from the city's light pollution was sought. A suitable location was identified near Sutherland in the Karoo. The new site opened in 1973 and in 1999 the South African Astronomical Observatory (SAAO) was incorporated into the NRF.

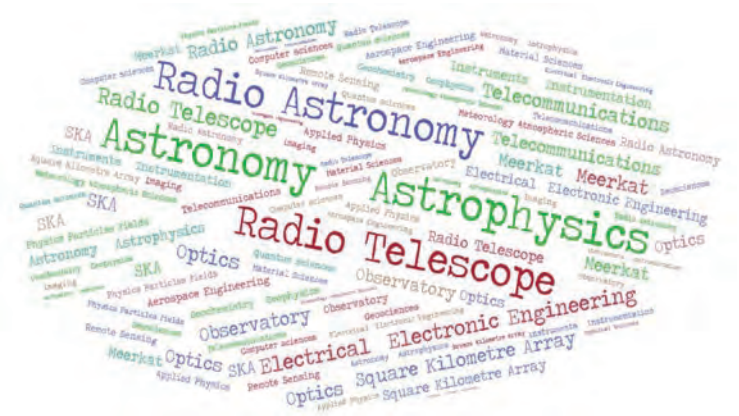
NRF-SAAO focus areas



South African Radio Astronomy Observatory (NRF-SARAO): The Hartebeesthoek Radio Astronomy Observatory (HartRAO) was South Africa's first radio astronomy observatory. It began as Deep Space Station 51, built in 1961 by the American National Aeronautics and Space Administration (NASA). In 1975, it was handed over to the Council for Scientific and Industrial Research (CSIR), which converted it to a radio astronomy observatory. In 1988 it was transferred to the FRD, and then to the NRF in 1999. The South African Square

Kilometre Array (SKA SA) Project was initiated in January 2003, and in 2012 South Africa was recommended to host the mid-frequency array (SKA-Mid) in the Karoo (with African partner countries). The Minister of Science and Technology established the South African Radio Astronomy Observatory (NRF-SARAO) as an NRF National Facility in 2017 as the successor to the SKA SA Telescope Project, and to continue the work of HartRAO and house the MeerKAT radio telescope, a precursor to the SKA-Mid.

NRF-SARAO focus areas



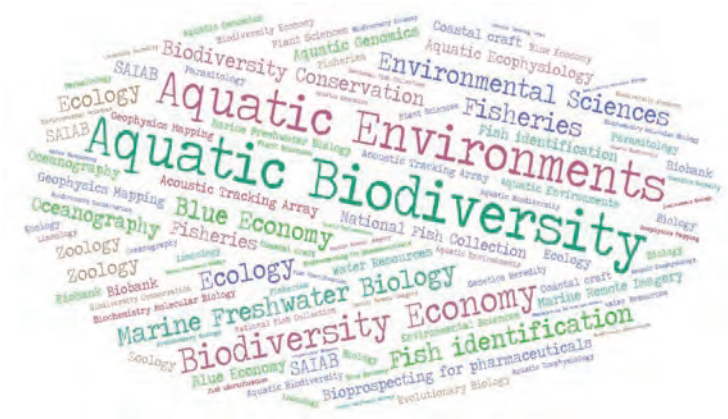
NRF-iThemba Laboratory for Accelerator Based Sciences (NRF-iThemba-LABS): This facility has its origins in the Southern Universities Nuclear Institute (SUNI) established in 1964, with the National Accelerator Centre (NAC) established in 1977 and administered by the CSIR. In 1987 the Separated Sector Cyclotron became operational and administration of NAC was taken over by the FRD. The NAC was incorporated into the NRF in 1999 and renamed NRF-iThemba LABS in 2001.

NRF-iThemba LABS focus areas



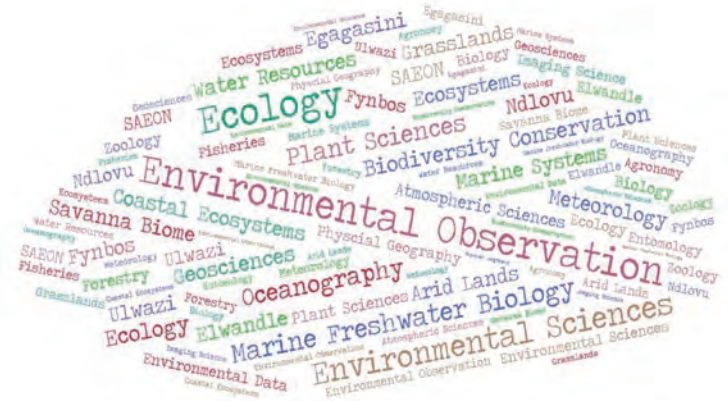
South African Institute for Aquatic Biodiversity (NRF-SAIAB): The JLB Smith Institute of Ichthyology (JLBSI) began in 1968 with seed funding from the CSIR and Rhodes University. It was administered and funded through the Department of Arts, Culture, Science and Technology before being transferred to the FRD. The JLBSI was renamed the South African Institute for Aquatic Biodiversity (NRF-SAIAB) in 2001.

NRF-SAIAB focus areas



South African Environmental Observation Network (NRF-SAEON): In addition to the four National Facilities mentioned above, the NRF manages the South African Environmental Observation Network (NRF-SAEON), which was established in 2002 and is awaiting final designation as a National Facility.

NRF-SAEON focus areas



This publication explores the positive impact that these facilities have had in a variety of areas, both within the research enterprise and in broader society. In 2020, the NRF adopted its Vision 2030, developed around four core concepts of **Transformation, Impact & Innovation, Excellence and Sustainability**. The Vision explains how these cross-cutting focus areas affect all of the NRF's activities and priority areas. This book surveys the achievements of the National Facilities through the lens of Transformation, Impact & Innovation, Excellence and Sustainability (TIES).

Transformation is essentially about fundamental change. In the South African context, transformation is understood to be a process of transition from the legacies of apartheid, with its ideologies and discriminatory practices, into a new democratic era with new or modified practices, institutions, values and beliefs, which have societal legitimacy. The science, technology and innovation sector plays a key role in the social, cultural and economic development of our country and, therefore, a key role in transforming the foundations of society. Part of transforming the knowledge enterprise is changing the way in which research and knowledge production relate to society and the economy. Knowledge and research can be used to support broad social and economic development, encourage critical discourse, and develop responsible and critically engaged citizens.

The NRF recognises the need to accelerate and purposefully transform the knowledge enterprise, responding to challenges such as equity of access and success for postgraduate students; the demography of the researcher cohort (race, gender, disability and social class); alignment between the knowledge enterprise and social and economic needs and challenges; and the development of a critically engaged civil society.

In responding to the transformative imperative, National Facilities have developed a range of programmes to drive transformation in South Africa's science system. These include a range of initiatives from human capacity development and artisan training programmes, to graduate student networks and interventions to drive redress at Historically Disadvantaged Institutions of Higher Education (HDIs). Transformative programmes also aim to empower educators and nurture learners and the National Facilities have made substantial contributions to develop and sustain the next generation of South African scientists and researchers. These programmes are showing their positive effect as a new and more inclusive cohort of researchers move into the science system and bring with them new ideas and priorities.

Impact and Innovation are about having influence or effect for change. The NRF's Research Impact Framework describes impact as *A beneficial change in society or knowledge advancement, brought about as a direct or indirect result of the NRF's research support interventions, whether planned or unintended, immediate or longer-term.* Knowledge impact refers to scientific advances in understanding, interpretation, methods, theory, application, and related advances that bring about positive change within and/or across disciplines and fields. Societal impact refers to the value that research adds to society across various spheres, whether social, economic, or environmental. Societal impact reflects the direct or indirect relationship between research, or the research process, and improvement in the quality of people's lives, inclusive of innovation, technological advancements, improved sustainability, and policy developments.

The NRF's pathways to impact (Figure 1) highlight the transition from research outputs, such as publications and prototypes, to outcomes

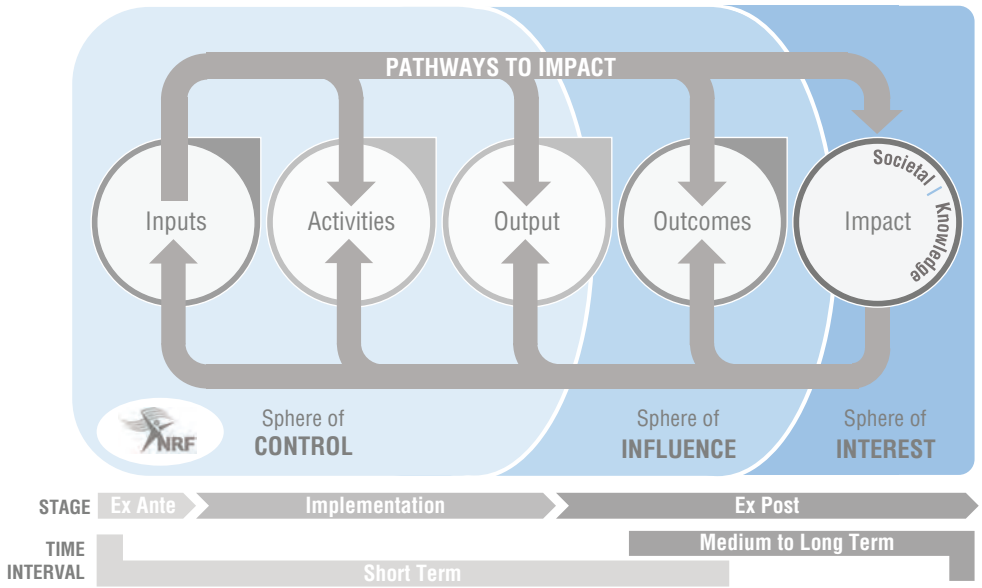


Figure 1: The NRF's pathways to impact

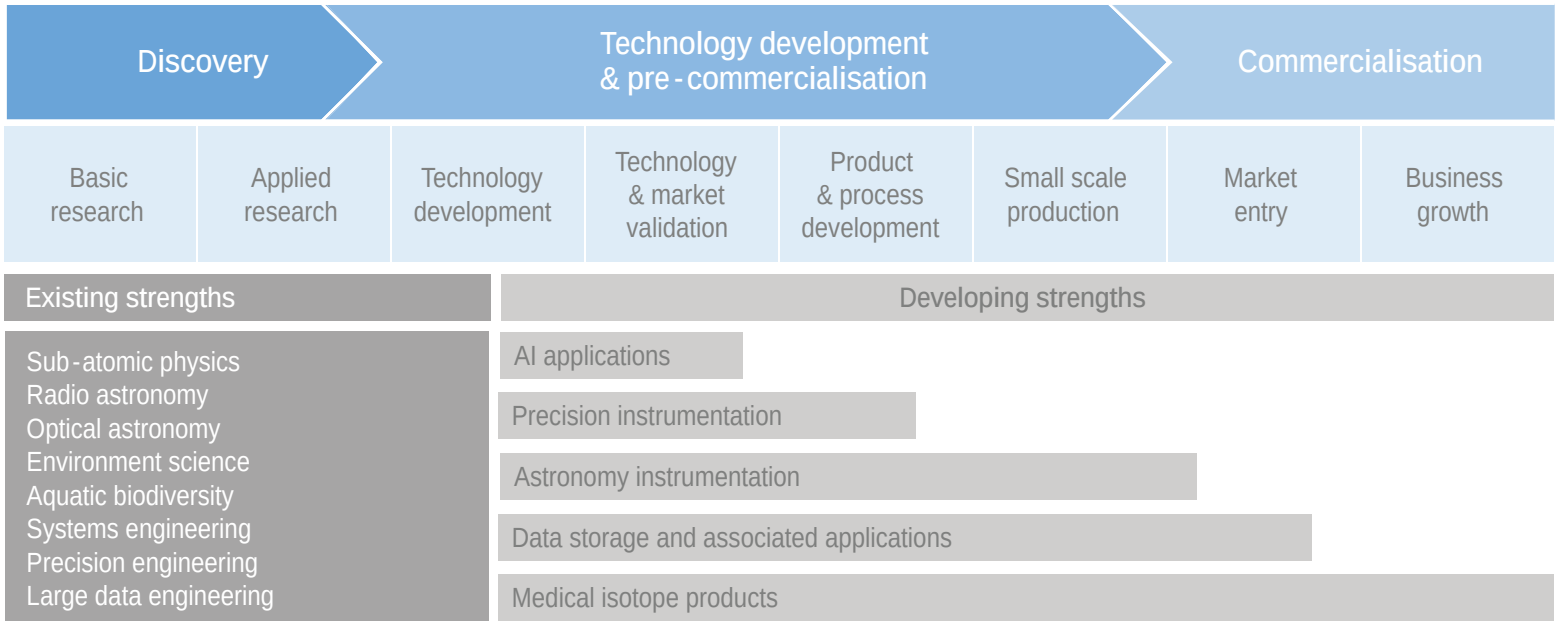


Figure 2: Pathways to innovation and National Facilities' existing and future strengths

where these outputs are taken up and used by others, and to the eventual achievement of beneficial change, whether social, economic, environmental, knowledge-based, or in innovative developments.

Within the TIES thematic framework, Innovation is embedded within the NRF's impact pathways and was highlighted in the Department of Science & Innovation's Decadal plan as a way to advance national development. Innovation is about using research for technology and product development, and in turn commercialisation, for the benefit of society.

The National Facilities display a variety of impacts, creating innovation value chains within their respective spheres of influence. Together with their users and partners, National Facilities have globally recognised strengths in foundational research and engineering (Figure 2). The NRF is actively leveraging these skills to translate foundational research into potential commercial products or techniques. Through their contributions to projects such as the National Ventilator Project, the National Facilities have shown their resilience, leadership and flexibility, along with their ability to respond to national imperatives during times of crisis. Building on internal intellectual property and expertise, the National Facilities aim to play a more prominent role in ensuring that research responds to the needs of South African society and the economy.

National Facility impact extends into creating long-term benefits for private and public health, societal benefits from large scale infrastructure investment, and collateral benefits for rural communities. National Facilities also contribute to ensuring food security, income security, effective sustainable governance, and management of natural resources such as water, energy, and biodiversity.

Excellence is the foundation that sets the standard. In the global knowledge and science system, excellence is often judged in terms of either a comparative evaluation or rating against benchmarks, criteria and goals. Excellence is central for the NRF. As the primary national funder of research, researchers and postgraduate students, the organisation uses excellence as a principle to enhance the global competitiveness of the South African science system. Excellence is expressed through investment in quality research, capable researchers and postgraduate students. The concept of research excellence is open to interpretations and context specific definitions. Emerging research excellence conceptual elements and criteria to which the NRF subscribes are scientific merit, ethics, originality, relevance, purposivity, methodological rigour and impact.

Excellence in the provision of research infrastructure is demonstrated in the conceptualisation, development, building and operation of

world class instruments. Over the last 25 years, the NRF has excelled in delivering highly complex research instruments either single-sited or distributed. For example, in the sub-atomic physics realm, NRF-iThemba LABS has commissioned cyclotrons, used to produce short-lived isotopes with a variety of medical uses, and tandetrons, used for Ion Implantation, Ion Beam Analysis and irradiation experiments. In optical astronomy, NRF-SARAO along with international partners built the Southern African Large Telescope (SALT) at Sutherland. In radio astronomy, NRF-SARAO built the MeerKAT radio telescope which will form a key component of the Square Kilometre Array Observatory (SKAO). In the environmental sector, NRF-SAIAB has developed a fleet of coastal research vessels with deep-water remote observation capability, while NRF-SAEON has established a globally recognised Long Term Environmental Research (LTER) network for South Africa.

Excellence at the National Facilities is also shown through Web of Science publications from the National Facilities. The data below highlights how the number of publications from the facilities has grown over the last two decades.

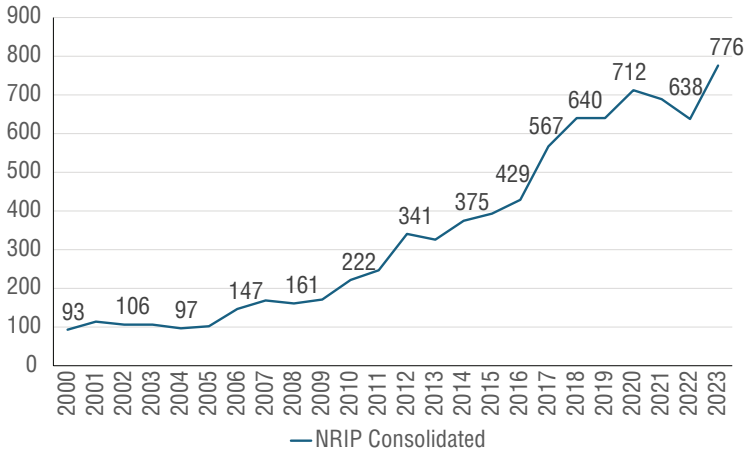


Figure 3: Number of Web of Science publications by National Facilities, 2000-2023

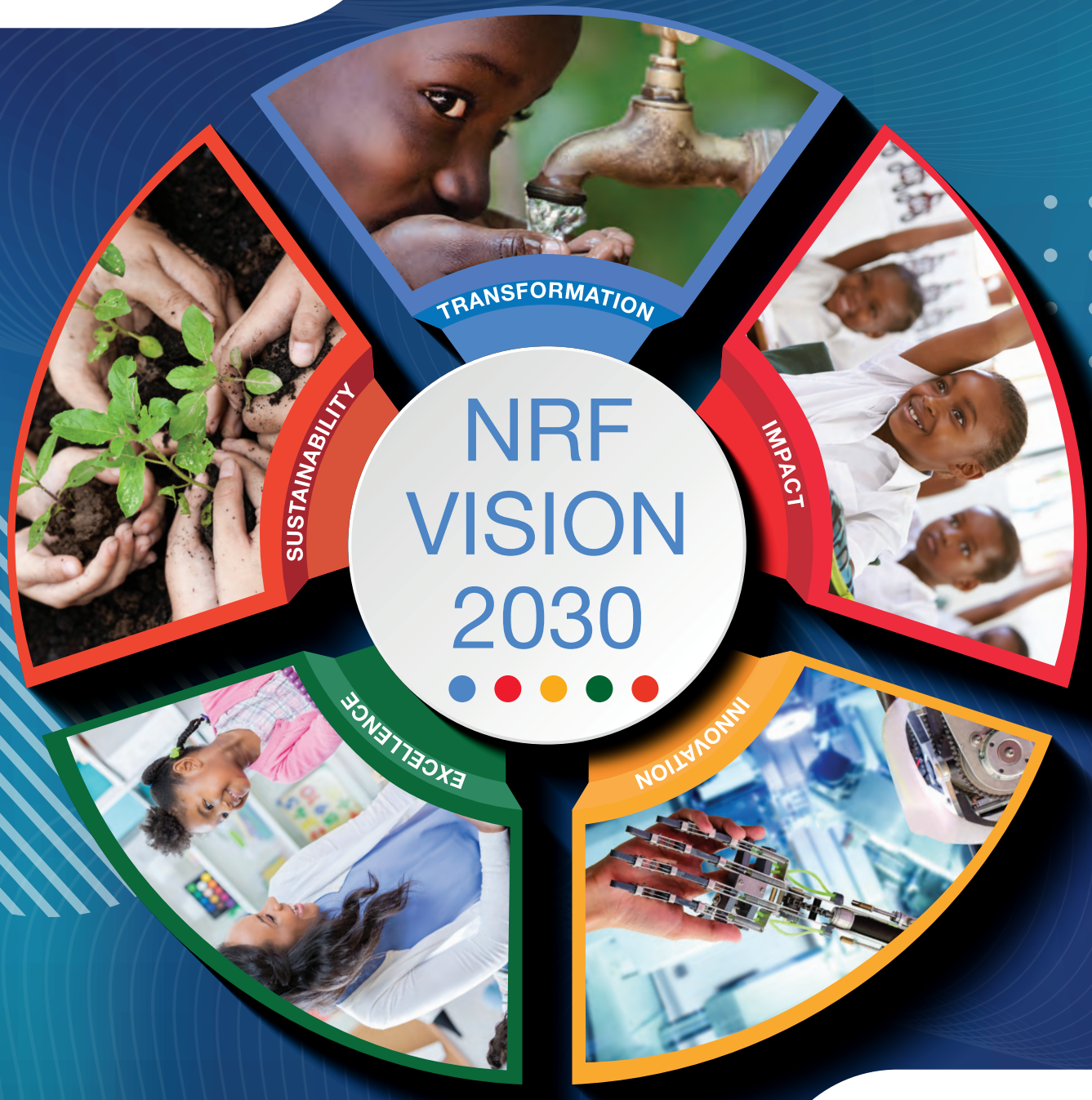
Sustainability is about building a better tomorrow today. The NRF's Vision focuses on organisational sustainability, developing researchers for a sustainable researcher cohort, developing and maintaining research infrastructures for the future, and research for national and global sustainable development.

NRF Vision 2030 highlights the need for financial sustainability. Large research infrastructure is expensive and requires continued investment. Over the last five years, National Facilities have made significant strides in ensuring income generation where appropriate, and in translating foundational research into innovative and commercial outcomes. NRF-iThemba LABS has led the way in terms of medical isotope production and sales while all National Facilities are developing an innovation portfolio and are actively interacting with agencies such as the Technology Innovation Agency (TIA).

In conclusion, the National Facilities not only play a central role in advancing the NRF's Vision 2030 and its focus on TIES, but also in contributing to the NRF's core mandate of supporting Government's priorities and contributing to national development for societal benefit.

National Research Foundation

25



science & innovation

Department:
Science and Innovation
REPUBLIC OF SOUTH AFRICA



The unexpected discovery of living coelacanths off Sodwana in Kwa-Zulu Natal in 2000 was a catalyst that changed the focus of underwater marine exploration and resulted in the establishment of the flagship African Coelacanth Ecosystem Programme (ACEP), the development of platform thinking and advanced research platforms and technological capabilities to explore and conserve South Africa's aquatic biodiversity. eDNA coelacanth distribution assessment is part of the ACEP Deep Connections Project. This coelacanth was photographed at Mzumbe (south-eastern coast of South Africa) by the ACEP Deep Connections Project team. Photo: ACEP/NRF-SAIAB

Sustaining success in aquatic biodiversity research for the Blue Economy

Albert Chakona and Lucky Dlamini

NRF-SAIAB is part of the NRF National Research Infrastructure Platforms (Programme 4), focusing on biodiversity, environmental sciences and conservation. Serving as a hub to facilitate national and international scientific research into the country's most precious resource – water – and the diversity of life supported by our oceans, coastal and inland freshwater systems, its mission is to conduct research to ensure the sustainability of Africa's marine and freshwater environments. NRF-SAIAB plays a crucial role by providing research platforms and specialist infrastructure that support a wide array of interdisciplinary and multi-institutional studies in aquatic systems.

To comprehend our current position and the journey that brought us here, it is essential to reflect on the 56 years since the Institute's inception. The foundational work of NRF-SAIAB has been pivotal in establishing the Institute as a global leader in aquatic biodiversity research.

The formative years

Since its establishment in 1968, the Institute has undergone tremendous changes to adapt to societal needs while maintaining its standing as a globally recognised centre of excellence for aquatic biodiversity research.

During its early years as the JLB Smith Institute of Ichthyology, research concentrated on exploratory and foundational biodiversity science. This initial phase laid the groundwork for understanding South Africa's diverse aquatic ecosystems. Researchers undertook extensive expeditions in South Africa and neighbouring countries, cataloguing their findings in the National Fish Collection at the Institute. This period was characterised by foundational work that mapped aquatic biodiversity, providing a crucial basis for subsequent taxonomic studies. Significant outputs from this phase included numerous scientific papers, books and book chapters, notably the influential *Smiths' Sea Fishes*, *Fishes of the Southern Ocean* and *A Complete Guide to the Freshwater Fishes of Southern Africa*, which effectively stamped the authority of Institute scientists on the discipline for the region. NRF-SAIAB quickly established itself as a global player in aquatic biodiversity research, setting the stage for more comprehensive studies in subsequent phases resulting in further significant publications, *Coastal Fishes of Southern Africa*, *Fishes of Southern African Estuaries from species to systems* and culminating in the production of arguably the largest fish book in the world, the five-volume, multi-authored, successor to *Smiths' Sea Fishes*, the *Coastal Fishes of the Western Indian Ocean* .

Diversification of research programmes

The year 1994 was a watershed year for South Africa and the Institute in particular when, under a new political dispensation, it was transferred from the Department of Education to the Department of Arts, Culture, Science and Technology. This move initiated a significant diversification of research programmes at NRF-SAIAB. Within the broader National System of Innovation, NRF-SAIAB played a crucial role in driving systemic changes in the science community when it became a National Research Facility managed by the NRF in 1999.

The unexpected discovery by deep-diving Trimix divers of a population of living coelacanths off Sodwana in Kwa-Zulu Natal in 2000 was a catalyst that changed the focus of underwater marine exploration and resulted in the establishment of the flagship African Coelacanth Ecosystem Programme (ACEP) with ring-fenced funding from the Department of Science and Innovation (DSI). Significantly, the multidisciplinary ACEP project was a catalyst for, and formed the South African contribution to, the larger international GEF-funded Agulhas and Somali Currents Large Marine Ecosystems (ASCLME) project exploring the Western Indian Ocean. NRF-SAIAB was selected

by the ASCLME management and administration as its host institution.

Through ACEP, NRF-SAIAB has played a notable role in driving change to ensure race and gender equity in the science system. Specifically, the ACEP Phuhlisa programme was developed to actively drive transformation and promote capacity building in marine science at Historically Disadvantaged Institutions (HDIs) not traditionally involved in marine science. The Phuhlisa programme expressly provides support to four HDIs to develop their marine science curricula and, with NRF-SAIAB platform support and the Joint Marine Laboratories Programme, to develop their own marine laboratories and the skills required to run them. NRF-SAIAB's role in driving transformation of the aquatic science landscape has evolved to encompass applied research, including aquaculture, fisheries management and conservation status assessments.

A further key development was the expansion of NRF-SAIAB's collections, acquiring new specimens from diverse regions and environments. This expansion required significant infrastructure development of the current site and a world-class, purpose-built, state-of-the-art natural history Collections repository and Collections Management Centre was constructed and officially opened in 2007. This in turn facilitated the repurposing of NRF-SAIAB's specialist library which was officially opened in 2010. Supporting a wider range of research projects and facilitating regional and international collaborations, scientific output increased significantly, with numerous publications in peer-reviewed journals covering a wide range of topics. This infrastructure development involved the incorporation of advanced facilities such as a digital X-Ray Unit and Biobank which, combined with the Collections and Molecular Laboratory, created a unique systematics platform for the region. This platform facilitated the Pan-African assessment of freshwater biodiversity conservation status and distribution, coordinated by national, regional and international experts. Increasingly, contributions to conservation and ecological and applied aspects initiated during the institute's formative years have assumed even more significance. Data sharing has also improved, with NRF-SAIAB becoming a key player in international biodiversity databases and networks. These efforts were crucial for global biodiversity assessments and informed international conservation policies.

Rapid infrastructure development and expansion

Since 2008, NRF-SAIAB's growth has been marked by rapid research infrastructure development and expansion, illustrating the Institute's relevance and central role in driving efforts to meet the strategic targets stipulated in the National Development Plan (NDP2030) and the United Nations' Sustainable Development Goals (SDGs). Significant investments in modern state-of-the-art platforms, leading-edge equipment and technology that facilitate comprehensive exploration of both marine and freshwater systems accelerated NRF-SAIAB's research capabilities.

Having previously relied on large ocean-going research ships for its marine science operations, NRF-SAIAB designed, built and equipped its own research vessel, R/V *uKwabelana* in 2010. In addition, it acquired a Sea-eye Remote Underwater Observation Vehicle (ROV) that allowed the marine science community for the first time to visually explore and sample coastal inshore waters. This positioned NRF-SAIAB to contribute to two National Operation Phakisa Labs through which South Africa has identified the potential to develop the Biodiversity Economy and the Blue Economy. Over the years, with significant funding from the DSI and the NRF, NRF-SAIAB acquired three additional marine research vessels (R/V *Phakisa* in 2016, the hard-keel inflatable *Hispidus* in 2018, and R/V *Observer* in 2019), including underwater remotely operated equipment facilitating deep-sea exploration and data collection. The construction of state-of-the-art integrated laboratories, such as the Aquatics Genomics Research Platform and the National Aquatic BioBank, and investment in advanced genetic and genomic tools, have enabled cutting-edge research and enhanced the study of genetic diversity among aquatic organisms. These advancements allow researchers to conduct comprehensive surveys of deep-sea ecosystems, uncover new species and document previously unknown habitats. Innovative techniques for sea-floor mapping and environmental monitoring were adopted, to enhance the institute's ability to assess and manage aquatic ecosystems. These efforts supported marine spatial planning and the designation of Marine Protected Areas (MPAs) and NRF-SAIAB has established itself as a world-class research institution, equipped with advanced research platforms and technological capabilities to explore and conserve South Africa's aquatic biodiversity.

Sustaining success and building capacity for the future

Under the auspices of the DSI, South Africa was a country contributor to the European Union's (EU) Horizon 2020 initiative. In 2017 the NRF partnered with EU's Horizon 2020 NUCLEUS project and nominated NRF-SAIAB as a case study through which to explore the extent to

which Responsible Research and Innovation (RRI) was integrated within its research agenda and business processes. NRF-SAIAB conducted a comprehensive internal assessment and, building on its culture of public engagement and transformative change, worked to identify ways to promote and facilitate the integration of RRI across a broad spectrum of activities. Participation in this global project culminated in representation on a global panel to discuss *Institutional Change in Research Organisations across the world* at the concluding Pathways to Transformation conference held in Brussels, Belgium in June 2019. Participation in the NUCLEUS project emphasised the importance of ensuring that research conducted through the NRF should be engaged and impact driven – resulting in the development of the strategic TIES framework, which forms part of NRF Vision 2030 for promoting pathways to impact and engaged research throughout the organisation.

With this in mind, NRF-SAIAB focuses on sustaining past successes while building capacity for future applied and innovative research, addressing contemporary challenges and leveraging aquatic biodiversity for sustainable development. NRF-SAIAB provides scientific leadership and expertise in aquatic biodiversity that is vital to national interests when dealing with issues that arise from exponentially increasing pressures of human population growth and infrastructure development.

Building on the foundations developed from interdependent research areas – i.e. systematics and genetics, aquatic biodiversity and ecology, and applied conservation biology – NRF-SAIAB has become increasingly aligned with more demand-driven, collaborative research that supports national and international imperatives, including strategic targets of the National Development Plan (NDP), Marine and Antarctic Research Strategy (MARS), Phakisa Programme and the Sustainable Development Goals (SDGs). This alignment occurs through three core research areas: (1) Taxonomy and BioDiscovery; (2) Ecology and (3) Global change research. These research areas are supported by the NRF-SAIAB research platforms: Bioinformatics, Ecophysiology, Genomics, Remote Tracking and Observation. In addition, bioprospecting will be a key focus area for the future. NRF-SAIAB researchers and a network of collaborators have already initiated investigations into the biotechnological applications of aquatic organisms for critical marine compounds, particularly pharmaceuticals. Nature-based solutions are also being explored to address environmental challenges such as climate change and habitat degradation. Sea-floor mapping continues to be crucial for marine spatial planning, providing detailed maps of habitats and resources to guide conservation efforts. Aquaculture and fisheries development remain priorities, with research aimed at the optimisation of techniques and promotion of sustainable practices to support food security and economic development. NRF-SAIAB remains committed to fostering innovation and applied research, and through strong alignment with Higher Education, NRF-SAIAB has made significant contributions to education and training to develop the next generation of scientists. Collaborative efforts with researchers, policymakers, industry partners and stakeholders will continue to be promoted to ensure that research findings translate into practical solutions to meet the changing needs of society.

Conclusion

On its journey NRF-SAIAB has transitioned from a singular focus on foundational research to a much broader focus on applied and innovative studies, highlighting its commitment to advancing aquatic biodiversity science for the Biodiversity Economy and promoting sustainable development for the Blue Economy. By maintaining a strong foundation, training future scientists, enhancing infrastructure and focusing on future-oriented research, NRF-SAIAB continues its mission to propel aquatic science research endeavours within the African region and across nations to advance aquatic research and conservation efforts through enhanced collaboration.



Calibration of the Eddy covariance instrument located in the Maputaland coastal plain. This meteorological system is used to measure gas, energy and momentum between ecosystems and atmosphere. Photo: NRF-SAEON

Reflecting on 22 years of sustained environmental observation, transformation and societal impact

Mary-Jane Bopape

The South African Environmental Observation Network (NRF-SAEON) was established in response to a growing recognition of the need for a coordinated and sustained environmental monitoring system in South Africa. The initiative began in the late 1990s when scientists and policymakers acknowledged the pressing need to understand and respond to environmental changes driven by both natural processes and human activities. The formal establishment of NRF-SAEON occurred in 2002, under the auspices of the NRF and the Department of Arts, Culture, Science and Technology (DACST) and now the Department of Science and Innovation (DSI). The formation of NRF-SAEON was influenced by global trends towards long-term ecological research (LTER) and the necessity of having reliable, long-term environmental data to inform policy and management decisions.

History and current makeup of NRF-SAEON

NRF-SAEON currently consists of four terrestrial nodes: the Ndlovu node in Phalaborwa, established in 2004 and hosted by South African National Parks (SANParks); the Fynbos node in Cape Town, established in 2008, initially hosted by the South African National Biodiversity Institute (SANBI) and now at the South African Astronomical Observatory (NRF-SAAO); the Grasslands node in Pietermaritzburg hosted by Ezemvelo KwaZulu-Natal Wildlife, established in 2011; and the Arid Lands node in Kimberley, established in 2011 and also hosted by SANParks. In addition, NRF-SAEON has two marine nodes. The Elwandle node, established in 2006, was initially hosted by the South African Institute for Aquatic Biodiversity (NRF-SAIAB) in Makhanda and is now based at Nelson Mandela University in Gqeberha. The Egagasini node, established in 2007, focuses on marine offshore systems and is hosted by the Department of Forestry, Fisheries and the Environment (DFFE). The uLwazi node for data and information management was established in 2018, evolving from NRF-SAEON's Information, Communication and Technology team.

The NRF-SAEON eNewsletter, launched in 2005, has grown from fewer than 100 readers to over 6 000 subscribers. The NRF-SAEON environmental science education programme (ESEP) began in 2004, and the graduate student network (GSN), launched in 2006, remains active and student-driven, promoting multidisciplinary and cross-ecosystem applications of LTER. The NRF-SAEON National Office, established in 2010, is based in Pretoria.

NRF-SAEON is also responsible for the implementation of three Research Infrastructures (RIs) of the South African Research Infrastructure Roadmap (SARIR): the Expanded Freshwater and Terrestrial Environmental Observation Network (EFTEON), the Shallow Marine and Coastal Research Infrastructure (SMCRI), and the South African Polar Research Infrastructure (SAPRI). The implementation of these research infrastructures is and will result in the establishment of more offices across the country. Together, the nodes, RIs, and National Office comprise NRF-SAEON's staff of over 130 people.

Purpose of NRF-SAEON

The vision of NRF-SAEON is to establish world-class environmental research platforms for a sustainable society. NRF-SAEON's primary purpose is to provide long-term, reliable, and high-quality data on environmental change, which is essential for understanding the dynamics of South Africa's diverse ecosystems. NRF-SAEON facilitates and conducts research through platforms, and these have grown into a diverse array of sites, instruments, infrastructure, datasets, models and staff, widely distributed across both marine and terrestrial environments. NRF-SAEON platforms enable researchers to conduct research that is critical for the detection, understanding and prediction of environmental change. These platforms are very diverse, providing data from terrestrial, freshwater and marine ecosystems, from sites ranging in size from a few hectares to hundreds of square kilometres. NRF-SAEON also integrates research

into education outreach activities and contributes to an improved understanding of earth sciences for learners, educators and the general public.

Key infrastructure

NRF-SAEON operates a comprehensive infrastructure network that spans various biomes and marine environments in and around South Africa. The infrastructure deployed by NRF-SAEON includes meteorological stations measuring variables such as temperature, humidity and rainfall; eddy covariance stations measuring carbon dioxide and water flux exchanges between land and atmosphere; groundwater depth and river flow level loggers; and camera traps for monitoring biodiversity and security. NRF-SAEON also manages vegetation plots used for experimentation in different parts of the country, strategically located across ecosystems such as savannas, grasslands, forests and wetlands. Key study sites include Mariepskop, Haenertzburg, Tierberg, Benfontein, Jonkershoek, Cape Peninsula, Maputaland and Cathedral Peak, with Cathedral Peak being the most heavily instrumented site, contributing significantly to research, policy development and student training.

EFTEON, one of the RIs, deploys eddy covariance towers, meteorological instruments, hydrological observations, soil measurements and biodiversity and productivity measurements across six landscapes: Greater Cape Town; the Kimberley area, Northern Cape and Western Cape Free State (KIMTRI); Garden Route Gateway; Northern Maloti-Drakensberg; Maputaland in Northern KwaZulu-Natal; and the Lowveld (Mpumalanga).

NRF-SAEON also operates coastal and marine observatories that monitor oceanographic conditions, marine biodiversity and the impacts of human activities on marine ecosystems. NRF-SAEON manages twelve of the fifteen platforms of the Shallow Marine and Coastal Research Infrastructure (SMCRI), while NRF-SAIAB runs three. The twelve platforms include the Two Oceans, Algoa Bay, Natal Bight, and Marion Island Sentinel sites, as well as eight less-instrumented satellite sentinel sites. The central office in Gqeberha houses the biogeochemistry lab, hyperbaric chamber and data management platforms, working closely with the uLwazi node. SMCRI platforms also include an aircraft with a lidar system, the South African National Coastal Temperature Network (SANCT), science engagement and the estuarine network.

SAPRI consists of Long-Term Observations (LTO) for land and ocean, data and communication, outreach, training and society, currently hosted by the University of Stellenbosch, with the PolarLab hosted by the University of Cape Town. LTO-Land ensures the continuity of long-term observation networks on the sub-Antarctic islands, Antarctica and ice shelves, while LTO-Ocean focuses on observation continuity in the Southern Ocean, sea ice, deep ocean sites and overlying atmosphere. Instruments deployed by SMCRI and SAPRI include vessel-based sampling, moorings and gliders.

All NRF-SAEON nodes and RIs invest in communication systems for data transfer from instruments in remote areas. The data management platforms hosted by the uLwazi node include centralised databases storing long-term environmental data collected from various observational platforms. The team adheres to standardised methods and protocols to ensure data consistency, quality and comparability across different sites and studies. NRF-SAEON recently received the CoreTrustSeal certification indicating the trustworthiness of its platforms as an international data repository. NRF-SAEON platforms ensure data accessibility through online portals and tools that provide researchers, policymakers and the public with access to environmental data, including data visualisation and analysis platforms to facilitate data use and interpretation.

Key research

NRF-SAEON conducts and supports a wide range of research activities aimed at understanding environmental change and its implications. Some of the key research areas include:

Climate change and ecosystem responses
NRF-SAEON's research in this area focuses on understanding how climate change affects South Africa's diverse ecosystems. Studies examine the impacts of rising temperatures, changing precipitation patterns and increased frequency of extreme weather events on biodiversity, water resources and ecosystem services. For example, long-term monitoring of savanna ecosystems provides insights into how changes in rainfall and fire regimes influence vegetation dynamics and animal populations.

Biodiversity and conservation
Biodiversity research is a cornerstone of NRF-SAEON's work encompassing studies on species distribution, population dynamics and ecosystem health. NRF-SAEON uses data from its observational

platforms to assess the status of threatened species, the effectiveness of conservation interventions and the impacts of land use changes on biodiversity. This research informs conservation strategies and policies aimed at preserving South Africa's rich biological heritage.

Hydrology and water resources
Given the importance of water in a semi-arid country like South Africa, NRF-SAEON conducts extensive research on hydrological processes and water resource management. Studies focus on understanding the interactions between climate, land use and water availability. Research in instrumented catchments helps to model water flow and quality, providing crucial data for managing water resources sustainably and ensuring water security for communities and ecosystems.

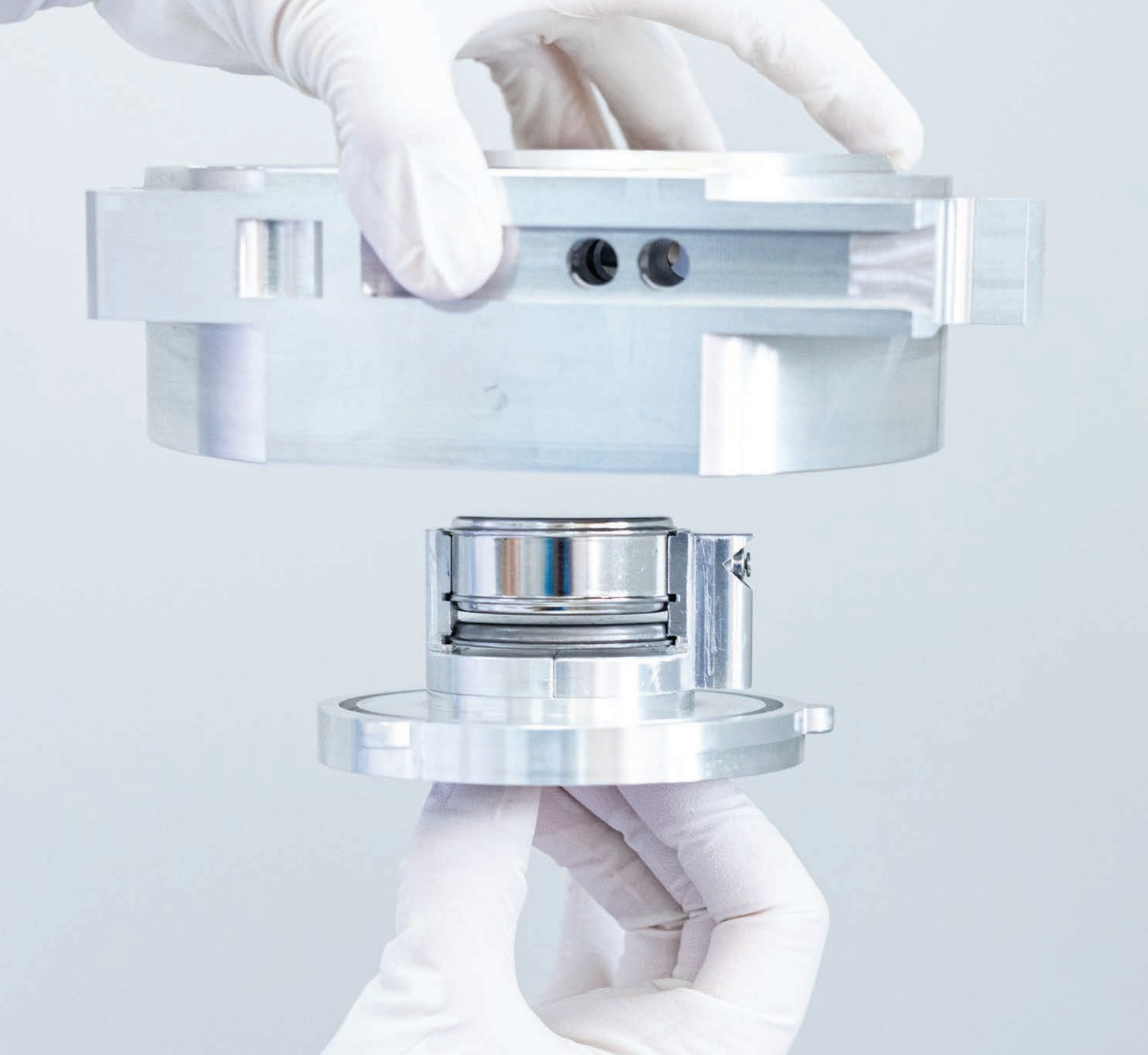
Marine and coastal ecosystems
NRF-SAEON's marine research addresses the health and functioning of coastal and marine ecosystems. Studies include monitoring sea temperatures, salinity, nutrient levels and marine biodiversity. Research on the impacts of human activities such as fishing, pollution and coastal development helps to inform sustainable management practices and policies to protect marine environments.

Land use and land cover change
Research in this area investigates the impacts of land use changes, such as agriculture, urbanisation and deforestation on ecosystems and their services. By integrating satellite imagery with ground-based observations, NRF-SAEON tracks changes in land cover and assesses their effects on biodiversity, carbon storage and soil health. This research supports land management practices that balance development needs with environmental sustainability.

Socio-ecological systems
NRF-SAEON's research also explores the interactions between human societies and natural environments. Studies examine how communities adapt to environmental changes and how their activities impact ecosystems. This interdisciplinary approach helps to identify sustainable practices that promote both human well-being and environmental health.

Conclusion

NRF-SAEON plays a pivotal role in monitoring and understanding environmental changes in South Africa. By providing high-quality, long-term data and facilitating cutting-edge research, NRF-SAEON supports informed policy development, decision-making and sustainable management of the country's diverse ecosystems. Through its collaborative networks and capacity-building initiatives, NRF-SAEON enhances the scientific community's ability to address complex environmental challenges and contributes significantly to global environmental science.



Target-holder assembly for isotope production. Photo: NRF-iThemba LABS

NRF-iThemba LABS advancing research, training and expertise in accelerator-based science for the betterment of society

Victor Tshivhase

NRF-iThemba LABS provides laboratories within which particle accelerators (linear accelerators and cyclotrons) are exploited as research tools to probe the fundamental structure and properties of matter, and to produce radioisotopes that can be used for diagnostics, imaging and therapy in nuclear medicine applications. The biggest accelerator is the 200-MeV Separated Sector Cyclotron (SSC) that is fed by two solid-pole cyclotrons used to pre-accelerate the projectiles before injection into the SSC. One injector is dedicated to accelerate protons to 3,14-MeV in order to generate 66-MeV protons for the production of radioisotopes. The production of radioisotopes will be migrated to the newly acquired 70-MeV cyclotron as part of the establishment of the South African Isotope Facility (SAIF), which will free up beamtime on the SSC for fundamental and applied research. The other injector is used to produce particle beams (light and heavy ions as well as polarised protons) as prescribed by the nuclear physics research community. In addition, NRF-iThemba LABS has two laboratories dedicated to research at the atomic scale using particle beams from a 3-MV Tandetron and a 6-MV Tandem accelerator. The 6-MV Tandem accelerator is located in Gauteng and equipped with an Accelerator Mass Spectrometry (AMS) facility for applied research related to cultural heritage and climate change. The impact of the national research infrastructure platform is experienced as a contribution to knowledge, human capital, skills development, and nuclear medicine through the provision of radiopharmaceuticals.

Research at the subatomic scale

In order to probe the structure and properties of matter at the subatomic level one needs high-energy particle beams. The specifications of the projectile, target and detection system are informed by the details of the experimental study that is undertaken. The experimental subatomic physics research programme can be grouped as BASIC SCIENCE (nuclear reactions, nuclear structure, and nuclear astrophysics) and APPLIED NUCLEAR SCIENCE (exploitation of neutrons in metrology and studies of radiation damage to electronics). NRF-iThemba LABS is one of three facilities in the world capable of producing quasi mono-energetic neutrons in the 40–200 MeV range. Major upgrades of the neutron vault were undertaken in 2019 to meet the requirements for a high-energy neutron metrology facility as specified by the National Metrology Institute of South Africa (NMISA). Additional developments have been actioned that include a rapid transport system to move neutron-induced reaction products away from the high-neutron field and in front of a dedicated counting station consisting of beta and gamma-ray counters.

The nuclear physics research instruments at NRF-iThemba LABS include a K600 Magnetic Spectrometer that is used mainly for nuclear reactions studies together with the AFRODITE (African Omni-purpose Detector for Innovative Technologies and Experiments) gamma-ray array used for nuclear structure studies. Recent developments in detection capabilities include coupling the K600 spectrometer to particle and gamma-ray detectors (BaGeL), the development of the African LaBr3 Array (ALBA) for high gamma-ray efficiencies, adding more Clover detectors to increase the solid-angle coverage of the gamma-ray array (AFRODITE+), and a setup for lifetime measurements using the Doppler Shift Method. It should be mentioned that BaGeL positions NRF-iThemba LABS as one of only two facilities in the world (the other being the RCNP in Japan) capable of performing coincidence measurements with the spectrometer at zero degrees.

Research at the atomic scale

The availability of accelerated particle beams from the 3-MV Tandetron and 6-MV Tandem create opportunities to conduct research in nanoscience, study the physics of thin films, investigate

trace element distributions and mobilisation in biological systems, analyse environmental and geological samples, and determine the age of archaeological artefacts using radio-carbon analysis with the AMS facility. Both laboratories, one in the Western Cape and another in Gauteng, are equipped with an Ion Beam Analysis (IBA) setup that includes a microprobe beamline with end stations for PIXE (Proton Induced X-ray Emission), RBS (Rutherford Backscattering) together with the capability of performing ERDA (Elastic Recoil Detection Analysis). The analyses of samples are furthermore extended through the availability of an X-ray Diffractometer (XRD) and an Atomic Force Microscope (AFM). A dedicated experimental beamline for low-energy nuclear-astrophysics was recently added to the infrastructure linked to the Tandetron laboratory in Cape Town. A new research focus in the field of proton beam writing (PBW), and low-energy focused ion beam (FIB) techniques for device modification, was introduced within the department.

Research to advance radiation diagnostics and therapy

NRF-iThemba LABS, through its research infrastructure platforms, has the ability to offer radiation beams of different modalities (proton, neutron, heavy ion, and photon) with a range of energies. This allows for the exposure of biological systems to differing radiation qualities to determine biological response functions. The biological response functions are, in turn, needed to impact and improve applications in radiation therapy and protection. The development of novel radiopharmaceuticals can be fast-tracked by studying *in-vitro* cell-receptor mediated uptake of radiolabelled compounds in specific cancer cell types. This provides fundamental support, and biophysical models, that can be used to improve cancer treatment strategies and decrease the growing number of cancer deaths in South Africa.

The protection and medical surveillance of radiation workers is of importance not only to NRF-iThemba LABS, but also for other state-owned enterprises involved in either energy generation and/or isotope production. The radiobiology laboratory of NRF-iThemba LABS remains the only bio-dosimetry laboratory in Africa that has several techniques available to perform triage screening for large-scale radiation accidents using the Metafer automated microscope. In addition, studies are conducted to improve the efficacy of proton therapy through the introduction of nano-gold particles that enhance the radio-sensitivity of the targeted tumour, to understand the cancer resistance of elephants, and to assess the impact of space-flight on astronauts.

Research and development technical services

Research as a key strategic objective presupposes the availability of in-house competence to address the technical needs associated with a specific nuclear physics experiment. This entails being able to respond to the challenges linked to the electronics, control (hardware and software interface), information technology, data analysis and management, high performance computing, detector technology, target manufacturing, and the mechanical design and development for a specific experimental setup. NRF-iThemba LABS committed dedicated resources to the establishment of the Technology and Innovation Platform (TIP) that will not only prioritise the development of technical competence, but will also explore possibilities for technology transfer and commercialisation of technologies.

Future: The importance of partnerships

The scientific endeavour is by nature future-focussed and ever evolving due to its inherent competitive nature. The recent acquisition of the new 70 MeV cyclotron will ensure that ALL beamtime from the SSC is available for basic research. This will allow for the accommodation of more international collaborators as they will be able to run their experiments for uninterrupted periods. In addition, it is envisaged that the availability of the SSC will pave the way for exploratory research on exotic nuclei that can only be probed with radioactive beams.

The establishment of SAINTS at NRF-iThemba LABS underscores the strategic objectives of research, training and specialised expertise in accelerator-based science. SAINTS was conceptualised as the overarching training strategy to develop human capacity and competence in specialised fields of interest for NRF-iThemba LABS. This includes subatomic physics, nuclear sciences, material sciences, radiation protection, radiochemistry, radiation biophysics, radiation detection, accelerator technology, data processing, artificial intelligence and machine learning. Technical entities and national research facilities such as NRF-iThemba LABS have faced challenges related to a shortage of skills and competencies arising from the gradual erosion of technically competent human resources and expertise in critical areas. The main contributing factors to the decline in technical competencies have been general attrition, retirements and the continuous emergence of new technologies. The SAINTS offers a platform for postgraduate student training and development in the medium- to long-term to grow the next generation of scientists

and technologists. Concurrently, the SAINTS creates an enabling environment within which NRF staff can develop professionally by undertaking teaching and learning activities to acquire new skills and to gain exposure to relevant and emerging technologies. SAINTS training and developmental interventions are offered in coordination and partnership with collaborating experts from higher education institutions (HEIs) and accelerator-based research facilities worldwide. The interventions are freely accessible as short courses and workshops, summer schools, vocational training programmes, and exposure to major accelerator-based international laboratory facilities.

Conclusion

Researchers at NRF-iThemba LABS are at the forefront of development and innovation through their participation in experimental physics programmes both locally and internationally. Collaborations such as the SA-CERN and the SA-JINR afford opportunities to staff and postgraduate students to participate in exchange programmes at the Large Hadron Collider (LHC) in Geneva, Switzerland, and the Joint Institute for Nuclear Research (JINR) in Dubna, Russia. New partnerships have been forged with African countries through joint projects related to environmental radioactivity linked to the mining sector. NRF-iThemba LABS continues to supply radiopharmaceuticals to public and private nuclear medicine departments nationally, and radionuclide products with longer half-lives are distributed to international clients. The investment in infrastructure renewal resulted in the acquisition of a dedicated cyclotron for the production of radioisotopes that will not only increase the production yield, but it will free up beam time on the SSC for fundamental and applied research. The additional beam time of the SSC will be used to develop the techniques needed for the production of alpha emitters for targeted-alpha-therapy (TAT), and theranostic isotopes that combine diagnostic biomarkers with therapeutic agents. The pursuit of excellence, and the commitment to transformation, has assisted NRF-iThemba LABS to become THE gathering place on the African Continent for research, innovation and collaboration on accelerator-based science.



MeerKAT telescope, a globally recognised cutting-edge research instrument consisting of 64 receivers, located within a protected ‘astronomy advantage area’ in the Karoo region of the Northern Cape Province. NRF-SARAO

Radio astronomy provides a window on the universe

Pontsho Maruping

NRF-SARAO was established in 2017 by the Minister of Science and Technology as a National Facility of the NRF, amalgamating the South African SKA project, and the Hartebeesthoek Radio Astronomy Observatory (HartRAO).

Origins

HartRAO was South Africa's first radio astronomy observatory. It is located in a valley in the Magaliesberg hills, 50 km north-west of Johannesburg in the province of Gauteng. It began as the Deep Space Station 51 and was built in 1961 by the National Aeronautics and Space Administration (NASA) of the United States of America. An 85-foot (26 m) diameter antenna was used to receive data from, and transmit commands to, many unmanned US space probes going beyond Earth's orbit. These included the Ranger, Surveyor and Lunar Orbiter spacecraft, which landed on the Moon or mapped it from orbit, the Mariner missions, which explored the planets Venus and Mars, and the Pioneers, which measured the Sun's wind. In 1975, the station was handed over to the South African Council for Scientific and Industrial Research (CSIR), which converted it to a radio astronomy observatory. In 1988 the observatory became a National Facility operated by the Foundation for Research Development (FRD), which became part of the NRF in 1999. Initially, the function of HartRAO was purely research in radio astronomy, but in the 1980s a new application called Space Geodesy (geodesy using space techniques) was implemented at HartRAO.

The South African Square Kilometre Array (SKA SA) project was initiated in January 2003 with the support of what is today the Department of Science and Innovation (DSI), then the Department of Arts, Culture, Science and Technology, DACST, and later the Department of Science and Technology (DST), and the NRF. It was led by a SKA Steering Committee chaired by Dr Rob Adam, then Director General of the DACST, with Dr Khotso Mokhele, President of the NRF, as the Deputy Chair. Dr Bernie Fanaroff was appointed as the Project Director. It was funded by the DACST through a ring-fenced funding stream managed for the project by the NRF. Dr Phil Mjwara succeeded Dr Adam as Director General and Chair of the SKA Steering Committee.

The SKA SA project was initially established to prepare and submit South Africa's bid to host the proposed international SKA radio telescope, which will be the world's most capable radio astronomy facility of its type. The South African bid was made jointly with seven other African countries: Botswana, Ghana, Kenya, Madagascar, Mauritius, Mozambique and Namibia. A small but extremely capable, enthusiastic and committed team based in Johannesburg worked very quickly to submit an Expression of Interest in May 2003. Following submission of a more extensive bid proposal, the South African site was shortlisted together with Australia in 2006. More extensive studies were carried out over the next five years, and a final response to a request for information – totalling 26 500 pages with a 150-page summary – was submitted in 2011. By this time, Zambia had joined the group of African partner countries.

In 2012 South Africa was recommended by an independent international panel of experts to host the SKA. The international SKA Organisation – by then a non-profit company registered in the United Kingdom – subsequently decided that the mid-frequency array would be built in two phases in the Karoo and the African partner countries, and the low frequency array would be built in two phases in Western Australia.

Purpose

As a National Facility under the auspices of the National Research Foundation (NRF), NRF-SARAO's mission is to establish South Africa

as a global leader in radio astronomy and associated technologies and disciplines by successfully hosting, and participating in the design and construction of, the SKA telescope and other radio astronomy and geodesy facilities. This mission is directed through four strategic objectives, which are aligned with the NRF vision and mission:

- To manage and optimise South Africa's contribution to, and benefit from, the international Square Kilometre Array (SKA) project;
- To establish and sustain globally competitive and transformed radio astronomy and space geodesy research and infrastructure in South Africa and abroad, where appropriate;
- To maximise the associated national socio-economic benefit from radio astronomy and space geodesy activities; and
- To promote radio astronomy and space geodesy capacity in Africa.

Key infrastructure

As an enabler of cutting-edge research in radio astronomy, NRF-SARAO currently operates two major research infrastructure platforms: the 26 m single dish at the Hartebeesthoek Radio Astronomy Observatory (HartRAO); and the MeerKAT telescope, a globally recognised cutting-edge research instrument consisting of 64 receivers, located within a protected 'astronomy advantage area' in the Karoo region of the Northern Cape Province. NRF-SARAO also plays host to a number of international projects such as the Hydrogen Epoch of Reionization Array (HERA), NASA and Russian Satellite Laser Ranging stations, and other co-located scientific instruments. This is due to both the excellent scientific qualities at NRF-SARAO-operated sites (particularly in the Karoo) for the hosting of radio astronomy, and related facilities as well as the critical mass of expert resources NRF-SARAO has established to develop and support the operation of next-generation scientific facilities locally and internationally.

Key research

NRF-SARAO's Hartebeesthoek site is one of only eight fundamental geodetic stations in the world – the term 'fundamental station' is used for special observatories which combine several space positioning techniques such as Very Long Baseline Interferometry (VLBI), satellite laser ranging, GPS, and Glonass, among others. These sites are the anchor points for the Global Geodetic Observing System. The Hartebeesthoek site is also one of only a few VLBI-capable sites in the southern hemisphere, as well as the only facility on the African continent. Therefore it plays a pivotal role in the International Earth Rotation Service (IERS) and the realisation of the Global Geodetic Reference Frame (GGRF).

At the heart of the Hartebeesthoek's instruments are radio astronomy dishes that participate in VLBI for Astronomy, Astrometry, and Geodesy – the telescopes at HartRAO participate in routine VLBI observations as part of arrays of radio telescopes across the globe. Together with HartRAO's suite of geodetic instrumentation, comprising Satellite Laser Ranging (SLR), Global Navigation Satellite Systems (GNSS) reference stations, and the Doppler Orbitography and Radio-positioning Integrated by Satellite (DORIS) system. Therefore the various activities of the observatory at Hartebeesthoek are steered and depicted by international agreements and resulting collaborations, as well as local law and regulations.

The MeerKAT telescope, as a precursor to the SKA, represents a major advancement in radio astronomy, offering unprecedented capabilities for the exploration of the Universe. MeerKAT's scientific discoveries have already made substantial contributions to astronomy. Since its inception, more than 300 articles containing MeerKAT data have been published. Many of the associated findings are ground-breaking, addressing key questions in modern astrophysics. Key astrophysics research areas that MeerKAT is already revolutionising include:

Galaxy formation and evolution

A MeerKAT survey of the Galactic centre region led to the showcase radio image that introduced the telescope to the world in 2018, and this project has also transformed scientific understanding of the region. The first major discovery made by MeerKAT was that of the 1 400 light-year radio bubbles that span the Galactic centre, evidence of an explosive event in the heart of the Galaxy several million years ago. Further afield, with its unsurpassed combination of sensitivity and angular resolution, MeerKAT is enabling new measurements of the star formation history of the universe all the way up to and beyond so-called 'cosmic noon', a time billions of years ago when the rate of star formation peaked. Also, as the most sensitive interferometer in existence for the study of neutral hydrogen (the fuel that eventually forms stars), MeerKAT has the capability to address one of the key questions related to galaxy evolution: how do galaxies keep forming stars over billions of years when their current reservoir of hydrogen does not appear to be sufficient? MeerKAT is already measuring low density gas in the outskirts of some nearby galaxies that is

significantly advancing our state of understanding this fundamental question.

Exploring gravitational waves with pulsars
Supermassive black hole binary systems at the centre of galaxies across the universe are expected to produce a dim hum of low-frequency gravitational waves that permeate space. For more than 15 years, researchers across the globe have observed a network of ultra-stable astronomical clocks in our galaxy, the so-called millisecond pulsars, to glean and eventually peer through this profound expected new window on the Universe. Since 2019, The MeerKAT Pulsar Timing Array has been monitoring the largest sample of pulsars to the highest precision of any existing array. The MeerKAT pulsar timing array, after only five years in operation, is already the single most sensitive such array, studying the largest number of millisecond pulsars to the highest precision. This will continue until it is surpassed by equivalent studies using the future SKA-Mid telescope.

Human capital development
The NRF-SARAO Human Capital Development (HCD) Programme was initiated to develop a community of scientists, engineers, technicians and artisans to ensure that NRF-SARAO fulfilled its mandate to design, build, operate and exploit the MeerKAT and SKA radio telescopes, and to secure South Africa's return on its strategic investments in radio astronomy. To this end, NRF-SARAO established a research capacity development programme that provides bursaries to science and engineering students from bachelor to PhD levels. The programme also includes Artisan Training that provides training to develop skilled artisans from local communities. To date 130 trainees have qualified as fibre technicians, IT technicians, electricians, boilermakers, fitters and turners, mechanics and instrument control technicians.

The results of a study to trace NRF-SARAO HCD alumni showed that more than two thirds of NRF-SARAO-funded students are currently employed in positions considered to positively impact on or contribute to South African and African academia and research, or to South African industry. Of these alumni, 67% are Black South Africans and 48% are South African women.

More importantly, NRF-SARAO has been able to create teams that have produced some innovative solutions in compute and storage, digitisation and several technology areas on which NRF-SARAO relies for the operation of MeerKAT and which can be broadly commercialised for other data-intensive environments.

Conclusion

A stakeholder inclusive approach has informed the implementation of South Africa's strategic investments in radio astronomy through NRF-SARAO. These investments have not only been realised in the development of the next-generation MeerKAT radio telescope which has derisked several technologies being applied to SKA-Mid, but also through the socio-economic impact that has been delivered across various sectors of society, at both local and national level. By adopting this approach, NRF-SARAO has been able to plan and deliver for impact, including at local level where socio-economically depressed communities located within the vicinity of MeerKAT and the future SKA telescope have benefited.



The NRF-SAAO Plateau, Sutherland, Northern Cape. Photo: NRF-SAAO

A pillar of world-class astronomy infrastructure in South Africa

Rosalind Skelton and Daniel Cunnama

The South African Astronomical Observatory (NRF-SAAO) has consistently demonstrated its commitment to the provision, development and maintenance of world-class astronomical infrastructure, solidifying South Africa's position as a global leader in astronomical research. Through continuous innovation, strategic collaborations and a dedication to technological advancement, NRF-SAAO has created an environment conducive to groundbreaking discoveries and scientific progress which include the application of fibre technology originally designed for telescopes to revolutionise agriculture and medical imaging, and ground-breaking research in various fields of astronomy including the study of stars, galaxies, black holes and exoplanets, and discoveries of supernovae, asteroids, near-Earth objects and novel object classes.

Origins and purpose

NRF-SAAO is the national centre for optical and infrared astronomy in South Africa. Our mission is to conduct fundamental research in astronomy and astrophysics, provide world-class facilities to scientists and promote astronomy and astrophysics in Southern Africa through research, education and outreach.

NRF-SAAO was founded in 1820 as the Royal Observatory at the Cape of Good Hope and is the oldest scientific institution in the country. It was initially controlled by the British Admiralty and intended for the improvement of navigation. The observatory's main duty was to chart the southern skies and provide a time service for passing ships. However, the observatory's focus soon shifted to scientific inquiry and exploration, and it became well-known for its impactful astronomical discoveries.

Today, the historic NRF-SAAO headquarters are still located in the suburb of Observatory in Cape Town, while the majority of the telescope facilities used for research are located approximately 370 km away in the Northern Cape Province. By the 1960s it had become clear that the observatory needed an outstation well away from the city to avoid light pollution and a hilltop near the town of Sutherland in the dry semi-desert Karoo was identified as a suitable location. In 1972, the Royal Observatory at the Cape of Good Hope and the Republic Observatory in Johannesburg were amalgamated to form the South African Astronomical Observatory and the Sutherland site was officially opened in 1973. It remains one of the darkest observatory sites in the world. There are now 24 telescopes of varying sizes on the plateau, including 10 owned or co-owned by NRF-SAAO and 14 hosted facilities operated by international organisations. Most of these facilities have time and data-sharing agreements with NRF-SAAO, offering a wide suite of instruments and telescopes with different capabilities to the South African astronomical community.

Key research

NRF-SAAO is involved in a wide range of astronomical research, including:

- *Transient and time-domain astrophysics*: This involves studying astronomical events that change rapidly over time, such as supernovae, gamma-ray bursts and other explosive phenomena. NRF-SAAO is well-positioned to respond quickly to these events, with multiple telescopes and instruments that can be utilised on-demand as alerts come in. This is invaluable as this area of research will expand with large international surveys of the sky such as the Rubin Observatory Large Synoptic Survey of Space and Time, and Square Kilometre Array in future.
- *Stellar astrophysics*: This includes research on the birth, life and death of stars, as well as the study of binary star systems and variable stars.
- *Galaxy evolution*: NRF-SAAO researchers study the formation, growth and evolution of galaxies, including the role of active

galactic nuclei (AGN) and the impact of the environment on galaxy properties.
- *Exoplanets and solar system studies*: NRF-SAAO is involved in the search for and characterisation of exoplanets, planets orbiting stars other than our Sun. It also studies objects within our solar system, such as asteroids and comets.

Infrastructure development and technological innovation

NRF-SAAO's infrastructure development is a testament to its unwavering pursuit of excellence. The Southern African Large Telescope (SALT), the largest optical telescope in the southern hemisphere, serves as a flagship example of NRF-SAAO's dedication to cutting-edge technology. Since its inauguration in 2005, SALT has undergone continuous upgrades and enhancements, including the installation of new instruments such as the High-Resolution Spectrograph (HRS) and the most recent addition, the Near Infrared Washburn Astronomical Laboratories Spectrograph (NIRWALS). These improvements have expanded SALT's capabilities and opened up new avenues for scientific exploration.

The development of a new detector for the Robert Stobie Spectrograph (RSS) on SALT, the Strategic Instrumentation Initiative (SII), to prepare for a new generation of instruments on SALT, and a laser frequency comb for the HRS that will enable the discovery of planets around other stars, are all ongoing projects that highlight NRF-SAAO's drive to stay at the forefront of astronomical instrumentation.

The development of the RSS Slitmask integrated field unit (IFU), the first capability of its kind in Africa, is another significant achievement by the NRF-SAAO's fibre-optic laboratory and high-precision mechanical machining workshop. This instrument will provide multiple spectra across a sizeable region simultaneously, greatly enhancing SALT's scientific capabilities for understanding galaxy formation and evolution.

While SALT is undoubtedly the crown jewel of NRF-SAAO's infrastructure, the observatory's commitment to excellence and innovation extends to all its facilities. The Intelligent Observatory (IO) initiative is a prime example of how NRF-SAAO is leveraging technology to optimise its research capabilities. By networking the telescopes at the Sutherland site into an autonomous system, NRF-SAAO is paving the way for more efficient and responsive astronomical observations. The Lesedi telescope, a fully autonomous telescope that can react to real-time data streams, is a testament to the success of this initiative. A recent upgrade of the 1.9 m telescope with an instrument selector port that enables seamless switching between instruments on the fly is a testament to NRF-SAAO's philosophy of maximising the efficiency and scientific output of its entire suite of telescopes.

In addition to developing its infrastructure, NRF-SAAO has fostered strategic collaborations with international partners. The Asteroid Terrestrial-impact Last Alert System (ATLAS) project, in partnership with the National Aeronautics and Space Administration (NASA), is an example of NRF-SAAO's involvement in global initiatives that benefit humanity by identifying potentially hazardous asteroids and enabling research to better understand solar system bodies. The PRIME telescope is another recent example of a collaboration that will enhance NRF-SAAO's offering in the infrared and expand the scope of astronomical research in South Africa.

Human capacity development

NRF-SAAO is deeply committed to developing human capital in the field of astronomy. It offers students the opportunity to work alongside leading researchers on cutting-edge projects in observational and theoretical astronomy, astronomical instrumentation and computer modelling. Many of these projects involve combining data from different wavelengths and collaborating with national and international partners.

NRF-SAAO staff actively participate in the National Astrophysics and Space Science Programme (NASSP), a collaboration between national astronomy facilities and universities, which has produced numerous graduates who now occupy key positions in international and South African astronomy. NASSP graduates are also making significant contributions to other fields, such as healthcare and rural education. The programme's success in addressing challenges and creating opportunities for aspiring scientists highlights its transformative impact on South Africa's scientific landscape.

The Stobie-SALT scholarship programme sponsors South African students to pursue PhD studies or exchanges at SALT partner universities abroad, with many returning to South Africa to contribute to the local astronomy community.

NRF-SAAO embraces diversity, attracting students from all over the world, including countries such as Rwanda, Uganda, Ethiopia, Mauritius, Sudan, Burkina Faso, Lebanon, Madagascar and more.

NRF-SAAO staff members also supervise and co-supervise MSc and PhD students registered at various South African universities, with many of these students spending a significant portion of their time at NRF-SAAO. The observatory appoints numerous honours students and interns annually, particularly unemployed graduates, across all departments.

Outreach, education and training

NRF-SAAO's dedication to education and outreach is evident in its comprehensive programmes that target learners and educators alike. Through teacher training workshops, curriculum development, and hands-on activities, NRF-SAAO has empowered educators to effectively teach astronomy-related concepts, to foster a deeper understanding of science among learners. The organisation's initiatives, such as career exhibitions, job shadowing programmes and a national astronomy quiz, have inspired countless students to pursue careers in science, technology, engineering and mathematics (STEM) fields, particularly astrophysics.

The SALT Collateral Benefits Programme, established alongside South Africa's first science and technology policy, has successfully connected science to society through various education, technology, tourism and community development initiatives. Interactive exhibits, collaborations with museums and partnerships with universities have increased public awareness of astronomy and inspired a new generation of scientists.

Conclusion

NRF-SAAO's unwavering commitment to world-class infrastructure development and research, alongside its dedication to education, outreach, and human capital development, has solidified its position as a leading astronomical institution. Through continuous innovation, strategic collaborations, and a focus on technological advancement, NRF-SAAO is not only pushing the boundaries of astronomical research but also fostering a vibrant and diverse scientific community in South Africa. The observatory's far-reaching impact extends beyond groundbreaking astronomical discoveries: it empowers educators, inspires learners and nurtures the next generation of scientists, engineers and astronomers. As NRF-SAAO continues to evolve and adapt to the ever-changing landscape of astronomical research, its legacy of excellence and its commitment to education and outreach ensure that South Africa remains at the forefront of astronomical exploration for years to come.


TRANSFORMATION
IMPACT
INNOVATION
EXCELLENCE
SUSTAINABILITY
NRF
VISION
2030

TRANSFORMATION:
The imperative for a better future

Our national transformation agenda calls for the urgency of transition from the legacies of apartheid, towards a new and inclusive democratic society.

Knowledge gained from scientific enquiry has a vital role to play in societal transformation, by encouraging critical discourse and developing responsible and critically engaged citizens. Scientific discovery and invention also advance a knowledge economy where the generation of new knowledge enhances and facilitates the development of society. This is a key part of our transformation agenda.

Over the next decade we will work harder to transform the equity profiles of the South African research workforce; the knowledge enterprise; and the relationship between science and society while building a diverse and fully inclusive learning organisation.







Top left: Dr Nokubonga Mbandzi-Phorego. **Top right:** ACEP Phuhlisa marine science students at the Walter Sisulu University launch of the Joint Marine Laboratories Programme. **Bottom:** Laboratory Technician demonstrating TOC-analyser at UNIZULU. Photos: Supplied

Collaborative programmes transforming marine science at South African HDIs

Lucky Dlamini

The African Coelacanth Ecosystem Programme (ACEP), NRF-SAIAB's flagship marine research initiative, plays a crucial role in driving transformation and capacity building in marine science. ACEP launched the Phuhlisa (Development) Programme in 2012, a dedicated initiative aimed at redressing imbalances in research demographics. The programme focuses on capacity building and fostering interest in marine sciences at four Historically Disadvantaged Institutions (HDIs): Walter Sisulu University (WSU), University of Fort Hare (UFH), University of Zululand (UNIZULU) and University of the Western Cape (UWC), to develop high-quality graduates in marine science.

The programme's aims are achieved through student development, supervisor development and building partnerships between National Facilities and HDIs. The Phuhlisa Programme has supported over 20 researchers and more than 160 postgraduate students, while its science awareness activities have reached learners, undergraduate students and the public. A key aspect of the programme is nurturing Black and female postgraduates within the marine sector.

In 2022 Dr Nokubonga Mbandzi-Phorego became the first-ever PhD graduate in the WSU Faculty of Natural Sciences and her narrative stands as one of the ACEP Phuhlisa Programme's numerous success stories. Her journey with the programme began when she enrolled for an Honours degree at UFH in 2014. From 2015 to 2016 she was stationed at NRF-SAIAB under the guidance of Professor Alan Whitfield for her MSc degree. In 2017, she undertook a DSI-NRF internship at NRF-SAEON (Elwandle Node) in Gqeberha. Dr Mbandzi-Phorego has steadily established herself within the science community and is now an NRF-SAIAB Professional Development Programme (PDP) Fellow.

The next phase of the Phuhlisa Programme focuses on the DSI/NRF-SAIAB Joint Marine Laboratories Programme (JMLP) which aims to advance marine research with a profound societal impact. The JMLP has established state-of-the-art research laboratories at the four HDIs, to create a collaborative platform through merging the expertise of these universities with that of NRF-SAIAB and its extensive network. These laboratories provide researchers and students access to advanced National Facility infrastructure, leading-edge technology and equipment, to enhance research quality and foster continuous growth.

The Rural Coastal Sustainability Laboratory at WSU's Mthatha campus addresses challenges faced by rural communities, focusing on food security and climate change adaptation. The other three laboratories are located at the science campuses of their respective universities. Each laboratory addresses key challenges such as marine pollution, good health and well-being. The UNIZULU laboratory specialises in marine and estuarine ecotoxicology, quantifying metal concentrations in coastal environments and organisms. The UWC laboratory focuses on understanding microplastics to improve ecosystems. The UFH Bio-economy & Bio-discovery Laboratory explores marine resources for potential applications in the marine pharmaceutical economy, targeting diseases such as diabetes and cancer.

The ACEP Phuhlisa and JML Programmes reflect transformative efforts in marine science, making ground-breaking contributions that reshape our understanding and promote effective stewardship of the oceans. The programmes exemplify the strong partnership between the HDIs which continues to solidify and transform the marine science landscape. The support and nurture of young marine researchers enhances their capacity to conduct and promote world-class research on the biodiversity of South African aquatic ecosystems, ultimately enhancing the quality of life for all South Africans.



Left to right: NRF-SAIAB PDP Fellows – Dr Phakama Nodo, supervisor Prof. Nikki James, Dr Kerry-Ann van der Walt, Dr Carla Edworthy and Dr Phumza Ndaleni at the 2022 Rhodes University's Department of Ichthyology and Fisheries Science graduation function. Photo: NRF-SAIAB

Women in water: NRF-SAIAB's Professional Development Programme

Lucky Dlamini

NRF-SAIAB has celebrated significant achievements through its Professional Development Programme (PDP) since its inception in 2011. Starting initially with PhD Fellows, this initiative aimed to empower early-career scientists, especially women, by providing them with opportunities for advanced research, skills development and professional growth in the field of aquatic biodiversity. The programme has supported over 40 participants, including more than 20 women, showcasing a notable transformation in race and gender representation. Through the nurture of female talent and promotion of professional development, NRF-SAIAB continues to address the gender gap in aquatic biodiversity research and conservation.

The NRF-SAIAB PDP Programme has created a supportive environment where female scientists thrive, and has attracted talented women from diverse backgrounds united by their passion for aquatic biodiversity. These women bring unique perspectives and strengths, and significantly contribute to NRF-SAIAB's research and outreach efforts. Mentorship and collaboration are significant aspects of the programme, with senior researchers at NRF-SAIAB playing pivotal roles as mentors guiding participants through complex research projects and helping them navigate the challenges of scientific inquiry.

Several success stories highlight the programme's long-term approach and impact. One such example is Dr Yonela Sithole whose journey began when she participated in NRF-SAIAB's 2011 Winter School during her undergraduate years at Walter Sisulu University. She joined the institute as a DSI-NRF Intern in 2013, pursued an Honours degree in 2014 and MSc studies in 2015. In 2023 she graduated as a PDP-funded PhD from Rhodes University. Following 13 years of capacity development investment, Yonela now holds a PDP Postdoctoral Research Fellowship position at NRF-SAIAB.

Similarly, Dr Phakama Nodo joined NRF-SAIAB in 2012 as an NRF intern after completing her Honours degree at Walter Sisulu University. Her internship sparked an interest in estuarine fishes which was honed under the guidance of experts such as Dr Angus Paterson, Prof. Alan Whitfield and Prof. Nikki James, leading to her MSc and PhD studies funded by the NRF. She published multiple papers and presented at seven local and international conferences. She earned an NRF Scarce Skills Scholarship in 2022 as a postdoctoral researcher at NRF-SAIAB to study the nursery role of shallow-water subtidal habitats for coastal fishes using remote underwater video in Algoa Bay. In June 2023 she was awarded a PDP Postdoctoral Research Fellowship to continue her work with NRF-SAIAB until 2026.

Dr Lizaan de Necker was awarded a PDP Postdoctoral Research Fellowship in 2020 and focused on schistosomiasis (bilharzia) research in South Africa. Her work updated knowledge on schistosomiasis-transmitting molluscs and parasites and examined the effects of climate change on the disease's distribution. Her project yielded significant outputs including technical reports, 17 dissertations, 27 conference presentations, a community workshop and two publications, with more manuscripts under review. Dr de Necker is now a Postdoctoral Researcher in the Department of Biology at the University of Leuven, Belgium, working on a collaborative project to restore and conserve pond ecosystems in the European Union.

These success stories provide powerful inspiration for future generations of female scientists. The PDP programme's impact extends beyond individual achievements, contributing to broader goals of gender equity and diversity in science.



The NRF-SAEON Graduate Student Network's (GSN) 15th annual *Indibano* held from 22–27 October 2023, with a focus on the theme 'Mountain Meet Seas: Exploring environmental interactions'. The event aimed to foster networking among 32 postgraduate students (MSc and PhD). Photo: NRF-SAEON

NRF-SAEON Graduate Student Network: Overview of transformation and linking the next generation of researchers

Kogie Govender

To promote transformation in environmental sciences, the NRF-SAEON Graduate Student Network (GSN) encourages networking among postgraduate students by providing opportunities for collaboration, mentorship and training for professional and personal growth. The GSN encourages students to link and share their scientific research. In the past two decades, the GSN has hosted 16 GSN conferences called the Indibano. *NRF-SAEON sponsors approximately 35 students to attend the* Indibano *every year. Through the GSN, students are connected to the research industry and industry experts to explore internships, further postgraduate studies and postdoctoral opportunities.*

The NRF-SAEON GSN *Indibano* provides a variety of tools and skills that attendees can use to develop their careers as emerging researchers. It offers training in technical skills and competencies such as Geographic Information System (GIS), data analysis using R-studio, Python and science communication. Such workshops provide much-needed skills for young scientists to develop their research capacity where knowledge of and access to big data and cognitive computing are essential for conducting research for a sustainable future. Science communication training enables them to communicate their scientific research effectively to the public.

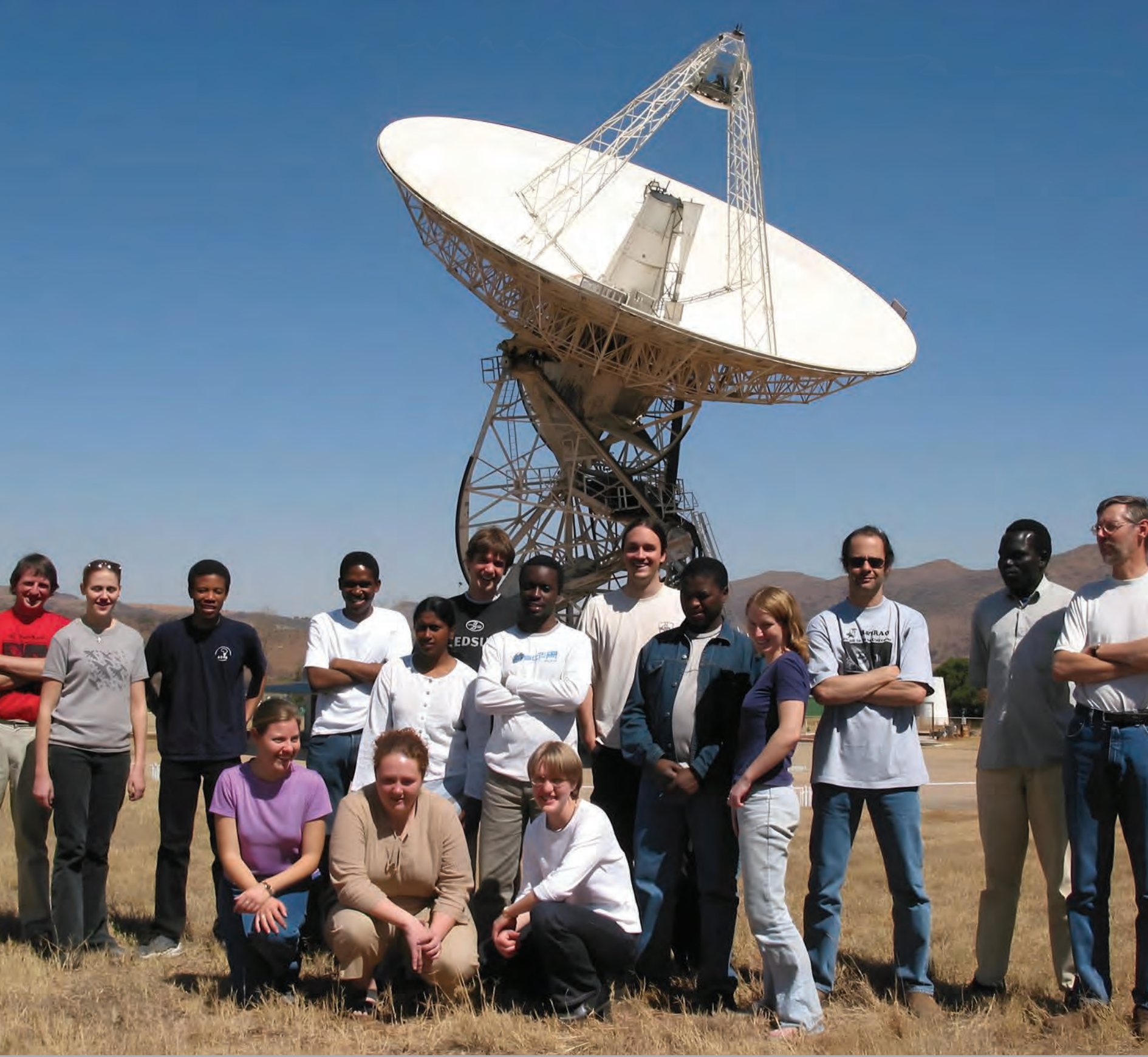
A culture of equity and inclusion has created an enabling environment through which students have access to NRF-SAEON's research platforms, scientists and institutional support. The network has a continental footprint as many of the students who join the online courses are from other African countries. Students from around the world can access the GSN website e-learning platform for course presentations and materials.

NRF-SAEON is committed to fostering a strong connection between experienced and young aspiring researchers to ensure seamless succession and continuous growth in the field. By providing mentorship, resources and opportunities for collaboration, the network aims to empower and inspire the next generation to pursue innovative research and make significant contributions in their respective fields. Through this transformation, the GSN strives to create a vibrant, diverse and inclusive research community that nurtures talent and fosters creativity.

Testimonial

Thobeka Nsibande: Past GSN Committee Member and Graduate Trainee in the Catchment Management Department of the UMngeni-UThukela Water Department.

"I became a member of the Graduate Student Network in 2020 during my Honours year. In 2021, as I began my MSc, my co-supervisor, who was also a node sponsor, urged me to apply for a committee position, which I achieved in 2022. GSN hosted numerous seminars and workshops. Through these events, I gained critical skills in data analysis, academic writing and project management. The exposure to diverse research methodologies and interdisciplinary approaches broadened my perspective and fostered innovation in my work. One memorable task was to assist in writing the GSN *Indibano* booklet, where I coordinated with keynote speakers to obtain their biographies and communicated with the NRF-SAEON MD. This experience significantly enhanced my communication skills, teaching me how to craft polite and effective emails. Knowing that I contributed something meaningful was incredibly rewarding. This support has greatly boosted my confidence, preparing me for a successful career in academia and beyond."



NASSP Honours students visit HartRAO in 2003 with Dr Mike Gaylard (HartRAO, extreme right) and Prof. Justin Jonas (Rhodes University, extreme left). Photo: NRF-SAAO

NASSP: Building a legacy of astronomers and data scientists

Patricia Whitelock

The National Astrophysics and Space Science Programme (NASSP), a collaboration between national astronomy facilities and universities, has produced 465 postgraduates since its inception in 2003. NASSP graduates now occupy key posts in international and South African astronomy, while others make significant contributions to fields as diverse as healthcare and rural education.

NASSP was started with two aims: firstly, to train Africans in astrophysics and space science and therefore position South Africa to make good use of the world-class facilities that were under construction and consideration; and secondly, to imbue smart young South Africans with the sophisticated data-handling skills needed by industry and commerce.

When the government approved the construction of the Southern African Large Telescope (SALT), the single largest telescope in the southern hemisphere, there were only about 40 PhD astronomers in the entire country. Half of these were in two National Facilities, NRF-SAAO and Hartebeesthoek Radio Observatory (HartRAO), while the rest were distributed among ten universities around the country. Very few of them were South Africans and they included only one woman and one Black person. The lack of local astronomers was the major threat to the success of SALT.

Addressing a desperate need for science development to counteract the legacy of apartheid, particularly the exclusion of Black people from scientific and technical careers, astronomy had a role to play as it draws on other crucial fields, particularly physics, chemistry, applied mathematics and computer science. Furthermore, astronomy can attract people into science, stimulating them to pursue careers in engineering, medicine or information technology. These factors, among others, motivated the Government's investment in SALT and, subsequently, in the next-generation radio telescope, the Square Kilometre Array (SKA).

NASSP was the solution put forward in the 2001/2 NRF strategic planning for astronomy. It would take students graduating in physics through Honours and Masters training to prepare them to start PhDs in astrophysics or to enter the workforce with good data-science skills. Initially hosted by the University of Cape Town (UCT) until 2016, it expanded to nodes at North-West University and the University of KwaZulu-Natal.

Bursaries were funded initially by the Ford Foundation and later by DSI/NRF. To meet the challenges experienced by graduates from historically disadvantaged institutions having no previous experience in astronomy, a highly successful Winter School at NRF-SAAO and an extended Honours programme at UCT were developed.

By 2023, NASSP had graduated 229 Masters, of whom 40% are Black and 30% women. The ratio of Black people qualifying has gradually increased over recent years, while the ratio of women remains roughly constant. A 2023 survey of NASSP graduates elicited 240 respondents of whom 114 have PhDs of whom approximately 65% are Black.

The NASSP programme has not only strengthened South Africa's astronomy community but has also produced skilled data scientists who are contributing to diverse sectors of the economy. This legacy of scientific excellence and diversity is a testament to NASSP's transformative impact on South Africa's scientific landscape.



International Student Practice 2024 hosted at the Joint Institute for Nuclear Research in Dubna, Russia. Photo: NRF-iThemba LABS

SAINTS: Advancing transformation

Rudzani Nemutudi

The Southern African Institute for Nuclear Technology and Sciences (SAINTS) is one of the four pillars supporting the Long-Range Research Plan of NRF-iThemba LABS that underscores the strategic objectives of research, training and specialised expertise in accelerator-based science. SAINTS was conceptualised as the overarching training strategy to develop human capacity and competence in specialised fields of interest for NRF-iThemba LABS, including subatomic physics, nuclear sciences, material sciences, radiation protection, radiochemistry, radiation biophysics, radiation detection, accelerator technology, data processing, artificial intelligence and machine learning.

Technical entities and National Research Facilities such as NRF-iThemba LABS have faced challenges related to a shortage of skills and competencies arising from the gradual erosion of technically competent human resources and expertise in critical areas. The main contributing factors to the decline have been general attrition, retirements and the continuous emergence of new technologies. SAINTS offers a platform for postgraduate student training and development in the medium- to long-term to grow the next generation of scientists and technologists. Concurrently, it creates an enabling environment within which NRF staff can develop professionally by undertaking teaching and learning activities to acquire new skills and to gain exposure to relevant and emerging technologies.

SAINTS training and developmental interventions are offered in coordination and partnership with collaborating experts from higher education institutions (HEIs) and accelerator-based research facilities worldwide. The interventions are freely accessible as short courses and workshops, summer schools, vocational training programmes and exposure to major accelerator-based international laboratory facilities.

SAINTS short courses, offered collectively by subject experts from NRF-iThemba LABS and collaborating HEIs, are designed to close academic and technical gaps that result in the slow throughput of MSc and PhD postgraduate students. Special workshops, designed to assist students to improve their soft skills such as technical writing, presentation skills and general professional communication, are available to equip students with critical tools to execute their research project competently and timeously in delivering theses, dissertations, scientific articles, conference presentations and proceedings.

The SAINTS office assists deserving and qualifying students to access NRF postgraduate support under the National Facility ring-fenced student funding programme, with designated South African demographic groups as the preferred beneficiaries. The majority of students participating in SAINTS-coordinated activities are from Historically Black Universities (HBUs). NRF-iThemba LABS has been able to enhance its footprint significantly across the African continent, specifically through online short courses that draw participation from countries such as Algeria, Botswana, Ethiopia, Ghana, Kenya, Nigeria and Zimbabwe.

The availability of an in-house focus on the promotion of science within the school context enables NRF-iThemba LABS to have a transformational impact on the National System of Innovation (NSI) from basic education through to higher education and finally into postgraduate education. SAINTS is a strategic transformative tool for NRF-iThemba LABS to develop, cultivate and grow a pool of technically well-equipped and globally competitive research scientists, technicians and engineers. It is an efficient tool to safeguard the future sustainability of the facility.



Artisan students at the training centre in the Karoo, Northern Cape. Photo: NRF-SARAO

Establishing a fit-for-purpose Human Capital Development Programme

Kim Anthony

Establishment of the NRF-SARAO Human Capital Development (HCD) Programme followed an instruction from the South African SKA Steering Committee to develop a community of scientists, engineers, technicians and artisans to ensure that NRF-SARAO fulfilled its mandate to design, build, operate and exploit the MeerKAT and the SKA radio telescopes, and to secure South Africa's return on its strategic investments in radio astronomy. The programme was devised in a structured and proactive way to be fit-for-purpose for enabling NRF-SARAO to deliver on this mandate.

At the inception of the programme, the cohort of radio astronomers and engineers with radio astronomy expertise in South Africa was very small and lacking demographic diversity. The imperative was to grow technical competence in academia and industry that would allow South Africa to compete successfully for SKA design and construction contracts and to grow the number of scientists who would conduct world-leading science with the SKA telescope. More than 1 600 grants have since been awarded to undergraduate and postgraduate students, early-career researchers and high-level faculty positions, as well as to students studying towards technical and artisanal qualifications.

The Artisan Training Programme aims to develop skilled artisans from the local community. To date 130 students from local communities in the Karoo in Northern Cape have become fibre technicians, IT technicians, electricians, boilermakers, fitters and turners, mechanics and instrument control technicians. The equity profile for the technician and artisan cohorts of the HCD programme targets Black South Africans.

A recent review of the research capacity development programme revealed that 75% of all NRF-SARAO university-based grants awarded have been to South Africans. There has been a particularly significant increase in representation of Black and women South Africans funded by NRF-SARAO at the Masters, PhD and postdoctoral levels since the inauguration of the MeerKAT radio telescope, culminating in an effective pipeline of human capital, and this trend is set to continue. Since approximately 2015, the number of awards of Master's scholarships to Black and female South Africans overtook that of the awards to White men, and since 2016 the number of PhD scholarships awarded to Black and female South Africans has been higher than to White men. As expected, for postdoctoral fellows the change has been slower, however, since 2020/21, the number of Fellowships awarded to Black and female South Africans has exceeded those awarded to White men.

The results of a study to trace NRF-SARAO HCD alumni showed that more than two thirds of NRF-SARAO-funded students are currently employed in positions considered to positively impact on or contribute to South African and African academia and research, or to South African industry. Of these alumni, 67% are Black South Africans and 48% are South African women; an indication that NRF-SARAO HCD is starting to create a more representative radio astronomy community.



The 2006 Bright Sparks had the opportunity to tour the Research Vessel, FRS *Algoa*. The learners were shown different workstations, instruments and equipment used on the ship. This was their first experience of seeing a working harbour and being on board a ship. Photo: NRF-SAIAB

NRF-SAIAB's science engagement legacy

Lucky Dlamini

The Bright Sparks Development Programme, initiated by NRF-SAIAB in 2005, significantly influenced science education and career development in South Africa, particularly in the rural Eastern Cape. Aimed at bridging the gap between disadvantaged learners and science careers, the programme used focus events such as National Science Week to identify high-potential Grade 10 learners as 'Bright Sparks' and provided them with essential exposure and support for three years until they wrote matric. The programme, which ran until 2010, inspired subsequent initiatives such as the NRF-SAIAB Winter School programme for historically disadvantaged higher education students, and later the Summer School which targets undergraduate students from HEIs across South Africa.

The Bright Sparks Development Programme was endorsed by the Eastern Cape Department of Education as a model for science advancement. Annually, 10 learners from township schools in the Eastern Cape were selected for an educational science tour. By visiting various science institutions, including NRF facilities, the learners gained insights into a variety of scientific disciplines and diverse career opportunities in science and technology, which inspired them to continue studying science through their schooling and into higher education. This experience was transformative and exposed them to cutting-edge scientific equipment and research facilities.

Learners were encouraged to form science clubs at their schools and to foster a culture of scientific curiosity and learning in their communities. In this way, the programme's impact extended beyond individual participants. The programme was particularly significant because it operated in one of South Africa's marginalised provinces, where access to quality education and resources for science education was limited. As the only National Research Facility in the Eastern Cape, NRF-SAIAB provided opportunities that were otherwise inaccessible.

This legacy inspired similar initiatives aimed at disadvantaged students at historically disadvantaged higher education institutions. The NRF-SAIAB Winter School programme, which ran from 2006 to 2012, aimed to supplement BSc (Hons) and MSc curricula. Students were exposed to training in the broader field of biosystematics and the 10-day course included lectures, practical/laboratory work and fieldwork, introducing participants to biological diversity in freshwater, estuarine and marine environments. Students also learned about modern developments in collections management, molecular laboratory techniques and Geographic Information Systems (GIS).

Building on these successes, NRF-SAIAB initiated the annual Summer School Programme in 2019, targeted at undergraduate students in their second and third years of study from higher education institutions across South Africa. The Summer School provides hands-on experience in aquatic biodiversity research, including fieldwork in estuarine and marine environments, and skills in data analysis. Some of its first participants have returned to NRF-SAIAB for further studies or joint internship programmes with organisations such as WWF-SA, DSI-HSRC and the Groen-Sebenza internships. A notable success story is Danielle Julius, a 2019 Summer School participant who later became a Groen-Sebenza intern at NRF-SAIAB and, as of 2024, a Seafloor Instrument Technician with NRF-SAIAB's MARIP platform.

These programmes underscore NRF-SAIAB's commitment to education and capacity building in South Africa, identifying and nurturing talented young scientists while it addresses broader social and economic disparities by empowering disadvantaged learners with the tools and experiences to pursue successful science careers.







Top: PhD student Mikhail de Villiers, whose passion for astronomy was ignited by the NRF-SAAO Astronomy Quiz.
Bottom: NRF-SAAO's job shadow programme inspires future scientists and engineers. Photos: NRF-SAAO

Empowering educators, inspiring learners, and nurturing future astronomers

Sivuyile Manxoyi

NRF-SAAO has transformed science education in South Africa over the past decade. Through extensive teacher training, learner workshops and innovative programmes, NRF-SAAO has reached over 286 000 learners and 8 500 teachers. This comprehensive approach has not only empowered educators but also inspired countless students to pursue careers in the fields of science, technology, engineering, and mathematics (STEM), particularly astrophysics.

Curriculum changes in South Africa, including the introduction of 'Natural Science', highlighted the need for teacher support in astronomy education. NRF-SAAO stepped up to fill this gap by becoming the primary provider of teacher development and support, collaborating with universities, educational organisations and science centres.

NRF-SAAO's teacher training programmes have equipped educators with the knowledge and pedagogical skills to effectively teach astronomy-related concepts, fostering a deeper understanding of science among learners. Through hands-on workshops, career exhibitions, job shadowing programmes and a national astronomy quiz, NRF-SAAO has sparked a passion for science and technology in countless young minds.

The success of NRF-SAAO's educational initiatives is evident in the growing number of students who choose to pursue STEM studies. Eighteen participants in the NRF-SAAO job shadow programme have gone on to study astrophysics, including MSc student Ulrich Green. The NRF-SAAO Astronomy Quiz has also ignited a passion for astronomy in participants such as PhD student Mikhail de Villiers (pictured).

NRF-SAAO's dedication to science education extends beyond South Africa's borders. The organisation collaborated with European partners on the Universe Awareness Programme, showcasing its commitment to using astronomy as a vehicle for STEM education and inspiration on a global scale.

NRF-SAAO's far-reaching impact on science education in South Africa cannot be overstated. By empowering educators, inspiring learners and providing a platform for career exploration, NRF-SAAO has played a pivotal role in the development of the next generation of scientists, engineers, and astronomers. The organisation's commitment to education and outreach ensures that the wonders of the cosmos continue to spark curiosity and ignite a passion for learning across South Africa and beyond.



NRF-SAEON Egagasini Node Marine Science Camp with learners conducting an intertidal survey on the rocky shore. Photo: NRF-SAEON

Learning for a sustainable future: NRF-SAEON Environmental Science Education Programmes (ESEP)

Kogie Govender and Caitlin Ransom

NRF-SAEON's ESEP promotes scientific learning by enhancing creative and critical thinking through the use of its research infrastructure (RI) platforms to inspire an interest in science. ESEP is facilitated by the NRF-SAEON science engagement team, scientists, technicians and other institutional stakeholders, and participants gain access to real-time data and knowledge. Visits to the RI enable participants to connect their classroom learning with how knowledge is applied in a real context. The RI also provides access to scientific equipment, software, dynamic modelling tools and interactive visualisations not available in a school setting.

The programme has six focus areas: school-based monitoring, educator support, learner support, awareness platforms and an eLearning platform. School-based monitoring projects provide opportunities for hands-on, inquiry-based learning and teaching. The projects are implemented in no-fee-paying schools to give learners from disadvantaged backgrounds the rare opportunity to participate in science and helping schools to access scientific equipment that they could otherwise not afford.

NRF-SAEON's Educator Training Programme is accredited by the South African Council of Educators (SACE) for high school educators in Geography and Life Sciences. The workshops equip educators with the latest scientific information and technologies that could contribute to innovative teaching strategies and to learners who take science in higher grades. Workshops also strive to increase environmental awareness, environmental responsibility and sustainability to inspire educators to become more conscious of the impact of human activity on the planet.

The learner support programmes enable continuous interaction between NRF-SAEON education personnel and school learners. The science camps are unique, out-of-school experiences that promote environmental science learning in a fun and engaging way where learners interact with scientists and learn how scientists work. During the science camps, learners design environmental science investigations, collect and interpret data and make inferences through discussions with scientists.

NRF-SAEON champions the use of citizen science projects, such as iNaturalist, to engage learners in hands-on data gathering experiences and as a valuable tool for teaching data fluency, which is crucial for young people's critical and ethical thinking about data and for informed decision-making in a data-centric world.

The ESEP has been innovative in the use of digital technologies through the NRF-SAEON Environmental Science eLearning platform. The virtual space enables NRF-SAEON to reach more beneficiaries from around South Africa and abroad. Beneficiaries can access these engaging and interactive resources to explore, learn and collaborate, which inspires curiosity, passion, critical thinking and problem-solving skills for environmental sciences.

Testimonial

Tania Duba: UCT PhD candidate. Tania was a beneficiary of the NRF-SAEON Kids Programme and science camps and workshops hosted by NRF-SAEON Egagasini Node.

"As a Grade 9 learner at the time, this task was exciting yet daunting. In the three years that I was part of the NRF-SAEON Science Club, I had numerous opportunities that developed my maths and science skills. … After Matric, I enrolled for an oceanography and environmental science degree at the University of Cape Town. I remained affiliated with NRF-SAEON and received support through academic supervision, bursaries and internships from my Honours research project to date as a PhD candidate."


TRANSFORMATION
IMPACT
INNOVATION
EXCELLENCE
SUSTAINABILITY
NRF
VISION
2030

IMPACT:
A better society through knowledge

As an agent of change and an engineer of progress, the NRF aims to make a positive, meaningful, and lasting impact. Impact is defined in two ways: 'Knowledge impact' is the contribution that excellent research makes within academia. 'Research or societal impact' is the contribution that excellent research makes to society, the economy, and the environment.

The NRF enables, facilitates and performs excellent research with direct and indirect impact, whether immediate or long-term, that extends the frontiers of knowledge and addresses national challenges.



Hot cell (containment chamber) for isotope production. Photo: NRF- iThemba LABS

Isotopes and health

Deidre Prince

NRF-iThemba LABS produced radioisotopes for the local and international nuclear medicine and research fraternity for more than 30 years. NRF-iThemba LABS is a licensed pharmaceutical manufacturer regulated by the National Department of Health (DoH), the South African Health Products Regulatory Authority (SAHPRA), and the South African Pharmacy Council (SAPC). The radiopharmaceuticals are produced in dedicated facilities by trained staff who adhere to current Good Manufacturing Practices.

The World Health Organization (WHO) predicts that cancer will become the leading cause of death on the African continent by 2030, with at least a million people in Africa dying of cancer annually. The early detection of cancer greatly increases the effectiveness of tumour control and treatment. This reality underpins the need for the continent to provide access to the required radiopharmaceuticals and diagnostic infrastructure to facilitate early detection.

The Nuclear Medicine Department at NRF-iThemba LABS currently provides products to more than 80 public and private nuclear medicine departments nationally, and longer half-life radionuclide products are distributed to nearly 100 international clients.

The radiopharmaceutical offering includes short-lived single-photon emission computed tomography (SPECT) products such as ^{123}I-radiopharmaceuticals, that are utilised for tumour localisation and the observation of the functioning of the heart, kidney, thyroid and brain. In 2006 NRF-iThemba LABS introduced the first commercial positron emission tomography (PET) radiopharmaceutical, ^{18}F-FDG, to the Western Cape nuclear medicine community. These tracers are now produced routinely using an 11-MeV cyclotron acquired in partnership with Nuclear Radioisotopes (NTP). ^{18}F-FDG and ^{18}F-API for the synthesis of ^{18}F-FMISO are also supplied to the Nuclear Medicine Research Infrastructure (NuMeRI) Node for Infection Imaging (NII), based at Tygerberg Hospital for clinical trials. In 2008 NRF-iThemba LABS developed the first ^{68}Ge/^{68}Ga generator for use in nuclear medicine and research facilities in South Africa and abroad. These generators are integral to the PET diagnosis of neuroendocrine tumours (NETs). The uptake of this generator by the market was facilitated by extensive clinical research that was conducted and published by NuMeRI, based at Steve Biko Academic Hospital, in South Africa.

NRF-iThemba LABS has long-standing collaborations and sales agreements with reputable global institutions. Rb targets are irradiated and exported for the production of ^{82}Sr API to produce ^{82}Sr/^{82}Rb generators for myocardial perfusion PET imaging. NRF-iThemba LABS is the sole producer of ^{22}Na solution and ultra-high vacuum ^{22}Na positron sources. These sources are supplied internationally to scientific research facilities for positron annihilation studies.

The establishment of the South African Isotope Facility (SAIF) in 2023 augments the production capacity for high-energy accelerator-based isotopes and enhances the capability for research and development of new products. The production of alpha-particle-emitting radioisotopes such as ^{211}At and ^{225}Ac for targeted-alpha-therapy (TAT), and theranostic isotopes such as ^{43}Sc / ^{47}Sc, ^{64}Cu and ^{67}Cu that combine diagnostic biomarkers with therapeutic agents, are envisaged. The capability to develop diagnostic and therapeutic products for nuclear imaging and treatment will create long-term benefits for the public and private health sectors.



Educational initiatives have resulted in the support of STEM education in the Karoo communities and schools surrounding the SKA site.
Photo: NRF-SARAO

Investment in radio astronomy maximises opportunities for societal benefit

Adrian Tiplady

South Africa's investments in radio astronomy have realised a wide range of socio-economic benefits at both the local and national level. Internal and independent socio-economic impact assessments have concluded that NRF-SARAO has made significant positive impacts on developmental objectives, including substantial contributions towards education, skills development and employment opportunities, as well as scientific innovations that benefit society as a whole.

In order to realise the range of benefits that may arise from investment in radio astronomy, a framework has been adopted to guide strategic interventions that maximise potential opportunities for benefit across the following pillars: Innovation & Industrial Spillover; Research Enterprise & Science Products; Education & Skills Development; Community & Cultural Investment; Business & Enterprise Development; and Public Good.

Independent economic assessment over the period 2011 to 2022, which encompassed the design, construction and operation of the MeerKAT telescope, suggests that an investment of R8.017 billion realised the following direct economic benefit within the national economy: R19.4 billion in increased production; R8.89 billion increase in GDP; 23 022 full-time equivalent (FTE) jobs created; R4.624 billion increase in household income, and 92 088 people having benefited from the increase in household income.

This economic benefit is set to increase by approximately 250% over the next 10 years with the award of over R3 billion in SKA construction contracts and long-term operations agreements.

Innovation activities in the design and construction of MeerKAT have led to an impressive intellectual property portfolio, including passive radar systems, low-cost and non-proprietary data storage and super-computing infrastructure, and data-intensive research methods and algorithms. This has established NRF-SARAO as a key innovator and technical leader.

The design and establishment of MeerKAT, coupled with a strategic and targeted Human Capital Development Programme, has enabled transformational scientific discovery for the local and global research enterprise. Educational and skills development initiatives have resulted in the award of over 1 500 grants and bursaries, establishing a diverse and sustainable South African research community in astronomy and related engineering disciplines. These initiatives have also resulted in the support of technical and artisanal training, as well as STEM education, in the Karoo communities and schools. surrounding the SKA site.

Community and cultural investments have sought to preserve the social fabric and cultural heritage of the Karoo, whilst addressing key social development challenges.

Business enterprise development initiatives have lowered the barriers to economic opportunity for local business in the Karoo. Young people and small, medium and micro enterprises (SMMEs) have access to procurement and employment opportunities through radio astronomy construction and operations activities. This increase in economic activity is catalysed through broader initiatives, such as astro-tourism in the Northern Cape Province.

Finally, investment in radio astronomy has realised a key public good as the skills and competencies developed are easily transferable and highly relevant in the era of the Fourth Industrial Revolution. NRF-SARAO's appointment to lead and coordinate the National Ventilator Project during the COVID-19 pandemic, resulted in the successful design, construction and distribution of 20 000 low-cost ventilators in approximately eight months.



Tour guide, Jeremy Stuurman, explains how SALT works. Photo: NRF-SAAO

SALT Collateral Benefits Programme: Linking science to society, transforming a community

Thembela Mantungwa

The SALT Collateral Benefits Programme, established alongside South Africa's first science and technology policy, has successfully connected science to society. Through diverse initiatives in education, technology, tourism and community development, the programme has leveraged the Southern African Large Telescope (SALT) to advance the economy, empower communities, and inspire a new generation of scientists.

The SALT Collateral Benefits Programme's wide reach across South Africa and the continent is evident in its four pillars of engagement and impact:

Science advancement: Interactive exhibits such as the popular SALT model at the Cape Town Science Centre and collaborations with museums have increased public awareness of astronomy.

Education and training: The programme's emphasis on education has led to the development of astronomy curricula at HBUs, providing opportunities for students previously excluded from the field. In one example, an alliance was formed with the former University of the North West located in Mahikeng (then Mmabatho) to introduce astronomy. This effort resulted in an approved programme introducing astronomy and even the installation of a training telescope.

African connection: The African Astronomical Society (AfAS), located at the South African Astronomical Observatory in Cape Town, strengthens ties with the broader African astronomical community, fostering collaboration and knowledge exchange.

Edu-tourism and community development: Sutherland has been transformed into an astro-tourism destination, attracting visitors eager to learn about SALT and the universe.

The programme's impact extends beyond astronomy. A community development centre, donated by the Department of Science and Innovation, provides free internet access and serves as a hub for community training. NRF-SAAO supports local schools with a dedicated mathematics teacher and supplies, addresses medical needs and provides technical assistance to community centres. Initiatives such as warm clothing collections for schoolchildren highlight the programme's commitment to holistic community well-being.

The SALT Collateral Benefits Programme demonstrates the transformative power of science engagement. By fostering education, stimulation of the economy and empowerment of communities, the programme has created a lasting legacy that extends far beyond the scientific discoveries made possible by SALT. This model of science for society serves as an inspiration for future initiatives that seek to bridge the gap between research and real-world impact.



Photographic record of an *Oreochromis* specimen from the Langspruit Dam in Mpumalanga. In order to ensure data accuracy, the field sample processing protocol included photographic records of tilapia specimens, that showed the name and GPS co-ordinates of the site where each specimen was collected. Each fish record was allocated a unique identification code to allow for a linkage between voucher specimens and genetic samples in the NRF-SAIAB National Fish Collection database. Photo: NRF-SAIAB

Tilapia mapping to support decision making for aquaculture development

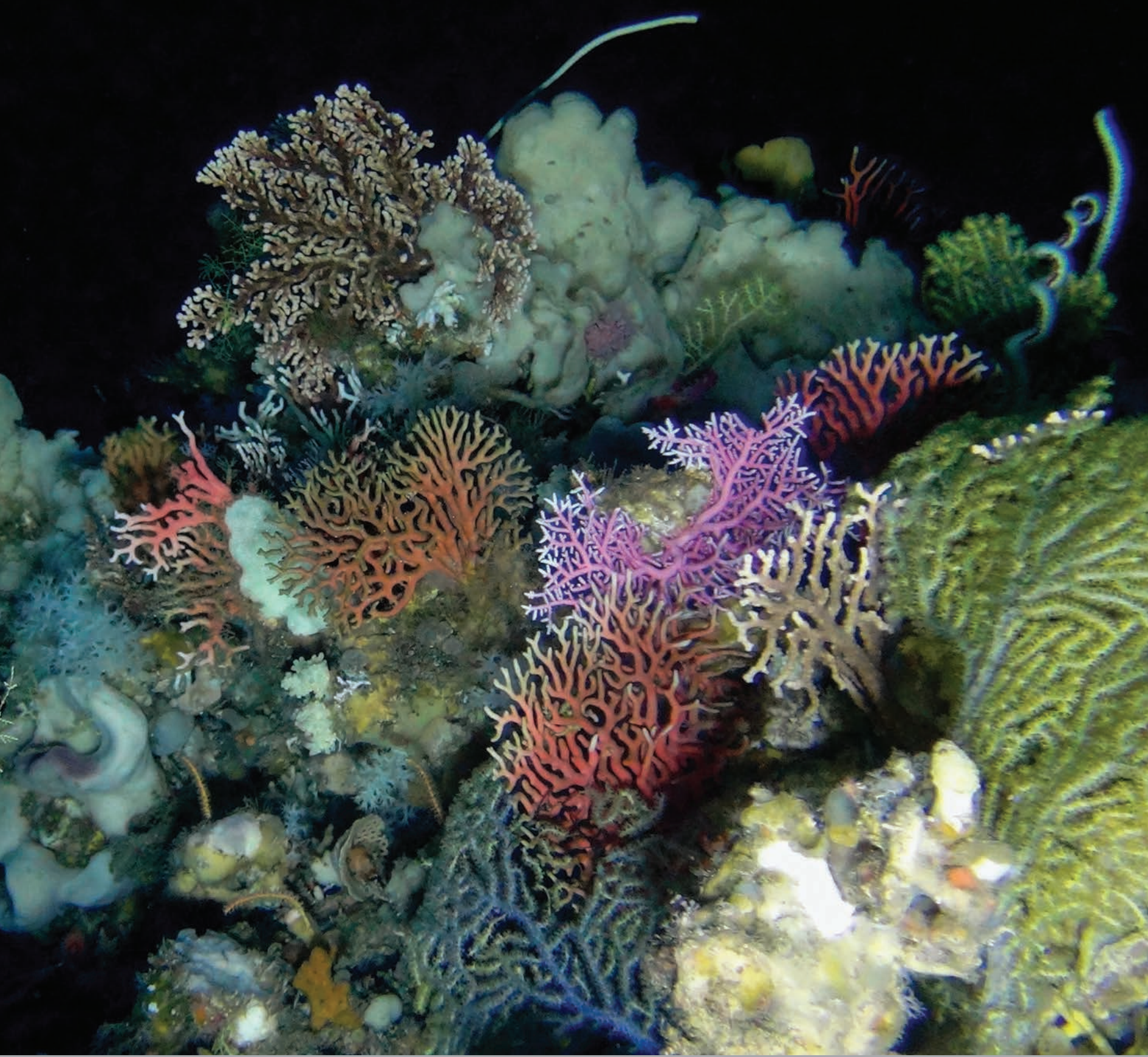
Albert Chakona and Mandla Magoro

The South African Government engages various stakeholders to promote socio-economic growth and address food and nutrition insecurity through sustainable development of the aquaculture sector. One of the preferred candidate species for warm water aquaculture is the non-native Nile tilapia, Oreochromis niloticus*, but it is a highly contentious species due to its negative ecological impacts. NRF-SAIAB undertook comprehensive mapping of the distribution of Nile and Mozambique tilapia,* Oreochromis mossambicus*, to provide credible data to guide the review of existing legislation, which includes streamlining licensing and permitting procedures in order to support responsible aquaculture development. This is in line with the White Paper on Conservation and Sustainable Use of South Africa's Biodiversity.*

Aquaculture development has been identified as a potential catalyst for socio-economic development in South Africa, to drive redress, create jobs and address food and nutrition insecurity. National and provincial Government authorities have engaged with the aquaculture community around the possible use of the non-native Nile tilapia in aquaculture. This matter has been contentious because this species is classified as an alien invasive species. Strict regulations are in place because this species is known to readily hybridise with native *Oreochromis* species and has been shown to outcompete native tilapias in the natural environment. However, from an aquaculture perspective it is the preferred species for a number of reasons, including its fast growth rate, and has significant economic potential. Management of such species presents considerable challenges to authorities who have to balance promotion of socio-economic development against their mandate to protect the environment. Aquaculture permits for Nile tilapia have been issued in the Gauteng, Free State, North West, Northern Cape, Western Cape and Eastern Cape provinces. However, the permitting and development of an aquaculture industry for this species in the Limpopo, Mpumalanga and KwaZulu-Natal provinces has been long debated.

Several biodiversity risk and benefit assessments (BRBAs) of Nile tilapia as an aquaculture species were undertaken during the past decade, and recommendations made at both provincial and regional levels. In addition, a comprehensive strategic environmental assessment (SEA) for marine and freshwater aquaculture development in South Africa was conducted which specifically addressed the risks and benefits of Nile tilapia. However, both the BRBA and SEA approaches lacked reliable and recent spatial data for these species, raising concerns about their overall recommendations.

In 2019, the Department of Forestry, Fisheries and the Environment (DFFE), through the South African National Biodiversity Institute (SANBI), contracted NRF-SAIAB to undertake comprehensive surveys to provide more accurate information on the distribution of Nile and Mozambique tilapia in the Limpopo, Mpumalanga and KZN provinces. This collaborative project, which, from its inception, included multiple stakeholders representing civil society, the aquaculture industry, academia and government, was completed in 2024. This study has, for the first time, generated the most comprehensive data (genetic tissue samples, voucher specimens and georeferenced presence/absence records) that will feed into an integrated environmental management (IEM) decision-making process. This will contribute towards achieving the Government's strategic objectives of driving sustainable socio-economic growth, whilst it maintains environmental integrity and the protection of the country's natural heritage.



Deep sensitive coral habitats which provide fish breeding habitat are vulnerable to trawling and mining impacts but now receive some protection in South Africa's new MPA network. Protection helps secure economic benefits through eco-certification and by supporting fisheries sustainability. This image is from the Amathole Offshore MPA. Photo: ACEP Imida Project

Deep impact: ACEP projects support improved ocean protection

Kerry Sink and Ryan Palmer

The establishment of 20 new marine protected areas (MPAs) in South Africa in 2019 made a key contribution to national plans for a sustainable ocean economy. The underpinning science included research from many projects facilitated through NRF-SAIAB's African Coelacanth Ecosystem Programme (ACEP). This includes foundational work to support ecosystem classification and mapping, biodiscovery research, fisheries research and transdisciplinary research to improve participation in ocean governance. MPA network design increases protection of marine ecosystems with consideration for other sectors such as the economic benefits from fisheries certification, planning for climate resilience, the integration of indigenous knowledge systems and protection of cultural heritage.

The South African National Biodiversity Institute (SANBI) contributes to sustainable development by the facilitation of access to biodiversity data, generation of information and knowledge, building of capacity and provision of policy advice. To ensure the sustainable development of South Africa's Blue Economy, over the past 20 years SANBI's Marine section has been instrumental in leading work based on sound science to support MPA expansion. This journey began in 2004 with the first National Spatial Biodiversity Assessment, which included terrestrial, freshwater, estuarine and marine realms. The assessment reported that South Africa's offshore environment was the least protected of any realms. Approximately 7.5% of land was protected compared to 0.4% of ocean territory. This sparked a dedicated research project which aimed to identify priority areas to form a network of offshore MPAs that supported the protection of 87% of South Africa's ecosystem types in 5% of ocean area, meaning the network is both spatially efficient and highly representative.

South Africa's Operation Phakisa provided the multi-sectoral platform needed to consolidate this research; focus dedicated research in priority areas through a dedicated research cruise; and co-ordinate multiple departments in implementing protection. ACEP provided funding as well as technical support and access to research infrastructure in support of MPA expansion by prioritising projects that focused on relevant MPA research and applied collaborative, multi-disciplinary approaches that develop technical and human capacity in offshore research. Technical and infrastructure support from ACEP includes survey data from more than 600 remotely operated vehicle dives which shed new light on outer shelf and slope ecosystems of the country.

The multi-disciplinary nature of the projects ensured that several data layers were collected per geographic area, in support of an ecosystem approach. Projects collected physical and biological oceanography data, geological and geoscience information, foundational biodiversity knowledge including taxonomic, genetic, benthic and pelagic data and social science. Several projects strove to inform marine spatial planning. This multi-disciplinary approach ensures that resources are maximised and that different project components are linked, to create a value chain which provides sound, integrated information to policy makers. Furthermore, projects disseminated findings through various media, including articles, film and animation. Arts-based approaches have also piloted improved participation in research with theatre and puppets playing a key role.

The significance of these achievements extends far beyond conservation boundaries. The establishment of these MPAs represents a milestone in South Africa's commitment to sustainable ocean management and the responsible and equitable stewardship of its marine resources for all South Africans.



The Coves is a site at Hartebeestpoort Dam that was covered in water hyacinth, that has been controlled with the control agent, *Megamelus scutellairs* – commonly known as the water hyacinth planthopper (see insert). Photos: NRF-SAIAB/CBC

Managing aquatic invasions in South Africa

Julie Coetzee

Managing invasive aquatic plant and fauna species in Southern Africa, significantly improves ecosystem services provided by waterbodies, particularly to those communities whose livelihoods depend on access to water. Biological control interventions for aquatic weeds have been largely successful, but prevention measures are also required to limit the proliferation of new invasive species. In addition, limited information on the impacts of invasive aquatic fauna species in Southern Africa highlights the need for greater research in this area.

Floating macrophytes have invaded fresh waterbodies in Southern Africa since the start of the 20th century, costing governments millions of dollars through losses to the freshwater economy and in control interventions. Through biological control interventions, using host-specific natural enemies, there have been significant reductions in the extent of these invasions and a return on biodiversity and socio-economic benefits. Not only is biological control the more cost-effective option, but its use also prevents many thousands of litres of herbicide being used in the aquatic environment. These benefits provide justification for the control of widespread invasive alien aquatic weeds in Southern Africa.

Classical biological control of these floating aquatic macrophytes in South Africa is considered one of the international successes in weed biological control. However, biocontrol of water hyacinth, the world's worst aquatic weed, has been constrained by a number of factors. These include cool winter temperatures that limit population growth of the biological control agents, highly eutrophic waters which enhance plant growth, and uncoordinated herbicide control programmes. NRF-SAIAB and the Centre for Biological Control at Rhodes University have been the first to show that by cutting out the use of herbicides and releasing control agents such as *Megamelus scutellairs* (a beetle that feeds on water hyacinth) after winter and flooding events, water hyacinth can be managed successfully using biological control as a stand-alone intervention, despite eutrophication and/or temperate climates.

However, rather than relying solely on such control interventions, unless the primary driver of disturbance, i.e., eutrophication through increased nitrates and phosphates, in aquatic ecosystems is addressed, a succession of invasions by new invasive macrophytes can be expected. In South Africa, such invasions are becoming more common, and require implementation of new biological control programmes. Therefore, interventions are now focused on active restoration of controlled sites to prevent the succession of invasion in managed sites.

In addition to invasive aquatic plants, the control of invasive aquatic animals is vital to maintain aquatic ecosystem structure and functioning. The recent discovery of two invasive crayfish in Southern African waters, one native to Australia and the other from USA and Mexico, is of particular concern due to scavenging behaviour and destruction of fish fry habitat, which have the potential to cause high economic cost to artisanal fisheries in Southern Africa. Negative impacts on native biodiversity and socioeconomic impacts have been documented in other continents, however there is very little information from Africa. Therefore, research into the mitigation of these impacts remains a priority for NRF-SAIAB as food security and livelihoods in invaded regions will be affected.



MSc student, Hima Rama, holds a tagged common carp at Groenvlei, Western Cape. These non-native fish are problematic pests in this Cape Nature-managed water. A removal project funded by Cape Nature and Gift of the Givers, and monitored by NRF-SAIAB scientists, has provided nutrition to the local communities during and since the COVID-19 pandemic. Photo: NRF-SAIAB

Inland fisheries management research informs new national policy

Josephine Pegg, dedicated to Olaf LF Weyl

Inland fisheries contribute to food security, livelihoods and income generation, and therefore play an important role in achieving the Sustainable Development Goals (SDGs) of No Poverty (SDG 1), Zero Hunger (SDG 2) and Responsible Consumption and Production (SDG 12). However, for the resource to be used in a way that meets these goals, sound scientific understanding of both the resource and the user is needed. This research has been undertaken by NRF-SAIAB scientists and collaborators and has informed the development of freshwater fisheries management priorities which now form national policy.

In February 2022, South Africa's National Freshwater (Inland) Wild Capture Fisheries Policy was approved by the Government for implementation, following many years of development and consultation. The policy is built on extensive research undertaken to understand both fish and fishers and ensure that fisheries develop in accordance with policy objectives without compromising resource sustainability and employment stability.

South African inland waters have unique characteristics on the continent – most fishing takes place on dams and the catch comprises high proportions of non-native fishes. In evaluating the potential for development of small-scale commercial fisheries, NRF-SAIAB scientists have explored the viability of a number of projects with a particular focus on the use of non-native species such as barbel (*Clarias garipinus*) in collaboration with SANParks Addo Elephant National Park, or common carp (*Cyprinus carpio*) in Lake Gariep in conjunction with the Department of Economic, Small Business Development, Tourism and Environmental Affairs (DESTEA). Additional research has examined the biology and fishery potential of underutilised species such as the estuarine round herring (*Gilchristella aestuaria*).

The quantification of existing fisheries has been a key step of the policy development process and this research has illuminated the large but also largely undocumented value of informal subsistence fishing. For example, research in North-West Province demonstrated that 60% of dams had subsistence fishing activity; whilst in the Free State, Lake Gariep supports 450 regular subsistence anglers. The groups' studies have shown how recreational angling can play an important role in wealth creation through job provision, tackle purchases, boat and vehicle sales, accommodation and associated expenditure, but it also raises challenges both in potential conflict with newly developed fisheries and conservation actions, because preferred target fish such as trout and bass may be subject to controls.

Ultimately, the success of any policy depends on its implementation, and implementation depends on effective operators. Under the DSI/NRF South African Research Chair Initiative, significant human capacity development has taken place both directly, through workshops and training events with fishery operatives and managers, and through supervision of over twenty postgraduate students, who are now placed in jobs in governance, industry and academia.



Grazing trial at the Grootfontein Agricultural Development Institute (GADI) investigates the visible effect of continual grazing and continual rest at Bergkamp camp. Photo: GADI

Understanding rangelands informs decision making and improves food security

Helga van der Merwe and Tshililo Ramaswiela

Rangelands cover large parts of South Africa and are used for extensive livestock farming, primarily cattle, sheep and goats, to produce agricultural products such as meat, milk, wool and hides. These products are used locally or exported. The correct management of these vast rangelands is vital to ensure the sustainability of the ecosystem goods and services they provide. Supporting sustainable agriculture safeguards food security, water provision, economic activity, biodiversity conservation and carbon sequestration. Therefore, understanding rangeland dynamics, past and present, is crucial. This becomes even more relevant under an unpredictable climate, where adaptation and resilience are needed to mitigate negative effects on communities.

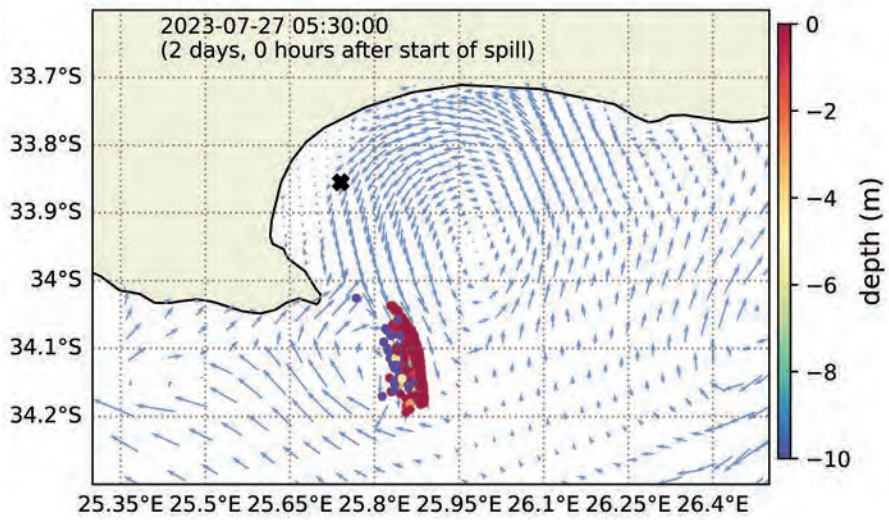
Nama-Karoo vegetation is dominated by long-lived dwarf shrubs and grasses that are short- (annual) or longer-lived (perennial). Good summer rains produce a quick response in the form of short-lived grasses, while perennial grasses take longer to establish. Dwarf shrubs respond slower to rainfall but have a longer growing season and are more drought tolerant than the grasses. Livestock and wildlife feed on the palatable grasses and shrubs. Heavy consumption of vegetation leads to a change in species composition thereby degrading the quality of forage and the environment.

Environmental conditions experienced in the Nama-Karoo are changing. An understanding of these changes is required in order to adapt and build a resilient agricultural sector that ensures a healthy environment, food and economic security in a changing climate. Because change happens very slowly in these systems, to improve our understanding of vegetation change in semi-arid rangelands, long-term monitoring is required. Consequently, the value of historical experiments and data sets is immense.

The Grootfontein Agricultural Development Institute (GADI) is a training, research and extension division of the Department of Agriculture, Land Reform and Rural Development. Grazing trials were initiated in the 1930s and 1940s outside Middelburg, Eastern Cape, and are some of the world's longest running field grazing trials. The trials lie on the ecotone between the Nama-Karoo and Grassland biomes and study aspects of vegetation dynamics. Studies include the investigation of change in grass and dwarf shrub components under various conditions. NRF-SAEON Arid Lands Node joined the GADI efforts in 2011 by archiving the existing detailed historical data and assisting with periodic resurvey of the trial paddocks. Because the environment has been changing, there is an increased abundance of grass, specifically in the eastern Nama-Karoo. This affects livestock breed choices and grazing regimes.

Long-term research provides some insight into the shrub-grass interactions in the Nama-Karoo and how these are affected by rainfall (amount and season) and livestock (type and stocking rate) which have allowed for the improved management of the rangelands. Karoo shrubs live longer than grasses, are more drought resistant and become essential forage in poor rainfall years when grass abundance is low. Shrubs may be fewer or less resilient because of the impacts of the higher levels of grass competition. However, the increased grassiness has boosted the number of fires in the region. Initial findings suggest a significant decrease in some Karoo shrub species following fire, but the potential long-term impacts are unknown.







Top and bottom right: Oiled African penguins (top) and Cape Gannet (bottom right) from the 2019 receiving vessel MV Chrysanthi S oil spill in Algoa Bay in the pre-wash area at SANCCOB. Photos: Courtesy of SANCCOB. **Bottom left:** An example of the forecast trajectory of an oil spill that can be provided by the SOMISANA team. Image: NRF-SAEON

Sustainable Ocean Modelling Initiative: A South African Approach (SOMISANA)

Jennifer Veitch

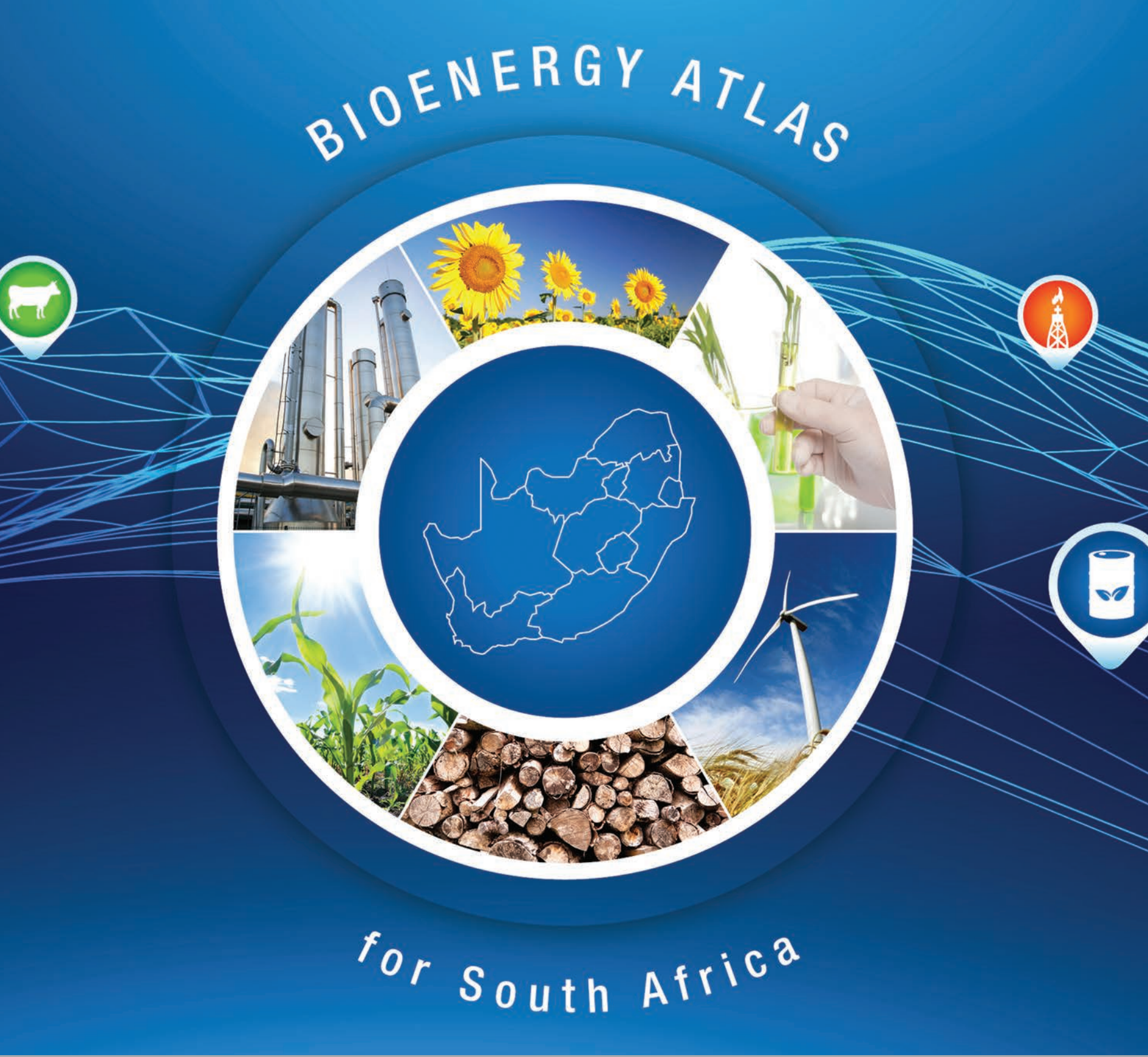
The vision of the Sustainable Ocean Modelling Initiative: A South African Approach (SOMISANA) is for a sustained and transformed critical mass of internationally recognised South African numerical ocean modelling experts who provide accurate information about the changing state of the ocean for enhanced impact. The meaning of SOMISANA is 'to work together', underscoring the role that we hope SOMISANA will play in facilitating collaboration and cooperation between various institutes in the generation of actionable ocean information in support of both ecosystem and societal resilience.

With the ratification of Operation Phakisa in 2014, an initiative to fast-track unlocking the economic potential of South Africa's oceans to ensure good governance of our coastal ocean, it has become more crucial than ever that operational information about the state of the ocean be available to stakeholders and policy makers. To this end, the Department of Forestry, Fisheries and the Environment (DFFE) has championed the development of the National Oceans and Coastal Information Management System (OCIMS) that provides various operational support tools for informed decision making. The SOMISANA initiative is part of the OCIMS consortium that, with the DFFE, includes the Council for Scientific and Industrial Research (CSIR) and the South African Weather Service.

The SOMISANA platform provides high resolution, five-day forecasts of various regions of the South African coastline in the form of an easy-to-navigate user-defined visualisation portal as well as data download links. Operational forecasts of temperature, currents, salinity through the water column, as well as sea surface height are provided. The greater Algoa Bay region as well as the south-west Cape coast were chosen as pilot sites for the forecast systems due to their being high-use regions. For example, Algoa Bay is home to one of South Africa's largest Marine Protected Areas (MPAs), important bird colonies and is a whale heritage area, yet it hosts an oil bunkering industry and is the only bay along the South African coastline with two commercial ports, one of which services the Coega Special Economic Zone, an industrial development complex that was established in 1999. Given the burgeoning industrial activity in and on the shores of Algoa Bay, operational and easily accessible information about the changing state of the ocean is needed in order to support the prevention and mitigation of marine pollution.

The ocean forecast system developed by the SOMISANA team includes a capability that allows for the tracking of oil spills, plastics, sewage, oil drums, containers and other floating objects that include persons lost at sea and various types of seagoing craft, from small, for example a raft or surfboard, to large, for example a coastal freighter or navy submarine. The tracking tool uses both the high resolution forecasts as well as the global forecasts so that South Africa's entire mainland exclusive economic zone is covered. By providing the five-day forecast of the trajectories of various types of marine pollution or items lost at sea, the SOMISANA team provided support for more efficient mitigation and search and rescue operations.

BIOENERGY ATLAS



for South Africa

Innovative bioenergy solutions can address energy security while promoting economic and environmental sustainability. Image: NRF-SAEON

BioEnergy Atlas of South Africa: Ensuring energy security through sustainable energy systems

Leo Chiloane

The BioEnergy Atlas for South Africa is a web-based platform that collates information, tools and data in support of the bioenergy industry in South Africa. It provides a detailed mapping of biomass resources nationwide, highlighting the regional potential for bioenergy production. The Atlas encompasses open access to data on agricultural residues, forestry residues and invasive species, and presents a clear picture of untapped bioenergy potential. Access to this information is helpful for the development of solutions to reduce dependency on fossil fuels and enhance energy security. Through the identification of viable bioenergy sources, the Atlas supports informed planning and decision-making on renewable energy infrastructure.

Launched publicly in March 2017, the Atlas included a hardcopy synopsis report supported by a web portal which mapped the potential for the production of energy from various biomass resources, including agricultural residues, pulp and paper mill residues, invasive species, fuelwood, solid waste, and other sources. The web platform has undergone two iterations since its launch. In the latest version of the Atlas, data scientists at NRF-SAEON's uLwazi node collaborated with local initiatives to feature local case studies, that highlight bioenergy's diverse potential to enhance the country's energy security. Case studies feature innovative uses of various bio-resources and inclusive, local approaches that drive these initiatives.

One standout case study is the Women in Biodiesel project, which showcases women's involvement in producing biodiesel from waste cooking oil. The BioEnergy Atlas team compiled a database of used cooking oil producers within each major metropolitan area in South Africa to determine the number and location of potential biodiesel facilities in each area. The information was supplied to the business acceleration organisation, Fetola, which used it to select small, medium and micro enterprises to enter an incubation programme to establish ten female-owned biodiesel businesses in South Africa. The initiative empowers women economically and contributes to energy security by providing a sustainable and locally sourced fuel alternative. This project exemplifies how gender inclusion in the renewable energy sector can lead to social and energy benefits.

The BioEnergy Atlas project team partnered with the World Wide Fund for Nature (WWF) to assess the volumes and spatial distribution of sugarcane and sugarcane residue in South Africa. This information was used to model the unit cost of producing transport fuels from sugarcane field residue and bagasse. It contributed to a report compiled by WWF and Boeing on the use of sugarcane as a feedstock for sustainable aviation fuels in Africa.

The Atlas includes a case study on the use of forestry residues as an energy source. The project team commissioned the Institute for Commercial Forestry Research to produce a dataset on the availability of forestry residue as a bioenergy feedstock. The team also created a toolkit for the calculation of the volume of forestry residue that can be sustainably removed from a forestry compartment based on soil parameters and forestry management objectives. These data were used to create energy and transport fuel production scenarios.

Collectively these case studies from the BioEnergy Atlas demonstrate how innovative bioenergy solutions can address energy security while promoting economic and environmental sustainability.









Top left: NRF-SAEON intern Ms Nosihle Mkhize assisting MSc student Thobeka Nsibande with intensive field work. **Top right:** Surface renewal instrument set over a ground stand of Eucalyptus to determine how much water they use. **Bottom left:** A burnt 7000-year-old Vasi pan peat wetland – an example of wetland degradation resulting from Eucalyptus plantation impacts. **Bottom right:** South basin at Lake Sibaya illustrating declining water levels. Photos: NRF-SAEON

Advancing water and income security in the unique Maputaland coastal plain

Susan Janse van Rensburg and Michele Toucher

Rural households within the Umhlabuyalingana Local Municipality (ULM) in Northern KwaZulu-Natal face water and economic insecurity. The area is a groundwater-driven system which is rich in wetlands and is dependent on local rainfall for recharge. Communities rely on these resources for food and livelihoods. As a result, an unprecedented decline in the water table exacerbated water insecurity and degraded wetlands, with cascading impacts on households. Evidence that commercial afforestation may be the cause led to calls to remove these. However, forests are a source of income. NRF-SAEON responded to the dilemma by working with communities to explore alternative water-wise income sources, tested under climate storylines.

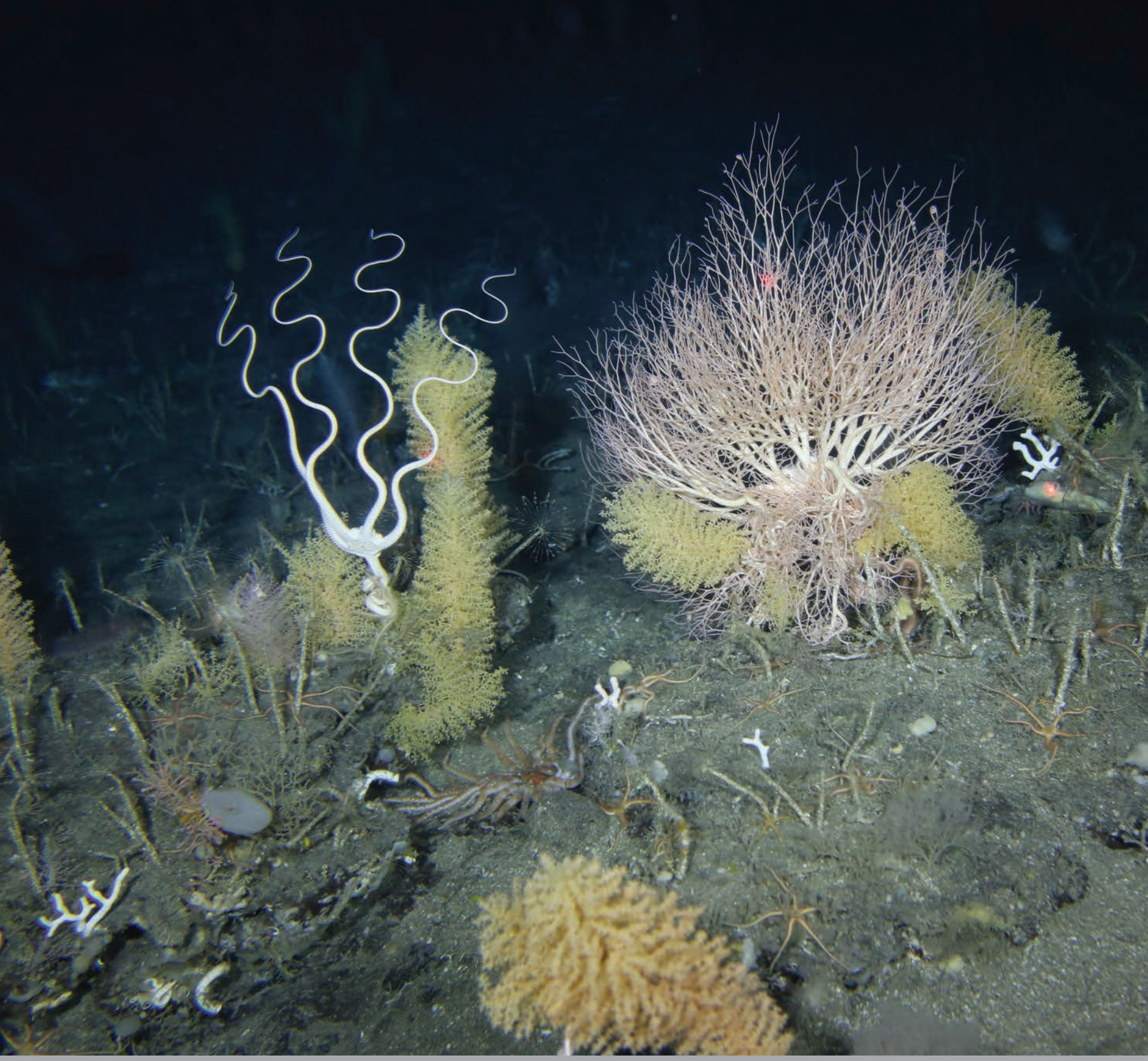
Lake Sibaya, South Africa's largest natural freshwater lake, is situated within the ULM. Being interconnected with the aquifer, its water levels reflect groundwater trends. From 2001, Lake Sibaya water levels started declining and ultimately dropped below the recommended level for maintaining the ecological integrity of the system and has not recovered above the threshold. This downward trend exacerbates societal vulnerabilities.

There is evidence that Eucalypt plantations and below average rainfall have contributed to the decline. However, the relative impacts are disputable. Despite the perceived income benefits, many community members recognise the detrimental effects of these trees on the groundwater. Responding to the plea 'give us an alternative and we will change', NRF-SAEON initiated a novel cross-disciplinary project, funded by the Water Research Commission (WRC), with collaborators from ASSET, UCT and UKZN, to develop a holistic system model to inform 'least regret' land use decisions in the context of an uncertain future.

NRF-SAEON started by engaging with the three participating traditional councils to understand key challenges and solicit ideas for alternatives. Its researchers then integrated hydrological, climate and economic models to assess the impact of these alternatives on the top four challenges identified under contrasting future climate storylines.

Despite prolonged drought conditions since 2001, NRF-SAEON's modelling suggested that water levels would not have dropped below the recommended level for maintaining ecological integrity if commercial forestry had never been introduced. Looking ahead, impacts of alternative preferences on the water resources under future climate scenarios were linked with the systems model, which was informed by socio-economic data from household surveys. Results, workshopped with the participating communities, demonstrated the importance of protecting the remaining grasslands in the area. Furthermore, some proposed alternatives provided a greater net benefit in relation to the four key challenges identified (water, employment, income and ecological integrity) than Eucalypts and were more resilient under a drier future.

A key impact of the project is that community participants are now open to and want to take tangible action to implement economically attractive and water-wise alternatives. NRF-SAEON brings multiple stakeholders and NGOs together to promote action-based interventions to support this. It is only through informed, participative land use choices today, that we can safeguard income, water security and resilience for future generations.



SkiMonkey towed camera enables photographic and video footage to be collected of invertebrate species on the seafloor. Photo: NRF-SAEON

Essential marine and coastal platforms for sustainable resource management and driving the Blue Economy

Nicole du Plessis, Juliet Hermes, Thomas Bornman, Tammy Morris and Lara Atkinson

NRF-SAEON manages marine and coastal observation platforms around South Africa's coasts and offshore environments. These are crucial for the development of the Blue Economy, which promotes sustainable ocean economic development and seeks to balance responsible economic growth with the health of marine ecosystems. Continuous long-term observations of marine ecosystems aid in sustainable resource management which is essential for ensuring food security, water quality and maritime safety. To protect coastal communities and infrastructure these observations, combined with models and remote sensing, help to predict natural disasters such as algal blooms and sea level rise. They also inform strategies to address climate change, offering vital societal benefits for South Africa's development agenda. Additionally, these platforms provide opportunities for the transformation of the marine science student and researcher cohort.

Through the management and expansion of marine and coastal observation platforms, organisations such as NRF-SAEON play a vital role in gathering long-term, continuous data on marine and coastal environments. This data is foundational for the understanding and management of the complexities of ocean ecosystems, to ensure that economic development activities such as fishing, tourism and maritime transport do not compromise the health of the ocean.

Sustainable resource management is heavily dependent on accurate and comprehensive ocean data. Ocean observations help track pollution levels and the health of marine habitats, directly impacting both marine life and human communities. Also, the ability to predict natural disasters such as algal blooms, storm surges and sea level rise is crucial for the protection of coastal communities and infrastructure. Further, understanding sea level rise and its potential impacts allows for the development of better coastal defenses and informed urban planning for coastal cities and towns.

As climate change continues to affect ocean temperatures, currents and sea levels, comprehensive data from ocean observations can guide the development of mitigation and adaptation strategies. This includes understanding how climate change impacts marine biodiversity, which is essential for the maintenance of ecosystem services such as carbon sequestration and nutrient cycling upon which humans rely. By integrating ocean data into climate models, scientists and policymakers can make more accurate predictions and develop effective responses to climate-related challenges.

Furthermore, the integration of ocean data into frameworks such as ocean accounting provides policy makers with a more accurate understanding of the ocean's value. This approach, supported by initiatives such as the NRF Community of Practice Ocean Accounts Framework, ensures that the contributions of marine ecosystems to the economy are fully recognised in policy decisions related to infrastructure development, disaster risk reduction and resource management, which ultimately promotes the resilience of ocean ecosystems and maximises economic benefits.

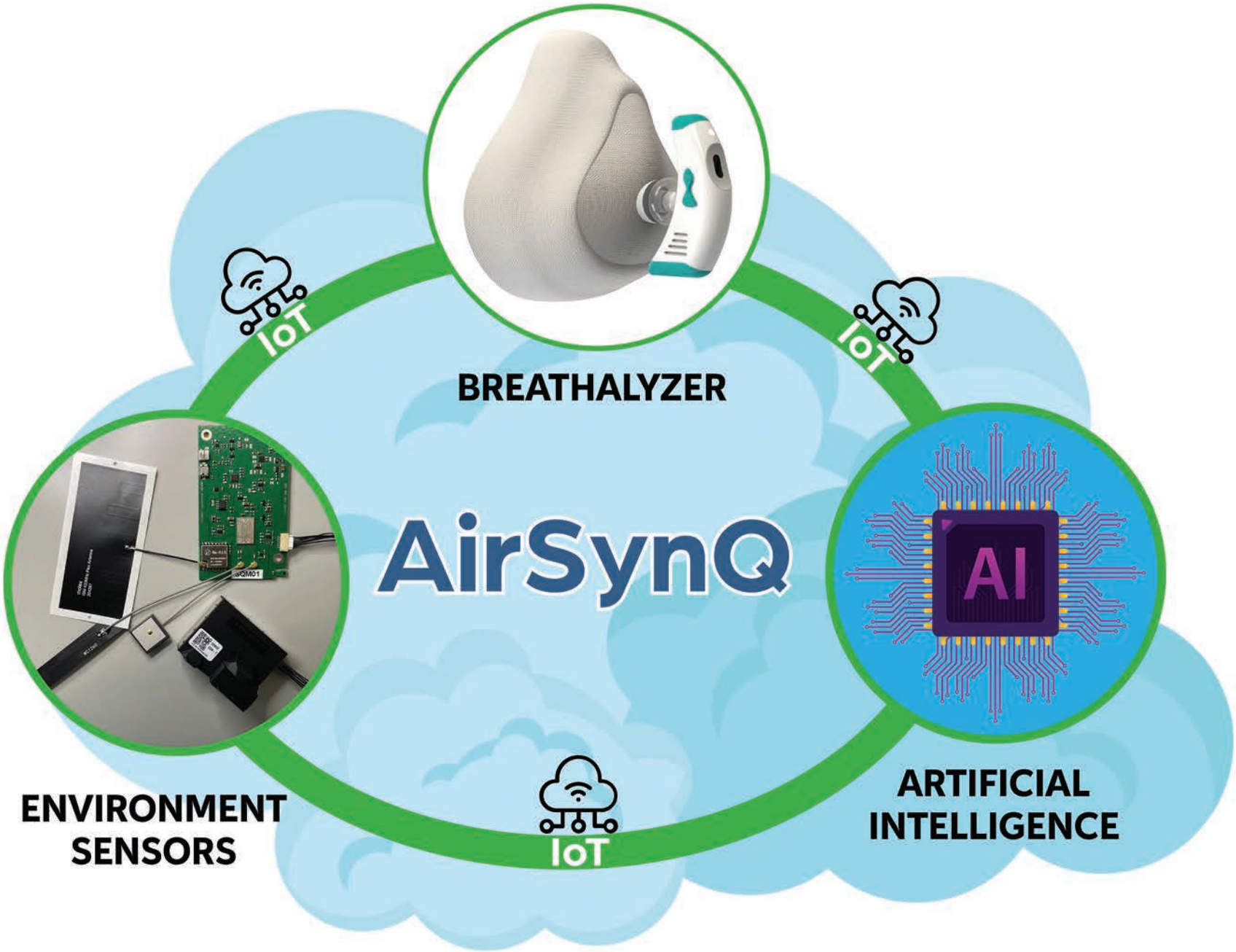
These platforms also serve as training grounds for the next generation of marine scientists and researchers, fostering a diverse and skilled workforce, which in turn enhances scientific research. Programmes on which NRF-SAEON collaborates, such as the UCT-managed SEAmester, South Africa's first 'school afloat', offer practical, hands-on experience, to ensure that students are well-prepared to contribute to the Blue Economy.

In conclusion, these observation platforms ensure the protection and sustainable use of ocean resources and ultimately foster economic growth and preserve the health of marine ecosystems.


TRANSFORMATION
IMPACT
INNOVATION
EXCELLENCE
SUSTAINABILITY
NRF
VISION
2030

INNOVATION:
Solutions for a better society

Within the TIES thematic framework, Innovation is embedded in the NRF's impact pathways and was highlighted in the Department of Science & Innovation's Decadal Plan as a way to advance national development. Innovation is about the use of research for technology and product development and, in turn, commercialisation for the benefit of society.



Use of AI to integrate breath analysis and environmental monitoring. Image: South African Consortium of Air Quality Monitoring

TIPping point: Advanced AI enhancing health outcomes in the Global South

Bruce Mellado

The Technology Innovation Platform (TIP) at NRF-iThemba LABS exemplifies the transformative impact of technology transfer and innovation in addressing air quality and public health challenges. Initiatives such as AI_r and AIrSynq, in collaboration with Conseil Européen pour la Recherche Nucléaire (CERN)*, demonstrate how advanced Artificial Intelligence (AI) and the Internet of Things (IoT) technologies can provide real-time monitoring and predictive insights, significantly enhancing public and occupational health outcomes in the Global South. This case study underscores the importance of leveraging cutting-edge research for societal benefit, highlighting the critical role of technology in fostering sustainable development and improving quality of life.*

The South African CERN Programme identified the critical need for technology transfer as a key strategy to advance technological innovation from CERN to South Africa. This strategy aligns with TIP, to create an ecosystem for innovation, incubation and industry collaboration.

The technology transfer strategy aims to expand the currently limited technology transfer within South Africa's NSI. It directly addresses key elements of the White Paper on Science, Technology, and Innovation (March 2019), which calls for a coherent response to the Fourth Industrial Revolution (4IR). The TIP fosters collaborative partnerships among research institutions, higher education and industry to establish world-class training which will enhance the local technological skills base, create specialised employment opportunities and support new industry players.

Air Quality Monitoring Innovation: The AI_r project, led by the South African Consortium of Air Quality Monitoring, addresses air quality monitoring challenges in the Global South. By integrating low-cost air quality sensors, IoT technologies and machine learning, the project provides real-time air quality measurements and predictive analytics. In collaboration with CERN Green Village, AI_r combines hardware components with an online web service to process and display data graphically, to facilitate predictive modeling.

The project has developed and deployed ten prototypes, demonstrating high accuracy and functionality. The next phase involves the deployment of these sensors in South African regions with poor air quality. The ultimate goal is mass production and deployment of these nodes throughout the Global South, to provide crucial data for public health, mining, real estate and other sectors.

Building on the success of AI_r success, AIrSynq merges advanced breath analysis with environmental air quality monitoring using IoT and AI technologies.

AIrSynq represents a significant advancement in public and occupational health by integrating breath analysis and environmental monitoring. AIrSynq bridges the gap between environmental conditions and individual health, and assesses the impact of climate change on public health. The system offers a detailed examination of airborne chemicals and exhaled breath, to provide a personalised approach to health monitoring. Unlike traditional methods, AIrSynq offers a holistic view, detects health risks early and enables timely interventions. This personalised health monitoring capability marks a major step forward from existing solutions, which often overlook individualised health insights.

Through AI_r and AIrSynq, the Technology Innovation Platform demonstrates the transformative potential of technology transfer and innovation. These projects show how advanced research and technology can address critical health and environmental challenges, to significantly benefit South African communities and the broader Global South.



Isocentric neutron gantry with tumour localisation and treatment plan. Image: NRF-ithemba LABS

Particle therapy as a treatment for cancer

Gillian Arendse

NRF-iThemba LABS was established as a National Facility that harnesses the capabilities of accelerated particle beams beyond fundamental research. The intention to include a focus on radiation therapy using fast neutrons and protons, was evident through the involvement of the Hospital Services Department of the former Cape Provincial Administration (CPA) from the onset in the early 1960s. The efforts related to the establishment of a particle therapy programme led to the worldwide recognition of NRF-iThemba LABS for its leading role in advancing the fight against cancer through innovative approaches and numerous scientific contributions. Until the official closing of the therapy programme in 2017, NRF-iThemba LABS was the only accelerator complex on the African continent and in the southern hemisphere that offered therapeutic beams of both fast neutrons and protons. A total of 1 834 patients were treated with neutrons and 524 patients with protons over the period of operation.

The long-term prospects for neutron and proton therapy could not be predicted in the 1970s, and it was therefore decided to build treatment vaults at NRF-iThemba LABS that catered for the stringent requirements of high-energy rotating (isocentric) neutron-therapy units. This resulted in excessive shielding for proton therapy, and treatment vaults that were large enough to accommodate possible future isocentric proton-therapy units, even though none had been designed at the time.

The contract for the construction of an isocentric neutron-therapy unit was signed in April 1983 and manufactured by Elven Precision Ltd in the United Kingdom. The neutron beam was produced by the reaction of 66-MeV protons on a beryllium target. The development of the necessary clinical protocols for neutron therapy followed from major collaboration efforts with South African oncology centres and included several randomised clinical trials. The treatment of patients, mainly for carcinomas of the salivary gland, breast, head and neck and paranasal sinus; sarcomas of the bone, soft tissue and uterus; and malignant melanomas, started in September 1988.

The 200-MeV proton therapy system, based on a horizontal fixed beam line, was designed and manufactured by the staff of NRF-iThemba LABS and became operational in September 1993. The full potential of proton therapy could be harnessed through the provision of an accurate beam delivery system; precise tumour and critical structure localisation; accurate and reproducible patient set-up; and accurate three-dimensional treatment planning. The proton therapy programme at NRF-iThemba LABS has contributed to the body of knowledge and experience that demonstrate the huge benefits of proton therapy as a cancer treatment modality. The concept and possible advantages of fixed non-orthogonal proton therapy beamlines was first suggested at NRF-iThemba LABS. Even though such a system was never installed at NRF-iThemba LABS, the concept has been implemented at the Hyogo Ion Beam Medical Centre in Japan and at the Oklahoma Proton Center in the USA.

There is a high expectation that South Africa will regain proton therapy in its full potential as a treatment modality to provide the means for improving the quality of life and the life expectancy of many cancer sufferers in the country.



A 80 Pb archival data storage system that has been deployed at the Karoo Data Rack Area (KDRA) in Klerefontein. The product represents the value of collaboration with local companies such as Tsolo Storage Systems (Pty) Ltd and demonstrates the importance of commercialisation as the product is a locally produced solution underpinned by software technology developed by NRF-SARAO and productised by Tsolo. Photo: NRF-SARAO

NRF-SARAO's innovation and commercialisation value chain

Mark Johnson

NRF-SARAO implements an innovation and commercialisation value chain to identify, develop and transfer high-tech NRF-SARAO products through internal development, licensing and joint development with industry to potential external markets. A key outcome of the MeerKAT project was NRF-SARAO's design and development of cutting-edge technologies and competencies that were not only invaluable to the instrument but also would have broader application across other markets such as the telecommunication, space, medical and defence sector.

High-tech products resulting from research and development, and technology products pioneered by NRF-SARAO include:

- *S3 Cloud Storage*: A cloud storage product that competes directly with major providers by delivering a fully compliant and equivalent product at a significantly reduced price point.
- *Archival data storage (Tape library)*: An archival data storage system that scales up to 5 000 slots / 80 PB in a single installation that uses IBM tape robotics with custom controllers and an open software stack.
- *Earth Observation (EO) Project*: NRF-SARAO developed and deployed the back-end infrastructure required for the Earth observation data cube for the South African National Space Agency (SANSA).
- *Energy efficient computer (IronHive)*: A ruggedised, embedded computer system-based micro-server that provides excellent energy centre infrastructure and substantial in-band storage.
- *Multiple point fibre-based cable measuring/time transfer system (KATS)*: The system has application as a self-contained continuously operating reference system (CORS) for geodesy or ionospheric, or other precision measurement via global navigation satellite system (GNSS).
- *SP-6G4S – D-Engine*: The SP-6G4S is a sampler and packetiser module that allows for the direct digitisation of signals up to a frequency of 6.4 GHz, with an instantaneous bandwidth of approximately 3 GHz.

NRF-SARAO has also been a catalyst for the growth of the South African engineering industry, with the development of several engineering companies such as the EMSS Antennae which went on to be awarded a R200 million contract from the Square Kilometre Array Observatory (SKAO).

Further, NRF-SARAO has invested in a system to track aircraft and other airborne instruments using passive radar. The Passive Radar System has been designed and built in collaboration with Peralex, a South African company specialising in the design, manufacture and implementation of cutting-edge solutions for modern digital signal processing problems, predominantly in the field of radio spectrum monitoring.

The Passive Radar System has been deployed to detect aircraft and airborne instruments not operating with transponders, which can be potentially damaging to the NRF-SARAO instruments such as the MeerKAT radio telescope, which contains very sensitive receivers. The system can mitigate the risks associated with airborne radio frequency interference without introducing a new transmitter to the area of use.

Other uses include tracking low-flying small aircraft and drones related to cross-border actions, such as animal poaching and smuggling. It can also be used for air awareness for small aircraft during fly-ins and air shows and for small regional airports or airports without conventional radars.

Since 2018, NRF-SARAO has tested and rolled out the Passive Radio System to three sites in the Karoo in the Northern Cape. The monitoring of the sites takes place from the NRF-SARAO Control Room and the Radio Frequency Interference office in Cape Town.



The LIFE ventilator, designed by the Council for Scientific and Industrial Research, is demonstrated by a CSIR staff member at its campus in Pretoria East. Photo: CSIR

NRF-SARAO and the National Ventilator Project: Resilience, flexibility and leadership in times of crisis

Justin Jonas

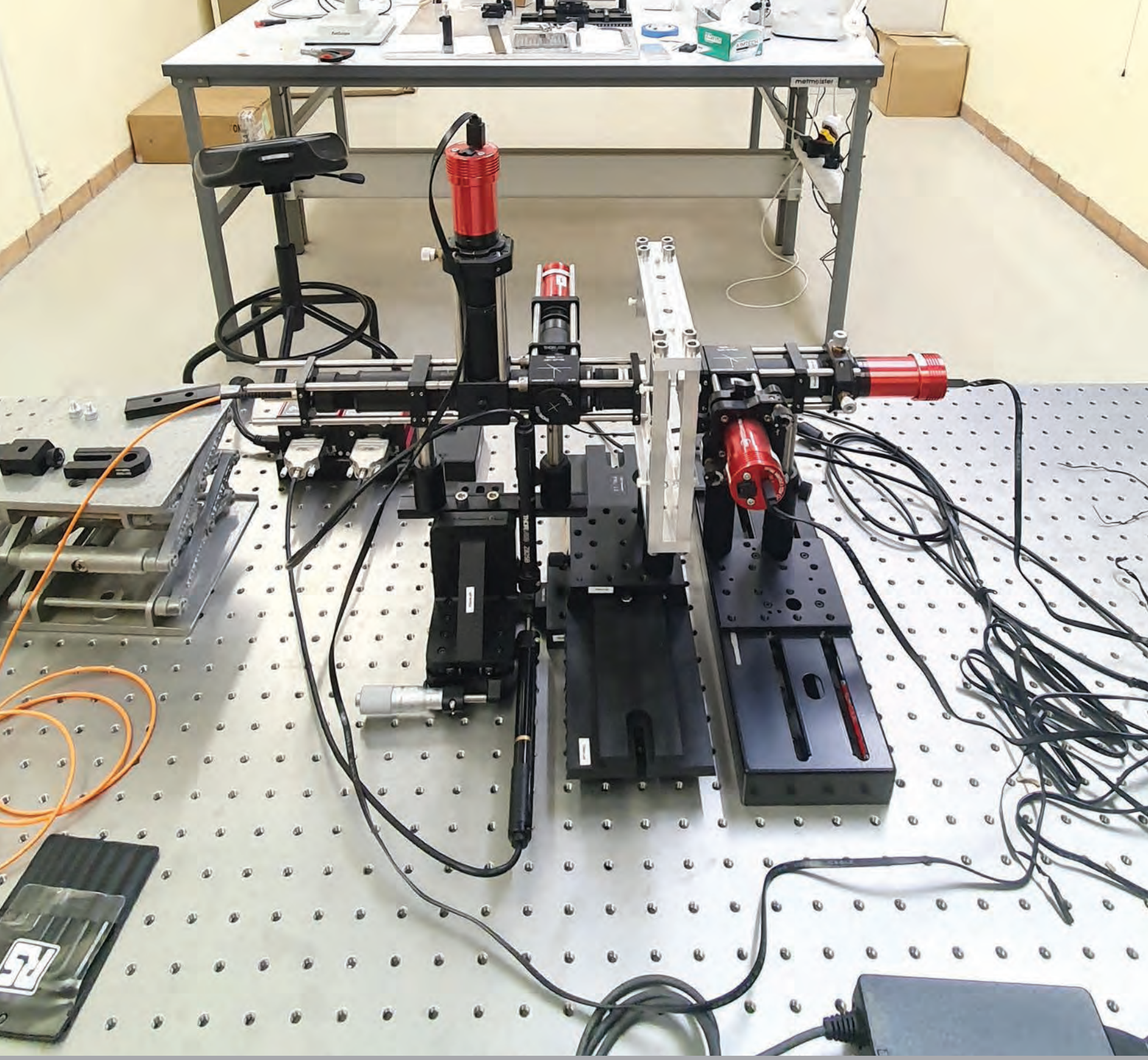
The South African National Ventilator Project (NVP) was a response to the instruction from the National Coronavirus Command Council (NCCC) to develop and locally manufacture respiratory support devices to be used in the treatment of patients with moderate respiratory distress associated with COVID-19. NRF-SARAO's key role in the successful execution of the NVP is an example of how the knowledge, skills and competencies within the National Research Facilities can be pivoted to applications in areas outside of the core business.

One of the major challenges in the response to the needs of COVID-19 patients was the provision of appropriate respiratory support therapy. In particular, there was a need to treat patients whose symptoms were too severe for simple oxygen mask therapy, but not severe enough for invasive ventilator support. The NCCC tasked the Department of Trade, Industry and Competition (DTIC) to rapidly deliver a solution using local industry for the design and manufacture of suitable respiratory support devices that would fill this gap. DTIC requested that NRF-SARAO take on the management of the project, having recognised how NRF-SARAO had successfully executed the MeerKAT radio telescope project. The skills and competencies that were required from NRF-SARAO were project management, systems engineering, specific engineering domain expertise, industry liaison and health product accreditation.

The project involved the development of new, low-cost non-invasive continuous positive airway pressure (CPAP) ventilator devices, similar to those that had been used successfully in Europe to mitigate the pressure on scarce and expensive invasive ventilator resources. A reference specification was developed for a CPAP device in March 2020 involving intensive work among the NRF-SARAO team, medical specialists, public healthcare practitioners and industry experts. A systems engineering approach was applied, to identify the critical requirements of the clinical therapy that was needed, given the constraints of the public hospital infrastructure into which the units would be deployed. Key non-clinical requirements were that the ventilators had to be simple to use and maintain, intrinsically safe, and suitable for low-cost production by South African industry. A budget of R500 million was provided by the Solidarity Fund.

A call for proposals to design and manufacture devices to the NVP/NRF-SARAO specifications was administered by NRF-SARAO under the auspices of the DTIC. Following a thorough and open process, six capable companies and consortia were selected to continue to the prototyping phase. Following the prototyping, manufacturing contracts for 20 000 units were then concluded with two entities, the Council for Scientific and Industrial Research (CSIR), and the SAVE-P Consortium. In addition to the devices, 50 000 disposable patient circuits (masks, filters, tubing and valves) were procured, and extensive training materials were developed and trialled. NRF-SARAO facilitated the approval of the devices by the South African Health Products Regulatory Authority (SAHPRA) for emergency use during the COVID-19 pandemic.

The NVP exemplifies NRF-SARAO's ability to use its diverse skills and robust systems engineering approach to deliver on technology development beyond the confines of radio astronomy.



High-precision fibre-optic apertures made at the NRF-SAAO for the Southern African Large Telescope. Photo: NRF-SAAO

Illuminating pathways: Optical innovations transforming agriculture, medicine, and beyond

Hitesh Gajjar

NRF-SAAO is a beacon of optical innovation, with breakthroughs that extend far beyond the stars. NRF-SAAO's advancements in fibre technology, initially designed for telescopes, are now revolutionising agriculture and medical imaging, and showcase the power of scientific research to address critical societal challenges.

Agriculture: Precision agriculture, the data-driven approach to farming, has been significantly enhanced by optical innovations. High-resolution imaging sensors, initially developed for astronomical telescopes, have found new life in multispectral and hyperspectral cameras mounted on drones and satellites. These cameras capture detailed images of crops across a wide range of wavelengths, to provide farmers with crucial information about plant health, water stress, nutrient deficiencies and pest infestations.

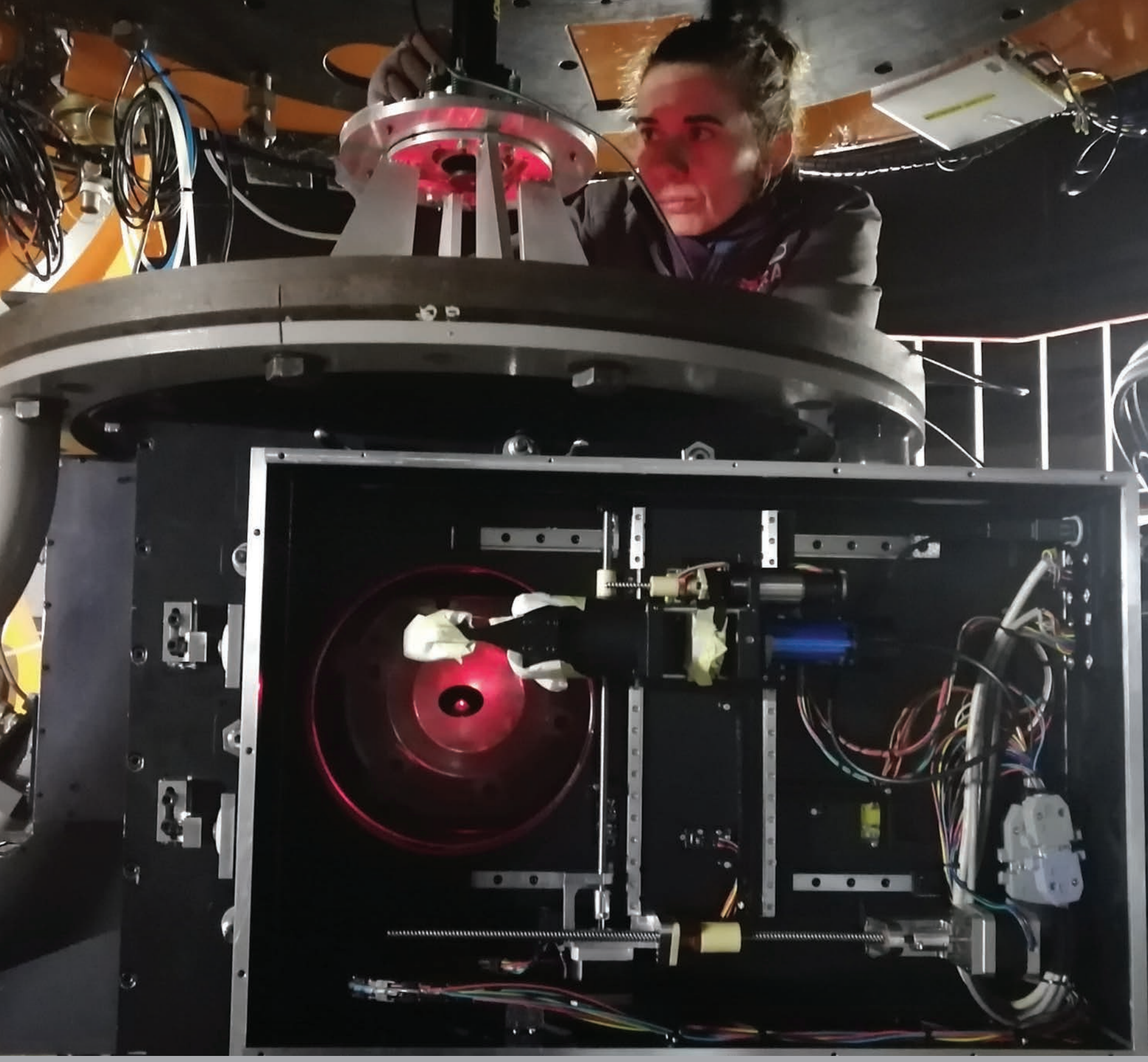
By analysing this data, farmers can make informed decisions about irrigation, fertilisation and pest control, and thereby optimise resource use, reduce environmental impact and maximise crop yields. NRF-SAAO's technology development in this area aims to not only increase agricultural productivity but also contribute towards sustainable farming practices, to ensure food security for a growing global population.

Medicine: The medical field will also benefit immensely from NRF-SAAO's advancements in optical technology. Fibre optics, initially used for transmitting light in telescopes, have revolutionised medical imaging techniques. Optical coherence tomography (OCT), a non-invasive imaging technique, employs light waves to create cross-sectional images of tissues. OCT enables early detection of diseases such as cancer, macular degeneration and glaucoma, leading to more effective treatments and improved patient outcomes.

NRF-SAAO's work in medical imaging does not stop there. The observatory is currently pioneering polarimetry fibre imaging, a cutting-edge technology that holds the potential to further enhance both astronomy and medical diagnostics. By analysing the polarisation of light reflected from tissues, polarimetry fibre imaging can provide valuable insights into tissue structure and composition, and potentially aid in the detection and characterisation of diseases. The first instrument of its kind is being assembled for testing and commissioning on the NRF-SAAO 1.9 m optical telescope.

A catalyst for innovation and societal impact: The potential translation of NRF-SAAO's optical innovations from astronomy to agriculture and medicine underscores the value of investment in scientific research. The knowledge and technologies developed for the exploration of the cosmos often find unexpected applications in diverse fields, to drive economic growth, improve health and address pressing societal challenges.

NRF-SAAO's commitment to pushing the boundaries of optical engineering exemplifies the interconnectedness of scientific disciplines and their collective potential to create a brighter future for all.



NRF-SAAO staff member installing newly designed and manufactured rapid instrument deployment hardware. Photo: NRF-SAAO

Revolutionising astronomy with AI and robotics

Stephen Potter

The South African Astronomical Observatory (NRF-SAAO) has transformed into an 'intelligent observatory' through the integration of AI and robotics. This cutting-edge approach has enabled fully autonomous telescopes and rapid response to astronomical events, even during the COVID-19 pandemic. NRF-SAAO's innovation has led to significant discoveries and record-breaking publication speeds.

At the turn of the millennium, the demand for automated astronomical facilities intensified, driven by the need for efficient surveys and rapid response to high-energy phenomena. There was an increase in pressure on observatories to respond quickly to rapidly evolving astronomical events, particularly the highly interesting high-energy phenomena such as supernova explosions, outbursts, colliding compact stars, gamma-ray bursts, asteroids and other solar system objects.

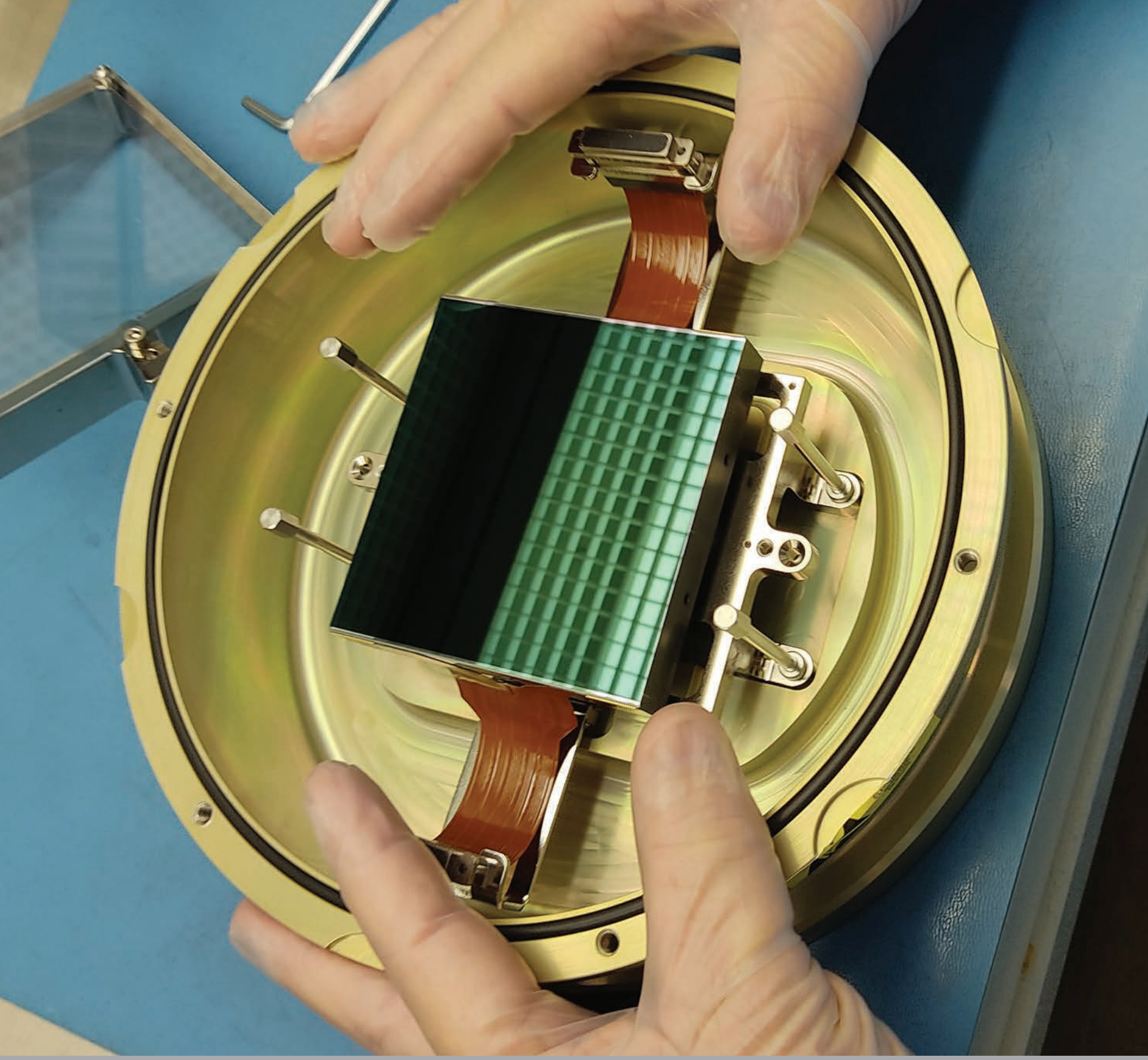
At that time, NRF-SAAO had a range of telescopes from new models to those more than 60 years old. By leveraging its technical expertise, the observatory upgraded its telescopes with in-house software controls, to eliminate manual operation.

NRF-SAAO's Intelligent Observatory (IO) programme further advanced this automation through the incorporation of cutting-edge technologies. The COVID-19 pandemic accelerated the IO programme which enabled NRF-SAAO to become a leading observatory in remote operations. Astronomers could control telescopes from anywhere, ensuring research continuity during lockdowns.

Post-pandemic, NRF-SAAO achieved full autonomy for one of its telescopes, which allowed it to execute predefined science programmes without human intervention. Additionally, AI-powered algorithms now monitor the astronomical network for alerts of significant events, automatically generating observation requests for the automated telescope. This agility has propelled NRF-SAAO to the forefront of transient event observations, and has led to discoveries of supernovae, asteroids, near-Earth objects and novel object classes.

On the 25th anniversary of the National Research Foundation (NRF), the IO programme set a new NRF-SAAO record for the fastest data-to-publication time, achieving this milestone in less than two weeks.

NRF-SAAO's Intelligent Observatory exemplifies how AI and robotics revolutionise astronomy. By automating telescopes and data analysis, NRF-SAAO has increased efficiency, responsiveness and discovery potential, and solidified its position as a leader in astronomical research and innovation.



The CCD as it arrives in its storage and transport case. Photo: NRF-SAAO

Enhancing astronomical research through in-house CCD detector integration

Kathryn Rosie

NRF-SAAO maintains key in-house technical skills and capabilities to develop and build state-of-the-art instrumentation for its telescopes, so astronomers have access to data that is modern and relevant in today's research landscape. The core piece of technology around which our astronomical instrumentation is built is the CCD detector. This highly sensitive device must be assembled and managed in a way that keeps it safe, cold and clean for it to deliver good data. Using in-house facilities and people, we integrate these devices into bespoke, purpose-built instrumentation designed to meet specific science goals.

The South African Astronomical Observatory is a National Research platform with two core outputs: knowledge and the people in whom it exists: the MSc students, the PhDs, the postdoctoral students and the 'knowledge workers' of South Africa. Between the secrets of the Universe and the astronomer who uncovers them, there are myriad pieces of machinery, optics, mechanisms, electronics and software that work together to bridge the gap between the stars and the students.

To obtain data from starlight, light particles (called photons) need to travel millions of light years through the cosmos, bounce off telescope mirrors and pass through lenses, to their final destination: the detector. The last thing a photon sees on its million-plus years' journey is a piece of silicon, whose job is to turn photons into something we can count: electrons. This piece of silicon is called the Charge Coupled Device, or CCD. And this piece of technology is the key to linking the light out there to the astronomer down here.

Here at NRF-SAAO, we have a proud history of having developed the tools and know-how to integrate these highly sensitive CCDs into packages which can be bolted onto telescopes. To do their job well, CCDs have to be kept cold (around -110°C), and completely free of any contamination or interference. This means installing it in a vacuum chamber to make sure there is no way for air (or heat!) to leak from the outside to the inside. Any stray static electricity could destroy the device. In addition, CCDs have to be kept precisely in place relative to the telescope – this means that while the telescope moves around, the CCD itself may not shift around in its mounting by more than a few thousandths of a millimetre.

All of these exacting requirements call for precision mechanical and electronic design, care and precision during manufacture, assembly and installation that will result in good data for the astronomer. At the NRF-SAAO facilities in Cape Town, we achieve this using our state-of-the-art workshop, in-house integration facilities and people. Outsourcing as little as possible, NRF-SAAO develops and maintains instruments for our telescopes and collaborates with other institutions around the world to contribute to the development of global astronomical instrumentation development.



Processing ACEP collection specimens from Algoa Bay. In addition to generating marine natural product (MNP) extracts for the isolation of bioactive compounds, the ACEP collection includes biological samples for genomics analysis and microbial cultures that are housed in the NRF-SAIAB collection. Left to right: Dr Xavier Siwe Noundou, Danielle Botha, Nasipi Ntsi and Dr Samantha Waterworth. Photo: RU-MNP Research Group

Combating antimicrobial resistance through harnessing South Africa's marine biodiversity

Rosemary Dorrington and Roxanne Higgitt

Global healthcare systems face an escalating threat of antimicrobial resistance and there is a critical need for novel classes of antibiotics to combat emergent drug-resistant pathogens. The SA/UK Antimicrobial Drug Discovery (ADD) Hub, led by DSI/NRF SARChI Prof. Rosemary Dorrington, seeks to address this problem by exploring the potential of marine organisms endemic to South Africa for the production of novel bioactive secondary metabolites, known as natural products. The ADD Hub and its partners have built an end to end marine natural products discovery platform that facilitates rapid identification of chemical novelty and the isolation of hit compounds for antimicrobial drug development.

Antimicrobial resistance (AMR), the 'silent pandemic', accounts for more deaths in sub-Saharan Africa than malaria and, without effective intervention, the mortality rate is expected to double by 2050, particularly amongst vulnerable, new-born infants. A decrease in research and development that followed the Golden Age of antibiotic discovery, together with an increase in AMR, has resulted in a critical need for new classes of antimicrobials to combat drug-resistant bacterial and fungal pathogens. Most clinically approved antibiotics were derived from antimicrobial natural products (NPs), i.e. small molecules produced in Nature and, therefore, the most likely source of new classes of antimicrobial compounds. Marine invertebrates, tunicates and their associated microbiota are major sources of chemically diverse, small molecules; marine NPs that can be potentially cytotoxic and serve as lead compounds for the development of new drugs to treat infectious and communicable diseases. South Africa has 3 650 km of coastline spanning nine marine bioregions that support an exceptionally rich diversity of benthic marine species, the majority of which have yet to be described, and which offer a largely untapped source of novel chemistry to support drug discovery efforts.

The SA/UK ADD Hub is a partnership between South African and UK researchers, which was established in 2020 to address the challenge of AMR. The aim for the Hub was to establish a cutting-edge research platform for antimicrobial discovery and to build a multi-disciplinary team of researchers with the specialised skills needed for the discovery of new antimicrobial compounds as leads for the pharmaceutical industry. Hosted by Rhodes University in the Eastern Cape Province, the ADD Hub, together with partners at NRF-SAIAB and NRF-SAEON, has built an end to end NPs drug discovery pipeline that facilitates rapid assessment of chemical novelty and isolation of hit compounds for antimicrobial drug development. The focus is on marine NPs with novel activities against drug-resistant microbial pathogens of relevance to South Africa, including *Acinetobacter baumannii* and *Staphylococcus aureus* (members of the prioritised ESKAPE class of bacterial pathogens) and the fungus, *Candida auris*, a new drug resistant fungal pathogen of concern in healthcare facilities. The ADD Hub has assembled a library of > 1 500 NP extracts derived from endemic marine sponges, soft corals, ascidians and microbial isolates that has yielded promising hits with antimicrobial activity against prioritised pathogens.







Top left: IMIsEE project logo. **Top right:** IMIsEE team and Transnet colleagues sampling at the port of Ngqura [From left: Nobuhle Mpanza (PhD candidate), Yonelisa Gxumayo (Transnet intern), Kerry-Ann van der Walt (Postdoctoral Fellow), Prof. Francesca Porri (PI), Sandisiwe Tyekela (Transnet intern). Central sitting: Siphelele Dyanti (PhD candidate)]. **Bottom left:** IMIsEE team sampling on the shore [From left: Jabulani Ndaba (PhD candidate), Prof. Francesca Porri (PI), Nobuhle Mpanza (PhD candidate), Vuyolwethu Mxo (PhD candidate), Nokubonga Mbandzi-Phorego (Postdoctoral Fellow), Siphelele Dyanti (PhD candidate)]. **Bottom right:** IMIsEE team sampling *Cyperus textilis* (*imizi*) [From left: Vuyolwethu Mxo (PhD candidate), Kerry-Ann van der Walt (Postdoctoral Fellow), and Nokubonga Mbandzi-Phorego (Postdoctoral Fellow)]. Photos: NRF-SAIAB

Coastal harmony: Weaving indigenous and scientific solutions for resilient shores

Francesca Porri

Increasing anthropogenic pressure on our coasts and oceans has significant impact on natural coastlines. Alteration of coastscapes can disrupt the balance of marine ecosystems and affect the livelihoods of people who depend on these environments, particularly in developing countries where there is often a higher reliance on natural resources for economic and social well-being. Social inequalities exacerbate these issues and, to address these challenges, it is essential to pursue mitigation, adaptation and rehabilitation options for coastal developments that include innovative and socially responsible solutions. These need to focus on the modification of shorelines in ways that maintain the long-term functionality of metropolitan coastal ecosystems, without compromising ecological integrity and the socio-economic needs of vulnerable communities.

Drawing on centuries of cultural and biological co-evolution, Indigenous People and local communities have developed multigenerational knowledge that holds substantial value in the design and implementation of nature-based innovations which mimic the structure and function of natural ecosystems. The involvement of Indigenous People and local communities in the support of innovations to restore functionality of ecosystems, however, remains insufficient. This gap is concerning, given the growth in academic and political emphasis on nature-based solutions, which are globally recognised for addressing economic development sustainably through mitigation of climate change, resolution of biodiversity crises and restoration of the functionality of coastal systems.

A non-conforming research project, Indigenous Marine Innovations for sustainable Environments and Economies (IMIsEE), which runs from 2022 to 2024 which and is funded by the NRF, seeks to bridge this gap. The project draws inspiration from both scientific and indigenous synergistic practices to foster a collaborative partnership between scientists and a local rural community in Hamburg, Eastern Cape Province. This transdisciplinary initiative uniquely combines innovative green eco-engineering approaches with indigenous cultural practices to address the adverse effects of coastal armouring on biodiversity.

Central to this research are natural woven, biodegradable structures made from the plant *Cyperus textilis* (locally known as *imizi*). These structures are co-created to retrofit the built marine environment, and aim to enhance the ecological value of coastal habitats and revitalise urban coastlines by boosting the natural biodiversity. *Imizi* is widely used by artisanal crafters, predominantly women in the rural areas of the Eastern Cape, for traditional sleeping and sitting mats, baskets and serving trays. Their indigenous knowledge and specialised skills are essential for crafting the woven structures required for this research.

By weaving scientific inquiry with innovative community co-creation and environmental stewardship, this transdisciplinary enterprise sets a precedent for collaborative approaches to address complex environmental challenges and promote sustainable science and development. By placing indigenous knowledge at the core of science and innovation co-production, the IMIsEE project embodies action research on impacted coastal habitats, and stands as a pioneering 'low-tech' eco-engineering endeavour in South Africa and is a unique contribution to a globally burgeoning field. Through an equitable and fair process, the active engagement by local communities in eco-creative innovations and transformative pedagogies will yield meaningful benefits for both people and the biological coastal communities.

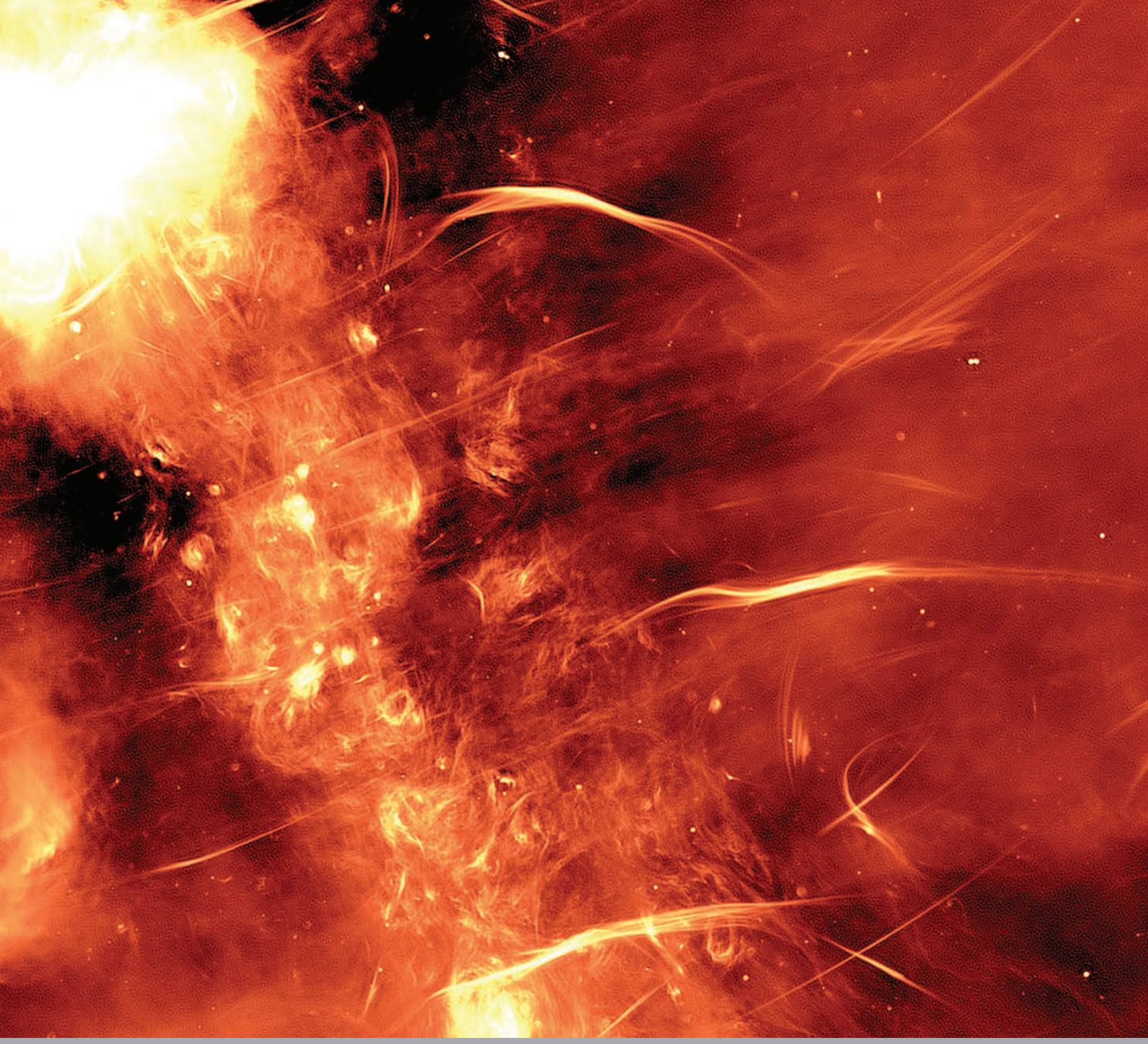
Overall, the impact of this research extends beyond academia, and aligns with broader societal concerns and aspirations for a more sustainable and resilient future.


TRANSFORMATION
IMPACT
INNOVATION
EXCELLENCE
SUSTAINABILITY
NRF
VISION
2030

EXCELLENCE:
The foundation that sets the standard

More than a benchmark, more than a goal, more than a distant destination, excellence is the foundation of rigour in scientific research. With this in mind, we use excellence as a principle to enhance the global competitiveness of the South African science system. We uphold excellence through investment in quality research, capable researchers and postgraduate students.

Excellence will continue to serve as one of our leading lights, defined by the criteria of scientific merit, ethics, originality, relevance, purpose, methodological rigour, and impact.



The edge of the 1 400 light-year radio bubbles is seen perpendicular to the Galactic plane, which runs diagonally down from the upper left of this image, where the bright region marks the home of our Galaxy's central 4 million solar mass supermassive black hole. The MeerKAT image also reveals numerous thin, magnetised radio filaments, which emit radio waves as energetic cosmic rays blown along in the Galaxy's nuclear wind interact with the complex magnetic fields in this region. Image: Ian Heywood

MeerKAT's unique capabilities enable ground-breaking findings

Fernando Camilo

After approximately 15 years of planning, development and construction, South Africa's MeerKAT telescope was inaugurated on 13 July 2018, when a now iconic radio image of the Milky Way's Galactic Centre was presented. The data underlying that image resulted in the first science paper based on the full MeerKAT array, published in the journal Nature *in September 2019. Through June 2024, more than 300 articles containing MeerKAT data have been published. Many of the associated findings are ground-breaking, addressing key questions in modern astrophysics. Three examples – all of which required MeerKAT's unique capabilities – are outlined here.*

Centre of the Milky Way: The MeerKAT survey of the Galactic centre region led to the showcase radio image that introduced the telescope to the world in 2018, and this project has also transformed our scientific understanding of the region. At the heart of our Galaxy is the supermassive black hole Sagittarius A*, weighing in at four million times the mass of the Sun. This chaotic and energetic region contains many phenomena that cannot be found in the more benign regions of the Galaxy, such as our own solar neighbourhood.

The first major discovery made by MeerKAT was that of the 1 400 light-year radio bubbles that span the Galactic centre, evidence of an explosive event in the heart of the Galaxy several million years ago. This result also suggested a tantalising connection between this event and the mysterious population of radio filaments that are only found in this region of space.

The MeerKAT Pulsar Timing Array: Pulsars are the ultra-dense rotating neutron star remnants of some supernova explosions that end the lives of massive stars. Pulsar timing arrays monitor sets of ultra-stable radio-emitting millisecond pulsars in our Galaxy, each spinning hundreds of times per second, with the primary, long sought, aim to detect ultra-low frequency gravitational waves expected to permeate the Universe.

To make such a detection requires the observation of a large number of pulsars to very high precision. Since 2019, The MeerKAT Pulsar Timing Array has been monitoring the largest sample of pulsars to the highest precision of any existing array. Preliminary searches show compelling evidence for spatial correlations consistent with gravitational waves and results already demonstrate the seminal contribution that MeerKAT will make to open up this new window on the Universe.

Gas accretion in action: Galaxies are gradually turning the gas they contain into stars. However, their star formation rates imply they should have run out of gas a long time ago. The fact that they have not, means they must be replenished from intergalactic space. So far, this accretion process has not been unambiguously observed, mostly because previous radio observations were not sensitive enough. MeerKAT now makes the required observations possible. The MHONGOOSE survey on MeerKAT is obtaining ultra-sensitive radio observations of nearby galaxies (up to 100 times deeper) and has made a tentative detection of this gas accretion.



The Southern African Large Telescope (SALT). Photo: NRF-SAAO/SALT

The Southern African Large Telescope (SALT): A powerful tool for discovery

Anja Schroeder, Encarni Romero Colmenero, Rosalind Skelton and Daniel Cunnama

SALT is the largest single optical telescope in the southern hemisphere and amongst the largest in the world. It has a hexagonal primary mirror array that measures 11 m across. The gathered light is fed into a suite of instruments from which astronomers infer the properties of planets, stars, galaxies and the structure of the Universe. SALT is owned by the SALT Foundation, a private company registered in South Africa. The shareholders of this company include universities, institutions and science funding agencies from Africa, India, Europe and North America. The NRF is the major shareholder, owning approximately one-third of the shares. Half of the operating costs are currently covered by the NRF, to ensure that half of the observing time is available to the South African community.

SALT provides a first-class and cost-effective facility for fundamental research in Africa. Strong ties with researchers around the world benefit local scientists and engineers in a stimulating, high-tech environment. This project demonstrates that the frontiers of science are not exclusively reserved for the developed world.

The productivity of an observatory can be measured by the number of published peer-reviewed papers based on data obtained at that observatory. SALT's publication rate demonstrates that it is a valuable resource for high-quality scientific research. Its impact extends beyond scientific publications, as it provides a platform for training the next generation of astronomers and engineers. It also shows that SALT is an affordable data machine, making it possible for astronomers across Africa to participate in high-quality scientific research.

The telescope's contributions to science are numerous and include:

Multi-messenger astronomy: SALT played a key role in the observation of the optical counterpart of a gravitational wave detection, marking a significant step in this new field of astronomy that combines observations of light and gravitational waves. The detection and study of electromagnetic counterparts of gravitational wave sources will be a major new area of investigation. South African researchers will not only participate but also potentially lead in this emerging new field of exploration.

A four-star system discovery: SALT identified a rare quadruple star system, contributing to our knowledge of stellar evolution. It consists of two short-period binaries that orbit each other and is the youngest known system. The findings enhance our understanding of stellar interactions and the evolution of stars.

A record-breaking discovery of super-hot white dwarfs: These stars, identified as helium-rich subdwarf stars, include white dwarfs and pre-white dwarfs with surface temperatures that exceed 100 000 degrees Celsius. One star reaches 180 000 degrees, significantly hotter than the Sun's 5 800 degrees. This research enhances the understanding of stellar evolution's late stages and showcases SALT's capabilities.

SALT's impact extends far beyond scientific discoveries. By fostering a vibrant scientific community and engaging with the public, SALT inspires and educates, to promote a culture of scientific curiosity and innovation both in South Africa and internationally.

SALT stands as a symbol of South Africa's scientific prowess and its commitment to pushing the boundaries of knowledge. Its contributions to astronomy, education and technology development have far-reaching implications, not only for the country but for our understanding of the Universe as a whole.



Published in 2022, the five-volume *Coastal Fishes of the Western Indian Ocean* is a monumental achievement by the NRF-SAIAB. It serves as an invaluable tool for identifying fish species that inhabit the coastal waters of the Western Indian Ocean (WIO). Image: NRF-SAIAB

Expanding taxonomic frontiers: *Coastal Fishes of the Western Indian Ocean*

Albert Chakona

The Western Indian Ocean (WIO) is a critical region for marine biodiversity and is estimated to harbour approximately 20% of the world's marine fish fauna. Insufficient and uneven research efforts across the region lead to challenges of misidentification and potential under-reporting of species in fisheries statistics. Accurate taxonomy and formal species names are crucial for reliable data, which is essential for the sustainable management and conservation of biodiversity and fisheries resources. To address this knowledge gap, NRF-SAIAB initiated an ambitious long-term project to provide consolidated information to aid accurate identification of the shallow-water fishes known from the tropical and warm-temperate waters of the entire WIO. The resulting publication, Coastal Fishes of the Western Indian Ocean, *is a comprehensive, five-volume work covering approximately 3 600 species across an extensive area from South Africa's Cape Point to India's southernmost point and including the WIO islands.*

This initiative was built on the success of the renowned 1986 publication, *Smith's Sea Fishes*. It surpasses its predecessor by providing in-depth coverage of species typically found in waters shallower than 200 metres. The publication includes illustrated keys to all taxa and orders of bony fishes, to aid non-experts in fish identification from family to species level. Most species are depicted in colour photographs or illustrations. This publication has significantly revitalised global interest in WIO marine biodiversity, with new collaborative projects being launched and new species discovered and described by international scientists.

Arguably the largest fish book in the world, its publication is the result of successful coordination by the editors, Philip C. Heemstra (NRF-SAIAB), Elaine Heemstra (NRF-SAIAB), David A. Ebert, Wouter Holleman (NRF-SAIAB) and John E. Randall, who collaborated with over 100 globally renowned taxonomists and illustrators over a 20-year period. This publication underscores NRF-SAIAB's, and South Africa's, pivotal role in global ichthyology. It will become a critical reference work for many years to come, aiding the correct identification of specimens collected from expeditions undertaken in the WIO, in particular the ongoing fisheries research surveys that are part of the Norway and Food and Agriculture Organization (FAO) Nansen Programme that was initiated in 1975.

NRF-SAIAB taxonomists participate in these surveys and contribute to species identification and training of local and regional scientists and fisheries professionals from WIO countries, including Oman, Mozambique, Tanzania, Kenya, Madagascar, Seychelles, Maldives, South Africa and the Mascarene Plateau. An extensive fish identification training workshop at NRF-SAIAB in 2024 contributed to building taxonomic capacity within the region. The ultimate goal is to contribute towards the successful implementation of the ecosystem approach to fisheries (EAF) advocated by the FAO, as well as to meet the strategic targets of the United Nations Sustainable Development Goals (SDGs) and biodiversity conservation priorities of the Convention on Biological Diversity (CBC). EAF principles, embedded in the Code of Conduct for Responsible Fisheries and emphasised in the FAO's Blue Transformation initiative, are crucial for the sustainable management of fishery resources in the context of global change. The book supports these principles by providing the necessary tools for precise species identification and data collection.



NRF-SAEON has a distributed network of almost 30 rain gauges and weather stations across the country. These enable us to understand the role of climate on the ecosystems we monitor. Nineteen of these stations automatically update data every five minutes and show weather conditions recorded in the last four weeks on live websites. Photo: NRF-SAEON

Understanding climate and global change in Southern Africa

Juliet Hermes, Susan Janse van Rensburg, Lindokuhle Dlamini, Leo Chiloane, Londiwe Mabuza, Ryan Blanchard and Tony Swemmer

The South African Environmental Observation Network (NRF-SAEON) has been at the forefront of monitoring and understanding environmental changes for more than two decades. Through the collection and analysis of robust data, NRF-SAEON provides critical insights that inform evidence-based policy decisions, guide research initiatives and support effective conservation strategies. Some of the key highlights of NRF-SAEON's contribution to understanding global change in Southern Africa are highlighted below.

NRF-SAEON has successfully established detailed, long-term observations of natural resources at rural sites throughout South Africa, including harvested resources (fuelwood, Mopane worms and medicinal plants) and non-consumptive resources (the vegetation and animals that sustain many rural economies through livestock farming and eco-tourism). Highlights from this novel research include capturing the impacts of an extreme drought to provide insights into how global climate change will impact rural livelihoods in the near future.

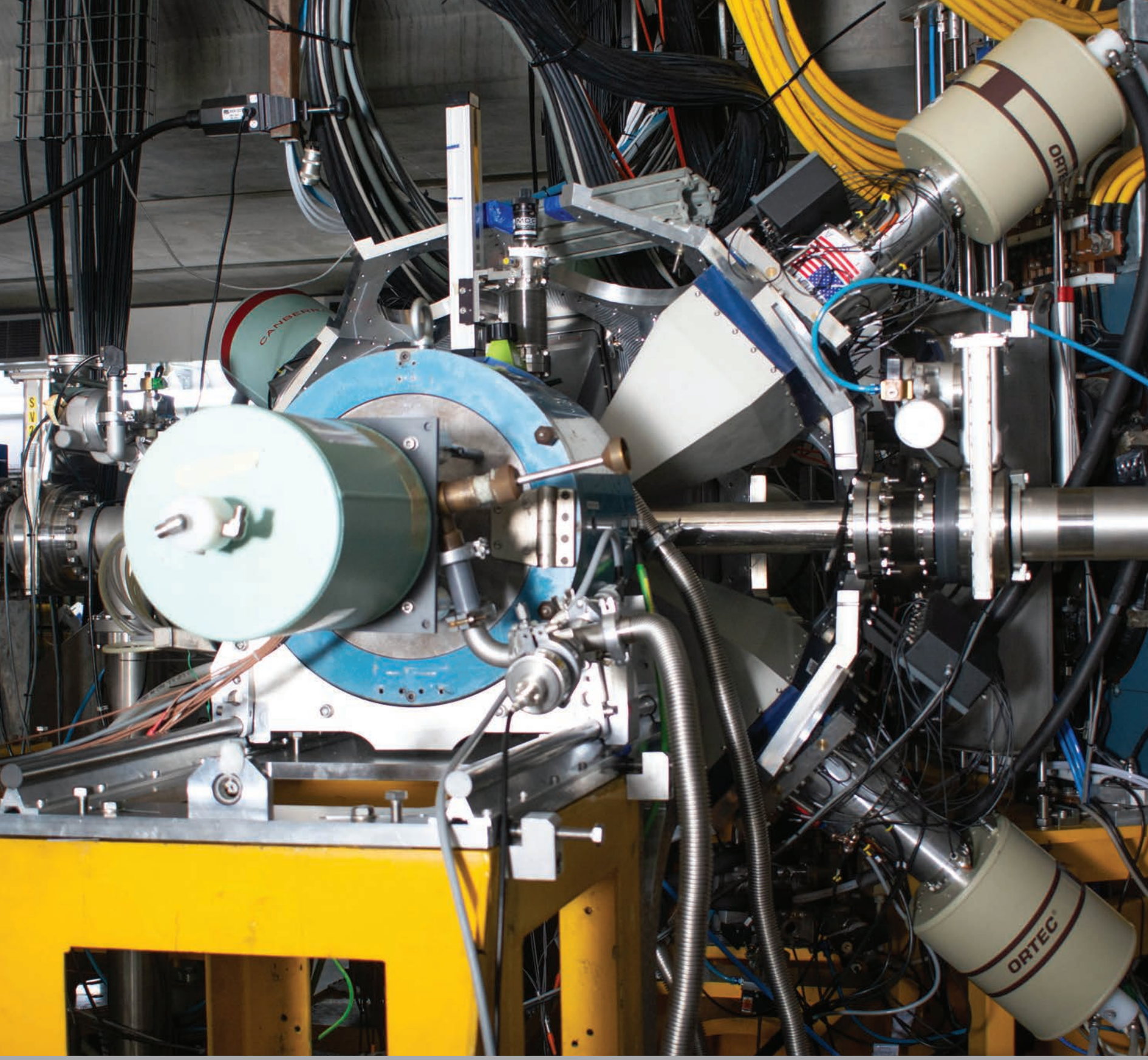
Mountains are key biodiversity hotspots and therefore require careful monitoring and preservation. In 2009, NRF-SAEON and SANParks collaborated to revive historical vegetation plots in Table Mountain National Park. By resampling and analysing data from historical surveys, evidence was found of climate change impact where longer warm dry spells negatively affected post-fire vegetation recovery, as well as the negative impacts of invasive alien plants.

South Africa is a water scarce country, and shortages of freshwater already constrain economic development and impact rural livelihoods. NRF-SAEON resurrected two large-scale, long-term river catchment experiments (Jonkershoek and Cathedral Peak) and initiated similar research in other parts of the country. These provide unique insights and clear evidence into how global climate change impacts the supply of water from strategic water source areas in the Drakensberg mountains, and appropriate strategies for mitigating such impacts.

South Africa is surrounded by three oceans, the Indian, the Atlantic and the Southern. NRF-SAEON marine and coastal research utilises this geographical advantage to provide observational and model data to understand changes in the ocean from short term, mesoscale variability through to long-term climate change. For example, changes in the Agulhas current and impacts on weather and coast; shifts in the fisheries in the Benguela large marine ecosystem; marine heat waves and impacts on biodiversity; extreme events such as storm surges, cyclones and rainfall; long-term changes in invertebrates and offshore fisheries.

NRF-SAEON's data platforms and tools such as the South African Risk and Vulnerability Atlas contribute to the understanding and mapping of global change in South Africa by providing online access to environmental observations and interactive applications. NRF-SAEON's open data policy ensures unrestricted access to quality data, fostering transparency and collaboration. This approach allows researchers, policymakers and communities to make informed decisions, implement effective strategies and improve climate resilience.

Grasslands provide vital ecosystem services such as carbon storage and water delivery. For example, plant diversity influences soil carbon, which influences hydrological processes. NRF-SAEON's assessment of long-term trends revealed that there has been a decrease in plant diversity under some grassland management regimes with no recovery after reversing poor management practices. Careful management of these social ecological systems outside of protected areas is required to maintain biodiversity to ensure sustained ecosystem service benefits.



Detector setup for coincident measurement with the k=600 magnetic spectrometer. Photo: NRF-iThemba LABS

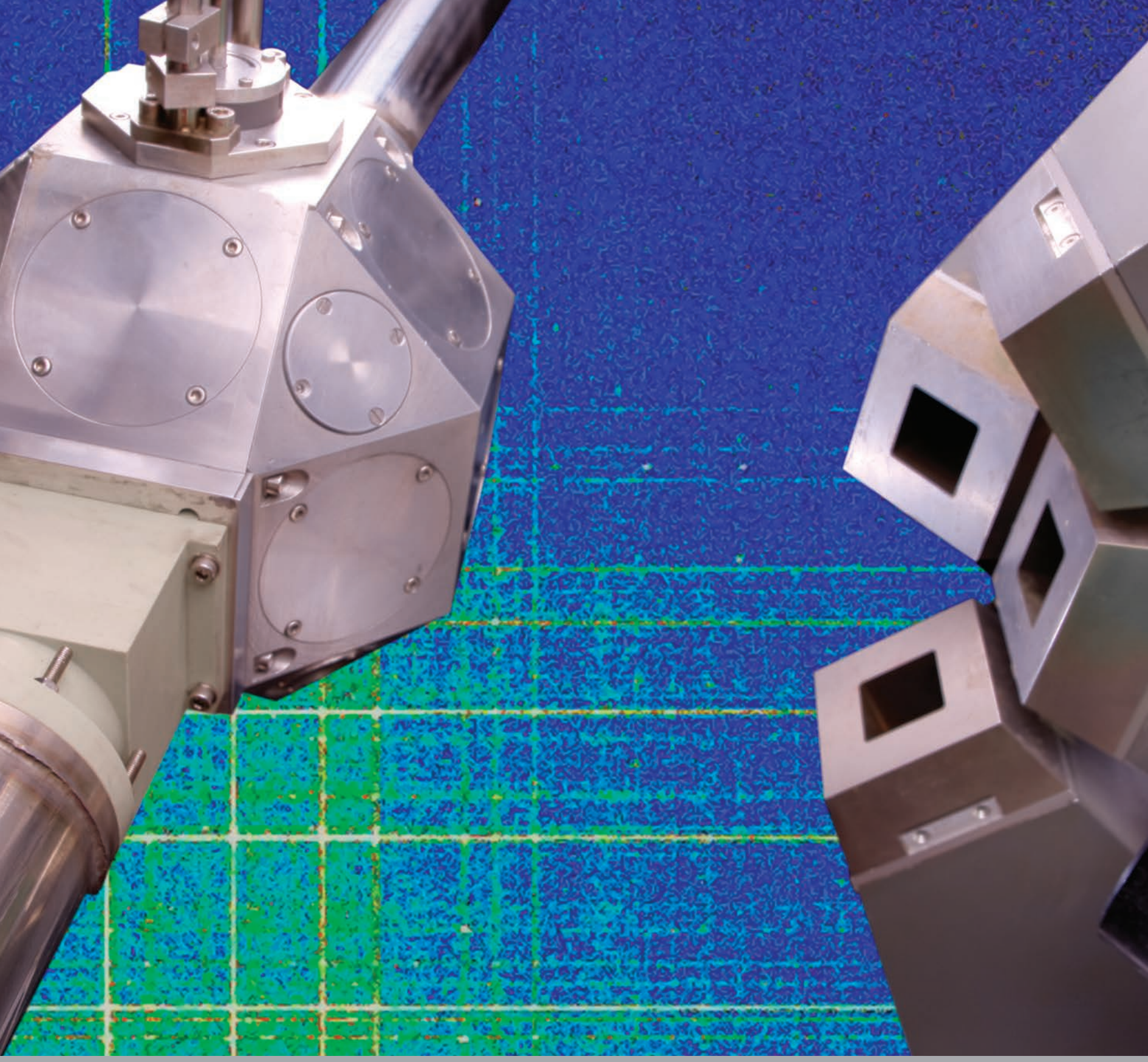
Advances in subatomic physics

Elena Lawrie, Peane Maleka and Retief Neveling

We and the world around us are made up of chemical elements which are defined by their distinctive nuclei and their particular properties. A clear understanding of the structure and reactions that govern nuclear matter is essential to various applications. The pursuit of basic research has facilitated the development of detection capabilities as well as analytical techniques for a myriad of applications. These applications and associated technologies impact society in various ways such as energy generation, diagnostic and therapeutic medicine, environmental protection and monitoring, space exploration, non-destructive tests of structural integrity in industrial applications, national security, and also assist in the authentication of art and the dating of archaeological artefacts.

Researchers and other external users at NRF-iThemba LABS use particle beams from the Separated Sector Cyclotron (SSC) in combination with state-of-the-art detection facilities to study various topics in nuclear structure, nuclear reaction physics, nuclear astrophysics and applications of nuclear science and technology. The K600 spectrometer is rated amongst the top two facilities in the world capable of high energy resolution measurements at 0° with low background conditions for medium energies. The upgraded gamma-ray detector array is rated amongst the top five facilities internationally. The neutron beam facility, which offers unique capabilities in the energy range of 30–200 MeV, resulted in NRF-iThemba LABS being designated by the National Metrology Institute of South Africa (NMISA) as responsible for providing traceability for the medium and high-energy neutron measurements in South Africa.

Over the past 25 years, access to these state-of-the-art infrastructure platforms by the local research community contributed to training students in fundamental and applied nuclear sciences. The South African knowledge economy and the nuclear industry benefits from this injection of a highly skilled and competent workforce who have been exposed to cutting-edge research at the forefront of science and technology. More than 200 students, including Postdoctoral Fellows, received training at NRF-iThemba LABS and have gone on to fill crucial roles in South Africa's scientific and industrial sectors. These professionals play important roles in South African and international universities, the National Nuclear Regulator (NNR), Square Kilometre Array (SKA), National Metrology Institute of South Africa (NMISA), the energy and technical industry and ESKOM (Koeberg Nuclear Power Station). More than 500 research outputs have been produced in the form of dissertations and articles published in peer-reviewed journals. As isotope production is migrated fully to the dedicated C70-cyclotron, a greater number of PhD and MSc graduates will continue to benefit as more beam-time becomes available on the SSC.



Scattering chamber and detector configuration for AFRODITE. Image: NRF-iThemba LABS

Gamma-ray spectroscopy

Elena Lawrie

The subatomic world is the world of the very small and the very fast. The invisible becomes visible through the interaction of a probe, the accelerated particle beam, with a target and the subsequent observation of the reaction products. The specific investigation dictates the properties of the probe, the target and the detection system. The workhorse of NRF-iThemba LABS is the Separated Sector Cyclotron (SSC) that is capable of accelerating tiny particles of matter such as protons, deuterons and heavier nuclei to speeds exceeding 50% the speed of light. The structure of an atomic nucleus can be studied through the detection of gamma radiation that is emitted from the excited nucleus that results from the collision of the beam with the target.

The nuclear physics research based on the study of the emitted gamma rays is called gamma-ray spectroscopy and it is a central focus of the research activities at iThemba LABS. A dedicated gamma-ray spectrometer called AFRODITE (AFRican Omnipurpose Detector for Innovative Techniques and Experiments) was constructed and commissioned at NRF-iThemba LABS in 1996. The spectrometer originally housed eight high-purity germanium clover detectors and provided a globally competitive research facility at the forefront of nuclear structure research. Since its inauguration, the array has been regularly upgraded and ancillary detectors were added to increase its power and performance. In addition, the gamma spectroscopy facilities were expanded by building a tape station set-up and installing a segmented clover detector. Scientists from around the world initiated collaborations and proposed scientific investigations using the gamma-spectroscopy facilities at NRF-iThemba LABS. Results were published in more than 100 research papers in ISI-accredited international journals, including the highest-impact international journals in our field. Four articles were published in *Physical Review Letters* and ten articles in *Physics Letters B*. The participation of strong international collaborations helped to create a research environment within which South African students and emerging researchers were trained and resulted in 22 PhD and 44 MSc degrees being awarded on gamma-spectroscopy projects. Many of these young researchers now hold academic and research positions, or work in the energy industry, and participate in the technological development of our country through the use of their acquired skills.

NRF-iThemba LABS continues to promote high-quality research and education in nuclear sciences and to provide cutting edge nuclear physics research facilities. Additions to the AFRODITE array have been made, and the GAMma-ray spectrometer for Knowledge in Africa, (GAMKA) provides unique capabilities that combine large-volume lanthanum bromide and high-purity germanium detector elements in a single dandelion frame. GAMKA was built by a consortium of iThemba LABS, Stellenbosch University, University of the Western Cape, University of the Witwatersrand and the University of Zululand.



Research scientist (Dr Christopher Mtshali) at work in the Tandetron Laboratory. Photo: NRF-iThemba LABS

Research excellence developing an African footprint through U2ACN2

Malik Maaza

NRF-iThemba LABS provides access to a multidisciplinary infrastructure platform that supports research and development in the field of nanoscience. A trilateral collaboration between the United Nations Educational, Scientific and Cultural Organization (UNESCO), the University of South Africa (UNISA) and NRF-iThemba LABS was consolidated in 2013 through the establishment of a Research Chair in Nanoscience and Nanotechnologies. The UNESCO-UNISA-Africa-Chair for Nanoscience and Nanotechnologies (U2ACN2) is managed jointly by UNISA and NRF-iThemba LABS. The U2ACN2-initiative trains and mentors early-career scientists and postgraduates and helps to position the contributions of Africa's researchers in the field of nanoscience, technology and innovation globally.

Since its inception the U2ACN2 has committed itself to improve the quality, impact and reach of nanoscience and nanotechnologies on the African continent through human capacity building. Facilitated through the supervision of postgraduate students and early-career researchers across the continent and some Global South countries, research conducted under the auspices of the U2ACN2 has resulted in publications in the prestigious *Nature* research journal and *Scientific Reports*, an open access journal publishing original research from across all areas of the natural sciences, psychology, medicine and engineering. The quality of the research is evident from the number of citations by international Fellows in other countries including Canada, China, New Zealand, Australia and Japan.

The transformation of research in nanoscience and nanotechnologies on the African continent has benefited immensely from the ability to bring researchers together to develop and nurture their skills. In 2022, U2ACN2 hosted 231 visiting scientists from Africa, the Middle-East and Asia. In the same year, three MSc and 29 PhD students were supervised, and five Postdoctoral Fellows were mentored. The U2ACN2 prides itself in attracting local talent from Historically Disadvantaged Institutions (HDIs) through targeted marketing and intentional relationship building.

The U2ACN2 research and development agenda is informed by the United Nation's Agenda for Sustainable Development with specific reference to the SDGs Energy, Water and Health. In recent years, there has been a vast improvement in output in the nanoscience and nanotechnologies field in South Africa and the continent. U2ACN2 outputs received more 5 000 citations in Scopus, Clarivate and Google Scholar. The U2ACN2 Chair was awarded the Mapungubwe Silver Order from South Africa's highest office, the first Galileo-Galilei Award from the International Commission for Optics (ICO) in Africa, the Jose Vasconcelos Award from the International Cultural Council (ICC-2019) and the Kennedy Medal from the International Union for Pure & Applied Physics (IUPAP-2024).

U2ACN2 patent innovation verified two significant Indigenous Knowledge know-hows from the Khoisan and Himba populations for green anti-bacterial skin cancer prevention and created a new generation of nanofluids for heat waste recovery and green bio-engineered nano-fertilisers.

The U2ACN2 is cementing its footprint on the continent through the establishment of the multidisciplinary African Centre of Competencies in Nanoscience and Nanotechnology for SDGs (ACCENTS) in partnership with higher education institutions and research, development and funding institutions from the North and South, in the belief that a focus on innovation and impact will lead to the creation of spin-off companies with research Fellows as Chief Executive Officers.



MeerKAT. Photo: NRF-SARAO

MeerKAT: A pioneering scientific instrument in its own right

Pontsho Maruping

South Africa will host the SKA Observatory's mid-frequency telescope (SKA-Mid). The development of the MeerKAT telescope as a precursor to the Square Kilometre Array (SKA) represents a significant milestone in the field of radio astronomy. MeerKAT, located in the Karoo region of South Africa, was designed to demonstrate the feasibility and effectiveness of the technologies and methodologies that would be used in the much larger SKA project.

The development started with a seven-dish MeerKAT precursor array, KAT-7, which was the world's first radio telescope array consisting of composite antenna structures. It was primarily built as a precursor to the 64-dish MeerKAT radio telescope array and to demonstrate South Africa's ability to host the SKA. However, it has proved to be a pioneering scientific instrument in its own right.

The construction of MeerKAT began in earnest in 2012 and was completed in 2018. It features 64 dishes, each 13.5m in diameter, with advanced radio receivers and digitisers. The array covers a maximum baseline of eight kilometres, to provide high-resolution imaging capabilities. MeerKAT incorporates several technological innovations, such as its use of composite antenna structures and sophisticated signal processing systems. These technologies serve as prototypes for the SKA's more extensive infrastructure.

SKA-Mid will comprise an array of 197 dishes, including 64 dishes of the MeerKAT telescope. A large concentration of the dishes will be in the core, while others will span out along three spiral arms, stretching 150 km end to end. This integration ensures continuity and leverages MeerKAT's existing infrastructure and expertise.

The SKA-Mid, located in South Africa, will benefit from MeerKAT's established presence and technological groundwork, and facilitate a smoother transition and scaling up of operations. The significance of MeerKAT as a precursor includes:

Technical validation: MeerKAT's successful operation has validated key technologies and methodologies that will be used in the SKA. This includes advancements in antenna design, data processing and system integration.

Operational experience: The experience gained from constructing and operating MeerKAT has provided valuable lessons in the management of large-scale radio astronomy projects, including logistics, infrastructure and international collaboration.

Scientific impact: MeerKAT's scientific discoveries have already made substantial contributions to astronomy, setting a high standard for what is expected from the SKA. Its findings have provided a glimpse into the potential of the SKA to revolutionise our understanding of the universe.

In summary, MeerKAT has played a crucial role in paving the way for the SKA. Its development and operational success have demonstrated the feasibility of the ambitious SKA project, and ensure that the world's largest radio telescope will be built on a solid foundation of proven technologies and methodologies.



The Southern African Large Telescope (SALT). Photo: NRF-SAAO/SALT

SALT: A beacon of world-class astronomy infrastructure in Africa

Daniel Cunnama

The Southern African Large Telescope (SALT), inaugurated in 2005, stands as a testament to South Africa's commitment to world-class scientific infrastructure. Over the past decade, SALT has not only facilitated groundbreaking astronomical research but has also driven technological innovation, human capital development and international collaboration, to solidfy its position as a premier astronomical facility in the southern hemisphere.

SALT's infrastructure development has been a continuous process of innovation and improvement. The telescope's unique design, featuring a 91-segment primary mirror array, presented unique engineering challenges that were successfully overcome by the SALT team. The initial years of operation focused on the refinement of the telescope's performance, to address issues such as image quality and optimise instrument capabilities.

Over time SALT has undergone significant upgrades and enhancements. The installation of the High-Resolution Spectrograph (HRS) in 2013 and the Near Infrared Washburn Astronomical Laboratories Spectrograph (NIRWALS) in 2022 expanded the telescope's capabilities, to enable a wider range of scientific investigations. The development of advanced software systems such as the SALT Array Management System (SAMS) and the data reduction pipelines has further streamlined operations and improved data quality.

SALT's commitment to technological innovation is evident in its ongoing projects. The development of a laser frequency comb for the HRS, the upgrade of the Robert Stobie Spectrograph (RSS) and the exploration of mini-trackers are just a few examples of how SALT continuously pushes the boundaries of astronomical instrumentation.

SALT's world-class infrastructure has enabled groundbreaking research in various fields of astronomy including the study of stars, galaxies, black holes and exoplanets. The telescope's location in Sutherland, with its pristine dark skies, provides a unique advantage for astronomical observations.

SALT's commitment to collaboration has fostered a vibrant international research community. Scientists from around the world have utilised SALT's capabilities, resulting in numerous publications in top-tier scientific journals. The telescope has also played a crucial role in multi-messenger astronomy, contributing to the observation of gravitational wave events and their electromagnetic counterparts.

SALT's impact extends beyond scientific research. The telescope has served as a training ground for a new generation of astronomers, engineers, and technicians, contributing to the development of a skilled workforce in South Africa. The SALT Collateral Benefits Programme (SCBP) has furthered this impact through the promotion of science education and awareness in local communities.

The presence of SALT in Sutherland has also stimulated the local economy through astro-tourism. The influx of visitors has created jobs and supported local businesses, demonstrating the broader socio-economic benefits of investment in scientific infrastructure.

SALT's journey over the past decade exemplifies the transformative power of world-class infrastructure development. By continuously pushing the boundaries of technology, fostering international collaboration and investing in human capital, SALT has solidified its position as a leading astronomical facility. The telescope's contributions to scientific research, education and socioeconomic development are a testament to the enduring value of investment in scientific infrastructure for the benefit of both the scientific community and society as a whole.



Target bombardment station. Photo: NRF-iThembaLABS/SAIF

South African Isotope Facility expands particle accelerator portfolio

Le Roux Strydom

NRF-iThemba LABS has contributed to research and development in accelerator-based sciences and technologies since the early 1980s. The workhorse of NRF-iThemba LABS is the Separated Sector Cyclotron (SSC) that is currently servicing two user groups, namely isotope production and basic and applied research, which includes the activities of radiation biophysicists. The radioisotopes are delivered weekly to more than 40 nuclear medicine departments at private and public healthcare units throughout South Africa and Namibia, and to more than 100 other clients worldwide. The establishment of the South African Isotope Facility (SAIF) expanded the portfolio of particle accelerators at NRF-iThemba LABS and resulted in increases in the research and training capacity, as well as the production capacity for radioisotopes, including new generation novel radioisotopes.

The acquisition of a dedicated cyclotron with associated infrastructure for the production of radioisotopes released the existing SSC for full time research and training. The new cyclotron is capable of producing two simultaneous beams of high-energy protons, that not only significantly enhances the isotope production capacity, but also extends the isotope research and development capability of NRF-iThemba LABS into alpha-particle-emitting radioisotopes for targeted alpha therapy.

The availability of diagnostic and therapeutic products for nuclear imaging and treatment creates long-term benefits for the public and private health sectors, improves health outcomes and lifts the technological base of the country. The dedicated cyclotron will result in a five- to seven-fold increase in production capacity that currently benefits about 5 000 South African patients.

The SAIF project, launched in 2018, was completed and commenced operating in December 2023. The required regulatory licence was granted in March 2022. A total of 157 man-years of labour were provided by the main contractor, Stefanutti Stocks, and various subcontractors over a period of 19 months during the construction of the main infrastructure for the new cyclotron. Approximately 3 100 cubic meters of new concrete, 354 tons of structural steel, 9.8 km of electrical cable and 150 000 bricks were used in the project. Fifty-two skilled and unskilled labourers from local communities were employed during the infrastructure construction phase. The new robotically controlled target stations for SAIF were fully manufactured and assembled by a local engineering company, TF Design, from concept and detailed designs developed in-house at NRF-iThemba LABS. It is envisaged that 53 new permanent positions will be created over a period of four years for the operation and technical maintenance support of the new cyclotron, target stations and infrastructure as well as in isotope production, radiation safety control and administrative support functions.

The transference of isotope production to the new cyclotron frees up the SSC for applied and fundamental research that probes the origin and properties of atomic nuclei. This not only improves our national and international standing as a world-class research infrastructure platform, but also strengthens and enhances our collaborations with local universities and similar research facilities abroad.



Calibration of one of NRF-SAEON's Eddy Covariance towers located in Cathedral Peak. This meteorological system is used to measure gas, energy and momentum between ecosystems and atmosphere. NRF-SAEON has several Eddy covariances located in various ecosystems across the country. Photo: NRF-SAEON

NRF-SAEON's National Long Term Ecological Research infrastructure (LTER)

Susan Janse van Rensburg, Paul Gordijn, Lara Atkinson, Helga van der Merwe,
Thomas Bornman, Gregor Feig and Mary-Jane Bopape

NRF-SAEON has grown immensely since its formal inception in 2002 with a distributed network of LTER sites across South Africa. NRF-SAEON's National Long Term Ecological Research (LTER) platforms range from the depths of the oceans to the highest mountains, encapsulating the diversity of biomes in South Africa. These platforms provide long-term observations, to enable research focused on detection and understanding of the impacts of human-induced change on earth system processes and ecosystem services on which people rely. The platforms provide infrastructure for student and researcher projects, postgraduate schools and a high number of data and platform users across a range of scientific fields.

NRF-SAEON platforms in the terrestrial and marine environments were identified strategically over the years and continue to expand according to funding availability and the South African Research Infrastructure Roadmap (SARIR). For the terrestrial environment, NRF-SAEON operates four nodes or offices in Limpopo, KwaZulu Natal, Western Cape and Northern Cape, that are responsible for sites in these provinces. For example, two long-term forestry research catchment initiatives (Cathedral Peak in the Northern Drakensberg and Jonkershoek in the Cape) were rescued and revitalised by NRF-SAEON and now form part of the LTER sites. The two sites are the most densely instrumented catchments in the country and are operated by the Grasslands Node in Pietermaritzburg and the Fynbos Node in Cape Town.

The Tierberg-LTER was donated to NRF-SAEON in 2014 and the large body of work (> 140 publications) that has materialised contributes towards our understanding and mitigation of Southern Africa's dryland degradation. The Arid Lands Node based in Kimberley is responsible for this site. Welverdiend in the Savanna Biome is a long-term site managed by the Ndlovu Node. NRF-SAEON is responsible for several other sites managed by the terrestrial nodes to address societally relevant challenges.

In the marine environment, sentinel sites and satellite sites around the coast of South Africa and the sub-Antarctic islands provide key long-term observations on changes taking place in the following ecosystems: pelagic, benthic, estuarine, kelp, sandy beaches and rocky shores. The continuous physical data (temperature, currents, waves, wind, etc.) are complemented with discrete sampling of essential chemical and biological variables.

NRF-SAEON hosts three Research Infrastructures (RIs) of SARIR. These are the Expanded Freshwater and Terrestrial Environmental Observation Network (EFTEON); the Shallow Marine and Coastal Research Infrastructure (SMCRI); and the South African Polar Research Infrastructure (SAPRI). The three RIs are largely modelled on NRF-SAEON's well-established network of terrestrial and marine nodes and will expand with the addition of new well-instrumented sites.

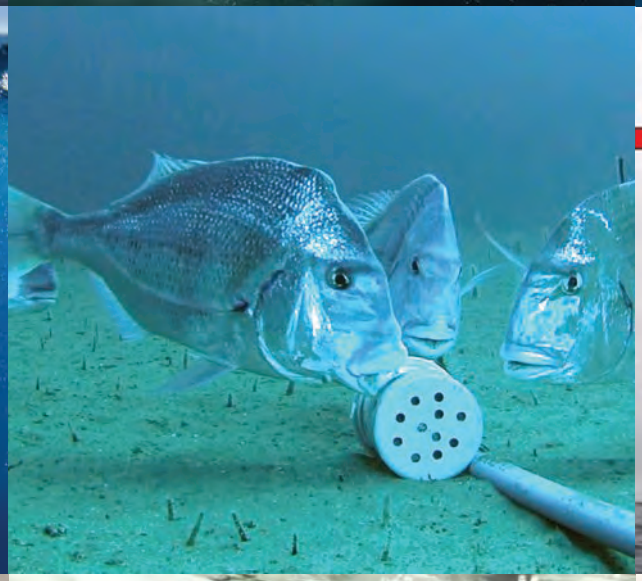
NRF-SAEON provides reliable long-term observational data to support process-level understanding in the scientific value chain, the development of remote sensing and modelling products and applications, and the support of national and global policy and, as a research platform, collaborates with universities and other research organisations to train students and conduct research. The open science, platforms and data associated with the sites have contributed to numerous students, as well as national and international research projects.





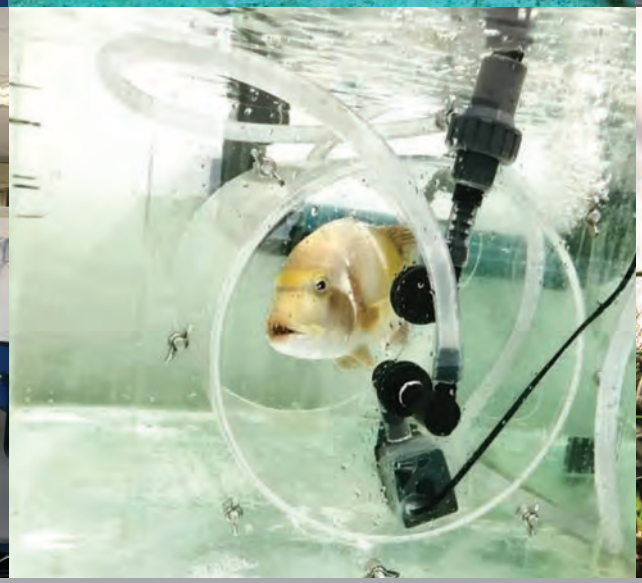














The NRF-SAIAB has developed significant marine and freshwater infrastructure platforms over the past 12 years, including research vessels and an equipment network to study aquatic animals movements (ATAP); cameras to assess presence and abundance of fish (MARIP); scanning the seafloor (GeMaP); laboratories for extracting and processing DNA to learn more about the genetics of individuals and ecosystems (AGRP); as well as the physiology of aquatic animals (AERP); and several gear types for sampling and fieldwork (FFU). Photos: NRF-SAIAB

Equipping researchers with research equipment: End to end integrated aquatic infrastructure

Taryn Murray, Anthony Bernard, Thamasanqa Wanda, Mandla Magoro, Lubabalo Mofu, Gwynneth Matcher and Ryan Palmer

As a freshwater-scarce, maritime nation, South Africa needs scientifically robust, evidence-led sustainable development of its aquatic resources. Significant technological advancements have expanded the scope of aquatic research in recent years. Over the past 12 years, NRF-SAIAB has developed high-level marine and freshwater infrastructure platforms, that facilitate research on a suite of different species occupying vastly different habitats (both shallow and deep) across freshwater, estuarine and marine environments. These platforms enable researchers to understand movement behaviour of species, monitor abundance and diversity in marine protected areas, map the seafloor, conduct ecophysiology experiments on important fishery species, determine genetic diversity and much more.

One of NRF-SAIAB's primary objectives is to conduct research that responds to global challenges while ensuring the sustainability of Africa's marine and freshwater ecosystems. To achieve this, several research and infrastructure platforms have been developed which collectively contribute to inland fisheries and freshwater ecology, constantly changing coastal systems, the Blue Economy and movement ecology of aquatic animals. These platforms answer urgent research questions associated with understanding and managing key socio-economic sectors within South Africa's marine, coastal and freshwater environments, as well as the mitigation of key global and climate change stressors. All collected data are crucial for understanding and supporting appropriate management of natural aquatic resources, to ultimately contribute to the well-being of South Africa's people.

NRF-SAIAB manages seven research platforms: National Coastal Craft Fleet; Acoustic Tracking Array Platform (ATAP); Marine Remote Imagery Platform (MARIP); Geophysics and Mapping Platform (GeMaP); Aquatic Genomics Research Platform (AGRP); Aquatic Ecophysiology Platform (AERP); and the Freshwater Field Unit (FFU). Each platform has its own associated infrastructure and equipment, which can be used to answer various research questions. The coastal craft are used extensively to conduct fieldwork. ATAP assesses the movements of aquatic animals including fishes, sharks, rays, skates and turtles. MARIP assesses the diversity and abundance of species in various coastal environments. GeMaP creates high-resolution bathymetric data used to describe the depth, shape and character of the seabed. The AGRP uses genetic techniques to characterise and barcode South Africa's rich aquatic biodiversity. The AERP conducts laboratory experiments to assess the resilience of important coastal fishery species in a changing climate. The FFU uses traditional fishing gear to learn more about the biodiversity of important and remote freshwater ecosystems. These platforms work together seamlessly to conduct marine and freshwater research from the molecular and organismal level through to the ecosystem level.

While each platform conducts its own research related to the associated infrastructure, these platforms are available to researchers from across South Africa through a competitive funding call managed by the African Coelacanth Ecosystem Programme (ACEP). Through fieldwork conducted using the platforms, NRF-SAIAB supports the research of more than 300 researchers and students from more than 50 institutions, which speaks to immense human capacity and scarce-skills development in marine and freshwater science in South Africa. All platform-collected data have direct societal and economic impact, working towards the sustainable development of fisheries, oil and gas prospecting, marine mining and enhanced understanding of our rich biodiversity, and ultimately lead to improved well-being, health and livelihoods.

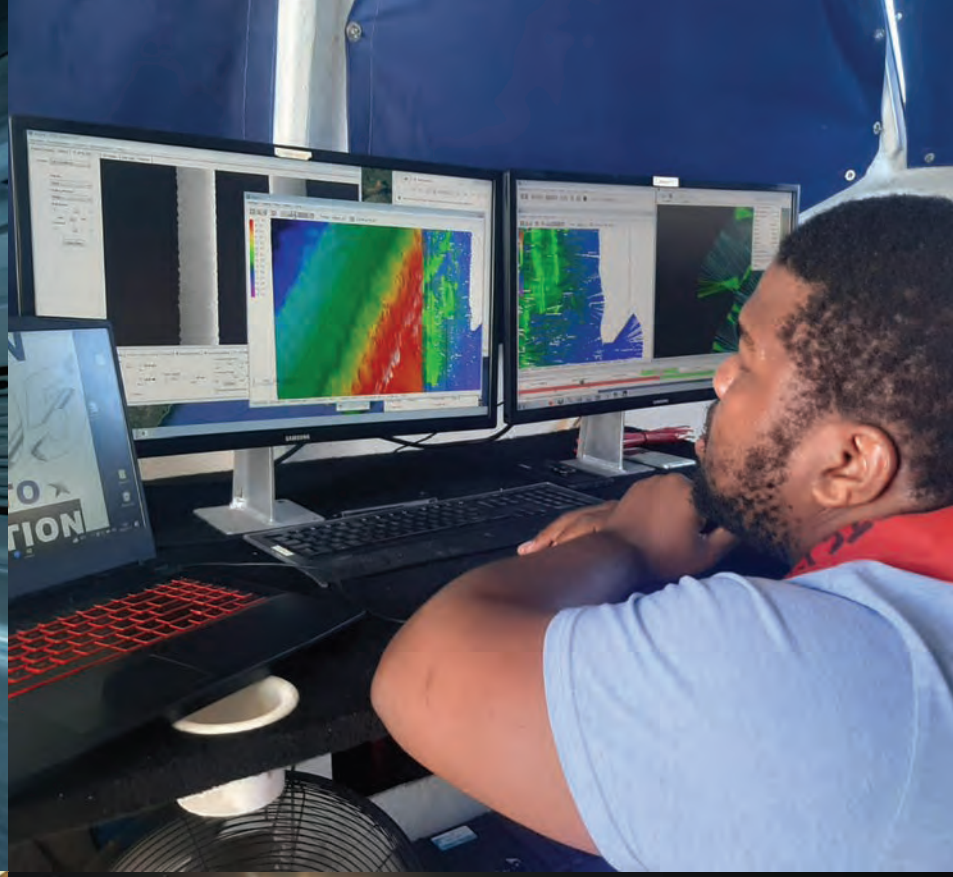

TRANSFORMATION
IMPACT
INNOVATION
EXCELLENCE
SUSTAINABILITY
NRF
VISION
2030

SUSTAINABILITY:
Building a better tomorrow today

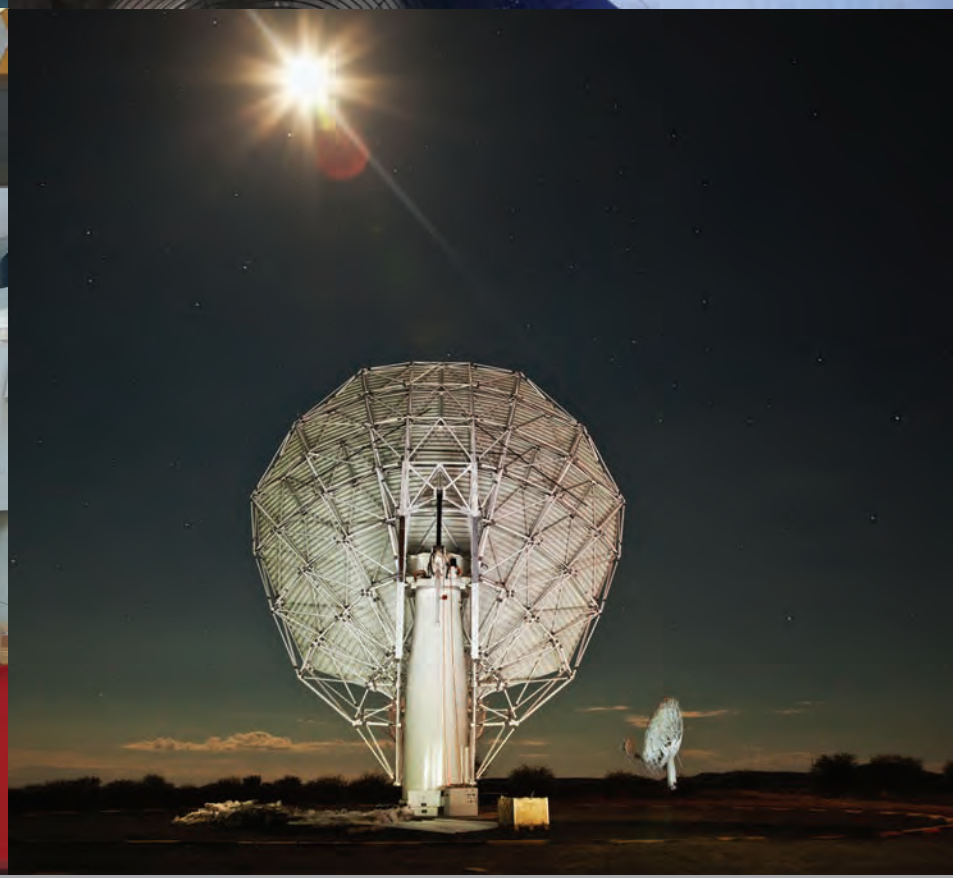
Sustainability means meeting current needs without compromising the future. For us, this is about ensuring the sustainability of internal operations, the external knowledge enterprise, and the national and global environment.

Internally, the NRF will ensure financial and operational sustainability. Without a sustainable and well-resourced knowledge enterprise, the sector will not be able to grow and benefit society, the economy and the environment. As we strive to meet our needs today, so do we strive to sustain a brighter future for all.









Top left: SAIF product delivery – NRF-iThemba LABS. **Top right:** Geophysics Mapping Platform – NRF-SAIAB. **Bottom left:** High precision machining capabilities at the NRF-SAAO. **Bottom right:** MeerKAT – NRF-SARAO

National Research Infrastructure Platforms (NRIPs): Portfolio of innovation

Mark Johnson

The National Research Infrastructure Platforms (NRIPs) have developed an extensive NRF intellectual property portfolio that is multidisciplinary in nature and focuses on providing next generation technology innovations in areas such as astronomy, nuclear physics, environmental monitoring and aquatic biodiversity.

These combined efforts have culminated in over two hundred innovations that have been instrumental in the support of large infrastructure projects such as MeerKAT, SALT and the South African Isotope Facility as well as other projects such as BioScape. Key innovations emanating from the National Facilities include the Intelligent Observatory (IO); Low Energy Radio-isotope Beam Production (LERIB); the Maximum Efficiency Spectrograph (MaxE); Geophysics Mapping Platform; Indigenous Marine Innovations for sustainable Environmental and Economies (IMIsEE) project and advanced hardware such as the digitiser, band 5 receivers, correlators and the Field Programmable Gate Arrays (FPGAs). This is complemented by the high-performance Compute and Data Processing Platform that is integral to all the NRIPs.

These innovations are not only of value to the infrastructure platforms but also have broader application. For example, advances in optical technology, such as the hyperspectral camera and polarimetry fibre imaging being pioneered at NRF-SAAO, although developed for astronomy, have also been applied to the agricultural and medical sectors and a similar opportunity exists for the Compute and Data Processing hardware and software.

Multidisciplinary competence, including engineering and scientific teams, has provided unique value in that NRIP projects have enabled teams to overcome unique technology challenges in specific thematic areas and more broadly. For example, broader impact has been achieved through the development of low-cost prosthetics for the healthcare sector and, in delivering on the National Ventilator Project, through the production of ventilators that were invaluable in supporting the South African healthcare sector.

The NRF has also initiated various commercialisation initiatives across the NRIPs including the South African Isotope Facility which enabled the production of radioisotopes for the global market using established commercial channels. This was complemented by a licence agreement completed with Wideband Receiver Solutions (Pty) Ltd and the equity acquisition in Tsolo Storage Systems (Pty) Ltd.

The NRF has made invaluable contributions to South African industry by supporting the development of a number of technology and engineering companies that have continued to grow following initial support from the NRF.



SKA and Hip Hop Science Spaza initiative at Carnarvon Primary, Carnarvon. Photo: NRF-SARAO

Ensuring a social licence to operate: NRF-SARAO case study

Adrian Tiplady

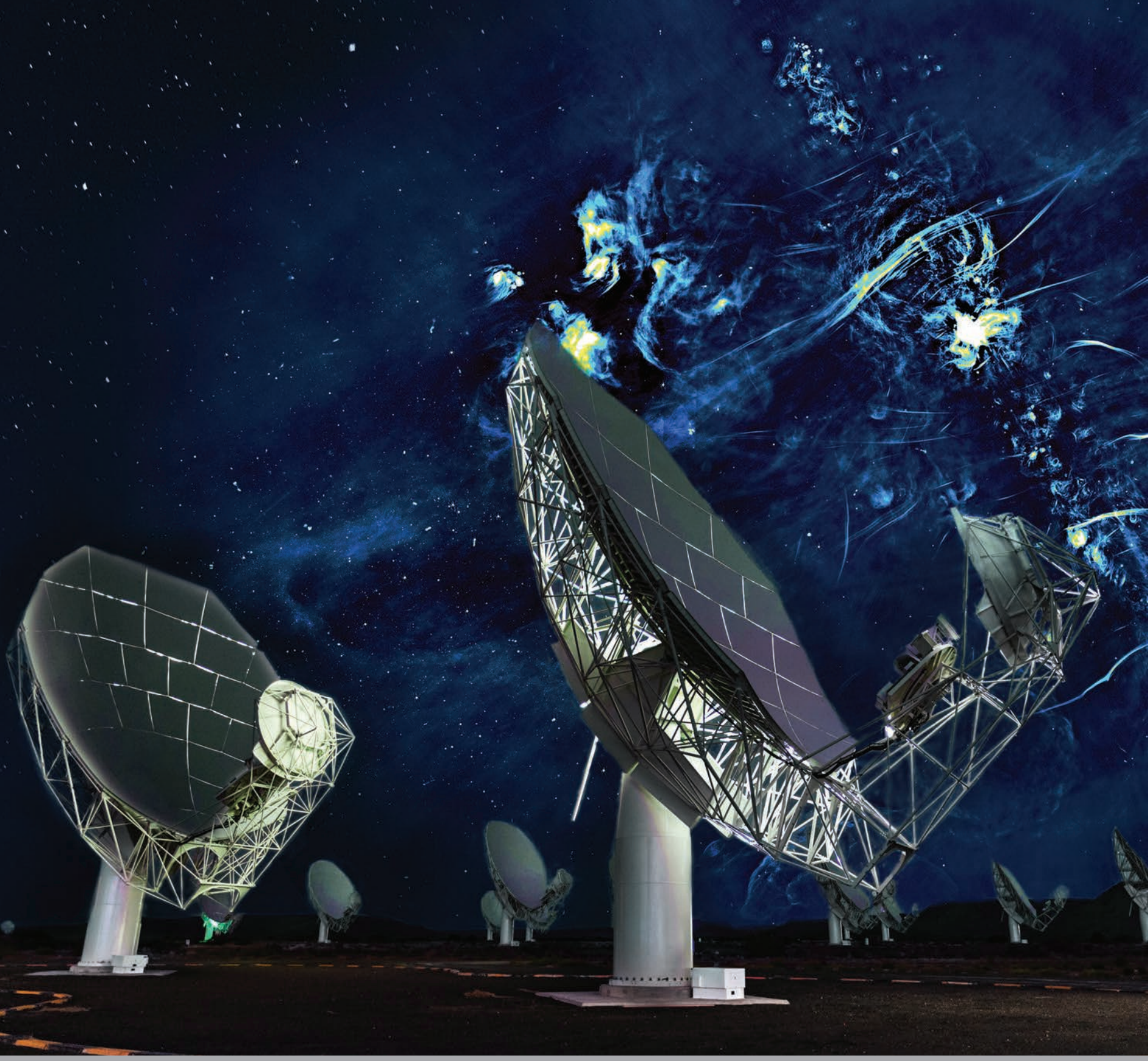
Increased global connectivity and access to information has resulted in the empowerment of society, and an active citizenry who are acutely aware of global risks, inequity and developmental challenges. Recognition of the need to address these broader societal issues, summarised in key policy documents and frameworks such as the National Development Plan, has placed stakeholder demands on organisations to become good corporate citizens – being 'economic' actors whilst contributing towards the achievement of national developmental goals. The multitude of stakeholder groups that are now relevant have established a complex value system that requires careful crafting of a value proposition for research infrastructures that goes beyond the 'scientific enablement' that typically guided establishment of new research infrastructures in the past.

To illustrate, funding agencies, particularly (but not exclusively) those in developing countries, view investment in research infrastructure as a vehicle for socio-economic development. The need for tangible socio-economic impact on shorter timescales is often more acute at a local level when research infrastructures are deployed in remote, socio-economically depressed rural environments. This is often the case for astronomical facilities, which seek locations far from major economic activity and urban centres – a proxy for optical and radio interference.

The development of a value proposition that delivers 'value' to a diverse group of stakeholders requires a 'stakeholder inclusive' approach. This approach has informed the implementation of South Africa's strategic investments in radio astronomy, implemented through the South African Radio Astronomy Observatory (NRF-SARAO). These investments have not only been realised in the development of the next-generation MeerKAT radio telescope, but also through the socio-economic impact that has been delivered across various sectors of society – at both local and national level. The approach is conceptualised as ensuring a 'social licence to operate'.

This 'social license to operate' can be described as the legitimacy of an organisation as perceived by its stakeholders. Evaluation and management of this requires definition of a clear value proposition, and the set of key stakeholders and their respective value systems, i.e. how the stakeholders value the value proposition being delivered. The approach recognises that a stakeholder-defined, multi-tiered value system and subsequent delivery of a multi-tiered value proposition by research infrastructures, is key to ensuring a 'social licence to operate.

By adopting this approach, NRF-SARAO has been able to plan for impact – particularly at local and regional levels where socio-economically depressed communities are located within the vicinity of MeerKAT and the future SKA telescopes. Ensuring a social licence to operate is seen as a critical success factor in the establishment and operation of these facilities, and strategic interventions to accelerate the 'research infrastructure impact pathways' are undertaken within the context of an impact framework.



MeeKAT. Composite image: NRF-SARAO

Science diplomacy: SA and the SKA project – facilitating scientific cooperation

Adrian Tiplady

The term 'science diplomacy' is often associated with the use of scientific collaborations among nations to address the common problems facing 21st-century humanity and to build constructive international partnerships. South Africa's participation in the international Square Kilometre Array (SKA) project is a key example of where diplomacy has facilitated scientific cooperation across the Global North and the Global South.

South Africa's bid, on behalf of Africa, to host the SKA project relied on the cooperation of at least eight other African partner countries – each willing to support the construction and operation of radio astronomy facilities in each of their countries. The first meeting of the African partner countries occurred in 2003, nine years before the awarding of rights to co-host the SKA telescope in Africa. With recognition of the role that science and technology could have on the socio-economic development of the continent, the diplomatic cooperation on the SKA culminated in the 2010 Declaration by the African Union Heads of State in support of the African bid to host the SKA. Similarly, in 2011 the European Parliament adopted Written Declaration 45 on science capacity-building in Africa, which recognised the need for greater collaboration with Africa in radio astronomy and the facilitation of inter-regional cooperation. This declaration resulted in the establishment of the Africa-European Radio Astronomy Platform.

These key diplomatic instruments strengthened the political support needed to facilitate the establishment of radio astronomy infrastructure and capacity on the African continent. Led by South Africa and working with key stakeholders in the African partner countries, we have seen a significant growth in capacity across the continent, including the establishment of the Ghana Radio Astronomy Observatory; deployment of training telescopes; establishment of institutional capacity at various universities; and ongoing skills development – often in partnership with international funding agencies.

From a system-wide perspective, science diplomacy has enabled South Africa to establish itself as an important global partner within the astronomy research enterprise and NRF-SARAO has leveraged millions of rand in income. Through the NRF and NRF-SARAO, South Africa has been able to strategically allocate resources and apply its considerable wealth of skills and expertise to radio astronomy.

Three areas in which South Africa and its research infrastructure workforce have become pre-eminent include:

South Africa's geographic advantage to host radio astronomy facilities: The country's ability to declare and protect astronomy advantage areas in the Karoo is unique in the world and facilitates the maximisation of scientific return from astronomy observations by next-generation radio astronomy facilities, such as the SKA.

South Africa as a global partner and leader within international governance structures: South Africa, and its research infrastructure workforce, has been able to adopt significant leadership roles and positions within the SKA Observatory governance structures and project, as well as other next-generation astronomical facilities.

South Africa as a technical leader: The delivery of the MeerKAT project has developed the skills and competencies necessary to deliver a next-generation facility such as the SKA project. As a result, NRF-SARAO and South African industry are positioned to deliver a variety of complex, technical work packages necessary to deliver the transformational science expected of the SKA telescope.



Schoolgirls and their female science teachers from rural Ethiopia attended an inspirational, capacity building programme that used astronomy and its multidisciplinarity to train them as advocates of STEM in their communities. Photo: IAU OAD/Scigirls Ethiopia

Astronomy for a better world

Kevin Govender and Ramasamy Venugopal

The last 25 years have seen significant challenges, including the rise of social media, fake news, divisive wars, a global pandemic, climate change-related disasters and a growing inequality that is revealed in all of the above. The partnership between the International Astronomical Union and the National Research Foundation to form the Office of Astronomy for Development has sought to use astronomy to tackle these and other challenges. Through its work, its global community and its longevity, it has demonstrated what is possible when one is intentional about realising the societal impact that can come from science.

In 2010, the NRF won a bid to host the International Astronomical Union (IAU) global Office of Astronomy for Development (OAD) at NRF-SAAO. Officially launched in 2011, the OAD has since issued an annual call inviting proposals for projects that use astronomy to address developmental challenges globally. Grants totalling € 1 321 903 have been awarded to 227 projects around the world, targeting audiences in more than 100 countries. The OAD also established 11 regional offices around the world, registered hundreds of volunteers and formed 17 partnerships with organisations across disciplines.

Varied projects have included the use of astronomy to inspire children in refugee camps, to develop data science skills among university students and to develop resources to assist those who are blind or visually impaired to experience science. Project leaders have included professional astronomers, science enthusiasts, students, schoolteachers and artists. The OAD maintains the principle of humility, in the belief that anyone anywhere can come up with ideas that use astronomy to improve the lives and livelihoods of people in their communities. The OAD's role is primarily to support and help them to realise their goals. This support comprises an online course on designing an astronomy-for-development project; a database of resources from past projects; and regular webinars and fundraising advice, with local support from the OAD regional offices.

The OAD is also able to be agile and responsive to the needs of the people it serves. In 2020 when the COVID-19 pandemic struck, the OAD pivoted overnight and issued an extraordinary call for proposals in addition to its annual call and awarded an extra € 40 000 to 43 projects that used some aspect of astronomy to address the negative effects of the pandemic.

Based on the lessons derived from multiple projects, with input from regional offices, interdisciplinary partners and the international development landscape, the OAD developed three flagship themes: (i) using astronomy to stimulate economic development through astronomy tourism and supporting small businesses; (ii) using the inspirational aspects of astronomy and dark skies to positively influence mental health among different target groups; and (iii) using the data science skills and infrastructure from astronomy to develop human capacity and to solve development challenges.

The OAD is more than just an office that carries out a mandate. It exists as an example of South Africa leading a global initiative to use science for the betterment of society, and it demonstrates to the world what is possible when we embrace the humbling and unifying perspective that astronomy so eloquently conveys.





Top: The NRF-SAAO Visitors' Centre in Cape Town features cultural exhibits which celebrate the rich heritage of the region, and highlight the connections between astronomy and indigenous knowledge systems. Photo: SALT Architects.
Bottom: The Southern African Large Telescope (SALT) in Sutherland. Photo: NRF-SAAO/SALT

Pioneering sustainable astro-tourism in South Africa

Daniel Cunnama

NRF-SAAO is at the forefront of developing sustainable astro-tourism in South Africa, leveraging its unique geographical advantages and world-class facilities. The national astro-tourism strategy focuses on three pillars: human capacity development and transformation; astronomy infrastructure development; and inclusive tourism growth and partnerships. In alignment with this strategy, NRF-SAAO drives economic growth in the Northern Cape region and fosters scientific literacy and community development.

NRF-SAAO's location in Sutherland, with its pristine night skies and minimal light pollution, has made it a prime destination for astro-tourism. The presence of the Southern African Large Telescope (SALT) has attracted 14 000 to 15 000 visitors annually, stimulating the local economy and creating jobs. This influx of tourists has spurred the development of astro-tourism infrastructure, including accommodation, restaurants and a planetarium, that further contribute to the region's economic growth.

Beyond economic benefits, astro-tourism provides a unique platform for education and awareness. Visitors to NRF-SAAO have the opportunity to learn about the Universe, celestial objects and the importance of preserving dark skies. This increased awareness fosters a deeper appreciation for science and astronomy, potentially inspiring future scientists and astronomers. NRF-SAAO has trained and employed eight previously disadvantaged youth as tour guides, and administrative and organisation staff all linked to the tours. The construction and operation of SALT and NRF-SAAO telescopes have led to the development of accommodation establishments, that have created 302 direct jobs and several indirect jobs.

NRF-SAAO's commitment to sustainable astro-tourism extends beyond simply attracting visitors. The organisation actively engages with the local community, to provide training and employment opportunities. This approach ensures that the benefits of astro-tourism are shared equitably, and contribute to the long-term well-being of the region. NRF-SAAO has also refurbished school laboratories, supplied schools with necessary materials and secured bursaries for local students.

NRF-SAAO works continuously to enhance the astro-tourism experience and expand its reach. Plans are underway to upgrade the Sutherland site, train more tour guides and improve astro-tourism offerings. From the Cape Town Visitors' Centre to the Sutherland Planetarium, these efforts aim to make astronomy accessible and enjoyable for all visitors.

NRF-SAAO is also committed to environmental sustainability. Through the promotion of responsible tourism practices and raising awareness about light pollution, NRF-SAAO works to preserve the pristine night skies that are essential for both astronomical research and astro-tourism.

NRF-SAAO's pioneering efforts in astro-tourism demonstrate the power of science to drive economic growth, community development and environmental conservation. By combining scientific research with sustainable tourism practices, NRF-SAAO creates a model for how astronomy can benefit society as a whole.

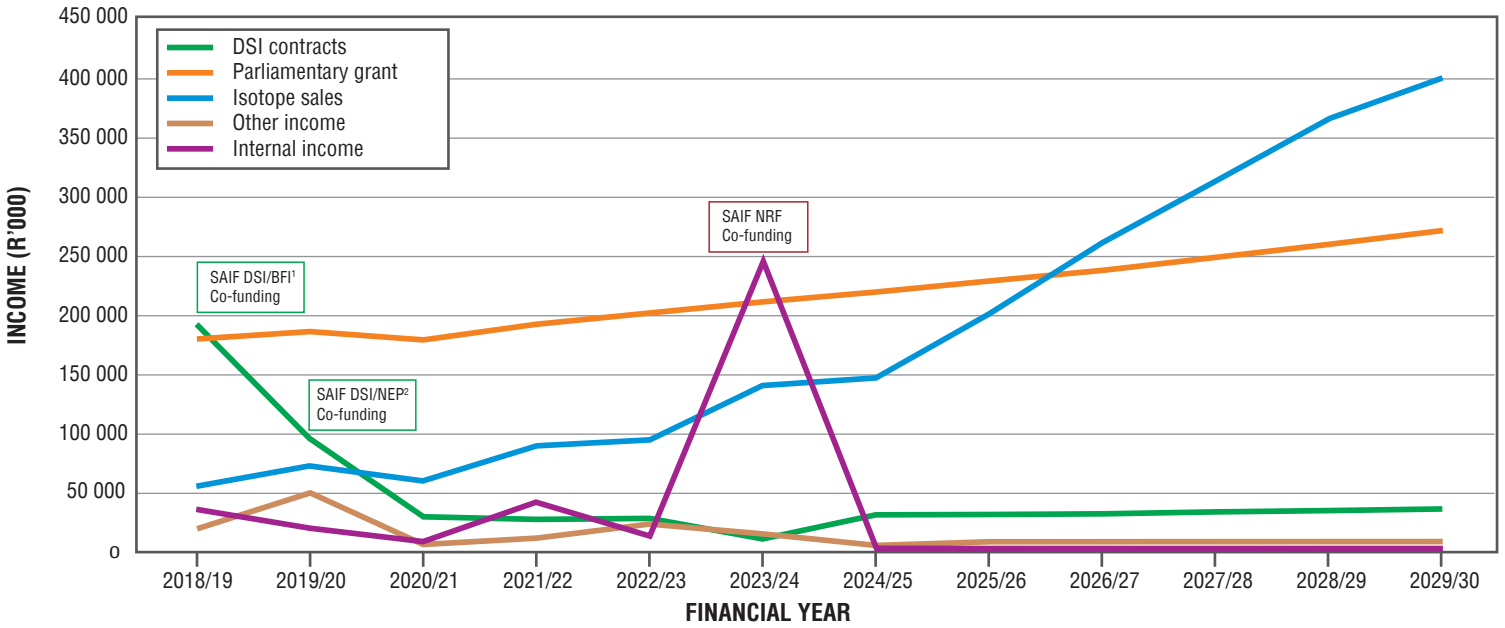


Figure 1: Income streams, 2019 to 2030

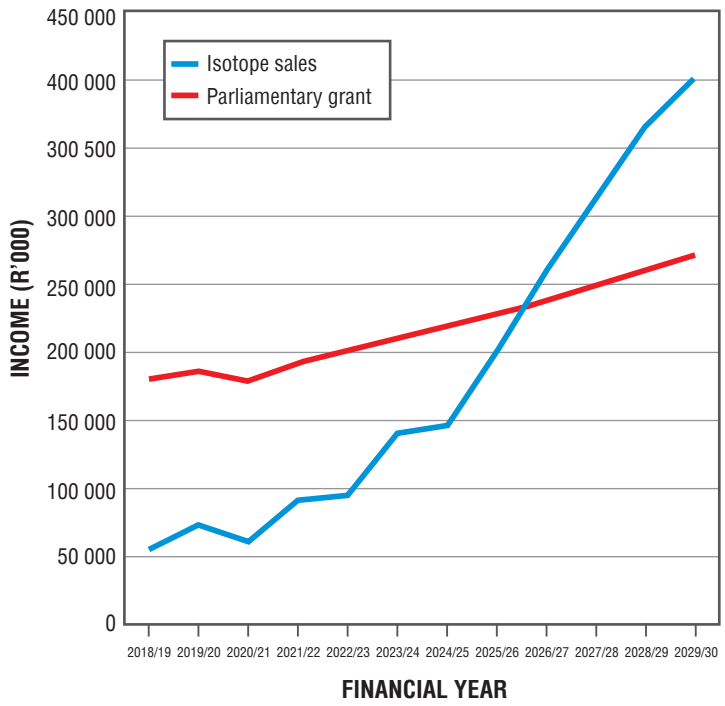


Figure 2: Income diversification, 2019 to 2030

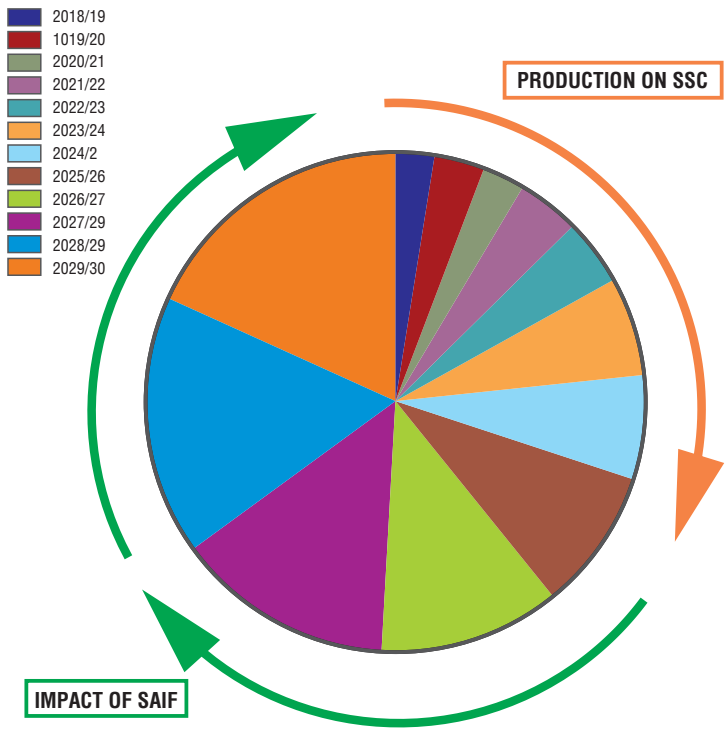


Figure 3: SAIF impact on isotope sales growth, 2019 to 2030

[1] BFI – Budget Facility for Infrastructure
[2] NEP – National Equipment Programme

Diversification of income

Vincent Spannenberg

NRF-iThemba LABS provides multidisciplinary research facilities under the Nuclear Cluster. It is reliant on parliamentary grant funding through the Department of Science and Innovation (DSI) to sustain capital and operational expenditure. Roughly 90% of the current PG is allocated to salaries which leaves very little room for infrastructure renewal and maintenance of the research infrastructure. NRF-iThemba LABS introduced a business model to diversify its income streams (Figure 1), thereby becoming less reliant on State funding to sustain operations and advance its research agenda.

The business model, which adopted a revenue generation culture, recognises that the financial and operational sustainability of NRF-iThemba LABS will remain constrained in the long-term without any direct State or strategic intervention(s). The establishment of the South African Isotope Facility (SAIF), which was identified as an infrastructure renewal project, serves as the driver to leverage State funding by deploying risk-based funding from the sales of radioisotopes. This approach naturally introduces and increases underlying medium to long-term associated risks, through the introduction of a systemic increased reliance on risk-based funding for fundamental and applied science. NRF-iThemba LABS recognises that this proven business model, underpinned by a significantly higher production and supply of radioisotopes, is yet to be fully understood. It will require consistent and continued due diligence and review.

Figure 2 depicts the parliamentary grant and isotope sales revenue since 2018/19, together with the projected sales for the next period until 2030. Nominal growth in the parliamentary grant is envisaged as depicted in the graph. The graph clearly demonstrates a significant change in income trends associated with the ramping up of radioisotope supply to both the local and international markets. Isotope revenue relative to total revenue (Figure 3) has increased from ±10% (2018/19) to ±40% (2023/24), less the capital investment to establish the South African Isotope Facility (SAIF). The sales plan projects the compound annual growth rate (CAGR) for most of the existing products to be between 12% and 30%, and total isotope revenue is expected to grow to more than 50% of the total NRF-iThemba LABS revenue by 2027, to a projected total isotope income of R400m (Figure 3) in 2030, dependent on favourable market conditions. Radioisotope sales are expected to surpass the State's parliamentary grant in 2026/27. Significant investments have been made to leverage this (isotopes) highly lucrative international market opportunity.

To this end, NRF-iThemba LABS is currently working on an income diversification approach to maximise resource efficiency, that includes leveraging the Technology and Innovation Platform (TIP) and SA-CERN in-kind contributions, to bolster and increase the current income from other sources, which includes international and local partners as well as the private sector. This will ensure mitigation against cost drivers such as electricity and statutory prices; replacement of obsolete and ageing equipment; cost related to skills competitiveness; and limited State funding for research equipment and infrastructure.

LOOKING FORWARD

Over the last 25 years, the National Facilities have flourished under the leadership of the broader National Research Foundation. They have also delivered, and continue to deliver, on all areas of the NRF's Vision for Transformation, Impact & Innovation, Excellence and Sustainability (TIES) in order to achieve **'Research for a better society'.**

All National Facilities, with the assistance of their partners and users, have made fundamental progress in terms of providing cutting-edge research infrastructure for the South African National System of Innovation. These Facilities not only service the South African research system, but also the regional and international research communities. Unquestionably, the National Facilities have firmly positioned South Africa and Africa within the global research infrastructure network.

The National Facilities' research infrastructure, in many cases built in collaboration with international partners, has demonstrated that South Africa has all the necessary expertise for building and the management of world class research infrastructure. These strengths include a deep competence in foundational research, innovation, engineering, project management, project finance and governance. When these strengths are combined with consistent and long-term Government support, through the progressive Department of Science and Innovation, South Africa can, and will continue to, play a leading role in the provision of cutting-edge global research Infrastructure.

In conjunction with the provision of research infrastructure, the National Facilities have actively addressed the inequities of the country's past through the development of a transformed cohort of postgraduate students and the next generation of researchers. In some disciplines, such as radio astronomy, this transformation was initiated off a very low base. The thriving research community around MeerKAT is testament to what can be achieved through directed, focused and sufficiently-funded interventions.

At any milestone anniversary, an organisation must reflect on its purpose and also how it should position itself moving forward. Globally, many within the research community have recognised that research cannot and should not work in isolation from society. How one best articulates the value of research to society is a discipline in itself. The NRF has adopted an Impact Framework that outlines the need to convert traditional research outputs such as postgraduate graduations, peer reviewed publications, etc., into short- and long-term outcomes and impact. The current suite of National Facilities has quickly adapted to using its traditional strengths in the areas of foundational research and infrastructure provision towards the achievement of societal impact and innovation.

In terms of innovation, the National Facilities have developed a comprehensive pipeline of potential applications arising from their basic research areas. Looking towards the future, the National Facilities will develop an Innovation Hub that will provide cross-cutting services to all National Facilities in terms of innovation support. A key component of the NRF's TIES strategy is that of financial sustainability. The National Facilities will, over the next decade, move towards diversification of their income streams through a combination of commercialisation of their capabilities and generation of funds through spinoff companies or licencing arrangements.



Historically, the National Facilities have operated relatively independently of the NRF, with oversight from the corporate structures. Going forward, the NRF is driving a 'One NRF' approach, which will see the National Facilities operate in a more integrated manner with each other and with the other operational areas within the NRF. This will deliver increased value and impact across the NRF. In the era of Big Data, Artificial Intelligence and precision instrumentation, the commonalities between the National Facilities are growing quickly. This provides the opportunity to collaborate and integrate operations such as engineering, data storage, data management and analysis. In addition to a more integrated NRF, a key imperative must be a concerted effort to ensure that the National Facilities and the 13 'new' research infrastructures associated with the DSI's South Africa Research Infrastructure Roadmap (SARIR) programme are aligned. Many of the new infrastructures have aligned or complementary mandates and, as such, offer the potential for deeper collaboration. The ability of the National Facilities to drive TIES is directly linked to the significant support that the National Facilities receive from their partners, users, collaborators and funders. Going forward, the National Facilities will deepen their collaborations with all actors within the NSI through the provision of new infrastructure, joint appointments, co-created research access programmes that link research infrastructure, grants and bursaries, joint research and innovation projects and shared research infrastructure.

Lastly, but certainly not least, is the recognition that a key gap in the suite of National Facilities is that of research infrastructure that supports the Humanities and Social Sciences (HSS). The NRF has recognised this as an area for further development and is currently investigating how best this research community can be serviced and supported through large-scale HSS infrastructure.









Angus Paterson

Deputy CEO, National Research Infrastructure Platforms at NRF

CONTRIBUTORS

We would like to thank the National Facility content coordinators and the many authors without whose contributions this record of achievement across the NRF National Facilities network would not have been possible.

NATIONAL RESEARCH FOUNDATION (NRF)

Fulufhelo Nelwamondo, PhD
Chief Executive Officer
Angus Paterson
Deputy CEO, National Research Infrastructure Platforms at NRF
Genevieve Simpson
Director: Research, Analysis and Advice, NRF Digital Transformation

NRF-SAIAB

Albert Chakona
Chief Scientist; Acting Managing Director
Lucky Dlamini
Communications and Stakeholder Relations Manager
Josephine Pegg
Research Associate
Francesca Porri
Senior Scientist
Kerry Sink
Marine Programme Manager and Principal Scientist, SANBI
Rosemary Dorrington
DSI/NRF SARChI Professor: Marine Natural Products Research
Mandla Magoro
Instrument Scientist: Freshwater Field Ecologist
Roxanne Higgitt
Research Manager SA-UK Antimicrobial Drug Discovery Hub
Taryn Murray
Instrument Scientist: Acoustic Tracking Array Platform
Ryan Palmer
Marine Platform Manager
Julie Coetzee
SARCHI Chair; Principal Scientist

NRF-SAAO

Rosalind Skelton
Acting Managing Director
Encarni Romero Colmenero
Deputy Director: SALT
Stephen Potter
Head of Astronomy
Hitesh Gajjar
Head of Instrumentation
Sivuyile Manxoyi
Head of SALT Collateral Benefits Programme
Daniel Cunnama
Science Engagement Astronomer
Patricia Whitelock
Consultant
Kathryn Rosie
Mechanical Engineer
Thembela Mantungwa
Communications Officer
Anja Schroeder
SALT Editor and Research Associate
Kevin Govender
Director: IAU-OAD

NRF-SAEON

Mary-Jane Bopape
Managing Director
Jennifer Veitch
Physical Oceonographer
Kogie Govender
Science Engagement Coordinator
Caitlin Ransom
Environmental Science Education and Communications Officer
Helga van der Merwe
Arid Systems Ecologist
Tshililo Ramaswiela
Field Technician: Arid Lands Node
Leo Chiloane
Manager: uLwazi Node
Susan Janse van Rensburg
Node Coordinator: Grasslands
Michele Toucher
Hydrologist
Nicole du Plessis
Science Officer: Egagasini Node
Juliet Hermes
Manager: Egagasini Node and SAPRI
Thomas Bornman
Manager: Elwandle Node and SMCRI
Tammy Morris
Ocean and Polar Coordinator
Lara Atkinson
Offshore Benthic Ecologist
Londiwe Mabuza
Research Administrator
Ryan Blanchard
Manager: Fynbos Node
Tony Swemmer
Manager: Ndlovu Node
Paul Gordijn
Ecological and Data Technician: Grasslands Node
Lindokuhle Dlamini
PDP Postdoctoral Candidate: Grasslands Node
Gregor Feig
Manager: EFTEON

NRF-SARAO

Pontsho Maruping
Managing Director
Adrian Tiplady
Deputy Managing Director
Fernando Camilo
Chief Scientist
Kim Anthony
HCD Head
Mark Johnson
Principal Intellectual Property Officer
Justin Jonas
Chief Technologist

NRF-iThemba LABS

Victor Tshivhase
Managing Director
Bruce Mellado
Senior Scientist (Joint appointment: Wits/iTL)
Deidre Prince
Head: Nuclear Medicine Department
Elena A. Lawrie
Research Scientist: SSC laboratory
Gillian Arendse
Manager: Communication and Stakeholder Relations
Le Roux Strydom
Head: Accelerators Operations and Technical Support
Malik Maaza
Africa Chair (U2ACN2): Nanoscience and Nanotechnology
Peane Maleka
Head: SSC laboratory
Retief Neveling
Research Scientist: SSC laboratory
Rudzani Nemutudi
Deputy Director
Vincent Spannenberg
Head: Finance and Business Administration

ACRONYMS

The list of acronyms has been restricted to those that are in common usage or appear frequently throughout the document.

ACEP	African Coelacanth Ecosystem Programme
AFRODITE	AFRican Omnipurpose Detector for Innovative Techniques and Experiments
CERN	*Conseil Européen pour la Recherche Nucléaire*, or European Council for Nuclear Research
CSIR	Council for Scientific and Industrial Research
DACST	Department of Arts, Culture, Science and Technology
DSI	Department of Science and Innovation
EFTEON	Expanded Freshwater and Terrestrial Environmental Observation Network
ESEP	Environmental Science Education Programme
FRD	Foundation for Research Development
GSN	Graduate Student Network
HartRAO	Hartebeesthoek Radio Observatory
HDIs	Historically Disadvantaged Institutions
HEIs	Higher Education Institutions
MPAs	Marine Protected Areas
NASA	National Aeronautics and Space Administration
NASSP	National Astrophysics and Space Science Programme
NRIP	National Research Infrastructure Platform
NSI	National System of Innovation
NVP	National Ventilator Project
OAD	Office of Astronomy for Development
RI	Research Infrastructure
SA	South Africa
SAIF	South African Isotope Facility
SAINTS	Southern African Institute for Nuclear Technology and Sciences
SANBI	South African National Biodiversity Institute
SANParks	South African National Parks
SAPRI	South African Polar Research Infrastructure
SARIR	South African Research Infrastructure Roadmap
SDGs	Sustainable Development Goals
SMCRI	Shallow Marine and Coastal Research Infrastructure
SOMISANA	Sustainable Ocean Modeling Initiative: A South African Approach
STEM	Science, technology, engineering, and mathematics
TIP	Technology Innovation Platform
U2ACN2	UNESCO-UNISA-Africa-Chair for Nanoscience and Nanotechnologies
UCT	University of Cape Town
WIO	Western Indian Ocean

TERMINOLOGY

The list provided below represents a selection of abbreviations with a particular technical application in the context in which they are used and is not exhaustive.

ADD	Antimicrobial Drug Discovery
AGN	Active Galactic Nuclei
AMR	Antimicrobials Resistance
CAGR	Compound Annual Growth
CCD	Charge Coupled Device
cGMP	current Good Manufacturing Practices
CORS	Continuously Operating Reference System
CPAP	Continuous positive airway pressure
EAF	Ecosystem Approach To Fisheries
Ecotone	A transitional zone by which two biomes are separated
ESKAPE	*Enterococcus faecium, Staphylococcus aureus, Klebsiella pneumoniae, Acinetobacter baumannii, Pseudomonas aeruginosa and Enterobacter* spp.
GIS	Geographic Information System
GNSS	Global Navigation Satellite Systems
ha	Hectares
HCD	Human Capital Development
HPC	High-Performance Computing
HRS	High-Resolution Spectrograph
IFU	Integral Field Unit
IO	Intelligent Observatory
km	Kilometres
LERIB	Low Energy Radio-isotope Beam Production
LFC	Laser Frequency Comb
LTER	Long-Term Ecological Research
LTO	Long-Term Observations
m	Metres
m.a.m.s.l.	Meters above mean sea level
MaxE	Maximum Efficiency spectrograph
NETs	Neuroendocrine Tumours
NPs	Natural Products
NTP	Nuclear Radioisotopes
OCT	Optical Coherence Tomography
PET	Positron Emission Tomography
PG	Parliamentary Grant
R&D	Research and Development
RI	Research Infrastructure
SLR	Satellite Laser Ranging
SPECT	Single-photon Emission Computed Tomography
SSC	Separated Sector Cyclotron
TAT	Targeted Alpha Therapy
VLBI	Very Long Baseline Interferometry











science & innovation

Department:
Science and Innovation
REPUBLIC OF SOUTH AFRICA

NRF National Research Foundation 25