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DRAFT

White Paper on Science, Technology and Innovation



science
& technology

Department:
Science and Technology
REPUBLIC OF SOUTH AFRICA



**The Minister of Science and Technology,
Ms MT Kubayi-Ngubane, has released this draft of the
2018 White Paper on Science, Technology and Innovation for public consultation.**

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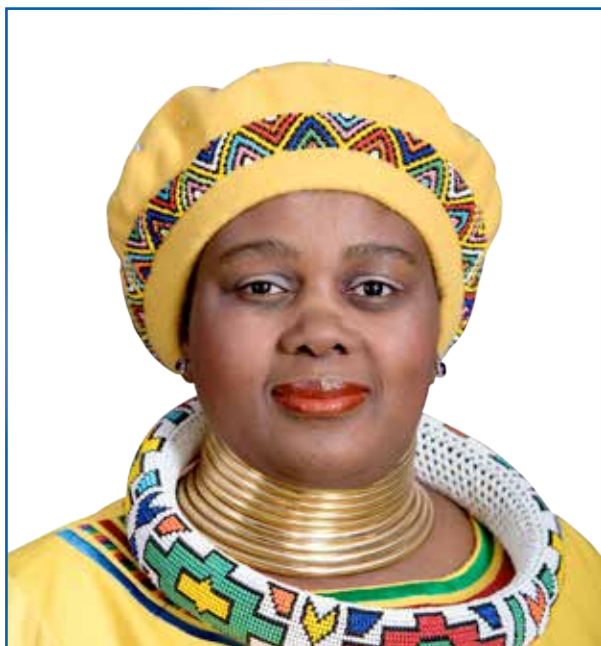
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“Scientific inventions, at all conceivable levels, should enrich human life ...”

Chief Albert Luthuli (first African winner of the Nobel Peace Prize)

Oslo, December 1961

Minister's Foreword



Since the adoption of the White Paper on Science and Technology in 1996, shortly after the advent of democracy, the South African government has been committed to using science, technology and innovation (STI) to develop the country and overcome the legacy of apartheid.

Recent reviews show that the South African National System of Innovation (NSI) has made significant progress between 1996 and 2016. For instance, the STI institutional landscape has expanded and the number of publications has grown three-fold. The participation of black people and women in the research and development workforce has increased considerably, and doctoral graduation rates have risen.

There are, however, still challenges. The NSI is not yet fully inclusive, and since 1996, South Africa's innovation performance (measured in patents and products) has

been relatively flat. Moreover, the world is continuously changing in significant ways due to rapid technological change, geopolitical shifts like the rise of India and China as economic superpowers, rapid urbanisation and the growing proportion of young people in South Africa, coupled with very high youth unemployment – to name a few. The Fourth Industrial Revolution, with its attendant risks and opportunities is also upon us. South Africa therefore needs updated policy responses to expand the role that STI can play in for instance re-industrialisation, service delivery, modernising the agricultural sector, and mitigating environmental degradation.

It is therefore with great pleasure that I introduce the Draft 2018 White Paper on STI which sets out government's long-term policy approach for the STI sector.

The Draft 2018 White Paper on STI is based on extensive review of various aspects of the NSI, as well as consultation with a wide range of role players such as relevant government departments, civil society, business and academia.

The Draft 2018 White Paper on STI emphasises the core themes of inclusivity, transformation, and partnerships. Proposals are made to address policy coherence, human capital development, knowledge expansion, innovation performance and increased investment. The aim is to build on our successes and adopt new approaches where required, so as to foster an NSI in which creativity, learning and entrepreneurship can flourish.

The National Development Plan (NDP) has identified STI as primary drivers of economic growth, job creation and socio-economic reform. The White Paper will be followed by a new Decadal Plan, which will ensure the implementation of the policy. However, the extent to which we thrive as a country will depend on how well we can ready ourselves for the dramatic changes coming to the world we know, and STI lies at the heart of this preparation.

MS MT KUBAYI-NGUBANE

MINISTER OF SCIENCE AND TECHNOLOGY, MP

DATE: 10 SEPTEMBER 2018

Deputy Minister's Foreword



Since the advent of democracy, a number of policies and planning frameworks have been developed to shape the growth and development trajectory of South Africa. While government has made significant progress in improving the socio-economic conditions of South Africans, the inter-linked challenges of unemployment, poverty and inequality remain.

On the science, technology and innovation (STI) front, the 1996 White Paper on Science and Technology was introduced. It is now 22 years since then and the global and local economies have seen major shifts. For instance, rapid technological advancement and the Fourth Industrial Revolution require updated STI policy responses from South Africa to thrive in this changing environment.

The Draft 2018 White Paper on Science, Technology and Innovation is therefore intended to position the national system of innovation to increase the contribution of STI to addressing the socio-economic challenges faced by South Africa.

I am confident that through efficient implementation of this new STI policy by various stakeholders in the public and private sector, the lives of our people and the fortunes of our communities will be transformed through STI.

MS ZANELE kaMAGWAZA-MSIBI

DEPUTY MINISTER OF SCIENCE AND TECHNOLOGY, MP

DATE: 10 SEPTEMBER 2018

Remarks by the Director-General



The Draft 2018 White Paper on Science, Technology and Innovation sets the long-term policy direction for the South African government to ensure a growing role for STI in a more prosperous and inclusive society. It focuses on using STI to help South Africa benefit from developments such as rapid technological advancement and geopolitical and demographic shifts, as well as respond to the threat associated with some of these global trends. In particular, the White Paper engages with the significant changes that are associated with the Fourth Industrial Revolution.

We do, however, not start from a blank slate. Since the adoption of the 1996 White Paper on Science and Technology, just after the attainment of democracy, the national system of innovation (NSI) has shown good progress. Institutions such as the Technology Innovation Agency were set up, significant advances in transformation took place, publications increased three-fold, and South

Africa built up extensive international networks through its science diplomacy efforts.

Recent reviews indicate that challenges remain, resulting in South Africa not yet fully benefiting from the potential of the NSI to help address our socio-economic problems. Policy on STI is still fragmented across government, business and civil society are not sufficiently involved, the NSI is significantly underfunded, and the participation of black people and women at the highest levels (e.g. as professors) remains too low – to name but a few.

To maximise the considerable potential of STI to help South Africa thrive in a challenging and changing environment, this Draft White Paper, while learning from what has worked in the past, introduces a number of policy shifts. Some of these relate to:

- Increasing the focus on inclusivity, transformation and linkages in the NSI.
- Enhancing the innovation culture in society and government.
- Improving policy coherence and budget coordination across government.
- Developing a more enabling environment for innovation.
- Developing local innovation systems.
- Supporting social and grassroots innovation.
- Expanding the research system.
- Developing high-level human capital.
- Endorsing a pan-African STI agenda.
- Increasing the investment in the NSI.

In the spirit of co-learning as well as to garner support for this ambitious agenda, the Draft White Paper has been based on extensive review of the South African NSI as well as input from a range of experts. Additionally, the Department received detailed technical input from relevant government departments, business, civil society and academia.

A Decadal Plan for science, technology and innovation (STI) will be developed to serve as an implementation plan for the White Paper over the period 2019 to 2029. The new decadal plan will take into consideration not only the White Paper, but also the review of the Ten-Year Innovation Plan (2008-2018), which has seen the attainment of significant milestones, as well as the results of the National Advisory Council on Innovation's 2018 foresight exercise.

With the release of this Draft White Paper for public consultation, I am confident that we will receive the input we need to refine the policy proposals to enhance implementation – thereby reaping the benefits of STI to help realise the objectives of the National Development Plan (NDP).

DR PHIL MJWARA

DIRECTOR-GENERAL, DEPARTMENT OF SCIENCE AND TECHNOLOGY

DATE: 10 SEPTEMBER 2018

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Abbreviations and Acronyms

AU	African Union
BRICS	Brazil, Russia, India, China and South Africa
DHET	Department of Higher Education and Training
DST	Department of Science and Technology
the dti	Department of Trade and Industry
GDP	gross domestic product
GERD	gross expenditure on research and development
ICT	information and communications technology
M&E	monitoring and evaluation
NACI	National Advisory Council on Innovation
NDP	National Development Plan
NRF	National Research Foundation
NSI	national system of innovation
OECD	Organisation for Economic Co-operation and Development
R&D	research and development
SADC	Southern African Development Community
SET	science, engineering and technology
SME	small and/or medium enterprise
SOE	state-owned enterprise
STI	science, technology and innovation

Glossary of Terms

Circular economy: Looking beyond the current “take, make and dispose” extractive industrial model, the circular economy is designed to restore and regenerate. Underpinned by a transition to renewable energy sources and system-wide innovation, it aims to redefine products and services to reduce waste and negative impacts.

Emerging researchers: People who are generally younger than 40 years and have not yet completed their PhDs or established themselves as active researchers, although they are employed in knowledge-based institutions.

Established researchers: People who have established themselves as independent researchers and have an active research track record. They produce the bulk of the research output and play an important role in training and mentoring younger and less experienced researchers.

Fourth Industrial Revolution: The Fourth Industrial Revolution has been defined as technological developments that blur the lines between the physical, digital and biological spheres. It integrates cyber-physical systems and the Internet of Things, big data and cloud computing, robotics, artificial intelligence-based systems and additive manufacturing. Compared to previous industrial revolutions, this one is evolving at an exponential rather than a linear pace, with potentially significant impacts on work, services, education and leisure.

Grassroots innovation: Grassroots innovation covers a diverse set of activities in which networks of neighbours, community groups and activists work with people to generate bottom-up solutions for sustainable development, in the form of novel solutions that respond to local situations and the interests and values of the communities involved, and where those communities have control over the process and outcomes.^{1|2}

Human capabilities: This implies a non-instrumental notion of human development, where developing the knowledge and skills of people has intrinsic value and goes beyond the narrowly defined science, engineering and technology skills required for the national system of innovation.

Innovation: An innovation is the implementation of a new or significantly improved product (good or service) or process, or a new marketing method, or a new organisational model in business practice, workplace organisation or external relations.

Megatrends: Global megatrends are social, economic, technological, environmental or geostrategic forces that are shaping our world in profound ways. The implications of these forces are broad and varied, and present tremendous opportunities and risks.

National Development Plan: The National Development Plan is a long-term South African development plan, developed by the National Planning Commission in collaboration with South Africans from all walks of life. It serves as an action plan for securing the future of South Africans as charted in the Constitution. It is founded on six pillars that represent the plan's broad objectives to eliminate poverty, reduce inequality and ensure a decent standard of living for all South Africans by 2030.

National system of innovation: There is no single accepted definition of a national system of innovation. What is important is the web of interaction in the system, as underscored in the following two quotations: "The network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies";³ and "that set of distinct institutions which jointly and individually contribute to the development and diffusion of new technologies and which provides the framework within which governments form and implement policies to influence the innovation process. As such, it is a system of interconnected institutions to create, store and transfer the knowledge, skills and artefacts which define new technologies".⁴

Office of technology transfer: An office of technology transfer tends to be located at a university or science council and is focused on facilitating the identification, protection and use of intellectual property that emanates from research and development for social and/or economic benefit. Researchers are the creators of this intellectual property. By managing and protecting it appropriately, the technology transfer function helps researchers to translate their intellectual property into useful and innovative products and services, creating an additional layer of impact for their research. It also gives industry access to this intellectual property to further develop and use it commercially or otherwise.

Open innovation: The basic premise of open innovation is to introduce more actors into the innovation process so that knowledge can circulate more freely and be transformed into products and services that create new markets, fostering a stronger culture of entrepreneurship and encouraging firms to use external and internal ideas, and internal and external paths to market, as they look to advance their technologies

Open science: Open science refers to an approach to research based on greater access to public research data enabled by information and communications technology tools and platforms, broader collaboration in science – including the participation of non-scientists – and the use of alternative copyright tools for diffusing research results.

Policy coherence: Achieving policy coherence involves the systematic promotion of mutually reinforcing policies across government departments in order to create synergies towards achieving agreed objectives and to avoid or minimise negative spill-overs in other policy areas. Policy coordination involves the alignment of programmes and activities across various role players in order to give effect to policy objectives.

Policy nexus: New institutional arrangements to facilitate collaboration in specific areas. Arrangements are based on written agreements that specify how to harmonise policy and coordinate the implementation of action plans.

Quadruple helix: The quadruple helix approach is grounded in the idea that innovation is the outcome of an interactive process involving government, academia/the research sector, the private sector and civil society, each contributing according to its “institutional” function in society. Inclusion of the fourth helix (i.e. civil society) is critical, as science, technology and innovation (STI) is increasingly evaluated by its social robustness and inclusivity. The fourth helix highlights new discoveries and innovations, such as eco-innovation, that help to improve social welfare.⁵

Research and development: Research and experimental development (R&D) comprises creative and systematic work undertaken in order to increase the stock of knowledge – including knowledge of humankind, culture and society – and to devise new applications of available knowledge.

Research infrastructures: Research infrastructures are facilities, resources and services used by the science community to conduct research and foster innovation.

Science diplomacy: Science diplomacy refers to scientific cooperation and engagement with the explicit intent of building positive relationships with other governments and societies. The Royal Society and the American Association for the Advancement of Science identify three main types of activities related to science diplomacy:

- Science in diplomacy: Informing foreign policy objectives with scientific advice.
- Diplomacy for science: Facilitating international science cooperation.
- Science for diplomacy: Using scientific cooperation to improve relations between countries.⁶

Social innovation: Social innovation is a sub-set of innovation which is cross-sectoral and distinct from business or technological innovation. Social innovation is context-specific; is underpinned by values; leads to specific outcomes which are a measurable improvement on existing practices; changes social relations with regard to governance; and empowers beneficiaries by increasing their socio-political capabilities and access to resources.⁷

Technology balance of payments: The technology balance of payments is a subdivision of the balance of payments which is used to collate invisible transactions relating to trade in technical knowledge and technology-related services between partners in different countries.⁸ It registers the commercial transactions related to international technology and technological know-how transfers. It consists of money paid or received for the use of patents, licences, know-how, trademarks, patterns, designs and technical services (including technical assistance), and for industrial research and development carried out abroad, among other things.

Transdisciplinarity: Transdisciplinary research is defined as research efforts conducted by investigators from different disciplines working jointly to create new conceptual, theoretical, methodological and translational innovations that integrate and move beyond discipline-specific approaches to address a common problem. A critical defining characteristic of transdisciplinary research is the inclusion of stakeholders in defining research objectives and strategies.

Executive Summary

This White Paper, which is based on extensive review of the national system of innovation (NSI), sets the long-term policy direction for the South African government to ensure a growing role for science, technology and innovation (STI) in a more prosperous and inclusive society. It focuses on using STI to accelerate inclusive economic growth, make the economy more competitive, and improve people's daily lives. It aims to help South Africa benefit from global developments such as rapid technological advancement and geopolitical and demographic shifts, as well as respond to the threats associated with some of these global trends.

Chapter 1: Introduction

More than 20 years after the adoption of the 1996 White Paper on Science and Technology, South Africa needs an updated STI policy – for two main reasons. Firstly, while reviews show good progress in the implementation of the 1996 White Paper, South Africa has not yet fully benefited from the potential of STI to advance the objectives of the National Development Plan (NDP). To illustrate, the STI institutional landscape has been expanded and there has been a threefold increase in publications, significant growth in the participation of black people and women in the research and development workforce, and a rise in doctoral graduation rates. However, challenges remain. The NSI is still not fully inclusive, and since 1996 South Africa's innovation performance (measured in patents and products) has been relatively flat. Secondly, as the world is rapidly becoming more technologically advanced, new STI policy responses are required to respond to the opportunities (such as for rapid economic growth) and threats (such as the loss of some traditional jobs) of such change.

According to recent reviews, the main factors constraining the performance of the NSI are the inadequate and non-collaborative means of STI agenda setting for the country, insufficient policy coherence and coordination, weak partnerships between NSI actors (particularly the inadequate involvement of business and civil society), inadequate monitoring and evaluation, inadequate high-level science, engineering and technical skills for the economy, an undersized research system, a poor environment for innovation, and significant levels of underfunding. If these constraining factors can be addressed, it will be possible to increase the impact of STI in South Africa. STI can be instrumental in improving public service delivery and decision making for public policy, thereby improving the quality of life of South Africans, particularly in poor communities. For instance, educational outcomes can be improved through equipping children with the thinking skills they will need in a technologically advanced world. STI can also help in increasing the competitiveness of existing firms; forming new technology-based firms; modernising existing industries such as agriculture and mining; and developing emerging industries such as those linked to the Fourth Industrial Revolution, thereby exploiting new sources of economic growth while promoting environmental custodianship to safeguard the future.

Since 1996, a solid foundation has been laid to achieve the ambitions outlined in this White Paper. To take this progress further and to realise the full potential of STI in South Africa, the vision of this White Paper is "Science, technology and innovation enabling sustainable and inclusive development in a changing world". The White Paper has three high-level goals, namely, to take advantage of opportunities presented by megatrends and technological change, to expand policy approaches that have worked and propose new approaches where necessary, and to promote a more inclusive economy at all levels.

This White Paper is not an implementation plan. The policy actions proposed here will be implemented according to decadal plans informed by technology foresight studies and consultation with all implementation partners (across government, business, academia and civil society) to ensure policy coherence and certainty. The decadal plans will detail technology focus areas, programmes to be initiated, institutional arrangements and funding required for these programmes, and ways to evaluate their performance. They will be reviewed and updated every five years, or as deemed appropriate by the Department of Science and Technology.

Chapter 2: Looking to the future

The world is changing rapidly and fundamentally. Drivers of global change are socio-economic and geopolitical

(e.g. demographic shifts, urbanisation, rising inequality and youth unemployment, and the rise of China and India as economic powers), scientific and technological (e.g. the blurring of lines between the physical and digital spheres as a result of information and communication technologies and the Fourth Industrial Revolution), and environmental (with climate change having serious consequences for the world's most vulnerable people).

These global changes have profound implications for the NSI. To illustrate, inter- and transdisciplinary knowledge is increasingly important, and research is becoming increasingly data-driven. This means that an open science approach is required to enable greater access to existing information. The success of South Africa's response to the Fourth Industrial Revolution, which will include ensuring that people are not left behind as society and the economy become more technologically driven, will depend on how well we exploit the pivotal role of information and communication technology (ICT) and harness the potential of big data. Furthermore, STI have a fundamental role to play in achieving the Sustainable Development Goals. South Africa's future is inextricably linked to that of the rest of the African continent, and therefore the potential of STI for African development and continental integration needs to be fully exploited.

To address the challenges and opportunities discussed above, the White Paper proposes several policy shifts, which are summarised below.

Chapter 3: A coherent, inclusive national system of innovation

In addition to measures to support partnerships among NSI actors at all levels, interventions aimed at improving the policy coherence and coordination, as well as the governance, of the NSI will be introduced. Among these is an Interministerial Committee on STI, under the guidance of the Minister of Science and Technology, which will set the STI agenda across government and commit public resources to priority STI programmes. The Interministerial Committee on STI will be informed by an annual STI Plenary involving government, business, academia and civil society, to be convened by the Presidency. The National Advisory Council on Innovation (NACI) will be strengthened to advise the Interministerial Committee on STI.

Policy approaches are introduced to increase coherence in critical areas such as education and skills development, the economy, and social development. Sector coordination will be improved through the adoption of collaborative sector research and development planning, as well as sector innovation funds to concentrate resources on priority sectors.

To fully exploit the potential of STI in South Africa, the STI institutional landscape will be expanded in line with the findings of the STI Institutional Landscape Review, and the governance of NSI institutions will be strengthened (including clarifying the mandates of government departments regarding public research organisations, and improving coordination across research institutions and funding agencies). Finally, policy approaches to enhance the monitoring and evaluation (M&E) capacity of the NSI will be introduced, for instance, regular foresight exercises will be conducted, and a new M&E framework for the NSI developed, with NACI being upgraded so that it can undertake this role.

Chapter 4: An enabling innovation environment in South Africa

To improve the environment for South African innovation, a number of policy approaches will be introduced, such as moving beyond research and development (R&D) to a broader conceptualisation of innovation, and supporting a whole-of-government approach to innovation (the so-called innovation compact) to ensure that all policies related to innovation (e.g. trade, competition, education and procurement policies) work together to support innovation in South Africa. Various mechanisms will be introduced to strengthen support to business (with a focus on small and medium enterprises) as well as to revitalise the role of state-owned enterprises in innovation. This White Paper further supports an enabling legislative framework, for instance, in the area of intellectual property rights from publicly funded R&D, and to increase the uptake of locally developed technologies through government procurement. The White Paper introduces policy approaches to develop local innovation ecosystems (e.g. integrating support for local and grassroots innovators into local economic development planning, and establishing more incubation facilities and local walk-in centres for innovation). To

bolster innovation for inclusive development, the White Paper introduces a significant policy shift in including civil society in STI planning at all levels, and devoting resources to developing civil society and to supporting grassroots and other neglected innovators.

The White Paper further focuses on the exploitation of new sources of growth such as the Fourth Industrial Revolution (a collaborative national platform will be established to respond to the risks and opportunities this brings), the circular economy and ICTs. The role of government as an enabler of innovation will be strengthened, for example, through programmes to build an innovation mindset from primary school level, to celebrate entrepreneurs and innovation role models, and to adopt innovative approaches throughout government operations.

Chapter 5: Expanded capabilities to support the knowledge enterprise

To exploit the full potential of knowledge, this White Paper aims to expand research outputs and transform the research institutional landscape, for instance, through programmes to improve the performance of historically disadvantaged universities. Furthermore, building on and expanding successful approaches over the past two decades, the profile of the researcher base will be transformed (for instance by activating the PhD-qualified “silent majority”, who do little research). The research system’s output of human resources will be improved (for instance through developing the human resource pipeline, providing increased support for students, increasing supervisory capacity, and transforming the demographics of the professoriate). In addition to a focus on academic outputs and PhDs, the White Paper supports a diversity of post-secondary education opportunities and the prioritisation of the development of technical skills for the economy, including a focus on education and training for a future of digital jobs.

To respond to a changing world, policy approaches are introduced to ensure an open, responsive and diverse knowledge system. These include adopting an open science paradigm, supporting a diversity of knowledge fields, a greater focus on inter- and transdisciplinary research and the contribution of the humanities and social sciences to addressing complex societal problems. The selection process of research focus areas will be institutionalised and the focus areas will be aimed at opportunities to meet the NDP’s objectives. There will be an enhanced focus on knowledge diffusion. The envisaged expansion and transformation of the research system will be further supported through policy approaches to upgrade and expand research infrastructure, including cyber infrastructure (e.g. through the establishment of a knowledge infrastructure fund at the National Treasury).

The realisation of the ambitions of this White Paper will in part depend on building an innovation culture in society and developing a science-literate and aware citizenry. The White Paper therefore pays attention to skills and institutional arrangements to support and coordinate science-engagement initiatives in South Africa. Finally, building on South Africa’s strong record in developing international STI partnerships, the White Paper introduces a systematic approach to expanding the internationalisation of STI and science diplomacy – with a strong focus on the African continent to support a pan-African agenda.

Chapter 6: Financing science, technology and innovation

Very few of the ambitions of this White Paper will be realised without adequate funding and the productive deployment of funding. The White Paper therefore recommits the government to increasing the levels of R&D investment in the economy so that gross expenditure on R&D reaches 1,5 per cent of GDP in the next decade. To achieve this target, provincial and local governments will actively contribute more to STI funding, and national STI-intensive government departments will set appropriate targets for STI in their budgets. Furthermore, the mandates of development finance institutions will be expanded to scale up funding for industrial innovation activities. International investments in STI will be appropriately positioned in South African trade and investment initiatives to attract STI-linked foreign direct investment, targeting multinational companies. As there is a specific need for increased commercialisation funding, a sovereign innovation fund will be set up to leverage co-investment by the public and private sectors.

To ensure that public STI funding is deployed productively, an STI investment framework will be institutionalised, under the auspices of the Interministerial Committee on STI, to serve as a mechanism for prioritising and allocating funds – involving collaboration between the Department of Science and Technology (DST), National Treasury and the Department of Planning, Monitoring and Evaluation in the Presidency (DPME). Finally, to improve funding efficiencies, the mandates and funding instruments and incentives of institutions such as the Technology Innovation Agency, the National Intellectual Property Management Office, parts of the Industrial Development Corporation and parts of the National Research Foundation will be harmonised, and the administrative capabilities of the relevant institutions improved (for example through simplified application procedures, improved turnaround times and standardised evaluation approaches, where appropriate).

Chapter 7: Concluding remarks

For South Africa to become a winning nation in the field of STI, and for STI to realise its potential as a driver of economic growth and social development, this White Paper introduces a number of policy shifts. The White Paper will be implemented through successive decadal plans. The indicators to measure the achievement of the policy intents expressed in the White Paper will be included in these decadal plans. To realise the intended impacts of STI in terms of sustainable and inclusive development (as envisaged in the Sustainable Development Goals and the National Development Plan), progress will be measured in inputs (e.g. investment in STI), outputs (e.g. increases in graduates, publications and patents) and outcomes (e.g. improved partnerships between NSI actors and increased policy coherence, yielding improved innovation performance).



CHAPTER 1

INTRODUCTION

Chapter 1: Introduction

Science, technology and innovation (STI) embody some of the best qualities of humanity, such as curiosity, creativity and aspirational thinking. Governments that invest, for instance, in STI in health and education, can vastly improve the quality of life of citizens and support social progress and stability. Furthermore, economists associate the competitiveness and long-term economic growth of nations with technological progress. Being such powerful drivers of change, science, technology and innovation have to be coordinated by government working with business, academia and civil society to ensure STI-led economic growth that is inclusive and environmentally sustainable.

In 1996, with the adoption of the White Paper on Science and Technology, the South African government committed to using STI to support the development of the country and to help overcome the legacy of apartheid. Twenty-two years later, building on STI-related achievements since 1996 and using South Africa's abundant resources, STI can significantly contribute to realising the National Development Plan's Vision 2030 and helping citizens thrive in a world where rapid technological change is both creating opportunities for improved quality of life and increased national competitiveness, and putting some traditional jobs at risk. As a small, open economy being impacted by these changes, South Africa needs to further develop its STI capabilities to respond to, and benefit from, the changing environment.

This White Paper sets the medium to long-term policy direction for government to ensure a growing role for STI in a prosperous and inclusive society in which the potential of all South Africans is realised. It proceeds from the starting point that, as Africans, we share a common history and, as humankind, a common future.

1.1 Why a new White Paper on STI?

There are two reasons for South Africa to renew its STI policy. Firstly, in a rapidly changing techno-economic environment, no White Paper can endure unchanged for two decades. Global megatrends such as demographic shifts, technological change and environmental degradation render even the near future uncertain and require new STI policy approaches. Secondly, recent reviews indicate that South African society has not yet fully realised the potential of STI to address the country's challenges.^{9|10|11}

1.2 The policy context

1.2.1 South Africa's socio-economic landscape

Social issues

Despite progress over the past two decades, poverty and unemployment still afflict most of the population. South Africa has among the highest inequality rates in the world. In 2014, 21,5 per cent of South Africans lived below the poverty line.¹² Black South Africans, particularly black women, continue to bear the brunt of poverty. Unemployment was 36 per cent in 2017 and remains racially skewed. Youth unemployment increased from 30 per cent in 1994 to 40 per cent in 2013, leaving many young people, most of them black, on the margins of society.¹³

"No modern society has scaled the heights of social progress without science and technology ... harnessing the force of science and technology to meet South Africa's developmental needs is among the surest ways out of the current quagmire of under-development ... research has shown that nations such as Japan, South Korea and Germany put science, technology and innovation in the service of their societies, with commendable results."

Kgalema Motlanthe, former president of South Africa, addressing the 2013 South African Science, Technology and Innovation Summit

Despite steady increases in enrolment at schools and universities,¹⁴ a report by the Human Sciences Research Council shows that South Africans continue to underperform in mathematics and science compared with other countries – an impediment to economic growth.

Economic issues

Economic growth has faltered, and the current account deficit has widened. Business confidence is low. The economy has underperformed compared to other emerging markets and commodity exporters. There is potential to increase the productivity of the South African economy through skills development, innovation, regulatory reform, investment in infrastructure, and information and communications technology. Greening the economy will be an important adjunct to such efforts.

The decreasing contribution of the productive sectors to South Africa's GDP is balanced by a shift towards services - a global phenomenon. However, it remains necessary over the short to medium term for South Africa to modernise and strengthen productive sectors such as manufacturing, mining and agriculture to absorb larger numbers of low-skilled workers. Increasing mechanisation and technological development run counter to this goal, presenting a complex techno-socioeconomic problem.

1.2.2 The National Development Plan

The National Development Plan Vision 2030 was introduced in 2011 to serve as South Africa's long-term planning framework. At the heart of the NDP lies the vision of creating a "virtuous cycle of growth and development", with success "measured by the degree to which the lives and opportunities of the poorest South Africans are transformed in a sustainable manner".¹⁵ The NDP envisages STI playing an important role in achieving its vision for 2030.

The NDP acknowledges that economic development takes time and that innovation should grow in importance in years to come. In the first phase (2012–2017), the focus should be on "intensifying research and development spending, emphasising opportunities linked to existing industries". In the second phase (2018–2023), the "country should lay the foundations for more intensive improvements in productivity" and "innovation across state, business and social sectors should start to become pervasive". As 2030 approaches, "the emphasis should be on consolidating the gains of the second phase, with greater emphasis on innovation, improved productivity, more intensive pursuit of a knowledge economy, and better utilisation of comparative and competitive advantages in an integrated continent".

The role of STI in South Africa's National Development Plan

The aim of the NDP is to address a set of core outcomes covering the following 14 focus areas: education, health, safety and security, economic growth and employment, skills development, infrastructure, rural development, human settlements, local government, environment, international relations, public sector, social protection, nation-building and social cohesion.

As will be evident from this White Paper, science, technology and innovation are key enablers that cut across all these focus areas. Subject to conditions such as social stability, investment in STI, education and skills development, science, technology and innovation are one way of feeding a virtuous cycle of economic growth and employment in the country.

Furthermore, effective STI policies and programmes will help ensure that gains made in addressing the NDP core outcomes will not be reversed by the impact of the Fourth Industrial Revolution, which is already fundamentally altering the nature of societies and business across the globe.

1.2.3 The evolution of the global STI policy environment

South Africa must take cognisance of the changing global STI environment. Policy trends across Organisation for Economic Co-operation and Development (OECD) countries have various implications for South African STI policy. Foremost among these is that OECD countries are shifting the composition of their STI funding by increasing public financial support to firms (at the expense of public research), amid a projected stabilisation of public R&D budgets. The OECD group is focusing on immediate economic priorities and policy efficiency gains (public research capacity, business innovation and entrepreneurship, governance, and framework conditions), rather than long-term issues (structural adjustment, sustainability and green growth). The OECD group is further setting up an agenda to advance responsible research and innovation.

A South African focus on responsible research and innovation would help local researchers to collaborate and compete with their foreign counterparts in a world where ethical concerns (for example, fair trade) and environmental concerns (such as emission standards) are increasingly influencing competitiveness.

Access to R&D funding has become increasingly competitive and countries are developing their research systems accordingly, and South Africa will have to follow suit. Any strategy to attract foreign R&D funding would have to take the shifting patterns of global funding into account, particularly the increasing role of large firms in the national R&D effort (meaning that international collaborative efforts will have to shift to firms). South Africa needs to concentrate on increasing the research capacity of domestic firms and strengthening their competitiveness in global value chains.

1.2.4 Looking to the future

Various megatrends (such as population growth and urbanisation), as well as technological advances are increasing uncertainty. These changes present opportunities and threats (for example, a changing manufacturing environment can lead to economic growth but also to the loss of traditional jobs). These intersecting megatrends span the geopolitical, economic, social, technological and environmental spheres. Innovation is required to address needs arising from these megatrends, such as protecting the environment and improving service delivery.

The lines between physical, digital and biological systems are becoming blurred, and governments around the world are planning for the Fourth Industrial Revolution. In particular, it is necessary to prepare for the ways in which artificial intelligence (AI) and advances in ICT will change the way society and the economy function.

New market opportunities are opening up. For example, the growth of a middle class in emerging economies and the high proportion of young people in national populations (the so-called “youth bulge”) in Africa are stimulating manufacturing, widening markets for mobile telephones, and creating ICT-enabled job opportunities for young entrepreneurs in the services sector. South Africa can benefit from these emerging market opportunities by using technology to modernise sectors such as agriculture and mining, and increase exports to growing markets in Africa and other emerging economies.

Already, traditional jobs are being lost to automation and traditional commerce is being disrupted by the move to online, fast, personalised services and products. The role of cryptocurrencies in the digital economy is uncertain.

The possibilities are exciting and the implications vast. Only countries that are prepared for these changes will thrive and STI lie at the heart of this preparation.

1.3 The evolution and performance of the national system of innovation, 1996 to 2016

1.3.1 South African STI policy since 1996

In 1994, the newly elected government inherited a fractured society, a fiscally drained state and an unsustainable, resource-intensive economic growth path. The pre-1994 STI system was small, exclusive and in line with the agenda of the apartheid state, rather than oriented towards inclusive sustainable economic development and social equity.

The democratic government began a period of comprehensive STI policy development. It adopted the 1996 White Paper on Science and Technology, the 2002 National Research and Development Strategy, and the Ten-Year Innovation Plan for South Africa (2008-2018). Various sectoral and cross-cutting STI strategies were also adopted for areas such as advanced manufacturing technology, biotechnology and human resource development. The organising framework for the 1996 White Paper, and the STI policies following on the 1996 White Paper, was that of a national system of innovation (NSI) – guided by prevailing global approaches to enhancing innovation performance. The 1996 White Paper conceptualised the NSI as “a set of functioning institutions, organisations, and policies which interact constructively in the pursuit of a common set of social and economic goals and objectives”.

The aim of early post-1994 STI policy development was (i) to transform the STI system to serve all South Africans, (ii) to counter STI policy fragmentation, (iii) to expand and transform human resources, (iv) to provide more support for research, (v) to build the required STI institutions, (vi) to increase innovation to support economic growth and socio-economic development, and (vii) to increase the financial resources to the system. Progress on these seven objectives can be traced throughout the discussion below on the high-level performance of the NSI.

1.3.2 High-level overview of the performance of the national system of innovation, 1996 to 2016

Developing the national system of innovation

As stated above, the 1996 White Paper adopted the concept of the NSI as an organising framework for STI policy and implementation. Since then, progress has been made in developing the required NSI institutions, such as the Technology Innovation Agency and the National Research Foundation (see Chapter 3 for more detail). Linkages have been strengthened and public support to business is growing (for example, through the R&D tax incentive, the sector innovation funds and other public-private partnerships). Science, technology and innovation are increasingly being incorporated into government plans, countering policy fragmentation to some level. The most significant indication that STI is being integrated into government planning is the central role of STI in the NDP. While challenges remain – for example, South Africa’s NSI is still too small and STI programmes are still fragmented – the government’s effort in setting up institutions, building NSI relationships and facilitating the coherence of STI programmes is beginning to have results.

Expanding the research system, and developing and transforming high-level human capital

Various instruments have been introduced to expand the research system, including the South African Research Chairs Initiative and the Centres of Excellence. Among the beneficial effects of these instruments was that they enabled the concentration of investment in South African research in areas of strategic importance. As a result, South African scientists are among the best in the world in fields such as clinical medicine, space science, computer science, pharmacology and toxicology, physics and immunology.

South African researchers have established productive international networks. Between 1996 and 2014, although the number of university research staff did not increase, research output trebled. PhD student enrolment increased by 350 per cent,¹⁶ which is encouraging, although it does strain supervisory capacity.

The participation of black people and women in the research system has grown substantially. In 2013/14, including doctoral and postdoctoral students, women comprised 44 per cent of R&D personnel, and black people 52 per cent. However, significant inequality persists, especially at the higher levels. Black women and men make up less than 5 per cent and 20 per cent of professors, respectively.¹⁷

Advancing South Africa's innovation performance

While South Africa's innovation performance between 1996 and 2016 has been relatively flat, there are encouraging recent trends. The 2016 Global Innovation Index showed that South Africa is strong in market sophistication and investment, and aspects of knowledge absorption and knowledge impact.¹⁸ Patent cooperation treaty applications have doubled, and South Africa's registration of plant cultivars is the highest in Africa and ranks 14th globally. While the technology balance of payments shows that South Africa remains a net importer of technology, there are large revenue flows from South African firms trading abroad in retail, financial services, communications, leisure, construction and logistics.

Increasing the financial resources of the NSI

Gross expenditure on research and development (GERD) as a percentage of gross domestic product (GDP) has not yet reached the 1,5 per cent target level, but it has held steady at about 0,7 per cent in a challenging economic environment, with the beginnings of a possible long-term upward trend apparent. Public resources for both public and private-sector STI have increased significantly (the DST's expenditure has increased nine-fold).

Overview of NSI challenges

According to recent reviews, the main factors constraining NSI performance are the following:

- Inadequate and non-inclusive means of agenda setting.
- A lack of policy coherence and coordination.
- Inadequate mechanisms for policy learning.
- Insufficient involvement of business and civil society.
- Inadequate high-level SET and technical skills for the economy.
- A research system that is too small.
- An environment that does not sufficiently enable innovation.
- Significant levels of underfunding.

Vision

Science, technology and innovation enabling sustainable and inclusive South African development in a changing world

Objectives

- Improved NSI partnerships, coherence and coordination.
- Strengthened and transformed NSI institutions.
- Increased human capabilities.
- Expanded research enterprise.
- Enhanced enabling environment for innovation.
- Improved financing NSI funding regime.

Approach

In pursuing these objectives, the approach will be to:

- Expand what has worked and propose new approaches where necessary.
- Take advantage of opportunities presented by megatrends.
- Promote inclusivity and transformation.

1.5 The implementation of the White Paper

This White Paper sets the medium to long-term policy direction for the NSI. It is informed by analysis of the evidence from a number of reviews of the NSI, experience gained in the implementation of STI policy over the past 20 years, and consultation with NSI partners – including both state actors such as STI-intensive government departments, universities and science councils, and non-state actors such as civil society, labour and business.

The White Paper is not an implementation plan. Its implementation will be directed by decadal plans, informed by foresight studies and consultation with all implementation partners to ensure policy coherence. The decadal plans will be reviewed every five years, or as deemed appropriate by the DST.

The role of the decadal plan in implementation and technology choices

It is the function of policy to set medium to long-term government policy direction, as in this White Paper. For a number of reasons, it is not the function of policy to present a detailed implementation plan or to prescribe specific technology choices

However, policy without a detailed, although evolving, implementation plan will have little impact. The decadal plans – which will be reviewed regularly based on implementation outcomes and technology foresight – will present technology focus areas to ensure that South Africa does not fall behind. Furthermore, these plans will provide specific guidelines to enable collective action across South African society on aspects such as how to make the required investments, which specific partnerships to develop over which period, and which indicators to use to measure progress.



CHAPTER 2

LOOKING TO THE FUTURE

Chapter 2: Looking to the Future

The world is rapidly changing and countries are grappling with how to use scientific advances to meet new challenges and build resilience in a fragile world. The potential of STI lies in helping South Africa and its NSI respond, not only to current problems, but also to opportunities offered by a changing, increasingly connected and globalised environment. The next section (Section 2.1) briefly examines the drivers of change, leading to a discussion of the implications of these drivers for the NSI (Section 2.2).

2.1 Drivers of global change

Social	<ul style="list-style-type: none">• Exponential population growth will see the global population reaching ~11 billion by 2100, increasing competition for resources.• Populations are aging and by 2050, 80% of older people will live in the developing world; and of these, 80% will have no regular income.• The youth “bulge” in Africa, coupled with high youth unemployment, drives inequality and social instability.• By 2050, the northern regions will be 84% urbanised and Africa 62% urbanised, which has potential for economic growth, but may also expose people to marginalisation, conflict and exploitation.• Increasing uncontrolled migration from war-torn and poverty-stricken regions to developed countries is already leading to social instability.• International mobility of highly educated individuals, supported by digital technologies, is driving global knowledge circulation. However, higher mobility also means higher competition for these human resources, with its attendant risks such as an African brain drain.• Slow progress on the gender agenda in many countries has the effect of stifling socio-economic growth.
Scientific and technological	<ul style="list-style-type: none">• Modern science and data are expanding exponentially, and scientists have access to an increasing range of data from multiple sources with variable quality.• Rapid change in and between disciplines is happening, science breakthroughs come about more quickly, and are translated into innovations faster.• The Fourth Industrial Revolution (FIR) is blurring lines between the physical and digital spheres, with legal, ethical and socio-economic consequences. The FIR further has consequences for public services, and the way we work, learn, produce, consume and interact.

Economic	<ul style="list-style-type: none"> • In 2017, 70% of the global population was living in countries where income inequality is increasing, stifling economic growth, health and education outcomes, as well as stability. • Young people are increasingly exposed to income inequality, thereby squandering the demographic dividend of countries with large young populations. • Technological change can promote social inclusion and economic growth, but can also cause the loss of many traditional jobs – a dire prospect, given South Africa’s high unemployment and high proportion of unskilled workers. • A growing middle class and increasing consumerism in emerging economies will increase the demand for goods and services worldwide. • Despite a backlash against the disruptive effects of globalisation, analysts do not foresee the large-scale retreat of globalisation. Instead of protective policies, a concerted effort towards more sustainable governance of the global economy would be the answer.
Environmental	<ul style="list-style-type: none"> • The challenges of climate change, and the degradation of the natural environment e.g. biodiversity loss will increasingly shape policies. The concept of a circular economy will likely come to dominate future growth discourse. • New policies will require new technologies, processes, services and business models.
Geopolitical	<ul style="list-style-type: none"> • The axis of the world’s economic and geopolitical power is shifting from west and north, to east and south, and the international landscape is increasingly multipolar. • These geopolitical shifts will create opportunities for South Africa and the African continent as a whole, provided inclusive long-term modernisation of the continent takes place and infrastructure investment is increased, e.g. in broadband.

It is imperative, therefore, that the South African government steers the STI system and shapes the evolution of an STI policy that can, not only respond to future risks and opportunities, but can also help shape the future.

2.2 Implications of the drivers of change for science, technology and innovation in South Africa

The drivers of global change have significant implications for South Africa’s STI policy. The remainder of this chapter defines the main ways in which policy should respond to these changes – thus serving as background for the rest of the White Paper.

2.2.1 Changing socio-technical systems

Current innovation thinking does not adequately respond to a world in rapid transition.¹⁹ A shift is required from thinking about systems in isolation to considering entire socio-technical systems and the values underlying them.ⁱ

In South Africa, which is still grappling with the legacies of its apartheid past, a focus on the evolution of socio-technical systems and their underlying values is acutely relevant. For example, apartheid spatial development patterns continue to obstruct the development of the inclusive systems of mobility. These insights have profound implications for South African STI policy, how programmes are conceived and implemented, as well as how impacts are evaluated.

ⁱ The current focus is on individual systems, for instance, a transport system. However, because of increasing inter-connectedness, this focus should shift from individual systems to entire socio-technical systems, for example a system of mobility (rather than a transport system). A socio-technical system links any number of related individual systems, e.g. fuel infrastructure, vehicle production, cultural practices and norms regarding public transport, road infrastructure and traffic systems, maintenance and distribution systems, and industry structures.

2.2.2 Embracing trans-disciplinarity and evolving research systems

Interdisciplinary research teams, and the integration of knowledge from different disciplines as well as from users, are necessary to deal with the complexity problems. This is increasingly being viewed by scholars and policy makers as “science for the future”, and as an example of strengthening the relationship between science and society by putting social concerns at the core of scientific research. Mainstreaming open science will allow universities, research centres and society to take advantage of the benefits of collaborative, transdisciplinary approaches to knowledge development and sharing.

2.2.3 Expanding knowledge development

An increased investment in science is critically important, since it is investment in science that has enabled knowledge breakthroughs in, for example, biotechnology, artificial intelligence, nanotechnology, synthetic biology and the basic sciences more broadly. Moreover, benefiting from technological change and the megatrends described in this chapter requires that the scientific knowledge base of the NSI be expanded across all scientific disciplines.

Basic research (in the physical, mathematical and life sciences) is essential for building the South African economy and keeping it competitive globally – thus giving effect to the basic social contract between science and society. Currently, South Africa has to compete with international competitor countries who have been pouring resources into scientific investment, and have adopted long-term planning and funding horizons. If we want to craft an innovative edge, then we must make funding for scientific research a national priority.

As the leading STI countries around the globe are all expanding their scientific base in order to remain at the forefront of knowledge development, the competition for high-level skills and for investment in science projects will increase exponentially. South Africa’s diaspora scientists remain a vastly untapped resource. Hence, South Africa needs to look beyond the “brain drain” and take advantage of its overseas community by strengthening international networks of diaspora scientists. Knowledge networks through which diaspora scientists can organise scientific exchanges, educational programmes, and other opportunities to build capacity and encourage innovation and knowledge production, need to be supported, both in their home country and their host countries. Properly leveraged, these “brain circulation” networks could help drive innovation and knowledge generation in South Africa, and improve science diplomacy between countries.

2.2.4 Facilitating open science and open innovation

Open science and open innovation represent significant opportunities for growing STI output and impact. Open science is a practice in which research and other data, including laboratory notes and other research processes, are made freely available under terms that allow people to re-use, redistribute and reproduce research and its underlying data and methods.²⁰ Increasing access to public science has the potential to make the entire research system more effective, participative and productive by reducing duplication and the costs of creating, transferring and re-using data.

Fostering digitally enabled open and collaborative innovation is also key. The basic premise of open innovation is to make the innovation process accessible to all active players so that knowledge can circulate more freely.²¹ Open innovation represents, at least in part, a reinvention of the organisational models that we have come to take for granted. In a networked world, it is no longer possible to ring-fence what we know or have invented and to create new value through internal means alone.

What is novel in collaborative innovation is the greater use of the Internet, digital technologies and social networks to foster learning, enable the co-creation of (codified) knowledge, and provide wide access to tools, data and resources.

2.2.5 Exploiting the pivotal role of ICT

South Africa will need to exploit the increasing convergence, sophistication and reach of ICT. The NDP, in particular, sees ICT underpinning a dynamic, inclusive and prosperous knowledge economy, in which seamless information infrastructure and systems will meet the needs of citizens, business and the public sector. Such a situation, in which advances in ICT are used to strengthen economic competitiveness, generate youth employment and enable an enhanced quality of life, can be described as a “digital advantage”. The attainment of digital advantage is crucial if South Africa is to participate effectively in the Fourth Industrial Revolution.

ICT is already playing an important role in transforming the educational system. More changes are expected in terms of new models for open-access, mobile, lifelong and ubiquitous learning beyond the traditional classroom. Integrating digital technologies into the provision of government services (e-government) and the management of cities (smart cities) has the potential to transform the scope and efficiency of public services.

More than ever before, research is data-driven. This means not only that the volume of data available to conduct research is growing exponentially, but also that research subjects, methods and practices, and visibility are changing irrevocably. New research fields will develop around data mining, machine learning, privacy and database interoperability to enable big data science. Big data analytics will open new research avenues and create new business models.

2.2.6 Harnessing the potential of big data

Advances in digital technology are making it possible to collect, store and process ever-expanding amounts of data generated through a wide range of systems and from a multiplicity of sources. “Big data” refers to extremely large and/or complex data sets that can be analysed computationally to reveal patterns, trends and associations, especially relating to human behaviour and interactions.

Whether it be geographical information, statistics, weather data, research data, transport data, energy consumption data, biometric or health data, the need to make sense of big data is leading to technological innovations and the development of new tools and skills. Improved analytics and processing of data will, for instance, make it possible to transform South Africa’s service industries, increase the productivity of all sectors, and achieve cost reductions through more personalised services and increases in efficiency.

The challenge is to harness the power of big data to enhance the quality of the evidence, insight and analysis that inform and shape our views. Big data presents a challenge to policy makers because it can offer real-time results that require rapid, adaptive policies in return. One of the important policy questions relates to the right trade-off between privacy, property rights and security, on the one hand, and allowing society to benefit from data-driven innovations and better ways of living, on the other hand.

2.2.7 Instilling a responsible research and innovation approach

Science, technology and innovation can help build a basis for a knowledge-based society and a healthy economy, but it can also cause harm. Although determining what is responsible is not an easy exercise as different stakeholders, with often opposing agendas, have to be taken into account, South Africans should develop a shared normative understanding of what is appropriate for our reality. A South African responsible research and innovation (RRI) approach would rest on the following pillars:ⁱⁱ (i) engagement of all societal actors throughout the process of framing societal challenges and developing joint solutions; (ii) addressing racial and gender transformation to unlock the full potential of South African society; (iii) improving the educational and skills profile of South Africans; (iv) increasing open access to STI; (v) maintaining a high level of ethics in terms of the relevance and acceptability of STI to society and environmental sustainability; and (vi) developing the required governance framework to drive the RRI agenda across the NSI.

ii Based on the 2012 European Commission’s Responsible Research and Innovation Framework, European Union.

2.2.8 Harnessing the Fourth Industrial Revolution

The Fourth Industrial Revolution is based on three sets of megatrends – physical, digital and biological²² – and involves a convergence of technologies and disciplines that is having a multisystem impact. Understanding the likely impact of the Fourth Industrial Revolution, both positive and negative, and preparing for these collectively and strategically will be key to South Africa's future resilience.

For instance, digitisation is expected to change the work environment in innovative ways, as online jobs, crowdsourcing and the ability of general workers and specialists to choose when, where and how long they work, might replace traditional employment models. Technological progress might also leave many people behind, increasing the premium for present and future workers to acquire special skills or education. Retraining and educating today's workers will be crucial to prevent skills mismatches, mass unemployment and growing inequality. Increased investment will be required to drive STI in response to these changes.

"We stand on the brink of a technological revolution that will fundamentally alter the way we live, work, and relate to one another. In its scale, scope, and complexity, the transformation will be unlike anything humankind has experienced before. We do not yet know just how it will unfold, but one thing is clear: the response to it must be integrated and comprehensive, involving all stakeholders of the global polity, from the public and private sectors to academia and civil society."

Klaus Schwab, Founder and Chairman of the World Economic Forum, 2016

2.2.9 Achieving the Sustainable Development Goals

The 17 Sustainable Development Goals (SDGs) adopted by the United Nations General Assembly on 25 September 2015 outline steps to promote economic, environmental and social well-being. The ambitious agenda of the goals presents an opportunity to experiment with and foster new forms of innovation for sustainable development. STI plays three main roles in the achievement of the SDGs. First, STI is a goal in itself as a driver of economic growth and job creation. Second, STI is central to the implementation of other goals; for example, new technological solutions can help address challenges around energy and food security. Third, scientific knowledge can help both to translate the targets associated with the SDGs into national policies and to evaluate their impact.

The idea of a circular economy is linked to the Sustainable Development Goals, but is mentioned separately for its particular relevance as a source of new growth across the globe. The concept implies systemic change and a shift to a low- or zero-waste, resource-efficient society, and entails major changes to methods of production and consumption. Beyond the potential to save materials and leave a smaller footprint on the environment, a circular economy would create economic opportunities as new services and business models emerge, transforming the relationship between producer and consumer, and products and their users.

2.2.10 Deepening African collaboration

The Southern African Development Community (SADC) and African Union (AU) strategies highlight the potential role of STI in achieving the goals of SADC and the broader objective of pan-Africanism. South Africa's linkages with the rest of Africa present opportunities to build and consolidate national, regional and continental systems of innovation. South Africa's cooperation strategies in Africa should therefore prioritise efforts to strengthen its own and partner countries' STI systems. The aim should be to promote and facilitate cross-border research networks, shared technology innovation platforms, mutual learning, an integrated African STI agenda that encourages development and competitiveness, as well as funding partnerships.

South Africa's strategic science diplomacy focus has already recognised STI as an important means of driving the developmental agendas of the AU and SADC. For instance, major minerals beneficiation projects, as highlighted in the SADC Industrialisation Strategy and Roadmap, will depend on crossborder cooperation in energy and transport infrastructure and input supply, and on the development of globally competitive industry sectors.

Some examples of how emerging materials and technologies will shape the near future

Graphene: A special form of carbon, graphene is very versatile. Its properties as the lightest and strongest material, compared with its ability to conduct heat and electricity better than anything else, mean that it can have many applications. It could be used in bioelectric sensory devices to monitor e.g. glucose levels, cholesterol and even DNA sequencing. Being flexible and thin means that graphene-based photovoltaic cells could be used in clothing; to help recharge mobile devices, or even in curtains to help power a home.

Regenerative medicine: Research in tissue engineering and molecular biology holds the promise of stimulating the body's own repair mechanisms to heal previously irreparable tissue and organs. Regenerative medicine also includes the possibility of growing tissues and organs in the laboratory and implanting them into the body when the body cannot heal itself.

Renewable energy technologies: Renewable energy is collected from sources that are renewable on a human time scale, such as sunlight, wind, rain, tides, waves and geothermal heat. Common applications are in electricity generation, air and water heating/cooling, transportation, and rural (off-grid) energy services. Advanced Energy Storage Technologies support the use of renewables to store energy during peak production and release it during peak demand. Furthermore, microgeneration technologies can be used by individuals, small businesses and rural communities to meet their own needs or supplement traditional grid-connected power.

Carbon capture and storage: This is the process of capturing waste carbon dioxide from large point sources, such as fossil fuel power plants, transporting it to a storage site, and depositing it where it will not enter the atmosphere – normally in an underground geological formation. Such technologies have the potential to mitigate the contribution of fossil fuel emissions to global warming and ocean acidification.

Artificial Intelligence (AI): AI, also known as machine learning, is intelligence demonstrated by machines in contrast to the natural intelligence of living organisms. It is the study of "intelligent agents", defined as any device that perceives its environment and takes actions to maximize its chances of successfully achieving its goals. Traditional areas of AI include the ability of machines to reason, represent knowledge, plan, learn, process language naturally, perceive and move and manipulate objects. With most businesses now investing in big data, the role of machine learning is set to increase dramatically over the next five years. For instance, by accessing and analysing data on user activity, machines can spot a potential closure of a bank account before it occurs. They can also track spending patterns and customer behaviour to offer tailored financial advice.

Modelling, Simulation and Gaming (M&S): In simple terms, M&S is a substitute for physical experimentation where computers are used to compute the results of physical phenomena. M&S is important in research, as it can represent real systems through mathematical models that simulate the dynamics of the system, and makes it possible to explore the behavior in ways that are often not possible, or too risky or too expensive in real life, for instance the testing of defense technologies. Gaming technology refers to a large range of technologies used in computer games such as facial and voice recognition, gesture control, artificial intelligence, and virtual and augmented reality. These technologies bring an interactive digital world into a person's perceived real world, and have applications in e.g. education and skills development, preventative health care and business conferencing to name just a few.



CHAPTER 3

A COHERENT AND INCLUSIVE NATIONAL SYSTEM OF INNOVATION

Chapter 3: A Coherent and Inclusive National System of Innovation

The NSI is central to South Africa's preparation for the future. This chapter focuses on how to improve the coherence and inclusiveness of the NSI, thereby realising its potential to transform society and shape a bright future for all South Africans.

3.1 Progress, gaps and focus areas in developing the NSI

The 1996 White Paper conceptualised the NSI as a “set of functioning institutions, organisations, and policies which interact constructively in the pursuit of a common set of social and economic goals and objectives”. It adopted the NSI approach to provide a coherent and integrated framework for national activities, with a focus on innovation rather than just research.

3.1.1 Progress in building the NSI and remaining gaps

Over the past two decades, meaningful progress has been made in establishing a range of institutions required for a functional system of innovation, such as the DST, the National Research Foundation (NRF), the National Advisory Council on Innovation (NACI), the South African National Space Agency (SANSa), the Technology Innovation Agency (TIA), and the National Intellectual Property Management Office (NIPMO). Furthermore, legislation governing intellectual property emanating from publicly funded research and development (R&D) has been promulgated.

However, the 2012 Report of the Ministerial Review Committee on the STI Landscape in South Africa found, among others, that the NSI is too small and not yet fully transformed, and that new governance approaches are required to address aspects such as the fragmentation of the STI effort across the NSI, and the aligning of the mandates of public research institutions to national priorities.

Although there has been progress in building government-business collaboration – for example, through increased support for industry via the R&D tax incentive and the sector innovation funds – the level of collaboration between all NSI actors needs to increase. In particular, civil society has to be brought into the formal NSI structures and networks, and support for and collaboration with business must be enhanced. A nuanced approach is required to address the unique needs of business sectors, and small and large firms, as well as to create linkages with state-owned enterprises (SOEs).

Relationships between STI-intensive departments have been strengthened. For example, the DST is working closely with the Department of Higher Education and Training (DHET) on human capital development, and with the Department of Trade and Industry on the inclusion of STI in government's plans to re-industrialise the South African economy. However, there is room for improving the incorporation of STI in the strategies of lead departments.

3.1.2 Approach to developing the NSI

South Africa was one of the first emerging countries to formally adopt the NSI approach as a way of thinking more holistically about innovation. However, the 2012 Report of the Ministerial Review Committee found that the NSI concept had not gained sufficient support across government, as well as across the NSI. The NSI remains a valuable organising concept, but it requires strong advocacy for it to become a shared goal. To this end, steps will be taken to enhance the inclusion of all innovation actors, with an emphasis on mutual learning, policy coherence and collaboration.

Actions in this White Paper to improve the functioning of the NSI relate to the following:

- Bringing more and different actors across society into the NSI fold to make it more inclusive.
- Intensifying interactions and partnerships, as well as enhancing coherence among NSI actors in pursuing common agendas.
- Improving the governance of STI institutions.
- Strengthening the monitoring, evaluation and policy learning function.

Policy intents and actions

3.2 Policy intent: Improve inclusion and build more linkages across the NSI

The themes of inclusivity and interactivity pervade this White Paper and are addressed in various ways in each chapter. A number of overarching issues are highlighted below.

3.2.1 Inclusion

The NSI concept will be retained as an organising framework, and a quadruple helix model of innovation will be encouraged to facilitate interactions and partnerships among business, government (including public research institutions), higher education institutions and civil society.

In particular, civil society is recognised as a potential link between the formal and informal parts of the NSI. Civil society serves to strengthen and incentivise collaboration with and between non-governmental organisations, public benefit organisations, publicly funded R&D institutions and science councils in identifying, developing, piloting and disseminating technology for public use. The White Paper will therefore explicitly bring civil society into the NSI fold.

In further pursuit of an inclusive NSI, and to build on the progress of the past 20 years, improving the representation of black people and women, as well as people with disabilities, will remain a priority at all levels – among undergraduates, in management positions in research programmes, in new technology-based firms, and in the professoriate (see Chapters 4 and 5).

Specific measures will be introduced to address the equality and empowerment of women, and to increase cooperation between relevant stakeholders, particularly involving the Department of Women and civil society. These will include the following:

- Improving gender representation in NSI institutions.
- Ensuring gender-sensitive research agendas.
- Providing targeted support to women researchers and techno-entrepreneurs.
- Developing gender-sensitive monitoring and evaluation mechanisms.
- Putting in place mechanisms to unearth bias against women in the NSI and to develop appropriate responses.

“Artificial Intelligence may soon become dangerously sexist as biases seep into programs, algorithms, and designs.”

www.foreignpolicy.com

3.2.2 Linkages

To increase interactions and collaboration, a more open approach to science, data and innovation will be adopted (see Chapter 5). Formal mechanisms (e.g. sector-based planning instruments) will also be institutionalised to improve interaction among actors. Furthermore, effort will be directed at, where necessary, strengthening collaborative R&D instruments such as Centres of Competence, the Technology and Human Resources for Industry Programme, and Sector Innovation Funds.

Requirements for interaction and collaboration will also be built explicitly into the mandates of science councils and higher education institutions. Additional support for the business sector will be provided to improve collaboration with government (see Chapters 4 and 6).

3.3 Policy intent: Enhance policy coherence and programme coordination in the NSI

3.3.1 Coherence of the NSI at the system level: An Interministerial Committee on STI

A standing Interministerial Committee on STI, chaired by the Minister of Science and Technology, will be established. The Interministerial Committee will comprise the relevant STI-intensive departments, the chairpersons of the government clusters, the National Treasury and the DPME. The committee will focus on setting a high-level public agenda for the NSI, approving decadal plans on innovation for South Africa, committing public resources to innovation, and reviewing reports on the performance of the NSI over three-year cycles.

Furthermore, the Interministerial Committee on STI will lead government in ensuring that the environment for innovation is optimal. Key requirements for building an enabling environment for innovation fall within the ambit of various government departments, such as those dealing with trade and competition policy, immigration and labour, procurement policies and STI. To facilitate policy coherence (and certainty), and thereby encourage long-term private sector investment, all of these departments need to commit to supporting innovation in their policies and programmes. Under the guidance of the Interministerial Committee, a whole-of-government innovation approach will therefore be adopted to ensure that the various policies that affect innovation are aligned – establishing, in effect, a South African innovation compact.

The DST will work with the Presidency and the National Treasury to facilitate the integration of the STI agenda and plans into government planning, under the auspices of the Interministerial Committee on STI.

3.3.2 Ensuring that STI enjoys support at the highest levels of government and business: An annual STI Plenary

To ensure that STI enjoys the required support and stature across government and society, an annual STI Plenary will be convened by the Presidency. The STI Plenary will include business, government, academia and civil society.

The STI Plenary will serve as a collaborative platform. The Interministerial Committee on STI will present its high-level STI plans and broad investment strategy for South Africa, as well as report on progress with priority national STI initiatives, for discussion with the NSI partners brought together by the Plenary. Importantly, business will also present its STI requirements and initiatives to the Plenary. The NSI partners will use the STI Plenary to collaboratively reflect on progress with STI initiatives, strategise to address challenges, make recommendations on actions required, and jointly commit resources for the recommended initiatives.

3.3.3 Ensuring that STI agenda setting and planning are based on ongoing stakeholder consultation and expert analysis: A strengthened National Advisory Council on Innovation

To support the Interministerial Committee on STI in carrying out its mandate, government recognises that in addition to the STI Plenary discussed above, there is a need for ongoing stakeholder engagement. The National Advisory Council on Innovation (NACI) will be strengthened to facilitate such engagement, for example, by following up on matters discussed at the STI Plenary.

Furthermore, the Interministerial Committee on STI will require expert studies and up-to-date performance and environmental information to support its decisions. To advise the Interministerial Committee, a strengthened NACI will undertake such studies, and will also function as an M&E institution for the NSI. As part of this, NACI will work with the DST to develop an annual high-level STI Investment Framework to support the commitment of public resources for STI by the Interministerial Committee on STI. It will also do regular environmental scanning to support the agenda-setting function of the Interministerial Committee. To help expand its capacity, NACI will work with other sources of technical expertise and data in the NSI, such as the Centres of Excellence and the South African Research Chairs.

Appropriate links will also be established between NACI and the Department of Planning, Monitoring and Evaluation (DPME) to help integrate STI into transversal government planning by the DPME, and to support funding prioritisation by the DPME and the National Treasury (e.g. via the annual Budget Mandate Paper). For instance, based on its new M&E function and on regular environmental scanning, NACI will prepare reports on the implications of geopolitical and demographic shifts, technological changes, environmental sustainability imperatives and other megatrends for government planning.

The NACI legislation will be amended to allow for this new role.

3.3.4 Building STI coherence through shared values

Coherence is strengthened when values, information and competencies are shared. To promote this end, several additional initiatives (discussed throughout the White Paper) will be launched. Examples include e-government, experimentation, upskilling officials in how to facilitate innovation, and increasing the mobility of employees among government, business, science councils and higher education institutions.

3.3.5 Coherence in critical policy areas

There are areas where it is particularly important to build policy coherence and strong collaborative STI relationships. As recommended by the 2012 Report of the Ministerial Review Committee on the STI Landscape, a number of well-functioning “core” policy nexuses will be established to harmonise and coordinate implementation plans – while taking account of the functions and roles of relevant government clusters. These policy nexuses includeⁱⁱⁱ:

- Education and skills development: This nexus will focus on education and training involving the DHET, the DST, the Department of Social Development, the Department of Basic Education and the Department of Labour.
- Economy: This nexus will focus on business and enterprise development, involving at least the DST, and the Departments of Trade and Industry, Economic Development, and Public Enterprises.
- Social: The focus of this nexus will be on social development and innovation for inclusive development, involving the DST and departments concerned with social and rural development, and the social security-health-education complex.

ⁱⁱⁱ Policy nexuses around ICT, environmental sustainability and the Fourth Industrial Revolution are discussed in later chapters.

3.3.6 Horizontal and sector/thematic coordination

Innovation has the potential to further modernise sectors of South Africa's economy that can absorb significant labour and contribute to exports. Examples are manufacturing, agriculture and mining, as well as the integrated value chains that link these to the services sector. Therefore, integrated STI planning for priority sectors will be adopted (as was done for Operation Phakisa), resulting in the development of sector STI plans. These will be used to coordinate the research effort across industry, science councils and universities, and to concentrate funding on priority initiatives.

The development and implementation of the sector STI plans will be driven by a committee involving all stakeholders, specifically business and industry associations. The DST, in collaboration with the relevant line department, will manage this committee. The sector STI plans will be supported by financial and non-financial instruments. Sector innovation funds, which have been introduced mainly in the agriculture and mining sectors, will be enhanced and expanded to include other priority sectors. Government instruments aimed at coordination, such as inter-ministerial committees, the cluster system and memorandums of agreement, will also be employed where appropriate to ensure coherent action across sectors to implement the sector STI plans.

Sector science councils will continue to report to their line departments. This will allow councils to conduct research and promote innovation to further modernise and enhance the competitiveness of relevant sectors. The science councils will increasingly help the country to translate research into products and services, demonstrate the use of knowledge in transforming society, and inform government policy related to the sectors.

All STI-intensive departments will be encouraged to set up STI units to facilitate coordination with the DST, industry, and other government departments and organisations, and to improve their STI planning competence. STI units will serve as sites of experimentation and help build a stronger innovation culture across government.

3.4 Policy intent: Strengthen the governance of public NSI institutions

While South African STI institutions are generally well governed, the 2012 Report of the Ministerial Review Committee did identify problems such as overlapping mandates and duplication of work, which are depleting the scarce resources of the NSI. Moreover, studies by the DST have shown that while sector-specific science councils necessarily focus on the needs of sector line departments, there have been instances where the science base of these councils has been neglected. These issues were raised in the 2017 report of the Science, Technology and Innovation Institutional Landscape (STIIL) Review Panel, which recommended that an overarching policy framework be developed that sets out the purpose and governance of public research (and innovation) institutions.

Consequently, under the guidance of the DST, such a policy framework will be developed to describe the purpose, functions and governance of public research institutions relevant to national development as guided by the NDP, taking into account the roles of all stakeholders. This will involve clarifying the general purpose of such institutions and the strategic mandates of the DST and other line departments in this respect, and taking into consideration the current capacities of these institutions. Interventions to enhance coordination across different public research institutions and funding agencies will also be developed. The work of the STIIL Review Panel will inform the implementation of the policy framework by way of the decadal plan.

As the mandates of public research institutions are refined according to this policy framework, an appropriate evaluation framework will be put in place to enable objective assessment of their efficiency levels. This will be a prelude to interventions to improve productivity across the focus areas of public research institutions.

The evaluation criteria will include requirements for expanding collaboration with civil society, industry and international partners (for example, to establish international research institutes). In particular, the requirement to maintain and expand the science base will be incorporated. The ambitions underpinning this White Paper – excellence, inclusion, collaboration and pan-African collaboration – will be built into the evaluation framework.

3.5 Policy intent: Expand the NSI

3.5.1 Establishment of new public STI institutions

If the NSI is to optimally support the NDP's ambitions, additional research institutions will need to be established in areas of strategic importance to South Africa's economic competitiveness, such as the Fourth Industrial Revolution. The 2017 report of the STIIL Review Panel will inform the expansion of the NSI to meet these aims. Regular foresight will also be conducted to help direct this expansion.

3.5.2 Expansion of the scientific knowledge base of the NSI

The DST and DHET will collaborate in implementing overarching measures to expand the science base of the NSI, including increased public investment in scientific research.

The DST will specifically target the expansion of selected strategic, emerging and underdeveloped STI areas to improve economic competitiveness through long-term and cross-cutting research, with a specific focus on postgraduate research. As discussed above, the DST will work with line departments and business to develop sector STI plans, which will form the basis for the expansion of research and knowledge creation in priority sectors and relatively mature domains where such activities will lead to increased competitiveness. The DST will further coordinate support for foundational aspects of the NSI, such as human capital development and infrastructure provision related to these STI priority areas.

3.6 Policy intent: Upgrade the M&E and policy capacity of the NSI

Agenda-setting and oversight of the NSI require effective monitoring and evaluation (M&E). Policy implementation needs to be improved by monitoring the progress of initiatives and assessing their impact to enable early corrective action. An effective M&E system will keep all stakeholders informed about what is and is not working. Processes need to be established to ensure that M&E information feeds into policy development and planning.

3.6.1 Institutionalising M&E for the NSI

NACI will be reconfigured to act as the national STI M&E institution, charged with analysing STI information and undertaking work to inform government planning on STI.

Good performance information forms the bedrock of any effective M&E system. NACI will therefore implement knowledge management systems (e.g. a national STI information portal) to enhance the analysis of NSI performance and support evaluation work informing strategies. In this, NACI will draw on the work of existing specialist centres collecting STI-related information. Existing institutional arrangements for data collection (e.g. innovation and R&D surveys) will be maintained and strengthened and, where necessary, expanded.

3.6.2 Skills for M&E in the NSI

The DST and the Department of Planning, Monitoring and Evaluation will cooperate with the higher education sector to expand the STI-related M&E skills base of the NSI.

3.6.3 New M&E framework for the NSI

South Africa will intensify its work on international STI measurement guidelines. Particular attention will be given to the Sustainable Development Goals, innovation for inclusive development, and the NDP objectives.

NACI will convene a high-level forum to develop a framework of indicators to monitor South Africa's NSI performance (see box below). The DST will work with NACI, the DPME and the National Treasury to ensure that the framework delivers actionable and comparable information that can inform the management and funding of NSI initiatives.

A monitoring, evaluation and learning framework for the NSI

This framework will include both quantitative and qualitative measures, as well as benchmarks relative to the rest of the world, covering at least the following:

- Investments/inputs into the NSI (funding sources and spending, people, infrastructure, partnerships/linkages) to indicate how the size, shape and strength of the NSI is evolving.
- The performance of the NSI (innovation activities, including R&D and outputs in terms of knowledge, products, technology transfer and applications).
- The behaviour of NSI actors.
- How the STI system is transforming the economy.
- Responsible research and innovation (RRI) indicators.
- The systemic impact of sustained investment in specific programmes/fields.
- A composite South African Innovation Index will be developed that responds to the specific needs of the country, for example, in terms of skills development, inclusive economic growth and transformation.



CHAPTER 4

AN ENABLING INNOVATION ENVIRONMENT IN SOUTH AFRICA

Chapter 4: An Enabling Innovation Environment in South Africa

Science, technology and innovation (STI) have significant transformative potential. For developing countries, STI, and specifically innovation, can support economic growth and employment, create livelihoods at grassroots level, and improve government performance and service delivery. While innovation is not the only factor in faster economic growth, industrialisation and inclusive development, it remains a significant and vital catalyst. Innovation can enhance South Africa's development and improve the quality of life of its citizens. It has the potential to:

- Improve public service delivery and decision making for public policy.
- Increase the competitiveness of existing firms.
- Form new technology-based firms.
- Renew and modernise existing industries.
- Develop new and emerging industries.
- Exploit new sources of economic growth.
- Improve the quality of life of South Africans, at local level, particularly in poor communities.
- Promote environmental custodianship.

"... this 10th South African Economic Update underscores the large untapped potential of innovation that could be mobilized to advance South Africa's economic and social development goals ... Despite widespread fears that automation will result in a loss of jobs, our estimates suggest that greater R&D efforts are likely to create more jobs rather than shed jobs in net terms. The resilience of the South African high-tech manufacturing sector, at a time when lower-tech manufacturing sectors are shedding jobs, illustrates this point. Moreover, innovation can improve the lives of millions of people, particularly poor people, by improving goods and services. Introducing disruptive technologies can lower barriers for competition and expand economic opportunities."

The World Bank, South Africa Economic Update, 2017

4.1 Performance, gaps and innovation focus areas

In 2016, the Cornell/INSEAD/World Intellectual Property Organization Global Innovation Index noted that South Africa's strengths lie in market sophistication and investment, as well as some aspects of knowledge absorption and knowledge impact. This progression was mostly due to enhanced competition, better use of talent and an increase in primary school enrolment. Although there is room for improvement, both of these indices point to strengths and progress in aspects related to innovation.

Although knowledge generation does not necessarily lead to innovation, South African patent applications granted in the United States between 1996 and 2016 (an indicator historically regarded as relevant, but becoming increasingly less of a focus as foreign markets change and technology types evolve) have not grown significantly. However, Patent Cooperation Treaty applications increased 100-fold over the 20-year period. Over the same period, there were significant increases in trademark applications – but, although these represent goods and services in the market, they cannot be viewed as a proxy for innovation performance.

The above statistics are not limited to the public sector but represent a combination of public and private sector where South Africa is recorded as the country of origin. A recent survey titled "The South African National Survey of Intellectual Property and Technology Transfer at Publicly Funded Research Institutions",²³ covering the period 2008 to 2014, shows progress made by South African higher education institutions and science councils to advance an innovation agenda. All institutions responding to the survey confirmed that they had established an office of technology transfer. In terms of outputs, the number of disclosures received by these offices more than doubled during the survey period. Significantly, comparative statistics with the United States reveal that a higher percentage of disclosures were converted into provisional patent applications in South Africa. The number of start-up companies in South Africa quadrupled over the period. Although this increase occurred off a low base, this is a positive development, as is the fact that 75 per cent of these companies were

based on publicly financed intellectual property. While the sustainability of these technology start-ups has yet to be proven, this positive statistic suggests growth in the sector and potential to improve the South African technology balance of payments.

Despite these encouraging growth trends, an analysis of the average rate of conversion of intellectual property disclosures to commercialisation/use by these institutions is about 7 per cent.^{iv} International benchmarking shows that the conversion rate from disclosures to licences for a mature system ranges between 15 and 30 per cent. In terms of this benchmark, the South African public innovation system appears to still be developing.

This chapter identifies aspects of unsatisfactory innovation performance. The proposals to address the shortcomings aim to:

- Ensure an inclusive innovation system.
- Integrate innovation strategies into local and regional economic development planning.
- Tap into new sources of innovation and growth.
- Foster an innovation culture across South African society.
- Improve collaboration across the quadruple helix to drive innovation.
- Harmonise policy instruments to support business.
- Stimulate learning and support the conversion of ideas to commercialisation.
- Ensure that South Africa's intellectual property system is in line with development objectives.

Policy intents and actions

4.2 Policy intent: Adopt a broader conceptualisation of innovation beyond R&D

The White Paper adopts a broader conceptualisation of innovation and its sources. This shift will recognise that the sources and nature of innovation go beyond R&D and radical innovation, and include imitative and incremental innovation, including design and engineering activities, on-the-shop-floor attempts to improve productivity, and investment in organisational learning, learning by doing, using and interacting, and observing what others are doing.²⁴ In developing countries, indigenous knowledge and know-how are particularly relevant.

The White Paper introduces a strong focus on addressing the needs of the business sector, government, communities and civil society (the “demand-side” focus), while recognising the need to maintain a supply-side, public goods competence.

To allow the various sources and types of innovation to come into play, closer collaboration between relevant government departments will be established, and their incentives aligned if necessary. However, a blueprint approach to innovation is neither feasible nor desirable.

As the sources of innovation are mostly outside government, the involvement of the business sector, civil society and academia in designing measures to support learning and innovation will be incentivised.

iv National Intellectual Property Management Office IP7 database

4.3 Policy intent: Adopt a whole-of-government approach to innovation

As discussed in Chapter 3, the White Paper aims to enhance policy coherence and programme coordination in the NSI. This will require formal mechanisms such as the proposed Interministerial Committee on STI discussed in Chapter 3, as well as infusing the whole of government and society with an innovation culture, and aligning policies (e.g. immigration and competition policies) that impact on innovation – in short, developing a national innovation compact.

In addition to the general innovation compact and the policy nexuses around critical policy areas, there is a need to strengthen the role of STI policy in enhancing the competitiveness of firms, sustaining high growth in the productive and services sectors, and supporting the development of new firms and industries. The NSI currently contributes to the Industrial Policy Action Plan, but there is room for the DST, science councils and relevant public entities across the NSI to achieve greater impact. The current contributions of the NSI to the Industrial Policy Action Plan will therefore be deepened to ensure that the programmes of science councils are aligned with priority industrial sectors, as well as with new growth opportunities identified by, among others, the Industrial Development Corporation. STI will be integrated into future frameworks and legislation to advance national industrial and economic objectives. An important step towards aligning STI and industrial policy will be the establishment of the proposed policy nexus on trade and investment.

4.4 Policy intent: Increase support for and collaboration with the business sector^v

4.4.1 Supporting business R&D needs

Public funding of private sector, needs-based R&D will be increased.

A 2016 study by the National Treasury on the effectiveness of South African science council partnerships with industry found that there was significant room for improving the focus of research on industry needs.²⁵ Therefore, support for and partnerships with industry will be made an explicit policy mandate of public research institutions, particularly science councils, and will be monitored as part of their annual performance plans. Furthermore, the mining R&D hub and other instruments to support the private sector will be strengthened.

4.4.2 Targeted technology development and deployment to support firms

In line with national priorities, sectors (and potentially subsectors) in which South Africa has a competitive advantage will be identified in collaboration with business, with the aim of targeting public support for R&D-led industry development and encouraging high-technology exports. The DST will also work with business to identify opportunities to acquire technologies from abroad when appropriate. This information will inform R&D planning and funding, as well as procurement strategies at national, provincial and local levels.

Efforts to localise and diffuse technologies will be intensified through existing and new technology-based support interventions (including the Technology Stations Programme and the Technology Localisation Programme). Sectors with growth potential will be targeted for funding support, for example, through expanded Sector Innovation Funds.

^v Notwithstanding recent progress on collaborating with the private sector (for instance in the Sector Innovation Funds), the OECD's criticism in 2008 that the South African NSI is too supply-side driven is still relevant in certain respects. Therefore, the White Paper unambiguously emphasises support for and collaboration with the private sector.

4.4.3 Global value chains

The growing importance of complex global value chains provides opportunities to attract foreign direct investment and associated benefits, including technology transfer. The extent to which a country will benefit from these global value chains depends on its absorptive capacity and the level of its R&D stock. Economies with higher levels of R&D capacity are more likely to maximise technology spill-overs and ensure greater technology diffusion. The absorptive capacity of enterprises may be further increased by supporting innovation and technology transfer activities.

The DST will work with relevant NSI partners to intensify support for technology transfer and absorption. This will include supporting early adopters, developing R&D capacity within firms, integrating local companies or sectors into global value chains, supporting clustering and agglomeration in key sectors, and offering incentives to attract foreign direct investment.

4.4.4 Public procurement

New and complex technology products (e.g. for satellites or civilian aircraft) usually require “launch customers” to help establish customer and market confidence in the product, as well as downstream maintenance and support. In most instances, such programmes rely on a “lead market” in the form of government procurement to help position the product for future sustainability.

Public procurement can also help ensure the sustainability of new and transformed broad-based black economic empowerment firms in or outside the existing supply chains of state-owned enterprises (SOEs), as well as increase the number of SMEs in these supply chains.

Therefore, strategies will be developed to ensure that government is the first customer when it comes to using locally developed technologies. Government’s infrastructure build programme is one example where locally developed technologies can be supported and tested.

A supportive legislative environment will be ensured, and where the success of new industry development efforts (e.g. in the fields of medical devices, ICT and environmental technologies) depends on government procurement, a formal strategy will be jointly developed by the DST and the government department responsible for procurement.

The role of the Public Finance Management Act, 1999 in R&D-related activities will be made clear (e.g. to differentiate collaboration and partnerships from procurement-related activities). Technology conditionality will be built into large procurement contracts (e.g. fleet procurement for rail) to ensure that South Africa acquires the latest technologies and that there is technology transfer in the localisation process. The Competitive Supplier Development Programme, championed by SOEs, will also be expanded to include local technologies.

4.4.5 Specific support for SMEs

Besides identified challenges such as access to finance and credit, and inadequate infrastructure, small and/or medium enterprises (SMEs) often struggle to innovate, perform R&D, access knowledge and absorb new technology. Therefore, the current model for providing broad-based support to SMEs (e.g. through walk-in support at technology stations) will be scaled up to ensure that even more SMEs can access services, equipment and support in product/technology commercialisation.

SMEs play an important role in the industrial value chain, and initiatives aimed at developing and/or upgrading them as suppliers to government and larger firms will be scaled up. Tailored technological support (e.g. through technology assistance packages) will be intensified to enable SMEs to meet the technical and commercial requirements for becoming qualified suppliers, both locally and globally. Links between SMEs and larger firms will be incentivised to diffuse technology and improve the ability of SMEs to innovate.

A comprehensive support package for SMEs in priority focus areas will be developed collaboratively by the relevant government departments. The existing instruments (e.g. those of the DST, the Department of Trade and Industry, the Department of Small Business Development, the Economic Development Department and the Department of Public Enterprises) will be aligned to support SMEs and emerging industries. As an example, both technological and other innovation support to SMEs will be provided to develop new markets or to support systems innovation. New support instruments (e.g. an R&D voucher scheme for eligible firms to cash in with registered R&D service providers) will be introduced.

In pursuit of an inclusive innovation system, particular attention will be given to supporting SMEs in informal settlements, rural areas and cooperatives. Furthermore, to support the transformation of the demographic ownership profile of technology-based firms (and in particular SMEs) in South Africa, guidelines will be developed by the DST, in cooperation with relevant NSI partners, to use intellectual property from publicly funded R&D under appropriate conditions to support women and black entrepreneurs when such intellectual property is commercialised.

4.4.6 Revitalising the role of SOEs in innovation

State-owned enterprises (SOEs) are important actors in the South African economy, given their role in providing infrastructure and services (e.g. energy, water, transport and communications). SOEs serve as clusters of expertise and have important linkages to various parts of the economy – as anchor institutions in their sectors, as channels for international knowledge spill-overs, and as hubs for human capital development. SOEs are funders, performers and collaborators in R&D and technological innovation. Ten such enterprises account for about 99 per cent of all SOE R&D. However, recent data shows a decline in SOE expenditure on R&D (from a peak in 2008/9), largely as a result of the termination of the Pebble Bed Modular Reactor (PBMR) Programme. To turn this trend around, the following strategies will be adopted:

- The implementation of the White Paper and the next iterations of the Industrial Policy Action Plan will require explicit plans on how the R&D programmes of SOEs will advance South Africa's R&D capability, technological innovation performance and industrialisation. A mechanism will be adopted, across all departments responsible for SOEs, for improving the coordination of long-term planning and funding for R&D programmes in SOEs.
- A national flagship programme directed at closing the engineering and design gap should be established, in line with national imperatives for human capital development and transformation. This will require existing programmes to be revised in order to strengthen the links between interventions for high-end skills and those meant to expand technical/vocational competencies required by SOEs relating to design, engineering and small enterprise development.
- Conditions will be created to encourage SOEs to continue R&D partnerships among themselves and with universities, science councils and the local business sector. The aim is to leverage broader knowledge and innovation networks for the benefit of the country. SOEs need a much larger base from which to draw research, engineering and other technical expertise.
- Domestic technological knowledge gaps require the sourcing of knowledge and R&D services from abroad. For such international sourcing arrangements to be beneficial, they should be linked to a particular strategy for technology transfer and/or localisation in cases where domestic capability is inadequate. Along with the "smart buyer" principles, strategic sourcing from abroad should be linked to national imperatives for technology accumulation, so that in the medium to long term SOEs in specific technology spaces will buy from local service providers and institutions rather than foreign firms.

4.5 Policy intent: Support commercialisation of publicly funded intellectual property

Offices of technology transfer in higher education and Schedule 1 institutions play an important role in identifying and protecting new technologies, sourcing licensing partners, and establishing firms to market new technologies.

Support for offices of technology transfer will be increased through existing instruments, initially to develop capacity, and, over time, on the basis of the quantity and quality of outputs. To support the transformation of higher education, the type of government support to these offices will be differentiated according to the research intensity and technology transfer maturity of the institution in question.

Substantial funding is often required for commercialisation, and to this end, a Sovereign Innovation Fund will be established.

4.6 Policy intent: Ensuring that legislation on intellectual property rights from publicly financed research and development responds to the changing policy context

The Intellectual Property Rights from Publicly Financed Research and Development Act (IPR Act), which came into effect on 2 August 2010, will be comprehensively reviewed. Among other aspects, the review will focus on support for openness, improved support for SMEs, expanded impact of offices of technology transfer, and the appropriate structure and positioning of the National Intellectual Property Management Office in the NSI.

4.7 Policy intent: Increase the spatial footprint of innovation in South Africa

Historically speaking, STI policy has mostly focused on R&D, perpetuating a system that has not optimally contributed to improving local economies. Furthermore, innovation-support institutions remain concentrated in the major metropolitan areas.

Improved spatial inclusivity will receive attention through a stronger role for innovation in rural development, and support for regional and local systems of innovation. These approaches will bring actors such as local government, regional development agencies, local chambers of commerce and community-based entrepreneurs into the regional and local innovation systems.

Local and provincial growth and development strategies will include innovation plans. “Innovation hubs” will be expanded to enhance provincial growth and development strategies, and promote provincial technology competencies. As part of these, cooperative research centres (involving industry, science councils and higher education institutions) and local innovation ecosystems will be developed, where appropriate.

Furthermore, a “no wrong door” policy will be adopted across government, particularly at local and provincial government level, which will see innovation-related enquiries routed efficiently to provide the required information or support. This intervention could initially be implemented through an appropriately located hotline or information kiosks.

4.8 Policy intent: Support innovation for inclusive development, including social and grassroots innovation

Innovation policy should enable all sectors of society to equitably access knowledge infrastructure and participate in creating and actualising innovation opportunities, and ensure that all individuals share in the benefits of innovation.

“Actions in support of broad-based and grassroots innovation and entrepreneurship can strongly sustain a process of inclusive growth.”

The Organisation for Economic Cooperation and Development (OECD), 2018

There is growing interest in broadening the concept of innovation to include innovation for inclusive development, i.e. innovation for societal benefit and the public good. Globally, there is greater activity and benefit in bottom-up, grassroots, distributed and local innovation. The public sector needs to become an enabler of innovation for inclusive development. This can be done, for example, by strengthening ICT applications for e-government, e-learning and e-health, and can include co-creation and user-led initiatives using socially innovative methods such as living labs. An innovation for inclusive development approach will involve widening the range of stakeholders and deepening their engagement in deliberative planning.

Local innovation ecosystems

Such ecosystems may consist of:

- Walk-in innovation centres (preferably established at accessible facilities such as post offices).
- Reconstructed living labs (core activities of the living lab are skills training, community development, social and disruptive innovation, mobile and Internet solutions, social enterprise incubation, impact investing and social franchising).
- Local incubators (preferably attached to an institution with a technology station, and mobile application laboratories).
- Science centres.
- Where necessary, product certification facilities.

Over the past decade, grassroots innovation, as a particular priority within the broader innovation for inclusive development agenda, has gained prominence in STI initiatives, both globally and in South Africa. Support for grassroots innovation will be a planning priority in all relevant initiatives. It will be funded accordingly, and monitored in all relevant M&E frameworks. Developers of local economic development plans, as well as provincial growth and development strategies, will be encouraged to include support for grassroots innovation.

A multi-tiered package will provide support appropriate to the level of development of grassroots innovators. Mentorship will be incentivised through a government-funded voucher system and awards, and complemented by corporate social responsibility programmes. Grassroots innovators will be capacitated and supported by, for example, supplier development programmes.

Government will further leverage the potential of publicly funded intellectual property to support grassroots innovation. South Africa will develop a country-specific, second-tier patent system, offering a cheap, no-examination protection regime for technical inventions that would not usually fulfil the strict patentability criteria. With the introduction of a substantive patent search and examination system at the Companies and Intellectual Property Commission, a preferential accelerated patent examination system will be introduced for SMEs, broad-based black economic empowerment firms, previously disadvantaged individuals, and young innovators, depending on criteria such as involvement of start-up firms.

Civil society will also be assisted in its many roles, including as a source of innovation, information, mentorship and networks. Efforts will be made to strategically link this sector to NSI actors such as technology stations and science councils. Its function as innovation intermediary between government and grassroots innovators will be strengthened. Training packages will be developed, using social media and digital technologies, to equip civil society with innovation development skills. Collaboration within the civil society sector will be strengthened and incentivised, including partnerships with publicly funded R&D institutions and science councils in piloting and distributing technology for public benefit.

Finally, government will introduce a dedicated Innovation for Inclusive Development Fund in a progressive and phased manner. The fund will target both neglected and marginalised groups of innovators, including the youth. The fund will also support innovations with high social returns that are unlikely to gain traction because of market and other failures.

4.9 Policy intent: Exploit new sources of growth

4.9.1 Support for emerging industries

To facilitate sustained and improved competitiveness, particularly in the context of the Fourth Industrial Revolution, the ability to incubate and support emerging industries is crucial.

Therefore, to maximise the growth of R&D-intensive and non-R&D-intensive emerging industries, joint planning and co-investment will be facilitated through improved partnering between firms, universities, science councils and government. Associated support initiatives with large business enterprises, SOEs and SMEs will be prioritised for government support.

4.9.2 The circular economy

The current economic crisis and climate change considerations present opportunities to move towards a green economy by accelerating eco-innovation. In particular, the circular economy represents a source of new growth. Leading firms and entrepreneurs are exploring green opportunities, looking to create and capture value from new business models. Policy makers are also increasingly paying attention to the need for radical and systemic eco-innovations as a powerful lever in enabling a long-term transition towards a greener economy.

To achieve this transition, private sector investment will be needed. The framework conditions and policies for firms and entrepreneurs will therefore incentivise private investment in green innovation. Policy tools to encourage demand for green technologies will include regulations, subsidies and tariffs, public procurement, standard-setting and consumer policy. Examples include green public procurement legislation and prizes for green technological innovations.

Further, a better understanding of emerging practices and business models related to eco-innovation is needed to enable government to elaborate appropriate policies, and to encourage industry to take up new opportunities. Government will therefore encourage experimentation and showcase radical and systemic eco-innovations, enhance the understanding of the role that new business models can play, and draw lessons for industry and policy makers to accelerate the deployment and diffusion of promising environmental technologies and solutions.

Public support for green innovation will be expanded, bearing in mind that greening the economy requires scientific discovery and inventions in areas other than energy and the environment. Other mechanisms to drive green innovation will include direct R&D grants to SMEs, providing risk capital for green technology through equity and debt finance, and supporting pilot plants for green technologies generally and for energy technologies in particular. The development of skills will require on-the-job training as well as the adaptation of tertiary and vocational training to meet new occupational needs. Networking and knowledge diffusion will also be supported through, for example, a programme to foster international exchanges among researchers in the field of environmental and sustainability research.

As numerous green economy initiatives are spread across government, a policy nexus and institutional arrangements will be put in place to promote coherence. The DST, the Department of Environmental Affairs and the Department of Trade and Industry, among others, will collaborate in establishing institutions to coordinate the diverse array of green growth strategies, programmes and initiatives.

4.9.3 A focus on ICT

In collaboration with its NSI partners, government will shape the future of the digital economy and society by cultivating a shared, trusted digital environment that drives inclusion, economic development and social progress.

Cabinet approved the ICT Research Development and Innovation Roadmap, entitled “Our digital future”, in 2013. The Roadmap identifies several strategic domains, including broadband services and infrastructure, ICT for development, sustainability and the environment, grand science, industry applications and the services economy. It is underpinned by up-to-date research on South Africa’s capabilities and development potential in the ICT sector, and aims to enable South Africa to exploit market opportunities in areas such as future wireless technologies, e-inclusion, green ICT, geospatial applications, biomedical sciences, smart infrastructure, mining, manufacturing, asset management, m-health, e-services, education, outsourcing and payment solutions.

The development of the domestic high-technology ICT sector will be prioritised within these domains. The overarching objectives are collaborative planning on ICT (involving government, business and civil society), a focus on universal access to ICT (with broadband as an urgent priority), the development of e-government and pro-poor ICT policies, and the positioning of South Africa to benefit from the Fourth Industrial Revolution.

To enable collaborative planning, a policy nexus encompassing the DST and relevant departments such as the Department of Telecommunications and Postal Services (DTPS) will, among other things:

- Drive the digital society in South Africa.
- Use big data at local government level to create jobs.
- Use open data to transform local government services.
- Create localised ICT hubs as Centres of Excellence.
- Modernise local government services.
- Use e-government services to transform local government services.
- Prioritise cybersecurity resilience.
- Support emerging start-up digital enterprises.
- Address the high cost of broadband in South Africa.

4.9.4 The Fourth Industrial Revolution

As discussed in Chapter 2, the Fourth Industrial Revolution involves a convergence of different technologies. This global trend has profound implications for South Africa and Africa. For instance, there are opportunities for increased economic growth through the modernisation of existing industries, but also a need to up-skill and re-skill the workforce for new technological job opportunities, as technological changes will have a significant effect on the world of work. Various initiatives are under way at policy, industry and technology level, and there has been engagement with international stakeholders such as the World Economic Forum. However, a coordinated national policy response is required, including considerable support and actions from policy makers.

If the full potential of the Fourth Industrial Revolution is to be realised, new institutional arrangements will be needed to manage convergence, as will expanded R&D aimed at the enabling technologies. These arrangements must support research at universities in disciplines relating to current base technologies while developing knowledge in new areas.

A high-level national collaborative platform will be established to position South Africa to respond to the opportunities and risks flowing from the Fourth Industrial Revolution. The platform will help identify and support priority STI programmes linked to the Fourth Industrial Revolution. This platform will be managed by a steering committee including relevant departments such as the DST, the Department of Trade and Industry and the DTSP, among others. Business and labour will also be included in the steering committee, as will the Department of Labour, to focus on strategies to address potential job losses in affected industries.

4.10 Policy intent: Strengthen government's role as an enabler for innovation

Governments often act to address market failures, taking the lead in making high-risk investments in, for instance, information technology (United States), biotechnology (United Kingdom), nanotechnology (Russia) and green technology (Spain). The private sector invests only after government has made the initial high-risk investment.²⁶ However, for government to play this role, it will need to develop a more innovation-enabling mindset and culture.

To help entrench a culture of innovation in government, the DST will work with the Centre for Public Service Innovation (CPSI) and other relevant national, provincial and local agencies on challenging the risk-averse mindset of public servants, using awards to motivate them and celebrating role models. More specifically, the DST will work with the CPSI to increase service delivery through initiatives such as e-government.

Furthermore, as experimentation is vital for improving service delivery, government will invest in demonstration projects and support risk procurement where appropriate. A critical dimension of initiatives to encourage experimentation will be to stimulate co-learning and co-creation among researchers, officials and users/buyers of technology. Civil society will also be empowered to play a stronger role in planning and implementing projects that lend themselves to experimentation.

No ambitious STI policy agenda, such as that set out in this White Paper, can be sustained without an enabling culture across society. STI is influenced by social and cultural values, norms, attitudes and behaviours, which may be described as an "innovation culture". An innovation culture thrives on inspiration, creativity, collaboration, problem-solving and risk-taking. It enables us to pursue ideas and learn from taking risks and making mistakes. Adopting this culture will require a shift to encourage South Africans in business, government and civil society to take risks on smart ideas. Establishing such a culture will take time. It will need to be nurtured and reinforced by a range of initiatives.

An innovation mindset needs to be fostered from the early stages of childhood. Therefore, curiosity, creativity, critical thinking, the ability to learn from failure, and entrepreneurial skills will feature strongly in programmes and curricula at various stages: in early childhood development, at school, and during post-school education and training. For example, the role of the arts in stimulating children's creativity will be strengthened.

The DST will therefore work with relevant government departments, such as the DHET, the Department of Basic Education and the Department of Social Development, to develop programmes to build an innovation mindset from early childhood.

Successful innovators, mentors and entrepreneurs will be celebrated as role models. Initiatives to achieve this will include advocacy and awareness, awards across society at all levels of government, and exchange and incubation programmes. Particular attention will be paid to equity considerations, ensuring that people who often do not have the opportunities to become innovators – such as the youth, women, people with disabilities and those with low levels of formal education – are coached, mentored and celebrated. These initiatives will be implemented as a partnership between government, the private sector, higher education and civil society.



CHAPTER 5

INCREASED HUMAN CAPITAL AND EXPANDED KNOWLEDGE ENTERPRISE

Chapter 5: Increased Human Capital and Expanded Knowledge Enterprise

The South African research system is diverse, with pockets of excellence, for instance in the biomedical field. This chapter outlines how these outputs can be reoriented and increased by expanding and transforming the research system in a rapidly changing and increasingly technologically advanced world. This will require attention to the supply of high-level skills, the openness of the system, the diffusion of knowledge, and access scientific infrastructure. Linkages between science and society, including public engagement, science diplomacy and internationalisation are central to openness.

5.1 Progress, gaps and approaches to expanding capabilities

5.1.1 Research and the next generation of researchers

South Africa has a strong and growing science and technology system, including world-class universities.²⁷ In 2014, total university enrolments (2/3 contact and 1/3 distance) approached 1 million, with postgraduate students constituting about 16 per cent of total enrolments (the NDP target is 25 per cent). Foreign students accounted for some 60 000 enrolments, mostly at postgraduate level. Undergraduate SET enrolment remains close to 30 per cent of the total.

Several flagship programmes to address the shortage of researchers have been introduced, including the South African Research Chairs Initiative and the centres of excellence. However, more programmes are needed. The DST has been working to increase the number of researchers by providing comprehensive bursary funding that compares favourably with entry-level salaries at each qualification level. The introduction of the Comprehensive Bursary Programme that targeted honours students improved the retention of postgraduate students.

Doctoral awards have more than doubled in the period 2002-2014. While the number of PhDs has increased to 41,8 per million of the population in 2015, it is still lower than the NDP target of 100 per million by 2030. An important driver in the production of doctoral graduates is the number of PhD-qualified staff at universities. By 2014, 43 per cent of research and teaching staff at universities had a PhD, which, although a substantial increase, is still far off the 75 per cent target set in the NDP. While the number of PhD-qualified staff increased by 65 per cent, the number of enrolled students increased by 350 per cent, leading to a supervisory bottleneck. This has been partly addressed through the increased number of postdoctoral students.

For the NDP targets for PhD productivity and PhD-qualified lecturers to be reached, more high-quality matric passes in science and mathematics are needed, and the decline in the number of female learners passing these subjects must be reversed (there was a 50 per cent decrease between 2008 and 2016).²⁸

In 2013, the Minister of Science and Technology approved a set of equity-based guidelines for bursaries and scholarships. These guidelines have contributed to transforming the postgraduate cohort. Although there is significant room for improvement, especially at the higher levels in the research system (discussed below), South Africa's gender-equity performance is better than many more advanced countries. Recent survey data reveals that women researchers made up 44,3 per cent of total researchers in 2014/15, which is a higher participation rate than that of many developed countries. Research outputs by historically disadvantaged groups are also growing; the share of scientific papers published by black authors has increased from 10 per cent to 32 per cent, while that of women authors increased from 20 per cent to 32 per cent in the period 1998 to 2014. However, racial and gender inequalities persist. Furthermore, the number of full-time equivalent researchers in the system has not increased significantly from 2005/06, the date of the earliest available data.²⁹

Whole-count research publications increased from 5 540 in 1994 to 15 542 in 2014, with the per-capita research output doubled between 2001 (0,39) and 2014 (0,84). The revised university funding formula of 2003 has had a positive effect on research outputs.

Despite the progress discussed above, South Africa's research system is restricted by inherited structural inequities, as reflected in the differing capacities of our institutions. Research performance varies greatly across different sectors (universities, industry and science councils), and within different institutions in the same sector. The higher education sector is responsible for nearly 90 per cent of all research publications, compared to about 8 per cent for all the science councils and national research facilities. Within the university sector, five universities produce more than 60 per cent of research outputs from the sector.

The aim of the National Plan for Higher Education was to transform the higher education system, bringing about institutional mergers to eliminate historical disparities, and the differentiation of universities according to mission.³⁰ Despite the plan, there are performance gaps between universities and universities of technology, and between historically advantaged and disadvantaged institutions. For example, three-quarters of the country's PhD graduates are produced by of its six universities.

South Africa has active global knowledge partnerships and long-standing collaborations with leading science nations, resulting in the increasing international mobility of researchers (inward and outward). South African researchers, through the work of the DST, have formalised access to global research infrastructure (for example the European Organisation for Nuclear Research). A recent bibliometric assessment of South African papers shows that more than 50 per cent were co-authored with international partners.^{31|32}

There are international concerns about the diminishing role of the humanities and social sciences in academia and the wider knowledge sphere. While, in South Africa, the evidence does not support concerns about the prioritisation of natural, physical and engineering sciences over the humanities and social sciences, it is necessary for the latter to play a stronger role in the science system, and not only in a narrow utilitarian sense or as mere supporting disciplines. The challenge is to incorporate the knowledge and insight of humanities and social sciences into research and innovation in the natural, physical and engineering sciences.

5.1.2 Infrastructure

Through the South African Research Infrastructure Roadmap and the Innovation Infrastructure Roadmap, there has been notable progress in all categories of research and innovation infrastructure. Five national facilities and one major project – the MeerKAT/Square Kilometre Array – have been established, as well as national preclinical facilities at higher education institutions. In terms of high-end infrastructure, a multipurpose fluorochemicals pilot plant, a titanium pilot plant and several technology demonstrators are in operation.

Cyberinfrastructure has also advanced through the Centre for High Performance Computing, the South African National Research Network, the Data Intensive Research Initiative of South Africa, and the National Integrated Cyberinfrastructure System. The ICT Research, Development and Infrastructure Roadmap is being implemented.

There are also international collaborations with, for example, the European Organisation for Nuclear Research (CERN), the Planck Telescope, large health science projects, the MeerKAT/Square Kilometre Array, the Southern African Large Telescope, and the iThemba Laboratory for Accelerator-Based Sciences.

5.1.3 Focus areas for expanding the knowledge enterprise

It is clear from the above that, despite good progress, the full potential of South Africa's research system and its human resources is yet to be realised. It is necessary to do the following:

- Improve research outputs.
- Expand and transform the research system and facilitating knowledge diffusion.
- Ensure an open, responsive and diverse knowledge system.
- Upgrade knowledge and innovation infrastructure.

- Develop skills for the economy.
- Improve international cooperation and science diplomacy.
- Create a culture of innovation and science literacy.

Policy intents and actions

5.2 Policy intent: Expanding research outputs and transforming the research institutional landscape

To expand the research system, the institutional landscape will be grown and diversified by establishing new research institutions and consolidating existing programmes after conducting the relevant studies. Lessons will be drawn from the 2017 Science, Technology and Innovation Institutional Landscape Review.³³

The DST and DHET, in collaboration with international partners and industry, will continue to strategically develop research-intensive universities, while actively supporting universities of technology and historically disadvantaged institutions. However, it is important to recognise existing areas of excellence in these institutions – as the type of institution is not the only factor affecting research performance. Programmes will be established to improve research capacity at these institutions. The twinning of research-intensive universities with historically disadvantaged institutions will be encouraged.

The university funding formula introduced in 2003 had a positive effect on research outputs. The system will maintain a strategic focus on increased incentives for research outputs – particularly for researchers doing inter-, multi- and transdisciplinary work.

The DST, the DHET and other relevant government departments will intensify focus and collaboration around the incentive programme for science councils to improve their research performance. Research partnerships between universities and science councils will be facilitated and supported. Moreover, the DST will deepen partnerships with R&D and STI-intensive government departments like DHET and the Departments of Energy and Environmental Affairs to strengthen support for the research enterprise.

5.3 Policy intent: Transform the profile of the researcher base

The DST and DHET will emphasise the development of black and women researchers at emerging researcher level (with a specific focus on black women), and mentor them beyond qualification to take up senior management positions in research management and science institutions.

Over the short term, an increase in the number of researchers will be achieved through focused, fast-tracking interventions that will tap into the PhD-qualified research-inactive “silent majority” of existing permanent academic staff, especially black staff and women. Interventions include the Thuthuka initiative, which seeks to advance the equity and redress agenda in the research sphere.

The DST will continue its support for the DHET’s *Staffing South Africa’s Universities Framework*, which aims to change the number and composition of university staff.

5.4 Policy intent: Improve the research system’s output of human resources

The White Paper adopts a broad view of human resource development in higher education, recognising the urgent need to:

- Take cognisance of the multidimensional nature of black students' lived realities (such as university fees, accommodation, nutrition and transport).
- Change the demographics of academic staff.
- Transform the curricula and research agendas.
- Cultivate greater awareness of African STI.
- Eliminate racism, sexism and all other forms of unjust discrimination.
- Improve academic success rates and expand student support, in particular for black students.

5.4.1 Supervisory capacity

Given the country's supervisory capacity constraints and the global research projects that it hosts, the need to attract world-class research talent by easing immigration rules cannot be over emphasised.

Government will expand instruments that have proven successful in research and postgraduate outputs such as the South African Research Chairs Initiative, and put in place programmes to establish full-time equivalent research positions at universities. Given the sustained increases in the number of PhD graduates, government aims to support and retain an appropriate percentage of each annual graduating PhD cohort in the postdoctoral programme for eventual absorption into the academic and research system.

The experience and expertise of ageing researchers will be harnessed, while putting in place research and supervision transfer skills programmes to benefit younger and emerging researchers.

In order to increase the proportion of university staff with PhDs, direct support for attaining a PhD will be prioritised, particularly for staff at universities where the proportion of PhD-qualified staff is below the norm. Twinning programmes with research-intensive universities and international institutions will assist in addressing the shortfall.

Postdoctoral fellows make an invaluable contribution to the research system by mentoring postgraduate students. The number of postdoctoral fellows hosted at universities and science councils has generally increased, but their contribution has not been optimised because their status has not been defined. The DST and DHET will formalise a set of guidelines on how to optimise the contribution of postdoctoral fellows.

To improve demographic representation among established researchers, the DST and the DHET will target and retain a significant number of black and women doctoral graduates in the postdoctoral fellowship programme, particularly South Africans. Foreign postdoctoral fellows will be targeted in strategic priority areas to alleviate supervisory bottlenecks. At the same time, the DST and the DHET will establish a programme for South Africans to pursue postdoctoral fellowships abroad, targeting black people and women.

5.4.2 The human resource development pipeline

The DST and DHET are the key government departments responsible for strengthening the postgraduate human resource development pipeline. They are supported by the Department of Basic Education and the Department of Labour.

Addressing the problems relating to the teaching and learning of English, Mathematics and Physical Science in schools must be at the heart of any STI strategy and is a prerequisite for an advanced STI system in South Africa. However, the South African schooling system is not yet delivering outputs at the required level.

A number of departments will therefore collaborate with the aim of building the STEM pipeline. The DST, in collaboration with the Department of Basic Education, needs to scale up existing initiatives to improve English, Mathematics and Physical Science at school. Developing a scientist or engineer begins early in life with the nurturing of children's health, curiosity and creativity. Early childhood development programmes will be expanded by the Departments of Basic Education, Social Development, and Health. The government aims to use the potential of STI to increase the reach and impact of such programmes.

Government will put in place specific interventions to enable all children (and, where appropriate, adults) to become digitally literate. Examples could include making greater use of mobile phone technology and existing public infrastructure in rural areas such as post offices, schools or libraries to introduce children to gaming and coding, and to teach adults digital skills. The private sector will be encouraged to partner with the government in these endeavours.

Structured mechanisms will be created by government to strengthen the links between researchers and scientists, on the one hand, and school teachers on the other, to encourage the introduction of scientific concepts from primary and pre-primary level (in particular in ICT-related skills training linked to the Fourth Industrial Revolution), as well as to enhance the development of appropriate educational technologies. The adoption of schools by universities and science councils could reinforce this approach. Furthermore, SET-based industries will be incentivised to adopt schools for support – although government will not abdicate its responsibility in this regard. Another, longer-term option, might be to link postgraduate funding to a quota of community service to assist with the teaching of SET in schools. Such a programme should, however, not compromise the time in which degrees are completed, or the graduation rates.

Currently, too few students are supported at too low a financial level, and public support for postgraduate studies needs to be increased, especially given that the gradual implementation of free higher education might result in increased postgraduate enrolments. Increased public support for postgraduate studies will also require government, industry and international funders to coordinate their efforts. A framework will be developed for cooperation across government, particularly with departments that have SET postgraduate bursary programmes.

In addition to research master's and PhDs, the NSI and the economy require technical and other skills that support innovation. Government will therefore expand its student support programmes to include the development of technical, engineering, entrepreneurship and innovation-related skills, such as in intellectual property management.

5.5 Policy intent: Strengthen skills in the economy

5.5.1 Diversity of post-secondary education

In South Africa, it is necessary to improve the responsiveness of the post-school education and training system to the skills needs of the 21st century, in particular innovation and technology-driven change that affects organisations and individuals alike. Currently, the education level and skills base is lower than that of many other productive economies. The pool of students who can potentially access university and science-based technical and vocational education and training (TVET) programmes is small in comparison to the country's demand for skills.

The main constraint is the inadequate quality of basic education (particularly in languages, mathematics and physical science). This impedes progression to and success in post-school education and training and the workplace. There needs to be a coordinated, system-wide effort to improve the quality of teaching and learning from the foundation phase of schooling, and to ensure stronger integration of government departments' strategies targeting skills development and education.

The availability of high-quality science, technology, engineering and mathematics graduates and teachers, especially secondary school mathematics and science teachers and early childhood development practitioners, is essential.

At technician level, there is an under supply of engineering technicians and associate professionals. The sector must develop enrolment targets in line with the skills needed for the labour market. This, in turn, requires assurance that TVET staff have the necessary competence and recent relevant experience.

Increased absorption of doctoral graduates into the economy is possible only if the acquired PhD-level skills and training are appropriate to the needs of industry, government and science councils, among others. Government and industry must be co-creators of human resources and nurture an increased appetite for PhD-level skills. Government will put in place incentives, for example, tax breaks for industries investing in funding PhDs from their own workforce.

Increased cooperation between universities, industry and government will increase the relevance of PhD training. Therefore, the diversification of knowledge workers through doctoral programmes facilitated jointly with industries, such as industrial doctorates, will be pursued. Government will also invest in tracer studies to understand the career paths and mobility of people with PhDs across different sectors (such as universities, science councils and industry).

Finally, open platforms could have an amplifying effect by dramatically increasing the pool of individuals available to address a given question and decreasing the time to develop solutions, ultimately decreasing the time to market. The DST will therefore continue to explore opportunities and barriers (for example, intellectual property and mission conflicts) for universities, science councils, government and the private sector to participate in open collaboration platforms.

5.5.2 Education and training for a future of digital jobs

The government will plan the future human resource needs of the country (according to the NDP and beyond) in a coordinated manner to ensure that scarce educational resources are optimised. More specifically, the DST will work with the DHET (and the Department of Basic Education) to integrate the need for STI skills into the South African National Skills Plan. The Department of Telecommunications and Postal Services, among others, will be involved in reshaping the country's skills development agenda in line with the jobs landscape of the future, prioritising digital skills. The STI policy nexus on education and training will serve as coordinating mechanism to avoid fragmentation of this effort across government and business.

Government needs to equip South Africa's youth with skills for the future, expose more students to coding and computational thinking, and train students in problem-solving and critical reasoning skills. South Africa, already facing skills backlogs, needs to capacitate its citizens to thrive in the changing world, and to ensure inclusive economic progress for the country. Our education system must equip students to be successful entrepreneurs, hold diverse jobs, and work across a number of industries.

To thrive, ICT skills will not be enough. South Africa's educators will design future-ready curricula that encourage critical thinking, creativity and emotional intelligence, and accelerate the acquisition of digital, science, technology, engineering and mathematics skills to match the way people will work and collaborate in the future, particularly in the context of the Fourth Industrial Revolution.

5.6 Policy intent: Ensure an open, responsive and diverse knowledge system

As discussed in Chapter 2, the world is facing challenges that require not only intensified knowledge development and research, but also new forms of knowledge production through open science and by combining inputs from different disciplines.

5.6.1 Open Science and Open Innovation

The OECD estimates that 30% of innovation in Europe is open in the sense of being shared. For example, the Philips Research Campus in Eindhoven invites industry participation with a view to facilitating collaboration between publicly funded and privately funded research. The Bill & Melinda Gates Foundation malaria project is also using data from a number of resources, because open innovation means that the disease can be addressed more quickly. It must be remembered, however, that open innovation does not mean “free”. Patents and intellectual property rights still apply, but only at the end of the innovation process.

The DST is actively examining the transition to open science and open innovation. This will call for appropriate regulatory frameworks and data skills development, as discussed below.

Incentives for open science will be fostered through education programmes and career development programmes for researchers. A focus on citizen science will also be introduced. Barriers to open science will be evaluated and where necessary removed, ensuring that legislation and practice support, rather than thwart, the principles of open and collaborative science. Government will therefore review these, taking into account certain aspects of intellectual property rights from publicly funded research and accepting that open science, open innovation and intellectual property, and the associated rights, are not mutually exclusive. Government will also review the policies and institutions governing access to research data and research publications.

As a general principle, publicly funded research and research data may, after a careful analysis, be made available (with some exceptions including data that can compromise sovereign security and which is of a confidential nature). Government will encourage researchers to deposit data arising from research in publicly accessible repositories, and to support open journal publishing and data sharing, providing access to data and other research outputs arising from publicly funded research. In this manner, research will be made more transparent, rigorous and efficient in stimulating innovation and promoting public engagement.

South Africa does not have formal protection for databases. Government will identify a licence system for depositing data and for the use of open data. What is in the public domain, what is not, or when it becomes available are pressing issues that need to be dealt with. Ensuring the needs and wants of the data provider are respected, and determining who can use the data, and under what conditions (research use, teaching and commercial use) are also important considerations. The Creative Commons licence is a good example for starting to draft specific licence types for different types of open data.

Contemporary open science and open innovation requires data to be findable, accessible, interoperable and reusable (FAIR) in the long-term, and these objectives are rapidly becoming expectations of funding agencies and publishers. The current Intellectual Property Rights from Publicly Funded Research and Development Act will be reconsidered to ensure that it supports the FAIR guiding principles for scientific data management and storage.

National data storage is a further matter that needs to be addressed. The DST will develop a long-term sustainable business model for a South African research data cloud. Institutional data repositories will be encouraged. More support is also needed for the harmonisation of repositories, which can take place through the Data Intensive Research Initiative of South Africa (DIRISA).

The DST, in consultation with Department of Telecommunications and Postal Services and DHET, will produce a national open science (and data) framework consisting of principles and guidelines for the adoption of open science in South Africa. The framework will be used as a vehicle for awareness raising and training on good practice.

The DST will work with the higher education sector and the relevant government departments to ensure data-related skills development for making efficient use of new scientific datasets, tools and methods.

Digital technologies are making the conduct of science and innovation more collaborative, international and open to citizens. In the next decade, as connectivity becomes ubiquitous, the shift to more distributed, networked and open organisational models will become commonplace. Those unable to make the change will be left behind. Therefore, government will prioritise funding for the provision of digital resources to the communities and institutions that need them the most.

As part of its commitment to African STI cooperation, South Africa will also work to advance the open science agenda elsewhere on the continent and within regional frameworks. The strategic role of the African Open Science Platform, hosted by the Academy of Science of South Africa, which promotes African-wide development and coordination of data policies, data training and data infrastructure, will be leveraged with the support of the DST and the National Research Foundation (NRF). In addition, South Africa is one of the founding members of the global Open Government Partnership, and took over the chair in 2015. As one of the signatories of this partnership, South Africa is committed to developing an open data policy framework and action plan.

5.6.2 Diversity of knowledge fields

Public investment in science and research (both fundamental and applied) is an investment in the nation's future, ensuring that South Africa has a productive economy and a healthy society, and contributes to a sustainable world. To this end, a general shift in focus towards innovation is required in the South African STI landscape. However, this does not imply an NSI overly focused on investment in experimental and/or applied research. Instead, a dynamic balance is needed, determined on the basis of, among other considerations, the status of the field of knowledge in question, perceived innovation opportunities, and the research intensity and structure of the industries involved.

Studies on the state of health of the different knowledge fields in South Africa will be intensified to allow the DST and other funding institutions to deploy research funding strategically and sustainably. However, support to all academic disciplines, that is, the arts (performing arts and visual arts), humanities (such as languages, literature and philosophy), social sciences (including economics, law, psychology and sociology), natural sciences (physics, chemistry, biology and so on), and applied sciences (engineering and technology, medicine, health sciences, agricultural sciences and computer science) must continue. Government policies need to recognise the importance of language, particularly in the home language of children, as the carrier of scientific meaning and information.

Many of the challenges facing humans in the near future, particularly in developing countries, will be solved by the engineering sciences (for example, infrastructure for rapidly growing cities and improved transport and logistics, water and energy infrastructure, and satellites to ensure information security for the state). Given the present shortage of skilled engineers in the country,³⁴ government will need to increase support for engineering science and research.

Regardless of the type of research being conducted, two requirements will remain important, namely, whether the research is aligned to the country's needs and delivering the required impact, and whether the research is of a consistently high standard (which to some extent overlaps with the first requirement). Government will therefore implement a framework for research evaluation and impact assessment, supported by a responsible research and innovation framework for the South African context.

Finally, the decolonisation of knowledge is an essential academic project that will inform institutional development and open up ways of rethinking the university curriculum to make the research enterprise more inclusive.

5.6.3 Role of the humanities and social sciences

The DST recognises the growing interconnections and complementarity between the natural sciences and the humanities and social sciences, the potential for creativity and innovation that these connections can generate, and the limits of using isolated scientific approaches to tackle societal challenges.

The purposeful inclusion of the humanities and social sciences in the national system of innovation will be prioritised, not only in the role of observer and commentator, but also in conceptualising, planning and executing innovation initiatives.

The DST and DHET will further ensure that the equipment and infrastructure required for the humanities and social sciences, for example, survey equipment and ICT infrastructure, is given prominence in the various equipment and infrastructure funding instruments in the NSI.

Relevant government departments will commit stable funding for a programme of social surveys and institutionalise several critical longitudinal socio-economic surveys, for example, on education outcomes (international comparison), South Africans' health behaviours, and aspects related to social cohesion and entrepreneurship.

5.6.4 Complex societal problems and inter- and transdisciplinarity

“Interdisciplinarity” is usually characterised by collaboration and the integration of concepts and methods (and in turn may lead to the creation of new concepts and knowledge). “Transdisciplinarity” takes this a step further and may represent a different kind of knowledge production, embracing both scientific and other types of knowledge and the involvement of a broader range of expertise, including, potentially, the end users of such research.

A transdisciplinary research process links societal problem-solving with scientific knowledge production in a process of co-producing knowledge. Close interaction with societal actors that can make decisions or take action, or may be affected in the respective field is key. To overcome the knowledge-action gap, the approach includes stakeholders from the beginning (co-design), deliberates on normative target questions (e.g. “What are more desirable futures?”), and co-produces knowledge on how to reach these targets.

Support for transdisciplinary research faces many obstacles. These include institutional and administrative rigidity, established specialisations among journals and professional societies, funder preferences and policies, and the incentives and constraints embedded in academic and research career tracks. It is important to address these, but there should not be a top-down forcing of inter- or transdisciplinary approaches. The idea is to build a more balanced research ecosystem that will stimulate creativity and advance our understanding of the world.

Universities and science councils will find creative ways, including incentives (e.g. funding for publications) for experienced and established cross-disciplinary researchers to mentor and guide cross-disciplinary research projects, as well as to play a role in strategic advice at the institutional level in promoting such activity.

The DST and DHET will encourage universities and science councils to intentionally promote transdisciplinary research by reducing institutional barriers to transdisciplinary research and interdisciplinary research teams. It will also develop structures to encourage input and participation from outside ongoing projects in such a way as to bring researchers from several institutions, representing multiple approaches, together in a transdisciplinary research environment. Funding agencies such as the NRF will support transdisciplinary research and create stepping stones for transdisciplinary careers.

Transdisciplinary research brings insights and ideas to people, but it is necessary to work on the skills involved. It is necessary to embed a transdisciplinary approach in academic institutions. The institutional culture is still predicated on publications rather than other outputs. Incentives such as increased funding for large multidisciplinary projects (that include the humanities and social sciences) and awards to increase awareness, will be put in place to stimulate this behaviour, at both national and institutional level. This dimension of knowledge generation will be included in the research evaluation and impact assessment framework to ensure that it is implemented.

5.6.5 Selection of key research areas, sectors and technologies

According to the OECD, it is important for countries such as South Africa (middle income, with small innovation systems) to focus their STI efforts.³⁵ However, NACI points out that an incorrect choice of focus area or focus strategy can be more damaging than a strategy of diversification.³⁶ Furthermore, analysts have noted that the resources of the South African NSI are too thinly spread to make a significant impact in priority areas. Some of the areas in which there has been good knowledge production may not necessarily be aligned to the areas in which innovation for socio-economic impact is most needed. The issue of selection is therefore both important and complex.

The DST will develop the process for the selection of focus areas as shown in the box below.

Selecting and supporting focus areas

- Identify the national STI priorities based on the Sustainable Development Goals and the NDP objectives. Examples of such priorities would include the need for a more inclusive economy; areas of social need, for example housing, health and education; opportunities for firm growth, exports and job creation; environmental sustainability; preparing for a more digitally advanced world and the disruption of the Fourth Industrial Revolution; building smart cities as centres of growth, and improving network infrastructure.
- Within these priorities, select focus areas, based on factors such as the capacity of South Africa to succeed in a field, for example, where a competitive or comparative advantage exists, and where the required critical mass of investment is feasible.
- Institutionalise the selection process and select the focus areas for the whole of government. The focus areas will be supported at the level of the Deputy President via the twice-yearly STI plenary meeting and the Interministerial Committee on STI to coordinate action on the focus areas.
- Concentrate resources at critical mass on the focus areas through an annual STI investment framework that would guide the allocation of research funding to national priorities, and that would ensure that funding flows to both the currently research-intensive institutions and historically disadvantaged institutions to make it possible to tap into the potential of the entire research system.

5.6.6 Knowledge diffusion

Government will enhance the spread of knowledge and encourage the sharing of ideas and research results by adopting an open science paradigm. Knowledge diffusion will also be improved through the enhanced coordination of STI activities across the NSI, which will facilitate the movement of researchers and knowledge between enterprises, universities, science councils and government. The increased absorption of people with PhDs and other highly skilled people into research-performing institutions will also enhance knowledge diffusion. Some of the mechanisms that could be used to achieve this are joint appointments and public-private partnerships.

Research cooperation will be improved. Investment in research programmes at the interface of various public research institutions (for example, universities and science councils), SOEs and industry will help build bridges for sustainable research cooperation, and ensure that skills produced by universities match those required by industry and science councils. Programmes at the interface will require easy movement of researchers between universities, science councils and industry. This will be achieved through, for instance, joint appointments, and staff and student mobility programmes.

The contribution of public research institutions and their outputs in supporting government policy and national priorities needs to be enhanced. This will include a programme similar to the Technology and Human Resources for Industry Programme. Research grant schemes to incentivise collaboration between universities and other public research institutions in inter- and transdisciplinary research will be developed.

Government will support increased networking and the diffusion of knowledge by leveraging existing global partnerships and knowledge networks better, introducing specific programmes for the secondment of South African researchers to institutions in other countries, providing increased support for training abroad, and providing enhanced support for conferences and workshops. An appropriate quota of international research cooperation engagements and resources will be channelled to historically disadvantaged institutions and universities of technology. Similarly, the role of office of technology transfers needs to be enhanced, creating demand for in-bound technology transfers.

South Africa's profile as a destination of choice for researchers and students from other African countries wishing to gain international experience and expertise needs to be promoted. Already, other African nationals are making significant contributions to strengthening the human resources available to the NSI. At the same time, programmes designed to afford international mobility, exchange and training opportunities for South African researchers and students should include a concerted pan-African focus, promoting the outward mobility of South Africans to centres of excellence and institutions elsewhere in Africa.

5.7 Policy intent: Support a science-literate and science-aware society

One of the prerequisites for an effectively functioning NSI is a society that is aware of the value and potential dangers of science, is able to evaluate the products of science, uses the processes of science in their daily lives (for example, asking questions, collecting and analysing evidence, and evaluating possible results), and engages in debate on science-related matters of public interest. Greater public awareness of scientific issues will also stimulate the interest of young South Africans in pursuing careers in science – thereby increasing the number of secondary students choosing subjects to prepare them for university studies in science, technology, engineering and mathematics fields.

In the current global “post-factual” society, raising science awareness is of increasing importance in efforts to provide credible alternatives to dubious sources of information. However, with growing access to the Internet and the proliferation of unverified information across digital media, these efforts are all the more difficult. In South Africa, the problem is compounded by issues in the education system and the fact that the spatial development patterns of apartheid have to a large degree persisted, particularly in rural areas, which means that many people live beyond the reach of science awareness campaigns.

Since 1996, the South African government, led by the DST, has made good progress in stimulating public awareness of science. Some gaps remain to be addressed, as detailed below.

5.7.1 The institutional environment

The role of the South African Agency for Science and Technology Advancement, as the national coordinator of science engagement in South Africa, will be entrenched through legislation. A system-wide science engagement coordination model will be instituted, going beyond the DST and its entities, enabling the higher education sector, industry, research councils, science centres and other relevant stakeholders to collaborate in science engagement.

Government will introduce an approach whereby a fixed percentage of the transfers by STI-intensive departments to their entities is to be spent on raising science awareness.

Support for existing science centres will be sustained, and support packages will be developed to establish more strategically positioned science centres, including world-class national flagship science centres or museums. This will involve private-sector co-funding.

5.7.2 Incentives for researchers

Scientists who participate in science engagement activities will be awarded continuing professional development points by the South African Council for Natural Scientific Professions.

Conditions for research training grants and research development programmes to science councils and public universities (e.g. research chairs and centres of excellence) will make it mandatory for recipient individuals and institutions to communicate their research to the public.

Initiatives such as early childhood development and digital literacy programmes can only produce the required results if society is science literate. It is therefore necessary to train scientists and researchers in science communication and science engagement skills. These trained researchers and scientists would then help to introduce developmentally appropriate engagement activities and projects for both adults and school learners. Government will aim to have these skills taken up in the curricula of SET students in the higher education sector.

5.7.3 The reach and effectiveness of science engagement activities

To increase the reach of awareness initiatives and promote access to information, science engagement activities will increasingly target the local government level, using appropriate communication technologies and techniques, including mainstream media and social media.

The development of science engagement and communication skills will be prioritised. Such skills development initiatives will target journalists, scientists, students, learners, educators and science interpreters.

Indicators to measure the success of system-wide science engagement performance will be adopted to inform an institutionalised survey on public perceptions of science and country comparison studies.

5.8 Policy intent: Upgrade and expand research infrastructure

Research and innovation infrastructure is recognised as a key element for boosting scientific knowledge generation, accelerating technology development, enhancing both technological and social innovation, and providing advanced scientific training for new generations of scientists and science managers. Furthermore, research and innovation infrastructure provides an enabling environment for established researchers to improve their performance and knowledge and innovation outputs.

The factors that underlie current challenges in the provision of research and innovation infrastructure include the following:

- A lack of long-term planning by institutions to meet the high demand for research and laboratory equipment.
- Inadequate funding to upgrade and replace old research infrastructure, lack of national accredited health (preclinical) research facilities, and the need to improve the overarching governance of distributed research infrastructure.
- Inadequate specialised skills related to research infrastructure, for example, for maintenance.
- Inadequate coordination across institutions in providing data-intensive research infrastructure, and lack of digitisation facilities.
- The challenges and gaps arising from the emerging imperatives for a competitive NSI, including a lack of capability to exploit the convergence of ICT fully to drive digital society and transformation.
- Insufficient access to research infrastructure for grassroots innovators.
- Inadequate provision of research infrastructure to support social research.
- The significant costs associated with innovation infrastructure and the lack of fully developed financial decision-making systems and partnership and financing models related to such infrastructure.

To renew and maintain the current infrastructure base adequately, a long-term coordinated planning approach for research and innovation infrastructure investment (across different departments, as well as the relevant SET) will be developed. The investment planning will make provision for renewal and replacement, as well as maintenance and technical support.

To help address the challenge of insufficient funding for research and innovation infrastructure across the entire innovation value chain, a national research infrastructure fund at the National Treasury will be established with long-term planning horizons. The level of investment in knowledge infrastructure will be increased to ensure that South Africa remains competitive in terms of knowledge and innovation outputs, as well as to train the next generation of researchers.

There is a specific need for increased investment in high-end infrastructure to support innovation, produce new products and develop new industries, among other things. Examples of this type of facility are those focused on resource beneficiation, such as pilot plants for the platinum powder industry and hydrogen fuel cells. The exact level of funding required would depend on the type of high-end infrastructure, but an agreed percentage of total funding will be used to support such infrastructure.

Lack of coordination and integration among departments in providing and accessing research infrastructure leads to bottlenecks and the duplication of effort. Government will establish an intergovernmental coordination and steering platform with a clear mandate and scope, strategy and policy guidelines, co-funding, shared procurement agreements, and joint planning principles to address the lack of coordination.

Government will retain the six national research facilities currently managed by the NRF as research infrastructure platforms. However, the implementation of the South African Research Infrastructure Roadmap will require many more. The management model will therefore be changed to facilitate scale-up, sustainability and improvements in the performance and establishment of these facilities.

Training and developing key human resources is critical to ensure the optimal and sustainable use of research infrastructure. Government will therefore introduce a mandatory requirement that infrastructure provision policies include human resource development support (scientific and technical) for infrastructure development and maintenance through internships, curriculum changes in higher education institutions, and absorption into the workplace.

Not sharing or integrating research infrastructure leads to isolated and duplicated approaches to research infrastructure deployment and use. To address this challenge, government will develop programmes and interventions that build a continuum of research infrastructure capabilities at institutional, regional and national level (vertical integration). It will also establish distributed national research infrastructure to optimise and share resources, including for the humanities and social sciences.

Grassroots and other categories of neglected innovators who are not part of formal systems of innovation need access to research infrastructure. Government will therefore establish open access (and mobility) research infrastructure support (excellence/evidence-based) platforms for grassroots and other neglected innovators, as well as to support innovation for inclusive development.

South Africa's national policies and strategies, including on investment planning for research infrastructures, must embrace a regional and continental focus. African regional e-infrastructures, such as dedicated high-speed research networks, will be essential for enabling intensified intra-African research collaboration, which South Africa needs and seeks to promote. Investment planning for large-scale facilities with expensive construction and operational costs should consider the possibility of jointly developing the facilities with other African partners as regional or continental facilities. Programmes and networks should also be developed to facilitate reciprocal access and collaboration between different African countries' national facilities. South Africa will work within the frameworks of the AU and SADC to support the formulation of African continental and regional research infrastructure policies and strategies.

Through partnerships with international research facilities such as the European Organisation for Nuclear Research, the European Molecular Biology Laboratory, the European Synchrotron Radiation Facility, and Russia's Joint Institute for Nuclear Research, South Africa has gained access to cutting-edge research infrastructure that cannot be duplicated in South Africa because of its complexity and the massive financial investment needed. These partnerships have provided South African scientists with an opportunity to conduct research at the frontier of knowledge; attracted prominent visiting scientists to South Africa; extended the PhD and master's supervisory capacity of South African higher education institutions; provided opportunities for training, and skills and technology transfer; contributed significantly to the internationalisation of South African world-class research; enhanced South Africa's visibility and footprint in the international scientific community; and leveraged international research funding from new partnerships. These partnerships will be intensified.

There are weak links and partnerships between the private and public sectors on investment in research infrastructure. Open-access research infrastructure support platforms will be established to encourage private-sector investment in research infrastructure.

To attract multinational corporations to locate their technological infrastructure in South Africa, incentives and the appropriate skills will be required. For South Africa to use public funding to support such facilities, it will be necessary to ensure that the new technological infrastructure is backed by a group of companies or by entire industrial sectors on the basis of their potential competitive gains, as well as scientific organisations.

It has become critical for the country to formulate the risks of adoption or non-adoption of an integrated digital strategy. To mitigate the risks, government will develop a South African integrated digital strategy setting out the key enabling role that the use of ICT will have to play. It will also develop national legislation/policy on digital data to regulate data sharing and access, ethics, privacy, and intellectual property at national level.

5.9 Policy intent: Expand internationalisation and science diplomacy

One of the strengths of South Africa's NSI, and a critical one given that it is comparatively small, is its extensive and active set of international partnerships. Over the past 20 years, global cooperation and support have contributed significantly to the growth and development of the NSI. However, well-resourced South African institutions find it much easier to take part in these programmes than historically disadvantaged institutions, and a more inclusive approach is needed.

"Science knows no country, because knowledge belongs to humanity, and is the torch which illuminates the world."

Louis Pasteur

South Africa will continue to prioritise support for the development of STI capacity in Africa and the implementation of the Science, Technology, and Innovation Strategy for Africa. Informed by the pan-African focus of South Africa's foreign policy and strategy for international STI cooperation, the country has a responsibility to contribute to STI capacity building in Africa. It is important to emphasise the importance of international engagement, not as an objective in its own right, but as an integral part of the overall further evolution of the NSI. The government's initiatives below relate to the strategic policy context, implementation modalities, and planning and coordination of international cooperation.

5.9.1 Enhanced strategic focusing

Rather than following an ad-hoc approach, science diplomacy will be strategically harnessed as an instrument to advance South Africa's foreign policy agenda and optimise the role of international STI cooperation in the implementation of Chapter 7 of the NDP, "Positioning South Africa in the World".

South Africa's engagements with African STI partners will be more strategically coordinated to ensure the implementation of the AU and SADC STI agenda, to better leverage synergies between the two agendas and avoid duplication. The government will facilitate support for a pan-African STI funding agency, including the joint publication of articles with researchers from the rest of the continent.

The Sustainable Development Goals will be the guiding multilateral policy framework for South Africa's international STI cooperation. It is anticipated that developments in the African and regional context will increasingly affect the NSI, as South Africa's political and economic integration deepens in the AU and SADC.

As competition for international cooperation opportunities intensifies, efforts to promote South Africa's profile as a global STI partner of choice will be stepped up. This will include initiatives such as institutionalising the management of Science Forum South Africa.

5.9.2 Efficiencies in international cooperation

To improve the NSI's innovation performance, a systematised framework for South Africa's engagement with international innovation partnerships (as opposed to the traditional academic and basic research-orientated focus of international cooperation) will be developed, with particular attention given to funding instruments.

Interventions will be developed to increase South African researchers' access to training opportunities abroad, responding to capacity needs in the NSI and ensuring that the NSI reabsorbs South Africans studying abroad, while also attracting skills to South Africa and fostering cooperation with the South African diaspora. The interventions will include a focus on attracting postdoctoral researchers to South Africa, with the specific aim of boosting South Africa's PhD productivity through increased supervisory capacity. The overall role of international cooperation in enhancing South Africa's research capacity, for example, through co-authorship, will be strengthened.

There will be an intensified focus on attracting STI-related investment into the country, and these efforts will be better aligned with government's general efforts to attract foreign investment into South Africa. The intent is to

secure at least 15 per cent of South Africa's GERD from international sources, and to grow this ratio over time.

A strategy will be developed to increase the participation of historically disadvantaged institutions in international collaborations, and to ensure that international collaboration does not perpetuate exclusion.

5.9.3 Planning and coordination for international cooperation

Coordinating mechanisms will be developed to ensure greater strategic focus and efficiency in international STI cooperation, avoiding fragmentation and duplication. These will include intelligence and information sharing, joint priority setting, and encouraging the exploitation of synergies.

Indicators and an M&E framework will be developed to better gauge the impact and outcomes of international STI partnerships. This will include systems for enhanced knowledge management of all South Africa's international STI cooperation initiatives (government and business).



CHAPTER 6

FINANCING SCIENCE, TECHNOLOGY AND INNOVATION

Chapter 6: Financing Science, Technology and Innovation

Very few of the ambitions of this White Paper will be realised without adequate funding. Financial resources directly influence the size, shape and strength of the NSI and its ability to support the NDP. The White Paper concludes with this chapter on financing South African STI.

6.1 Progress in financing STI, gaps and focus areas to increase NSI financial resources

Recent reviews,^{37|38} all point to the fact that the South African NSI is underfunded, both at the aggregate level and at the level of STI in critical sectors of the economy, such as agriculture and mining. Furthermore, the reviews note that funding is not appropriately spread across the entire innovation value chain, and that foundational STI functions such as human resource development and infrastructure provision are underfunded. To enhance South Africa's innovation performance, increased funding is also needed for leveraging international funding and resources, technology transfer activities, and public incentives to encourage private sector research, development and innovation (RDI).

"R&D has played an important role in helping middle-income countries such as South Korea advance to high-income status. While South Africa needs to spend more on R&D in general, the institutional set-up also needs to improve the link between innovation and the productive needs of business. Government should partner with the private sector to raise the level of R&D in firms. Public resources should be targeted to build the research infrastructure required by a modern economy in line with the country's development strategy."

South Africa's National Development Plan, 2011

Gross expenditure on research and development (GERD) in constant 2010 rand terms and as a percentage of GDP has increased slowly over the past two decades. However, South Africa's global share of R&D declined by 25 per cent over the period 2007 to 2013, while India and China grew their shares by 18 per cent and 92 per cent respectively. GERD as a percentage of GDP was 0.8 per cent in 2015/16, a small improvement from the 0.77 and 0.73 per cent reported in the previous four R&D surveys. This improvement is significant, however, since it took place in the context of slowing GDP growth, which stood at 2.5 per cent in 2013, 1.7 per cent in 2014 and 1.3 per cent in 2015.

The relatively low level of GERD and the near stagnation of GERD as a percentage of GDP, particularly in comparison with other emerging economies, is a concern, and it is important to understand the figures in more detail. The business sector, which includes local private enterprises (large businesses, SMEs and start-up firms), SOEs and multinational enterprises, has a significant influence on the overall trend of GERD. Between 2004 and 2015, business funding of R&D increased by 93 per cent, whereas government funding increased by 138 per cent – government therefore being responsible for the bulk of the increase.

However, there are signs that this trend is changing. For instance, the business sector contributed to the bulk of GERD recovery in 2013 and 2014, although the increases were off a low base. In fact, this sector remains the largest performer in the history of the South African R&D survey. Furthermore, foreign funding for R&D decreased from 15.3 per cent in 2004/05 to 13.0 per cent in 2015/16, which is a relatively small decrease over a period straddling the 2008/09 global financial crisis, pointing to resilience in South Africa's ability to attract foreign funding for R&D.

Over the past two decades, public resources for innovation have increased significantly: the budgets of all departments active within the NSI have increased in real terms, led by the DST, whose expenditure has increased nine-fold since 2005/06.³⁹ Government funding of R&D has continued to grow steadily and sustainably over the past five years, amid slow growth conditions. In addition, sectoral public investment in R&D is taking place via sector-specific science councils such as Mintek, the Agricultural Research Council and the South African Medical Research Council.

Despite these signs, increased funding by all sectors, not only for R&D but for STI in general, remains critical. Government funding is necessary to catalyse investments in areas where other actors have limited incentives to fund. For a developing country like South Africa, the rationale for government investment in STI is even greater, given that the country not only needs to catch up in several dimensions of economic growth and development, but also needs to establish new science, engineering and technology capabilities for its long-term competitiveness.

However, government funding on its own is insufficient for growing the NSI to its full potential; increased private sector involvement in resourcing the NSI is vital, both to advance private sector objectives and to support the government in RDI initiatives for the public good. Furthermore, a modern, open economy must attract higher rates of international funding and resources for RDI. With South Africa now more integrated globally than it was in 1996, it faces a new test, namely, to match its peers in attracting the shifting global RDI investments that continue to favour emerging economies. It will therefore need to provide equitable co-investment to attract funding from international partnerships.

Finally, in addition to the problem of general underfunding of the NSI, the 2012 Report of the Ministerial Review Committee on the STI Landscape⁴⁰ highlighted the need to improve the allocation of public funding to STI priorities, as resources are often too thinly spread to achieve impact in areas critical to South Africa's development. There is also room to increase the productivity of funding.

To address the reasons for the situation described above, this chapter contains policy proposals to:

- Increase funding to the NSI, with a focus on increasing business and foreign investment in STI, as well as to encourage provincial and local governments to invest more in STI as part of their development strategies.
- Improve the allocation of public funding for STI and the coordination of public investment to ensure that government's STI priorities are appropriately funded.
- Enhance the efficiency of funding in the NSI.

Policy intents and actions

6.2 Policy intent: Increase levels of funding

Government recommit to the target of increasing the intensity of R&D investment in the economy so that GERD reaches 1.5 per cent of GDP in the next decade, and an aspirational 2 per cent a decade later. A number of specific interventions aimed at realising this objective are discussed below.

Provincial and local governments will actively contribute more to STI funding and, over time, will set appropriate targets for investment in STI as part of their growth and development strategies. Examples of investment opportunities are incubation and testing facilities.

National STI-intensive government departments will set appropriate targets for STI in their budgets. In particular, line departments will commit a percentage of their budget for sectoral research, development and innovation plans and invest in their line science councils accordingly.

Development finance institutions – the Industrial Development Corporation and the Development Bank of Southern Africa – will scale up funding for industrial innovation activities. This approach will help establish a closer interface with the Technology Innovation Agency and scale up the overall level of government support for RDI. This will serve to close a critical gap in funding for large-scale projects that require government funding commitment to catalyse large-scale private sector action. The approach will also accelerate South Africa's investments in other parts of Africa, in the context of the African Union's Agenda 2063. In this regard, possible partnerships with the BRICS Development Bank will be explored.

International investments in STI will be included and appropriately positioned in the Trade and Investment South Africa initiative based at the Department of Trade and Industry to attract STI-linked foreign direct investment. The focus will be on promoting foreign direct investment, including targeted engagements with multinational companies. In terms of scope, international investment is considered to include direct investment by multinational corporations that fund and perform R&D, as well as mutually beneficial partnerships in human resource development, scientific infrastructure, knowledge networks and collaborative R&D.

New funding models across the innovation value chain will be used. Examples include corporate social investment, crowdfunding, and partnerships/collaborations between actors across different sectors and borders. The growing sector of corporate social investment funds and non-profit organisations presents opportunities to advance grassroots and social innovation, for example, through venture capital funding. Government will introduce instruments such as matching funding and awareness raising to make greater use of these opportunities.

There is a specific need for increased commercialisation funding. A sovereign innovation fund will be formed to leverage co-investment by the public and private sectors to address gaps in technology commercialisation. The fund will be designed to complement and enhance existing funding instruments, and to provide large-scale funding for the development and maturation of radical innovations and emerging industries. Within the public sector, agencies such as the Technology Innovation Agency, the Industrial Development Corporation and the Development Bank of Southern Africa, in cooperation with the National Treasury, can contribute to this fund.

6.3 Policy intent: Develop funding priorities

To guide long-range planning and budgeting for the STI sector, decadal plans identifying priorities for STI will be developed by the DST in collaboration with relevant role players across the public and private sectors. The STI decadal plans will identify funding requirements per priority sector across the entire innovation value chain – both supply-side (e.g. research and human resource development funding needs) and demand-side (e.g. co-funding incentives, public procurement commitments to assist with commercialisation, and sector innovation funds).

In the short term, new industries that add value to South Africa's mineral and agricultural resources, and move the country higher up the value chain, as well as initiatives linked to the Fourth Industrial Revolution, will be prioritised in the decadal plans. Long-term priorities will be determined according to the assessment of market drivers, the strategic use of techno-economic studies (including analyses of competitive advantage), the identification of lead users and industrialisation partners, governance arrangements, and funding requirements (see Chapter 5 for more detail on the selection of focus areas).

The decadal plans will further assist the DPME in drafting its annual Budget Mandate Paper on funding priorities for government.

6.4 Policy intent: Institutionalise a framework for guiding public STI investment

The DST, working with NACI, will develop a public STI investment framework. NACI's role will be to undertake foresight studies and provide an independent STI M&E function (including regular analysis of public STI spending). The framework will be based on analysis of STI funding requirements in line with strategic and sovereign priorities, as well as consultation across government through an interdepartmental STI budget committee at the level of director-general, including national and provincial governments with significant STI mandates.

The STI investment framework, under the auspices of the Interministerial Committee on STI, will guide funding allocations by the National Treasury, based on the Budget Mandate Paper. To achieve this, government will institutionalise an appropriate process, as part of its Budget Mandate Paper development process and Medium-Term Expenditure Committee process, to enable the interdepartmental STI budget committee to provide advice on funding needs for STI priorities and related programmes identified by the STI investment framework. Each department will, however, remain responsible for overseeing transfers to its public entities, and monitoring and reporting on key deliverables.

6.5 Policy intent: Improve funding efficiencies

Although the case for increased funding is clear, it will also be necessary to optimise existing funding through improved coordination (across government, as well as between the public and private sectors), reduce duplication of effort and improve synergies. Furthermore, to ensure optimum results from investments, the efficiency of public NSI institutions, to which most of this funding is deployed, will need to be enhanced where necessary.

The South African funding regime currently consists of many different institutions with varying mandates and levels of funding, creating a landscape that is difficult for any innovator or institution to navigate. To simplify the application processes and reduce duplication, the functions and funding instruments of the following institutions, among others, will be harmonised: The Technology Innovation Agency, the National Intellectual Property Management Office, relevant sections of the Small Enterprise Development Agency, the Technology and Human Resources for Industry Programme, the Support Programme for Industrial Innovation, elements of the Industrial Development Corporation, and parts of the NRF. The intention is to ensure a seamless transition between functions and instruments.

The administrative capabilities of the relevant institutions will improve efficiency through, for example, simplified application processes, uniform application forms, "one-stop shop" approaches (including an information/application portal) for addressing questions and assisting applicants, standardised approaches to evaluation, and more information sharing, especially among SMEs.



CHAPTER 7

CONCLUDING REMARKS

Chapter 7: Concluding Remarks

For South Africa to become a winning nation in the field of STI, and for STI to realise its potential as a driver of economic growth and development, this White Paper proposed various policy shifts. These include the following:

- Increasing the focus on inclusivity, transformation and linkages in the NSI.
- Enhancing the innovation culture in society and government (adopting a whole-of-government approach to innovation).
- Institutionalising approaches to improve policy coherence and programme and budget coordination in the NSI.
- Instituting monitoring and evaluation systems.
- Developing an enabling environment for innovation.
- Including and supporting civil society and business, with a focus on SMEs, in government planning and funding.
- Developing local innovation ecosystems.
- Supporting social and grassroots innovation.
- Improving the human resource development pipeline and instilling an innovation mindset from basic to tertiary education.
- Developing the next generation of researchers and ensuring that PhD graduates fit the needs of the economy.
- Endorsing open data, open science and open innovation approaches.
- Supporting inter- and transdisciplinary approaches to knowledge development
- Prioritising a pan-African STI agenda.
- Increasing investment in the NSI and optimising the productivity of these investments.

The indicators to measure the achievement of these, and the other, objectives of the White Paper, will be developed as part of the implementation plan for the White Paper (the Decadal Plan). However, the truest test of this White Paper will be the impact that it has in realising the potential of STI to support the achievement of the National Development Plan's objectives as well as the Sustainable Development Goals.

"This 2018 White Paper on Science, Technology and Innovation is principally about impact."

Remark during consultation with Universities South Africa (USAf), 2017.

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