Department of Science and Technology Ministerial Review Committee on the Science, Technology and Innovation Landscape in South Africa

FINAL REPORT

MARCH 2012

To :The Honourable Minister of Science and Technology ,
Mrs GNM Pandor MP

science & technology
Department:
Science and Technology
REPUBLIC OF SOUTH AFRICA

TABLE OF CONTENTS

PREFACE

The mandate given to the Ministerial Review Committee has been a challenging one for a number of reasons, not least because of the complexity of the object **of study. In asserting the inclusive definition of the National System of Innovation (NSI) (rather than a restricted definition), the Committee set itself the task of appraising, and making recommendations on, a very extensive landscape of human endeavour, marked by widely differing t**erritories and strongly divergent fields of practice.

The Committee was conscious of the prior efforts of numerous reviews and evaluations that recommended significant NSI organisational and structural changes, only to see things remain as they were. Some of our advice may therefore carry echoes of previous recommendations, but now with measures that are intended to achieve the policy effects that we seek for the system.

We believe that this report provides fresh reflection on the issues and brings into discussion a range of considerations not assembled in this way before. We are aware of important dimensions that deserve further attention, however, either because their salience has been illustrated in the report or because the limitations of time and resources have not permitted their inclusion.

The process for preparing this report included a number of interviews with expert individuals, and the Committee is grateful for the important insights that were gleaned in this way. Furthermore, the report was to be informed by the commissioning of a number of specialist writers, identified by the Committee, to produce commissioned reports on one or another dimension of the planned report. While a great deal of excellent work has been delivered by these writers, some have inevitably been constrained in the levels of investment possible, especially in terms of time available for fresh empirical enquiry. The content of the specialist reports thus generally reflects the existing fields of expertise of the writers, and their capacity to undertake further desk research at short notice in response to our commissions. So, while some limited fresh research was undertaken to inform some reports, this has been somewhat less than the subject matter deserves. As the report indicates, there is an argument to be made for a strong research and evaluation capacity to be established, dedicated to informing the future strength and direction of the NSI. We trust that the discussions raised in this report will inform future research agendas, both in the short and longer term.

On behalf of the Committee, I would like to express our appreciation to the Minister for the opportunity afforded this Committee to undertake this project of national importance, and for the guidance and direction we have received from her. The importance of this work is reflected, perhaps, in the willingness and commitment of the various informants and specialist writers that we have approached in the course of this project, and we are grateful to them for their generous time and considered insights. I would like to thank the Committee for their participation in producing this report, and the investment they made among their many other pressing commitments. In particular, I would like to express our appreciation to the report writers, Professors Wieland Gevers, Michael Kahn and Robin Moore, and to Ms Rita Sikhondze and Professor Robin Moore for the management of the project. We acknowledge with thanks the efforts of the DST Secretariat that was allocated to support the work of the Committee, in particular Mr Mlungisi Cele, Ms Miyelani Mashimbye and Ms Zoleka Ndlovu.

The Committee thus presents this report for the Minister's consideration.

Professor Loyiso Nongxa
Chairperson: Ministerial Review Committee on the National System of Innovation

March 2012

BACKGROUND

REMIT OF THE COMMITTEE

In July 2010, the Minister of Science and Technology, Minister GNM Pandor commissioned a Ministerial Committee to review the current science, technology and innovation (STI) landscape in South Africa, proposing a two-phase study that would both appraise the present as well as provide considerations for the future. The responsibilities of the Committee, and the purposes of the respective phases, are outlined below.

The **purpose** of the Ministerial Committee was to:

- Review the science, technology and innovation landscape and its readiness to meet the needs of the country
- Appraise the degree to which the country is making optimal use of its existing strengths
- Assess the degree to which the country is well positioned to respond rapidly to a changing global context and meet the needs of the country in the coming ten to thirty years.

The study must provide the nation with an understanding of what is being achieved in and by the National System of Innovation (NSI).

It must identify what is required from the state in order to ensure an adequate and growing investment in enhancing innovation that:

- Will deliver a sustained and durable knowledge-based economy
- Is geared to advance the national objectives of economic growth, jobs, better health, quality education and responsiveness to the needs of the most marginalised
- Facilitates the increased involvement of other key stakeholders.

According to the **terms of reference**, the work of the Ministerial Committee was to be undertaken in two phases.

Phase One: The Contemporary NSI Landscape

In the first phase, the Committee conducted a desktop study of the contemporary NSI landscape and, in particular, an assessment of:

- The OECD Review and its recommendations
- Key policies, strategies and reports of the DST and its public entities including the science councils and the national facilities (particularly in the period 2004 – 2009)
- The role of the private sector in science, technology and innovation

From this preliminary work, the Committee produced advice to the Minister on:

- The degree to which the recommendations of the OECD Review had been acted upon
- The adequacy of existing documentary data to inform an assessment of the strengths, shortcomings and responsiveness of the system in addressing the purpose above.

The work of the Committee during Phase One formed the basis for the continuation of Phase Two of the investigation.

Phase Two: Recommendations for the future of the NSI

During Phase Two, the Ministerial Committee was tasked to implement the scope of work developed in Phase One, as approved by the Minister. Based on the analysis of Phase One, and the further work undertaken in Phase Two, the Committee was to:

- Report on the performance of the system of science, technology and innovation, with particular reference to the following aspects of the system:
    - Size and shape
    - Governance and structure
    - Resourcing and financing (including human resource development)
    - Capacity to monitor and evaluate the impact of the system on the growth of a knowledge-based economy and in meeting the priorities of national development
    - Readiness of the system to adapt to changing circumstances.
- Make recommendations to the Minister on the steps that should be taken to strengthen the national system of science, technology and innovation, and to enhance the country's innovation capabilities, with particular reference to:
- Structure and governance of the system, including roles and responsibilities of different actors within the STI system
- Roles and responsibilities of the DST, including its relationship with other government departments
- Human resource and infrastructure capabilities
- Recapitalisation and funding requirements.

In particular, Phase Two was expected to make recommendations regarding:

- The framework conditions to achieve coordination and coherence of the components of the NSI to ensure a functional and effective system that will deliver innovation-driven national economic and social development
- The appropriate institutional arrangements and structures (existing, or to be established) that will direct the NSI, and will highlight and prioritise future challenges and research needs, and set out a suitable timeframe for addressing them

- The location and levels of investment responsibility for the NSI, including government, business, foreign support and other sources of funding and specifically to propose an investment plan for the NSI.

Process

In addition to desktop studies, the Committee was expected to engage with key stakeholders within and outside the national system of science, technology and innovation.

The Committee submitted its Phase One report to the Minister in November 2010. This report was presented to Cabinet and to the Parliamentary Portfolio Committee on Science and Technology.

In January 2011, the Minister advised the Committee to proceed with Phase Two of the exercise. The report on Phase Two was delivered to the Minister in November 2011.

This Final Report comprises the reports of both Phase One and Phase Two, and an overarching Executive Summary. Appendix 2 contains two diagrams illustrating the structure of the proposed institutional government research and innovation funding system.

COMPOSITION OF THE MINISTERIAL COMMITTEE

The Committee was constituted as follows:

Professor Loyiso Nongxa (Chair)
Professor Wieland Gevers (Deputy Chair)
Professor Cheryl de la Rey
Professor Brian Figaji
Professor Michael Kahn
Professor Thokozani Majozi (appointed 1 September 2011)
Professor Phuti Ngoepe
Professor Mmamokgethi Setati
Mr Michael Spicer
Dr Alysson Lawless (a member during Phase One)

The Committee was assisted by a **Secretariat** provided by the Department of Science and Technology:

Mr Mlungisi Cele
Ms Miyelani Mashimbye
Ms Zoleka Ndlovu

The report writing was undertaken by:

Professor Wieland Gevers
Professor Michael Kahn
Professor Robin Moore

The following were responsible for project management:

Professor Robin Moore
Ms Rita Sikhondze

APPROACH AND ACKNOWLEDGEMENTS

During Phase One, the Committee requested a number of **briefings**, and would like to express its appreciation to the following, many of whom were accompanied to the briefing sessions by members of their respective senior executive teams:

Ms Marjorie Pyoos	Department of Science and Technology
Dr Albert van Jaarsveld	National Research Foundation
Dr Sibusiso Sibisi	Council for Scientific & Industrial Research
Dr Steve Lennon	National Advisory Council on Innovation
Dr Phil Mjwara	Department of Science and Technology
Dr Molapo Qhobela	Department of Science and Technology
Dr Olive Shisana	Human Sciences Research Council

The Committee also commissioned a number of **briefing papers** that contributed seminal content to this report:

Professor Wieland Gevers (2 papers)
Professor Michael Kahn (2 papers and 1 presentation)

Mr Michael Spicer (2 papers and 1 presentation)
Professor Phuti Ngoepe (1 paper)

In its Phase Two deliberations, the Committee conducted a number of **interviews with expert informants**, and would like to express its appreciation to the following:

Ms Luci Abrahams	Learning Information Networking Knowledge Centre (LINK), University of the Witwatersrand
Ms Ferrial Adam	Gauteng City Region Observatory (GCRO)
Professor Erik Arnold	Technopolis
Emeritus Professor Martin Bell	University of Sussex
Professor Haroon Bhorat	Development Policy Research Unit (DPRU), University of Cape Town
Professor Ben Cousins	University of the Western Cape
Professor Owen Dean	Spoor and Fisher
Mr Simphiwe Duma	Technology Innovation Agency
Professor David Everatt	Gauteng City Region Observatory
Mr Mahesh Fakir	The Presidency
Mr Roger Jardine	CEO, Aveng (Pty) Ltd
Ms Rhoda Kadalie	Impumelelo
Professor David Kaplan	University of Cape Town
Professor Mohamed Karaan	Stellenbosch University
Ms Geci Karuri-Sebina	South African Cities Networks
Professor Murray Leibbrandt	Southern Africa Labour and Development Research Unit (SALDRU), University of Cape Town
Ms Bridget Letty	Institute of Natural Resources
Professor Rasigan Maharajh	Institute for Economic Research on Innovation (IERI)
Mr Mabhule Makhine	Greenhouse Project
Professor Gillian Marcelle	University of the Witwatersrand
Dr Phil Mjwara	Department of Science and Technology
Dr Shadrack Moephuli	Agricultural Research Council (ARC)
Professor Seeraj Mohammed	University of the Witwatersrand
Mr Sam Morotaba	Department of Labour
Dr Kuben Naidoo	National Planning Commission Secretariat
Ms Jayshree Naidoo	Development Bank of Southern Africa (DBSA)
Dr Thiambi Netshiluvhi	National Advisory Council on Innovation (NACI)
Dr Siyabulela Ntutela	Technology Innovation Agency
Mr Hermann Oelsner	Darling Wind Farm
Professor Francis Petersen	University of Cape Town
Mr Nkahloleng Phasha	Department of Labour
Dr Nicolas Pons-Vignon	University of the Witwatersrand
Mr Stephen Porter	University of the Witwatersrand
Professor Anastassios Pouris	University of Pretoria
Dr Nick Segal	Independent Consultant
Dr Sibusiso Sibisi	Council for Scientific & Industrial Research
Mr Garth Strachan	Department of Trade and Industry
Professor Mark Swilling	Stellenbosch University
Professor Alex van den Heever	University of the Witwatersrand
Professor Servaas van der Berg	Stellenbosch University
Professor Karl von Holdt	University of the Witwatersrand
Professor Eddie Webster	University of the Witwatersrand
Mr Nimrod Zalk	Department of Trade and Industry

The Committee also commissioned a number of **specialist reports** that provided seminal contributions to this report:

Professor Ben Cousins
Professor Michael Kahn
Professor David Kaplan
Ms Geci Karuri-Sabina
Professor Rasigan Maharajh
Professor Gillian Marcelle
Professor Francis Petersen
Dr Nick Segal
Dr Rolf Stumpf
Professor Alex van den Heever
Dr Gerhard von Gruenewaldt and Dr Anthon Botha

The Committee's deliberations were strongly informed by these various contributions, and this report has drawn extensively from the insights provided in this way. A full list of the documents and references accessed by the Committee is available in the bibliography of this report.

EXECUTIVE SUMMARY

FRAMEWORK FOR THE SOUTH AFRICAN NSI

In July 2010, the Minister of Science and Technology, Minister GNM Pandor, MP, commissioned a Ministerial Review Committee to review the South African science, technology and innovation landscape with respect to its readiness to meet the needs of the country, the extent to which the country was making optimal use of its existing strengths, and the degree to which the country was well positioned to respond rapidly to a changing global context and to meet the needs of the country in the coming ten to thirty years.

The Committee was also required to identify what would be required from the state, as well as from other key stakeholders, in order to ensure an adequate and growing investment in innovation that would deliver a sustained and durable knowledge-based economy geared to advancing the national objectives of economic growth, job creation, better health, quality education and responsiveness to the needs of the most marginalised.

In particular, the Committee was required to make recommendations on the future structure and governance of the system, including the roles and responsibilities of different actors within the system; the roles and responsibilities of the Department of Science and Technology (DST) including the relationship with other government departments; human resource and other capabilities; and the recapitalisation and funding requirements.

The focus of the Committee's work was the relevant policy framework established since the adoption of the White Paper on Science and Technology in 1996, while the point of departure was the last systematic review of the South African National System of Innovation (NSI) conducted by the Organisation for Economic Cooperation and Development (OECD) in 2006/2007. The Ministerial Review Committee was in essence tasked to provide the nation with an understanding of what was really being achieved by the NSI as the key driver of knowledge-based economic growth and associated inclusive national development, and to recommend ways in which the system could be made more effective.

In order to fulfil its task the Committee submitted draft reports in two phases: firstly to provide an appraisal of the existing NSI landscape and secondly to provide recommendations for the future system. This executive summary distils the insights of both of these reports, the fuller versions of which constitute the main text of the full report that follows this summary.

Conceptual framework for innovation

Innovation is the capacity to generate, acquire and apply knowledge to advance economic and social purposes. It includes both the search for frontier technologies driven by research and development (R&D), as well as the forms of learning and adaptation that might be market led or socially driven. Innovation is fundamentally uncertain, highly contextual and path dependent, but it is at the heart of moving the country from its present mix of resource- and efficiency-driven economic activity to one that is driven by the generation and application of knowledge. It is about doing new things in new ways.

Every country has a national system of innovation, which is the sum total of activities that contribute to innovations of any kind, whether as improved practices or as new products. When a deliberate, concerted and sustained effort is made to enhance the effectiveness and efficacy of the system through focused support and improvements in system design, based on the acceleration made possible in learning organisation mode, the otherwise inchoate system becomes a national system of innovation (NSI). The adoption as policy of the White Paper on

Science and Technology in 1996 signified that South Africa would follow this approach; the explicit intention was to improve the lives of all the country's people in this way. Innovation would achieve this in two ways: indispensably, through progressively increasing economic growth and enhanced participation in the economy, but, just as importantly, by innovative and pervasive personal and social development of the nation's people.

The achievement of focus and coherence in a national system of innovation is often brought about through an acute sense of crisis that galvanises the commitment and priorities of the key social partners. The South African system is currently sensing powerful demand signals of this kind, collectively constituting a call for the country, with all its profound creative and productive potential, to unite in the hunt for innovative answers to, not least, the crises of joblessness, inequality and poverty.

Government is embarking on a New Growth Path, a long-term project that argues for concerted interventions in the economy to construct a developmental state that "authoritatively, credibly, legitimately and in a binding manner is able to formulate and implement its policies and programmes". Innovation, and the national innovation system that nurtures it, will be pivotal in realising the New Growth Path.

Policy framework 1997–2007

The policy blueprint of the 1996 White Paper found effect in the establishment by statute of the National Research Foundation (NRF) in 1998, the National Advisory Council on Innovation (NACI) also in 1998, and the formation of the Department of Science and Technology (DST) in 2002. A Ministers Committee on Science and Technology (MCOST), with oversight of the NSI as a whole, had operated for several years from 1994 but then fell away. A major development was the creation of two sources of competitive funds for R&D, the Innovation Fund (1997) and the Biotechnology Regional Innovation Centres (2001). The 2002 National R&D Strategy then specified that an Annual Science Budget document would be prepared from data drawn from departmental budgets, to reflect all government R&D expenditure, including all agencies (and including in particular the support offered by the Department of Education to institutions in the higher education sector).

Key organisational arrangements for government-managed research were elaborated in the promulgation of the New Strategic Management Model for South Africa's public S&T system in 2004. The newly established DST then had line responsibility only for the public research organisations (PROs, also called science, engineering and technology institutions or SETIs) that were considered to be multi-sectoral (CSIR and HSRC), as well as for the systemic funding agency, the National Research Foundation (NRF). The other SETIs reported to, and were funded by, their respective sectoral departments, together with assigned scientific and technological service laboratories.

The governance role of the DST in this New Strategic Management Model was firstly to be the development of policy on standards for science, engineering and technology institutions (SETIs) (which took the form of a regimen of new governing board appointments and five-yearly external reviews). Secondly, the DST was responsible for the development of a prospective National Science and Technology Expenditure Plan, which in practice has thus far been limited to the annual production of a retrospective report on direct government expenditure on science and technology activities (STAs). Compilation of an annual retrospective National Survey of Research and Experimental Development (National R&D Survey) is also a significant DST role.

Summary of the findings of the review of the South African NSI by the OECD

The Organisation for Economic Cooperation and Development (OECD) was commissioned by the DST to conduct a review of South Africa's innovation policy (effectively the NSI). This review was the most comprehensive overview of the NSI since the SETI System-wide Review of 1998.

Published in 2007, the OECD Review constituted one of a series of highly regarded OECD country reviews of innovation policy conducted according to a well-developed methodology. The distinguished OECD experts concluded that:

- The NSI insufficiently supported a transition from strong reliance on a resource-and commodity-based economy to one that would be characterised by value-adding and knowledge-intensive activities.
- There seemed to be only limited horizontal coherence and integration between agencies in the NSI, and no Cabinet-level coordinating body had yet been successful in devising and monitoring national level strategies for innovation, and marshalling the resources needed for these.
- NACI's mandate was hamstrung by the fact that it reported to the DST and thus had no structural location that would afford it the authority needed for effective coordination of a national system.
- Business was insufficiently involved in building the National System of Innovation (NSI), at the levels of both large and small firms.
- The concept of a national system of innovation had as yet gained limited currency, both in the extent to which it was understood as something wider than the sum of traditional research and development (R&D) activities, and in the extent to which it had been fully absorbed into the strategies of key actors (including government departments and higher education institutions).
- The notion of innovation – in all its dimensions, including technical, economic and social – was poorly understood, especially on the demand side.
- The functioning of the NSI was seriously impeded by the deficit in high-order skills, particularly in the area of design, engineering, entrepreneurship and management;
- Institutionalisation of science, technology and innovation measurement capacity was inadequate.
- The NSI was making an inadequate contribution to poverty reduction and wider inclusion in the mainstream economy.
- The levels of innovation required in the economy would only be possible if there was a considerable expansion of university research, especially to provide the necessary research-capable human resources at all levels of qualification.
- South Africa would need to compete for high-end skills in the global talent pool where advanced economies were implementing immigration measures to attract high-level scientific and technological competencies (not least from South Africa).

No formal response to the OECD Review of the NSI was ever made public. Shortly thereafter, the DST's Ten-Year Innovation Plan (TYIP) appeared, but some of the most central recommendations

of the OECD Review were not addressed in the plan, especially bringing the private sector more centrally into the NSI, and resolving the considerable vertical and horizontal coordination difficulties arising from the current governance and institutional architecture of the NSI. This was especially problematic because the TYIP's new 'Grand Challenges', to be spear-headed by the DST and designed to steer the resource-based economy towards a knowledge-based economy, were spread across the operating domains of many government departments, and represented priority areas of government such as energy generation, climate change, the bio-economy, and human and social dynamics. The fundamental need for a platform authoritative enough to coordinate and steer both state and other sectoral innovation remained unresolved.

Since the OECD Review, significant public policy initiatives within the NSI have been the establishment by statute of the Technology Innovation Agency (TIA), the passage of the IPR from Publicly Financed Research law (Act No. 51 of 2008), and the establishment of the associated National Intellectual Property Management Office (NIPMO), in alignment with an evolving industrial policy framework. These initiatives were first flagged in the 2002 National R&D Strategy.

SUMMARY OF THE FINDINGS OF PHASE ONE: THE CONTEMPORARY NSI LANDSCAPE

The Phase One report, concluded in November 2010, made a number of findings and observations that informed the priority lines of enquiry pursued in the Phase Two exercise, concluded at the end of 2011. The Phase One findings are summarised as follows:

- Although the 1996 White Paper on Science and Technology articulated a compelling vision for a national system of innovation that would drive national economic and social development, this vision has not been adopted widely enough across the range of government departments to achieve the intended pervasive impact. The goal of a common understanding of the role of research and innovation in achieving the priority goals of the country, and the need for more closely coordinated activities to achieve these ends, remain elusive.

- The measures that government has taken (especially related to the roles and powers of the DST and NACI, as designated coordinators of an otherwise fragmented and diverse NSI) have yet to find sufficient effect. A consequence of this is that South Africa has achieved only very limited horizontal and vertical coherence and integration of purpose and effort between the various agencies of the NSI.

- This limited level of coherence and coordination is reflected in the fact that, in or under sectoral government departments, R&D activities appear to be highly fragmented, with the risk or even the reality of duplicated or contradictory effort, and the erosion of attention to R&D generally within these sectors.

- Another aspect of the limited level of coherence and coordination is that the role of business (both established and emerging enterprises) has been inadequately included in the conception and coordination of the NSI. In particular, the growth of small and medium enterprises (SMEs) needs greater attention, but the country's efforts as a whole

are insufficiently supporting a transition from strong reliance on a resource- and commodity-based economy to one that is characterised by value-adding and knowledge-intensive activities. This has implications for government's priorities in relation to employment creation and poverty alleviation.

- Innovation activities should be seen as involving more than just formal R&D, so that innovation in pervasive public service delivery systems is seen as equally urgent, legitimate and mutually supportive of parts of the NSI as are the more conventional design and engineering activities.

- The practical emphasis of the state's investment in innovation has historically focused on 'big science', rather than sufficiently supporting the technological requirements of the business economy and social development priorities. Demand-pull approaches to the development of the NSI should be given as much attention as science supply-push approaches.

- The shortfall in human capital development is the key weakness of the NSI. While the inadequacies of the schooling and training systems are widely acknowledged, with consequent shortages of well-equipped school-leavers, artisans and technicians, deeper insights are also needed into the throughput of postgraduates, and the production and retention of public sector academics, researchers and science council staff. Measures to optimise the availability of highly skilled individuals remain a vital framework condition.

- There are clearly distorted and/or inadequate resource flows in the NSI, both in quantity and nature, between its actors and in the system as a whole, whether this is for formal R&D or venture capital for start-ups and innovative enterprises.

- Adequate knowledge infrastructure is a crucial condition for a well-functioning NSI. This refers to the set of universities, vocational colleges and state laboratories with equipment for research and utilities such as reliable energy supply, communications and transport, and especially ICTs such as broadband and computing power. The earlier National Research and Technology Audit and its later NACI-commissioned update concluded that the public research system was seriously under-capitalised, and that inputs of around R700 million at current prices would be needed annually over six to seven years for its renewal, around double what is currently being invested.

- South Africa's NSI must be conceived as an internationally open system, with in-flows and outflows of all kinds, including skilled people.

- Provision must be made to strengthen the capacity of the NSI to operate as a distributed learning organisation that is responsive to signals from within the system and to the wider environment.

- This responsiveness of the NSI with respect to meeting its intrinsic mandate is most critically dependent on effective and participatory joint policy-making, planning and coordination at the central NSI policy-making platform. It is essential that this platform is well-defined in its composition, so that a clear-sighted regulatory environment is achieved, keeping in mind the distinctive capabilities and contributions of the various participants. It is certain that the exclusion from the NSI central policy platform of some actors (such as the private sector), or the persistence of insulated silos (e.g. in some government agencies) contributes to the weakness of the current system. Instead, the NSI central policy matrix should be reflected in clearly articulated and shared purposes, custom-designed organisational structures and dedicated resource flows. Clearly exercised political will is a paramount condition needed to achieve this coordination.

- This systemic responsiveness depends on the availability and analysis of the science, technology and innovation indicators, both quantitative and qualitative, needed for monitoring and evaluation, and for planning and management**.** System-level information as well as enterprise-level insights are needed to understand what underpins strength and responsiveness – or their absence. Although the NSI of the future will continue to require visionary leadership, it crucially requires systems of oversight and analysis to inform implementation and strategic intervention where necessary, and to inform the purposes and modalities of the NSI.

The Committee's critique of the current shortcomings in the functioning of the NSI is not a destructive one but rather a 'critically constructive' one.

STRUCTURE OF THE DISCUSSION AND RECOMMENDATIONS

In its discussion of the issues noted above, the Committee structured its deliberations for the purposes of this executive summary along the following lines:

i. Mechanisms for prioritisation and agenda-setting in the NSI, as well as oversight of the system

ii. Provision of an enabling environment for innovation in the private sector and social spheres, through appropriate policy and regulations and the promotion of knowledge transfer and exchange

iii. Strengthening of relevant human capital development and other components of knowledge infrastructure

iv. Policy learning, resting upon monitoring, measurement and evaluation

v. The use of funding as a key lever for steering the system.

This is reflected in each of the following five sections of the executive summary.

In each case, the discussion firstly sums up the Committee's assessment of the current situation before laying out the Committee's recommendations for how the system could be strengthened into the future.

SECTION 1: GOVERNANCE OF THE NATIONAL SYSTEM OF INNOVATION

Assessment

The compelling vision for innovation-driven national economic and social development articulated in the 1996 White Paper has not been adopted widely enough by the Cabinet or within the range of government departments to achieve the intended pervasive impact. The mechanisms for relevant priority- and agenda-setting that government has adopted are not very effective, especially those affected by the intrinsic constraints on the scope-of-function of the DST (the designated policy coordinator of the NSI as a whole) that have mostly been imposed, explicitly or implicitly, by the 2004 New Strategic Management Model. A clear focus in public policy on business as the largest NSI actor is still absent nearly five years after the OECD review.

Department of Science and Technology

Despite the above shortcomings of the NSI, the Committee considers the public recognition of the DST as a 'good government department' to be well-deserved. Pioneering initiatives and successes have included:

- The launch of the Innovation Fund and Biotechnology Regional Innovation Centres;
- The setting up of National Centres of (Research) Excellence and the more recently introduced Centres of Competence, as well as the South African Research Chairs Initiative (SARChI)
- A very successful programme of international liaison for research exchanges, collaboration and the general enhancement of available resources
- The currently aggregating and further evolving major components of the National Space Programme
- The key departmental contributions in the Industrial Policy Action Plan, such as the tax incentive scheme for company R&D, the setting up of TIA, NIPMO and university technology transfer offices, and support towards the costs of patenting
- The operation of a spectrum of schemes to enhance R&D cooperation between business and higher education
- Fostering the growth of the Academy of Science of South Africa (ASSAf)
- Many on-going interventions in the technical and knowledge-using capacitation of small and medium firms (through technology stations) and other enterprises featuring prominently in the Minister's current performance agreement with the President.

Balanced against these achievements are the reservations expressed by the OECD Review panel five years ago about the functioning of the NSI as a society-wide system, which is largely congruent with the assessment of the current situation in the present review:

- There is still no common understanding of the NSI and its purposes across government departments and beyond, and there is uneven support for it, even where it appears to be understood.

- The New Strategic Management Model (NSMM), established in 2004, emphasised a cross-cutting role for the DST in setting common governance standards and quality assurance mechanisms in place for each SETI. In the case of sector-specific science councils, the function of the DST would be to develop interventions in the case of market failure, under-subscription or where there were technology gaps of a strategic nature. The NSMM provided for sector-specific research agencies to remain in the domain of their respective line departments – the Medical Research Council (MRC) with the Department of Health; the Agricultural Research Council (ARC) with the Department of Agriculture, Forestry and Fisheries etc. The DST, largely as a result of the NSMM organisational model set up in 2004, has not been in a position to create a coherent, truly systemic policy framework to promote and coordinate the NSI, and has been obliged instead to throw its energies into activities that it seems to have undertaken in the manner of a 'line department', rather than as a system-wide facilitator.

- The trust placed in voluntary inter-departmental cooperation across the system has not, perhaps predictably, been vindicated. For example, even a very promising and well-formulated collaboration agreement between the DST and the Department of Higher Education and Training (DHET), already drafted in August 2010, had not been signed by the beginning of 2012, while the Knowledge Economy Forum activities and structures initiated by the DST in order to mobilise joint action across departments have petered away.

- Virtually no prospective NSI planning as envisaged in the White Paper has been possible (although the Committee understands that a funding cluster on Research, Development and Innovation will be adopted in the next Medium-Term Expenditure Framework), and the retrospective annual STA Report on government expenditure in these areas does not enjoy wide distribution or exposure.

- NACI has been effectively constrained to 'advise' only in the same limited NSI domains in which the DST can operate.

- Supply-side thinking remains pervasive (with continued emphasis on the linear model of innovation), leading to a continuing poor response to market and social demand.

- There is still too little systemic coherence and sense of common purpose between the private sector, government, higher education and civil society in NSI functioning in its broader sense (including governance, decision-making and allocation) or in the agenda for national development.

The key performers of research, development and innovation are private-sector business and state-owned enterprises (SOEs), on the one hand, and public higher education institutions and science councils, on the other. A degree of systemic agenda-setting and prioritisation can be achieved in the private sector itself, especially if it is effectively drawn into the overall governance and delivery vehicles of the NSI, while SOEs are in principle directly amenable to systemic approaches and interventions designed to enhance innovation (see Section 2 of the Executive Summary: The enabling environment for innovation in the private and social sectors).

An example of enhanced systematisation would be wider stakeholder participation in public-sector funding processes than is currently the case, where for practical purposes only portions of water and energy research are informed in this way. The generally successful introduction in other countries of sectoral funds, administered by boards drawn from a variety of stakeholders, suggests that the benefits already generated by the existing public researcher industry incentive

schemes could be extended if some public R&D funds were granted by sectoral boards rather than by the traditional panels of the NRF (this would have to be 'new money', as the existing agency provision is wholly inadequate).

The state itself is potentially a powerful site of innovation, both in how it delivers on its mandate and how it forges common purposes with other social partners. Civil society also provides a platform for innovative initiatives and brokerage potential between social actors, while having only limited capacity to take innovation to scale.

The overall conception of the NSI must thus take the full range of social actors into account, and work to marshal their distinctive capacities towards addressing the socio-economic development imperatives of the era. These large and complex challenges will mostly not be resolved in the short term, but the means must be constructed now for systemic collaboration between the various sectors in the longer term.

Structure of the public sector NSI

The current structure of the public sector actors that contribute to the NSI was well described in the 2007 OECD Review, and in summary this operates at four levels:

i. High-level institutions statutorily mandated to provide policy advice to government on innovation, or innovation-related functions, including the National Advisory Council on Innovation (NACI), the Council on Higher Education (CHE) and the National Science and Technology Forum (NSTF)

ii. Government ministries and departments

iii. Research and innovation agencies, including the National Research Foundation and the Medical Research Council

iv. Research-performers, including universities and science councils, along with providers of scientific and technical services (STS).

The systemic challenge contained in the idea of the NSI is the need for these agencies, at their various levels, to achieve a collective coherence in the complementarity of their functions, and a coordinated impact that makes the best of the resources invested in these entities. The challenges of coherence and coordination run both vertically up and down the levels of authority in the system as well as horizontally between the agencies. As the evaluations provided by the OECD and numerous other reviews have suggested, and as this Committee has noted in its comments above, there is much that must still be done to optimise the functioning of the system.

In particular, a greater clarification of roles between various agencies is needed in order to sharpen mandates and rein in mission creep; greater effects can be achieved if the efforts of specialist capacities in addressing complex challenges are well coordinated; and the best-informed intelligence from all quarters of the system must be gathered in setting priorities and deploying resources. There is a need for stronger reciprocal channels of communication, including

more strategically configured evaluations of the performance of the system and its constituent agencies.

The need for greater coherence and coordination has long been understood, and a variety of statutory and voluntary mechanisms have arisen to these ends. In addition to the organisations already noted above, and various government-driven efforts to achieve coherence across clusters of departments or across priority outcomes, there are numerous sectoral bodies such as Higher Education South Africa (HESA, for higher education institutions) and the Committee of Heads of Organisations of Research and Technology (COHORT, mainly for science councils). The contribution of these devices to the strengthening of the NSI varies, but there is little doubt that much more can be achieved than is presently the case.

The problem of coherence and coordination is perhaps best illustrated in the case of the science councils. With mandates periodically renewed by national legislation in the form of amendments to their respective statutes, these agencies follow a quality assurance system elaborated by the DST and based on five-yearly 'fitness-for-purpose' external and partly international reviews. These reviews of the SETIs have in many ways been less positive about these organisations than their own annual reports, citing duplication and overlaps, a lack of cooperation, and in some cases, mission drift or uncertainty.

A key issue in the research-performing science councils is the governance arrangement introduced in 2004 with the New Strategic Management Model (NSMM) for public research organisations; fragmentation and a distinct lack of systemic coherence are but two of the symptoms of dysfunction associated with the NSMM. The tension between strategic autonomy and a government laboratory service role is mostly only weakly resolved. The SETI review system is unpopular, because it revives and recycles the unresolved problems, and is tending to run down because of lack of support. There appear now to be no systematic, well-founded criteria for the establishment, re-mandating or disestablishment of science councils. Mission drift is rife, and direct competition with higher education institutions for resources, staff and contracts is prevalent.

The public perception of the scientific and technological service laboratories operated by sectoral departments has deservedly not been good, particularly those associated with the justice system. It is typical to hear of six-month delays in measuring blood alcohol levels or DNA-based identifications holding up trials and impairing the administration of justice. The notion of a service organisation, that must necessarily keep pace with advancing knowledge, doing its job in the environment of an administratively preoccupied government department seems to be strange and highly at odds with the vision for a knowledge economy in any case; every instinct suggests that agencification, public–private partnerships or relocation to an appropriate science council would in some, or even many, of these cases be a far better solution.

There is an absolute requirement for coherent information-gathering and analysis for effective agenda-setting and prioritisation in the NSI, and for the achievement of clearer and better-aligned institutional missions and functioning among the agencies of the system. Analysis of indicators and other information to inform the workings of high-level policy debate has necessarily to be

supplemented by the systematic, multi-perspective generation of evidence-based advice on complex issues. A role along these lines is now being built for and by the Academy of Science of South Africa (ASSAf), an arm's-length statutory body.

Recommendations

In general terms, the Ministerial Review Committee recommends that the clear and inspirational White Paper conception of the NSI be publicly re-endorsed by government as a potentially decisive driver of national economic and social development, indicating clearly that the NSI must be pervasive and truly systemic in its design and functioning, and that its functionality is core to any systematic national approach to creating jobs, addressing poverty and providing fulfilling life opportunities to all South Africa's people and communities. What is needed more than ever is a high-level expert body that will offer guidance to the NSI as a whole, a role that neither the defunct MCOST nor NACI has been able to fulfil.

Recommendation 1: The Committee recommends the establishment of a compact (15–20 person) statutory National Council on Research and Innovation (NCRI) to carry out the task of prioritisation and agenda-setting for the NSI, oversight of the system and high-level monitoring of its evolution, outcomes and developmental impact. The Council should be chaired by the Deputy President to emphasise its seniority and its pervasive systemic functions across government and society. The Minister of Science and Technology should be Deputy Chair and Implementation Coordinator because of the key facilitation role of the Department of Science and Technology in the NSI as a whole. The membership of the NCRI should include the ministers from key departments, and influential figures from the private sector, higher education and civil society best positioned to advise on issues of development and innovation. The NCRI must ensure that optimal framework conditions prevail and that financial resources are adequate and must receive system-wide evaluations. It must act to build trust through promoting a culture of responsiveness and administrative fairness. The Council must be equipped to make the hard calls to meet demand and to create supply.

The Committee is of the opinion that failure to establish such a high-level steerage mechanism for the NSI will mean no coherent strategy and no real progress for many years to come. The 2008 review of NACI pointed out the urgent need for the creation of such a body; NACI itself, as currently constituted, is not equipped to perform its proposed roles.

A first task for the Council must be to map out the demands on the research and innovation system for the next decade, and then to advise on broad measures needed to galvanise system actors to these ends, including advising on the mix of public research organisations needed to take up system or market failure.

The Council would make recommendations on future Grand Challenges, major allocations, major equipment needs and new sources of funds. The Council should receive and comment upon all system-wide evaluations, as well as maintain a watching brief on large projects with annual budgets in excess of an amount to be determined by the DST from time to time.

The Council must ensure consistency of efforts to address the supply of high-level resources, from schooling and from further and higher education and training, from other sites of training and across government, the private sector and civil society as a whole. It would be expected to identify policy inconsistencies and recommend appropriate changes.

Recommendation 2: A unitary Research and Innovation Vote should be established, designed to extend beyond the original version that operated until 2005, to function as a macro-coordinating mechanism to ensure that the country's public researchers in all public research-performing institutions (i.e. both higher education institutions and science councils), are adequately supported to perform their work. The NCRI, in consultation with cognate advisory bodies, should provide the oversight of the broad size and shape of this allocation. The NCRI should not be responsible for making specific budget allocation decisions, however.

Particular attention needs to be given to the adequacy of public funds awarded to research performers throughout the system as grants (to higher education institutions) or budgets (to science councils). There has been clear recognition for some time (in successive NRF and MRC SETI reviews, for example) that the average amounts of funding made available in agency mode have been inadequate for their multiple purposes of generating new knowledge and human capital as well as innovations. The total amounts allocated by the NRF and MRC, as well as the incentive schemes for industry for public researcher collaboration, must accordingly be increased to about twice their current levels as soon as possible.

In this context, the Committee is of the opinion that the public grant-making agency function should be consolidated within the NRF, so that a common policy framework and better-coordinated delivery model can be built, incorporating and generalising the successful instruments of promotion (Centres of Excellence, Centres of Competence, Research Chairs and major equipment provision) that have been introduced with such significant impact in recent years. This would incidentally also facilitate re-considering the mandate of the MRC as a science council.

Recommendation 3: The present NACI should be transformed into a new statutory Office for Research and Innovation Policy (ORIP**).** This arms-length body should compile evidence regarding both success and failure across the system in order to inform policy and planning by the NCRI and the DST, and associated policy nexus platforms. Among other things, ORIP should monitor the research investment climate, to determine and advise on any inhibiting factors and the performance of the system in responding to priority needs identified by the NCRI. The ORIP should, for example, be responsible for the National R&D and Innovation Surveys, and for designing information and indicator systems, technology foresight and social fabric studies; and the development of a researcher database (see Section 4 of the Executive Summary: Monitoring and evaluation, for details). ASSAf should work closely with the proposed ORIP to ensure that sound, multi-perspective, evidence-based reviews of key issues in the NSI are conducted.

Recommendation 4: The Ministry and Department of Science and Technology should henceforth primarily function as a pervasive, systemic formulator and coordinator of NSI-related policy and strategy, consistent with the decisions of the NCRI, allocating macro-resources, promoting system

learning through the oversight of effective and integrated monitoring and evaluation, maximising international cooperation and resources, systemically overseeing public research organisations, and providing best-possible knowledge infrastructure (people, equipment and facilities, and cyber-infrastructure) within the public sector.

Recommendation 5: In order for the NSI to be systemic in the fullest sense, the Committee recommends that the NSI needs at least three well-functioning 'core' policy nexuses, each structured through a written collaboration agreement spelling out how policy harmonisation and the coordination of implementation action plans would be ensured:

- One focused on post-school education and training involving the Department of Higher Education and Training (DHET) and the DST
- One focused on business and enterprise development, involving at least the departments of Trade and Industry (the dti), the Economic Development (EDD), Public Enterprises (DPE) and the DST
- One focused on social development and social innovation, involving the DST and departments concerned with social and rural development, and the social security, health and education complex.

The Committee states that failure to create well-functioning policy nexuses as described will very likely be associated with serious and continuing stasis at the very core of the NSI.

Recommendation 6: Because grant-making is not only a question of the amount of funding but also of its efficacy, the Committee recommends the purposeful elaboration of a new, additional mode of public grant-making based on the principle of cooperatively allocated sectoral funds. The priority sectors for such a mode would be identified by the NCRI from time to time (e.g. based on the Grand Challenges' of the TYIP). Boards would be established, involving all NSI stakeholders, to articulate the precise demands and to develop translational solutions. While in principle the funding could be drawn from the levies already raised against the depletion of some natural resources (minerals), as is done in Brazil and Norway, it would be easier to apply to this purpose some of the urgently required increase in total agency funding (see Recommendation 2). The sectoral funds could address both technological and social innovation dimensions of a focus area; one of them could, for example, be a Social Innovation Fund (perhaps in partnership with private sector philanthropy) to address social innovation needs identified by the NCRI.

The new funds should be structured so that they constitute well-informed consultative forums, including industry and government actors, for the identification of sector-specific strategic priorities and the development of corresponding research and innovation agendas. Reports and recommendations from the funds should inform the deliberations of the NCRI, and vice versa, investing the funds with both systemic alignment and gravitas.

Recommendation 7: The present organisational model for government research (the DST-run science councils, the sectoral science councils and the in-house S&T technical service organisations) needs to be revised to permit coherent, integrated and optimised mandates to be designed in each case within common policy frameworks, so that strategically directed funding flows can be applied across all these significant components of, and contributors to, the NSI. The Committee recommends that the NCRI should commission a review of the science councils and all other public research organisations (PRO)s, including, but not limited to the National Health Laboratory Service (NHLS), the scientific sections of museums, and Onderstepoort Biological Products.

The review must enable Government to make hard choices. It should review the reporting lines, missions, future functions and resource requirements of the science councils and PROs (including whether to terminate them, modify their mandates or establish new ones). It should take careful account of international practice and of variations in the role of such organisations over time and at different levels of development. The review should also consider how science councils, other SETIs and the private sector could become more fully involved in postgraduate supervision and human capital development generally.

The establishment principles and mandates of research-performing science councils should be redefined and used to review each of these organisations in a 'fitness of purpose' exercise, along with the periodic 'fitness for purpose' SETI reviews.

Efficiency, effectiveness and funding considerations would attend a decision to move into the science councils many of the scientific and technical services that are currently housed in government departments, which are likely to be both more functional and innovative if they were incorporated into a relevant science council or another body. This would also apply if most or all of the national facilities currently operated by the NRF were relocated to other bodies.

The science councils and public research organisations (PROs) would be asked to engage with the review by providing:

- An analysis of their offerings, broken down as essential services (including extension services), public goods research and client-oriented research, with associated revenue, outputs and impact
- A plan, including financial and staff requirements of how they would (i) address poverty and under-development, and (ii) simultaneously develop mechanisms to meet client demand and effect technology transfer.

SECTION 2: THE ENABLING ENVIRONMENT FOR INNOVATION IN THE PRIVATE AND SOCIAL SECTORS

Assessment

South Africa is currently trapped in a low growth trajectory. In the 1960s, the country's GDP per capita was higher than that of Mexico, Malaysia and Korea; since then, these nations have surged, while South Africa has stalled. The reasons for this hiatus are manifold and contested. South Africa has been free of armed conflict for almost two decades, yet has still to find a common vision that will take the country forward, rapidly, fairly and decisively. The work of the National Planning Commission (NPC) and its Vision 2030 represents a salutary concerted effort to build a common future. The Committee for its part attributes a substantial part of the failure to grow to the absence of systemic innovation that senses and creates innovations in the social and market spheres.

In getting to grips with the reasons for this, one can identify a continuing deep-seated gap between business and government with respect to the NSI that undoubtedly has its roots in a multiplicity of historical, political, philosophical and social factors, which will require careful and sustained attention to resolve. The recommendations made in Section 1 of the Executive Summary: Governance of the National System of Innovation are designed to bridge real or imagined gulfs through increased participation, joint decision-making, and benefit-sharing. Such an approach must be accompanied, however, by a policy framework that recognises that business in South Africa must be a large-scale funder and performer of R&D, and therefore a key strategic partner for government to engage with. Since government exerts controls on this extensive activity only indirectly, the aim should be substantially to enhance the conditions under which innovation is achieved in the business sector.

Performance-promoting framework conditions will also need to be developed to support innovation in civil society and in the public service itself.

The most ambitious recent interventions in the NSI have been the statutory establishment of the Technology Innovation Agency (TIA) and the companion National Intellectual Property Management Office (NIPMO). The transmutation of the 'Foundation for Technological Innovation', as proposed in the 2002 National R&D Strategy, into TIA some eight years later suggests that bringing about such an agency was not easy in terms of winning the support of National Treasury, as well as finalising the concept and design. The impression gained by the Ministerial Review Committee is that both TIA and NIPMO need an early function-promoting 'fitness of purpose' review, especially in the light of the high expectations, perhaps apprehensions, of many NSI stakeholders. The incorporation into TIA of the Innovation Fund, the four Biotechnology Regional Innovation Centres (BRICs), the Tshumisano incubators and the Advanced Manufacturing Technology Strategy (AMTS), with their varied histories and organisational forms, to become a single coherent organisation is surely not something that could have been achieved overnight.

This report considers below the two priority areas of business and social innovation.

Business enterprise

The business sector has to be a prime participant in addressing some of the larger structural factors that condition the shape of the economy. This will include diversifying away from the country's traditional reliance on the minerals and energy complex, reconfiguring the manufacturing base (and indeed all human activities) towards a green economy and more labour-absorptive production methods, opening access to markets to a greater diversity of players in the economy, especially new entrants, and ensuring that productive assets (new businesses, successful farms, etc.) bring prosperity to a widening proportion of the population.

The tax incentive scheme offered by the DST for R&D conducted by firms is still appreciably under-subscribed, apparently largely due to process obstacles associated with bureaucratic requirements, but perhaps also for other reasons.

The high rate of reporting of innovative activity in the last two national Innovation Surveys contrasts with the almost static rate of patents awards at the US Patent Office – it seems there is innovation, but few internationally patentable products and processes. While the low rate of patenting in part reflects the high proportion of commodities and original equipment manufacturer (OEM) products in South Africa's exports, it is obvious that a three-decade stasis points to a failure to diversify or capitalise on local knowledge generation, despite considerable expertise in sectoral systems of innovation such as mining, pulp and paper, viticulture, chemicals and telemetry. Structural constraints, recognised in a number of studies over the years, point to the need for a constructive dialogue between business and public research organisations on how to focus the country's limited resources towards the major issues of the day – growth, employment and equity.

In seeking explanations for this, one could point to the alarming fact that the contribution of local business to R&D conducted in higher education institutions and public research organisations has actually fallen over the last decade, from about 17% in 1997 to about 10% in 2007, which is odd when the NSI is based on the notion that these repositories of extensive intellectual and knowledge resources should be readily available to innovative firms in external or collaborative R&D mode. Such a view is confirmed by the repeated finding in innovation surveys, both in South Africa and internationally, that innovative businesses have a low regard for the local public research sector in terms of where they obtain their information. This picture is rather different from that in the USA, where the research universities provide a significant proportion of the ideas that lead to industrial innovation. There is evidence that much world-class innovation is not translated into intellectual property because of a culture that undervalues the importance of doing so. Unique low-grade heat recovery systems developed in South Africa's power stations are a good example of where patents have not appeared.

In this context, the accuracy of the official figures for technology balance of payments must also be queried. The level of outflows is comparable with a number of countries whose technological development is similar (e.g. Portugal, Norway and Hungary), but South Africa's receipts are many orders of magnitude smaller. While part of this discrepancy may be definitional, it could also

partly be due to behaviours inherited from the 'sanctions-busting' era of the past, and partly an indicator of an absence of local innovations in the market place. A thorough investigation of the data collection and interpretation is urgently needed (see Recommendation 32 below).

While the outcomes of the dti's Technology and Human Resources for Industry Programme (THRIP) (which provides both industrial funding and partnership to public researchers) and the smaller Support Programme for Industrial Innovation (SPII) have in general been positive, the slow development of productive triple-helix relationships between government, higher education institutions and business is a serious problem and a probable reflection of the same general phenomenon of a knowledge transfer gap between industry and public researchers (perhaps another manifestation of the innovation chasm much talked about in policy documentation). Another reflection of this issue is afforded by the Industrial Policy Action Plan (IPAP) of the dti, which, aside from mentioning the Council for Scientific and Industrial Research (CSIR), shows limited understanding of the importance of the science component of the research and innovation system.

It is possible that the public research system has not focused enough on fostering the kinds of critical-mass groups that are user-friendly to other NSI stakeholders or that readily fit into the helices of cooperative, innovative enterprises. To this end, the system should in future consider the way in which funding and incentive systems, as well as the intellectual property rights regime, actively encourage business and other social actors to collaborate for shared purposes.

An open National System of Innovation

A fundamental quality required of the enabling environment for innovation is the openness and permeability of the system. The capacity for learning, adaptation and novelty depends on the free flow of talent and ideas within and across organisations, national systems and globally. This has implications for the mobility of talented people, the availability of knowledge and lessons from elsewhere, and the freedom for new insights to arise across and between fields. Both immigration policies and intellectual property regimes need to be judiciously calculated to enable systemic openness for planned and fortuitous chemistries of innovation. Allowing foreigners to apply on equal terms for vacant posts in South African research institutions, business and industry acts as a competitive stimulus and a bench-marking tool in the system; it also permits the country to enlarge the pools in areas of talent shortfalls and to introduce fresh ideas into the relatively small and introspective research community. The legal framework and regulatory regimen for work permits and visas must be simplified and rendered as user-friendly as possible. The proposal of the National Planning Commission that foreign doctoral graduates be granted work permits for up to seven years reflects the kind of new thinking that is urgently needed.

The NSI requires active measures that will promote collaboration across boundaries within the national system and more broadly across the globe. This should include arrangements for the optimal utilisation of research infrastructure and the promotion of a culture of sharing and support for access to research facilities, including encouraging reciprocal access to equipment held by the private sector and state-owned enterprises.

International collaboration and linkages are indispensable components of healthy knowledge transfer and exchange. The DST, often using the NRF as its agent, has done a sterling job in promoting and managing cooperation schemes with selected countries in a variety of formats. A particularly significant achievement has been to make South Africa one of the principal beneficiaries of the European Union Framework Programmes. Less effective, perhaps, has been the use of the International Council for Science (ICSU) to leverage resources for the development of the individual disciplines represented by ICSU.

In this context, the benefits from South Africa's involvement in the African Union's S&T activities, including those related to the New Partnership for Africa's Development (NEPAD), have so far been less obvious, with some success stories (e.g. the African Science and Technology Indicators Initiative) and a number of less dynamic activities. They remain an essential part of the way in which the NSI can harness outside elements and create value for all participants.

An Enabling Public Sector

The state-owned business enterprises account for a substantial segment of business R&D conducted in the country. Government can obviously exert a reasonable measure of policy control over innovation in state-owned enterprises, several of which are major performers of R&D, both here and elsewhere, and account for the 20% of total business R&D expenditure that is sourced from government. State-owned enterprises also have considerable potential for energising innovation through their large-scale procurement activity and through international linkages; they are also extensively involved in technology transfer, with attendant opportunities for local adaptive innovation. The Industrial Development Corporation (IDC) and the Public Investment Corporation (PIC) are additional, potentially important levers for innovation.

An innovative public service stimulates innovative business enterprise and can energise the entire NSI. Examples of dramatic improvements in the public service efficiency include:

- The ease with which passports and ID books are now issued and renewed
- The massive transformation of the tax-collection system introduced by e-filing
- Much-simplified, online employer and worker registrations and payments by the Unemployment Insurance Fund.

These are examples of how government through innovative service delivery can create not only a sense of future possibilities, but can also develop processes that are core to business activity and make investment wheels more workable. This is vital for both established and emergent enterprises. There is, of course, still a great deal to be done in the many areas of public service delivery that must underpin a well-functioning NSI, especially in regard to the regulatory and science-technology services operated in line departments responsible for health, agriculture, the environment, police, etc.

The Committee noted the recent formation of TIA and that the agency has not yet had time to establish a track record of performance. The Committee noted, however, that the strategy for the

constitution of TIA involved the inclusion of a number of pre-existing agencies, and wondered about the fit between the capabilities provided by these residual bodies and the role that TIA should play in the future. Given the insight into the current and future NSI generated during the Ministerial Review process and the role TIA should play into the future, the Committee believes that TIA should benefit from formative evaluation sooner rather than later to ensure that the mandate and powers accorded to TIA are appropriate for the planned future trajectory of the NSI, and that TIA is appropriately equipped with the skills and capability to fulfil this role.

Social Innovation

Social innovation, or innovation for development, is concerned with the pre-eminent national priorities arising from poverty and joblessness. The responsibility for addressing the continuing legacy of poverty can no longer be seen as government's alone, but as a collective one, embracing all role-players including the private sector, civil society and poor communities themselves. Equally, the responsibility for achieving appropriate levels of employment cannot be confined to the formal economy alone. Although there is a distributed responsibility for these social purposes, there is a vital role to be fulfilled by government in constituting the social innovation dimensions of the broader NSI in a systemic fashion, and in orchestrating the contributions of the various social partners.

The thinking about development in poorer communities needs to ascribe a much greater potential for creative and active agency within communities, rather than seeing them only as recipients of service delivery. At the same time, however, the powerful structural conditions that operate to limit this agency must be acknowledged. The full range of societal actors is needed in order to mobilise their respective resources towards releasing the collective capacity for innovation.

There are outstanding examples in civil society of how individual non-government organisations (NGOs) have succeeded in crafting niche functions in the development arena, and now have the potential to provide models for innovative approaches on a larger scale. Among other things, a vital brokerage capacity to support partnerships for developmental purposes needs to be exercised. Other civil society partners for social innovation could include the media, labour unions and faith-based groupings.

Far-sighted elements in the corporate sector have increasingly acknowledged that business has a set of responsibilities beyond optimising shareholder returns, and corporate philanthropy has already made significant contributions to the public sphere; some estimates put the spend in 2010 at over R5 billion. The innovation challenge is to see whether this collective investment can be marshalled and directed in a sustained manner towards a small number of priority strategic purposes.

New approaches to philanthropy have emerged in the form of social venture capital, or impact investment. These represent an effort by private sector interests to achieve significant impact through targeted and sustained investment in strategic social projects, drawing on money from multiple corporate donor sources. This is informed by an inclination towards the collective action needed for any truly systemic character in an NSI. Social entrepreneurship has also appeared as a

means of advancing development goals; taking many forms, such social enterprises are businesses with primarily social objectives whose surpluses are principally re-invested for that purpose in the business or community. Both social entrepreneurship and impact investing are informed by the view that development activities should be, in one way or the other, sufficiently value-generating as to be inherently sustainable in their own terms. The social value of the innovation needs to be integrated into economic activity if it is to survive beyond the sponsorship of its initiators.

The challenge for government is to change the way that public services are delivered, for all citizens but especially the poor, rather than to see the solution in increased budget allocations. This involves easily informed policy development and strategy development, but also the capability of public delivery platforms. The intention is to institutionalise learning organisation capability, and the capacity for swifter adaptive behaviour, often informed by higher levels of citizen and civil society participation. Various examples exist of exciting and far-sighted innovations undertaken by government (including the Community Work Programme), characterised by a highly innovative partnership between government, NGOs and community-based organisations.

Although South Africa is confronted with urgent priorities in terms of socio-economic development, the role of social innovation in the NSI is currently under-conceptualised and under-developed. The activities associated with social innovation (in their varied and evolving forms) need to be clearly understood in the public mind as highly valued investments in the future, with implications for many fields of practice in the public and private sectors, and in personal lives.

Deliberate measures and incentives should thus be directed towards the field of social innovation, including areas of public service delivery, social development initiatives and the activities of the private sector and civil society. The incentives must induce business to contribute and participate, local and regional government to be innovative in what they do, and civil society to play its indispensable part. Strategies for addressing poverty and inequality are in fact as much a matter for concern in well-established sectors of industry as they are in community-level initiatives. Activities that constitute social innovation represent a sub-set of strategies by which the NSI as a whole addresses the developmental priorities of the country. Deliberate measures are needed to support and steer such activities in all sectors (public, private and civil society), in terms of the identification and dissemination of good exemplars, taking successful pilots to scale, improving funding opportunities, training to strengthen absorptive and adaptive capacity, and brokerage or facilitation of partnerships (e.g. between government and NGOs) in innovative projects.

The most important contribution of government to improving the innovation environment is an education and training system that provides large numbers of people with enough knowledge capital and knowledge-informed skills to equip them for lifelong learning within a spectrum of positive career trajectories; this is further elaborated in Section 3 of the Executive Summary: Human capital and knowledge infrastructure. What must be mentioned here is the lack of mobility caused by current immigration policy, meaning that catalytic effects on local training and capacity development cannot easily be achieved by imported high-level skills, or that enterprises

requiring a range of complementary skills may not be initiated because of critical gaps in the team.

Recommendations Related to Business Innovation

Recommendation 8: Systematic efforts should be made to bring industry and government closer together, and to strengthen the response of the system to demand signals from business and industry, on the one hand, and social spheres, on the other**.** The effective participation of the private sector should be structured into all levels of the system, including participation in the NCRI; strong establishment of the skills bases; encouraging reciprocal access to equipment held by the private sector and state-owned enterprises; and a repertoire of policy instruments within the respective three proposed nexuses of (i) the DST and DHET (focusing on higher education), (ii) the DST, the dti, EDD and DPE (focusing on industry and business in general) and (iii) the DST with the various departments whose portfolios have implications for social development and social innovation, and the linkage of social security measures with education, health, etc. These should be directed to the sustainable development of the economy through efforts to promote competitiveness, the establishment of firms and job creation, and poverty reduction (see Recommendation 5).

Recommendation 9: Government departments that form the key pillars of the research and innovation system and must draw to their ranks staff with direct experience of the business, civil and research environments so as to enable cross-sectoral collaboration and to boost the absorptive capacity of organisations for reciprocal learning and adaptation. A concerted effort must be made to bridge the knowledge transfer gap between local companies (big and small) and public-sector researchers and administrators, in order to ensure that the nation's considerable intellectual resources are utilised to a much greater extent. These capacities should become the subject of deliberate skills-building and case-study research to boost South Africa's collaborative abilities across all sectors within the NSI.

Recommendation 10: The research investment climate must be improved through a review of present and further possible incentive schemes for their accessibility, simplicity and effectiveness, with broadening as required. These measures should include:

- The Technology and Human Resources for Industry (THRIP) industry–public researchers linkage programme should be expanded further, to a target of double its present level.
- The excellent and thorough reporting system of the Support Programme for Innovation in Industry (SPII) should be adopted in other schemes (and perhaps in all public grant-making above a threshold level of award, together with the requirement of beneficiaries to participate fully in the annual National R&D Survey.
- Additional, specially tailored grants and concessions are required by small- and medium-sized enterprises to enable them to access advanced scientific and technological expertise.
- The regulatory environment for research permits should be streamlined to remove obstacles and speed up approvals, thereby reducing the need for burdensome appeals.

- Regulations and the approval processes for foreign researchers should be streamlined to speed up the issuing of work permits. Consideration could be given to including special treatment of R&D inputs of goods sourced under the local procurement mechanism.

- Overall, more imaginative and flexible sources of public capital support for innovation activities should be devised, including but not limited to low-cost loans, replacement of loans by grants, renunciation of state equity components, access to publicly owned buildings and land at zero cost, etc.

- The government system of company support and incentivisation should thus embrace a diversified approach that caters to size and sectoral distinctions; small companies generally cannot access incentives in the same way that large firms do, and different categories of firms, with different technological capabilities and potential for transitions to enhanced innovation capacity, should have tailor-made schemes. This implies that a sufficient number of well-informed and skilled intermediaries are available in government departments and their agencies to facilitate such transitions.

- Industry–public researcher links may be further strengthened through improved tax concessions on company grants, scholarships and bursaries deployed in public sector research institutions. Interfaces and the mobility of skills should be maintained between national disciplinary associations and related business sectors; research institutions and their funders should deliberately build groups that begin to bear some of the characteristics of the R&D divisions of companies.

Recommendation 11: The Technology Innovation Agency (TIA) should immediately be externally reviewed in terms of 'fitness for purpose', aimed mainly at promoting its success as a pivotal new element in the NSI**.** The National Intellectual Property Management Office (NIPMO) should likewise be formatively reviewed after a further period of initial functioning.

Recommendation 12: Immigration policies and intellectual property regimes need to enable the openness of the NSI.

Recommendations Related to Social Innovation

Recommendation 13: An explicit strategy should be developed for the advancement of social innovation within the National System of Innovation**.** This strategy should include**:**

- The launch of a multi-stakeholder forum, mandated by the National Council on Research and Innovation (NCRI), to advise government on a limited number of national social innovation priorities that should become iconic projects for the NSI and standing items on the agenda of the NCRI

- The establishment by the DST of policy instruments, and the necessary skills base, needed to foster the field of social innovation, including (but not confined to) initiatives aligned to the priority projects identified by the NCRI.

- The establishment within the proposed Office for Research and Innovation Policy (ORIP) of a strategy for monitoring and evaluation of social innovation activities, including social fabric studies, that draws on a range of methodologies and sources of data in the country,

in order to compile a synoptic view of this complex field of endeavour, sufficient to inform policy and action;

- The establishment, within the DST and/or other agencies, of the brokerage capacity and popularisation function needed to foster the multi-partner, cross-sectoral collaboration that is required to address complex social innovation issues such as those to be prioritised by the NCRI

- The establishment of a Social Innovation Fund (in partnership with private sector philanthropy), to be administered by the DST, intended to support the NCRI priority projects and other social innovation initiatives.

All the above incentivising and regulatory instruments will require appropriate levels of reportage into the sets of indicators to be developed or overseen by the proposed ORIP for the monitoring and steerage of the NSI (see Section 4 of the Executive Summary: Monitoring and Evaluation).

The Committee has observed that, in general, part of the enabling environment is the disposition of the population towards the notion of innovation and the capabilities that characterise an innovative society. The Committee believes that the 'appetite for innovation' of the whole population should be fostered by well-designed and well-executed interventions using broadcasting and other media, the systematic upgrading of public education including science centres, the award of medals and prizes, and through ASSAf hosting consensus conferences. In other words, achieving thorough commitment to innovation in all spheres of activity requires some attention to how this is understood and appreciated in the national psyche. This has implications beyond policy measures, and would require national leadership to play its role in this regard.

SECTION 3: HUMAN CAPITAL AND KNOWLEDGE INFRASTRUCTURE

Assessment

The achievement of an innovative and technology-rich economy and society depends on the depth, width and overall quality of the reservoir of human capital, meaning a sufficient complement of people who have expertise informed by knowledge and the experience of research, with the breadth of vision to provide leadership for innovation; inspiring teachers who have achieved mastery of their subjects; technical personnel at a variety of levels; entrepreneurial, driven business-people; competent managers and public servants; and a citizenry that can effectively participate in an economy in which knowledge is as important as exploitable mineral resources and a well-trained labour force.

Human capital development in modern science (broadly understood as empirical enquiry) and technology usually requires institutional infrastructure (including appropriate and adequate space, logistics, administration, strategic support, readily available consultative advice and collaboration, and research students), hardware in the form of equipment and related facilities and specialised services, and connectivity and information technology in general.

Visitors to South African higher education and public research institutions (science councils and similar) are usually impressed with the visible plant, the sense of good order and the apparent functionality, in general; they believe that the country has invested well in these mostly well-run institutions. The truth is that many problematic issues bedevil the main components of the public research sector.

The present human capital development system in South Africa is unfortunately locked into sets of interdependent 'pipeline jams', with piecemeal interventions having thus far served only to make the system more refractory to positive change. The interventions have actually produced a peculiar and rather general resistance to the idea of any further policy change in a supposedly 'fatigued' system. Higher (and further) education and training are the responsibility of the DHET, not the DST.

The NSI depends almost entirely on the effectiveness of the basic education and post-school systems. The NSI cannot work well if the available human capital is not adequate or equal to the task.

Beginning with schooling, South Africa's overall education system has many core fundamentals that are comparative positives in the fast-changing world, including a balance between prescribed content and choice in the processes of knowledge and skills acquisition, between formal and informal learning time, and between the exercise of the mind and the body. These features have made South Africans highly competitive when they have had the benefit of well-functioning institutions. Bringing all or most of the country's schools, colleges and higher education

institutions up to full functionality is thus something that does not require the re-setting of these fundamentals, but the inherently simpler challenge of 'making them work' in the ways that they should.

Most of the requirements for making the public education and training system work as the basic enabler of a knowledge economy are not yet in place, despite the best intentions:

- Access to effective pre-school education, a critical success factor, is limited to those who have the means.
- The social capital of parental and community involvement and support, at home and in school or college, is likewise strongly stratified in society or variable in quality or availability.
- A fully developed first-language competence is difficult to reach in the case of the vast majority whose first language is not English, impairing the general intellectual enskilling involved in reading, communication, subtle understandings, argumentation, and the capacity for personal and social growth based on useful knowledge.
- Whether one agrees with its dominance or not, proficiency in the use of English (the major language of instruction in the higher education institutions) in oral expression, writing and reading is still the preserve of a minority of learners and students.
- The continuous development of mathematical literacy (essentially the power of abstract and predictive thinking) is still seriously deficient, as is general numeracy.
- Direct experience of technological manipulation, in classrooms as well as outside, is yet another ingredient of 'brain-and-hands' capabilities that is denied to most, as is the ability to understand the application of physical and life science in everyday life.

The education and training (or re-education and re-training) of school teachers is a fundamental priority for the nation in terms of human capital development, yet the system is currently in considerable disarray. The current model for teacher and trainer production (in terms of qualification types and structures, as well as enrolment planning and bursary support, etc.) requires thorough re-examination – a knowledge economy is impossible without teachers who both understand their material and are skilled in transferring it to their charges. Extremely important, despite being controversial, is that teaching/training is not classified as an essential service, which it undoubtedly is, at all levels from basic to higher education – the nettle simply has to be grasped.

The parlous state of the vastly too small and flawed technical college system is associated directly with the problem of a massive waste of human potential through high rates of dropping out from schooling; failure in the national senior certificate examinations; or passes in this examination without higher education admission. The absence of a large number of competent middle- and lower-level artisans constitutes a crippling barrier to the economic survival of the nation, let alone its ability to earn its living as a knowledge economy. The Committee is in general support of the approach towards this issue adopted in the DHET's recent Green Paper on Post-School Education and Training (without prejudice to a more detailed examination of its proposals).

The Committee is painfully aware of the huge cultural challenge presented in the well-intentioned effort to re-orient school students toward vocational careers, and notes the long-standing debate on the vocational school fallacy.[1]

Higher Education

The present situation with respect to the pipeline performance in the higher education and training system can be summarised as follows:

- Despite sustained efforts to increase admission to higher education for academically deserving but financially disadvantaged students, the overall participation rate in higher education has remained at approximately 17–18% during the past five years; increased higher education participation rates constitute one of the defining features of countries that have made successful transitions from efficiency-driven economies to innovation-driven ones. (This conclusion does not detract from the immense achievement of the higher education system in shifting its demographic profile towards greater population representivity in a very short time.)

- An increasing emphasis on efficiency and effectiveness in higher education has not been translated into a corresponding increase in undergraduate graduation rates; low graduation rates and high drop-out rates at all levels of study continue to characterise South Africa's higher education system.

- Innovation-driven economies tend to have strongly differentiated higher education systems in which universities of applied science or technology play an important role in human capacity provision; during the past decade, it has proved extremely difficult to strengthen universities of technology by increasing their share of student enrolments.

- During the past decade, it has also proved difficult to increase enrolments for advanced postgraduate study; particularly disconcerting is the very slow progress being made in achieving greater levels of race and gender equity in enrolments at this level of study. The survival of many postgraduate programmes is contingent on the enrolment of foreign students.

- Graduation rates for masters and doctoral degree study have not improved significantly during the past decade, and signs exist of longer completion times for these levels of study which are hampering the provision of an adequate supply of highly skilled R&D personnel for improving the country's science, technology and innovation performance.

- There has been an upward creep in the average age of completion of doctoral degrees, due partly to the long time taken for completion, as well as late commencement of study.

- Disciplinary ageing due to failure to reproduce the existing researcher cadre.

- Significant barriers to the expansion of the postdoctoral sector (a particularly important component of the supply of person power in research and development in advanced countries) exist in South Africa in the form of inappropriate tax regimens and academic staff progression structures.

[1] The vocational school fallacy refers to the belief among education policy-makers that school students would be inclined to enter vocational schools rather than staying with the academic orientation of schooling. Student expectations were often at variance with what education planners and education ministers believed what was good for them, and for the economy. http://education.stateuniversity.com/pages/2537/Vocational-School-Fallacy.html

The above conclusions are the basis of the characterisation of South Africa's higher education and training system as being essentially locked in stasis, incapable of increased or better performance because of inter-locking constraints and a vast inertia (policy fatigue) in terms of change-directed policy and practice. This is the case despite the restructuring of institutions, the application of numerous new regulatory policies and the introduction of institutional audits, the dedication of a new ministry and department to this sector, and the successful intervention of the DST in establishing Centres of Excellence and Research Chairs distributed through the sector, supported by limited major equipment provision (see below). (It should be noted that some institutions have obtained outside support for the establishment of large-scale research institutes (with multiple principal investigators), which will require state support to continue to operate at their initial impressive levels, perhaps through the extension of the concept of Centres of Excellence and Research Chairs concept to Research Institutes).

An important example of continued stasis is afforded by the recent Consensus Report on the PhD degree by the Academy of Science of South Africa (ASSAf), which has provided the most complete and evidence-based set of proposals available to date to address pipeline difficulties in postgraduate education in South Africa. The study has confirmed the fact that the current system, already comparatively unproductive in terms of annual numbers of doctoral graduates (about 1000 per year), is severely stretched, and that asking it to increase doctoral graduates five-fold without the concerted implementation of a number of proposals is not realistic. The total numbers of research-active academic staff capable of postgraduate supervision remains static, and their capacity to reproduce themselves is limited by the pressures on their professional lives arising through the necessary but under-resourced simultaneous expansion of the higher education system.

The attainment of post-qualification job-competence is a much-neglected segment of the human capacity development pipeline. The fast-changing globalised world requires, in general, a framework of undifferentiated education and training that permits ready follow-through adaptation to specific professional or vocational requirements through a period of structured experiential learning. Wastage at this level is particularly damaging after the extensive earlier investment in the people concerned. Competence in the public service has been assured in countries such as the UK and India through a well-run public service examination system; post-appointment training is essential but cannot compensate for effective pre-appointment preparation and rigorous selection.

Engineering is a good, but not the only example of extensive wastage due to incomplete training and delayed or discontinued professionalisation; conversely, there are many degree qualifiers for whom no appropriate job-adaptation pathways are available, for example, the higher education institutions have not concentrated enough on offering high-quality postgraduate diplomas in 'job readiness' mode.

The pervasive lack of capacity in the public service is another symptom of 'failed pre-job training, and a major hindrance to the achievement of innovation in public administration and service delivery. There is still no system of public service examinations in this country, despite the extensive and successful use of such systems in countries closely linked to South Africa, such as the United Kingdom and India.

Postdoctoral fellowships have become perhaps the most important route for the adequate preparation of academics and researchers who can work independently and innovatively, acquire and productively utilise grants, effectively supervise postgraduate students, and generally catalyse growth in the knowledge economy. Apart from the present counter-productive taxation policy for such fellows, their entry into full academic service is impeded by the antiquated structure and organisation of the academic employment system at higher education institutions. The impressive scale of recent salary improvements for academic staff – partly fuelled by competition between higher education institutions (HEIs) and science councils and partly by general corporatisation of the operating model for HEIs – coupled with liberal application of the ad hominem promotion system and the virtual elimination of probation, has made the creation of every new post a matter of serious long-term budgetary concern.

The steering and orientation mechanisms that are aimed at addressing specified policy priorities through the generation of appropriate numbers and types of trained and skilled people, mainly the Programme and Qualification Mix policy of steering offerings at different public institutions, has so far worked mainly as an efficiency measure, rather than as a potentially valuable tool for preferentially growing a workforce to meet needs in a particular strategic area or for implementation of a particular plan. There are in fact quite astonishing contrasts at graduation ceremonies – hundreds of business science students, and only a handful of plant virologists, for example.

The cultivation of a cadre of young astrophysicists through a concerted medium-term recruitment and resourcing plan has thus far been an outstanding success, including its success in terms of the desired transformation results. The specification of the broad areas in which new DST/NRF Research Chairs are to be situated looks set to be another useful and effective focusing device. The largely unplanned (because it is mainly foreign-funded) proliferation of a large pool of postgraduate and postdoctoral workers of high quality in the molecular biosciences, related to the twin pandemics of HIV and TB infection, is an example of how human capital can be built up quite quickly in a national priority area. (This phenomenon warrants a thorough and urgent case study of how world-class activity can be rapidly developed in a particular priority field.)

Physical and Cyber-infrastructure

There have been repeated attempts to gauge the situation regarding physical infrastructure in public research institutions, and to obtain an idea of the shortfalls and future needs. The summary position is that a credible roadmap for medium-cost and major equipment is urgently needed; there are many problems with the adequate servicing of major equipment due partly to shortages of appropriately trained personnel; and the principle of sharing special equipment and facilities is a necessary and even beneficial aspect.

The national facilities currently operated by the NRF are an essential component of the NSI; these are uniquely expensive and complex machines or instrument aggregations that are affordable in only one place but are calculated to produce many benefits and spin-offs. The national facilities have caused a number of serious management problems in recent years, distracting and detracting from the core business of the NRF as the national agency for public research grants; some of the present national facilities are perhaps also ill-conceived in terms of any set of criteria for the establishment and maintenance of such facilities. The recent creation of a statutory

National Space Agency may provide a stimulus to the reconsideration of the national facility system within the NRF, associated as it is with the probable transfer of two of the biggest facilities to the new body.

Information technology for research and development has received considerable attention in recent years as cyber-mediated activities have mushroomed in research practice. Movement towards a national broadband-provision system (SANReN) has been vexed and slow, despite its potential of making a huge difference eventually to virtually all public researchers in the country. The rapid march of technological progress in this field indicates that a professionally and consultatively developed cyber-infrastructure roadmap for the NSI is urgently required.

Related to this is the requirement for researchers to have ready and affordable access to the current scientific literature, much of it still provided within the high-inflation commercial model of 'pay to read', based in most institutions on costly bundled subscriptions that dominate library budgets. By contrast, the local scholarly journals, which are important modes of dissemination in certain disciplinary areas and essential vehicles for the maturation of young scholars and scientists, are poorly visible (in either print subscriptions or commercial e-access) beyond a small traditional readership. The setting up by ASSAf of the state-subsidised SCiELO-South Africa, an internationally connected free-online e-publication platform equipped with full indexing capability, soon to be linked to the dominant Thomson-Reuters Web of Knowledge system, is a necessary adjunct to the peer review-based quality assurance model also being applied by ASSAf to all South African scholarly journals. A report on the possible advantages of the kind of national licensing model for commercial journals already deployed in Brazil, Chile and Pakistan is under preparation by ASSAf – the Committee supports such a licence in principle if it is genuinely cost effective and generally advantageous.

The coverage of innovation in the public media is currently fitful and generally mediocre. How many 'people in the street', or even school teachers or university lecturers, would know the concept of the NSI? The credible job done by the South African Agency for Science and Technology Advancement (SAASTA) does not mean that more could not be done, on a much broader terrain of public involvement. This is yet another of the under-developed systemic aspects of the NSI, and in its own way one of the most important ones.

Recommendations Related to Human Capacity Development

Recommendation 14: In order to meet the human resource development requirements of a knowledge economy, a planned, concerted, well-resourced and sustained programme of action in all areas of human capital development should be undertaken by all the relevant policy-makers and performers.

Recommendation 15: Teaching at all levels should be declared an essential public service within labour and other legislation and relevant regulations.

Recommendation 16: The technical colleges must urgently be revitalised, doubled, trebled or quadrupled in number, and organised through appropriate policy into a manageable system analogous to that already in place for higher education, with a similar level of autonomy (essentially the implementation, after full debate and consultation, of the DHET Green Paper on Post-School Education and Training).

Recommendation 17: The present stasis in higher education could be addressed through open-minded consideration of reforms. These might include revising the basic bachelors qualification model at universities, curriculum reform in the direction of greater breadth and versatility , and creating a clear differentiation of masters degree programmes into those that represent a strong focus on research training, those that are concerned with applied science and technology, those that involve advanced or multidisciplinary course-work and theory including subject teaching, and those that are professional specialisations including the performing arts.

Recommendation 18: The Programme and Qualification Mix policy of steering offerings at different public institutions should be used in conjunction with special preferential funding schemes for the development of scarce skills, in order to grow a workforce to meet the needs in a particular strategic area or for implementation of a particular plan.

Recommendation 19: Careful attention should be given to the improved functioning and throughput of compulsory post-qualification training programmes, and consideration given to the introduction of public service examinations linked to appropriate courses and qualifications offered by higher education institutions.

Recommendation 20: Public resourcing (both from outside and inside institutions) should be focused on departments or research enterprises that are demonstratively capable of attracting and hosting large numbers of successful postgraduates**.**

Recommendation 21: Opportunities in the academic job market should be widened to increase the population of productive academics**.** This would entail restructuring the present standard model of academic employment to increase the entry of talented younger scholars and scientists

and open up opportunities generally. Specific attention is needed to address the remuneration of postdoctoral fellows.

Recommendation 22: The average value of grants made to researchers by the agency services of the NRF and MRC should be increased to levels that are commensurate with the outputs that are desired, while the number of DST/NRF Research Chairs and Centres of Excellence should be judiciously increased (with the emphasis on 'brain gain'). A new category of DST/NRF Research Institutes is needed for multi-focus, high-level research concentrations with critical mass and a clear long-term trajectory.

Recommendations Related to Knowledge Infrastructure

Recommendation 23: To address the growth targeted by government in national R&D (GERD) in relation to GDP, driven to a very significant extent by increased public sector investment, the Committee recommends that the existing infrastructure needs not only to be expanded in a commensurate manner, but restructured in terms of its elements to ensure a higher degree of effectiveness and efficiency in its deployment.

Recommendation 24: To this end, there is a strong case for the establishment and step-wise roll-out of an Infrastructure Roadmap for South Africa, probably best driven by the new NSI governance structures proposed in this report.

Recommendation 25: An appropriately constituted National Advisory Panel on Cyber-infrastructure, reporting to the proposed National Council for Research and Innovation (NCRI), would be a suitable body to deal with cyber-infrastructure at strategic and policy levels, including fast broadband, and to draw up a roadmap for integrated implementation over time**.**

Recommendation 26: The extent and status of the knowledge infrastructure in the private sector and state-owned enterprises (SOEs) should be surveyed, and the linkages evaluated between this highly R&D-active sector and the universities and science councils.

Recommendation 27: The DST-subsidised, free-online, fully indexed e-publication platform, SciELO-South Africa, set up by the Academy of Science of South Africa (ASSAf) in order to render a large part of the content of South Africa's scholarly journals visible worldwide, should be expanded and sustained.

Recommendation 28: The subsidised national licensing of e-access to high-impact, international core commercial journals should be effected following the release of the current ASSAf advisory study on this topic.

SECTION 4: MONITORING AND EVALUATION

Assessment

The notion of the NSI that was introduced in the 1996 White Paper on Science and Technology was intended to be fundamentally transformative in its purpose, a renewal intended to reach all dimensions of business, scientific and socio-economic activity. The achievement of intended change is difficult and may take time. Knowing what is happening depends on the availability of top-quality information, the ability to access and interpret it, and the capacity to use the information to achieve adaptation in performance.

Progress in improving the functioning of the NSI is currently still hampered by the absence of an assigned responsibility for ensuring the availability, collation, maintenance (and even analysis) of the science, technology and innovation indicators, both quantitative and qualitative, needed for monitoring and evaluation, and for planning and management of the NSI as a whole. Although evidence is available from a number of sources for some dimensions of discrete activity in the system, there is no comprehensive synopsis available, even in conception, that reflects the need to 'see' the system in its totality, and to assess how it might fulfil its contribution to national development.

There are some useful windows into selected parts of the system. For example, the annual National Surveys of Research and Experimental Development (usually known as the National R&D Surveys), provide reliable data on R&D expenditure in different sectors, the human resources deployed and overall major funding flows within and from outside the country. The surveys, performed on contract by the HSRC through its Centre for Science, Technology and Innovation Indicators (CeSTII), have rightly become part of the working language of all NSI participants. It should be noted, however, that many indicators are not fully 'unpacked' in the published survey reports, nor are they sufficiently meta-analysed to yield their true worth. The DST has commissioned the Human Sciences Research Council (HSRC) to do a study of indicators appropriate to the aspiration of a knowledge economy; the proposals should be widely discussed among stakeholders and well-evaluated before adoption.

The South African Innovation Surveys, also conducted by CeSTII, provide vital and intriguing insight into business sector innovation, and point to important continuing trends, such as the relatively high innovative activity in firms, but at the same time (and following international trends) the surprisingly low propensity for the acquisition of knowledge from higher education and research councils, as already noted in Section 2 of the Executive Summary: The enabling environment for innovation in the private and social sectors. Similarly, the surveys reveal that investment in innovation is constrained by a lack of funds, while at the same time only a small proportion of innovating companies are accessing, or are able to access, public funds for these purposes. There is, however, no sense of what further research and intervention might have been directed at these phenomena between the surveys and thus what might have been learnt about the operation of the system, especially the interaction between the key players reflected in the data. Provision for sustained research into the dynamics of the system is lacking, and the Innovation Survey can therefore not adequately inform policy steerage.

The annual Science and Technology Activities (STA) Report, retrospectively compiled by the DST, expands on NSI-related publicly funded expenditure, mostly directly by government departments, presenting data under the headings of education and training, services and innovation. The report suffers from methodological problems that have thus far not been amenable to correction despite serious effort, and also fails sufficiently to 'unpack' the data provided or adequately to meta-analyse them in policy terms. Moreover, the report does not make provision to compare the science and technology activities against the originally prospective budgets of the participating departments, in accountability mode.

The DHET compiles an increasingly informative and detailed annual report on the accredited research outputs of higher education institutions, in numbers of actually graduated research postgraduates (masters and doctoral) and peer-reviewed publications in scholarly journals, books and conference proceedings, most recently also categorised by scholarly field. Knowledge of the relevant policy is required to understand the numbers, as publication output units are not equal to the numbers of actual papers because of the fractionation of authorship by institutional affiliation and the denial of credit to authors who are not working at public higher education institutions in South Africa. A further issue is the use of a single, rather low 'quality threshold' for accreditation of any particular output, above which the quality of all publications is assumed to be the same.

The Higher Education Information Management System (HEMIS) is a valuable source of information about this sector, as are the comparable databases maintained by the NRF in regard to its grantees. Neither of these databases is easy to access or user friendly.

The Research Information Management System (RIMS) is only partially in place, facing implementation issues in part caused by prior commitments made by a number of institutions to other installed enterprise resource management systems.

The requirement for key performance indicators in the annual reports of science councils has induced them to make public many more output indicators than in the past. Very few, if any, summative compilations of the combined science council production of patents, publications and research student graduations have been done to the Committee's knowledge. For higher education institutions, the Council on Higher Education (CHE), for example, publishes an annual summative review of some of the outputs.

A number of scholars distributed among various institutions have begun to map the publication performance of the country's researchers, mainly using the widely known, well-developed and readily mined databases of the Thomson-Reuters Web of Knowledge (WoK) journal citation reports. While the fact that the indexed databases are selective makes this a rigorous bibliographic tool (based on the concept of a core literature, in which 80% of the significant information is supposed to appear in only 20% of all published journals), the bias in favour of advanced countries and English-language journals operates to the disadvantage of journals published in other regions, especially emerging or developing countries (the company has recently expanded the indexes through the addition of about 1500 regional journals, resulting in South Africa's share rising three-fold to about 70 indexed journal titles). SA Knowledgebase is a

private bibliographic and demographic database that seeks to capture all accredited publications produced from South African addresses, with a substantial capacity for demographic analysis, comprehensive field-specific studies, and institutional-specific analyses. It is important that bibliographic studies emanating locally should fully contextualise their observations in the 'real world' of the research and innovation system, something which has not always been the case.

The country's comparative performance in the WoK indexes is variable, with a static figure of just over 0.3% of total authorships in recent years. Collaboration has increased markedly, judged by data on author addresses, and the field-specific citation rates are sometimes higher than, and sometimes lower than, the world averages.

Monitoring information on social innovation is available, but from disparate sources. Intriguing survey information is available in the regular editions of Trialogue's *CSI Handbook* (the most recent 13th edition reflects 2009/10 activity), which among other things confirms the diverse effect of the very considerable R5.4 billion in annual corporate social investment (CSI) expenditure, distributed across twelve development focus areas analysed in the report. The handbook points to increasing incidences of working partnerships between corporates and non-profit and public sector collaborators, and increasing determination for CSI investment to be aligned with stakeholder interests. The information provided in this resource, however, is a reflection of private sector funding of development projects, and provides little insight into the levels and destinations of social innovation funding made available through the philanthropic community.

Equally valuable insight into social development activity can be obtained from other NGO sources. The Impumelelo Social Innovations Centre, for example, has rich information about particular projects (or portfolios of projects in some cases), often assembled into regional maps of innovation activity. These 'innovation landscapes' have potentially powerful value for the planning and brokerage of collaborative approaches to larger innovation priorities, and provide a model for how this information (with its detailed case-study material) could be made available through a more comprehensive centre for innovation system intelligence.

A different level of evidence-gathering and analysis is represented by the steadily increasing capacity of ASSAf to produce independent, multi-perspective, consensus reports on key issues affecting the NSI and the nation more broadly. This is an essential activity in terms of policy development, complementary to the quantitative analysis based on indicators and other proxies.

Even so, while there is a surfeit of data, there is a dearth of information, and it is evident that no entity in the NSI currently has the following capacities:

- **System-mapping:** What innovation activity is occurring across the various sectors, with a particular interest in those areas of activity currently under-reflected in existing measures? Private sector activity and formal R&D are best represented at present, although as yet inadequately understood. Innovative reforms in the public sector are more difficult to track, although several existing avenues provide rich windows into this activity. Much more elusive are the wide variety of innovations and adaptations in

communities, both urban and rural, that arise spontaneously or are supported by non-profit organisation (NPO) or CSI activity.

- **System-analysis:** What do is known about the state of the enabling conditions that the Committee believes are required to release the innovative potential within the system, and how are the various actors in the system responding to these conditions? What can be learnt about how bottlenecks and constraints work to limit this potential, and how incentives are able to release it? How robust are existing theories about system dynamics, and about South Africa's contextual specificities?

- **System-building:** What intelligence can be made available to inform and equip each of the system-building measures noted earlier in this section? In addition, periodic capability reviews of key agencies in the NSI should be commissioned, and progress in fulfilling recommendations needs to be monitored.

- **System-steerage**: What measures are best advised to produce deliberate, desired system effects? National goals of sustainable, labour-absorptive growth and poverty alleviation require that policy and investment decisions prompt adaptive behaviour. How can the evaluation capacity best guide these planning decisions? System-steering work involves at least three levels of activity, including those producing projections (such as foresight exercises and scenario-building techniques), those informing policies (both *ex ante* and *ex post* impact-assessment studies) and those informing programmes (contextual and project-specific intelligence geared to optimise a particular intervention).

- **System-evaluation:** What trends are discernible, and what is the impact of the investments in innovative and adaptive behaviour? There is wide acknowledgement of the difficulties associated with estimating systemic impact accumulating over a period of sustained investment in targeted measures, especially in elusive quality-of-life measures. The monitoring and evaluation (M&E) capacity must enable the derivation of compelling indicators and analytically powerful qualitative insights. Ultimately, the capacity is required to assemble a synoptic view of emergent patterns across the system, and the relationships that might be at work among them.

- **System-learning:** One of the founding conceptions of the system is that it is an interactive, relational system of mutually reinforcing learning and adaptation. One of the functions of the monitoring and evaluation (M&E) capacity is to provide a knowledge base and a communicative nexus for cognitive exchange and accumulation within the system, both within sectors and across them. This has to be done deliberately and inclusively, so as to draw on local and distributed knowledges arising from the sites of innovative activity, and to ensure the widest possible distribution of the questions, the debates and the insights that must inform the growing vitality of the system.

- **System-foresight:** The extensive investment made in Research and Technology Foresight in 1998 has not been followed up with further exercises of this kind.

Recommendations

Recommendation 29: The intention behind the proposal for the establishment of an Office for Research and Innovation Policy (ORIP) (see Recommendation 3) is to establish a centralised facility to serve as a repository of evaluation information on the NSI, and an expert site for its distillation and distribution to inform strategy and steerage at the highest levels and more broadly.

Secondly, the agency should encourage good-practice evaluation much more widely in the system than is presently the case. The strength of a complex, relational and multi-actor NSI will arise from strong M&E capacity distributed through every part of the system, where all sites of practice are making decisions based on astute localised insight. This distributed, localised knowledge needs also to be assembled centrally to inform system-wide strategic views, both for state steerage and to inform thinking throughout the system. Part of galvanising the system towards a number of national priorities is the need to keep all the players informed about what is happening, what is working and what is not. Sustaining shared commitment over time depends on the capacity for collective learning, and the ability to become a learning society.

Recommendation 30: The Committee recommends that the mandate of the proposed Office for Research and Innovation Policy (ORIP) must include systematic monitoring and evaluation for the entire NSI, as outlined above. The approach should be based on the different elements outlined above, namely system-mapping, analysis, building, steerage, evaluation, learning and foresight. This would include:

- Provision of the research and intelligence needed for the functioning of the proposed National Council on Research and Innovation, from which ORIP would receive its strategic mandate and its systemic authority.
- Provision of the research and intelligence needed for the policy-making and regulatory functioning of the DST and the proposed three policy-incubating nexuses focused respectively on higher education, the business sphere and social innovation (see Recommendation 5).
- Design the range of instruments and methodologies needed to fulfil the systemic functions outlined above, and contract and outsource those that ORIP cannot practically undertake itself. Among other things, consideration should be given to the future location of the Centre for Science, Technology and Innovation Indicators (CeSTII), support for and cooperation with CREST's SA Knowledgebase, and functional linkages with the Higher Education Information Management System (HEMIS) and the intended Research Information Management System (RIMS).
- Oversight of the follow-through on review reports of public research organisations and other NSI-related institutions.
- Oversight of a policy that all major research, development and innovation projects attracting significant levels of state funding (above an amount to be determined by the DST from time to time) should be subject to statutory evaluation, the results of which should be publicly available through ORIP.
- Maintenance of a system whereby publicly funded databases relevant to the national R&D system make their data available to ORIP (and thus to the public) through appropriate data access protocols.
- Extraction of the optimal meta-analytic value from all NSI-related surveys, evaluations and indicator studies in order to inform the strategies and purposes of the NSI.

Recommendation 31: The Committee recommends that the role of the Academy of Science of South Africa (ASSAf) should be strengthened and broadened to provide independent evidence-based advice on key issues relevant to the NSI. These might come in various formats such as

commentaries on policies or draft legislation; full consensus studies; facilitated forum-type conferences and workshops; and other thorough investigations.

Recommendation 32: A thorough investigation of data collection and interpretation related to the NSI is urgently needed. Particular considerations in this regard include:

- The NCRI and national government priorities relating to social development and social innovation must be included within the range of instruments and indicators deployed by ORIP. In addition, ORIP should seek to recruit NGOs and company corporate social responsibility directors in a sustainable network of information-gathering and analysis.
- The Committee recommends that an annual summative review of the outputs of all the science councils and other public research or S&T-based technical service organisations be considered. The annual summative CHE review of higher education should include the key indicators selected by ORIP for monitoring and evaluation of the system as a whole. The annual report on higher education research outputs produced by the DHET should be expanded after detailed consultation among stakeholders, and made public.
- The accuracy of the official figures for the technology balance of payments should be subjected to scrutiny.

Recommendation 33: The annual Science and Technology Activities (STA) Report compiled by the DST should be linked to the new prospective research, innovation and development cluster budget for the year in question, to enhance accountability and to provide a valuable complement to the National R&D Survey for the same year. This should be associated with a greater degree of linkage in that survey to contexts and policy outcomes.

Recommendation 34: Ten years after the most extensive exercise of its kind in this country, attention must again be given to foresight studies, as well as carefully designed social fabric studies as a basis for effective social innovation.

SECTION 5: FINANCING THE NATIONAL SYSTEM OF INNOVATION

Assessment

At a high level, the Committee believes that the NSI in South Africa is now generally in stasis, heavily stabilised and constrained within itself, and can be only be moved to a different state by investments aimed at the country becoming a knowledge economy. The means by which the system is resourced thus become critical levers for the steerage of the system, and for its general vitality.

The biggest constraints are the stuttering pipeline of trained and knowledgeable people, at all levels; the inadequate investment in the research teams that do exist; not keeping up with infrastructure requirements; and failing to incentivise private investment in innovation, both within and from outside the country. Financing of the system must henceforth be driven in a new and more purposeful manner.

South Africa has maintained a steady growth in R&D expenditure over the past decade, with GERD growing in current prices from about R4 billion in 1997/98, to about R21 billion in 2008/09. The ratio of GERD as a percentage of GDP has also expanded over this period, indicating the growing role of R&D within the economy. From 2007/08, however, there was a decline in GERD as a percentage of GDP for the second year in succession, from 0.93% in 2007/08 to 0.92% in 2008/09. The 1% target remains elusive.

The Committee applauds and supports the government's intention to increase the R&D intensity (GERD) of the country to the ambitious target of 1.5% of GDP within a few years; this target is obviously dependent on the actual growth of GDP over this time. It is important that the investment is well planned and concerted in nature, based on a thorough understanding of the causes of the inertia.

Comparison of the 2008–2009 data with those for 2007–2008 shows an increase in total 'real' spend of only 1.3%, while the total number of researchers and R&D personnel has generally been static, and actually fell when expressed as a percentage of the total employment in the country, to only 1.4 researchers per 1000 persons employed.

The higher education institutions (HEIs) need to increase the volume of high-quality human capital generation (in the form of greater numbers of well-trained honours, masters and doctoral graduates as well as postdoctoral fellows, drawn from the talent of the whole population) as well as that of research outputs (like high-impact peer-reviewed articles and scholarly books), commercially exploitable patents and potential innovations generally. Many of the required concerted interventions are outlined in Section 3 of the Executive Summary: Human capital and knowledge infrastructure; some of these will require expenditure of funds held by HEIs or granted them by government agencies and/or business.

The Committee also recommends the re-organising of a much better-resourced external government agency system to focus primarily on the purposeful and adequate resourcing of the well-performing, multiple-output research groups, while providing considerably increased overall support for such groups, appropriately designed in terms of operational, capital and human resource provision, at various levels.

In the science council sector, the question of 'new target' resourcing flows depends largely on what the individual and grouped mandates of these government-owned organisations should be in future. The competitive advantage arising from the marked systemic economies of scale, the multiple beneficial outputs of HEI-based R&D, the constant entry of talented newcomers, the richness of the multiple-discipline environment, and the independence of the general mind-set, makes a strong general case for HEIs undertaking a very large percentage of the total national R&D that is not performed within business enterprises.

There would be funding implications associated with a decision to move into the science councils some of the scientific and technical services that are currently housed in government departments, or to relocate most or all of the national facilities currently operated by the NRF to other bodies.

Private business and industry, the most important source of finance for, and performer of R&D in the NSI, is a key strategic partner for government to engage with in promoting R&D investment in the country. It is deeply disturbing that business- and industry-funded R&D in the public sector has fallen over the period 2001/02 to 2008/09; while transfers to universities have doubled, engagement with the science councils fell by two-thirds.

Government obviously exerts much more control over state-owned enterprises, several of which are major performers of R&D, both here and elsewhere, and account for the 20% of total business R&D expenditure that is sourced from government. State-owned enterprises have considerable potential for energising innovation through their large-scale procurement activity and through international linkages. They are also extensively involved in technology transfer, with attendant opportunities for local adaptive innovation.

An important strategic instrument is the so-called triple helix between government/science councils, HEIs and business/industry; quadruple helix formation takes place when civil society also becomes directly involved. The Committee regards it as extremely important that every effort is made to ensure the smooth initiation and sustainable operation of such complex partnerships so that the decline in business/industry funding in the public sector can be reversed. There is a particular need for seamless funding arrangements in multi-helix innovation strategies, along innovation chains and over time in each enterprise. Stimulation of this activity will assist in increasing the proportion of 'applied' and 'experimental development' research performed at HEIs, promoting the overall uptake of cutting-edge information and innovation by business .

The current stable of incentive schemes run by the dti and TIA/DST is investing about R600 million of government money in innovation projects in business/industry, most of it actually spent in HEIs

and science councils. The tax benefit for business R&D activity that meets set criteria is being taken up increasingly despite administrative problems. The tax expenditure or tax revenue forgone due to the R&D tax incentives is estimated to be just over R1 billion for the period 2005/06 to 2008/09. The DST estimates an amount of R632 million for the year 2009/10 (DST 2011: 7d).

Venture capital for innovation is actually readily available in South Africa, but the total amount invested is very small; it appears that certain tax and exchange control regulations impair the ability of fund managers to create value.

The role of foreign firms in the South African economy has increased considerably in the last decade, with foreign direct investment (FDI) rising from 1% of GDP in 2003 to about 4% in 2009. Regrettably, most of the investment is in equity purchases or share portfolios rather than in innovative industry. Everything possible must be done for South Africa to become the preferred destination on the African continent for R&D-related foreign direct investment.

The country also has a widening balance of payments; domestic demand should increasingly be met through domestic capacity, as a matter of some urgency.

The Committee believes that the creation of a knowledge economy in South Africa will require in respect of the business sector much higher R&D expenditure by business/industry, probably as much as 50% more than at present; a greater degree of partnership between business/industry and HEIs and science councils, representing the outsourcing rather than the performance of part or all of the R&D concerned, preferably in well-regulated and well-facilitated triple- or quadruple-helix arrangements; expansion of the incentive schemes offered by the dti and TIA/DST, both in total amounts applied and in the range of enterprises serviced in this way; assisting more purposely the realisation of innovative capacity in small and medium-sized businesses; enhancing the national capacity to transfer and adapt new technologies as much as the capacity to create new ones; facilitating and optimising through appropriate legislation, regulation and administrative practice the potential of local firms to recruit high-level staff from other countries, and to maximise their impact; energetically promoting foreign direct investment so that multi-national companies carry out globally applicable R&D in this country rather than elsewhere; mobilising the skills of business to enhance social innovation and improved service delivery in the public sector; and expanding the venture capital industry as well as the application of corporate social investment in achieving innovation in various different ways.

The so-called government sector of the annual R&D survey is a rather heterogeneous but potentially highly significant component of the NSI.

A matter that deserves attention is the reportedly low spend of many central line departments of government on R&D, which suggests that problems encountered in service delivery or policy implementation are not being innovatively addressed. The government departments concerned are prime candidates for a much-expanded programme of steered and assisted social innovation. The financing of these newly focused activities would depend on the organisational

arrangements, the wide participation of sponsoring and/or partnering companies, the interplay between different levels of government, and the way in which the developmental state is re-envisaged by government in the next few years.

Recommendations Related to Financing the NSI

Recommendation 35: Public resourcing of R&D conducted at HEIs should be significantly increased, with a focus on the best-performing, multiple-output research groups, the extension of the system of Research Chairs and Centres of Excellence to Research Institutes, and the provision of improved infrastructure. Furthermore, consideration should be given to the subsidisation of national licences for high-impact commercial journals and the free-online e-publishing platform, SciELO-South Africa, for high-quality local journals.

Recommendation 36: The public funding of the science councils should be adjusted to match their newly formulated individual and collective mandates.

Recommendation 37: Business/industry should be encouraged and incentivised to increase its R&D expenditure, probably as much as 50% more than at present, through much more pervasive triple and quadruple helix formation with government/science councils and the HEIs, and involving extensive outsourcing of the R&D required for business innovation.

Recommendation 38: The incentive schemes offered by the dti and TIA/DST should be expanded, both in the total amounts applied and in the range of enterprises serviced in this way, with a special focus on the realisation of innovative capacity in small and medium-sized businesses.

Recommendation 39: Everything possible must be done for South Africa to become the preferred destination on the African continent for R&D-related foreign direct investment (FDI).

Recommendation 40: The potential of local firms, HEIs and science councils to recruit high-level staff from other countries should be facilitated and optimised through appropriate legislation, regulation and administrative practice.

Recommendation 41: Measures should be devised to encourage government departments to improve service delivery through research, development and innovation, including the effective use of the annual survey of government expenditure on science and technology activities, to draw up prospective expenditure plans annually for such activities.

CONCLUSION

Awareness of the social dimensions in all technological activity has informed the Committee's deliberations. The Committee believes that technology impacts on peoples' lives both positively and negatively; people in turn shape the uses and development of technology in similar ways.

It is the considered view of the Ministerial Review Committee that the research and innovation system is key to a better life for all. To this end, considerable renewal of South Africa's knowledge base (in all its forms) is needed, with attendant fiscal implications at a time of fierce competition for resources. The justification for investing in a resurgent NSI is that this should ultimately deepen the impact of human and budgetary resources. Research and innovation have previously delivered in response to the demands of the day. The imperative now is to lay the foundations of a new contract between the research and innovation system and society at large. The new contract is predicated upon a participatory articulation of economic and social needs, and their fulfilment through innovation activities. As such, the research and innovation system needs to be advanced as a values-driven and deeply embedded part of society, championed by compelling and inclusive leadership.

PHASE ONE: THE CONTEMPORARY NSI LANDSCAPE

SECTION 1: CONTEXT OF THE OECD REVIEW, AS REFLECTED IN PREVIOUS POLICY AND REVIEW DOCUMENTS

1.1 Preamble

This overview is developed to outline the policy ambitions, and some of the systemic measures, proposed since 1996 to advance a **National System of Innovation (NSI)** for South Africa. This overview is based on a desktop review of the **principal policy documents** and **review reports** that the Ministerial Review Committee has been able to access. The material noted in this section is **necessarily selective**, intended best to provide a sketch of the priorities and debates that constituted the discursive context for the OECD study, many of which remain continuing preoccupations for those concerned with the future success and vitality of the NSI.

Innovation is the capacity to generate, acquire and apply knowledge to advance economic and social purposes. It includes both the search for frontier technologies driven by research and development (R&D), as well as the forms of learning and adaptation that might be market led or socially driven. Innovation is fundamentally uncertain, highly contextual and path dependent, but it is at the heart of moving the country from its present mix of resource- and efficiency-driven economic activity to one that is driven by the generation and application of knowledge. It is about doing new things in new ways.

The **Department of Science and Technology (DST)** and its predecessor department (the Department of Arts, Culture, Science and Technology – DACST) over the last decade and a half have been placed at the centre of the government's adoption of the National System of Innovation model as a framework to make innovation a key driver of economic growth and improvement of the quality of life of all citizens.

The idea of a National System of Innovation (NSI) rests on the importance of linkages and interactions among organisations and institutions in the creation of knowledge, its transfer and the development of innovations. There are technological and non-technological forms of innovation, involving changes in production, products and processes.

The main actors in an NSI are business (mostly private sector but some state-owned), government research laboratories and universities. Business innovations either improve efficiencies in production and/or generate products that enter the national and global markets. Government research laboratories and universities conduct research and develop skills, sometimes in partnership with business. They also contribute to policy development and improvements in public service delivery.

Government plays many roles in the NSI: by setting framework conditions, providing infrastructure as services and utilities, promoting human resource development, as well as 'business' innovator (e.g. through state-owned enterprises), and research performer (e.g. through the science councils).

'Deliberate' framework conditions that shape a system of innovation include policies and regulations for skills supply and immigration law, foreign exchange regulations, tax incentives, the regime for state loan finance, equity stakes and grants, and the protection of intellectual property. Framework conditions enable firms to invest in innovation and to promote the flow of information, and they encourage the circulation of skilled people. 'External' framework conditions are those imposed by the increasingly globalised operating environment.

The South African government has taken a number of **measures to establish institutions**, **governance systems, resourcing initiatives and general framework conditions intended to create a supportive environment for innovation**. This has arisen from several strategic initiatives aimed at giving effect to the intentions of the NSI. These include the White Paper on Science and Technology (1996), the National Research and Technology Foresight Study (1997–1999), the National Research and Development Strategy (2002), and the New Strategic Management Model for South Africa's S&T system (2004), with its Policy on Governance Standards for Science, Engineering, Technology and Innovation Institutions (SETIs) and framework for the development of a National Science and Technology Expenditure Plan.

At key points since 1996, a number of **review exercises** have been conducted. The evolving policy framework was (and still is) intended as the basis by which leadership, coordination and cooperation could be achieved over a wide and highly diverse set of actors engaged in innovation, either through research and development or in other ways. Arising from the original 1996 White Paper on Science and Technology, it was anticipated that the NSI would have a pervasively positive influence on economic and social development in the country.

The theme of this section will be the **framework conditions** in which leadership and coordination might be provided for the NSI (or indeed frustrated), as well as the ability of innovation to act as a key driver of national development. The analysis provided in this report concerns itself mostly with the system-wide arrangements advocated in succeeding policy and review documents, the degree to which implementation has been achieved, and the extent to which these measures have had the intended effect. In particular, therefore, the report focuses on the governance structures, the institutional architecture and the resourcing patterns associated with this complex and ambitious endeavour. It is these issues, then, that act as the organising criteria for the narrative that follows. Although this account is necessarily skeletal, we have sought to provide sufficient detail to illustrate the persistent issues that have implications for the success or failure of the policy of placing innovation at the heart of national economic and societal development.

1.2 1996 White Paper on Science and Technology

The founding document for the notion of an NSI is the 1996 White Paper on Science and Technology (DACST 1996). This remains the most complete description of the vision of a country

that uses innovation for economic competitiveness, national development and service delivery. It is worth noting this particular vision in some detail, since it sets in place the basis for the institutional and governance architecture for the South African system.

Purposes

The 1996 White Paper responds to the global knowledge economy and competitive pressures on the South African economy due to global market forces. In this context it focuses on the need for "**increased coordination of innovation policies and strategies**" and a "**problem-solving, multi-disciplinary approach to innovation as a mechanism of growth and development**". The NSI was intended to have a "**high measure of strategic and creative interaction amongst its constituent elements**". The core vision was to "harness the diverse aspects of S&T through the various institutions where they are developed, practised or utilised". A prime objective of the NSI was "to enhance the rate and quality of technology transfer from the science, engineering and technology (SET) sector by the provision of quality human resources, effective hard technology transfer mechanisms, and the creation of more effective and efficient users of technology in the business and government sectors". Government R&D was meant to positively affect the "quality of life of citizens in the areas of environmental sustainability, health care provision, meeting basic needs at community level, reducing the cost of infrastructure provision, and providing safety and security to all". It is important to note, as already indicated, that as a conceptual device, the NSI does not involve only R&D (or S&T) but that there is a range of sources of innovation. These creative (or reformative) activities are understood to be complex processes arising from both formal and planned initiatives as well as informal and fortuitous activities. In this conception, formal R&D stands as one (very important) part of the overall system of innovation.

The reasons given in the White Paper for adopting the NSI approach were:

- **It affords an opportunity to think of means for the promotion of coherence and integration among national activities, two factors which have been sorely neglected in the South African S&T system of the past.**
- **It offers a means of identifying what needs to be done without automatically tying the necessary functions to any particular existing institution or organisation.**
- **It focuses attention on *innovation* – on doing new things in new ways – rather than simply on the production of knowledge.**

This is not to say that innovation systems-thinking is a 'one-size-fits-all' specification. The concept should be understood as a constant 'work in progress' that has wide contemporary appeal in a rapidly changing world, that is still undergoing refinement in the light of that change combined with international experience and continuing analysis, and can create an inspiring model for an emerging nation.

Conception

In summary, the White Paper conceptualises 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". Government has to see to it that these NSI components**

are in place, that they interact, and that there is an agreed set of goals and objectives for a knowledge society/economy. In this regard, it allocates to itself the function of policy formulation and regulation, while public- and private-sector stakeholders would share in the other functions of finance-allocation, actual performance of R&D and innovation, infrastructure provision and human resource development.

Participants

The White Paper provides a conceptualisation of which **stakeholders** might be included in the NSI. Government players include central policy departments (e.g. the Presidency, Treasury and some functions of DACST) and line departments (including Defence, Health, Education, Communications, Trade and Industry, Agriculture, Transport, etc.). Outside government were general agencies (e.g. the National Research Foundation), specialised domain agencies (e.g. the Water Research Commission), research-performing SETIs, state corporations, private business and industry, higher education institutions, and non-governmental organisations (NGOs). This provides a sweeping and inclusive vision of all knowledge-intensive participants contributing to the national aspirations set out in the White Paper.

Governance and institutions

The White Paper goes on to describe the **institutions to be established** in order to promote the development of a well-functioning NSI. These were in essence to be a national Ministry and Department of Science and Technology (DST), a Ministers' Committee on Science and Technology (MCOST), a National Advisory Council on Innovation (NACI), a National Research Foundation (NRF), an Innovation Fund, and major national research facilities managed by government. The MCOST was to be composed of all Ministers whose portfolios encompassed a significant S&T component; it was to be the principal policy-coordinating and information-disseminating body for S&T matters across government.

NACI was charged with carrying out 'enquiries, studies and consultations' with respect to the functioning of the NSI, at the request of the Minister of Arts, Culture, Science and Technology. It was to be advisory rather than operational. The key, and very significant, structural aspect of the proposal for NACI was its placement within the DST, and its designation as being advisory only to the Minister of Arts, Culture, Science and Technology who, by means of MCOST, should coordinate government line departments and their associated SETIs and agencies in the NSI. NACI was duly established in 1998 as a statutory body with the Director-General of Arts, Culture, Science and Technology as its CEO.

Resourcing

The White Paper specified that an **annual 'Science Budget document' would be prepared from data drawn from departmental budgets, to reflect all government S&T expenditure, including all its agencies (and including, in particular, the support offered by the Department of Education to institutions in the higher education sector**). Further, a policy of **tax incentives for industry** would be introduced to encourage R&D in the private sector, while the agency-type **Innovation Fund** was to encourage longer-term, large innovation projects in the higher education sector, SETIs, civil society and business. With these measures, the White Paper envisaged a

regime of resourcing that would coordinate government R&D activities and provide incentives for innovation more broadly.

Commentary

The preceding summary of the 1996 White Paper has been deliberately selective in its extraction of the main ingredients of this landmark document. **What remains after 14 years of eventful follow-up is the impressive aspiration to generate and use knowledge cooperatively in order to develop the whole country as an innovative, creative and prosperous society**. The NSI is thus an assertion that systemic innovation of this ambitious kind requires forms of governance and coordination to achieve the wise and effective use of resources, and the optimum development and mobilisation of South Africa's talent pool.

Much of the subsequent history of the NSI has centred on the realisability of the assumptions made in the White Paper about the nature and capacity of units of government expected to participate cooperatively in the NSI, the relationship between the elements that 'steer' and those that are 'steered', the overall resourcing of the public S&T system amidst huge unmet developmental needs, and the onward march of the globalised operating environment.

Apart from the apparently short-lived inter-ministerial MCOST and the intrinsically 'hamstrung' design of NACI, the most critical structural issue in the NSI created by the White Paper was the setting up of a separate **Ministry and Department of Science and Technology** to achieve ambitious systemic national goals, mostly in other ministers' or departments' 'backyards'. This was likely to lead to frustration at the level of the Ministry and Department of S&T as it sought to lead NSI development mostly by energetic advocacy at the highest level (Cabinet and Ministerial cluster), or by default within its own circumscribed domain. It is true to say that no other line department of government (except perhaps the Department of Trade and Industry) has shown much visible interest in the NSI as a 'mental model' crucial to its own strategies and preoccupations – that has been left to the DST.

The following sections outline subsequent initiatives that have sought to bring further definition to the NSI, or to fine-tune some of its public sector constituents. These are arranged chronologically.

1.3 1998 system-wide reviews of public-sector SETIs

Following the publication of the White Paper, a **cross-cutting review** of 11 different science, engineering and technology institutions (SETIs) was commissioned by MCOST, organised by the DST, and intended to take stock of the public R&D landscape in order to prepare the ground for policy development arising from the White Paper. It included separate individual reviews of each of these SETIs, as well as a review of the role of government in supporting S&T.

In spite of the ambitions and measures of the White Paper, the review found that the public sector institutions were still characterised by "poor interactions and networking", constituting "a

major weakness of the South African SET system". The most significant deficit was "between the SETIs and the higher education sector." As result, it was said, "nearly all ideas in the government SETIs were internally generated and most innovations were not pursued to their maximum potential". The review went as far as to state that these problems (which the review considered remediable) were greater than those posed by the overall inadequate funding levels. The review recommended that "provision should be made for system-wide independent oversight, evaluation and strategic advice to government", and that "numerous opportunities should be provided to facilitate linkages and interactions across disciplines, sectors and institutions", in order to "create a stimulating environment and an innovative climate throughout the entire system".

NACI's mandate was addressed in the system-wide review by recommending that it should focus on "advice to government on the development of its overall strategy, on the prioritisation of its activities, and on resource allocation to all SETIs". It is important to note that these were systemic recommendations relating to the whole government and the NSI, rather than being specific to the DST domain.

1.4 1997–1999 National Research and Technology Foresight process

The very participatory **National Research and Technology Foresight (NRTF**) **exercise**, which published its outputs in 1999, was intended to "**put real content into the NSI and thereby develop a framework of goals within which our technology programmes can be shaped"**. The initiative differed from other NSI-related interventions in its detailed examination of the main sectors of the economy and society, and it produced carefully debated consensus recommendations that outlined a mix of medium- and long-term opportunities and obligations in relation to a twenty-year horizon.

The immense effort of the NRTF was not rewarded with take-up in line departments or even in the policy trajectories of the DST itself. The main legacy of the exercise (as in the case of the Green and White Papers before it) was the entrainment of a large number of potential participants in the national S&T policy-making and development agenda, some remaining engaged in a diversity of ways, and others becoming passive onlookers or active critics from the vantage of their main preoccupations.

1.5 2002 National Research and Development Strategy

The adoption by the Cabinet of the **National R&D Strategy (NRDS**) (DST 2002) seems to have been a response by the newly independent DST to government's concern that the NSI was not taking shape as expected. It focused on key perceived weaknesses of the NSI such as inadequate funding, lack of growth in numbers of high-level S&T personnel, apparently declining R&D in the private sector (although this was not in fact the case), the absence of a new policy framework for intellectual property, and general fragmentation of government S&T activity.

Of the initiatives proposed by the NRDS, the following four are significant for the purposes of this report, since they form part of the reiterated themes that have preoccupied innovation stakeholders since the White Paper, namely:

i. The establishment of a **Foundation for Technological Innovation** to enhance coordinated agency activity in order to focus on closing the perceived 'innovation chasm'. This took nearly eight years to become a reality in the shape of the new **Technological Innovation Agency (TIA**), established by statute in 2009.

ii. The initiation of five major new **S&T Missions**, deliberately spread across areas in which the DST would have a reasonable degree of traction, namely:

- Information technology involving a set of 'technology platforms'
- Biotechnology
- Technology for manufacturing
- R&D in the natural resources sector
- Technology for poverty reduction.

iii. The Missions were ambitiously to function as organising principles for concerted cross-boundary collaboration in pursuit of common goals.

iv. The NRDS sought a radical increase in skilled human capital for a **knowledge economy**, **and proposed strong and effective cooperation between the (then) Department of Education and the DST for this purpose**. The **South African Research Chairs Initiative (SARChI**) is seen by many as probably the main, and perhaps the only, significant outcome of this overall effort.

v. Lastly, and very significantly, the NRDS sought to deal purposefully with the continuing structural and functional fragmentation of the S&T system. It proposed that the DST annually draw up a three-year **R&D Plan** for the whole country, dovetailing with government's Medium-Term Expenditure Framework (MTEF) and "capturing its key targets and investments". The R&D Plans would include the programmes of each line department of government, including the targets expected of parastatals and sector-specific SETIs. The accompanying national R&D budget, foresight inputs and risk assessments would also be provided by the DST, working together with the other departments and agencies. Each government department would set R&D goals for the institutions reporting to them, and allocate funds separately earmarked both for 'service R&D work' and for self-directed R&D. Each department's R&D Plan would be a component of the national R&D Plan prepared by the DST.

The NRDS recommended that all **sector-specific institutions** be placed in their sectoral line departments. It appears that this view was based on the notion that the other recommendations to reduce fragmentation would all be successfully implemented, with the DST able to exercise a coordinating role as the master integrating entity of the NSI.

The adoption of the NRDS by Cabinet, however, created a very challenging situation for the DST in the complex political environment of the country. In terms of the NRDS, the DST was intended to have the capacity to draw peer departments and multiple stakeholders together into a single national NSI, in the face of the inevitable impulse of these entities to operate autonomously.

A warning sign in the NRDS was its preoccupation with the public sector segment of the overall NSI, which was to become a key point made in the 2007 OECD review of the NSI, and by business commentators later (see Section 1.9 of the Phase One report).

1.6 2002 review of National Advisory Council on Innovation

The 2002 review was the first review of the National Advisory Council on Innovation (NACI) since its inception in 1997. The review concluded that it was vitally important that the government should continue to seek and to receive well-researched advice on both policy and performance within the NSI, from a group of experienced and active people drawn from the many different areas within the system. It was felt that this need would best be met through the activities of a strengthened National Advisory Council on Innovation, which would continue to maintain an active dialogue with the Cabinet through the Minister of Science and Technology.

The main device suggested for strengthening NACI was to make it operationally independent of the DST, with a CEO who was not the Director-General of the Department, and to give it the freedom to work more widely within the NSI, despite the report-back channel being through the Minister of Science and Technology. The principal and most encompassing role of NACI was thought to be advising on policy matters in the domain of innovation, and the view was that it should not concern itself with the provision of technical advice on immediate and pressing issues. It was recommended that NACI should prepare a systemic review of the NSI every three to four years.

1.7 2004–2006: Implementing the new strategic management model for South Africa's S&T system, the policy on governance standards for SETIs, and the realisation of a National Science and Technology Expenditure Report/Plan

The **New Strategic Management Model (NSMM**) was cast in precisely the same terms as the documents already discussed, but sought to sharpen the definitions and make some preliminary provision for 'market failure' or incapacity on the part of line departments in respect of their R&D functions and institutions within the NRDS conceptual framework, as already described.

The NSMM emphasised the **cross-cutting role of the DST in setting common governance standards and quality assurance mechanisms for each SETI**, irrespective of its location in the system. At the same time, however, the model reaffirmed the view that sectoral research agencies should remain within the domain of their respective line departments: thus the Medical Research Council (MRC), for example, was to remain in the domain of the Department of Health, and the Agricultural Research Council (ARC) in the domain of the Department of Agriculture, even though they both had considerable cross-cutting and overlapping activities. The Council for Scientific and Industrial Research (CSIR), by contrast, as a clear 'cross-cutter' was to be moved to

the purview of the DST, away from its previous reporting relationship to the Department Trade and Industry (the dti), as were the other cross-cutter agencies, the Human Sciences Research Council (HSRC) and the Africa Institute of South Africa (AISA). Uncontroversially, the National Research Foundation (NRF), housing also the Innovation Fund, remained in the sphere of the DST.

A critically significant part of the NSMM document described the nature of the ENVISAGED partnerships between the DST and other departments in sector-specific S&T. Among other things, the document notes: "**In the case of sector-specific science, the function of DST would be to develop interventions in the case of market failure, under-subscription or where there are technology gaps of a strategic nature. Examples here include those areas where sector departments are not ready to drive the necessary sector-specific technology programmes due to capacity deficiencies."** The DST was also to assist in the case of national priority programmes with best practice advice on S&T aspects, including developing financial instruments for that purpose.

The question is thus whether a 'consultant' role for the DST is really adequate in cases of departmental incapacity, and whether it is feasible to expect the DST to intervene in the case of a failed stewardship of a sector-specific SETI.

One of the residual centralisations of the NSMM was the assignment to the DST of the annual process of assembling **National Science and Technology Expenditure Reports**, to be used for the generation of a single **government S&T expenditure plan** covering and integrating all DST and sectoral R&D plans. This was intended to "guide the clusters and government as a whole on the deployment of resources … while retaining absolute accountability in the relevant departments".

The expenditure reports collate expenditure in three different categories across the large number of government departments (23 of the 34 departments) with significant **Science and Technology Activities (STAs).** The three categories are Scientific and Technological Innovation (STI, about 63%), Scientific and Technological Education and Training (STET, 20%) and Scientific and Technological Services (STS, 17%). National Treasury assists in compiling the reports by mining the relevant information from its annual Estimates of National Expenditure (ENE) in respect of the departments concerned, supplemented by questionnaire-derived information and direct consultations with departments. The Ministerial Review Committee had access to three successive National S&T Expenditure Reports, which appear to provide the beginnings of an informative cross-system view of government S&T expenditure. Closer inspection revealed, however, that the highly significant contribution to national STA of the Department of Education (now the Department of Higher Education and Training) was not reflected in the reports, while some high figures reflected in the reports were problematic (such as the more than R2 billion attributed to STET by the Department of Health, which represented a questionable set of data in that the large sums earmarked for education and training in academic hospitals were not spent exclusively, or even extensively, on activities that could be categorised as S&T). The generation of three successive annual National S&T Expenditure Reports has not, to the knowledge of the Committee, led to the generation of a National S&T Expenditure Plan.

All in all, the NSMM represented a major intervention in the public component of the NSI, providing clarity on certain definitions and mapping a perhaps optimistic view of the role of the DST in its limited, but now better-defined, domain by advising or cajoling its departmental peers into meeting the demanding requirements set for each of them in creating a well-functioning segment of the NSI.

1.8 Observations from SETI reviews up to 2007

A number of individual SETI reviews were conducted in the period preceding the OECD review. It is not the intention to present a summary of all of these other than to point out several insights that resonate with the themes already illustrated.

The **2005 SETI review of the NRF** provided an example of the difficulties associated with blurred mandates, and the need for sharper differentiation of agency roles. The report drew attention to a widely held perception that the DST was increasingly performing agency functions that could, and should, have been assigned to the NRF or other agencies or SETIs. In some cases, "potential NRF grantees had applied directly to DST for funding because they thought they could get more". On another tack, and with respect to the relationship of the DST with the then Department of Education's (DoE's) Higher Education Branch, the review panel considered that **the greatest importance needed to be attached to harmonisation of the policies and practices of the DoE (advised by the Council on Higher Education – CHE) in relation to higher education institutions, on the one hand, and those of the DST and the NRF, on the other**. The review panel found little evidence that the DST (by itself or through the NRF) and the DoE (by itself or on the advice of the CHE) had addressed the obvious inter-dependencies between their policies and funding instruments. The NRF reviewers recommended the urgent achievement of a greater degree of complementarity between the DST and NRF Missions, on the one hand, and those of the DoE and the CHE/Higher Education Quality Committee (HEQC), on the other.

The **2001 SETI review of the MRC,** by contrast, gave some attention to another dimension of systemic coherence, this time between sectoral agencies and their government line departments. The review report expressed concern about the MRC's relationship to the national Department of Health (DoH), noting that the department felt that "the Council should be more responsive to its needs, and pay more attention to translation of research to serve the country's needs".

1.9 Conclusion

In concluding this section, it becomes apparent that a powerful and compelling vision for an innovation-driven national economic and social development was articulated in the 1996 White Paper on Science and Technology. **This vision has unfortunately not been adopted widely enough in the range of government departments to achieve the intended pervasive impact**. Yet no argument has been advanced in the review reports referred to, nor in the interviews conducted by the Committee, that the vision is inappropriate; the concerns are about how to make the NSI work more powerfully and pervasively. Some initiatives (e.g. the NRTF and the NRDS) have sought to this end to deepen the NSI's definition and content, while others (notable the NSI reviews and the NSMM) have argued for modification to the architecture of the governance and implementation arrangements.

Emerging from this overview of the documents and processes are a number of concerns and questions that go to the heart of the country's capacity to organise and sustain a well-functioning and effective NSI. These are outlined below, and are intended to provide key questions for discussion in subsequent sections of this report.

- A persistent theme has been **the lack of effectiveness of the means that government has mobilised, especially those centred on the roles and powers of the DST and NACI as designated coordinators of an otherwise fragmented and diverse NSI**. We have seen some blurring of the boundaries between the functions of various important public sector agencies, while line-function sectoral agencies have maintained impermeable boundaries and operated quite autonomously in spite of declared policy intent. Consequently, there have been instances of duplication, dissipation or disruption of effort, and the loss of opportunities for powerful multi-agency collaboration to address complex needs. The fundamental question is whether the chosen model (together with modifications and enhancements, as noted above) is, in its fundamental architecture, the most appropriate one.

- Another recurring theme is the **absence of a clear focus in the DST on business** as the largest NSI actor, and the need to create optimal framework conditions for the whole NSI.

- The White Paper envisaged that the finances, infrastructure and human capital for the NSI would be generated jointly and cooperatively between the public and private sectors. To date, the question remains how the high-level goals and objectives of the whole system can best be arrived at, together with a **resourcing plan** (i.e. what resources will be needed, and where they will be sourced), in order to make the achievement of the goal of innovation-driven development a realistic proposition? To what extent have the measures that have been implemented succeeded in securing the resources needed for the system to serve its purposes?

- What measures are needed to **optimise the framework conditions** required for 'performing actors' in the NSI to link up responsively with one another to mutual benefit, so that resources (of all kinds) can be directed to the greatest effect?

- A number of initiatives have been undertaken that were intended to produce a **coordinating and enhancement effect**, including the MCOST, the NRDS, the NSMM, the Ministerial cluster model and, very recently, the Knowledge Economy Forum. What levels of success have these measures enjoyed, and what is to be learned from these about models of coordination appropriate for the South African context?

- Foundational to the notion of a national system of innovation is that the **'mental model'** is broadly shared among those that are intended to participate in it. Is this currently the case? Can we work further to clarify and deepen system-wide appreciation of the concept and its modalities?

- Given that **foresight exercises**, and their cohesive effect in achieving shared understandings and common purpose, are so central to the success of national innovation systems elsewhere, can we account for the seeming under-exploitation of South Africa's strong investment in 1997–1999 in such an exercise? How can this kind of work be institutionalised in the future, including at project level?

- A necessary **role for NACI of achieving a coherent and responsive** system is a powerful theme running throughout the discussions, and seems central to improving the governance architecture and system-level management of the NSI. How should NACI (or some successor device) be better structured, positioned and empowered to carry out the functions assigned to it?

These themes, emerging clearly in the pre-2007 formative years, will find expression again in the deliberations of the OECD Review, considered in the next section of this report, and will be persistent factors informing the deliberations of the Ministerial Review Committee.

SECTION 2: CONCLUSIONS AND RECOMMENDATIONS OF THE 2007 OECD REVIEW

This section summarises in abbreviated form the observations and recommendations of the 2007 Review produced by the Organisation for Economic Co-operation and Development (OECD), *OECD Reviews of Innovation Policy: South Africa* (OECD 2007).

2.1 Challenges

The **OECD** was commissioned by the DST to conduct a **review of South Africa's innovation policy**. Published in 2007, the review constituted one of a series of highly reputable OECD country reviews of innovation policy, and was based on a **country self-assessment** prepared by NACI and an extensive series of interviews with stakeholders in the country's innovation system (NACI 2006).

The Ministerial Review Committee set out to assess the validity and cogency of the findings and recommendations of the OECD Review in three contexts. The first and most direct was scrutiny of the evidence provided for them by the internationally experienced panel concerned; the second, comparison with the preceding self-assessment or background report; and the third, the opinions of respondents. Strikingly, no significant disagreement with the report was revealed in any of these ways. It was thus assumed that the Ministerial Review, in its first phase at least, did not need to launch an in-depth assessment of the OECD review report, which thus serves as a convenient and sound point of reference in the evolution of the South African NSI.

The standing of the OECD itself does not need to be interrogated; it is a highly appropriate and constructive external agency for the kind of review of the local NSI needed ten years after the release of the White Paper that signalled the adoption of innovation as a key driver of national development.

The OECD Review noted that the context of the analysis was a society still in transition from a social economy sharply skewed along racial lines with deep disparities of poverty and wealth. The country faces the dual challenge of integrating its economy into a highly competitive global market while simultaneously providing employment opportunities that would mitigate the joblessness and poverty of a large proportion of the population.

The Review noted that post-1994 South Africa had inherited a relatively strong national S&T system, but one that had been structured to meet the needs of the previous social order. Although significant measures have been taken to restructure this system for the contemporary needs of the country, and the slowly improving, if uneven, performance of this system was noted, the NSI was perceived as still inadequate to address the urgent challenges that the country faces.

In particular, the NSI was characterised as **insufficiently supporting a transition from strong reliance on a resource- and commodity-based economy to one that is characterised by value-adding and knowledge-intensive activities**. Although some areas of the services sector are growing, the economy has yet to achieve the labour-absorption capacity it urgently needs. Equally, the NSI seems to be inadequate in its contribution to alleviating poverty and proving jobs. Indeed, the report notes that there may be little understanding of the role the NSI should play in addressing social imperatives.

Among the obstacles identified as impeding the functioning of the NSI is the **serious deficit in high-order skills**, particularly in the area of design, engineering, entrepreneurship and management (DEEM). This skills shortage is exacerbated by a global labour market that draws top talent towards the developed world. The second, and related, key obstacle is the deficit of university-based research and research training.

2.2 Findings

The OECD Review notes that South Africa's R&D-related assets include a strong, yet very limited, set of established higher education institutions, a good system of research councils and a nucleus of technologically-strong, innovation-performing business enterprises. The country has also introduced improved governance architecture, which includes a dedicated government department for science and technology (the DST), the National Research Foundation (NRF), and the National Advisory Council on Innovation (NACI). Initiatives such as the Technology and Human Resources for Industry Programme (THRIP) have been successful in promoting cooperation between universities and industry.

However, the policy landscape has many dimensions that warrant systematic attention, including:

- The **concept of a 'national system of innovation' has as yet gained limited currency**, both in the extent to which it is understood as something wider than traditional R&D activities and in the extent to which it has been fully absorbed into the strategies of key actors (including government departments and universities). The importance of R&D is well understood and supported, but there is far less understanding of the **notion of innovation** – in all its dimensions, including technical, economic and social. It is this latter understanding, and its potential to reach into all dimensions of society and the economy, that is a critical lever of development.

- Where there are far-sighted initiatives (often from the DST), these may find only limited effect in implementation. This may be due to the uneven commitment to the underlying notion of the NSI, the inevitable silo-effect of **organisational boundaries, or simply a shortage of skills**

- A **limited level of investment is spread too thinly** over a wide variety of disparate purposes and projects. There is insufficient identification of priorities, and inadequate capacity to marshal resources from different quarters to address these priorities at critical mass.

- The agencies that do exist (science councils, funding agencies, universities, etc.) may be **insufficiently differentiated**, with a consequent diffusion of roles and a weakened capacity to fulfil specialised roles needed for a sophisticated and responsive NSI.

- There seems to be only **limited horizontal coherence and integration** between agencies in the NSI, whether these are research and funding councils, or government departments. In particular, there is no Cabinet-level coordinating body to devise and monitor strategies for innovation at national level, and the resources needed for these. Although NACI sees its mandate as encouraging coherence (and no doubt enjoys success in various ways), its function is compromised by the fact that it reports to the DST and thus has no structural location that would afford it the authority needed for effective coordination.

- Similarly, there is **insufficient linkage between various levels of government**, with consequently weak integration between national, provincial and local levels.

2.3 Recommendations

The OECD Review concedes that its recommendations are selective and do not constitute a comprehensive formula for action. Instead they proceed from the review team's perceptions of priority areas, and from the features they believe to be factors supporting the success of national systems of innovation elsewhere. The recommendations include:

Widen system perspectives that help to shape innovation policy

Such measures could include:

- Include the role of business more fully in the conception and coordination of the NSI

- Give greater recognition to a wider array of activities (than only traditional R&D) that do, or could, contribute to the NSI

- Encourage and support greater integration with the international innovation system, including the two-way flows of knowledge and skills, and the reciprocity between international and local policies and strategies

- Understand more clearly (through evidence-gathering where necessary) the demand side need for innovation, to enable greater responsiveness from supply-side measures.

Re-examine the major national innovation priorities and missions

- Define the priorities for innovation increasingly in terms of sectors where innovation needs to find effect, rather than more narrowly in terms of particular technologies. For example, a comprehensive assessment of how the innovation strategy should address the structure of the economy, both in terms of its preoccupations (e.g. knowledge-driven rather than resource-dependent) and its reach (e.g. increasing inclusion of the so-called 'second economy')

- Strengthen the governance systems that would best enable the identification of such sectoral priorities.

Improve the governance structure of the innovation system

- Establish a body at Cabinet level to provide a synoptic and holistic overview of strategies, policies, participants and resourcing. This body should be able to ensure the coordination of the innovation-related priorities, activities and resourcing of the various government departments

- Reposition the structural location of NACI to a Cabinet-level instrument of governance, with the mandate to achieve effective advice and coordination across government departments
- Strengthen the mechanisms and instruments to support the interfaces that prompt innovation and the production of skilled human resources
- Establish and monitor appropriate forms and levels of functional specialisation.

Strengthen the human resource base for science, technology and innovation

- Strengthen the pipeline of progression from school to university
- Address the conditions and impediments that limit the access and success of large numbers of students (especially black students) into the education system
- Create conditions to increase in the number, and the rate of completion, of postgraduate students
- Reform the cost structure for university studies, which inhibits access to the more costly fields of study
- Strengthen measures and investment to support the human resource development activities of business
- Put measures in place to enhance the international reticulation of skills, including a review of immigration policy.

Improve the funding of university research

- Further enhance the mechanisms designed to focus research attention on areas of social and economic priority
- Review the funding formula for university research subsidies to provide stronger incentives for high-quality research
- Provide carefully directed resources for the long-term project of building research capacity among historically disadvantaged individuals.

Develop greater differentiation in public R&D and innovation support organisations, especially to the benefit of small and medium enterprises (SMEs)

- Achieve greater acknowledgement of the diversity and diverse needs of SMEs
- Strengthen measures to support innovation in SMEs, including the provision of specialist organisations and resources
- Provide greater support for start-up enterprises, including government loans on favourable terms and with mitigated risk-sharing
- Provide the means to strengthen SMEs' access to the support that research and innovation organisations can provide
- Provide regional and cluster-based technology parks and innovation centres, sometimes associated with industrial parks.

The OECD Review represented a much-needed outside look, by seasoned professionals, at ten years of policy-making and implementation of the agenda set in motion by the 1996 White Paper on Science and Technology. The response of the various NSI actors to the OECD Review, especially that of the DST as 'coordinator' of the system, would be a good indication of the ability and willingness of the system to engage in critically informed policy learning.

SECTION 3: RESPONSES OF SELECTED NSI ACTORS TO THE OECD REVIEW

This section is aimed at sketching the responses to the OECD Review and the resultant initiatives of selected players in the NSI, insofar as these could be gleaned from available documentation and interviews granted by key figures. The account cannot be considered as comprehensive, since this phase of the report has been based on a desk-top research exercise. [A more systematic empirical exercise would yield greater insight, and this was undertaken in Phase Two of the review.[2]]

In some cases, the responses of the agencies discussed in this section are based on their own reports of the measures they have undertaken related to the recommendations of the OECD review, while in other cases the responses are inferred from subsequent activity. While some material is self-reported, other material has been gleaned from the commentaries of other actors.

3.1 Department of Science and Technology (DST)

The responses of the DST to the OECD Review have been derived partly from formal documentation (especially the Ten-Year Innovation Plan), partly from a newly formulated response document provided by the Director-General (DG) of Science and Technology, partly from informative briefings by the DG and other senior officials, partly from perusal of agendas and minutes of various inter-departmental cooperation bodies established by the DST and partners in government, and partly from perspectives provided more widely.

A senior official informed the Ministerial Review Committee that the DST's **Ten-Year Innovation Plan (TYIP**) (DST 2007), released in 2008, constituted the formal documentary response of the DST to the recommendations of the OECD Review, while the legislatively driven inauguration of the **Technology Innovation Agency (TIA**) addressed system architecture recommendations. The Committee learned of the production of a Cabinet Minute in relation to the OECD Review, which was not available because of the confidentiality surrounding such documents, but was said not to constitute a formal DST response to the report. A departmental six-page summary of **DST responses to the 2007 OECD Peer Review of the South African National System of Innovation** was subsequently received, which proved extremely useful in systematically addressing the DST response to the OECD recommendations.

The DST started working on the TYIP before the OECD Review exercise, and this might explain why the relationship between the two documents is somewhat tenuous and sometimes contradictory. Puzzlingly, no reference is made in the TYIP to the OECD Review, and a number of central recommendations seem not to be addressed in this document. **These include the need to bring the private sector more centrally into the NSI, meeting the infrastructure requirements of a knowledge economy, and (perhaps most importantly for a policy document) resolving the**

[2]Additional perspectives on some organisations are included in Section 1 of the Phase One report, which provided an overview of the pre-2007 NSI.

considerable systemic difficulties arising from the current governance and institutional architecture of the NSI.

The TYIP, as originally disseminated, reads more as an elaborate 'vision statement' than a fully developed action plan. Nonetheless, the notion of the '**Grand Challenges**' has entered the discourse of the NSI community, especially the science councils. Consonant with the OECD Review's areas of focus, the TYIP characterises the priority pillars of the NSI as **human capital development, R&D, and knowledge infrastructure**. The 'Grand Challenges' are to be spear-headed by the DST and will "offer tremendous opportunities for steering our resource-based economy towards a **knowledge-based economy"**. Notably, the responsibility for addressing the Grand Challenges is necessarily spread across the operating domains of many government departments. Unlike the five new Missions of the 2002 National R&D strategy, most of which were more-or-less under the control of the DST itself, the 'Grand Challenges' represent huge general priority areas of government such as energy generation, responses to global change, space, the bio-economy, and human and social dynamics. According to the TYIP, the measures available to the DST to fulfil this responsibility will include appropriate policy development, additional or reprioritised funding, coordinated planning and implementation, focused international collaboration, and public–private partnerships. A good example of a cross-sectoral project is the Space Agency, which requires collaboration across SETIs and government departments.

The failure to transform a key Mission of the 2002 NRDS, namely **Science and Technology for Poverty Reduction,** into a Grand Challenge is noteworthy, as it seems to fly directly in the face of the recommendation of the OECD review to **close the gap between the 'first' and the' second' economy** in order to mobilise political commitment, and obtain advantageous benefits on both the supply and demand sides of the system.

The TYIP does not directly address the structural difficulties of achieving the Grand Challenge outcomes, occasioned by the **lack of systemic authority invested in the DST or NACI**. It also appears that these problems have increased rather than decreased during the period since 2007 when the OECD Review was published.

The DST from 2007 introduced a **Knowledge Economy Forum (KEF**) to consider progress towards the knowledge economy across broader government. The KEF has met only once a year, but its agendas and minutes reveal a determined if drawn-out attempt to provide information to sister departments about DST initiatives, to exchange perspectives, and to build a system of coordination and cooperation. The mandate of the KEF, as reflected in the terms of reference (as originally drafted in 2007), is to "strengthen the capacity of scientific and technological activities within government departments; choose research priorities that will have a direct impact on the reduction of poverty and the improvement of the quality of life of our people". It goes on to say that "the Forum will ensure that there are programmes to increase the rate and quality of innovation in South Africa and that there is expansion and intensification of initiatives relating to knowledge dissemination and sharing, as well as public understanding of science and technology knowledge".

The stated objectives of the KEF are:

- To develop a **network** through which government departments can share experiences, good practices in S&T policy and strategy development, and management to improve coordination of the sectors and services to the sector R&D community
- To provide a **platform** to discuss knowledge economy budget cluster policy priorities for funding and implementation for the benefit of all sectors
- To design and implement **policies** aimed at improving effective coordination and service delivery to sector R&D stakeholders
- To examine the **progress** that is being made in establishing the national S&T expenditure plan, **highlighting the barriers** that prevent its implementation and offering workable solutions
- To serve as a **resource** to policy-makers and decision-makers by providing road maps for higher growth in the S&T system and research sector
- To identify **key performance indicators** and discuss the performance of the NSI as whole, or focus on specific sub-systems, such as the National Agricultural Research System (NARS) or the National Health Research System
- To play an **advocacy** role for S&T policy within government and ensure continued recognition of the knowledge economy within the government cluster system and the National Treasury
- To ensure **effective implementation** of the governance framework, especially developing linkages between line-function departments and their science councils.

The impression created by the documentation surrounding the KEF between 2006 and 2009 is that the forum has sound terms of reference and that the attendant signing of memoranda of agreement (MoAs) between the DST and inter alia the departments of Trade and Industry, Minerals and Energy, Defence, Transport, Agriculture, Water Affairs, Environmental Affairs and Housing has been well-intentioned and well-conceived. (The departments of Health and Education are notably absent from the list). In each case, **cooperation frameworks** have been created on the basis of signed MoAs, and provision has been made for **joint coordination committees** drawn from the participating departments. In most cases, these committees have in fact met (but at best only on an annual basis) and sought to fulfil their assigned functions, with some successes (as described below). There have nevertheless been concerns within the forum about the long intervals between meetings, the absence of senior representatives, and the generally slow movement of the joint agendas; these concerns appear to be well justified.

The Ministerial Review Committee was told that despite the best efforts of the DST described above, the R&D activities in sectoral government departments in practice constitute a **highly fragmented system**, with both the risk and the reality of duplicated or contradictory efforts, and the erosion of attention to R&D generally within these sectors (see below). There were cases where, by contrast with the DST which said it gave “exemplary support” to its base of R&D institutions, other line departments provided inadequate sector planning and budgeting for research institutions under their respective mandates, and caused delays in the timeous appointment of boards, with concomitant governance risks. There were also concerns about the

maintenance of research equipment serving R&D initiatives as well as serving industry, and the erosion of scientific and technical professionals staffing R&D in these sectors.

Legislation has now been passed that **revises the management of NACI** by establishing a CEO position outside the DST staff structure. The extent to which the proposed change will permit NACI to function more effectively and transparently is not discernible at this stage, yet is a very important issue, and it is a pity that this necessary and symbolic step has not yet been visibly accompanied by attention to the mandate, scope of operations, and more systemic functioning of NACI.

The suggestion in the OECD Review to move away from heavy dependence on resources to knowledge-intensive production, and to close the gap between the first and second economies, has prompted the DST to develop the kind of **sectoral focus** originally expressed in the 1998–1999 National Foresight Exercise, "seeking to leverage off earlier investments where key industry capabilities had been developed". The Technology Innovation Agency is designed to make a significant contribution across the private and public sectors in this way.

The DST has responded to the OECD Review's identification of a perceived bias towards public sector institutions by "**adopting the Innovation Survey as a core instrument for measuring industry performance**", and by committing itself to "working at industry sector level with the dti". Both the **Innovation Survey of 2005**, covering the period 2002–2004, and the more recent **Innovation Survey of 2008** (DST/HSRC 2009, 2011) revealed a very high degree of innovation in South African business enterprises, comparable with that of many OECD member states, much of it generated locally, and with a significant impact on profitability. The total spend on innovation was estimated at about 3% of total turnover. The overall favourable picture was marred by a **low level of public funding of business innovation activity** (aligned with the finding that funding of innovation was the main constraint encountered by business), a **low incidence of innovation-related information coming from universities (5%) and government research performers (3%),** and a **low level of patent registration**. It is not clear whether the DST picked up these issues when the Innovation Surveys were released, and what was done to improve matters. Presumably, the 'adoption' of the Innovation Survey as a key tool capable of informing policy will be associated with more energetic and coordinated action in future.

It remains moot whether the 'adoption of the Innovation Survey' is really more than an opening move in a new approach to including business in the steering mechanisms of the NSI and attending comprehensively to the design of optimal framework conditions of the system. The rest of that agenda is not yet clear.

A number of measures are also currently under way under the DST's own control or in partnership with other departments or organisations. The Ministerial Review Committee was briefed on projects aimed at addressing the following priority areas:

- **Poverty reduction and job creation**: Programmes supported by the DST that address poverty and the need for accelerated job creation include small-scale (pilot) initiatives to grow the bio-economy through agro-processing, aquaculture and agronomy, involving

partners in other public sector NSI agencies such as research councils and universities. Further measures are aimed at promoting sustainable human development, including access to clean water, affordable energy, innovative housing technologies and ICT connectivity. Projects are under way to provide educational support through the internet and social media. These initiatives are being pursued using modelling and risk-assessment technologies that are apparently becoming increasingly sophisticated. The Committee is in no position to assess the effectiveness or even the appropriateness of these projects, but the question arises whether the DST is achieving a proper balance between its policy-making, coordinating and implementation roles.

- **Technology and industry initiatives**: A number of ambitious programmes are currently in place, although (as noted by the DST) not yet sufficiently resourced and/or amenable to impact assessment. These include:
    - **Advanced Manufacturing Technology Strategy:** Value-adding in smart materials, electronics and production technologies)
    - **Advanced Metals Initiative:** Value-adding to natural resources in the four thrust areas of light metals, precious metals, speciality steels and new metals
    - **Biotechnology:** In human health, animal health, plant health and industrial applications)
    - **Information and Communication Technologies (ICT):** Key programmes in geomatics, wireless and mobile technologies, human language technology, and access technologies for people with disabilities. There is also a special programme on cyber-infrastructure that includes SANReN (the South African National Research Network) for advanced connectivity and the High Performance Computing Centre, and more recently, the space programme, with the launch of the satellite, SumbandilaSat.
    - **Science and Technology for Social Impact:** Sustainable livelihoods and sustainable human settlements, with second-economy targets in job creation and household-level benefits from alternative technology solutions for off-grid communities.
    - **Human Capital Development Strategy:** Currently being finalised (after much delay), with some instruments already being implemented (namely research chairs and centres of excellence).
    - **Human and Social Dynamics:** A broad strategy for this Grand Challenge is also being brought consultatively to final form, with implementation plans that use the policy and financial instruments already developed, notably research chairs, centres of excellence, special bursaries for postgraduate study, forums and collaborative programmes, etc. It is not clear whether the humanities will be positioned more favourably in the new approach than in the traditional **'handmaiden' role** assigned to them in the NSI thus far.

Institutional instruments have been introduced for developing a 'critical mass' of capacity in what have been described as '**emerging research areas**', such as investments in a number of nanotechnology platforms. At the other end of the spectrum, **Centres of Competence** have been established to drive efforts to develop industry-relevant products for commercialisation. The approach of the Centres of Competence is to operate at industry level, with various role-players contributing different competencies that allow South Africa to compete in global markets. The

availability of two contrasting modes of intervention in Centres of Excellence and Centres of Competence demonstrates an evolving ability to fit the investment to specific kinds of intervention.

The **New Strategic Management Model (NSMM**) for the public sector SETIs is being re-considered, because of significant failures in achieving its objectives, but no progress has been made to date, and considerable resistance is being encountered to the current piecemeal approach. The Committee was not provided with details of the new thinking in this area.

Efforts to achieve better vertical coordination between layers of government are focused on the development of a series of **Provincial Innovation Systems**, currently including Limpopo, Free State, Gauteng, North West, and Northern, Western and Eastern Cape provinces. In order to achieve sustained activity, **Provincial Innovation Forums** are being established, to bring together the leadership from industry, government and the research communities in the provinces. Science Parks are similarly intended to mobilise and energise industry through research partnerships. Advice from NACI was received on this important approach, but the extent to which that advice informed the present plans is not clear, and the Committee has not seen any agendas or minutes of Provincial Innovation Forum meetings, or details of early-stage outcomes. Any extension of these initiatives to the equally important local government level has not been evident so far.

In the context of the DST's response to the OECD recommendations, reference can again be made to the report compiled for **Business Leadership South Africa** (BLSA 2010), to be described in Section 4 of the Phase One report: A business perspective on the role of the DST, which reflects the results of a survey aimed at tapping the perceptions of the business sector of the role of the DST in the post-OECD Review era. Business affirms the vital role that the DST should play in promoting the technological base needed for economic growth and competitiveness, and for job creation; given South Africa's context as a developing country, the intervention of the State is considered very necessary in this regard. There is a strong view, however, that the activities of the DST tend to be focused on the 'science' dimension of its mandate and rather less on the 'technology' dimension, especially the technologies and incentives that support industry and business. This is reflected in the low levels of awareness by the business sector of the current role played by the DST, and the **low business profile among senior DST executives**.

The report acknowledges the range of well-intentioned initiatives supported by the DST, but comments that these have yet to find full fruition. One example is the tax rebate on R&D investments which, as yet, has limitations that restrict access to potential benefits, curtailing its incentivising intentions. Furthermore, the lack of venture capital and 'angel funding' – as well as of incentives for technology-based industries – stand as barriers to growth, including for black-owned business. Comparative views suggest that successful provision in this regard by other comparable countries acts as a draw-card away from South Africa. It was felt that the relative lack of business-experienced personnel in the DST accounted for the way in which its activities tended to be skewed towards science, and the experience of business that the DST was 'user-unfriendly'.

The striking contrast between the self-assessment by the DST of its vigorous and positive response to the OECD Review, and the perceptions of many in the business community, suggests that the Ministerial Review Committee's initial study of the science, technology and innovation landscape will need considerable deepening in Phase Two of its work.

In summary, DST presented to the Committee its vision for the development in South Africa of a pervasive 'knowledge economy', building on and extending progress already made, and using a range of programmes that are believed to be generally consonant with the advice offered in the OECD Review. It is clear that a determined though seriously constrained attempt is being made to overcome the structural problem of inter-departmental coordination and the achievement of common strategic purpose through bilateral agreements and the creation of Provincial Innovation Forums in the provinces. Attention is also being given to the DST's role in helping to deliver on the priority areas of the government's Medium-Term Strategic Framework.

There appears to be much room, however, for a review of the DST's capacity to develop and support the infrastructure needed for vigorous science and innovation throughout the economy, and the best ways in which that capacity can and should be applied. Attending to the needs of the private sector appears to be a particular area of future re-focusing of the DST. Most critically, however, the over-riding issue of governance in the system needs to be addressed as a matter of urgency, because it is only through better governance arrangements that the DST can focus on its main role of advocacy and coordination of the provision, within government as a whole, of the optimal framework conditions for shaping the NSI.

3.2 National Research Foundation (NRF)

In responding to the OECD Review, the NRF has focused in particular on observations that the agency had become over-extended, and that its resource base had become too thinly spread across a wide range of activities, with the result that – among other things – critical scale was often not achieved. In response, the NRF has moved to rationalise the programmes under its control, including the Centres of Excellence, the Flagship Projects and the National Facility clusters. The challenge remains to balance investment between the foundation disciplines and areas of strategic focus (including priorities identified in the National R&D Strategy and the Grand Challenges).

Given the limited resourcing available to the NRF and the need for the agency to address simultaneously its mandate to **build research-capable human capacity**, support the advance of key fields of study and address priority areas of socio-economic development, the NRF has moved to sharpen the focus and methodologies for the allocation of funding. In addition to rationalising priority focus areas for investment, the NRF has deepened the competitive nature of funding decisions and strengthened the role of peer review in arriving at these decisions. These moves have, however, tested the availability of the expertise needed for the reviewing and adjudication protocols.

The NRF acknowledges that there is still only **limited understanding of what it means for the country to be internationally competitive within a global knowledge economy**. Better understanding is required of the collaboration needed between sectors and the scale of investment needed for an effective NSI. In particular, investment in higher education for the production of research-capable skills needs to be strengthened. There is a concern that some private sector investment in R&D is directed overseas when it could be performed locally, and efforts are needed to determine what would be necessary to make local R&D the best option available to the firms involved. A great deal of innovation, however, should not only be technologically driven in the traditional sense, but should also address social, political and environmental priorities, and these areas of focus are not adequately provided for.

At the level of government, there remain **insufficient levels of coordination between departments**, with a reluctance to participate in the competitive grant-making system. Role-diffusion in the responsibilities assumed by public-sector agencies in the NSI continues to be a problem. Tighter vertical differentiation is needed across the four-level distribution of functions seen as the optimal structure for public-sector NSIs, namely: (i) high-level institutions statutorily mandated to provide policy advice to government on innovation, or innovation-related functions, including the National Advisory Council on Innovation (NACI), the Council on Higher Education (CHE) and the National Science and Technology Forum (NSTF); (ii) government ministries and departments; (iii) research and innovation agencies, including the National Research Foundation and the Medical Research Council; and (iv) research-performers, including universities and science councils. This differentiation should assist in identifying sectorally strategic priorities for resourcing, rather than just project-specific priorities, as is often the case. Currently, however, the role of the NRF spans perhaps three of these layers in that it provides advice, is a funding agency and also supports research-performing activities. This places further strain on its resource base and its capacity to fulfil what should be its primary function of being an autonomous research and innovation funding agency.

3.3 National Advisory Council on Innovation (NACI)

Two review exercises of NACI were carried out in 2003 and 2008, each arriving at broadly similar conclusions and recommendations. The reports noted NACI's dependent relationship with the DST which had a number of counterproductive effects, including widespread perceptions of a lack of autonomy, limited capacity to influence national-level strategy and planning for the NSI, a relative lack of resourcing and the low profile of its work. Recommendations arising from these reports include:

- **NACI's role should be strengthened as an agency that informs and advises government at a national level on the strategy and planning for a truly national and coherent NSI**. Measures to this end should include the formation of a body or platform, ideally convened by the President, which directs and coordinates the activities of the various NSI stakeholders (departmental and sectoral) towards common strategic priorities.

- The Act mandating the existence, constitution and role of NACI should be amended to, among other things, install a permanent CEO for NACI in place of the DG of the DST, as is currently the case. Furthermore, the resourcing of NACI should be arranged to enable greater autonomy from the DST and an improved capacity to fulfil its mandate.

- NACI should arrange for **greater visibility** of its work in order to boost the profile and credibility of the agency, and its capacity to influence actors in the NSI.

- NACI should **include the private sector** more centrally in its membership and deliberations.

NACI's response to these recommendations provides for a number of measures. These are noted below, together with queries that the Ministerial Review Committee may wish to pursue:

- The formulation and implementation of a National Innovation Strategy which achieves coherence across innovation-related priorities of various government departments and public sector agencies
- The commissioning of a system-wide review to consider the horizontal and vertical coherence and alignment of NSI agencies
- The establishment of a NACI-CHE task team to address the human capital requirements of a NSI
- The creation of a task team to bring business into innovation policy
- Commissioning a study to map the national infrastructure needed for effective innovation
- Convening of a dti-DST working party to identify gaps in existing incentives for innovation.

Notably absent from the measures noted above are resolutions to address the matter of the **NACI Act** which constrains the independent and national-level function that the agency should play. Although NACI has specified in detail what these changes should be (see *NACI Response to the 2008 External Review)*, this seems not to have been addressed except for the recent amendment to the NACI Act that has removed the designation of the Director-General of the DST as its CEO and has made this a full-time post. NACI notes that past and current Ministers have not been opposed to changes much more extensive than this one, and the current Minister awaits the advice of this Ministerial Review Process.

3.4 Council for Scientific and Industrial Research (CSIR)

The CSIR notes that the single most significant observation made about itself was that the CSIR does too many things, and its activities are thus somewhat fragmented. There is a need for greater capacity to be directed towards fewer activities, in an effort to achieve critical mass around selected strategic priorities. Although there has been a steady improvement in the quantity and quality of the CSIR's outputs (in the form of ISI publications, patents, etc.), the biggest problem continues to be the **breadth of its mandate**, in that the organisation can be called on to do anything that may be said to have 'technology' in its definition. The CSIR has been expected to respond to needs ranging from the highest levels of policy to very operational project implementation. As a consequence, the CSIR's work has **proliferated across a wide range of fragmented activities** and, given its finite resource base, has become over-committed. The CSIR is presented with a continuing flow of compelling projects, but has no adjudicating platform to decide on competing priorities: "We're very good at starting things, but hopeless at closing them down." Often the decisions made within the CSIR on the adoption or terminations of projects were informed by the contingencies of resourcing rather than strategic planning.

It seems that the proliferated, fragmented and over-committed activities of the CSIR are a reflection of, among other things, a larger systemic failure to provide coordination for the NSI.

3.5 Human Sciences Research Council (HSRC)

The HSRC sees itself as an integral constituent of the NSI, uniquely positioned to bring its skills base to bear on the **social and economic developmental challenges** confronting the country. The council's capacity for basic, strategic and applied research in the human sciences informs, among other things, the formulation, implementation, monitoring and evaluation of policy. This legislatively mandated responsibility for carrying out **evaluations of government programmes** of action inevitably involves reflections on the achievements of other government departments.

The research agenda of the HSRC is directly guided by **national development priorities**, as well as the **Millennium Development Goals (MDGs**). As an illustration of the council's contribution to the social preoccupations of the NSI, its current research programme includes Democracy, Governance and Service Delivery; Economic Performance and Development; Education and Skills Development; HIV/AIDS; Sexually Transmitted Diseases and TB; Human and Social Development; and Population Health, Health Systems and Innovation. The absence of the humanities in this broad agenda is noteworthy, and reflects what has been called the '**handmaiden role' of social science** in supporting the efforts of the natural sciences, engineering and business in the NSI.

While the HSRC pursues strongly structured programmes of research, including large-scale cross-sectional and longitudinal studies, the organisation nevertheless strives to be alert to the possibilities of unanticipated developments and the need to respond swiftly when these occur. The HSRC's research-based datasets are used extensively for further analysis by other organisations, illustrating the role of the council as an interactive constituent of the NSI. The HSRC also strives to contribute explicitly to innovation-related purposes through advice on policy formulation, the development of assessment instruments and indicators and, importantly, research on innovation activities themselves. This is reflected in a number of studies focused on industry–university interactions aimed at the development of innovative technologies. Among other things, the HSRC produces the **annual National R&D Survey** and the **Innovation Survey**.

Currently, a large proportion of the HSRC's income is derived from competitive donor-funded or partner-funded projects, which tend towards shorter-term and contingent purposes, rather than enabling more powerfully dedicated attention to development priorities. Funding streams from the private sector are also constrained by the fact that social and human sciences research is explicitly excluded from the R&D tax incentive scheme. The HSRC further notes that the assumption that the national skills shortage is confined to the SET disciplines is misjudged, and that the social sciences are in similar need of top quality researchers.

In summary, the HSRC constitutes a focused resource, directed at the need for social, economic and political innovation; while the university sector has collectively a far greater skills and financial resource base in the human and social sciences, these resources are understandably (and necessarily) directed towards divergent and autonomous research priorities, of which the humanities are a large and neglected part. There is clearly room, however, for some of these resources to be directed concertedly towards common purposes, and in longer time-frames. Insights emerging from the Ministerial Review Committee's discussion with the HSRC raise again the need for tighter governance over the differentiation and specialisations of the research councils, coordination across agencies and sectors, as well as the need for improved and longer-term funding to be directed towards key innovation priorities.

3.6 Conclusion

The commentaries above confirm that many of the **observations made by the OECD Review speak to real and enduring issues running through the NSI**. It is also clear that these issues are not to be taken lightly, since they threaten the notion that innovation can be made a prime driver of the development of the nation, nor will these persistent issues be amenable to perfunctory measures. Many of them are bigger than the agencies that wrestle with them, and require concerted political will at the highest levels, together with strongly determined efforts to effect to the vision. There can be no doubt about the support, in good faith, for the concept of the NSI and its promise; yet there is an underestimation of what it will take to make it happen, examples from elsewhere notwithstanding.

The theoretical basis of a national system of innovation has undergone refinement over the years as increasing numbers of examples have become available for analysis. It is important that each country that has adopted the idea keeps up with the best thinking and experience in the field, and the intervention of some of the best of these in conducting the OECD country review of South Africa in 2007 is in some ways an input of considerable consequence**. The Ministerial Review Committee has learnt a number of things from the OECD Review that it believes should be fore-grounded in the Committee's advice to the Minister:**

- **Business enterprise should be placed at the heart of an innovation system.**
- **Innovation activities should be seen as involving more than R&D, so that design and engineering activities, and innovations in pervasive public service delivery systems, are also seen as legitimate and mutually supportive parts of an NSI.**
- **An NSI must be an internationally open system, with two-way inputs of all kinds, including skilled people.**
- **Demand-pull innovative approaches should be given as much attention as supply-push approaches**.

Of all the issues becoming visible from the narratives given above, the most pressing matters concern the need for strengthened and coordinated governance at the highest level (including the recognition and elaboration of best-practice in terms of the key insights listed above), dramatically improved resourcing to critical mass directed at a limited number of priority areas, urgent measures to address the broad range of skills needed for the vitality of the system, and the much greater involvement of business in the NSI policy arena.

SECTION 4: A BUSINESS PERSPECTIVE ON THE ROLE OF THE DEPARTMENT OF SCIENCE AND TECHNOLOGY

At the request of the Ministerial Review Committee, **Business Leadership South Africa** (BLSA) provided a commentary – based on a necessarily limited survey of private sector experiences and perceptions – on the role DST had played in using its resources (financial, regulatory and otherwise) to advance the role and interests of the sector, not least by promoting an innovation mind-set among the business community and other actors in the economy.

Although the commentary makes only one passing mention of the NSI, it nevertheless asserts that the state should play a very active role in terms of advocacy, support and resourcing to promote a technology-rich economy and society. It argues, for example, for stronger collaboration between state, industry and higher education. However, given all the international evidence (confirmed by the OECD review) that it is business at the firm level that is critical to innovation (just as it is the private sector that is the engine for economic growth), the BLSA report expresses its clear disappointment that the state has tended to encourage investment in big science (e.g. the Square Kilometre Array – SKA) rather than forms of technology that would strongly support the private sector from the point of view of short-term economic growth, more access to global markets and positively impacting on export revenue. **It is global best practice for the state to engage with business to identify areas where the greatest assistance could be leveraged by the state and to create funding mechanisms to enhance the acceptance of new technologies within the industrial sector**.

For example, there are many areas in the manufacturing, electronics and telecommunications sectors where South Africa needs bolstering to leverage its local market so that it can be more competitive. One of the greatest successes was the large-scale interaction between automotive industries, research establishments and universities which gave birth to the **Automotive Industry Development Programme (AIDP)**. Through facilitated workshops, it was possible to identify the real needs of the automotive industry and in particular what local South African manufacturers could do to enhance their share of the automotive industry from a component point of view. From this intervention, a number of initiatives were identified and various research projects were executed, including collaborative programmes with international research agencies such as the Fraunhofer Society. In order to do this, the state would have to change its stance from providing funding for so-called 'blue skies' research to 'hard-nosed' implementation programmes, in which the state would work together with the private sector to establish specialist facilities and programmes to provide such support.

Business is strongly of the view, therefore, that innovation and technology are fundamental for economic growth, competitiveness and job creation. The organisations that drive the economy (both large firms and SMEs) would benefit from a **top-level coordinated approach** that marshals the resources of the economy to collective benefit, not least through cooperative programmes. Given South Africa's developing country context, the intervention of the state is very necessary in this regard, but the state must intervene from a position of **deep understanding of firms' behaviours and needs in the innovation and technology realm.**

Cooperative programmes are ones in which the state enters into a partnership with a group of companies, most of them too small to fund their own research programmes, and all of them requiring a specific technology to enhance their global presence. The group enters into a so-called pre-competitive research environment, where in addition to state support, each organisation pays its way, albeit at a nominal rate. The research work is undertaken on behalf of the group, and the findings are made available to all the organisations that participate. It is up to these organisations to exploit the findings of such research. For example, a group of steel office furniture manufacturers identify that one of the challenges facing the sector is in the finishing of the products to meet a new European Union quality specification. These companies would be invited to participate in a cooperative programme. The research protocol would be decided by the participants, who would be party to the on-going research process until the final outcome of a new technology to meet the requirements has been successfully implemented.

At this stage, however, it is felt that the DST and its work have little or no profile in many areas of the private sector. The state-sponsored support programmes that do exist seem to operate sub-optimally (e.g. the R&D tax incentive) and are seen by some to be 'business-unfriendly', having limitations that restrict access to potential benefits, thereby curtailing the incentivising intentions. Government policies (among them an inappropriate **immigration policy** and the uncertainties associated with the **Intellectual Property Laws Amendment Act**) serve as disincentives to the growth of a technology-strong industrial sector.

Cabinet-level coordination should also address the perception in some private-sector quarters that technology lies in the portfolio of the dti rather than with the DST (and that the DST is, in effect, an extension of the education portfolio), and instead consolidate a high-level coordinated approach to innovation. In this regard, a properly repositioned and appropriately empowered NACI is essential. Business notes examples from elsewhere (e.g. Finland) where government-funded agencies exist with the aim of facilitating multi-party and cross-sectoral partnerships, and anticipates that the function of the Technology Innovation Agency will be directed to this end.

The **growth and vitality of the SME sector** is crucial to both job creation and the health of the economy, both of which are priorities for the NSI. There is a concern that the efforts of government have focused in large measure on the small-scale retail sector, but instead need also to invest strongly in SME operations in the technology sector, especially to advance black-owned enterprises. Business notes that government has achieved only low levels of success in promoting the emergence and sustainability of new SMEs. Furthermore, a lack of venture capital and 'angel funding' inhibits innovation among SMEs and the birth of start-ups. One consequence of this is that skilled individuals and entrepreneurs tend to migrate to countries where better-developed incentives are available.

The BLSA report recommends that the DST needs to invoke extraordinary measures to promote the emergence of **black-owned technology companies in the SME sector**. It is evident that what is needed is a new approach, which would include the establishment of a mentoring process by retired business executives, who would be able to act as mentors for the establishment of such operations. The issue of venture capital and 'angel funding' requires state intervention in terms of promoting a new mind-set amongst financiers. Key to this is the need to 'simplify' processes by removing obstacles to enable easier access to funding. In this regard, the nascent Technology Innovation Agency needs to get off the ground and play its role. Once again, this requires a

uniquely different approach, and government is considering measures similar to those that are currently being explored to assist people in buying their first house. Measures put in place in Scotland through Scottish Enterprises, and in Wales through the Welsh Development Agency are just a few examples of the innovative thinking that will be required on the part of government.

The BLSA report thus recommends that models from elsewhere (e.g. India, Malaysia, Wales and Scotland) that demonstrate far more innovative thinking be considered for adaptation to local conditions. In particular, judicious selection criteria for identifying start-up ventures, and strong and sustained mentoring, seem to be important factors contributing to success.

Business is of the view that **government funding for engineering and technology training and research** needs differentiated and priority status, as has been the case in some other successful newly industrialising countries. Universities should include support for the economy among their priorities, and should see an increase in special funding arrangements to this end. While universities should constitute the major source of human capital for top-level skills (and they need to be appropriately resourced for this task), it is essential that the value of foreign expertise is recognised, and that clear action is taken to secure such expertise. The key national goals of the country, which are meant to be supported by the NSI, cannot be attained without significant increases in both domestically grown human capital *and* foreign expertise.

The BLSA report thus recommends a much stronger capacity in government to govern and coordinate the innovation system. This includes reform of the role and structural location of NACI towards greater independence and a system-wide purview. Furthermore, the state (through, inter alia, the DST) should provide a much more supportive environment for large firms and SMEs, especially for black entrepreneurs. The state could widen its pro-business initiatives and ensure that supportive measures (such as the tax incentives and the availability of venture capital) are more expansive and accessible. Altogether, the private sector would like to see a highly incentivised and facilitated environment that would enable sustainable business to flourish.

Business believes that the DST is insufficiently resourced with high-level business-experienced personnel that are able to operate at sophisticated levels with business on STI priorities, fully understanding the South African business landscape and 'the business of business'. This may be one of the reasons for the emphasis on science rather than technology, and may also partially explain the perception **of the business community that the DST is user-unfriendly**. The private sector is very keen to work in partnership with the DST, but this kind of capacity in the DST and, indeed among ministerial advisors too, is a *sine qua non*. Business believes that closer partnerships with government, higher education and the science councils are essential to addressing national challenges, and that government should play a stronger catalysing role in bringing together the various actors and creating the conditions for cooperation and innovation. The DST needs to be agile; it needs to use agencies such as NACI to give direction as to new technologies that should be investigated; it needs to forge far closer links with business leaders; and above all, it needs to get its own agency, the Technology Innovation Agency, running.

In conclusion, it is important again to emphasise that given the short time-frame and the desk-top research approach envisaged in the terms of reference for the first phase of the Ministerial Review, the BLSA report was necessarily limited and relied on perceptions rather than hard data. The report argues that **the business world is given low priority in the policy formulation of the DST**. Beyond the Innovation Survey, little else is known about the way that business goes about introducing innovations, how it evaluates risk, makes investment decisions, and the consequences of this for training, and for job creation or destruction. Business suffers from even more weaknesses than other parts of the NSI when it comes to systematic data collection, evaluation and monitoring with respect to business activities in relation to the NSI. **An NSI that is not based on a deep understanding of behaviour at the level of firms and the needs in the innovation and technology realm in South Africa is an NSI that is doomed to failure.**

SECTION 5: APPRAISAL OF DOCUMENTARY EVIDENCE CONSIDERED FOR STUDY

This section of the report addresses the aspect of the remit that charges the Ministerial Review Committee to assess "the extent to which data derived from the documents reviewed are able sufficiently to inform an assessment of the strengths, shortcomings and responsiveness of the system in addressing [its] purpose".

The Committee interpreted this mandate as an opportunity to review what **sources of knowledge are available on the performance of the NSI, what those sources tell us about the current state of the NSI, and what signals are emerging about the future form and needs of the system**. The availability and quality of information – and intelligent analysis – are crucial to the future design, implementation and monitoring of the system. Inevitably, a discussion of the sufficiency of available data must involve an appraisal of what the data currently enables one to know, and the gaps in that knowledge base which need to be addressed. What is known about the NSI, and how this is known, are intimately inter-related, and thus the desired knowledge base is related to the definition and purposes of the NSI.

The selection criteria for which documents should be considered for this part of study were derived from the definition of the NSI conceived in the 1996 White Paper on Science and Technology discussed earlier in this report. Broadly speaking, the NSI concept includes a wide range of social and economic actors whose activities and interactions give rise to innovation in all its forms – including technological, non-technological, social and public. Innovation is understood here to be a complex process involving continuous learning that takes many possible forms and is found in many sectors of society. Innovation activities could be generated by policy initiatives of the state (e.g. industrial policy), collaboration by multiple actors in joint projects, new business or industrial initiatives, organisational change, R&D, acquisition of new technology (including machinery, software and technology), deliberate adoption or adaptation of existing technology (e.g. SARS e-filing), advertising and marketing, the development and protection of intellectual property and various forms of knowledge transfer, both formal and informal. Participants thus include actors from the private sector, public sector research, higher education institutions, government and civil society.

This section of the report will thus analyse the data made available to the Ministerial Review Committee in terms of this conceptualisation of the NSI. The documentary evidence considered by the Committee is largely drawn from DST policies, plans and reports, associated NACI studies, NACI advice to the Minister, some key documents of the Department of Education, the OECD review process and various publications relating to the science councils and national facilities. In the main, these documents were produced in the period 2004–2010. However, as will be seen below, the evidence base considered in this section extends more widely.

5.1 System Objectives

In structuring the account that follows, the first step was to identify the **key dimensions of the NSI**, and then consider what **data** are available to assist in drawing conclusions about the

performance of that dimension. The discussion identifies each dimension under consideration, the documentation available, and then comments on the adequacy of the information provided in these documents, in terms of the extent to which it is possible to derive insight into levels of performance associated with the dimension in question, and whether this is sufficient to inform possible intervention.

The 1996 White Paper provides a number of yardsticks for assessing the performance of the system and argues that a well-functioning NSI would have the following features:

Government should have ensured that:

i. **South Africa has in place a set of institutions, organisations and policies that give effect to the various functions of a national system of innovation.**

ii. **There is a constructive set of interactions among those institutions, organisations and policies.**

iii. **There is in place an agreed upon set of goals and objectives that are consonant with an articulated vision of the future which is being sought.**

This would be achieved through government addressing:

iv. **Policy formulation and resource allocation at the national level, and**

v. **Regulatory policy-making.**

A second set of mandates is shared among government, business and higher education, comprising:

vi. **Performance-level financing of innovation-related activities**

vii. **Performance of innovation-related activities**

viii. **Human resource development and capacity building, and**

ix. **Provision of infrastructure.**

To these should be added two other aspects that are covered in the White Paper, namely:

x. **Performance measurement and evaluation, and**

xi. **Knowledge transfer.**

A systematic evaluation of a national system of innovation would thus need to consider the extent to which each of the above eleven features is in place and their respective levels of performance. In the interests of brevity, however, the eleven yardsticks above will be distilled down to six attributes (i) framework conditions, (ii) human resources, (iii) knowledge infrastructure, (iv) performance of innovation activities, (v) knowledge transfer and (viii) performance measurement and evaluation. These are addressed below.

5.2 Framework Conditions (Items i, iii, iv, v & vi)

The **framework conditions** noted here include two broad categories: firstly the NSI-related institutions and regulatory systems established by government, and secondly the financial practices that operate within and across key NSI actors. These provide the conditions that shape the character and behaviour of the NSI and its various participants.

In terms of the institutional and governance architecture, the Ministerial Review Committee considered a number of documents that reflect the evolution of the structural features that constitute the NSI, including the 1998 Synthesis Report of the National Research and Technology Audit, the 1998 System-wide Review, 2007 OECD Review, reviews of various science council and national facilities, the 2006 NACI OECD Background Report and numerous academic works that address questions of policy, institutional landscape, performance and direction. These commentaries have been summarised in Section 1 of the Phase One report: Context of the OECD Review, as reflected in previous policy and review documents. They, together with the narratives provided to the Committee by senior leadership figures, provide a reasonably coherent qualitative account of the success or otherwise of these structural measures. The Committee believes that the adequacy of this level of documentation has been assessed in Section 1, and the discussion in this section is thus confined to the resourcing issues associated with the NSI.

A key framing condition for the NSI is the effective financing of performance-level innovation activities. Funding flows to, and within, the NSI directly from the private and public sectors, as well as indirectly from the public sector in the form of various incentives. In terms of direct public sector financing, National Treasury is the hub where decisions are taken in respect of funding. The flows run into tens of billions annually. The 2008/09 R&D Survey (DST 2010) records national gross expenditure on R&D of R21 billion; business expenditure on innovation is of the same order of magnitude. The understanding of the effect of this funding is, however, very limited. Some examples include:

- The DST no longer manages the **Science Vote**, and even when it did, it had limited influence over the detailed way that the Vote was utilised by the autonomous science councils. As to the benefit of this investment, the science councils do not report in detail on the value added as a result of their research activities.

- The nascent **Technology Innovation Agency (TIA**) now includes two key funding agencies: the Innovation Fund and the Biotechnology Regional Innovation Centres (BRICs). These two agencies have disbursed in excess of R2 billion, but little is known of the impact of this investment.

- The dti injects grants through the **Technology and Human Resources for Industry Programme** (**THRIP) and the Support Programme for Industrial Innovation (SPII)**, which are rated as important by their beneficiaries, but again the real impact is unknown. It is not known if these mechanisms represent a genuine strength for the NSI. For example, there is anecdotal evidence that SPII involves considerable transaction costs, with up to a third of the value of the grants ending in the hands of middlemen.

- The DST, through the NRF, provides **second-stream income to the universities** as well as non-directed scholarships to students. The reward for university research in the form of the journal article subsidy of the Department of Higher Education and Training (DHET) is now over R100 000 per full authorship of a recognised publication, but the outcomes and impacts of this funding are unknown. The NRF also does not publish detailed results of

the research that it funds, nor are data on the progression of its grantholders provided for public scrutiny.

- With regard to **intellectual property rights**, the DST encourages patenting activity by providing grants for the associated costs of patent filing. Related measures such as the Exchange Control Regulations and the Intellectual Property Rights from Publicly Funded R&D (Act No. 51 of 2008) introduce complexities, however, that may disincentivise investment in research and development.

- The **Public Investment Corporation** and the **Industrial Development Corporation** constitute channels for the funding of state-owned enterprises, especially to support early stage development and industrial expansion and thus the introduction of new technologies and innovations into firms and the market. There seems to be no single coherent platform from which to consider the impact and future direction of such funding. It is too early to tell how the Industrial Policy Action Plan will impact upon innovation.

- One of the more helpful government reports (DST 2009) addresses what is probably the most important state incentive provided for R&D investment by the private sector, namely the **tax rebate** of 150% on R&D expenditure, which also allows for accelerated capital item depreciation. The report noted that the conditionalities of the tax rebate (its exclusions and its reporting requirements) impose **limits on the extent to which this benefit may be accessed.** This brief report on the first two years of the operation of the tax rebate incentive noted that while BERD for the two years in question was in the order of R15 billion and involved some 700 firms. The tax expenditure or tax revenue forgone due to the R&D tax incentives is estimated to be just over R1 billion for the period 2005/06 to 2008/09. The DST estimates an amount of R632 million for the year 2009/10. (DST 2011:7).

The three annual **National S&T Expenditure Reports** generated by the DST since 2007 provide the best available information on state funding (by about two-thirds of the government departments) on what are defined as three sub-categories of **Scientific and Technological Activities (STAs)**. A total spend of over R12 billion is reported, just under 2% of the national budget, of which the lion's share is spent by the departments of Science and Technology (29%), Health (20%), Public Enterprises (19%), Environmental Affairs (6%), and Minerals and Energy (6%). The methodology is based on the UNESCO *Manual for Statistics on Scientific and Technological Activities*, and the OECD *Oslo Manual* for the collection and use of data on innovative activities. These are undoubtedly sound, but the data presented in the expenditure reports may not take into account local circumstances and practices that bedevil attempts to render them readily and usefully interpretable**.**

It is evident that the documentary basis for quantitative assessment of resourcing issues in the NSI is insufficient and underdeveloped, making a key framework condition needed for a modern innovation system poorly amenable to policy development or corrective action. In particular, a specific knowledge gap pertains to the effectiveness of the financial incentives, both direct (in the form of transfers and grants) and indirect, that pass through the DST. Evaluations of the actual outcomes of the policy instruments are thus generally unavailable, or at best descriptive.

5.3 Human Resources (Items vi & viii)

The **failure of human resource provision is the key weakness of the NSI**, representing a joint failure across government for which no short-term solution is in operation. The failure is not through a lack of finance; many well-intentioned and thoughtful initiatives have been launched. However, the problem remains, and the documentary evidence on the development of human resources, with its successes and failures, is inadequate to tell the full story. Where there are measures in place, for example the Dinaledi Schools or the South African Research Chairs Initiative (SARChI), there are **no publicly available evaluations** of these projects. Some examples of key deficiencies in the knowledge base on the public sector domains of human capital development include:

- There is limited analysis of **school performance** available, despite the plentiful official statistics. Such analyses should include gender, race, class, regional location of schools and subject choice as variables. In particular, there is insufficient understanding of the **stocks and flows of school students** into secondary level science and mathematics. Some of the best analyses and recommendations for action have been produced by the Centre for Development Enterprise (CDE), but seem not to have been taken up in policy-making.

- Information regarding **school teachers** in terms of their skills and qualifications is only poorly available. The role of teacher unions in advancing or hindering the professionalism of teaching needs investigation.

- The **survival of first-time-entering students** at university generally, and especially in SET courses, has been documented in part but is not yet fully understood. The 2009 HSRC study (Letseka et al. 2009) only partly fills an important gap. Lawless (2005), in an investigation of human resources for the civil engineering profession, reported that the number of enrolments increased by 225% from the late 1980s until 2003, while graduations increased by only 25% ; this trend has been dominated by increased enrolments at universities of technology, which have largely adopted an open-door policy with high dropout rates, which may relate to the poor preparedness of those entering, financial constraints, lack of integration into the academic system, and lack of confidence to participate, coupled with the problem of providing for the required experiential training (the one year of practice required in industry before technicians can graduate), which is a major bottleneck and additional challenge. The Balintulo review (NSFAS 2010) points out that the National Student Financial Aid Scheme of South Africa (NSFAS) databases are inadequate to understand the fate of such students, layered by social class and other variables.

- Deeper insight is needed into the **throughput of postgraduates**, layered by level, discipline, source of funds, gender, group, social class and nationality. There is no complete database of masters and doctoral degree-holders. An estimate is needed of the **efficiency of grant-making and scholarship support**, disaggregated as above. What is the proportion of foreign students in postgraduate programmes, and what effects might these proportions have on the estimates of employable citizens that are being produced?

- Insufficient information is available on the production, retention, mobility, replenishment and turnover of **public sector academics and researchers** (see Blankley and Kahn 2005; NACI 2006). Clear insight is needed into the factors underlying these patterns and into interventions that will shift performance curves in the right directions.

- Insufficient data exist on the **demographics of science council staff**. There are no fully comparable data at present with which to compare the 1994 group-gender study (Motala 1994).

- It is not clear what data are available on the **mobility of highly skilled individuals**, both outward and inward, as well as an appraisal of the efficiency of measures to optimise the latter (an important framework condition).

The fact of the human resource crisis in the public sphere is relatively clear. The specific data, and the underlying reasons for the perpetuation of the crisis, are masked. This seriously limits the scope and extent of necessary remedial responses.

5.4 Knowledge Infrastructure (Item ix)

The White Paper on Science and Technology referred to the 'provision of infrastructure', but for present purposes, this will be broadened here into '**knowledge infrastructure'** referring to the set of universities and vocational colleges, state laboratories, and associated utilities such as reliable energy supply, communications and transport, and especially ICTs such as broadband and computing power.

In 2006, NACI published *A Study on the Required Physical Infrastructure to attain the Vision of the NSI* (Botha & Von Gruenewaldt, 2006), which served as an update of the earlier **National Research and Technology Audit**. The study concluded that the public research system was **seriously under-capitalised** and that inputs of around R700 million at current prices would be needed annually over six to seven years for its renewal. This should be seen against the present level of capital expenditure by the universities and science councils as reported in the National R&D Survey, namely around R350 million a year. The estimates by Botha and Von Gruenewaldt imply that the level of investment in public sector R&D capital items is only one-third of the desired level.

Although a number of significant infrastructural investments have been made (e.g. the SEACOM African cable system, Centres of Excellence, Southern African Large Telescope and Karoo Array), it seems the necessary information is not available to assess whether the **shape and size of the public component of the NSI** is optimal. To decide whether the mix of public facilities is appropriate would require an in-depth needs-driven study that would seek to understand demand for technological and non-technological innovations from potential users. A forward-looking study might expand its purview beyond the traditional existing public sector agencies and might, for example, explore the value of, and the return on, the provision of provincial institutes for renewable energy or appropriate technology, or the kinds of roles that metros and municipalities might be empowered to play in promoting innovation.

5.4 Performance of Innovation Activities

The discussion below outlines the innovation-related performance of the private sector in South Africa, and the paradox of a strong track record in industrial innovation on the one hand and a relatively stagnant economy on the other hand, with both manufacturing and job creation performing at below-par levels compared to the country's benchmark counterparts. Since it is this paradox that South Africa's future NSI must confront – and which the OECD Review suggests is being neglected – it is necessary to outline the situation in some detail.

By all accounts (and the Innovation Surveys provides particularly convincing evidence), **South African private enterprises are highly innovative**. One indicator of this propensity is to be found in the JSE Main Board, and the inclusion of nine of the top ten firms on that board among the world's largest as listed in the FTSE Top 500. The top fifty companies are active in mining and mineral resources, other natural resources, financial services, media and telecommunications, retail and industrial holding. They reflect the product of South Africa's industrial revolution with its foreign-financed mineral exploitation leading the way to an economy **self-sufficient** in everything except consumer durables, motor vehicles and high-technology items. There was, and remains, a marriage between resource exploitation and financial capital, with needs-driven spin-outs having emerged on the way. The minerals–energy complex has further generated a large support services industry, which includes equipment manufacture and providers of scientific and technical services (including design, engineering, hydrological, geological, software and modelling).

Considerable technological learning has gone into the evolution of these firms, and this learning arises from interaction among firms locally and globally, and with other knowledge producers such as universities, science councils and department-based research institutes. It is important to understand their **collaborative roles** in solving the problems of production, management and marketing and the way these forms of collaboration provide a model for how some dimensions of the NSI can be grown for the future.

Lending empirical support to these observations is the fact that South African **business expenditure on R&D (BERD),** at close to 60% of gross domestic expenditure on R&D (GERD), is one of the highest such proportions among the emerging economies. R&D expenditure by the service sector, at 27% of BERD, is also high.

It is reasonable to conclude that the prowess of South African industry rests on its ability to advance its knowledge through interaction with business peers, the development and integration of new entrants to industry, the identification of research problems for collaboration with researchers locally and globally, and the protection of intellectual property, as appropriate. To a large extent, the policy documents made available to the Ministerial Review Committee are silent on these strengths of the private sector, but they also fail to reflect a grasp of the underlying conditions that make for strength, or indeed for weakness.

To take a specific example, the Space Science Technology Grand Challenge in the DST's Ten-Year Innovation Plan (TYIP) speaks of satellite construction and the development of launch capacity, but without reference to the underlying defence and aerospace industry, especially its telemetry component. The Farmer to Pharma Grand Challenge shows a similar **lack of connection** with agribusiness at one end of the value chain and pharmaceuticals at the other. There is limited reference to what industry does, the constraints it faces and how state regulation and culture help or hinder private sector innovation. Another example is that the TYIP wishes to restrict foreign-funded clinical trials, despite it being a strength of South Africa's health sciences that ethically sound and scientifically robust clinical trials are conducted in this country by local scientists.

To illustrate more clearly the paradox between strong innovation capabilities but poor economic performance that was referred to earlier, it is necessary to turn briefly to indicative data generated for the study by the so-called Harvard Group (Hausmann 2007), which looked at the prospects for the South African economy. Briefly, the report documents the following:

- Between 1960 and 2004, the **real value of South Africa's exports grew by only 34%,** while export growth was 169% in Argentina, 238% in Australia, 1887% in Botswana, 385% in Brazil, 4392% in Malaysia, 1277% in Mexico and 120% in New Zealand.

- There were **declines in jobs**: in 2004, mining employment was 29% lower than in 1994; and agriculture shed 112 352 jobs between 1994 and 2004.

- In contrast with other high-growth countries, the decline in primary sector jobs was not compensated with increased employment in manufacturing. Between 1994 and 2004, **manufacturing jobs decreased by 11.7%.**

- Mineral exports per capita have been on a **downward trend** over the past 45 years, and finding other areas of economic activity to replace them has been slow and difficult. Moreover, specialisation in mining does not facilitate the move into other sectors, because it uses capabilities that cannot be easily adapted to other activities.

The above implies that there are structural reasons why the economy and its labour-creating ability appear to be stuck. These are framework conditions, termed the '**binding constraints'** that lie beyond the realm of innovation policy formulation undertaken by the DST. For example, it is mineral exports that keep the country solvent by reducing the current account deficit and allowing for the purchase of imported technologies, durables and luxury goods.

It is mining that has spawned the chemicals and steel industries and of course the financial services sector, but mining skills do not easily spill over into other sectors. Consequently employment has not grown. The solution proposed by the Harvard Group is the creation of a **parallel job market for first-time job seekers**, but this has proven to be politically unacceptable. The failure to create jobs cannot thus always be placed at the door of the NSI, as it is often conventionally understood. Rather, and in this context, job creation is shaped by broader framework conditions that include the power of organised labour and the political process. This is the realm of social and economic innovation.

This illustrates the point that much of the discussion above speaks relates to technological and non-technological innovation but says little about **social innovation**. In this regard, one of the most powerful social innovators is government in that new laws and regulations are intended to lead to social change, and sometimes do. Included in this domain are educational, agricultural, health, and safety and security innovations. The ways in which new patterns of behaviour might emerge to replace old ones, and the role of service delivery in this process, are poorly understood. It is commonplace, for example, to assert that the lack of clean water is a technology failure and thus a 'problem of the NSI'. However, this is not strictly true, since the necessary 'hard' technologies are well understood. It might be more correct to speak of a 'political system' failure.

This discussion above illustrates what is probably the biggest 'silence' in South Africa's policy and institutional architecture: the nexus between the key knowledge-intensive social actors, one of the most powerful being the private sector. The role of the private sector, and its relationships with other sectors (especially government, higher education and civil society), will be fundamental to the strength of the NSI in the future.

5.5 Knowledge Transfer

This discussion will outline a number of means that can be used to monitor and measure various forms of **knowledge transfer**. The key question arising from this is the extent to which these measures can be considered synoptically in ways that provide a wide view of this dimension of the innovation landscape, and which can then inform appropriate policy or institutional interventions.

Knowledge transfer occurs in two ways – through codified and tacit forms. The codified forms include scientific publications, patents, copyright, registered designs, registered breeds and organisms, and plant varieties. Tacit knowledge transfer involves less formal interaction among people and institutions. Universities, for example, prompt both modes of transfer: research is translated into formal publications, and universities' education and training functions are subject to formal assessment. Less formally, however, succeeding generations of graduates circulate in the innovation system, absorbing and transferring knowledge as they move.

This discussion sets out four modes of measurement that are typically used as proxies for knowledge transfer of one kind or another.

- **Bibliometric studies of scientific publications** provide indicators of knowledge transfer from the science base. Cross-sectional analyses enable comparative views across institutions and across national systems. For example, NACI commissioned CREST to perform such a study (NACI 2007), which was able to show the fields in which expertise is concentrated, how this compares with peer countries, the relative activity level, and the extent of the reproduction of expertise through doctoral studies. A further study of university publication performance was undertaken by Pouris (2006). His and the CREST study are broadly consistent in showing that South Africa's top expertise is confined to only a limited number of fields at a very limited number of sites. Notable strengths are to be found in the health sciences, geosciences and plant sciences.

  A longitudinal view over time is provided by Kahn (2010) who studied ISI article counts for the periods 1990–1994 and 2004–2008, which demarcate the term of democratic government. The study was able to track fields of continuing strength, new strength and declining strength, as well as overall patterns. A worrying example of the latter is the fact that state-sector publications stagnated over the period covered by the study.

  These findings from bibliometric analysis have significant policy implications, among them an assessment of the extent to which the TYIP is realisable, given South Africa's current reservoir of intellectual capital; a determination of what drives the article counts generally and by subject area; an appraisal of the extent to which policy acts as a driver; and an evaluation of the sustainability of the science base.

- The second measure is that of **innovation outputs**, often reflected in the number of patents or other forms of IP that are registered. In this regard, the paper-only database of the SA Patent Office continues to be an obstacle to analysis. It is clear, however, that South Africa files a small number (about 120 per annum) of patents at the US Patent and Trademark Office or through the Patent Cooperation Treaty.

  Another indicator of the levels of innovation outputs can be found in the **Technology Balance of Payments (TBOP)**, where South Africa records an apparently significant deficit in terms of its technological trade balance. Whether the data provided by NACI are a true reflection of the depth of the deficit, or a signal of some strategic undercounting, is a matter for Reserve Bank investigation.

  One form of IP that is important to the country, and yet which receives very low public attention, is that reflected in **plant variety registrations**. In this regard, South Africa is among the top ten in the world. This vitality is linked to the research strengths in plant sciences in the universities, the Agricultural Research Council (ARC) and others. However, none of the reviewed policy documents reflect this area of strength, or address the importance of plant varieties for their IP value.

- Measures of knowledge transfer are also to be found in **surveys of research, development and innovation**. For example, an important insight arising from the results of the Innovation Surveys of 2005 and 2008 is that firms acquire most of their information for innovation from other firms, their suppliers, customers and competitors. As is the case across the OECD, firms in the main do not acquire such information from universities or public research institutions. In that sense, South African firms are normal. The National R&D Survey, however, shows that firms that *do* perform R&D (a minority) tend in fact to have collaborative links with universities and science councils.

It is clear, however, that the way in which knowledge spill-overs have operated historically, and how they operate now, are unknown. Although government wishes to see the commercialisation of publicly funded R&D through its transfer to companies, mechanisms to this end, that are contextually sensitive, do not exist in South Africa. In less formal ways, however, there is a steady flow of ideas and people out of large firms, who then create start-ups at localities such as the Innovation Hub. Much more information is needed to understand the trajectory of such entrepreneurs.

5.6 Performance Measurement and Evaluation

Robust instruments for performance measurement and evaluation are required for an effective **management information system (MIS**) that will serve the planning and monitoring requirements of any NSI. Although the series of R&D and Innovation Surveys recommended by the White Paper on Science and Technology have been implemented, the MIS requirement of the NSI nevertheless remains poorly served. There are many databases, but little information in the public domain. There is **no coordination** of S&T information or indicators, and thus inevitable duplication and gaps.

The Ministerial Review Committee notes that the DST is in the process of soliciting a service provider to create a website that will host available information, which is a step in the right direction. The **Research Information Management System (RIMS**) may also improve system

knowledge once fully implemented. NACI collates existing information into the S&T Indicator series, but adds very little in the way of further analysis.

Impact evaluations are few and far between, so that deeper tests of strength are absent. Two examples will serve to illustrate. In 1998 the Norton and Kaplan **Balanced Scorecard (BSC**) approach with associated **key performance indicators** was introduced in the science councils, and it still forms the base of their performance compacts with their respective accounting authorities. Many of the indicators have tended to be outputs-based rather than outcomes-based, however. Despite this constraint, the BSC is structured to capture both quantitative and qualitative key performance indicators (KPIs), so it should be possible to detect policy changes resulting from science council research. The same applies to technology transfer, as for example the CSIR work on reducing cash-in-transit thefts. The BSC system constitutes a potentially rich source of management information, but the extent to which attainment of KPI targets attracts reward or sanction is unknown, as is the impact of the BSC.

The second is the Higher Education Management Information System **(HEMIS)**, the successor to the South African Post-Secondary Education (SAPSE) system. HEMIS together with the Research Outputs Database is central to the relationship between the DHET and its clients, the universities, since it is the means for determining subsidy payments. These databases should be readily available to the work of policy analysts, academic researchers, managers and students who would draw on the information according to their needs. This is currently not the case, as HEMIS is not resourced to provide such a resource and has fewer than a handful of dedicated staff. (One may compare this situation with the non-statutory Higher Education Statistics Agency of the UK with its ninety staff.)

Another key dimension is missing, namely the ability to rate research groups. Current practice is to rank individual researchers – South Africa is one of few countries to do so. The rise of multidisciplinary and transdisciplinary research adds to the case for the development of a different system of appraisal that recognises the myriad forms of academic and research excellence.

It goes without saying that a weakness in the area of sound and strategic management information will continue to hamper efforts to provide a coherent and coordinated NSI, which remains the overarching objective of the discussions in this report.

5.7 Conclusion

This section has sought to ask whether the Ministerial Review Committee is sufficiently informed to perform an assessment of the strengths, shortcomings and responsiveness of the system. The answer is a **very qualified 'yes'**, in as much as knowledge of the NSI itself is limited. This would be true of any NSI. Merely listing GERD, BERD, PhDs per million of population, ISI counts and USPTO patents tells but one part of the story.

The clearest gap revealed in this section is the absence of responsibility for ensuring the availability, collation, maintenance (and even analysis) of the science, technology and innovation indicators, both quantitative and qualitative, needed for monitoring and evaluation, and for planning and management. This includes both system-level information as well as enterprise-level insights to understand what underpins strength and responsiveness – or their absence. Case studies and narrative evidence, for example, provided through the Technology Top 100 process or other performance recognition schemes such as the National Science and Technology Forum (NSTF) awards, are important adjuncts to this understanding.

It is perhaps easier to make a system assessment when the system in question undertakes a highly specific and large task as in the US Manhattan Project, the NASA Moon Shot, or Korea's drive to become a world leader in visual display unit (VDU) and dynamic random-access memory (DRAM) chip technology (both of which were foresight-led). In these cases, the challenge placed before the NSI is clear: the technology either succeeds or it fails, and the country captures the market for the particular technology.

Currently, such large-scale challenges are not placed before the South African NSI in forms that would enable such judgements of success. It could be argued that the Pebble Bed Modular Reactor (PBMR) was such a project, even if that project was not within the mandate of the DST and did not feature in the National R&D Strategy. In an earlier period, the government of the day demanded fuel and weapons self-sufficiency of the NSI, and got it (at high cost). The spill-overs of that investment are of value into the present epoch. One example is to be found in contemporary 'pay-as-you-go' innovations that depend on data security technologies developed in the 1980s. The future spill-overs from the R11 billion invested in the PBMR cannot yet be known.

South Africa has a relatively small system of innovation. Albuquerque (2003), in comparing Brazil, Mexico, India and South Africa, coined the term **'immature systems of innovation**' to describe these countries. This may be harsh, as each of these countries demonstrates strength in certain scientific fields and produces some world-class innovations. In the case of South Africa, the NSI appears able to support food security; it is currently unable to institutionalise renewable energies. It is able (at high environmental cost) to re-arrange hydrocarbons into polymers; it is unable to secure the next generation of the highly skilled. It is able to support South Africa's transnational companies; it is currently unable to engineer vaccines. It is able to generate a stream of service sector innovations; it is unable to disseminate social innovations that reduce poverty.

The concerns are obvious: pockets of strength aside, the outputs of the NSI have moved largely sideways over fifteen years. Moreover, certain functions have declined, and capacity has been lost.

Although the NSI of the future will continue to require visionary leadership, it crucially will also require systems of oversight and analysis to inform implementation and strategic intervention where necessary. The extent and quality of information available are essential not only for monitoring and evaluating the current system, but also to inform the purposes, size, shape and modalities of the NSI that South Africa would like to see in the future.

SECTION 6: RESPONSIVENESS AND ADAPTATION WITHIN THE NSI

The preceding sections have sketched the landscape of the South African NSI, signalling the original conception of how it could be made to work well, the measures and initiatives taken over a number of years to improve its effectiveness, and the various efforts made to stimulate and fine-tune the system, including the landmark OECD Review and the responses to this report. In the course of this account, a number of abiding themes have arisen that appear to be critical for the success of the system into the future. In a large-scale, highly complex and situation-dependent system, policy intent is seldom followed readily by policy effect. The purpose of this section of the report is to provide **an analysis of factors that appear to shape the structure and function of the current NSI**.

The section identifies a number of factors, from the systemic to the practical, that currently shape responsiveness, and that are likely to determine the adaptive capacity of the system into the future.

6.1 Conceptual Understanding of a National System of Innovation

The notion of a well-functioning NSI, as outlined in the White Paper on Science and Technology and subsequent policy documents, is an ambitious and inclusive one, projecting a vision of diverse actors who pursue endeavours aligned towards common purposes, in favourable 'framework conditions' generally optimised by government. **The Ministerial Review Committee's own consensus 'mental model' for an NSI was described in Section 1 of the Phase One report:** Context of the OECD Review, as reflected in previous policy and review documents. The concept of the NSI has, nevertheless, proved to be open to **widely divergent interpretations**, however, and the various actors have brought their distinctive interests to bear on how they relate to the idea, if they relate to it at all. In its deliberations, the Committee has become aware of a variety of **'mental models'** at work, shaping the way that participants have engaged with the system. These mental models determine interpretations at the highest levels of systemic governance, as well as at more practical levels where collaboration over shared objectives seems clearly desirable. Some of these are outlined below.

The ambition of the concept itself, its relative abstraction and its attempt to embrace players in many corners of society, lends itself to multiple, often vague, interpretations and varying notions of what a commitment to improving the system might entail. The aspirational inclusion of a large number of independently operating but mutually reinforcing individuals, institutions and organisations invites different ideas about how the NSI is to be advanced, and by what mode of organisation.

A key issue is the unresolved tension between the idea of generating a well-functioning NSI in either a **loosely coordinated or a tightly coordinated way**. In the former case, the NSI is a mega-system whose summative effect arises from the functions of a large number of differently mandated, independently operating actors. In the latter case, the NSI is also a mega-system, but one that leverages its desired effects from the deliberately fostered and closely orchestrated cooperation of a number of constituent entities. Strictly speaking, the looser the coordination,

the better the specific mandating of the actors has to be to achieve the same result. A useful metaphor to extend this thinking is the notion of a factory producing excellent motor cars through the purposeful training and role-specification of each worker, in a smoothly operating production line that can continue unchanged over time. This is contrasted with the more recent and highly successful approach, in which the well-trained workers are encouraged continuously to think about what they are doing, suggest improvements, and cooperate with management and one another in an evolving factory system that continually improves – the learning organisation.

The first of these metaphoric models is one in which a number of independent entities respectively operate to good and intended effect if they are encouraged or mandated to perform separate functions that ultimately, through self-interest, contribute to bigger purposes. The contrasting second model recognises that even well-designed and well-functioning entities that operate in a complex and largely unpredictable environment need a considerable amount of systematic and sustained coordination and integration in order to achieve the desired outcome. Clearly, dominance of one model or the other would have considerable implications for how a constituent player commits (or is prepared to commit) to the system as a whole.

Not surprisingly, given that South Africa has a mixed economy, many of the actors (whether they are in the steering heart of the system or in the performing, 'coal-face' sectors) prefer an autonomous approach to fulfilling their own mandates and roles, compatible with a higher comfort level than would be prevalent if more closely collaborative, learning organisation approaches were adopted.

A series of other divergent 'mental models' are at work at other levels in the NSI dynamics. These derive from the varying inflections that actors bring to their respective missions. While ostensibly there seems to be a shared investment in the overarching purpose of improving the NSI, the players inevitably bring their own preoccupations and priorities that help shape what they want to see resulting from the NSI enterprise. Some see global competitiveness as the leading goal; others argue for '**big science'**, and yet others cite the imperative of service delivery linked to poverty alleviation. Even with the last priority, the question remains whether the conditions of the poor will best find relief from the trickle-down benefits of accelerated growth, or from government programmes of direct intervention. Should higher education strive above all else to maximise participation in undergraduate programmes, or should realistic resources also be ring-fenced for postgraduate training and research? Even where all goals are accepted as virtuous by the players, the pre-eminence of one over another in the mind of some actors has consequences for how effort and resources should be prioritised. In subtle (and sometimes not-so-subtle) ways, purposes are easily divided, but are costly to bring into convergence.

It is the achievement of convergence, whether strongly-directed or indirectly encouraged, that is the greatest imperative for the NSI, and also the most challenging to achieve. Most of the other factors that influence the adaptive capacity, or the responsive inclination, of the system are related to this fundamental principle.

6.2 Systemic Operational Qualities of the NSI

The need for convergence to achieve innovation rests on the assumption that South Africa's priorities are to address the big, complex problems confronting society now and in the future, for example the outcomes sought by the **Government's Medium-Term Strategic Framework (MTSF).** These challenges are much, much bigger than any one player and require multiple capacities to be brought together to engineer new ways of doing things. Given the priority of convergence, how should a structure be conceived for those components of the NSI that are open to the mandate of government?

The responsiveness of the NSI with respect to meeting its intrinsic mandate is most critically dependent on effective and voluntary joint policy-making, planning and coordination at the **central NSI policy-making platform**. It is essential that this platform is well-defined in its composition, so that a clear-sighted regulatory environment is achieved, keeping in mind the distinctive capabilities and contributions of the various participants, and the potential for learning organisation feedback and associated functional improvement. It is certain that the exclusion from the NSI central policy platform of some actors (like the private sector), or the persistence of insulated silos (in government agencies) contributes to the weakness of the current system. Instead, the NSI central policy matrix should be reflected in clearly articulated and shared purposes, custom-designed organisational structures and dedicated resource flows. Autonomous silos at the levels where policy should be made and co-coordinated are probably one of the key barriers to responsiveness in the NSI as a whole. The absence of clearly exercised political will is another.

A **tripartite model** may be useful at this stage for showing how structure can influence responsiveness in an NSI. Three concentric parts of the model could be envisioned, as constituted by a Central Policy-making Platform, surrounded by a Policy Coordinating Platform, which is surrounded in turn by the landscape of Performing Agents. Each of these is outlined below.

The Central Policy-making Platform is the forum for the development of national strategy and prioritisation at the highest levels of governance, in effect creating the favourable framework conditions needed for a well-functioning NSI. This is where the priorities in innovation-driven development are identified, and where the commitment to collaborate by sectoral leadership is secured.

The Policy Coordinating Platform provides several key functions, the first of which is the forums needed for coordination and execution of priority projects identified by the central policy structure, where fine-grained discovery of common purpose is forged, and the modalities of collaboration laid out. The members of this central policy structure are sufficiently powerful to direct and mandate their respective base organisations into the collaborative endeavour

The third level, that of the NSI Performing Agents as the name suggests, is where the 'coal-face' collaboration and project performance is undertaken. This level is constituted by the research-performing divisions of government departments, science councils and industry; technology-intensive companies; those tasked with education and training, especially in research training;

and innovation-oriented business more broadly. Importantly, this would include civil society organisations and public service agencies that operate at local and provincial government levels.

Responsiveness requires overlap and travel between the various layers to overcome vertical insulations – this is a caution in any system of hierarchies. Strong coordination in the activities of the two policy-focused platforms enhances responsiveness, while looser and more spontaneous coordination may be appropriate and effective in the constellation of NSI performers. The system as a whole must, nevertheless, display the behaviour of 'learning organisations' at individual and summative levels.

6.3 Availability of Human Capital

There can be little doubt that the achievement of an innovative and technology-rich economy and society will depend on the depth and width of South Africa's reservoir of human capital. It is essential to populate the system with a deep pool of top-level research-experienced expertise, with the breadth of vision to provide leadership for innovation, as well as skilled and creative technical personnel, competent managers and a citizenry with the interest and ability to support public and private enterprises in a knowledge economy.

Given the many challenges in South African basic education and the post-secondary system, the debate over whether or not prioritising the production of doctoral graduates is the path to a knowledge-intensive society is not surprising. The poor quantity and quality of high school and further education qualifiers, and that of higher education graduates, as well as the low number of doctoral graduates currently emerging, remain the main threats to the desired success in supporting a knowledge-based economy in the next decade and beyond. The DST's ambition in the TYIP to multiply the current output of doctorates several times over can certainly be endorsed in principle, but the current incapacity to make this happen is unlikely to change for the better unless a more determined effort and much increased investment is made in this direction.

The delay in the implementation of the new **Higher Education Qualifications Framework (HEQF**), with its potentially strong effect on the quality side of the problem, is only one of the several supply-chain issues involved in reforming and enlarging **senior postgraduate studies** in the country. The Consensus Report on the PhD degree by the Academy of Science of South Africa (ASSAf) has provided the most complete and evidence-based set of proposals available to date to address these and other difficulties. The study has confirmed the fact that the current system, already comparatively unproductive in terms of annual numbers of doctoral graduates (about 1000 per year), is severely stretched, and that asking it to increase doctoral graduates five-fold without the concerted implementation of a number of proposals is not realistic. The total numbers of research-active academic staff, capable of supervising postgraduate students, remains static, and their capacity to reproduce themselves is limited by the pressures on their professional lives arising through the necessary but under-resourced simultaneous expansion of the higher education system.

While the **SARChI research chairs** programme is one of the most effective antidotes to the heavy pressure of teaching on capable researchers, it has experienced a regrettable implementation

hiatus, and also a limitation of focusing mainly on the natural sciences, virtually ignoring critically important areas such as education and service delivery. The recent introduction of mathematics education, literacy and numeracy chairs, jointly funded by the DST and the private sector with a focus on attending to South Africa's education challenges, is a step in the right direction. This initiative needs in any case to be re-configured and implemented in other priority areas that are critical for South Africa's development. The conditions of the award of such chairs provide viable and attractive career options for top intellects, as well as providing the basis for expanded postgraduate and postdoctoral training in the fields of activity concerned. Without doubt, this programme is also associated very positively with the learning of important lessons about research stimulation by the managers of higher education institutions, creating an important strategic perspective needed to support this process and render it sustainable.

In terms of the need for much larger numbers of **engineering professionals**, attention to schooling and improved higher education will only address part of a bottleneck that is a key framework condition of South Africa's NSI, as also identified in the OECD review report. The proper education and training of engineering professionals is a two-stage process, the first being a tertiary qualification and the second **comprehensive workplace-based training towards professional registration**. Professional registration requires that applicants reach a level of competence that allows them to take full responsibility for projects. Guided, structured experience in the workplace is essential to achieve this level of competence, and requires long hours from experienced staff to ensure that adequate skills transfer takes place. Unfortunately, current investment in enhancing the skills of graduates and ensuring that they are adequately integrated into the workplace is lacking. It was normal until a few years ago for an engineer to become registerable within four or five years of graduation, but few are now ready to register in under seven years, with the majority only registering well into their thirties. Unemployed graduates are a further challenge that has become commonplace, as companies are reluctant to employ those without experience, as they are expensive to train.

The ambitious current **plans to double the number of engineers and technicians** graduating by 2016 must be reviewed in the light of the workplace-training bottleneck outlined above, as well as the number of engineering posts available to absorb such numbers. Many innovations in engineering arise in the field rather than in the laboratory as a result of challenges faced in design, construction, manufacturing, production, operations or maintenance processes. Innovative solutions at times develop cumulatively as successive adaptations are made to address identified weaknesses. A significant percentage of South Africa's engineering infrastructure relates to services provided by the public sector. Over the years, public sector technical structures have been dismantled to the detriment of service delivery. Without experienced technical personal to initiate new approaches, ensure adequate management and maintenance, and ensure adequate training of the new cadre, innovation will not take place. The country's capacity to employ young graduates and develop capacity to innovate in all elements of service delivery has been substantially reduced. Without rebuilding structures and training capacity in the public sector, the number of graduates envisaged in the future will not be absorbed into the workplace.

It is a matter of concern that, given the choice, companies employ graduate engineers in preference to their technician counterparts. It is thus likely that the increased number of graduates will be employed, and technicians will find it increasingly difficult to find work and training opportunities unless the number of posts is increased. South Africa's ratio of engineering staff per 100 000 is significantly lower than the developed and much of the developing world.

Drastic measures need to be taken to rebuild public sector structures to absorb and train the increased number of graduates, to ultimately ensure innovative service delivery.

Good-quality, high-capacity training programmes in the science and engineering fields of study is a *sine qua non* for a technology-rich economy, and the discourses on skills are overwhelming preoccupied with the shortages in this regard. This focus ignores the fuller conception of innovation that includes all its facets, including social, economic and political innovation. The need for these forms of reform and creativity is overwhelmingly urgent as a priority social and moral project for the country. Job creation and poverty alleviation literally depend on these modes of innovation.

Failure to implement new technologies is often rooted in the **interface between the social and the technical**. We have insufficient understanding of how social systems sometimes work against new modes of doing things, whether these are new software systems, new working practices in mining, new health service programmes, or efforts at schooling reform. The needs for sophisticated skills in the human and social sciences, and the economic sciences, are as important as the SET disciplines. In this context, the DST's current attention to the Grand Challenge of **Human and Social Dynamics** is therefore welcome. It would be perilous to neglect this area.

Given that the schooling system, as well as the post-secondary system, remain bottlenecks in preventing the through-flow of the country's talent into top-end positions in the knowledge economy, skills must be drawn from all quarters, because they are needed to boost skills-production and knowledge-production systems, and because the country needs to lodge itself in the global arena. **Immigration policies** that currently slow the flow of global intellectual capital into the country must accordingly be reviewed. Graduates and professionals are highly mobile and command a premium internationally, and policy must enable the reticulation of talent inwards.

The Ministerial Review Committee concludes that the interface between the human capital production pathways and innovation-driven economic growth and societal progress is a critical problem for the functioning of the NSI in South Africa that has thus far been resistant to resolution. It is emphatically not just the high end that is problematic. The inability to perceive that innovation in education and immigration is a fundamental necessity for innovation in the economy and society is another aspect of the problem. Without the 'feedstock' of trained and able people, the NSI will be a hollow aspiration.

6.4 Public Funding Flows in the NSI

Resource allocation is a core issue in the responsiveness of the innovation system to the alterations in both the 'involuntary' framework conditions imposed on an NSI, both by the globalising operating environment and the 'voluntary' steering mechanisms decided on by government.

The annual National S&T Expenditure Reports of the DST (Section 1.7 of the Phase One report) do not yet provide the accuracy, reliability and logic that are needed for fully appropriate policy-making in the public sector. The omission of the critically important **transfers to research performers in higher education by the relevant department** is an unacceptable shortcoming, while the inclusion of similarly large expenditures on health services is inappropriate. The annual the **annual National Survey of Research and Experimental Development (usually known as the National R&D Survey)**, performed by a centre in the HSRC covers both the private and public sectors, and has been a most helpful resource. The survey follows the OECD *Frascati Manual* guidelines, and is thus not designed to address issues of functionality and return on investment, which would require a different set of investigative tools.

Working on high-level data such as those described above, government has increasingly sought to ensure that growth in overall research and development funding continues. Gross expenditure on research and development (GERD) in current Rands advanced five-fold between 1997/08 (R4 billion) and 2008/09 (R21 billion); the ratio of GERD to GDP has hovered just under the set target of 1.00 for three years. The investment of R18.6 billion in research and development in 2007/08 grew to R21 billion in 2009/09. The share of business has settled at about 56% of the total investment, with about 20% each for government and higher education. The most informative data are those showing the resource flows between NSI actors.

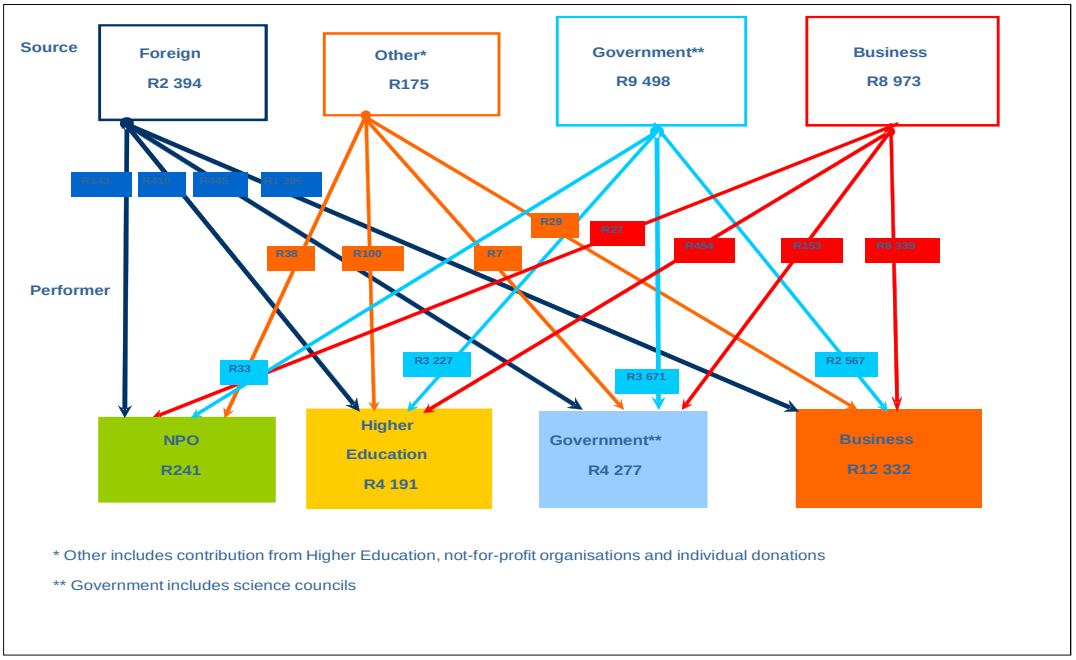


Figure 1: Major flows of funding for R&D, 2008/09 (R' millions)

It is clear that an understanding of the types of resource flows shown in this analysis (Figure 1) can contribute materially to the optimisation of framework conditions in the NSI. This needs to be aligned with outputs and impacts, and the identification both of bottlenecks and critical enhancement opportunities.

Another evolving information system is the **Research Information Management System** (**RIMS**), which has also emanated from the New Strategic Management Model (NSMM). Since there is no existing single database that can provide real-time information on R&D activities of publicly

funded institutions in an integrated fashion, to enable decision-making based on a systematic view, the DST has set up a Strategic Steering Committee, composed of representatives from the science councils and universities, to drive the project ultimately to develop a national, integrated RIMS that will bring together the highly fragmented picture of R&D investment in higher education institutions and science councils in South Africa, and provide specific indicators to monitor the overall performance of this part of the NSI. The web-based monitoring tool will capture data and produce reports on research inputs, outputs and processes of all the research institutions, including data on who is funding R&D in South Africa, where the R&D is being conducted, how much government spends on R&D, and what the outputs and perhaps some outcomes of the activity are. RIMS is also aimed at providing reliable and comparable data for national surveys, as well as routine information required by different statutory bodied and stakeholders, and essential fiscal information to decision-makers.

The general conclusion is two-fold: there are clearly distorted and inadequate resource flows in the NSI, both in quantity and nature, between its actors and in the system as a whole. The present ability to interpret the data and therefore beneficially to steer the system is wholly inadequate because of incomplete and inaccurate databases.

6.5 Overall Adaptive Capacity within the NSI

The international experience (including that of Finland, Malaysia, and Korea) has illustrated richly the importance of **active interventions by the state** in facilitating the culture and practice of innovation. The practice of nurturing young entrepreneurs and incubating new start-ups is well understood, although often difficult to implement properly. However, the practice of facilitating the convergence of different organisations in a common enterprise towards a shared purpose is less well understood and relatively poorly provided for.

The Ministerial Review Committee believes that more attention should be given to the role that the Technology Innovation Agency might play in this regard, and wonders whether the agency is adequately equipped with personnel who are sufficiently senior and experienced in facilitative work of this nature. The Committee notes the example of Finland, where agencies such as TEKES (the Finnish Funding Agency for Technology and Innovation) and SITRA (the Finnish Innovation Fund) play a vital role in enabling that country to maintain its status among world leaders in innovation. It seems vital for South to significantly grow its capacity for independent facilitation (which enables partners to find common cause in a vision of a shared and aspirational future). This is important for technical innovation, and especially for social innovation.

As mentioned earlier (in comments made by the BLSA), cross-sectoral and even cross-departmental collaboration require particular forms of expertise located internally in the organisation. Individuals positioned at the interface of collaborating organisations need to be able to manage cross-boundary interactions through, firstly, having the intellectual tools to overcome parochial specialisms and see the potential of collaboration and hybridity. Secondly, they need the skills of facilitation to manage interfaces and integration, since successful collaboration depends on the consistent application of social, intellectual and managerial skills.

As already noted in Section 1 of the Phase One report: Context of the OECD Review, as reflected in previous policy and review documents, the **policy-mandated requirement for external monitoring and review of the public-sector NSI actors, and indeed of the entire NSI, has been only fitfully met over the last six years**. Several review reports seem to have been overlooked or ignored, while others have been rejected as irritating intrusions by under-informed outsiders. There are indications that the SETI review system has little momentum, with long-delayed starts and inappropriately small panel sizes, only for the recommendations to find little traction. It should be understood that conducting a review is a highly professional social practice, and that the methodologies of rigorous enquiry and effective repair are undertaken systematically, embracing all role-players, and keeping in mind that there are seldom short-cuts to successful reform. **In many ways, close and responsive attention to the feedback provided to the NSI central policy platform by means of these reviews is part of much-needed learning organisation behaviour.**

Some of the SETIs' comments to the Ministerial Review Committee indicated that difficulties in terms of an organisation's capacity for responsiveness and adaptation might arise from factors bigger than the organisation itself, including structural factors, resource flows, human capital constraints or political dynamics. The device of commissioning a review may well generate valuable insight, but the responsibility for engineering the necessary change may not sit effectively in the portfolio of any one individual, because the problem at hand may be multi-faceted and systemic.

Importantly, however, when signals are received that modifications are required to support responsiveness or adaptation, the state steering capacity needs the capacity for 'nimbleness' in its own right. Enthusiasm for change (a vital resource for adaptive responses) may be short-lived in any one context and can evaporate in the face of systemic blockages. The steering capacity (wherever it resides) should have the authority to achieve resource allocation and reallocation, regulatory adjustment or acquisition of strategic skills quickly. The effective tuning of the system depends on this.

From the above, it can be seen that the skills and powers to generate convergence of purpose, practical collaboration and robust organisational performances lie at several levels: in the hands of adaptively oriented individuals within organisations, in the responsibilities of facilitative agencies that engineer convergence and resilient partnerships, and in the powers of those with the authority to bring about change at systemic levels.

The capacity for responsiveness and adaptation ('adaptive capital') cannot be taken for granted; it has to be recognised as a distinctive competence that must be formed and accumulated quite deliberately as part of a national system of innovation.

PHASE TWO: RECOMMENDATIONS FOR THE FUTURE OF THE NSI

SECTION 1: INTRODUCTION

South Africa faces interesting times. Thirty years in the future, China is projected to be the largest economy of the multi-polar world, followed by the United States, then India, Japan and Germany. Brazil will rank seventh, Russia 15th and South Africa 30th. Currently South Africa is the 28th largest economy in the world (Ward 2011).

Of course this is but one model of the future. Who, thirty years ago, could have predicted the impact of the nascent ICT revolution, the coming end of the Cold War, or the rise of the BRIC (Brazil, Russia, India, China) countries? China's experiment with the market economy was but two years old, and India had not deregulated. Generals and colonels ruled much of Latin America, and apartheid looked strong. Predicting the future is not an exact science.

So, how do we best seek to prepare ourselves for a future in which South Africa can be an increasingly successful country ?

1.1 Summary of the findings of Phase One

The preceding Phase One report made a number of findings and observations that informed the priority lines of enquiry pursued in the Phase Two exercise. For convenience, the Phase One findings can be summarised as follows:

- Although the 1996 White Paper on Science and Technology articulated a compelling vision for a national system of innovation that would drive national economic and social development, this **vision has not been adopted widely enough** across the range of government departments to achieve the intended pervasive impact. The goal of a common understanding of the role of research and innovation in achieving the priority goals of the country, and the need for more closely coordinated activities to achieve these ends, remain elusive.

- The measures that government has taken (especially related to the roles and powers of the DST and NACI, as designated coordinators of an otherwise fragmented and diverse NSI) have yet to find sufficient effect. A consequence of this is that South Africa has achieved **only very limited horizontal and vertical coherence and integration** of purpose and effort between the various agencies of the NSI.

- This limited level of coherence and coordination is reflected in the fact that, in or under sectoral government departments, **R&D activities appear to be highly fragmented**, with

the risk or even the reality of duplicated or contradictory effort, and the erosion of attention to R&D generally within these sectors.

- Another aspect of the limited level of coherence and coordination is that the **role of business (both established and emerging enterprises) has been inadequately included** in the conception and coordination of the NSI. In particular, the growth of small and medium enterprises (SMEs) needs greater attention, but the country's efforts as a whole are insufficiently supporting a transition from strong reliance on a resource- and commodity-based economy to one that is characterised by value-adding and knowledge-intensive activities. This has implications for government's priorities in relation to employment creation and poverty alleviation.

- Innovation activities involving more than just formal R&D are not yet being directed to innovation in **enhanced public service delivery systems,** which is seen as equally urgent, legitimate and mutually supportive of parts of the NSI as are the more conventional design and engineering activities.

- The practical emphasis of the state's investment in innovation has historically focused on 'big science', rather than sufficiently supporting the technological requirements of the business economy and social development priorities. **Demand-pull approaches** to the development of the NSI should be given as much attention as science supply-push approaches.

- The **shortfall in human capital development** is the key weakness of the NSI. While the inadequacies of the schooling and training systems are widely acknowledged, with consequent shortages of well-equipped school-leavers, artisans and technicians, deeper insights are also needed into the throughput of postgraduates, and the production and retention of public sector academics, researchers and science council staff. Measures to optimise the availability of highly skilled individuals remain a vital framework condition.

- There are clearly **distorted and/or inadequate resource flows** in the NSI, both in quantity and nature, between its actors and in the system as a whole, whether this is for formal R&D or venture capital for start-ups and innovative enterprises.

- There is still **inadequate knowledge infrastructure,** a crucial condition for a well-functioning NSI. This refers to the set of universities, vocational colleges and state laboratories with equipment for research and utilities such as reliable energy supply, communications and transport, and especially ICTs such as broadband and computing power. The earlier National Research and Technology Audit and its later NACI-commissioned update concluded that the public research system was seriously under-capitalised, and that inputs of around R700 million at current prices would be needed annually over six to seven years for its renewal, around double what is currently being invested.

- South Africa's NSI is still **far from an internationally open** system, with in-flows and outflows of all kinds, including skilled people.

- Provision is not yet being made for the strengthening of the capacity of the NSI to operate as a **distributed learning organisation** that is responsive to signals from within the system and to the wider environment.

- The responsiveness of the NSI with respect to meeting its intrinsic mandate is most critically dependent on effective and participatory joint policy-making, planning and coordination at a **central NSI policy-making platform, realisation of which has not yet been achieved.** It is essential that such a platform is well-defined in its composition, so that a clear-sighted regulatory environment is achieved, keeping in mind the distinctive capabilities and contributions of the various participants. It is certain that the exclusion from the NSI central policy platform of some actors (such as the private sector), or the persistence of insulated silos (e.g. in some government agencies) contributes to the weakness of the current system. Instead, the NSI central policy matrix should be reflected in clearly articulated and shared purposes, custom-designed organisational structures and dedicated resource flows. Clearly exercised political will is a paramount condition needed to achieve this coordination.

- Systemic responsiveness is still impaired by the **under-developed capacity for analysis of science, technology and innovation indicators, both quantitative and qualitative, needed for monitoring and evaluation, and for planning and management.** System-level information as well as enterprise-level insights are essential for the understanding of what underpins strength and responsiveness – or their absence. Although the NSI of the future will continue to require visionary leadership, it crucially requires systems of oversight and analysis to inform implementation and strategic intervention where necessary, and to inform the purposes and modalities of the NSI.

The Committee's critique of the current shortcomings in the functioning of the NSI is not a destructive one but rather a 'critically constructive' one.

SECTION 2: FRAMEWORK FOR THE SOUTH AFRICAN NSI

It is clearly evident from the Phase One observations summarised above that that South Africa has yet to achieve the full systemic dimensions and effects that are intended in the country's National System of Innovation (NSI). South Africa is still confronted with a number of problematic issues, including: the establishment of an effective approach to governance (both system-wide and intra-sectoral), the need to achieve greater inclusion across various sectors of society, the need for a more effective resourcing framework, the problem of inadequately skilled human capacity, and the need for more effective informational and system-steerage capabilities.

Where innovation does occur successfully, it is mostly in the traditionally technology-rich settings and seems to much less prevalent in other sectors in which urgent economic and social challenges must be addressed. The need for the economy to be vigorously and sustainably integrated globally must stand alongside the need to address poverty and unemployment. These are very large and complex challenges that require the concerted and aligned participation of all arms of government and all major social partners.

Kahn (2011a) identified case studies where the achievement in some national systems of the necessary coherence, alignment and investment in an NSI has arisen demonstrably as a consequence of a **sharp and commonly-held perception of a 'crisis'** that must be confronted as a matter of a national emergency. These demand signals, according to Kahn, may act as focusing devices needed for the achievement of coherence, of both purpose and effect, in a system of innovation. The Committee has interpreted the Diagnostic Report of the National Planning Commission (NPC 2011a) as a clear indication of a 'national crisis' in the country's ability to map a pathway to an inclusively prosperous future for its people (see below). Together with other prevailing signs and symptoms in relation to the economy, the 'wake-up call' is loud and clear. The subsequent proposals emerging from the draft National Development Plan call for significant and far-reaching changes in all spheres of endeavour in the South African society. (NPC 2011b). The Committee firmly believes that knowledge application and innovation are crucial to South Africa's ability to achieve its national goals in what amounts to crisis conditions. It is therefore necessary to accord top priority to the issues dealt with in this report.

This section outlines the set of conceptual assumptions that informed the Committee's deliberations, and that underpin the recommendations that follow in this report. These conceptual observations are made because of their practical implications for policy. The discussion will cover the purposes of a system of innovation, the activities that should be included in the definition, and the results that can be ascribed to these activities. The Committee will also reflect on the systemic dimensions of the NSI, as well as on the participants and their responsibilities.

2.1 Purposes, Players and Products

Essentially, the Committee adopted an **inclusive view of innovation as being the capacity to generate, acquire and apply knowledge to advance economic and social purposes** (Marcelle

2011). There are several implications of adopting the broad definition, the first being that it includes both the R&D-driven search for frontier technologies as well as the forms of learning and adaptation that might be market led or socially driven.

The concern is that notions of innovation that are overly conflated with science and technology (S&T) obscure the salience of other forms of innovation that are vital for economic growth, for the prosperity of livelihoods in a developing country context, and for the capacity of government to deliver on its mandate. Indeed, the critique has been levelled that South Africa's system has tended to favour 'big science' at the expense of the formal business sector, emerging enterprises, public sector innovation and community-level development. A definition that embraces this full range of domains is one that acknowledges the complexity of the urgent need to transform the economic and social fortunes of the population, with implications for the transformative work that is required in every corner of society to achieve sustainable futures.

Innovation should thus be understood to include both the production and technologising of new knowledge as well as the ways in which existing knowledge (local or imported) is adapted for local contexts. Innovation is thus an activity (indeed, an imperative) that belongs in all settings, no matter how sophisticated or modest the technologies at hand. In other words, the practice of innovation (or applied learning) needs to be radically domesticated into the grasp of all citizens, in all spheres of activity, making each citizen an engineer of transformation, growth and sustainability.

An implication of this is the need for a **policy framework** that provides for the full spectrum of innovative activities (from leading-edge, new-to-the-world developments at the one end, to functional imitation at the other), and to accommodate these in the indicators used to check on how well the country is doing as an innovative society.

2.2 Systems and Sustainability

Innovation, however, has value only in as far as it translated into reliable, resilient sets of practices that have intended and sustained effects. This is where the systemic dimensions must be considered.

Although the NSI is conceived as a national system, this refers more to the efforts to govern and steer its activities rather than reflecting the complexities of how innovation in fact arises. Any national system might be constituted by a multitude of sub-systems that are geographic, sectoral or institutional in nature, each of which may be promoted or hindered its own right, directly or indirectly. Innovation in public service delivery is in fact achieved at provincial, metropolitan or district levels, while industrial or commercial innovation may be achieved at sector-level or (more often) firm-level (Marcelle 2011). Innovation for development happens within distinct communities, or even at the level of individual smallholder farmers. At the same time, the national system (and its components) is more or less porous to cross-border flows – both regional and global – and depends for much of its vitality on these.

The characterisation of the NSI as 'national' thus reflects a desire to see innovation achieve **transformative effects across the social economy**, and provides a framework through which policies and measures to this end can be devised (Maharajh 2011).

The national view is therefore vital for achieving a strategic perspective for both analysis and planning. This broader context should not, however, distract from understanding – and making provision for – the way in which innovation actually happens in specific productive settings. Indeed, it is probably the failure to appreciate the difficulty of achieving adaptive behaviour that accounts for the skewed patterns of development that have characterised South Africa's democratic history thus far, namely, the **unequal patterns of development** in which innovation has continued to flourish in traditionally strong sectors of the economy, but less so in other areas needing urgent and thorough development. Where innovation has been left free to proceed along trajectories defined by historical precedent, it becomes a dynamic that inadvertently has the effect of deepening inequalities and imbalances, rather than ameliorating them (Abrahams and Pogue 2009). This constitutes the imperative for system steerage at a national level, as well as the imperative for building system capability at sites of productive activity.

The specificities of precisely how innovation happens in sites of productive activity (firms, government departments, communities, etc.) seems under-researched, and this report makes some recommendations as to how such research and monitoring should be conducted into the future. There are, however, some foundational precepts, with implications for policy, that can be summarised with confidence. Some of these are highlighted below.

The first precept is that **enterprises are located within and are affected, directly or indirectly, by the enabling or framework conditions that prevail in the broader environment**. These include the suasion of macro-economic regimes, the strength of financial institutions and systems, the adequacy and cost of the communications infrastructure, the output of the education and training system, and the regulatory measures associated with human and intellectual capital. Government has a strong role to play in each of these dimensions, a role that is strengthened when it is informed by insights from other social partners. A very important component of the enabling environment, however, is the normative one, which is the set of consistent signals about pre-eminent social values and the collective purposes that society strives to advance. Any approach to the risk-taking that is inherent in innovation will involve an appraisal of the extent to which South Africans live in a high-trust society of shared values, common purposes and predictable rules.

The second precept is that **enterprise-level innovation depends on both the capacity of individuals within an organisation and the collective capability of the organisation as a whole** – which should be more than the sum of its parts. The ability of an enterprise to mobilise learning and translate it into innovative productive activity depends on what it knows and can do already. Prior knowledge is a powerful conditioning factor for future learning. The absorptive capacity of an organisation tends to develop cumulatively (Cohen and Levinthal 1990), relying not only on the strength of individuals, but on what they can do together.

Innovation is inherently characterised by hybridity, where **different knowledges** are brought to bear to produce changed effects. Innovation arises from collective action and is therefore intensely social, depending on the strength of relationships for success. This has implications for the kinds of capabilities that are needed in a workplace committed to innovative and transformative behaviour: managers of innovation need to be able to marshal diversity towards aspirational futures, just as much as to command technical strength.

This relational theme provides the third point, which is that the **transfer of knowledge and collaborative activity across organisations is a vital component, both in generating innovation and in sustaining innovative practices over time**. Studies of developments in the private sector show that much is owed to cross-enterprise flows within the sector, as well as, to a lesser extent, across other sectors such as higher education.

South Africa's contemporary challenges require massively strengthened collaboration within and across all key sectors (i.e. government, the private sector, higher education and civil society), but the country's track record in this regard is still somewhat limited. It is the strength and complexity of the interactions between these social actors that reflect well-functioning or mature systems. South Africa's future NSI must confront the brokerage arrangements that are required to radically deepen the relational capital within and across sectors to achieve the purpose of innovation. Some promising examples stand out, where cross-sectoral approaches have been applied to address social innovation priorities: one example is the collaboration achieved between government, civil society and communities in the Community Work Programme.

A final consideration is that **systemic innovative capacity is accumulated over time through sustained investment** in the constitutive dimensions noted above. This is an investment in measures that might not be materially productive in the short term, but that will create the conditions for success in the longer term. An entailment of the commitment to a NSI is a willingness to invest in risk-taking, uncertain outcomes and futures with unpredictable time horizons.

2.3 The South African Imperatives

To conclude this part of the report, it is appropriate to keep in sight the priorities that the re-fashioned and strengthened South African system should address into the future. It should be recalled that the concept of a national system of innovation was introduced as an organising framework for the 1996 White Paper on Science and Technology. The objectives were articulated as follows:

- Promoting innovation and employment creation
- Enhancing quality of life
- Developing human resources
- Working towards environmental sustainability
- Promoting an information society

- The generation of knowledge (DACST 1996).

As already mentioned, the National Planning Commission has recently summarised the vast challenges confronting contemporary South Africa, and has identified them "in the deep conviction that significant progress is possible in all these areas" (NPC 2011). The overall challenge is starkly summed up in one formulation: **"Widespread poverty and extreme inequality persist."** The contributory or constituent challenges include the following:

- Too few South Africans are employed.
- The quality of education for poor black South Africans is substandard.
- Poorly located and inadequate infrastructure limits social inclusion and faster economic growth.
- South Africa's growth path is highly resource-intensive and hence unsustainable.
- Spatial challenges continue to marginalise the poor.
- The ailing public health system confronts a massive disease burden.
- The performance of the public service is uneven.
- Corruption undermines state legitimacy and service delivery.
- South Africa remains a divided society.

The implication is to underscore the urgent need for **a full-spectrum, fully national system of innovation that reaches into all productive activities contributing to livelihoods in all sectors of society.** Innovation is thus not only the preserve of established, technologically adept business and other kinds of science-rich domains, but is rather an imperative that runs at the core of the country's transformative project. It is full-spectrum in that it must address all corners of the economy, it must include all social actors, and it must provide for inclusive and sustainable futures.

It was noted earlier in this section that focus and coherence in a national system of innovation are often achieved through an acute sense of crisis that galvanises the commitment and priorities of the key social partners. The South African system is currently sensing **powerful demand signals**. It is not that government has not articulated the crisis of poverty and inequality; indeed it has – and done so repeatedly. It is that the call for the country, with all its profound creative and productive potential, to unite in the search for the innovative solutions must be powerfully heard.

In the sections of the report that follow, the Committee makes recommendations as to how various components of the system should be configured, and how essential framework conditions should be consolidated. The responsibilities to fulfil these recommendations are distributed across many social actors, although the emphasis of this report is inherently on the measures that should be led by government. In all cases, however, the means to achieve the strength of the components, and the collaboration of the various players, will depend, to a very large degree, on

the quality of compelling leadership that makes the case for collective, deep investment in innovation at both organisational and personal levels.

SECTION 3: GOVERNANCE OF THE NATIONAL SYSTEM OF INNOVATION

3.1 Introduction

The current role played by the state in the National System of Innovation has failed to deliver the transformations in policy and system performance needed to realise the potential of the South African innovation system to drive development and growth, and to contribute to social justice. In the view of the Committee, South Africa requires a new social contract between state institutions and state funding on the one hand, and the rest of the research and innovation system on the other. This implies **substantial reform in how the NSI is governed and managed**.

Government is embarking on the New Growth Path (EDD 2010), a long-term project that argues for concerted state intervention in the economy to construct a developmental state. The UN Economic Commission for Africa (ECA 2011: 95) describes a developmental state as one that "authoritatively, credibly, legitimately and in a binding manner is able to formulate and implement its policies and programmes. This entails possessing a developmentalist ideology that privileges industrialisation, economic growth and expansion of human capabilities." This project seeks to tackle poverty, joblessness and sluggish economic growth.

Innovation, and the innovation system that nurtures it, will be pivotal in realising the New Growth Path.

Government, with major stakeholders, must agree on the major goals for the future innovation system. It is the prime responsibility of the state to ensure that the innovation system functions optimally. This section lays out the governance framework needed to attain this by considering:

- A **vision for the future trajectory of the NSI**, noting: (i) the purposes it must serve over the next thirty years, and (ii) the evolution of the system over that time period
- A **vision for the role of the state** (as opposed to other players), in the short, medium and long term, through a comprehensive policy landscape; an enabling set of framework conditions; coordination mechanisms and direct participation; human resource development and mobility; provision of knowledge infrastructure; and mechanisms for knowledge transfer and dissemination, including intellectual property rights
- The state **governance structure** needed to coordinate the operation of various departments and functions of government in the achievement of key innovation priorities, with use being made of the experience of other countries
- The **role of the DST**, in relation to the rest of government, in pursuing the function and goals of the innovation system
- The role and positioning of **higher education and training, the science councils, NACI and TIA and the need for possible new state agencies**

- How the state may **optimise the role of the major non-state actors** (private sector, civil society and community-level groups) in the innovation system.

In laying out a scheme for the enhanced governance of the innovation system, the overarching goals of the innovation system are central. It is necessary to explain for whose benefit the innovation system functions. Innovation systems effect multiple functions: they produce and circulate new knowledge and knowledge workers; they produce, adopt, adapt, transfer and disseminate innovations; they perform public services; and they exhibit the ability for learning and renewal, including foresight. As explained in the previous section, innovation is both technological and non-technological, and occurs in the formal and informal sectors, and in the social domain.

Looking forward thirty years into the future, the ICT revolution will still be offering surprises, even as the nano- and biotechnology revolutions accelerate. As is now well-understood, the ICT revolution, like other technological revolutions before, is embedded in its own techno-economic paradigm (Perez 2002). Each techno-paradigm shapes society and is in turn shaped by it. The outsourcing of business processes is one example of the ICT techno-economic paradigm; just-in-time manufacturing is another; and robotic welding is a third.

A **plausibly optimistic vision**, looking thirty years hence, is a society where absolute poverty and unemployment have been more than halved; where the burden of infectious disease has fallen to a quarter of its present levels; where sustained economic growth of 6% is the reality; where carbon emissions per capita are halved; where the gap has narrowed between educational attainments achieved by black and white, rich and poor, urban and rural, and overall South Africa's position in education and health on the Global Competitiveness Index has risen from its present 129th rank to better than 50th; and where life expectancy is above 65 years.

In such a vision, cheap and reliable hydro-power may energise sub-Saharan Africa; electric cars may be a reality alongside high speed rail; heavy industry may be producing ships, oil rigs and locomotives; the country may be the fifth largest producer and exporter of generic medicines; arable land under production may have doubled; chemicals, including bio-fuels, may underpin new industries and be a strong element in exports; South African universities may constitute the higher education hub of Africa, and the East and Southern African Research Area may be a major player in the larger African Research Area. New art and cultural forms may flourish. South Africa may be among a small set of countries able to launch satellites.

Realising this kind of a vision by making the state's roles in the NSI more effective is only possible if the national system of governance addresses not only individual parts of the system but – crucially – the fact that these parts must be interconnected. Overall performance can only be improved by raising the performance of the individual parts at the same time as ensuring their interconnection and coherence. The governance framework of an effectively functioning innovation system outlined below is a contribution to realising this vision.

Governance of innovation systems encompasses prioritisation, agenda setting, the formulation of policies and regulations, crafting strategies, plans and incentives, their oversight, and the accountability of those entrusted with implementation. An essential feature of accountability is policy learning that rests upon monitoring, measurement and evaluation, for review and synoptic purposes. The ability to detect bottlenecks, inefficiencies and perverse behaviours arising in policy implementation, and to act thereon, are elements of sound governance systems.

Governance is deeply embedded in a country's institutional make up, its history and culture. The governance of innovation systems can therefore be expected to demonstrate echoes of society as a whole. Governance forms are time bound, and what appears to have made sense at a particular juncture may no longer do so when viewed through the spectacles of the present, let alone future exigencies.

In order to synergise the governance and orientation of the innovation system with the objectives of the New Growth Path, it is necessary to understand the present shape and form of the innovation system. How did it originate; what are its strengths and weaknesses; what are its governance norms; what needs to change; and how can this be achieved?

3.2 The Legacy Innovation System

The origins of the innovation system (see Kahn 2011a) lie in the mining-led industrial revolution that triggered the rise of the mining oligopolies (Innes 1984; Wheatcroft 1985) and what was arguably **'Developmental State I'** that set out to secure the interests of the then power-holding minority. Initially, Developmental State I rested on state enterprises (energy, communications, iron and steel, irrigation schemes), later adding a military-industrial complex. It combined free-market principles with high degrees of regulation and administered prices. In the 1970s, rising worker militancy, the collapse of the Portuguese dictatorship in Mozambique, the Soweto Revolt, the cost of the Bantustans, runaway arms expenditures, the oil crises, and the overthrow of Shah Pahlavi's Iran, presaged the end of apartheid. One of the first shifts was the 1979 privatisation of Sasol, followed by the corporatisation of South African Railways and Harbours and Eskom, and the 1989 privatisation of ISCOR. When democracy came, the dismantling of Developmental State I was well under way, with agriculture the next to be deregulated. The shrinking of military procurement and the new realities of globalisation forced further adjustment upon the private sector. Accordingly, South Africa's market leaders now generate perhaps one half of their revenues abroad, and one might properly speak of three economies, not two – a rich domestic economy, a poor informal economy and a rich offshore economy.

From 1990, the economy grew slowly, eventually peaking at 5% growth before falling back to 3%. Inflation was tamed, with inward foreign direct investment (FDI) patchy and largely confined to acquisitions, while outward FDI expanded. Unemployment remained high, and HIV-AIDS pushed life expectancy back to the level of the 1950s.

The 2005/06 **Accelerated and Shared Growth Initiative for South Africa (ASGISA)** was then conceived to overcome the binding constraints that retarded growth. One push was for infrastructure renewal; another was to promote biofuels, timber, food production and

processing, chemicals, metals beneficiation (including capital goods), creative industries, clothing and textiles, and durable consumer goods. Hausmann and Klinger (2006) showed that agriculture, pharmaceuticals, machinery and chemicals were sectors offering export potential in the mode of Korea, Taiwan and Singapore.

The innovation system beginnings lie in mining, agriculture and health based on research organisations such as Elsenburg (founded in 1898) and Onderstepoort (1908), the South African Institute for Medical Research (SAIMR) (1913), the South African Sugarcane Experiment Station (1925), and Mintek (1934), a joint programme between government and the young University of the Witwatersrand.

The importance attaching to the founding of the **Council for Scientific and Industrial Research (CSIR)** in 1945 cannot be overstated. Originally the CSIR operated national laboratories[3] in basic and applied research for government and industry. Over time, its spin-outs included the Atomic Energy Board, Human Sciences Research Council (HSRC), Medical Research Council (MRC) and Water Research Commission (WRC), as well as the National Research Institute for Oceanology at Stellenbosch University. The CSIR also established industry research associations for leather, paint, fish-processing and sugar milling with funding from industry levies and the state.

Outside the CSIR, a 'securocratic' system of innovation was centred on Roodeplaat, near to the Plant Protection Research Institute, the Onderstepoort Veterinary Institute, the University of Pretoria medical school and the police forensic laboratories in Pretoria. In the Cape was the telemetry system of innovation that brought together the Institute of Maritime Technology and various companies active in radar technology, together with signals and electrical engineers at the universities of Cape Town and Stellenbosch and Cape Technikon. Other **sectoral systems of innovation** functioned in energy, grain, viticulture, forestry, pulp and paper, and materiel. Today's South African market leaders were, and remain, actors in those sectoral systems, for example Sasol, SAB Miller, Distell, Sappi and Barloworld.

Together with the universities, the then technikons, technical colleges, industry training centres, and private research laboratories, the system of innovation took shape with the addition of the South African Bureau of Standards (1945), HSRC (1968), MRC (1969), Foundation for Research Development (FRD) (1990), Agriculture Research Council (1990) and Council for Geoscience (1992). The science councils followed the Bush principle: "Give us the money; we shall give you the results."[4] Even so, trading with the market was encouraged, and on average the CSIR earned 40% of its income from contract research from the late 1960s onwards (Walwyn and Scholes 2006).

The **universities**, supported by incentive programmes (including the journal subsidy and the FRD rating system) produced world-class science in catalysis, environmental science, clinical medicine, ornithology, marine sciences, geology, metallurgy, plant and animal sciences, and archaeology.

[3] Physics, Chemistry, Buildings, Personnel Research

[4] In 1945, Vannevar Bush advised President Truman that new products and processes "… depended on new principles and new conceptions which in turn result from basic scientific research". This is the simplest formulation of the linear model of innovation.

The Department of National Education included supply-side support for research in its model of higher education and funding,

Though nominally restricted by the academic boycott, the innovation system was open, absorbing technologies and ideas on technology management from wherever these could be sourced. As the doctrines of the Chicago School disseminated around the world, local economists pushed ideas of the lean state. A manifestation was the 1988 principle of framework autonomy to make the science councils more market-friendly.

The innovation system attempted to deliver to the demands of the time – self-sufficiency coupled with a space for individual research agendas. It comprised ethnic and class-based higher education institutions that produced the highly skilled and carried out research, companies that produced innovations to fit the needs of the apartheid-constrained domestic market, and so-called 'Own Affairs' science councils that supported the state and business. That was the contract of the day between science and society.

3.3 Towards a Transformed Innovation System

Immediately ahead of the inception of democracy, the Mass Democratic Movement (MDM), assisted by a mission of the International Development Research Centre (IDRC), examined the S&T system. It concluded that the system displayed a leadership vacuum, promoted sectional interests, was underfunded, poorly coordinated and needed "to demonstrate that it can apply its technical skills to the real developmental needs of the majority" (IDRC 1993: 23).

The IDRC mission report, together with the work of the ANC Science and Technology Group and the industry-MDM STI Initiative, laid the basis for the White Paper on Science and Technology (DACST 1996). This instrument articulated the need for the introduction of the concept of a **national system of innovation defined as follows: " … in its broadest conception, (as) the means through which a country seeks to create, acquire, diffuse and put into practice new knowledge that will help that country and its people achieve their individual and collective goals**" (DACST 1996: 18). Its effectiveness is measured by improved economic performance and measures of the quality of life." Against this definition, the pre-1994 innovation system, being biased toward sectional interests, failed.

In the democratic period, the transformatory changes were the rationalisation and de-racialisation of higher education, the introduction of the Council on Higher Education (CHE), the relegation of science policy advice from the Presidency to the new National Advisory Council on Innovation (NACI), the introduction of competitive funding through the Innovation Fund and Biotechnology Regional Innovation Centres, the abolition of the Science Vote, and the establishment of the Academy of Science of South Africa (ASSAf). Progress was made in promoting a culture of **performance measurement**, notably through the 1998 adoption of a Balanced Scorecard performance measurement system for the science councils and the 2002 revival of the National R&D Surveys.

The universities and science councils retained their positions as legally autonomous bodies, with the governance of the universities determined through the Higher Education Act (Act No. 101 of 1997), and the status of the science councils through their respective enabling legislation.

Notable progress was made in achieving employment equity on boards, in science councils and in other public research organisations, while the proportion of women researchers, at 39%, places South Africa in the top quintile by international norms. The proportion of black researchers in the science councils rose from fewer than 5% in 1994 to 49% by 2008.

As already described in the Phase One Section of this Report, the 2002 **National R&D Strategy, NRDS (DST 2002**) sought to re-orient the system by declaring five new technology missions. A second objective was to provide what government hoped would be a more strategic approach to **scientific and technological activities (STAs)** across government. Inter alia, this involved abolition of the Science Vote, the transfer of the CSIR to the DST, and the granting of a coordination role to the DST.

The subsequent experience of the DST merely in attempting to report on the budgets for scientific and technical activities across government, let alone to steer them, is evidence of the difficulties of executing such coordination. Other subsidiary objectives included the establishment of the Foundation for Technological Innovation (today's Technology Innovation Agency), the revision of patent law and the introduction of an enhanced tax incentive for R&D.

The CSIR duly moved from the Department of Trade and Industry (the dti) to the DST, and the HSRC lost its agency function to the new National Research Foundation (NRF). With the 2005 **scrapping of the Science Vote**, the science councils became even more autonomous of the DST than previously.

Potentially, the government-owned and government-run, large-scale, research-performing organisations, each with a specific legislated mandate, are a collective asset that could cost-effectively complement the higher education system. Nonetheless, the Committee believes that a careful 'zero-based' re-examination of the situation is necessary at this time, to form an orderly policy basis for the establishment, merger or closure of science councils in the future, and to guide future short- and long-term resourcing and planning decisions. For one, the largely unsatisfactory present condition of the **scientific and technical services** in several line departments certainly needs imaginative attention, as the likelihood of innovation and flair is very low in environments in which the world of enquiry-based science is far away. It is possible, for example, that the respective forensic service laboratories of the Department of Health and the South African Police Service would provide better, quicker and technologically more up-to-date forensic tests, if these organisations were made the responsibility of another public organisation, either the **MRC** (which started life as a grant-making agency for health research done at higher education institutions [HEIs], but now effectively competes through its intramural programme with HEIs for staff and contracts for similar projects and activities) or perhaps more organically, the National Health Laboratory Service (NHLS).

The **Council for Geoscience** was developed as a rebranding of the old Geological Survey, and the ARC was formed as a merger of various Department of Agriculture research institutes. The logic of their formation, perhaps conducted in some haste in the twilight years of apartheid, suggests that re-thinking may be overdue. The larger issue of food security has been taken care of; widespread poverty and inequality call for quite different responses by public research organisations.

The **NRF** currently carries the responsibility for the so-called **national facilities**, although there is an inherent conflict of interest between running this group of unique and expensive entities and the primary agency functions of the foundation – the real logic of the arrangement has never been entirely clear. The national facilities are indeed starting to spin off into other agencies as the contradiction of their NRF placement becomes ever more apparent and problematic (NRF 2011). The national facilities actually constitute a distributed, research-performing 'science council', and the question has to be asked why they are still run by an essentially specialised grant-making organisation. Thus the South African Nuclear Energy Corporation (NECSA) could take over the iThemba Laboratory for Accelerator-based Science (iThemba LABS), the new Space Agency the observatories, and the Department of Environmental Affairs the National Zoological Gardens.

A second and major reason for a serious re-think of the science councils is the problem of an inadequate coherent cross-system policy, ineffective coordination of their activities, and disparate funding models. This has arisen from the problematic implementation of the **New Strategic Management Model (NSMM)** in 2004 (see the Phase One part of this Report for details) which effectively fragmented the science council system into a few core DST-run entities and a majority of sectoral entities reporting to, and funded by, specified line departments; the NSMM (vainly, as it turned out) sought, by sharpening a number of policy definitions, to emphasise the cross-cutting role of the DST in setting common governance standards and quality assurance mechanisms in place for each science, engineering and technology institution (SETI), irrespective of its location in the system, and making some preliminary provisions for 'market failure' or incapacity on the part of line departments. These provisions were intended to blunt the impact on national coordination of moving government R&D organisations to their sectoral departments. Unfortunately, it meant that science councils which had received top attention in the DST moved to situations in their new organisational locations where they did not receive priority attention.

A critically significant part of the NSMM document described the nature of the partnerships-to-be between the DST and other departments in sector-specific S&T. Among other things, the document notes: "In the case of sector-specific science, the function of DST would be to develop interventions in the case of market failure, under-subscription or where there are technology gaps of a strategic nature. Examples here include those areas where sector departments are not ready to drive the necessary sector-specific technology programmes due to capacity deficiencies." The DST was also to assist in the case of national priority programmes with best practice advice on S&T aspects, including developing financial instruments for this purpose. The question was really, however, whether a 'consultant' role for the DST was really adequate in cases of departmental incapacity or incoherence, and whether it was feasible to expect the DST to intervene in the case of a failed stewardship of a sector-specific SETI.

The need for a common mechanism for planning and budget development for the science council system is further exemplified by the current prevalence of **duplication of focus areas in the science councils**, where, for example, the volume of health research performed in the CSIR, the

HSRC and the ARC probably much exceeds that performed by the MRC. (The agency function of the MRC, the last to remain outside the NRF, apart from the rather differently conceptualised Water Research Commission, is by now a virtual step-child of that organisation, with a minority share of the baseline budget as well as of the extensive administrative machinery. The question should be asked whether this is this sensible.) Another matter that deserves attention in this context is the reportedly **low expenditure of many line departments on Science and Technology** Activities (STAs), which suggests that problems encountered in service delivery or policy implementation are not being innovatively addressed. This is hardly good practice in a knowledge economy.

There are further signs of disquiet that suggest that a new social contract must be formed between what might better be termed the research and innovation system, and society. Starting with the August 2005 call of Cabinet for evidence of the benefits of spending public funds on R&D, to the scepticism expressed in meetings of the Parliamentary Portfolio Committee on Science and Technology, there is a mood that demands change and value for money, with S&T being held to account. Poverty appears to be intractable, and economic growth stuck. 'Show us the benefits' is now a serial question.

The foregoing comments serve as context for introducing the Ministerial Review Committee's assessment of the 2007 OECD review of South Africa's innovation policy in the Phase Two part of this Report. The review strongly challenged the DST's conception of the system of innovation, claiming that its **"mental models of how the innovation system operates [are] over-focused on the role of the state"** (OECD 2007: 5), and that this should be changed, with firms being placed more centrally to policy considerations. [This view is unsurprising in that it represents OECD orthodoxy.] Even so, it resonates with the DST stance; despite contrary evidence from the National R&D Surveys, the DST steadfastly maintains that the private sector is failing to join government in supporting national objectives, thereby justifying its own activist approach.

To bridge this gap requires measures that (i) strengthen the incentives for firms to become involved in innovation that will serve national objectives; (ii) build links between universities/science councils and industry; and (iii) build absorptive and technological capacity in industry at all levels.

The OECD Review (see also the Phase One sections of this Report) also recognised positive aspects – the mere fact of innovation system survival, the availability of system information, departmental leadership, and the high industry expenditure on R&D.

The OECD Review then offered a number of recommendations: policy intervention should only arise from market and systemic failure; the need for action to address inequalities; a commitment of government to openness, participation and transparency; and the need to build critical mass. Other recommendations covered the need for a mechanism for high-level decision-making, shifting from supply-side to demand-side interventions, from the selection of technologies to identifying 'sectors' in which innovation would be implemented; the review of negative consequences of immigration policy; and new roles for the Industrial Development Corporation (IDC). A review of higher education research funding was also called for in order to provide

"stronger incentives for, and greater selectivity in resource allocation to, high quality work", while arguing that measures for "ring-fenced funding are needed to foster the emergence of newcomers to the competition" (OECD 2007: 14). It was noted that small and medium enterprises (SMEs) deserve special support measures.

It is important to note that **business appears to have an equal misunderstanding, if not mistrust, of the government role**. Among the nine country studies conducted for the Committee (Kahn 2011a), none shows such lack of alignment as in South Africa between the major private sector players, and the public components of the innovation system.

The DST's response to the OECD's recommendations has been measured, and has included the establishment of a NACI-CHE sub-committee on human resource development, and a change to the NACI Act to allow for the appointment of an independent CEO.

Despite the recommendations of many external reviews – the reviews of NACI in 2003 and 2008, and the system-wide reviews of 1998 and 2006 – it is the view of the Committee that there is considerable institutional congruence between the pre- and post-1994 innovation systems, with attendant problems of focus, accountability, autonomy, fragmentation and inadequate performance measurement and evaluation. To a large extent, the public component of the innovation system continued in its previous areas of niche expertise, the major exception being the **impressive expansion of infectious diseases research**, and this in spite of, not because of, government policy. International networks and the availability of donor funding were, and are, crucial in allowing this to take place. Various recommendations for changes in system governance have not come to fruition.

The Committee acknowledges the many positive achievements of the DST, including South Africa's ability to effect large projects such as the Southern African Large Telescope (SALT) and MeerKAT, and the world class bid to host the Square Kilometre Array. Other noteworthy interventions are the South African Research Chairs Initiative, the university Centres of Excellence and Centres of Competence, the achievements in genomics and early humanoid research and South Africa's participation in many international scientific projects. The Committee also recognises the achievements of the private sector in effecting innovations and pursuing new market opportunities.

The **DST is essentially a policy department**, and oversees transfer payments to the statutory bodies for which it has responsibility, while major responsibility for grant-making is the role of NRF, WRC and MRC. What has emerged over time is a change in the activities of the DST, in that the department is also taking on the role of research activist, if not experimenter, perhaps addressing perceived market failure within the public sector. This gives rise to the question of whether a policy department should be so engaged, or whether this is the province of the science councils or other organs of state.

It would be reasonable to describe the current innovation system as decentralised, in that there is no high-level coordinating mechanism in place. The fact that until 2009 the responsible Minister

was not selected from the ruling party, together with the position of the Ministry of Science and Technology in the hierarchy of government ministries, almost certainly compounded the absence of such a coordinating mechanism. Seen from the perspective of government, funding mechanisms appear to constitute the principal steering devices that have been deployed; others are the promotion of employment equity and preferential procurement. No fundamental shifts are in evidence.

The key concerns of the Committee may be summarised as follows:

- An uncoordinated approach in various parts of the system to resourcing innovation-related activities, with the failure to attain critical mass in any strategic direction
- The slow growth of innovation-related skills in all sectors of the system
- Mission creep and loss of capacity in public research organisations as well as the growing obsolescence of parts of the knowledge infrastructure
- An inadequate base for evidence-based decision-making, and in many cases weak accountability for the expenditure of public funds
- The need to leverage existing innovation potential more effectively, and to grow the national innovative disposition more broadly.

3.4 Emergent Policy

The next matter for consideration is the advocacy of the New Growth Path to institute a developmental state. The developmental state agenda notwithstanding, the Committee is concerned that the New Growth Path document (EDD 2010) says little about innovation, R&D and technology, instead being content, with one exception, to repeat the indicators of the Ten-Year Innovation Plan. This is insufficient to build a prosperous state whatever its design may be, and would position South Africa outside mainstream thought on the importance of innovation (see for example, OECD 2005a, 2010). The Committee also notes that it is a major contention of the Ten-Year Plan that, "To build a knowledge-based economy positioned between developed and developing countries, South Africa will need to increase its PhD production rate by a factor of about five over the next 10–20 years" (DST 2008b: 25), hence the target that 3000 PhDs in science, engineering and technology will graduate annually by the year 2018.

There is a serious problem of mismatch between the intentions of the New Growth Path, the Ten-Year Innovation Plan and the Twelve Outcomes of government and their associated Delivery Agreements. Delivery Agreement 5 nullifies the DST's PhD target by setting a much lower rate of production. Output 5 calls for 1350 PhD graduates by 2014 along with the provision of 100 postdoctoral fellowships. The figure of 1350 may be compared with the HEMIS 2009 figure of 1380 doctoral graduates, while the 100 postdoctoral fellows are far below the 627 recorded in the official 2008/09 National R&D Survey. Where the undercount for the postdoctoral fellows may have arisen through error, that derived from HEMIS does not. **Delivery Agreement 5, if implemented, would amount to a slow strangulation of the research side of the innovation system. The goal of reaching the target for GERD as a percentage of GDP of 1.5% will be unattainable.**

The **Industrial Policy Implementation Plan 2 (IPAP2)** is more specific on the role of innovation, asserting that the state should operate at three levels (the dti 2011: 76):

- Leveraging industrial development through state support for the commercialisation of new technology innovations; including those arising out of research and development at state institutions such as the CSIR
- Consolidation of existing commercial opportunities from research work previously carried out, but which has not been fully commercialised, and with respect to technologies that can be acquired in order to upscale production capabilities in defined sectors where opportunities exist
- A much clearer alignment between demand-side skills needs and training programmes and the deployment and operationalisation of new technology and industrial processes.

For reasons unknown, the CSIR, the largest science council, gains the central role IPAP2, and no other science councils are mentioned. Despite the observed potential for employment creation in agriculture, mining and pharmaceuticals, there is silence regarding the ARC, Mintek, MRC, HSRC and Council for Geoscience. Their acronyms do not even occur in the IPAP list of abbreviations although the SABS does. The mistrust and misunderstanding between government and the private sector has already been alluded to. Here one finds a lack of understanding on the part of the Economic Development Department (EDD) and the Department of Trade and Industry regarding potential actors within the state itself.

How then should the innovation system be brought to bear upon the economic and social needs of the country? The next step is to look at how **other countries** have approached the issue of governance of their innovation systems.

3.5 Comparative Perspectives

Nine country innovation systems were studied with respect to the mechanisms employed for prioritisation and agenda-setting, their institutional make-up, framework conditions, and modes of policy learning.

The countries span a diversity of history, economic structure and national polities, especially with regard to regional autonomy. **Each innovation system is unique to itself while bearing superficial resemblance to others, since there are generic elements**. Central to this is the realisation that "… the benefits of countries' science, technology and innovation policies, including specific policy instruments, cannot be adequately assessed outside the specific context of the national innovation system for which they are designed" OECD (2005a: 7).

Among the countries studied, Australia, Norway and Brazil are three commodity exporting countries. The **Australian system** bears the closest superficial resemblance to South Africa. The Australian innovation system is larger, but its set of institutions is similar. What stands out is Australia's commitment to representative, transparent, high-level prioritisation and policy learning through institutionalised monitoring and evaluation, and foresight. This is embodied in

the expert-member **National Innovation Council** chaired by the Prime Minister, the Office of National Assessment, and the National Centre for Innovation Research. The responsible Ministry is a **combined Ministry of Innovation, Industry, Science and Research** (similar to the UK Department of Business Innovation and Science). A salutary lesson is the Commonwealth Scientific and Industrial Research Organisation's (CSIRO) long, costly and ultimately successful experience in enforcing its Wi-Fi patent rights. Where New Zealand has moved most strongly to push its public research organisations (PROs) to the market, invoking strict application of the client–contractor principle, Australia has retained its PROs and promoted the partnership scheme of the Cooperative Research Centres.

Public research organisations play a very small role in **Norway**, and unsurprisingly it is the **Minister of Research and Higher Education who chairs the Cabinet committee** responsible for prioritisation and coordination. Norway has lower than average innovation indicators, but high growth. Three important features are its culture of administrative fairness, statutory evaluation studies and institutionalised strategic intelligence (through NIFU-STEP, the Nordic Institute for Studies in Innovation, Research and Education - Centre for Innovation Research). The relatively weak coordinating authority in the figure of the Minister has endured because of the culture of fairness in Norway, but there is also recognition of fragmentation and weakness in addressing demand-side needs. The relative lack of coordination in Norway is the result of "… the lack of a national arena for setting consensual priorities" (OECD 2008: 155). Norway has also raised state revenues for R&D through taxes on resource rents.

Brazil, by virtue of size, is in a class of its own, showing how a federal system of innovation can function in practice alongside a strong commitment to building state-level regional systems of innovation. This is possible since the Brazilian states are empowered to raise taxes that may then be deployed towards innovation support through **state-level innovation funds**, for example, FAPESP (the Foundation for Research Support of the State of São Paulo). At federal level, there are a number of practices and instruments that may be adapted to the South African situation: administrative transparency, the CV database Plataforma Lattes, the Innovation Fund (FINEP), the resource levy-supported sectoral funds and the incubator movement. The arms-length **Center for Strategic Studies and Management Science, Technology and Innovation (CGEE)** plays an **i**mportant role in supporting policy learning.

Malaysia stands somewhere between commodity producer and high-technology factory producing items under licence for export. With its Bumiputera affirmative action policy, Malaysia presents the chance to observe how such a policy plays out over time. Malaysia succeeded in the export market through the exploitation of cheap labour, authoritarian rule and government subsidy. It now faces stagnation since its universities and research base have not been sufficiently developed. The country experiences brain drain, in part driven by quota policies. Whilst STI information is centralised in the **Ministry of Science, Technology and Innovation**, doubts have been expressed as to the validity of some of this work.

Finland, Korea, Austria, Sweden and Belgium are export-led economies. **Finland** has a high-level stakeholder-based steering committee, the **Research and Innovation Council**. While a recent external evaluation was critical of Finland's present willingness to adapt, the response to the 1987 OECD review was exemplary for its engagement, and may well have empowered Finnish policy-makers to respond to the crisis of the collapse of their trading relationship with the USSR post

1992. The modus operandi of TEKES (the **Finnish Funding Agency for Technology and Innovation**) is worth noting: the TEKES board, together with the major stakeholders, determines the thematic programmes; roll-out is through a mix of grants and loans, without equity stakes or a share of resultant intellectual property. TEKES claims this has had positive effects – companies have increased their commitment to R&D, strengthened university–industry links and international collaboration. TEKES' major successes include Nokia, software firm Rovio, and dairy processor Valio with its low-lactose products. Finland, like Brazil and South Africa, shows wide regional disparities.

South Korea's experience between 1910 and 1945 resonates with South Africa's history of discrimination. The Korean response was different, since Korea is highly authoritarian, and is not open for emulation with the exception of one aspect – education. The high accord and expectation given to educators is an essential ingredient of Korean success. Korea also functions with a very **high-level innovation council** and makes extensive use of foresight. The particular style of governance is uniquely Korean, reflecting the country's deep culture as well as the power of the family-owned *chaebol* conglomerates and their closeness to government.

In the early years of Korean industrialisation, R&D was state driven. It is important to note that Kim (1997) questions how much publicly funded R&D was actually transferred, let alone commercialised. What was important was the role of state research laboratories in deepening the skills base.

Perhaps the most important learning from Korea and Finland is that education matters, and that skilful location of universities, based on government–industry–community participation can catalyse regional and industrial development. Brazil's recent experience in attracting foreign-funded R&D centres is a confirmation of the importance of having a critical mass of engineers and researchers.

Belgium and Austria are both small open economies. They exhibit a diversity of governance forms with strong regional dimensions. Both have evaluation mechanisms in place, but these show limited efficacy. Belgium's CV database is worth noting, as is the fluid employment regime that characterises Imec at Leuven. Austria leads the way in extending state incentives to start-ups in their 'before profit' phase, in other words, a direct subsidy for R&D.

Sweden offers the paradox of high R&D expenditure with lower than expected outcomes. Sweden, like Finland, made a rapid shift from a resource-based to a knowledge-based economy. It also has deep education traditions and a small public research sector. Direction of the innovation system is at a lower ministerial level, and has come somewhat late in the day. Like South Africa, Swedish companies appear to prosper more internationally than locally. The implication is that companies know best where to invest and take risk, and presently that is less at home and more abroad.

Evaluation has high priority in most of the nine countries, with Korea, Malaysia and Brazil perhaps making least use of this. A number of the countries have institutionalised STI information

systems: MASTIC in Malaysia, Belspo in Belgium and NIFU-STEP in Norway perform valuable work. In a number of countries, foresight is also institutionalised.

All of the nine countries show **interest in promoting industry–science relations**. The OECD (2005a) argues that the **main value of science to industry is the provision of skills, followed by new knowledge, new technologies, new methods and equipment prototypes**. Transfer involves recruitment, networking and the capture of codified information by means of open publications or restricted contract work. Occasional spin-outs involve the migration of staff and tacit knowledge into new companies. Industry–science links involve signalling between the research and industrial systems about what the important problems and the potential solutions are, thereby improving the alignment between the activities of the research system and societal needs.

The last issues to be considered are **intellectual property rights** and the importance of patents as indicators of market potential. Little mention is made in policy documents of the position of the state with respect to ownership of IP resulting from the use of public funds. The governments of Finland, Canada, Korea and the United States forego ownership of IP resulting from publicly funded R&D. The experience in the United States since the Bayh-Dole Act is that firms have often shied away from working with universities out of concern that their intellectual property would be jeopardised. For companies to invest in R&D is risky; actions on the part of government that increase that risk should be a matter of last resort. As Edquist (2009) argues "... for public intervention to be motivated in a market economy, (1) private actors and markets must fail to achieve the objectives formulated (i.e. a problem must exist), and (2) public actors must have the ability to solve or mitigate the problem".

Korea and Finland point to the **important role of crisis** in re-orientation. Apartheid South Africa met the crisis of international isolation with 'Total Strategy'. Chile, faced with a crisis of stagnation, decided to move up the agriculture value chain by improving its wines, producing out-of-season fruit and vegetables for Northern markets, and embarking on aquaculture (focusing on salmon). Finland moved into high-technology exports. Such demand signals are an essential focusing device for the system of innovation.

These pointers will be woven into the recommendations to follow below.

3.6 Towards a Research and Innovation System?

The National Planning Commission has declared poverty to be the major crisis facing the country. This is a view with which the Committee associates itself.

Poverty is multi-faceted, so that electrifying an informal settlement (a technology solution) in the wrong place (a political legacy) barely impacts the drivers of poverty. Electrification plus apartheid planning is still apartheid. Such service delivery shortfalls reflect deep political and system failure, rooted in South Africa's legacy and structures, rather than resulting from a poverty of technology.

If the innovation system is to adopt the war on poverty as its major mission, then the system actors must (i) draw on their core competences and (ii) construct additional mandates. This melds legacy and vision, and conjures the image of two-headed Greek god, **Janus, who looks both back and forward**. The war on poverty is the 'Janus Mission' for the emergent research and innovation system The Janus Mission will be the game-changer.

It is important to clarify the reference to the research and innovation system. Through numerous interactions with parties both inside and outside government, the Committee is persuaded that **the concept of the national system of innovation has failed to gain adherents beyond the Department of Science and Technology**. There are many reasons that may explain this lack of traction: the position of the Ministry of Science and Technology in the hierarchy of government departments; fear and distrust of science and technology engendered during apartheid exclusion; lack of appreciation of the long-term value of S&T; trade union hostility to the 'creative destruction' of new technologies. To this may be added the persistence of the research-led linear model of innovation, a misconception perpetuated in the media stereotype of the white-coated scientist (usually a white male) bringing some new wonder object out of the laboratory. It is time for a real change. The distinction must be highlighted: **research may lead to innovation, but it is not innovation**. This is more than a semantic distinction.

To affect this shift, the Committee proposes major changes in system governance. It is useful therefore to reiterate what is expected with respect to the governance of the research and innovation system:

- **Agreed mechanisms for prioritisation and agenda setting**
- **Ensuring an enabling environment for innovation of appropriate policy and regulations, including protection of IPR and provision of direct and indirect incentive schemes**
- **Provision of knowledge infrastructure and promotion of human resource development, including mobility**
- **Mechanisms to promote knowledge transfer and exchange, including dissemination, networking and internationalisation**
- **Exercise of oversight, and the accountability of those entrusted with implementation**
- **Policy learning, resting upon monitoring, measurement and evaluation, for review and synoptic purposes.**

Most important is the overall purpose of the research and innovation system. The system makes use of scarce resources and must account for its choices (doing the right thing) and implementation (doing the thing right). The interdependence among the different parts of the innovation system means that piecemeal efforts to improve its performance are not effective on their own. The higher education system cannot expand to meet development needs if the schools fail to educate children properly. They cannot grow by importing and training foreign nationals if immigration policies force those foreign nationals to leave South Africa once they are trained. Companies cannot increase their R&D effort if the universities do not do research and postgraduate education in fields relevant to them, and they may struggle to innovate in the absence of technical services such as metrology. Compared with peer countries, what is singularly

lacking in South Africa is the ability to define and implement mutually consistent policies across different parts of government that enable the development of the national system of innovation and therefore economic growth and development. To do this, **South Africa needs a body for high-level coordination, prioritisation and agenda-setting in the research and innovation system.**

The Committee therefore offers a set of recommendations designed to achieve a governance architecture that is fit for purpose. In so doing the Committee rejects the adage that 'restructuring is an admission of lack of strategy'. The Committee's carefully considered opinion is that restructuring cannot wait; that the inherited structures must be shifted decisively; and that all affected parties are urged to embrace the advocated changes. The Committee argues for a new research and innovation system in which the social sciences, humanities, natural sciences and engineering work in harmony. The change is to be promoted through a high-level consensus-seeking body.

3.7 The Department of Science and Technology

Despite the shortcomings of the NSI, the Committee regards the **public recognition of the DST as a 'good government department'** to be well-deserved. Pioneering initiatives and successes have included:

- The launch of the Innovation Fund and Biotechnology Regional Innovation Centres;
- The setting up of National Centres of (Research) Excellence and the more recently introduced Centres of Competence, as well as the South African Research Chairs Initiative (SARChI)
- A very successful programme of international liaison for research exchanges, collaboration and the general enhancement of available resources
- The currently aggregating and further evolving major components of the National Space Programme
- The key departmental contributions in the Industrial Policy Action Plan, such as the tax incentive scheme for company R&D, the setting up of TIA, NIPMO and university technology transfer offices, and support towards the costs of patenting
- The operation of a spectrum of schemes to enhance R&D cooperation between business and higher education
- Fostering the growth of the Academy of Science of South Africa (ASSAf)
- Many on-going interventions in the technical and knowledge-using capacitation of small and medium firms (through technology stations) and other enterprises featuring prominently in the Minister's current performance agreement with the President.

Balanced against these achievements are the reservations expressed by the OECD review panel five years ago about the functioning of the NSI as a society-wide system, which is largely congruent with the assessment of the current situation in the present review:

- There is still **no common understanding of the NSI** and its purposes across government departments and beyond, and there is uneven support for it, even where it appears to be understood.

- The New Strategic Management Model (NSMM), established in 2004, emphasised a cross-cutting role for the DST in setting common governance standards and quality assurance mechanisms in place for each SETI. In the case of sector-specific science councils, the function of the DST would be to develop interventions in the case of market failure, under-subscription or where there were technology gaps of a strategic nature. The NSMM provided for sector-specific research agencies to remain in the domain of their respective line departments (the Medical Research Council [MRC] with the Department of Health, the Agricultural Research Council [ARC] with the Department of Agriculture, Forestry and Fisheries etc. The **DST, largely as a result of the NSMM organisational model set up in 2004, has not been in a position to create a coherent, truly systemic policy framework to promote and coordinate the NSI**, and has been obliged instead to throw its energies into activities that it seems to have undertaken in the manner of a 'line department', rather than as a system-wide facilitator.

- **The trust placed in voluntary inter-departmental cooperation across the system has not, perhaps predictably, been vindicated**. For example, even a very promising and well-formulated collaboration agreement between the DST and the Department of Higher Education and Training (DHET), already drafted in August 2010, had not been signed by the beginning of 2012, while the Knowledge Economy Forum activities and structures initiated by the DST in order to mobilise joint action across departments have petered away.

- Virtually no prospective NSI planning as envisaged in the White Paper has been possible (although the Committee appreciates that a **funding cluster on Research, Development and Innovation** has been adopted in the current Medium-Term Expenditure Framework), and the retrospective annual STA Report on government expenditure in these areas does not enjoy wide distribution or exposure.

- **NACI has been constrained** to 'advise' only in the same limited NSI domains in which the DST can operate.

- **Supply-side thinking remains pervasive** (with continued emphasis on the linear model of innovation), leading to a continuing poor response to market and social demand.

- There is still **too little systemic coherence and sense of common purpose between the private sector, government, higher education and civil society in NSI functioning in its broader sense** (including governance, decision-making and allocation) or in the agenda for national development.

The key performers of research, development and innovation are private-sector business and state-owned enterprises (SOEs), on the one hand, and public higher education institutions and science councils, on the other. A degree of systemic agenda-setting and prioritisation can be achieved in the private sector itself, especially if it is effectively drawn into the overall governance and delivery vehicles of the NSI, while SOEs are in principle directly amenable to systemic approaches and interventions designed to enhance innovation (see Section 2 of the Executive Summary: The enabling environment for innovation in the private and social sectors).

An example of enhanced systematisation would be **wider stakeholder participation in public-sector funding processes** than is currently the case, where for practical purposes only portions of water and energy research are informed in this way. The generally successful introduction in other countries of **sectoral funds**, administered by boards drawn from a variety of stakeholders, suggests that the benefits already generated by the existing public researcher industry incentive schemes could be extended if some public R&D funds were granted by sectoral boards rather than by the traditional panels of the NRF (this would have to be 'new money', as the existing agency provision is wholly inadequate).

The **state** itself is potentially a powerful site of innovation, both in how it delivers on its mandate and how it forges common purposes with other social partners. **Civil society** also provides a platform for innovative initiatives and brokerage potential between social actors, while having only limited capacity to take innovation to scale.

The overall conception of the NSI must thus take the full range of social actors into account, and work to marshal their distinctive capacities towards addressing the socio-economic development imperatives of the era. These large and complex challenges will mostly not be resolved in the short term, but the means must be constructed now for systemic collaboration between the various sectors in the longer term.

3.8 Structure of the Public Sector National System of Innovation

The current structure of the public sector actors that contribute to the NSI was well described in the 2007 OECD Review, and in summary these operate at four levels:

i. High-level institutions statutorily mandated to provide policy advice to government on innovation, or innovation-related functions, including the National Advisory Council on Innovation (NACI), the Council on Higher Education (CHE) and the National Science and Technology Forum (NSTF)

ii. Government ministries and departments

iii. Research and innovation agencies, including the National Research Foundation and the Medical Research Council

iv. Research-performers, including universities and science councils.

The systemic challenge contained in the idea of the NSI is the need for these agencies, at their various levels, to achieve a **collective coherence in the complementarity of their functions**, and a coordinated impact that makes the best of the resources invested in these entities. The challenges of coherence and coordination run both vertically up and down the levels of authority in the system as well as horizontally between the agencies. As the evaluations provided by the OECD and numerous other reviews have suggested, and as this Committee has noted in its comments above, there is much that must still be done to optimise the functioning of the system.

In particular, a **greater clarification of roles** between various agencies is needed in order to sharpen mandates and rein in mission creep; greater effects can be achieved if the efforts of specialist capacities in addressing complex challenges are well coordinated; and the best-informed intelligence from all quarters of the system must be gathered in setting priorities and deploying resources. There is a need for stronger reciprocal channels of communication, including more strategically configured evaluations of the performance of the system and its constituent agencies.

The need for greater coherence and coordination has long been understood, and a variety of statutory and voluntary mechanisms have arisen to these ends. In addition to the organisations already noted above, and various government-driven efforts to achieve coherence across clusters of departments or across priority outcomes, there are numerous sectoral bodies such as **Higher Education South Africa (HESA**, for higher education institutions) and the **Committee of Heads of Organisations of Research and Technology (COHORT**, mainly for science councils). The contribution of these devices to the strengthening of the NSI varies, but there is little doubt that much more can be achieved than is presently the case.

3.9 Recommendations

In general terms, the Ministerial Review Committee recommends that **the clear and inspirational White Paper conception of the NSI be publicly re-endorsed by government as a potentially decisive driver of national economic and social development, indicating clearly that the NSI must be pervasive and truly systemic in its design and functioning, and that its functionality is core to any systematic national approach to creating jobs, addressing poverty and providing fulfilling life opportunities to all South Africa's people and communities**. What is needed more than ever is a high-level expert body that will offer guidance to the NSI as a whole, a role that neither the defunct MCOST nor NACI has been able to fulfil.

Recommendation 1: The Committee recommends the establishment of a compact (15–20 person) statutory National Council on Research and Innovation (NCRI) to carry out the task of prioritisation and agenda-setting for the NSI, oversight of the system and high-level monitoring of its evolution, outcomes and developmental impact. The Council should be chaired by the Deputy President to emphasise its seniority and its pervasive systemic functions across government and society. The Minister of Science and Technology should be Deputy Chair and Implementation Coordinator because of the key facilitation role of the Department of Science and Technology in the NSI as a whole. The membership of the NCRI should include the ministers from key departments, and influential figures from the private sector, higher education and civil society best positioned to advise on issues of development and innovation. The NCRI must ensure that optimal framework conditions prevail and that financial resources are adequate and must receive system-wide evaluations. It must act to build trust through promoting a culture of responsiveness and administrative fairness. The Council must be equipped to make the hard calls to meet demand and to create supply.

The Committee is of the opinion that failure to establish such a high-level steerage mechanism for the NSI will mean no coherent strategy and no real progress for many years to come. The 2008 review of NACI pointed out the urgent need for the creation of such a body; NACI itself, as currently constituted, is not equipped to perform its proposed roles.

A first task for the Council must be to map out the demands on the research and innovation system for the next decade, and then to advise on broad measures needed to galvanise system actors to these ends, including advising on the mix of public research organisations needed to take up system or market failure.

The Council would make recommendations on future Grand Challenges, major allocations, major equipment needs and new sources of funds. The Council should receive and comment upon all system-wide evaluations, as well as maintain a watching brief on large projects with annual budgets in excess of an amount to be determined by the DST from time to time.

The Council must ensure consistency of efforts to address the supply of high-level resources, from schooling and from further and higher education and training, from other sites of training and across government, the private sector and civil society as a whole. It would be expected to identify policy inconsistencies and recommend appropriate changes.

Recommendation 2: A unitary Research and Innovation Vote should be established, designed to extend beyond the original version that operated until 2005, to function as a macro-coordinating mechanism to ensure that the country's public researchers in all public research-performing institutions (i.e. both higher education institutions and science councils), are adequately supported to perform their work. The NCRI, in consultation with cognate advisory bodies, should provide the oversight of the broad size and shape of this allocation. The NCRI should not be responsible for making specific budget allocation decisions, however.

Particular attention needs to be given to the adequacy of public funds awarded to research performers throughout the system as grants (to higher education institutions) or budgets (to science councils). There has been clear recognition for some time (in successive NRF and MRC SETI reviews, for example) that the average amounts of funding made available in agency mode have been inadequate for their multiple purposes of generating new knowledge and human capital as well as innovations. The total amounts allocated by the NRF and MRC, as well as the incentive schemes for industry for public researcher collaboration, must accordingly be increased to about twice their current levels as soon as possible.

In this context, the Committee is of the opinion that **the public grant-making agency function should be consolidated within the NRF**, so that a common policy framework and better-coordinated delivery model can be built, incorporating and generalising the successful instruments of promotion (Centres of Excellence, Centres of Competence, Research Chairs and major equipment provision) that have been introduced with such significant impact in recent years. This would incidentally also facilitate re-considering the mandate of the MRC as a science council.

Recommendation 3: The present NACI should be transformed into a new statutory Office for Research and Innovation Policy (ORIP). This arms-length body should compile evidence regarding

both success and failure across the system in order to inform policy and planning by the NCRI and the DST, and associated policy nexus platforms. Among other things, ORIP should monitor the research investment climate, to determine and advise on any inhibiting factors and the performance of the system in responding to priority needs identified by the NCRI. The ORIP should, for example, be responsible for the **National R&D and Innovation Surveys**, and for **designing information and indicator systems, technology foresight and social fabric studies; and the development of a researcher database** (see Section 6 of the Phase Two report: Monitoring and evaluation, for details). ASSAf should work closely with the proposed ORIP to ensure that sound, multi-perspective, evidence-based reviews of key issues in the NSI are conducted.

Recommendation 4: The Ministry and Department of Science and Technology should henceforth primarily function as a pervasive, systemic formulator and coordinator of NSI-related policy and strategy, consistent with the decisions of the NCRI, allocating macro-resources, promoting system learning through the oversight of effective and integrated monitoring and evaluation, maximising international cooperation and resources, systemically overseeing public research organisations, and providing best-possible knowledge infrastructure (people, equipment and facilities, and cyber-infrastructure) within the public sector.

Recommendation 5: In order for the NSI to be systemic in the fullest sense, the Committee recommends that **the NSI needs at least three well-functioning 'core' policy nexuses, each structured through a written collaboration agreement spelling out how policy harmonisation and the coordination of implementation action plans would be continuously ensured:**

- **One focused on post-school education and training involving the Department of Higher Education and Training (DHET) and the DST**
- **One focused on business and enterprise development, involving at least the departments of Trade and Industry (the dti), the Economic Development (EDD), Public Enterprises (DPE) and the DST**
- **One focused on social development and social innovation, involving the DST and departments concerned with social and rural development, and the social security, health and education complex.**

The Committee states that failure to create well-functioning policy nexuses as described will very likely be associated with serious and continuing stasis at the very core of the NSI.

Recommendation 6: Because grant-making is not only a question of the amount of funding but also of its efficacy, **the Committee recommends the purposeful elaboration of a new, additional mode of public grant-making based on the principle of cooperatively allocated sectoral funds**. The priority sectors for such a mode would be identified by the NCRI from time to time (e.g. based on the Grand Challenges' of the TYIP). **Boards would be established**, **involving all NSI stakeholders**, to articulate the precise demands and to develop translational solutions. While in principle the funding could be drawn from the levies already raised against the depletion of some natural resources (minerals), as is done in Brazil and Norway, it would be easier to apply to this purpose some of the urgently required increase in total agency funding (see Recommendation 2).

The sectoral funds could address both technological and social innovation dimensions of a focus area; one of them could, for example, be a Social Innovation Fund (perhaps in partnership with private sector philanthropy) to address social innovation needs identified by the NCRI.

The new funds should be structured so that they constitute well-informed consultative forums, including industry and government actors, for the identification of sector-specific strategic priorities and the development of corresponding research and innovation agendas. Reports and recommendations from the funds should inform the deliberations of the NCRI, and vice versa, investing the funds with both systemic alignment and gravitas.

Recommendation 7: The present organisational model for government research (the DST-run science councils, the sectoral science councils and the in-house S&T technical service organisations) needs to be revised to permit coherent, integrated and optimised mandates to be designed in each case within common policy frameworks, so that strategically directed funding flows can be applied across all these significant components of, and contributors to, the NSI. **The Committee recommends that the NCRI should commission a review of the science councils and all other public research organisations (PRO)s, including, but not limited to the National Health Laboratory Service (NHLS), the scientific sections of museums, and Onderstepoort Biological Products.**

The review must enable Government to make hard choices. **It should review the reporting lines, missions, future functions and resource requirements of the science councils and PROs (including whether to terminate them, modify their mandates or establish new ones).** It should take careful account of international practice and of variations in the role of such organisations over time and at different levels of development. The review should also consider how science councils, other SETIs and the private sector could become more fully involved in postgraduate supervision and human capital development generally.

The establishment principles and mandates of research-performing science councils should be redefined and used to review each of these organisations in a 'fitness of purpose' exercise, along with the periodic 'fitness for purpose' SETI reviews.

Efficiency, effectiveness and funding considerations would attend a decision to move into the science councils many of the scientific and technical services that are currently housed in government departments, which are likely to be both more functional and innovative if they were incorporated into a relevant science council or another body. This would also apply if most or all of the national facilities currently operated by the NRF were relocated to other bodies.

The science councils and public research organisations (PROs) would be asked to engage with the review by providing:

- An analysis of their offerings, broken down as essential services (including extension services), public goods research and client-oriented research, with associated revenue, outputs and impact
- A plan, including financial and staff requirements of how they would (i) address poverty and under-development, and (ii) simultaneously develop mechanisms to meet client demand and effect technology transfer.

If fully implemented, these seven recommendations will bring about the deep structural transformation needed to enable the research and innovation system to engage with the war on poverty, enhance competitiveness, build the human resource base and contribute to improved well-being.

SECTION 4: ENABLING ENVIRONMENT FOR INNOVATION IN THE PRIVATE AND SOCIAL SECTORS

4.1 Role of the Private Sector in Innovation

The terms of reference of the Review pose the question of "whether the country is making optimal use of its existing strengths and whether it is well positioned to respond rapidly to a changing global context and thus to meet the needs of the country in the coming ten to thirty years". This question applies to the public and private sectors of the system of innovation, separately and conjointly.

To answer the question, the discussion starts with the economy, then turns to what it does in terms of renewal, expansion and innovation.

South Africa has a market economy, in which entrepreneurs play the leading role. It is this open and vibrant economy that has brought South Africa into the G-20 and the BRIC club. The economy shows dynamism and innovativeness, the Rand is freely convertible and highly traded, and the JSE has a market capitalisation among the top 20 of the world, yet the economy appears to be trapped in a low growth trajectory. In the 1960s, GDP per capita in South Africa was higher than that of Mexico, Malaysia and Korea. They have since surged ahead, while South Africa has stalled.

The 2010–2011 Global Competitiveness Index (WEF 2010) provides more detail. South Africa is categorised as a **factor-driven economy**. Of the 139 countries measured, South Africa is ranked 54th, down from 45th the previous year. While South Africa is in 9th position for financial development, business sophistication is ranked 38th, innovation 44th, technological readiness 76th, labour market efficiency 97th and health and primary education 129th. This seems to be paradoxical – sophisticated financial systems alongside poor health and education outcomes. The cynic might retort that there is no paradox, and that this is an artefact of South Africa's previous and present inequalities. The indicators certainly raise interesting questions as South Africa aspires to becoming an innovation-driven economy. It is apposite to note that HSBC places South Africa at rank 30 in the year 2050, down two places from the current position.

The **composition of GDP** has shifted dramatically over the last half century. Currently GDP is made up of agriculture, forestry and fishing (2.7%), mining and quarrying (7.3%), manufacturing (18.6%), electricity, gas and water (2.3%), construction (2.4%) and services 66.7%. The main feature is the rise of manufacturing and the fall of the share of mining. As such, the economy resembles that of an OECD member state. It is services led, and agriculture at 2.7% plays a small role, although it employs 9% of the workforce.

The same shift is seen in the **composition of exports** (Edwards and Alves 2005), in which the value of manufactured goods has surpassed mining. In the 1970s, gold made up 60% of exports; by 2000 this was down to 29%. Nonetheless, South Africa's exports still comprise commodities to

a large extent, along with motor vehicles and components, none of which embody South African intellectual property. There is no IP in a gold ingot or ton of coal. The IP in a German coupé is owned in Stuttgart, not East London.

A relatively **small number of companies dominate the economy**, some with roots going back nearly two hundred years; others, especially in telecommunications, are naturally younger. Many 'local' companies are the successors of originally foreign-owned companies since acquired by local interests; Altron is a good example. In similar vein, South African transnational corporations (TNCs) acquire companies abroad. This is the nature of globalisation, with mergers and acquisitions in all directions, and some 'greenfield' investment too. The international expansion of South Africa's TNCs is mainly through acquisitions, as for example the case of SAB Miller buying up brewers from Patagonia to Perth. Australian BHP purchased South African Billiton; South African Old Mutual purchased Swedish Skandia. These are the dynamics of an open economy.

Foreign mergers and acquisitions are not enough, however. The domestic economy must expand and thereby create employment opportunities, and it is the private sector that must make this happen. So far this has not occurred.

What then is to be done? The simple answer is for South Africa to focus, build on what it has, and grow what it does not have.

According to Hobsbawm (1962) industrial revolutions require two things, the prospect of high profits and a monopoly position. Diamonds and gold powered South Africa's industrial revolution, and, with cheap labour, offered fabulous profits, thereby creating the mining houses. What did not happen was Hobsbawm's second stage, the emergence of a strong capital goods market. The plausible vision referred to in Section 3.1 above suggests what such a capital goods sector might look like.

The turning point came in the 1970s as 'peak gold' was reached. Today South Africa produces less than one quarter of that level. Fortunately, platinum ('white gold') has come to South Africa's rescue, and it now exceeds the export value of gold. The issue is that mining involves the wasting of an asset. Diversification of the economy did occur, but too much effort went into the fruitless quest of preserving white hegemony at any cost. The large space between mining and services has to be filled by yet more productive activity. The 1990 turning point saw globalisation without industrial deepening, except for automotives and a few other niche players.

Figure 2 illustrates how this **industrial deepening** might come about. It is an adaptation of the well-known illustration of Finland's diversification from growing pine trees to becoming a leader in pulp and paper and associated machinery (Routti 2007; Kahn 2007).

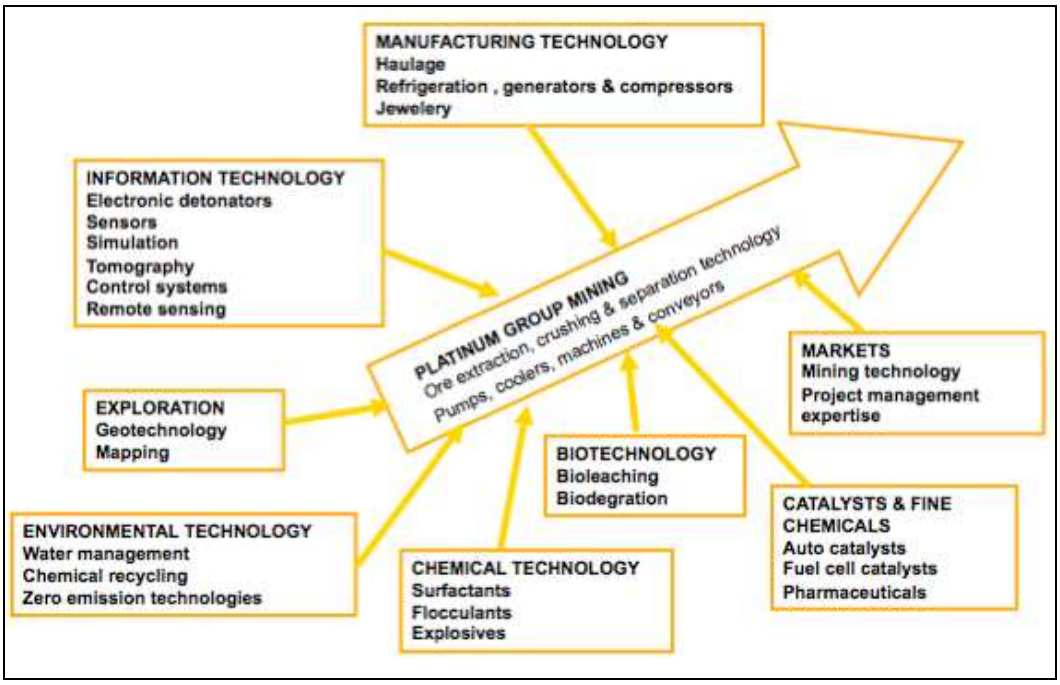


Figure 2: Securing competitiveness in the platinum group mining sector

This diagram makes the case that **diversification** is not only possible, but that it has already happened. Electronic detonators were a spill-over from defence R&D and the expertise in catalysts that started with Sasol's desire to break the US monopoly on the supply of iron catalysts. Bioleaching of minerals was a Gencor technology. That company no longer exists, and BHP Billiton is a leader in the field. Though few in number, South Africa holds patents in virtually every box in Figure 2 and has expertise in the others. Further horizontal diversification is desirable, possible but constrained.

At the same time, **infrastructural weaknesses** have compromised the real potential of mining exports and employment creation.

The reasons for the constraints on diversification are complex and disputed. It is agreed, however, that there are risks in the actions of starting a business, introducing new product lines and re-organisation. Factors that increase that risk may induce those with excess capital to seek opportunities with lower risk and higher returns elsewhere. This is the essence of free markets.

Innovation entails the introduction of new or significantly improved goods or services, or processes into a market or organisation. That is the standard definition for business, and is relevant to this discussion. Innovation activities are diverse and include the search for information, bringing in new skills, reverse engineering, design, R&D, training and protecting intellectual property.

The private sector is the most important source of finance for, and performer of, R&D; it is a key strategic partner for government to engage with in promoting R&D investment in the

country. The private sector consists of local businesses, including small, medium and large enterprises, foreign-owned companies in South Africa and other foreign R&D-intensive companies that invest in South Africa in a variety of other ways.

Government has little direct control over the private sector in respect of self-driven R&D but plays a critical role in creating favourable framework conditions for product and process innovation, as well as 'steering the ship' to support mainstream policies and attain national objectives. Government obviously exerts much more influence over state-owned enterprises, several of which are major performers of R&D, both here and elsewhere, which accounts for the 20% of total business R&D expenditure sourced from government. This is mainly sourced from government; increasing R&D in this sector is therefore relatively simple if the will to do so is present.

It stands to reason that factors that increase the risks associated with innovation may impede its introduction. The adage should be remembered that 'necessity is the mother of invention'. For necessity some might substitute the word 'crisis.' Above all, South Africa's historical record shows a people that can innovate 'out of a bind'.

Two sources of evidence serve to inform the thinking about private sector innovation in South Africa, and placed together they constitute another paradox. The first and most commonly used evidence is the award of **patents at the United States Patent and Trademark Office (USPTO**); the second is softer and arises from what is known as the **Innovation Survey** (OECD 2005c).

Put concisely, South Africa's patenting intensity has remained static over three decades, but is showing signs of revival with 91, 93 and 116 US patents in 2008, 2009 and 2010 respectively. Other countries such as Brazil and Norway that are also commodity exporters show a much faster rise in patenting levels. South Africa is lagging behind. It is some consolation to recognise that South Africa has a historic depth of patenting in technologies such as catalysis, ore separation and transportation, and electrical switching.

According to the official Innovation Surveys for 2002–2004 and 2005–2007, the proportion of South African companies claiming to have introduced innovations is among the three highest of the 60 or so countries that carry out such surveys. It is paradoxical that South African companies innovate, but do not patent; they innovate, but this does not translate into new jobs.

Part of the reason lies in the **types of innovations** that are introduced, which are mainly incremental and adaptive. In this, South Africa is similar to many other countries, including Denmark. Korea, in its industrialisation over the period 1963–1987, was awarded only 343 USPTO patents and largely engaged in imitation and reverse engineering; over the same period, the South African tally was 1744. This is the historic depth. The low levels of patenting activity arise from the fields in which South Africa is at the technological frontier, and in which it is necessary to register patents. Many of South Africa's high-technology exports are in the military domain where patenting is avoided in order to protect trade secrets. For medium-high technology such as

automotive products, South Africa is an original equipment manufacturer (OEM), which involves no local patents.

To this picture must be added other evidence from the Innovation Surveys. As in other countries, South Africa companies get their ideas for innovation mainly from other companies. Suppliers make changes that impact on the manufacturer; customers demand something new; the competition nibbles at market share. To innovate is to survive and prosper.

In the schema of innovation systems, the private sector, universities and public research organisations synergise toward innovation. The issue is where public research organisations feature in the complex activity of innovation.

As noted above, the prime sources of innovation for companies are other companies. Companies will collaborate with outside entities if it makes sense in terms of risk, financial reward and protection of their intellectual property. As in other countries, South African companies attribute much lower importance to universities and public research organisations as sources of information for innovation. A concern is that there has been a decline in the perceived importance to innovation of universities and public research organisations over the period 2004 to 2007. The universities, science councils and other public research organisations remain the primary sources of the highly skilled that bring to business new ideas and competences in the use of advanced scientific equipment.

Generally speaking, according to the definition of innovation, universities and public research organisations are not in the business of innovation. Universities are essentially in the business of teaching and research, while the public research organisations perform essential services and conduct applied research. Innovation should not be confused with research. Without universities, companies would be starved of the highly skilled and the new ideas that they bring.

There are two important exceptions to this characterisation of public research organisations, namely to those working in agriculture and health. In both cases they are also major sources of innovation. South Africa is 13th in the world (2.6% of the total) for the registration of plant varieties, an achievement involving the private sector, universities and the ARC. This goes a long way to explaining the country's food security, and why South Africa is a successful exporter of agricultural products. There is a sectoral system of innovation in agriculture.

Two further aspects of the relationship between the private sector and higher education are important. The first is that by world norms, the R454 million of **local private sector funding of research in the universities** was among the highest in the world at 10.8%. (If foreign private sector funding were added, the figure would be considerably above the world norm.) Moreover, roughly half of the R454 million flows as a result of THRIP. The second is that the private sector, locally and globally, has high regard for the leading research universities, hence the inclusion of the Universities of Cape Town, the Witwatersrand and KwaZulu-Natal in the international league tables.

National Treasury, the dti, the Harvard Group, and others have sought to understand what is holding South Africa back and then to craft policy for the economy to break out of its constraints. The dti's Industrial Policy Action Plan and EDD's New Growth Path represent the government's response to this. DST for its part has sought to revitalise the innovation system through the Ten-Year Innovation Plan.

According to Harvard academics Hausmann and Klinger (2006), South Africa's export predicament is central to the argument that for South Africa to grow, it must export. Their paper concludes, "A lagging process of structural transformation is part of the explanation for stagnant exports per capita. **Slow structural transformation in South Africa is found to be a consequence of the peripheral nature of South Africa's productive capabilities**." The paper notes that South Africa is an outlier among comparator countries, but has strengths in four sectors in which existing technological capability can be expanded to grow export markets, namely agriculture, machinery and equipment, chemicals and pharmaceuticals. It is because of the structure of the economy that South Africa's innovative activity remains incremental, and, as measured by patents the country is lagging.

Three expert contributions were commissioned to inform this section.

Segal (2011) provided a case study on the generation of intellectual property by examining 'dry cooling' power station technology. Eskom is a world leader in this area, but patenting does not protect the IP as "it is not in the culture of the electricity supply industry, perhaps particularly in the power utilities themselves, to think proactively and certainly protectively about management of its intellectual property. This attitude is inevitably reinforced by the fact of so many utilities internationally being publicly owned monopolies that typically do not compete with one another" (Segal 2011: 9). Eskom has a great deal of know-how, but no associated product to export in this case.

Kaplan (2011) addressed industrial policy, noting that the inputs to innovation[5] appear to have been accompanied by stagnation or low growth in outputs, which points to inefficiency. Since the system is thus sub-optimal, "**the first-order policy priority should be improving the efficiency of the system rather than expending more resources**". He goes on to argue that there is no correspondence between the dti/EDD industrial policies and the technology and innovation policy of the DST, and then offers two suggestions that echo with the Harvard advice: firstly, that attention should be given to working with existing technological competences and migrating these into new areas of production rather than trying to emulate the world leaders at the technology frontier; and secondly, that South Africa should invest in sectors that exhibit a "high ratio of training and innovation per increase in unit of output".

It is the social impact of innovation that Marcelle (2011: 4) seeks to address since, "The biggest challenges facing countries in the developing world include poor health services, lack of affordable housing, environmental sustainability, energy, poverty, urban management, and a range of other issues that affect quality of life." This implies a different focus for R&D efforts, since in her view local "R&D aimed at producing technological breakthroughs at the technology frontier is almost negligible" (ibid 4). Her assessment (ibid 5) is that, "**The average South African**

[5] Business expenditure on R&D in 2008 Rand almost doubled over the period 2001/02 to 2008/09.

firm does not have active learning as a distributed networking process in which firms learn through interaction within a highly differentiated network including strategic alliances and collaborating competitors."

These three inputs share a common theme of how companies go about learning, adapt to the environment and formulate appropriate strategies.

The list of plausible areas for export growth suggested by Hausmann and Klinger (2006) is considered one by one, seeking evidence for strength and alignment with industrial and innovation policy, namely: agriculture, machinery and equipment, chemicals and pharmaceuticals.

Evidence of strength in **agricultural development** has already been mentioned, citing prestige in plant cultivars. This is matched with research across related fields (plant science, ecology, environmental science) that make up some 20% of South Africa's total scientific output. Agriculture is the theme of the 'Farmer to Pharma' Grand Challenges of the Ten-Year Innovation Plan (TYIP).

In the **machinery and equipment** sector, there are pockets of expertise in mechanical engineering and mechatronics in the universities (and universities of technology) that extend into the private sector through the Denel group and heavy engineering works on the East Rand, and include companies such as Bell Engineering and Defy (Segal 2011). In the period 2000–2004, South Africa was ranked 13th in the patent class for power conveyors (Pouris 2009), an activity involving mechanical and electrical engineering. There is also expertise in Eskom, Transnet, the CSIR and ARC. However, South Africa has dropped in the rankings and is now ranked 18th for Power Conveyors. Heavy equipment is a field that South Africa could enter, given the will, as sketched out in the thirty-year scenario (see Section 3.1 above) South Africa has the steel and the energy, and the expertise can be grown. A decision is needed in this regard.

The evolution of Bell Engineering and Defy may be noted in passing. Both companies found it necessary to enter into technology-sharing agreements with foreign partners. Bell Engineering shares technology development with 31.6% shareholder John Deere of the US but remains based in South Africa, while Defy has left Franke Holdings of Switzerland and is now owned by Arcelik of Turkey, the third largest white goods manufacturer in Europe. Bell Engineering and Defy began as small family concerns, which is nothing new. Pick n Pay and Bidvest also started small, and became large. While there is a vast literature on macro-economics and labour economics, there is a huge gap in the knowledge of how small and micro enterprises emerge and prosper. One may look with admiration at the two hundred company case studies assembled under Kim (1997) that provided a basis for understanding the shift in Korea from imitation to innovation. That approach is certainly worth copying in South Africa.

Interestingly, if by equipment is meant **electrical equipment**, then South Africa is already a niche player, exemplified by UEC, Reunert, Circuit Breaker Industries, Tellumat, the former Omnipless (now Cobham), the Denel group and others, many of which use know-how arising from defence-

related research spill-overs. These are all world-class companies, some of whose technologies are patented, and some not. Over the period 2000–2004, South Africa was ranked 18th in the patent class Communication: Electrical. These companies contribute to South Africa's small volume of high-technology exports. It should be noted, however, that over the period 2006–2010, South Africa slipped to 24th rank in Communication: Electrical alongside Norway.[6] It is the residual expertise in the Telemetry Cluster of Innovation that makes the Space Science and Technology Grand Challenge an interesting possibility. Whether this should be a Grand Challenge priority is another matter.

Most of the South African patents at USPTO have been awarded to Sasol, essentially in Chemical Engineering and related fields. Sasol increasingly also holds patents in other countries where it is involved in production; its patent share is ranked at number 4 in the world. Sasol maintains its own large laboratories and links closely with local universities. Where Sasol identifies expertise abroad, as in Scotland, it also makes R&D investments, but its strength lies in home-based R&D. Chemicals are already an export product.

South Africa has strengths in **pharmaceuticals** in companies such as Aspen, Adcock-Ingram and Cipla, but is currently not involved in drug discovery. Over the period 2000–2004, South Africa was ranked 22nd in the patent class Drug, Bio-affecting and Body Treating Compositions. The related scientific fields of biochemistry, biotechnology, pharmacology, microbiology and virology make up some 15% of scientific publications. It must be recognised that **drug discovery** requires massive investments and a great deal of patience. It should also be taken into consideration that South Africa has slipped in the Drug patent class ranking to number 34, below Cuba. Taking these considerations into account, South Africa's prospects become somewhat dimmer.

Pharmaceuticals may feature in both IPAP and the TYIP, but there are issues to be addressed, including bureaucratic hurdles and possibly hostile regulators. An example is found in the section of the TYIP that confuses foreign direct investment and clinical trials. By definition these are different things. To exclude clinical trials from South Africa would be an error of judgement, since professionally managed clinical trials (as they are in South Africa) are a source of learning both for South Africa and for foreign companies and essential to proving efficacy. Exclusion would be short sighted, and it would cripple the South African pharmaceutical industry to restrict foreign company clinical trials. Openness is essential to success in pharmaceuticals, including the possibility of South Africa conducting clinical trials in foreign countries if it wishes to become a global player in this field.

The background role played by public research organisations, especially the science councils and universities is integral to the above discussion, as explicated in the discussion of the governance of the NSI.

If the arguments made in Section 3 for the revision of the **mandate of science councils are accepted, these organisations would variably be special purpose vehicles of government, or of a**

[6] http://www.uspto.gov/web/offices/ac/ido/oeip/taf/tecstc/clstc_gd.htm

sector or sectors of government, designed and funded to perform operational R&D directly linked to government functions and especially service delivery, as well as R&D that is not easily or optimally done at HEIs.(whether for reasons of justified secrecy; or continuing linkage to an indefinitely required scientific/technical public service; or based on a unique facility in terms of cost and scale; or simply, and probably temporarily, to supply a skills-set that no HEI [yet] possesses; or for other valid reasons). They would essentially conduct R&D for the private sector only on the client–contractor principle, and at full cost recovery.

The discussion of the areas where South Africa has technology strength, at least as evidenced in the awarding of US patents, shows that South Africa is a small player. Elsewhere in this review, the South African innovation system was compared with that of Norway in terms of size and scientific productivity. The same holds for the above-noted patenting activity, with the exception of Fischer-Tropsch catalysis where South Africa is strong in relative terms – on par with France and ahead of Germany, where the technology began ninety years ago. Norway, despite its oil and gas reserves, is not involved in Fischer-Tropsch technology.

An important aspect of the environment for innovation is the **regulatory framework for intellectual property rights**. As noted earlier, local companies innovate, but do not patent. It is necessary to understand this behaviour. The Committee' therefore approached patent attorneys in order to gauge the suitability of the intellectual property regime and received the following responses, in summary:

- Over-enthusiasm on the part of patent applicants often confuses know-how with invention; these are quite different things.
- Patenting in the US is costly and only makes sense for those that intend to sell in that market.
- South Africa's non-examining patent regime is advantageous in speeding up IP protection.
- The patenting side of the Companies and Intellectual Properties Commission (CIPC) is functioning satisfactorily (in part because patent attorneys have close working relations with CIPC.)
- The Technology Innovation Agency has taken too long to become operationalised and has thus introduced further delays and uncertainties for beneficiaries.

The regulatory environment, although well intended (involving clinical trials, field trials and bio-prospecting) is increasingly burdensome for its users.

There has now been a significant change in the status of patents in respect of exchange control. The Oilwell (Pty) Ltd v Protec International Ltd judgement of March 2011 no longer views patents as 'capital' whose movement is subject to section 10(c) of the Exchange Control Act. Uncertainty remains, however, since there are indications of a desire on the part of government to effect greater rather than less control over national intangibles and resource assets.

It is a matter of concern that the European Patent office will no longer capture South African patent data manually. The installation of a state-of-the-art electronic database for patent management at CIPC is thus a critical issue for the dti, and by implication, the DST.

The message is that being internationally competitive extends to all facets of the innovation system, requiring high-quality staff, and institutions and regulations that enable, rather than hinder. The work of Kaplan (2011) and Pouris (2009), as well as evidence submitted to the Parliamentary Portfolio Committee on Science and Technology, give rise to concerns that the present **IP law and other regulation of research** are counter-productive. While it is too early to assess the impact of the Intellectual Property from Publicly-funded Research Act (Act No. 51 of 2008), the delays inherent in the new NIPMO suggest that there may be more problems in the future.

Moreover, there are signs that local and foreign companies may, as occurred in the United States after the Bayh-Dole Act, limit their cooperation with universities especially where sensitive IP is concerned. Even the attempt to segment ownership of IP through full-cost payment may push companies to outsource their R&D to other private providers rather than to universities.

The submission from **Business Leadership South Africa (BLSA)** received in Phase One of the review argues for an active role for the state in science and technology, but expresses concern that there is an over-emphasis on 'big science' at the expense of interventions that could make a difference to business, notably to address the lack of venture capital and 'angel funding'. In the view of the BLSA, this leads to the migration of "many top people and companies to countries where the governments provide well-structured incentives". BLSA also believes that, "In many respects, the roles and functions of DST are relatively unknown and the key role players are simply not visible", while otherwise sound incentive programmes appear not to address the needs of industry, and the implementation agencies are not user-friendly.

While the Committee does not necessarily endorse each and every sentiment reported herein, it is clear that there is a serious disconnect, and the Committee hastens to add that it is a systemic disconnect, with deep roots and many drivers.

The Committee reiterates **the importance of synergy between the two pillars of government that enable the entire system of research and innovation, namely the DST and DHET on the one hand, and the dti on the other.**

The mechanisms that a number of countries use to achieve this are combinations of steering and selection agencies (e.g. TEKES in Finland and FINEP in Brazil) with **'sectoral' or 'industrial' innovation funds**. The Committee considers the introduction of such funds as an essential way of bridging the industry–science gap, and **shifting the emphasis from supply-side science towards demand-led innovation**. These new Industrial Research and Innovation Funds should be structured so that they constitute well-informed consultative forums – including industry and government actors – for the development of sector-specific strategic priorities for research and innovation. Reports and recommendations from the funds should inform the deliberations of the

National Council on Research and Innovation (NCRI), and vice versa. This linkage to the peak authority should invest these funds with both systemic alignment and systemic gravitas.

4.1.1 An Open National System of Innovation

A fundamental quality required in the enabling environment for innovation is the openness and permeability of the system. The capacity for learning, adaptation and novelty depends on the **free flow of talent and ideas within and across organisations, national systems and globally**. This has implications for the mobility of talented people, the availability of knowledge and lessons from elsewhere, and the freedom for new insights to arise across and between fields. Both **immigration policies** and **intellectual property regimes** need to be judiciously calculated to enable systemic openness for planned and fortuitous chemistries of innovation. Allowing foreigners to apply on equal terms for vacant posts in South African research institutions, business and industry acts as a competitive stimulus and a bench-marking tool in the system; it also permits the country to enlarge the pools in areas of talent shortfalls and to introduce fresh ideas into the relatively small and introspective research community. The legal framework and regulatory regimen for work permits and visas must be simplified and rendered as user-friendly as possible. The proposal of the National Planning Commission that foreign doctoral graduates be granted work permits for up to seven years reflects the kind of new thinking that is urgently needed.

The NSI requires active measures that will **promote collaboration across boundaries** within the national system and more broadly across the globe. This should include arrangements for the optimal utilisation of research infrastructure and the promotion of a culture of sharing and support for access to research facilities, including encouraging reciprocal access to equipment held by the private sector and state-owned enterprises.

International collaboration and linkages are indispensable components of healthy knowledge transfer and exchange. The DST, often using the NRF as its agent, has done a sterling job in promoting and managing cooperation schemes with selected countries in a variety of formats. A particularly significant achievement has been to make South Africa one of the principal beneficiaries of the European Union Framework Programmes. Less effective, perhaps, has been the use of the International Council for Science (ICSU) to leverage resources for the development of the individual disciplines represented by ICSU.

In this context, the benefits from **South Africa's involvement in the African Union's S&T activities**, including those related to the New Partnership for Africa's Development (NEPAD), have so far been less obvious, with some success stories (e.g. the African Science and Technology Indicators Initiative) and a number of less dynamic activities. They remain an essential part of the way in which the NSI can harness outside elements and create value for all participants.

4.1.2 An Enabling Public Sector

The **state-owned business enterprises** (SOEs) account for a substantial segment of business R&D conducted in the country. Government can obviously exert a reasonable measure of policy control over innovation in state-owned enterprises, several of which are major performers of

R&D, both here and elsewhere, and account for the 20% of total business R&D expenditure that is sourced from government. State-owned enterprises also have considerable potential for energising innovation through their large-scale procurement activity and through international linkages; they are also extensively involved in technology transfer, with attendant opportunities for local adaptive innovation. The Industrial Development Corporation (IDC) and the Public Investment Corporation (PIC) are additional, potentially important levers for innovation.

An innovative public service stimulates innovative business enterprise and can energise the entire NSI. Examples of dramatic improvements in the public service efficiency include:

- The ease with which passports and ID books are now issued and renewed
- The massive transformation of the tax-collection system introduced by e-filing
- Much-simplified, online employer and worker registrations and payments by the Unemployment Insurance Fund.

These are examples of how government through **innovative service delivery** can create not only a sense of future possibilities, but can also develop processes that are core to business activity and make investment wheels more workable. This is vital for both established and emergent enterprises. There is, of course, still a great deal to be done in the many areas of public service delivery that must underpin a well-functioning NSI, especially in regard to the regulatory and science-technology services operated in line departments responsible for health, agriculture, the environment, police, etc.

The Committee noted the recent formation of the **TIA,** and that the agency has not yet had time to establish a track record of performance. However, the Committee observed that the strategy for the constitution of TIA involved the inclusion of a number of pre-existing agencies and wondered about the fit between the capabilities provided by these residual bodies and the role that TIA should play in the future. Given the insight into the current and future NSI generated during the Ministerial Review process and the role TIA should play into the future, the Committee believes that TIA should benefit from formative evaluation sooner rather than later to ensure that the mandate and powers accorded to TIA are appropriate for the planned future trajectory of the NSI, and that TIA is appropriately equipped with the skills and capability to fulfil this role.

4.1.3 Recommendations

Recommendation 8: Systematic efforts should be made to bring industry and government closer together, and to strengthen the response of the system to demand signals from business and industry, on the one hand, and social spheres, on the other. The effective participation of the private sector should be structured into all levels of the system, including participation in the NCRI; strong establishment of the skills bases; encouraging reciprocal access to equipment held by the private sector and state-owned enterprises; and a repertoire of policy instruments within the respective three proposed nexuses of (i) the DST and DHET (focusing on higher education), (ii) the DST, dti, EDD and DPE (focusing on industry and business in general) and (iii) the DST with the various departments whose portfolios have implications for social development and social innovation, and the linkage of social security measures with education, health, etc. These should be directed to the sustainable development of the economy through

efforts to promote competitiveness, the establishment of firms and job creation, and poverty reduction (see Recommendation 5).

It is clear that a 'one size fits all' approach to company support will be ineffective. A diversified approach is required that caters for size and sectoral distinctions. Small companies generally cannot access incentives in the same way that large firms do. Technopolis, the UK innovation policy consultancy, has developed a schema (Figure 3) that assists in understanding the varying needs and capacities of firms according to their research and technological capability.

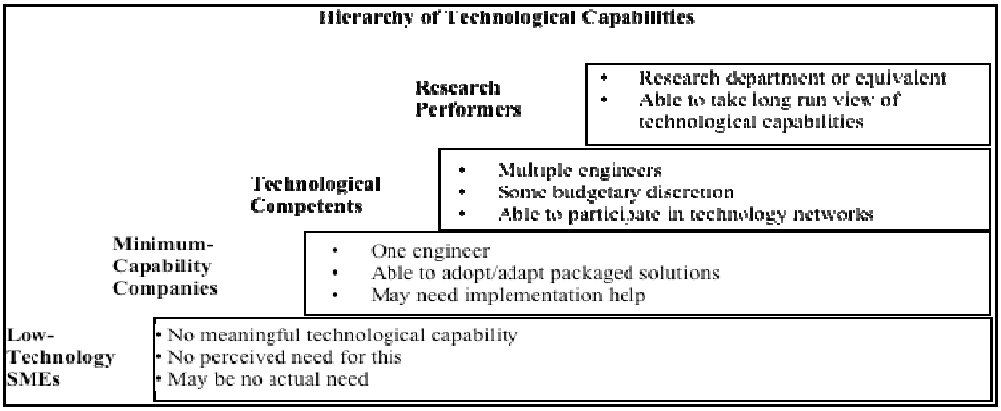


Figure 3: Firms' characteristics and technological capabilities (Arnold 2011)

The essential message of this hierarchy of technological capabilities is that companies do not operate on a level playing field. SMEs lack the in-house skills to access incentives, even where they are aware of these. To overcome this, Austria, for example, makes its tax incentives available to start-ups before they show a profit. Other countries have adopted technology voucher schemes to provide assistance to small firms that lack in-house technology expertise. As these firms develop capacity, they can then benefit from incubators and more sophisticated support.

This implies that there should be sufficient well-informed and skilled intermediaries available in public sector agencies to facilitate transitions to more sophisticated levels of capability. However, Kaplan (2011) notes, "The DST has very few staff with any knowledge of business."

This situation mirrors the dti's IPAP, which, apart from mentioning the CSIR, shows limited understanding of the importance of the science component of the research and innovation system.

Recommendation 9: Government departments that form the key pillars of the research and innovation system and must draw to their ranks staff with direct experience of the business, civil and research environments so as to enable cross-sectoral collaboration and to boost the absorptive capacity of organisations for reciprocal learning and adaptation. A concerted effort must be made to bridge the knowledge transfer gap between local companies (big and small) and public-sector researchers and administrators, in order to ensure that the nation's considerable intellectual resources are utilised to a much greater extent. These capacities should become the subject of deliberate skills-building and case-study research to boost South Africa's collaborative abilities across all sectors within the NSI.

Internationalisation has seen the volume of scientific production rise somewhat, despite a hiatus in the number of full-time equivalent researchers. However, South Africa's ability to generate new technologies has not grown apace, as measured by US patent awards. South Africa is in grave danger of falling even further behind, and the HSBC's prediction of South Africa's future at rank 30 begins to take on predictive rather than speculative form.

It has been noted that the economy and the innovation system are open, yet South Africa has singularly failed to attract international research centres in manufacturing industry, and with the exception of the Meraka Institute, in ICT as well. This diagnosis is supported by Kaplan (2011), who notes the absence of multinational corporations establishing large R&D centres in South Africa, as well as low levels of patent co-invention.

The summary report of the Harvard Group made the case that when it came to employment creation, it was not a question of high-technology skills versus labour-intensive technologies. Instead, the lack of high-level skills retarded the growth of employment in the economy at all levels.

There really is no debate that **skilled human resources** are critical. Kaplan (2011) advances the case by arguing that the choice of sectors for investment should be informed by the extent to which increased output will be associated with an increase in innovation and training. The Committee's recommendations on human resource development are outlined in Section 5 of the Phase Two report: Human capital and knowledge infrastructure.

South Africa is failing to attract know-how and expertise. The reasons advanced for this hiatus in 'R&D FDI' include the regulatory environment as well as perceptions concerning the availability of skilled staff. There are claims that South Africa does in fact have a very large corpus of engineers who are otherwise employed in management roles, and could well be induced to move back to engineering, given the opportunity. This may be a myth, but it is necessary to test it. To be internationally competitive, it is necessary to draw in new technological skills by all means possible.

These various shortfalls in the framework conditions and knowledge transfer environment lead to the following recommendation.

Recommendation 10: The research investment climate must be improved through a review of present and further possible incentive schemes for their accessibility, simplicity and effectiveness, with broadening as required. These measures should include:

- The Technology and Human Resources for Industry **(THRIP**) industry–public researchers linkage programme should be expanded further, to a target of double its present level.
- The excellent and thorough reporting system of the Support Programme for Innovation in Industry **(SPII)** should be adopted in other schemes (and perhaps in all public grant-

making above a threshold level of award, together with the requirement of beneficiaries to participate fully in the annual National R&D Survey.

- Additional, specially tailored **grants and concessions** are required by small- and medium-sized enterprises to enable them to access advanced scientific and technological expertise.

- The regulatory environment for **research permits** should be streamlined to remove obstacles and speed up approvals, thereby reducing the need for burdensome appeals.

- Regulations and the approval processes for **foreign researchers** should be streamlined to speed up the issuing of work permits. Consideration could be given to including **special treatment of R&D inputs** of goods sourced under the local procurement mechanism.

- Overall, more imaginative and flexible sources of **public capital support for innovation** activities should be devised, including but not limited to low-cost loans, replacement of loans by grants, renunciation of state equity components, access to publicly owned buildings and land at zero cost, etc.

- The government system of **company support and incentivisation** should thus embrace a diversified approach that caters to size and sectoral distinctions; small companies generally cannot access incentives in the same way that large firms do, and different categories of firms, with different technological capabilities and potential for transitions to enhanced innovation capacity, should have tailor-made schemes. This implies that a sufficient number of well-informed and skilled intermediaries are available in government departments and their agencies to facilitate such transitions.

- **Industry–public researcher links** may be further strengthened through improved tax concessions on company grants, scholarships and bursaries deployed in public sector research institutions. Interfaces and the mobility of skills should be maintained between national disciplinary associations and related business sectors; research institutions and their funders should deliberately build groups that begin to bear some of the characteristics of the R&D divisions of companies.

Recommendation 11: The Technology Innovation Agency (TIA) should immediately be externally reviewed in terms of 'fitness for purpose', aimed mainly at promoting its success as a pivotal new element in the NSI. The National Intellectual Property Management Office (NIPMO) should likewise be formatively reviewed after a further period of initial functioning.

Recommendation 12: Immigration policies and **intellectual property regimes** need to enable the openness of the NSI.

4.1.4 Further Comments and Considerations

The selection of the four areas of agriculture, machinery and equipment, chemicals and pharmaceuticals (which Hausmann and Klinger [2006] suggested would offer export potential) even if accepted, is too broad to serve as a focusing device. The Committee has therefore recommended the establishment of the National Council on Research and Innovation, along with the Industrial Research and Innovation Funds, where the more detailed work of specifying demand, ensuring supply, and allocating resources will be articulated (see previous chapter).

The OECD review, like many others before and since, drew attention to the dire condition of the **informal economy and the unemployed**. The Committee endorses that concern, noting that private sector innovation has a long way to go in more proactively introducing life-changing innovations into communities. The generally positive impact of mobile telephony has been noted. The 'please call me' cell phone function is a South African innovation. The efficiency with which the poor recycle materials has been observed. South Africa is good at distributing alcohol to the remotest areas, but less effective at distributing genuine necessities. Frugal innovation, and innovations that target the needs of the less wealthy consumer, are leading challenge for the South African business sector.

On a positive note, the OECD review observes that, "There exists a nucleus of technologically strong, innovation-performing business enterprises, and that this base appears to be broadening. R&D expenditure by business enterprises[7] has been rising in recent years and constitutes a larger fraction of total R&D than in most other economies with similar levels of per capita GDP or similar R&D/GDP ratios. Moreover, corporate R&D seems unusually locally connected – for instance, business funding accounts for a larger share of university R&D than in many other countries" (OECD 2007: 5).

The Committee is also positive about the future role of the private sector in the innovation system. What is needed, however, is a clear commitment from government to invest actively in building people and eliminating blockages, some of which are ideological rather than technical, or ethical. The Committee believes that there are stronger convergent than divergent interests in the respective agendas of the public and private spheres in South Africa, and that it is a priority for the South African NSI in the future to find the means to share and advance these purposes together. The goal should be a positive research and investment climate, built on a strengthened commitment to shared futures.

4.2 Social Innovation and Sustainability

The Committee's consideration of '**social innovation'**, or **'innovation for development'**, has as its starting point the pre-eminent national priorities related to poverty and joblessness that have been identified by government. As noted earlier in this report, the founding conception of the NSI was that of a system that would serve the full spectrum of developmental imperatives faced by the country. These challenges have been cogently and urgently outlined in the National Planning Commission's Diagnostic Report (NPC 2011), which acknowledges the dangerous persistence of "widespread poverty and extreme inequality".

The idea of social innovation is a broad one, necessarily embracing a wide range of activities. Wikipedia notes that it "refers to new strategies, concepts, ideas and organisations that meet social needs of all kinds – from working conditions and education to community development and health – and that extend and strengthen civil society". The Committee believes, however, that the

[7] The business sector funds 45% of formal R&D and performs 58% of it. These proportions demonstrate that South Africa has an important platform of industrial R&D competence upon which to build – although it could be argued that the share of business is high because of constraints (especially people and money) that limit the state's ability to invest in human capital for innovation and research, both via the knowledge infrastructure and in more direct partnership with industry.

imperatives of the South African context require that the pre-eminent focus should be on "any **appropriate technologies or interventions that can address the challenges of poor communities**" (Petersen 2011: 2), and this has been used as a means of structuring the discussion in this section.

Invoking the notion of 'social innovation' in relation to 'poverty' might be interpreted as using special modalities, set apart, to treat an issue that all other parts of the NSI can then ignore, as if the phenomenon of poverty, and the communities who experience this condition, stand separate from the rest of the economy, and can be treated as such. This is obviously not the case. As already argued, and as will be shown below, the NSI must be considered as a full-spectrum endeavour with implications for all quarters of the society and economy. All systemic choices carry social consequences. Poverty and inequality are as much a matter for concern in well-established sectors of industry as they are in community-level initiatives. Activities that could be categorised as social innovation simply represent one sub-set of strategies through which the NSI as a whole addresses the developmental priorities of society.

Although distinctions are often made between formal/informal, first/second, rural/urban, or commercial/subsistence economies, or between townships and suburbs, these categories in fact mask a more complex and subtle set of dynamics that characterise how South Africans (especially poorer South Africans) sustain their livelihoods, and how they are located spatially in the economic geography. These complexities do not reduce in any way the urgency of the social and economic crisis that South Africa faces, but they do require that an understanding that addressing the crisis requires complex and multiple strategies undertaken at every level of enterprise, and that the responsibility is shared among all actors in society.

The responsibility can no longer be seen as government's alone but as a collective one, embracing all role-players, including the private sector, civil society and poor communities themselves. Equally, the responsibility for achieving appropriate levels of employment cannot be confined to the 'formal' economy alone. Social innovation should thus be seen as a fundamental component of a sustainable society and economy, integrally continuous with other priority areas for innovation in the South African system. Although there is a distributed responsibility for these social purposes, there is a vital role to be fulfilled by government in constituting the social innovation dimensions of the broader NSI in a systemic fashion, and in orchestrating the contributions of the various social partners.

4.2.1 Defining Social Innovation

The idea of social innovation is relatively recent in international and local literature, and generally speaking refers to **changing social and economic practices so as to improve the life chances of poorer sectors of society in the context of sustainable livelihoods into the future**. There is much enthusiasm and advocacy to be found, but very much less in terms of research and analysis of how 'innovation for development' is to be undertaken, especially in the South African context.

At the heart of the idea is a foundational shift in thinking about how development in poorer communities should be approached. Cousins (2011) notes that constraining approaches to development include "the idea that the periphery (townships, informal settlements, communal

areas, the rural sector in general) cannot be a source of dynamic economic activity; that for the poor, development means primarily the delivery of services; and that development is something you 'get' not something you 'do'. A key constraint on self-employment is South Africa's wage culture, evident in the priority given to employment above all else by poor people, and the way that many projects and self-help initiatives are structured". Instead, Cousins argues, much **greater potential for creative and active agency should be ascribed to communities**, and development processes are (or should be) "a process of continuous adaptation, problem-solving and opportunity-exploiting under pressure [with] continuous adaptation to maximise well-being in changing conditions" (Chambers 1989: 10).

Indeed, Cousins confirms observations made more widely that there is strong evidence of **creative and hybrid livelihood strategies** undertaken by individuals who operate across the traditional binaries of 'formal' and 'informal', or 'rural' and 'urban'. Complex patterns of social economy have been forged that have enabled people to sustain themselves in the most precarious of situations, and a proportion has found the means to prosper. The potential for innovative agency at community level must be accepted as a foundational principle that should govern future approaches to social innovation; at the same time, however, it should be acknowledges, as does Karuri-Sebina (2011) does, that "the supply of innovation solutions emanating from within townships is questionable … Townships no doubt have their own local livelihood strategies that have evolved over time; however, how this potential gets identified and valorised has not been significantly explored. The relatively weak human capital base in townships, and the nature of their co-dependence with their 'host towns' (to which they serve as dormitories), has largely led them to being centres of reproduction rather than production, hampering much of the local creativity and potential".

Cousins (2011) points out that there are **powerful structural conditions that operate to limit the exercise of individual agency**, and the challenge is to address the complex historical maldistribution of economic, physical, educational and spatial goods that still sustains South Africa's deep polarisation of wealth and poverty. To do so, the project of social innovation must recruit the full range of societal actors who are able to mobilise the social and economic resources at their disposal, and do so in ways different from before.

Each of the sectors noted below has distinctive and evolving roles to play, and each must confront the challenge of how they will integrate innovation as part of the modus operandi of fulfilling these roles into the future. The project of achieving sustainable social and economic futures is unlikely to be resolved through one tumultuous wave of innovations that delivers a new and sustainable equilibrium, but rather entails a state of continuous readiness for innovation in the uncertainty of changing futures.

4.2.2 Actors in Social Innovation

This section of the report will make observations about the changing roles of some sectors, before providing recommendations about systemic and other measures that should be taken within the NSI.

Civil society

South African society does not lack the inherent ability to innovate novel ways of organising itself. This is reflected in the creation of *stokvels* as community savings systems, or in the variety of methods used by those outside the banking system to effect financial transactions and funds transmissions to rural and even cross-border families and networks. Some of the most effective reclamation and recycling systems have arisen in the informal sector (and are of considerable benefit to the formal sector recycling industry). There is a rich array of **creative strategies** devised by those outside the reach of 'formal' systems in order to secure their livelihoods.

Similarly, for decades before 1994, South African **community-based organisations (CBOs), NGOs and unions** provided the organisational and skills base for much of the resistance activity that eventually became the mass democratic movement and paved the way for a globally unique transition to democracy and the adoption of a widely admired constitution. It should not be forgotten that both apartheid and social democracy are social technologies, each with their intended and unintended consequences. Innovation in any one direction is not inherently benign and virtuous and indeed will always be normatively inflected. South Africans have demonstrated their capacity to be innovators and leaders in achieving an extraordinary political transition, but now need to do the same with the fundamental social and economic order of the country, in the face of the formidable path dependencies set up in the old order.

Organisations from the non-profit sector have obviously long been key players in the field of development and will always continue to be vital actors because of their variety, capacity for specialisation, agility of response and proximity to the contexts of development. As the country seeks to achieve increasingly systemic effects, the role of NGOs and CBOs can only grow in salience, especially when multi-partner initiatives need agents with contextually specific intelligence, established access to communities and specialised forms of expertise.

There are outstanding examples of individual NGOs that have succeeded in crafting niche functions in the development arena, and now have the potential to provide the platform (or at least a template) for system-wide functions that, the Committee argues, are essential for the vitality of the future NSI. Very briefly, these include the following.

- **Impumelelo** Social Innovations Centre: This NGO offers a system of awards for leading examples especially of social innovation, not least in the service-delivery systems of government. The award system is a successful device for attracting information about – and thus enabling a mapping of – innovation activity across the countryside. The local awards are linked to counterpart international award systems, enabling both comparative benchmarking and dissemination of innovation. The role of these kinds of recognition-systems in growing a network and community of innovators, and advancing a culture of innovation, cannot be under-estimated.

- **Inyathelo** is the South African Institute for Advancement: This NGO brokers the development of fundraising skills across a wide range of non-profit organisations, strengthening their capacity for endogenous development, and has consistently sought to make national development priorities visible and available to grant-makers and beneficiaries alike. Again, Inyathelo seeks to raise the profile and influence of philanthropy, and thus encourages greater (and more strategic) investment in

philanthropy from a widening circle of donors and investors. The South African Private Philanthropy Circle is an Inyathelo initiative.

- The **Green House Project** is based in the Johannesburg inner city and seeks to create and recreate the city ecologically, socially and economically in sustainable ways. The project provides practical demonstrations of how to build, cultivate and recycle resources (materials, energy and water) in ways that bring sustainable benefit to people and the environment. With the City of Johannesburg as its key partner, the project disseminates to both organisations and communities the practical strategies that are available to promote 'green livelihoods' and enhanced quality of life in an urban setting. The project disseminates innovative approaches to green building design, sustainable energy systems, sustainable water and sanitation management, zero-waste culture and organic food, medicinal plants and landscaping.

- **Prolinnova** (Promoting Local Innovations) is a global organisation supporting agricultural research and development through identifying, supporting and disseminating farmer innovation capacities. In South Africa, the programme involves partnerships between several NGOs, university-based research institutes, provincial departments of agriculture and the ARC.

In each of the four examples noted above, we see a **vital brokerage capacity** emerging that assists in the development of networks and partnerships, the emergence of shared perspectives and the possibility of collective investment in common developmental purposes, which are important pre-conditions for systemic approaches to social innovation.

In considering collective action, we need also to draw on other distinctive capacities in civil society whose traditional institutional strengths position them to play complementary roles in innovative social projects. The media is a natural partner, and unions and faith-based groupings have this potential too.

Private sector

Far-sighted leaders in the corporate sector have long acknowledged that **business has a role and set of responsibilities in society that extend beyond optimising shareholder value**. Although the extent of this role in supporting social development and ensuring environmental sustainability is still strongly contested, there are powerful examples where corporate philanthropy has made significant contributions to the public sphere (in higher education, for example) and to social development through corporate social investment (CSI) and broad-based black economic empowerment (BBBEE) schemes. Indeed Henry (2011) estimates that corporate South Africa's CSI expenditure in 2010 amounted to over R5 billion. In one of the most significant investments in the promotion of innovation, the Business Trust earmarked R35 million in 2009 for the Shared Growth Challenge Fund, which was designed to incentivise private sector innovation aimed at growing the inclusion of the poor in the formal economy. The pressure on the private sector to expand the scope of accountability is reflected in the growing sustainability reportage required in contemporary governance codes such as King III, sector charters and enterprise development codes.

In many cases, however, the return on **CSI budgets** has had to be justified to shareholders in terms of its marketing, human resources and/or political equity value, and has had to demonstrate relatively short-term benefit to firms. This had had the effect of scattering a large amount of investment across a multitude of projects, with varying results. This variability has seen a sharply escalating interest in monitoring and evaluation of the impact of CSI expenditure, not always with the complexity of social development purposes being kept clearly in view. The issue of securing confidence in the likelihood of deferred returns, and ways of measuring developmental progress along the way, is a concern for all actors committed to sustainable development.

"CSI is an investment in human and social capital. By investing in creating opportunities for all South Africans, we are not only tackling poverty, but getting to the root of inequality. Being poor in the midst of plenty enrages people who know that they have not enjoyed the same opportunities as others. On the other hand, social justice leads to social stability, which leads to people who are committed to the future. When we have social justice, we have an alignment between the interests of the private sector, the public sector and individuals – everyone will win.

The private sector has far to go in realising its opportunities to transform this country. We're the only country in the world where corporate social investment is mandated, yet we are under-performing when it comes to the impact of CSI on our society. A birds-eye view of the CSI sector shows a fragmented landscape of once-off projects. The private sector knows all about strategic planning, so why is business falling short here? I believe it is because CSI is driven by a compliance culture, not by a vision of a sustainable investment in the country we all passionately want to live in." Mamphela Ramphele (2010: 20).

The innovation challenge facing the CSI sector will be to see whether this collective investment can be marshalled and directed to combined effect towards a small number of strategic purposes, so that **sustained investment** is made over time to address the complex conditions associated with such purposes, trusting that greater impact and lasting effect will be achieved in this way. Further, the growing insight into the complexity of these goals suggests that collaboration with other social partners will strengthen the likelihood of success.

It has been have seen that the emergence in developed economies of a new generation of **philanthropists**, as a variation away from the venerable foundations (such as Carnegie, Mellon, Rockefeller, Ford, etc.) that have supported charity and development work over the past half-century and longer. The new breed includes the likes of the Bill and Melinda Gates Foundation, the largest donor to development research (another synonym for social innovation), and an innovation in donor funding practising what has been called social venture capital, or what the *Economist* (2010) has dubbed 'philanthrocapitalism'). Organisations such as the Acumen Fund, New Philanthropy Capital, Venture Philanthropy Partners and New Profit are involved, investing money in non-profit ventures on behalf of corporate donors, but bringing business-minded approaches to evaluating the impact of the investment. The significance of these developments is that they represent an effort by private sector interests to achieve significant impact through targeted and sustained investment in strategic social projects, drawing on money from multiple corporate donor sources. It is this impulse towards collective action that is necessary for the achievement of any truly systemic character in an NSI.

Ultimately, however, the business sector has to be a prime participant in addressing some of the larger structural factors that condition the shape of the economy. This will include shifts at the level of diversifying away from the traditional reliance on the minerals and energy complex, reconfiguring the manufacturing base (and indeed all human activities) towards the green economy and more labour-absorptive production methods, opening access to markets to a greater diversity of players in the economy, especially new entrants, and ensuring that productive assets (new businesses, successful farms, etc.) bring prosperity to a widening proportion of the population.[8]

A new phenomenon in recent years has been the emergence of **social entrepreneurship** as a means of advancing development goals. Representing a range of hybrids between business enterprises and socially committed initiatives, and taking many forms, social enterprises "are businesses with primarily social objectives whose surpluses are principally re-invested for that purpose in the business or community. They are not driven by the need to maximise profit for shareholders and owners" (EU 2010).

Although this form of enterprise is more strongly present in developed economies, and some BRIC countries, than seems apparent in South Africa, this may well be a modality that gains salience as our capacity grows for collaboration between sectors, and as our national appetite for development-focused entrepreneurialism takes hold. One of the functions of South Africa's future NSI will be to have agencies that are able to profile and popularise initiatives of this nature. Although the examples of cooperatives and networks are sometimes cited as instances of social enterprise, a sober view is that any such enterprise should be, in one way or another, substantively value-generating so as to be inherently sustainable in its own terms. The social value of the innovation needs to be integrated into economic activity if it is to survive beyond the sponsorship of its initiators (NACI 2010).

Public sector

In the South African development context, the state remains the player chiefly mandated, and most resourced in financial terms, to leverage change in the lived experience of the poor. But, as the NPC Diagnostic Report points out (NPC 2011), the backlog is immense. The challenge for government is to change the way that public services are delivered, rather than to see the solution in increased budget allocations.

The shift is underpinned by a number of realisations already alluded to above; firstly, there is a recognition that the capacity for comprehensive social services afforded by post-war social democracies in northern Europe is not an option given the scale of South Africa's need and the size of the fiscus. Resources of all kinds need to be recruited from other societal partners, and communities themselves are powerful agents of change and development. Secondly, there is a realisation that delivery contexts for the provision of services are widely diverse and subject to rapid change. Thirdly, current levels of organisational capacity in the public service (especially at local level) remain constrained (Von Holdt 2010).

[8] A promising related development in South Africa is the recent establishment of the South African Private Philanthropy Circle which, among other things, will seek to encourage partnerships between private donors, government and the corporate sector.

The strategy is thus to focus predominantly on institutional restructuring directed at transforming the responsive capacity of public service provision, in terms of achieving optimally informed policy- and strategy-development, but also at the level of the capability of public delivery platforms. In each case, the intention is to institutionalise learning organisation capability, and the capacity for swifter adaptive behaviour.

At the level of policy- and strategy-development, the state has long sought to achieve integrated planning and oversight of the various functional areas that contribute to complex fields of activity. The current system of **twelve priority outcomes and the related performance contracts overseen by the Presidency** are intended to achieve this top-level coherence in government planning, and this system will be supported and informed by the activities of the Department of Performance Monitoring and Evaluation. In the case of services that together add up to the system of social security, five separate government departments administer one or another function in the multi-dimensional array of provisions (not counting education-related departments, whose functions could be seen as potentially collateral).

As Van den Heever (2011) notes, there are opportunities to link these various forms of provision in order to achieve complementary and multiplier effects. These include:

- **Social security and labour activation:** South Africa has to date implemented very few programmes which tie social security interventions, such as unemployment insurance or social grants, to labour activation strategies, including reintegration strategies for people who are disabled regardless of the cause. Although historically unemployment insurance and labour activation have fallen within the policy authority of the Department of Labour, very limited use has been made of combined strategies, and limited investment seems to have been made in the development of the possibilities of the delivery platform.

- **Social security, education and health:** Significant opportunities exist for various social security benefits to be tied to education and health interventions. Social grant registries contain information on around 17 million or more past beneficiaries, who for one reason or another were severely disadvantaged. Their locations are known as well as their income and asset status. Whether by way of conditions or incentives, health and education programmes can be tied to the needs of known grant recipients. Similarly, information contained in the registries for unemployment insurance and the South African Revenue Service (SARS) can be used. However, such linkages are limited by the narrow implicit mandate of all the departments concerned and the delivery platforms. There are significant examples internationally where conditional payment criteria are associated with various grants, intended to prompt complementary and optimal use of the services provided by the state. Brazil's 'Borsa Familia' is frequently cited, as is the counterpart example in Mexico.

In other areas of development, similar challenges exist in coordinating the efforts of multiple departments, including (importantly for social innovation purposes) **rural development** where separate programmes have been developed for rural development, land reform, agricultural development and water reform. In such cases, the need is for a compelling shared vision that is translated into a programme of coordinated mandates overseen by the forms of strong authority needed to bring about the adaptations and responsiveness required for innovative public service delivery.

Furthermore, public service departments that have strong implications for social innovation need to ensure that their policy- and strategy-development processes are appropriately participatory at the outset to include other societal partners needed to achieve the systemic effect intended. Effective partnerships require significant investment in achieving shared vision, a clear sense of division of responsibilities as well as the resilient mechanisms for the kinds of learning, revision and conflict management that inevitably accompany partnerships for innovation.

It is vital to the development of effective regulatory measures, and subsequent effective delivery capacity, that these be sufficiently evidence-based, from the systematic analysis of current contexts, to the regulatory impact assessment and to the *ex ante* evaluations. The activities of the state, and the partnerships with other social actors, will have a much greater chance of success when properly informed with good research and evaluation.

Essentially, innovation in modalities of public service delivery rest on the realignment of the responsive relationship between the platforms of delivery and the citizenry being served. Various examples exist of exciting and far-sighted innovations undertaken by government, including the Community Work Programme that has already provided employment opportunities for over 100 000 individuals, and has been characterised by a highly innovative partnership between government, NGOs and community-based organisations. The Working for Water programme reflects another successful partnership between government, a university and communities. Further, Impumelelo has documented many municipal-level sites of significant innovation, very notably from eThekwini.

Although significant further research is needed to understand the conditions that make for responsive and adaptive public service provision in South Africa, current insights suggest that **innovative sites of delivery** are characterised by being:

- Well-informed and strongly motivated by central vision and purposes articulated in state public policies
- Contextually sensitive to the distinctive social and economic conditions at that site, and capable of adapting to these conditions
- Alert to larger developmental dynamics in that context (including other public service initiatives or purposes being driven by other sectors) that could provide additive and mutually-reinforcing opportunities
- Information-rich, and able to read and respond to information with agility
- Granted a degree of independence and discretion – and the high-level capabilities – needed to formulate context-specific responses that serve to advance central strategic purposes
- Possessed of an institutional culture that is sufficiently learning-oriented to seek demand signals from the immediate context, to seek alternative models of practice suitable for local adaptation, and to sustain a judicious level of risk-appetite
- Able to enlist and sustain resilient relationships with other social partners.

To conclude, although South Africa is confronted with urgent priorities in terms of socio-economic development, the role of social innovation in the NSI is currently under-conceptualised and under-developed. **The activities associated with social innovation (in their varied and evolving forms) need to be clearly understood in the public mind as highly-valued investments in the future**, with implications for many fields of practice in the public and private sectors, and in personal lives.

Although social innovation activities are under-represented in strategic, planning and budgeting frameworks, there is nevertheless a rich (if limited) field of existing practices and organisations that can be referenced as exemplars and informants for a much fuller set of public policy initiatives that can stimulate and scale-up social innovation to the levels needed in South Africa today.

4.2.3 Recommendations

Recommendation 13: An explicit strategy should be developed for the advancement of social innovation within the National System of Innovation. This strategy should include:

- The launch of a **multi-stakeholder forum**, mandated by the National Council on Research and Innovation (NCRI), to advise government on a limited number of national social innovation priorities that should become iconic projects for the NSI and standing items on the agenda of the NCRI
- The establishment by the DST of **policy instruments**, and the necessary skills base, needed to foster the field of social innovation, including (but not confined to) initiatives aligned to the priority projects identified by the NCRI.
- The establishment within the proposed Office for Research and Innovation Policy (ORIP) of a **strategy for monitoring and evaluation of social innovation activities**, including social fabric studies, that draws on a range of methodologies and sources of data in the country, in order to compile a synoptic view of this complex field of endeavour, sufficient to inform policy and action;
- The establishment, within the DST and/or other agencies, of the **brokerage capacity** and popularisation function needed to foster the multi-partner, cross-sectoral collaboration that is required to address complex social innovation issues such as those to be prioritised by the NCRI
- The establishment of a **Social Innovation Fund** (in partnership with private sector philanthropy), to be administered by the DST, intended to support the NCRI priority projects and other social innovation initiatives.

All the incentivising and regulatory instruments proposed in order to provide an enabling environment for innovation will require appropriate levels of reportage into the sets of indicators to be developed or overseen by the proposed ORIP for the monitoring and steerage of the NSI (see Section 6 of the Phase Two report: Monitoring and evaluation).

The Committee has observed, that in general, part of the enabling environment is the disposition of the population towards the notion of innovation and the capabilities that characterise an innovative society. The Committee believes that the 'appetite for innovation' of the whole population should be fostered by well-designed and well-executed interventions using broadcasting and other media, the systematic upgrading of public education including science centres, the award of medals and prizes, and through ASSAf hosting consensus conferences. In other words, achieving thorough commitment to innovation in all spheres of activity requires some attention to how this is understood and appreciated in the national psyche. This has implications beyond policy measures, and would require national leadership to play its role in this regard.

SECTION 5: HUMAN CAPITAL AND KNOWLEDGE INFRASTRUCTURE

5.1 Human Capital

This section argues that meeting the human resource development requirements for the NSI, as a first-priority essential ingredient of an evolving '**knowledge economy'**, will require a planned, concerted, well-resourced and sustained programme of action by all the relevant policy-makers and performers.

This is because the present human capital development (HCD) system is locked into sets of inter-dependent 'pipeline jams', with piecemeal interventions having so far served only to make the system more refractory to positive change. In fact, the interventions have produced a peculiar and rather general resistance to the idea of any further policy change in a 'fatigued' system.

Simply throwing money at the problem will not solve it, in the Committee's view. Each proposed intervention, as policy or as practice, has to be weighed not as a microcosm of much-talked about pros and cons in each case, but in the context of the 'big picture and the big push' to a new and much-improved situation, where every enterprise in both the public and private sectors can readily assemble its complement of appropriately skilled and knowledgeable people, and where skills and knowledge are themselves the key starting assets of many such enterprises.

The objective of a 'big push' in HCD should be to create a **significantly expanded 'pyramid' of skilled people** who can develop, run and service an innovative knowledge economy. The concerted approach that the Committee regards as essential will require re-examination of some current shibboleths in the collective mind of many participants, integration of public policy-making and purposeful resourcing by the state, innovation of practice within academia, the active involvement of business and industry, and general support from civil society.

In essence, what is required is the following:

- The optimal development of the country's talent through much more effective schooling, post-schooling education and training, and the general promotion both of job competences and adaptive versatility
- Meeting the knowledge and skills requirements needed to address the economic and developmental challenges confronting society, and achieving the priority outcomes identified by government
- Investing in the national capacity for research, deep understandings and knowledge transfer
- Taking a long-term view of the development of knowledge fields and applications
- Promoting free circulation of talent

- Developing the skills base within government necessary for efficiency, effectiveness and innovation in its functions
- Promoting within the 'national psyche' a respect for knowledge and skill, and an appetite for innovation as a way of life.

The achievement of an innovative and technology-rich economy and society will thus depend on the depth, width and overall quality of the country's **reservoir of 'human capital'**, meaning people who have knowledge-informed, research-experienced expertise with the breadth of vision to provide leadership for innovation, as well as inspiring teachers who have achieved mastery of their subjects, technical personnel at a variety of levels, competent managers and public servants, and a citizenry that can effectively participate in an economy in which knowledge is as important as exploitable mineral resources and a well-trained labour force.

The Committee looked for examples of countries that may provide lessons for South Africa in situations that are, of have been, similar. Ireland may come closest in its two-decade trajectory from peripheral backwater nation to something approximating an 'EU tiger' (before the recent global recession, the occurrence of which in itself is a different lesson for South Africa). Ireland concentrated in its HCD approach on first degrees, including language skills, then on massively bolstering the activity of the higher education system in masters degrees, especially in applied fields, and then on enhanced R&D at doctoral and postdoctoral levels in both basic and applied fields. The country did not hesitate to bring in foreign group leaders and to invest heavily in strong teams. Foreign investment in industrial plants and skills-intensive enterprises became a torrent as the local people needed for the purpose became readily available.

From this and other examples, it can be seen that adequate and sustainable pipeline flows in HCD require bottom-up growth of national skills, free recruitment of outside talent, and an early emphasis on applied fields which are adequately backed by a basic- knowledge pool.

5.1.1 Education System

Schooling

South Africa's overall education system has many fundamentals at the core that are comparative positives in the fast-changing world, including a balance between prescribed content and choice in the processes of knowledge and skills acquisition, between formal and informal learning time, and between the exercise of the mind and the body. These features have made South Africans highly competitive when they have had the benefit of well-functioning institutions. Bringing all or most of the schools, colleges and higher education institutions up to full functionality is thus something that does not require the re-setting of these fundamentals, but the inherently simpler challenge of '**making them work'** in the ways they should.

Access to **effective pre-school education** is another fundamental positive for any child, as is the 'personal capital' of parental and community involvement and support, at home and in school or college. Yet another positive is a **fully developed role of the 'first-language subject'** in the general intellectual enskilling involved in reading, communication, subtle understandings, argumentation

and the capacity for personal and social growth, besides the core subject content of the grammar and literature of the language concerned. Proficiency in the **use of English** in oral expression, writing and reading is equally important.

The continuous development of **mathematical literacy** (essentially the power of abstract and predictive thinking) plays an equally important and parallel role at all levels of education, as does general **numeracy**. Direct experience of **technological manipulation**, in classrooms as well as outside, is yet another ingredient of 'brain-and-hands' capabilities, as is the ability to understand the application of physical and life science in everyday life.

The education and training (or re-education and re-training) of **school teachers** is a fundamental priority for the nation in terms of HCD. Organisations such as the Centre for Development Enterprise (CDE) and the Joint Education Trust (JET) have contributed much of real value to the menu of what needs to be done by those who run and those who work in the schooling system. The current model for teacher/trainer 'production' (in terms of qualification types and structures, as well as enrolment planning and bursary support, etc.) requires thorough re-examination – a knowledge economy is impossible without teachers who both understand their material and are skilled in transferring it to their charges. Extremely important, despite being controversial, is that **teaching and training must be re-classified as an essential service**, which it undoubtedly is. The nettle simply must finally be grasped.

The Committee wishes to emphasise here the need to focus on the process fundamentals in a concerted approach to schools improvement, knowing that this is the area where the most significant positive impacts on national HCD will be achieved. Every school that is added to the present much-too-small complement of functional institutions represents a 'catalysis' of hundreds of high-potential minds for the system, over long time periods. The Committee thus argues strongly for **practical policy-making and enhanced practice**, since without this happening, it is doubtful that the downstream 'supply chain' of post-school education and training will actually be able to provide the quality and numbers of capable and skilled people required for a knowledge economy.

Technical colleges

The Committee is in no doubt about the need to attain a **much-expanded technical college system** in South Africa. The massive waste of human potential currently associated with 'dropping out' from schooling, as well as with failures in the national senior certificate examinations or passes without higher education admission, is a crippling barrier to the economic survival of the nation, let alone its ability to earn its living in knowledge economy mode.

Programmes promoting **adult literacy and education** outside the formal institutional framework, but drawing strength from it, must be greatly expanded and rendered more effective and user-friendly.

The **technical colleges** (now about 50 in number, with about 300 000 students) should urgently be re-vitalised, doubled, trebled or quadrupled in number, with a commensurate increase in student numbers, and organised through appropriate policy into a manageable system analogous to that already in place for higher education. They should be adequately resourced in terms of staff, equipment and facilities, and their geographical scope widened to promote accessibility and to lower user costs. They should be productively partnered and diversified with relevant industrial sectors. The National Qualifications Framework (NQF), through upgrading of the system of qualifications and unit standards, should be effectively harnessed to increase access, promote transferability and ensure quality in this system. **Enhanced articulation** possibilities should be provided for learner movement between schools and different types of post-basic institutions, through better combinations of school subject options and facilitated access arrangements.

The **curriculum content** of technical college programmes should be such as to ensure that mainstream applied/technical skills are acquired along with prescribed minimum levels of mathematical/numeracy and language/communication skills.

Every effort should be made to render technical colleges essentially tuition-free to all, or at least most, students in the form of loans convertible to bursaries on qualifying with the certificates concerned. For this, the National Student Financial Aid Scheme (NSFAS) should be expanded and/or, if necessary, relevant legislation amended to deploy the huge resource of the National Skills Fund (NSF) in the technical college sector.

Technical colleges should effectively be used to ensure that no young person is left behind before reaching their early twenties. Setting them up literally requires a 'Marshall Plan' (just as the schooling system does.) While the Committee is not in a position to cost its recommendations for technical colleges, it is mindful of the more than R7 billion annual income of the NSF, and believes that reconsideration of the related legislation may be a good start to finding the means for reforms that would address a large number of the most serious challenges that the country now faces, while bringing in returns of immeasurable economic and social value.

Higher education

Stumpf (2011), in his background paper to this report, summarised the present situation with respect to the 'pipeline performance' in the higher education and training (HET) system:

- Despite sustained efforts to increase admission to higher education for academically deserving but financially disadvantaged students, the overall **participation rate** in higher education has remained at approximately 17–18% during the past five years; increased higher education participation rates constitute one of the defining features of countries that have made successful transitions from efficiency-driven economies to innovation-driven ones.

- An increasing emphasis on **efficiency and effectiveness** in higher education has not been translated into a corresponding increase in undergraduate graduation rates; low graduation rates and high drop-out rates at all levels of study continue to characterise South Africa's higher education system.

- Innovation-driven economies tend to have strongly **differentiated higher education systems** in which universities of applied science or technology play an important role in human capacity provision. During the past decade, it has proved extremely difficult to strengthen universities of technology by increasing their share of student enrolments.

- During the past decade it has also proved difficult to increase enrolments for advanced **postgraduate study**. The very slow progress in achieving greater levels of race and gender equity in enrolments at this level of study is particularly disconcerting.

- **Graduation rates for masters and doctoral degree study** have not improved significantly during the past decade, and there are signs of longer completion times for these levels of study, which are hampering the provision of an adequate supply of highly skilled research and development personnel for improving the country's science, technology and innovation performance.

- There has been an upward creep in the average **age of completion of doctoral degrees**, which is in part consistent with the long time taken for completion, as well as late commencement of study.

- Significant barriers to the expansion of the **postdoctoral sector** (a particularly important component of the supply of person power in research and development in advanced countries) exist in South Africa in the form of inappropriate tax regimens and academic staff progression structures.

These conclusions are the basis of the characterisation of South Africa's HET system as being essentially locked in stasis, incapable of increased or better performance because of inter-locking constraints and a vast inertia (policy fatigue) in terms of change-directed policy and practice. This is the case despite the restructuring of institutions, the application of numerous new regulatory policies, the introduction of institutional audits, and the dedication of a new Ministry and department to this sector. It could be argued that what appears to be stasis is really a period of consolidation after much policy and system turmoil, but the Committee fears that this is not the case, as shown by the repetitively depressing conclusions of the analysis summarised above.

An important example of continued stasis is afforded by the recent consensus report on the PhD degree by ASSAf (2010), which has provided the most complete and evidence-based set of proposals available to date to address pipeline difficulties in **postgraduate education** in South Africa. The study has confirmed the fact that the current system, already comparatively unproductive in terms of annual numbers of doctoral graduates (about 1400 per year), is severely stretched, and that asking it to increase doctoral graduates five-fold without the concerted implementation of a number of proposals is not realistic. The total numbers of research-active academic staff capable of **postgraduate supervision** remains static, and their capacity to reproduce themselves is limited by the pressures on their professional lives arising through the necessary but under-resourced simultaneous expansion of the higher education system.

A concerted, innovative approach must be adopted to allow the higher education system to overcome the constraints that still shackle it despite the structural interventions of recent times. There must be preparedness to examine all of the assumptions that have underpinned the thinking up to the present. Much-improved functionality in the universities and universities of

technology simply has to be achieved in order to increase access, and to raise participation and completion rates.

The Committee believes that **applied disciplines** should represent the major part of qualifier output, supported through service course provision by **basic disciplines**. The latter must, however, be well maintained, at a level that will permit them to make their own contributions to knowledge and innovation, and especially for the reflectiveness that their approach can bring to innovation and inspiration.

The Committee does not advocate a simple division of higher education fields into science, technology, engineering and mathematics (STEM) and 'the rest', but a **more useful division into the 'more applied' and 'more basic' sides of each group of fields.**

In line with strong advocacy of a concerted, 'big picture-based' approach to achieving these objectives, the Committee urges careful and 'zero-based' consideration of measures that seem to have great potential:

- **Reform of the basic bachelors qualification structure** at universities, possibly involving the adoption in a number of fields of four instead of three years of study, with serious consideration given to a generic 'two-plus-two' model of four-year study in which the mid-period break-articulation point in many degree courses is sufficiently well designed to permit high-performing entrants from parts of the technical college system to 'transfer in' without having to re-start at the beginning of the four-year programme. (Such a system has been very successful in Florida, where public higher education is based on a central university offering the four-year bachelors degree and a large number of well-distributed community colleges offering two-year diplomas with exit value as well as articulation with the university degree.)

- Additional **curriculum reforms** at universities to require greater breadth of the main bachelors-degree programmes in terms of enriching course options taken from outside the degree specialisation of each programme, as well as other, more designed-in features. (Such reforms can increase the efficiency of higher educational programmes by achieving economies of scale for smaller departments.)

- Greater use of the 'summer term' concept to enable students who fail courses to repeat them in a different learning mode, yielding better 'diagnostic' insights as to the real causes of failure and better outcomes. (This approach can be very cost-effective if well designed and managed.)

- Operational **differentiation of the profession of 'higher education academic'** in terms of teaching, research and professional specialisation, to permit capable but specialised exponents of each modality to make their contributions at the highest level.

- Similar **differentiation of institutions**, with different mandates with respect to educational level, disciplinary or professional areas, research intensity, size and/or geographic focus.

- In a departure from present policy, it may be necessary to carefully examine the implications of a clear differentiation of **masters degree programmes** into those that

represent a strong focus on research training; those that are concerned with applied science and technology; those that involve advanced or multidisciplinary course-work and theory, including subject teaching; and those that are professional specialisations, including performing arts. (The Committee appreciates the 'long fight' that has given rise to the present emphasis on minimum content of original research in masters programmes, but suggest that the attainment of a knowledge economy and society will require a re-think of this approach in favour of regarding reflective and integrative knowledge as also having value.)

- Again as a departure from present thinking, one might carefully look at the idea of enhancing research-focused **doctoral programmes** with required course-work and skills acquisition, and the acceptance and introduction of doctoral programmes based on advanced theory, technological innovation and/or the highest levels of professional practice (see note to previous recommendation).

- Greatly extending aid and incentives offered to **full-time postgraduate students**, in the form variously of adequate bursaries, convertible loans, 'in kind' support in respect for example of teaching assistantships, subsidised ICT equipment, facilitated accommodation and transport, and generally improved working conditions, coordinated if possible through an effective postgraduate centre or research office.

- Encouraging continuous self-reflection and **skills planning** by postgraduates, aligned with the periodic progress reviews conducted by teaching departments, and providing effective career advice and job facilitation, including in-study internships in the public service and/or industry wherever and whenever this is possible.

- **Focusing public resourcing** (both from outside and inside institutions) on departments or research enterprises that are demonstratively capable of attracting and hosting large numbers of successful postgraduates (in other words, concentrating on the 'rating' of such productive 'units' in addition to, or instead of, that of individual scholars, as at present).

- Fostering and sustaining **local scholarly journals** that simultaneously provide opportunities for 'first publications' of postgraduates and young scholars generally (which should be virtually compulsory achievements for all postgraduates), as well as experience of peer reviewing and editing of research articles, in addition to growing a local 'sense of community' in the disciplines or focus areas concerned.

The Performance Agreement between the President and the Minister of Science and Technology for 2010–2014 stipulates her involvement, together with that of the Minister of Higher Education and Training, in reaching the following **targets by 2014**: 20 000 honours degree graduates; 4500 masters degree graduates; and 1350 doctoral graduates. According to the latest HEMIS data for 2010 from the DHET, reaching these targets by 2014 should not prove to be insurmountable, and in some cases they were already exceeded in 2010. The Committee is not supporting these figures or suggesting others in this report (although the Committee is disturbed by the large discrepancy between the doctoral graduate targets in the ministerial agreement and in the Ten-Year Innovation Plan of 2008 – see Section 3 of the Phase Two report: Governance of the NSI), as the Committee believes that the advocated changes in common degree structures (as listed above), if implemented, would necessitate a thorough revision of these targets, including postgraduate diplomas in the set (see below), adding new four-year bachelors degrees pitched, as are honours degrees, at Level 8 on the NQF, at least three kinds of masters degrees at Level 9, and an expansion of the possibilities of the doctoral degree at Level 10. The Diplomas and

Advanced Diplomas in the revised HEQF (previously National Diplomas and BTech degrees) should be included in these targets.

5.1.2 Becoming Job-competent

The Committee regards the attainment of post-qualification job competence as a much-neglected segment of the HCD pipeline. In a sense, the fast-changing globalised world requires (in general) a framework of undifferentiated education and training that permits ready follow-through adaptation to specific professional or vocational requirements through a period of **structured experiential learning**. Wastage at this level is particularly damaging after the extensive earlier investment in the people concerned.

Engineering affords a good example. There is a specific need for large numbers of engineering professionals to take care of much of the delivery end of an innovative, knowledge-based society. The proper education and training of engineering professionals is a **two-stage process**, the first being a tertiary qualification and the second a comprehensive workplace-based period leading towards professional registration, which requires that applicants reach a level of competence that allows them to take full responsibility for projects. Guided, structured experience in the workplace is essential to achieve this level of competence, and requires long hours from experienced staff to ensure that adequate skills transfer takes place. Sadly, current investment in enhancing the skills of graduates and ensuring that they are adequately integrated into the workplace is lacking, so that whereas it was normal until a few years ago for an engineering to become registerable within four or five years of graduation, few are now ready to register in under seven years, and the majority only register well into their thirties.

The Committee suggests inter alia the following measures and approaches:

- Fast-track intensive training in general organisation and management, public administration, human resource management, and other selected areas of **broad job enablement**

- Review all **post-qualification prescriptions required for professional registration**, in order to assess how appropriate and effective they are, and how accessible to all eligible persons, in partnership with the relevant professional bodies, industry and the public service

- Specifically review the role of **postdoctoral fellowships** in the preparation of academics/researchers who can work independently and innovatively, acquire and productively utilise grants, effectively supervise postgraduate students, and generally catalyse growth in the knowledge economy. This would entail revising the present counter-productive taxation policy for such fellows, drastically increasing the availability and adequacy of such awards, and linking their service with a restructured academic employment system at higher education institutions (see below)

- Expanding **work placements** such as are built into the TIPTOP sub-programme of the dti's THRIP incentive scheme (see Section 7 of the Phase Two report: Financing the system).

5.1.3 Professional Academics

To develop a much larger cohort of professional academics and researchers in South Africa, among whom there would be a much greater proportion of black people and more women than at present, the Committee recommends:

- Widening opportunities in the **academic job market** to recruit and retain a much larger complement of outstanding scholars and scientists who can in turn attract, inspire and effectively supervise increasing numbers of postgraduates, by a systemic investigation of the possible advantages of restructuring the present standard model of academic employment in favour of a system of professorships that starts with a large number of non-tenured, mid-career or emerging researcher positions of assistant professor (with a five- to six-year employment cap) and smaller numbers of tenured associate, full and distinguished professorships acquired by direct competitive appointment or ad hominem promotion. (This proposal is meant to involve the employment of more people than is now the case, through a combination of lower average salaries and more posts established, some of them by converting 'soft money'-funded posts into substantive appointments)

- Creating a grant system specifically designed for the **mid-career, non-tenured emerging researchers** to enable them to productively establish their projects and groups

- **Doubling (at least) the value of grants** currently being made to established researchers by the agency services of the NRF and MRC, based on the ratings of the groups rather than the individuals concerned (see above), and aimed at increasing both the quality and the number of researches thus supported

- Recognising (usually mostly anonymous) **voluntary scholarly work** such as peer-reviewing research articles or grant applications, as well as examining dissertations, by promoting a system of recording and accumulating task ratings that can become part of normal evidence of performance quality, in CVs for example

- Enlarging the **circle of research excellence** by expanding the number of DST/NRF Research Chairs (with an emphasis on 'brain gain') and DST/NRF Centres of Excellence, and creating a **new category of DST/NRF Research Institutes** for multi-focus, high-level research concentrations with the kind of critical mass and long-term trajectory that characterised the national institutes of the 'old' CSIR

- Aligning the **agency operations** of the MRC with those of the NRF in terms of the policy instruments available (possibly by incorporating the former into the latter), and addressing the present overall inadequacies of research support in health, agriculture and the broadly conceived humanities and education, by specific measures designed to produce coordinated growth of research activity and researcher numbers across the entire public sector (see Section 3 of the Phase Two report: Governance of the NSI, and Section 7: Financing the system of this report, dealing respectively with governance and public funding of R&D in South Africa)

- **Improving infrastructure** in (and for) the entire HEI sector, as proposed in Section 5 of the Phase Two report: Human capital and knowledge infrastructure.

- **Opening up posts in South Africa** to competitive entry of highly qualified and productive scholars and scientists from other countries in Africa and further afield

- Strengthening the roles of the **Academy of Science of South Africa (ASSAf)** and of the newly established **South African Young Academy of Science (SAYAS)** as authentic 'voices' of the leading scholars and scientists in the country.

The Committee considers the estimates of the **resource requirements** for a greatly increased supply of high-level human capital for the NSI prepared by the DST in its July, 2010 submission to the National Treasury (2011–2013 Medium-Term Expenditure Framework) to be the approximate minimum of what would be required for the full implementation of the above recommendations (which the Committee has not been able to cost due to the many uncertainties). The proposals made by the DST require new investment of the order of R1.5 billion annually by 2015; implementing this concerted set of additional recommendations for higher education institutions would increase this cost, perhaps up to R2 billion per annum, but the Committee's view is that the overall objective of creating a balanced skills pyramid, drawn from the whole population, will require a large number of refinements of the core investment model, as well as factoring in the proposed massive expansion of the technical colleges and the 'rescue' of the schooling system.

5.1.4 Public Service

The Committee believes that a skilled and knowledgeable public service is absolutely essential in a well-functioning NSI. It needs to be stocked with **qualified and competent people** able to work creatively and effectively together, within and across departments and ministries and at the different levels of government. The demands that will be made on such people will be above the ordinary, and both qualifications and curricula, on the one hand and in a more general sense, and the recommended public service entrance examination system, on the other, will need tailoring to ensure that both appropriate content knowledge and an open mind-set are inculcated in all or most of the candidates involved. The Committee has found (without going into detail in this report) that written communication and decision documentation is deficient in the NSI-related policy arena generally, with concerns about transparency and effective actioning of plans and decisions, and adequate monitoring and evaluation.

The current reliance on post-appointment training through the Public Administration Leadership and Management Academy (PALAMA) cannot compensate for thorough pre-appointment education and rigorous selection, which in countries such as the UK and India are promoted by a well-run system of 'public service examinations'.

5.1.5 An Adaptive Mix of Skills and Knowledge

Within the general framework of human capital development dealt with so far, the steering and orientation mechanisms aimed at addressing specified policy priorities through appropriate numbers and types of trained and skilled people need to be discussed, at both the system (cabinet-authorised) and local (within departments and ministries) levels.

The **Programme and Qualification Mix policy** of steering offerings at different public institutions has so far worked mainly as an efficiency measure, rather than as a potentially valuable tool for preferentially growing a workforce to meet needs in a particular strategic area or for implementation of a particular plan.

The cultivation of a cadre of young astrophysicists through a concerted medium-term recruitment and resourcing plan has been an outstanding success, including in terms of its desired transformation results. The specification of the broad areas in which new DST/NRF Research Chairs are to be awarded is another useful and effective device. The largely unplanned (because it is mainly foreign-funded) proliferation of a large surplus of postgraduate and postdoctoral workers of high quality in the molecular biosciences related to the twin pandemics of HIV and TB infection, is another example of how human capital can be built up quite quickly in a national priority area.

Essentially, the policy tools for a focused expansion of the highly skilled workforce exist already; they just need to be applied in a planned, coordinated and well-resourced manner.

5.1.6 A Systemic Approach to Productive Human Capital

The sociology of successful science has taught that teams are usually built around the inspiration and drive of individuals with the gift of leadership. This widely shared view is no longer adequate.

The completely different modern understanding of metabolic control in living cells is that all system components help to determine the overall performance of a metabolic process, and to different extents under different conditions. This means that the support of particular groups must be designed to bring together component individuals with appropriate skills to enhance the overall performance of the whole group. As mentioned above, moving the current NRF rating system towards one that makes provision for the rating of **highly productive groups** rather than individuals would greatly help to multiply the distributive effects of resource provision. The early identification and targeted support of natural or evolving leaders in the system is another important priority.

Different forms of **support should be coordinated and customised** to meet the needs of particular groups, rather than making periodic general competitive calls for a particular kind of resource, like expensive equipment, for example.

The Committee suggests that the **national associations of the different established disciplines** should undertake critical reviews of all aspects of their fields, including student recruitment at all levels, curricula, new developments and potential interdisciplinary 'gold mines', and their service role to society and the economy.

Monitoring the evolution of new and significant study fields is important, and is currently based in the NRF. The powerful **international unions of the International Council for Science (ICSU**), with their under-utilised national committees, operated by the NRF as South Africa's adhering body, can surely assist in providing international context and support for such endeavours. The recent renaissance of physics in South Africa can be ascribed in no small measure to the intensive DST-supported self-review of that discipline.

5.1.7 Free Circulation of Talent

The importance for a knowledge economy of the **unrestricted movement of talent and skills** across national boundaries cannot be over-emphasised.

Allowing foreigners to apply on equal terms for vacant posts in South African research institutions and business/industry acts as a competitive stimulus and a bench-marking tool in the system; it also permits enlarging the pools in areas of talent shortfalls and introducing fresh ideas into the relatively small and introspective South African research community. This free circulation is enshrined in the SADC Protocol on Education and Training, but South Africa's immigration regulations appear to be implemented in ways that frustrate the intent of the protocol.

There is in any case no valid argument for excluding foreign scholars and scientists from local ranks, whether from other African countries or further abroad; each entrant will generate more work for locals than the jobs that will be taken away. The legal framework and regulatory regimen for work permits and visas must be simplified and rendered as user-friendly as possible. The recognition system for foreign qualifications must also be efficient and fair.

5.1.8 The Wider Public: Attitudes and Values

The citizens of a country that has become a knowledge society must necessarily accept the ethos of knowledge and skills as high-value assets, and must support innovation as the (main, if not only) lifeline to future prosperity and national self-regard.

The Committee is convinced that the '**appetite for innovation'** of the whole population can be fostered by well-designed and well-executed interventions at the grass-roots level, as well as through the systematic upgrading of public education, as advocated in this section.

The **public broadcaster** should be involved in presenting a mix of entertainment and excitement about innovation in all spheres of life and society.

The system of **science centres** is an extremely important part of public engagement with science, technology and innovation. The country unfortunately still lacks a prestigious National Science Centre to act as the core of a distributed national system; such an investment would have many beneficial consequences.

Innovation should be positively presented in the media and government, and followed up publicly to demonstrate its benefits. Schools should celebrate innovation in ways that leave a permanent impression of its value and interest. Much else can be done.

Lastly, the need for effective partnership and a 'big-picture-based' policy-and-practice debate that could be fostered through **consensus conferences** that bring scientists and the public into open debate concerning topics of pressing interest. The tensions between environmental conservation and the desire for access to land for farming or mineral exploitation is an example of a matter that lends itself to such debate. Consensus conferences are different from public hearings; they attempt to reach a scientifically informed consensus, and as such are an important learning process for scientists and the public alike. The Academy of Science of South Africa would be the natural convenor of such consensus conferences.

It will be evident that the enhancement of human capital development advocated in this report absolutely requires close cooperation and common purpose between many government departments, but especially those overseeing basic education, higher education and training, and science and technology. Public institutions such as schools, technical colleges and higher education institutions will be the targets of policy change and altered practice. Business and industry can make major contributions all along the way, as can non-government organisations and many other players and stakeholders. Inspirational leadership will be indispensable from top to bottom.

This Committee has no doubt that the agenda of people development is more central than any other to the aspiration for South Africa to become an innovative winning nation.

5.1.9 Recommendations

Recommendation 14: In order to meet the human resource development requirements of a knowledge economy, a planned, concerted, well-resourced and sustained **programme of action in all areas of human capital development** should be undertaken by all the relevant policy-makers and performers.

Recommendation 15: Teaching at all levels should be declared an essential public service within labour and other legislation and relevant regulations.

Recommendation 16: The **technical colleges must urgently be revitalised**, doubled, trebled or quadrupled in number, and organised through appropriate policy into a manageable system analogous to that already in place for higher education, with a similar level of autonomy (essentially the implementation, after full debate and consultation, of the DHET Green Paper on Post-School Education and Training).

Recommendation 17: The present stasis in **higher education** could be addressed through **open-minded consideration of reforms** such as revising the basic bachelors qualification model at universities, curriculum reform in the direction of greater breadth and versatility , and creating a clear differentiation of masters degree programmes into those that represent a strong focus on research training, those that are concerned with applied science and technology, those that involve advanced or multidisciplinary course-work and theory including subject teaching, and those that are professional specialisations including the performing arts.

Recommendation 18: The Programme and Qualification Mix policy of steering offerings at different public institutions should be used in conjunction with special preferential funding schemes for the development of scarce skills, in order to **grow a workforce to meet the needs in a particular strategic area** or for implementation of a particular plan.

Recommendation 19: Careful attention should be given to the improved functioning and throughput of compulsory post-qualification training programmes, and consideration **given to the introduction of public service examinations** linked to appropriate courses and qualifications offered by higher education institutions.

Recommendation 20: Public resourcing (both from outside and inside institutions) should be focused on departments or **research enterprises that are demonstratively capable of attracting and hosting large numbers of successful postgraduates.**

Recommendation 21: Opportunities in the academic job market should be widened to increase the population of productive academics, possibly by **restructuring the present standard model of academic employment** to increase the entry of talented younger scholars and scientists and open up opportunities generally. Specific attention is needed to address the remuneration of postdoctoral fellows.

Recommendation 22: The average **value of grants made to researchers** by the agency services of the NRF and MRC should be increased to levels that are commensurate with the outputs that are desired, while the number of DST/NRF Research Chairs and Centres of Excellence should be judiciously increased (with the emphasis on 'brain gain'). A new category of DST/NRF Research Institutes is needed for multi-focus, high-level research concentrations with critical mass and a clear long-term trajectory.

5.2 Knowledge Infrastructure for Innovation

Knowledge infrastructure is defined as the specific requirements for building and sustaining an innovative society based on the value chain of knowledge generation, transfer, storage and assimilation.

In essence, this definition could (and probably should) be extended to include higher education institutions and science councils, as well as the totality of their staff and students, but this is not usually done, despite their importance in the system. (**Strong knowledge institutions** are actually the best indication of sound infrastructure in innovation systems.) Similarly, national infrastructure such as government, cities and towns, transportation and communication networks, banks and financial institutions, etc. are not included.

The focus in this section of the report is thus on the specific enablement of knowledge value chains in the NSI by built-for-purpose **spaces, equipment (large and small), scholarly information**

services and cyber-infrastructure, as well as the staff and organisational systems required to operate and maintain these entities.

Adequate, appropriate and up-to-date knowledge infrastructure for innovation is essential in all fields of activity within the NSI, and in all sectors involved in it, including innovation for social development.

This section of the report is based in large measure on the specialist report by Von Gruenewaldt and Botha (2011) commissioned for the Ministerial Review Committee.

It should be noted at the outset that knowledge infrastructure is peculiarly subject to a number of special phenomena:

- There is a strong gradient in extent to which much of the equipment and many of the facilities are at the **cutting edge** (since quality and capability inflation are marked in the laboratory instrumentation field). Many scientists will take much trouble to acquire new equipment, preferably at the leading edge, and lose interest in it once newer and more powerful versions have been acquired (many laboratories are replete with equipment that has lost its charm despite still being serviceable).

- The obvious measure of **sharing expensive equipment** is fraught with the issues of who will maintain and service the instrument, as well as psychological questions related to ownership and competitive advantage.

- Institutions tend to be parsimonious when it comes to **technical servicing and maintenance** of equipment that their researchers have acquired, while suppliers tend to over-price service contracts. Much available equipment is therefore not used to full capacity.

- **Surveys of equipment infrastructure needs** are notoriously unreliable for the above and other reasons; much interpretative skill is needed to understand the real situation.

- **Cyber-infrastructure** is even more subject to extremely rapid technological change.

Two guiding interventions by government have addressed backlogs and planned (non-cyber) infrastructure for the future: the **National Research and Technology Infrastructure Strategy** developed by the NRF in 2004, and the **study commissioned by NACI** in 2006, which is in current use as a baseline for funding research infrastructure applications. More recent commissioned studies have reviewed progress in rolling out the **National Equipment Programme (NEP)** and the **National Nanotechnology Equipment Programme (NNEP),** including an emphasis on shared or joint use of equipment items at national and regional levels.

The DST has recently invested substantially in large science projects and in the creation of national cyber-infrastructure. This has contributed significantly to the current high-end knowledge infrastructure base.

To address the growth planned in national R&D (GERD) in relation to GDP up to the target of 1.5% set by government, driven to a very significant extent by increased public sector investment (see Section 7 of the Phase Two report: Financing the system), the existing infrastructure needs not only to be expanded on a continuous basis, but restructured in terms of its elements, to ensure a higher degree of effectiveness and efficiency in its deployment.

This section summarises and reviews the various components, initiatives and interventions that constitute the present status of knowledge infrastructure for innovation in South Africa. In addition, it also highlights several shortcomings that require attention in order to optimise this infrastructure within the NSI.

5.2.1 General Research Infrastructure

As mentioned above, several programmes have been initiated by government to address the state of specialised research equipment and facilities over the last five years. Some facilities have been upgraded, and there has been large emphasis on acquiring and managing high-cost, multi-user research equipment at universities, science councils and national facilities.

South Africa has also attracted attention as a partner and host in some large **international astronomy programmes** such as the Southern African Large Telescope (SALT) and MeerKAT, possibly hosting the future Square Kilometre Array (SKA) and as a partner in the Cherenkov Telescope Array (which is under development). Its role in the Southern Oceans and Antarctica has been recognised. Renewal of the research base on Marion Island and the replacement of the research vessels have been funded in recent times.

A suite of programmes addressing expensive research equipment and equipment required for implementing the **Nanotechnology Strategy** has been devised. Some other strategic imperatives such as hydrogen technology and fuel-cell development are being supported by applying the **Centre of Competence** model, which brings a spectrum of specialised research equipment together.

The status of the system with respect to smaller, still expensive but more routine equipment that that is no less essential is much less satisfactory. Government has regarded this segment of infrastructure as a part of the overall 'block subsidy' system in which it is assumed that the overheads for teaching and research are adequately covered; in this case, the overhead is the general, non-unique equipment base.

Agencies such the NRF and the MRC as have tended to limit expensive, entry-level middle-range equipment awards and/or to put them in (usually unsuccessful) competition with operating costs or people in block grant utilisation. HEI managements also have the general tendency to under-value this kind of middle-range equipment in setting-up plans for young staff or new appointments, despite the once-off nature of the associated expenditure.

The result of these trends is that expensive, entry-level or middle-range equipment (often the key to progress in solid, laboratory-based, multi-student research programmes) is in many respects the weakest link in infrastructure at HEIs and, to a lesser extent, at science councils (see below).

National (research) facilities

National (research) facilities are the expression of a set of selected and specialised aspirations that can each be satisfied only once in the country because of high cost and great complexity (but not all of the current national facilities meet this description). A new and innovative approach to proclaiming national facilities and providing strategic mobility to existing ones is urgently needed in the light of national needs and priorities. Decisions must be made in each case as to whether individual national facilities should be further developed within their current framework; whether operational control should be devolved to another sector-specific entity in the NSI; or whether they should be decommissioned (see Section 3 of the Phase Two report: Governance of the NSI).

It is clear that national facilities as a range of unique, focused 'big science' facilities with large equipment and operating budgets are potentially huge assets to the NSI, or considerable liabilities in terms of opportunity cost.

Research platforms

The development of centralised or distributed **research platforms** for enhanced competitiveness in research and innovation may be an important enabling tool for optimal use of expensive new infrastructure. This may be achieved through the Centre of Competence approach with a specific focus on bridging the innovation chasm; through new technology clusters; or by way of mission-driven implementation of programmes linked to sector-specific national strategies.

Much of the infrastructure investment may have to be made at the interfaces of triple- or quadruple-helix enterprises, where life-cycle approaches to equipment procurement will help to manage the risks and distribute the benefits to the participants.

International facilities

The DST is apparently in the process of developing a framework and guidelines regarding membership of and access to **large global research infrastructure facilities**. The membership and access to facilities such as CERN, JINR and various synchrotrons are presently governed by separate agreements with a substantial annual investment, and the purpose of developing a new framework is among others to consolidate and streamline processes and procedures, assess the return on investment, and design criteria for assessing the need and the benefit. This review process will look at both outbound access and usage of facilities and inbound access and usage of local mega-facilities. The Committee recommends that this work be brought to early completion.

5.2.2 Technological Infrastructure in Specific Service Domains

The role of innovation in high-level technical service delivery cannot be over-estimated. Several government line departments currently manage services where old technology is used and where no or weak links with the general field-specific 'march of science' exist (e.g. police and health department forensic laboratories). Other services are in fact embedded in knowledge organisations, but may not be regarded as priority components, such as national agricultural public assets with the ARC and biodiversity facilities within the South African National Biodiversity Institute (SANBI).

All these services need to be accorded priority in reviewing organisational arrangements and upgrading infrastructure so that world-class services can be rendered to a plethora of users.

Expensive entry level research equipment

As mentioned above, expensive entry-level **research equipment** is a common requirement in the setting-up or consolidation phase of new research groups in higher education institutions, creating so-called 'well-found' laboratories suitable for scaled-up postgraduate training and research. A funding scheme separate from that for major equipment is needed to provide matching support to HEIs for this purpose, bearing in mind the basic public subsidisation model of these institutions (see Section 7 of the Phase Two report: Financing the system).

Scientific and technical support staff

The dearth of appropriately **qualified technical support staff** has already been mentioned. These are often instrument-focused scientists who are researchers in their own right, but also experts in the use of a particular facility, capable of promoting the facility among researchers in various disciplines, facilitating the necessary training in its use, devising innovative uses in different disciplines, and staying abreast with the newest developments in the field. The availability of such technology specialists should be planned into all purchases of such facilities.

The second need is for properly trained technical support and maintenance staff with specialised skills in electronics, optics, vacuum systems, operational software and mechanics. A concerted national effort should be made to train such **technical specialists** through the mobilisation of existing skills in science councils and national facilities together with the universities of technology and/or technical colleges.

User forums for planning

There is a lack of facilitation to involve users of specific types of equipment, or clusters of equipment using specific technologies, to plan future equipment acquisitions through programmes such as the National Equipment Programme (NEP), the National Nanotechnology Equipment Programme (NNEP) and the Strategic Research Infrastructure Programme (SRIP). Such **user forums** should discuss strategically what they as a community require, where the technology

is going, where to focus the efforts when money is made available, and what should be priorities in equipping the community on a regional and national basis.

It is important to do **life-cycle planning** for each item of major equipment or high-level facility, and to assign the responsibility for sustainable operation.

Sharing and access

As mentioned above, optimal utilisation of much research infrastructure is seriously hampered by the lack of a culture of sharing and support to access research facilities. Sharing schemes need to be built into all grants for major instrumentation, with appropriate resourcing arrangements, which can simultaneously address service and maintenance issues.

Remote access

A new generation of equipment is emerging that allows for **networking and linking** researchers to equipment through broadband links. Virtual use of equipment (from remote stations) must become a strong consideration in future.

A research infrastructure roadmap

Funding and the development of research infrastructure has to date not been guided by any particular process that has interrogated the infrastructure needs in a holistic and synergistic fashion. Even where research infrastructure has been created in accordance with sector-specific strategies, this has been done on an ad hoc basis without any overarching guidelines and synergies. There is a strong case for the establishment and step-wise roll-out of an **infrastructure roadmap for South Africa**, probably best driven by the new NSI governance structures proposed in this report (see Section 3 of the Phase Two report: Governance of the NSI).

5.2.3 Capacity of Knowledge Repositories to Support Innovation

The state of **special knowledge collections** in South Africa requires immediate and significant attention. A recent audit has pointed out the state of these collections and has made some remedial recommendations, including the establishment of a National Collections Facility for the four national natural science collections in the museum environment and a number of other collections of importance. A similar approach could be adopted for historically significant and culturally valuable knowledge repositories presently curated and digitised at great expense by universities and other institutions. A policy framework would be needed whereby such collections could be classified to be of national importance and significance and become freely accessible for research in order to qualify for incorporation, and hence also for support from the proposed National Collections Facility.

5.2.4 Cyber-infrastructure

Significant public investment in **high-performance computing**, **fast broadband networks** and **very large database storage** has been made in the last few years, much of it through the Meraka

Institute at the CSIR. The capacity of our local cyber-infrastructure to support leading-edge innovation will always be challenged by the fast overall development of ICT, and it is likely that this environment will require a constant stream of funding to remain on par with global standards.

5.2.5 A National and International Responsibility

South Africa's responsibility towards international partners and scientists from around the world to maintain and expand the cyber-infrastructure is further underlined by the setting up of **international facilities**. The community responsible for developing and using this cyber-infrastructure is at the beginning of a learning curve, and planning for data-stream transfer and processing will have to be done carefully, so that close synergy between the users and providers of the facilities and services can be established. Use of grid computing, and cloud computing and storage will increase.

5.2.6 Decision-support Tools

All these developments will require close cooperation between government and the expert community involved. Decision-support tools such as various types of science, technology and innovation (STI) **observatories** must be developed in order to provide policy-makers with evidence-based information and strategic analysis, both for designing and implementing effective socio-economic development-oriented policies and action plans, and for assessing the efficacy and impact of existing STI policies.

Organisations such as the **Centre for Science, Technology and Innovation Indicators (CeSTII**), officially designated by the DST to fulfil such one such observatory role, constitutes a key infrastructural component within the NSI. The demographic and bibliographic **SA Knowledgebase** system held by Stellenbosch University at CREST is another unique resource.

Soon-to-be-available decision-support tools, such as the **Research Information Management System (RIMS)** could be considerably enriched and expanded through appropriate linkages and collaborative initiatives with the above-mentioned players as well as the Higher Education Management System (HEMIS), NEXUS in the NRF, and others.

These key information repositories would naturally feed into the system-integrative and virtual observatory work of the proposed Office of Research and Innovation Policy (ORIP).

5.2.7 Access to Information

ASSAf has made much progress in setting up the DST-subsidised, free-online, fully indexed e-publication platform, **SciELO-South Africa**, designed to render a large part of the content of South Africa's scholarly journals visible worldwide, to increase its impact and to enhance collaboration. This should be expanded and sustained, linked as it is to quality assurance through the Academy's discipline-grouped peer review programme.

The Committee also strongly recommend the **subsidised national licensing** of e-access to high-impact, international core commercial journals, following the release of the current ASSAf advisory study on this topic.

Both these interventions are likely to be highly cost-effective in terms of their impact on national research productivity and human capacity development generally.

5.2.8 Dedicated Human Resources

South Africa has to build the human capacity to specify and use the evolving cyber-infrastructure. The local demand for high-end computing provides a nucleus for creating a local South African industry, which would be an emerging one in the global context as well. South Africa should be able to operate and host advanced high-end computers and to build parts of its own computer infrastructure, including software development and computer engineering capability.

5.2.9 National Research and Education Networks (NRENS)

Without affordable broadband internet access available to all contributors and participants, no knowledge economy can be established.

The problematic current situation with the separately conceived and operated public-sector networks **SANReN (South African National Research Network)** and **TENET** (the **Tertiary Education and Research Network of South Africa**) must urgently be resolved so that these can co-exist productively or merge into a single system. Users should have a strong role in advising on the future of a South African National Research and Education Network (NREN) as part of the strategic national infrastructure.

Although SANReN is increasingly addressing much of the national connectivity demands, it does not have a fast link internationally, limiting its usefulness. This linkage is currently a high priority.

Special needs

It is estimated that there are at least 14 000 **remote and distributed sensing and measuring** devices around South Africa. Currently the data collection and storage methodologies used for these are in the main archaic and ineffective, and intelligent use of the NREN would make a big difference in permitting standardisation and a common access mechanism.

The bandwidth, speed and storage needs of the national and global astronomy communities for the **MeerKAT and SKA** projects are genuinely formidable, and planning for this has helped to accelerate the pace of national cyber-infrastructure provision, as well smooth the growth path of SANReN.

5.2.10 A National Roadmap for Cyber-infrastructure

A system of national cyber-infrastructure encompasses local, regional and international relationships for which a coherent strategy is required. No formal roadmap for cyber-infrastructure in South Africa exists, although some of the components are in place. Well-considered projections of the applications for cyber-infrastructure are needed. While some South African researchers already utilise the tools of the existing cyber-infrastructure, there are many more who could benefit, including the benefit of significant enhancement of their research impact.

It is necessary to advocate interventions in especially the higher education system so as to produce a differently trained cyber-ready cohort of researchers. The social sciences and humanities domains present many opportunities. The imperative in the South African situation is therefore both respond to those pushing the boundaries as well as to reach those whose work could benefit from these tools. A cyber-infrastructure road-map has to address different levels and cater for different datasets.

An appropriately constituted **National Advisory Panel on Cyber-infrastructure**, reporting to the proposed National Council for Research and Innovation (NCRI) (see Section 3: Governance of the NSI), would be a suitable body to deal with cyber-infrastructure at strategic and policy levels, and to draw up a roadmap for integrated implementation over time.

5.2.11 Connecting Business to the Public Cyber-infrastructure

The question arises as to whether, and when, business should be connected to the evolving public cyber-infrastructure. It is desirable that when business does become connected to national cyber-infrastructure developed to support the public research and innovation environment, the focus should be on research, just as the SANReN licence is specific for R&D and education. NRENS everywhere in the world are very different from commercial networks and operate on different principles.

5.2.12 New Ways of Collaboration for Innovation

Not only are high connectivity, broad bandwidth, ultra-high speed of transfer and vast data-processing capacity important in South Africa's cyber-infrastructure, but also the software and user interfaces that become available for real-time individual and group collaboration.

Social networking and professional networking are causing a revolution in how people, interest groups and communities of practice make contact and connect. This has not been optimised yet for research collaboration, and it is foreseen that virtual teams and instant communication will increasingly become the norm, as a new generation of scientists and researchers that has grown up in the fast-changing mobile, connected and collaborative environments start entering the mainstream of research and innovation.

5.2.13 Organisational Change Related to Infrastructure in Leading Knowledge-focused Institutions

Universities, science councils and national facilities will have to consider major changes in how they organise themselves as they face changing demands for different kinds of infrastructure in an evolving NSI. This will require visionary leadership and adaptive capacity in these institutions, and willingness to be part of a learning collective.

The mobilisation of separate disciplines to address complex challenges and national priorities has become an essential way of managing research. Several vehicles have been created by government (in particular the DST and the dti) to provide environments where knowledge can be shared and combined better among researchers, frequently across sectoral lines. The Centres of Excellence and Centres of Competence have proved that such new approaches to focus research can be extremely successful in creating and using advanced forms of infrastructure.

Creating **open networks of collaboration**, having access to knowledge repositories, and enhancing the mobility of data, ideas and people in the virtual (remote user) context will greatly benefit an evolving and competitive NSI.

5.2.14 Knowledge Infrastructure in the Private Sector and State-owned Enterprises

No survey or evaluation has to the knowledge of the Committee conducted, to assess the extent and status of the knowledge infrastructure in the private sector and state-owned enterprises (SOEs), nor have the linkages between, and inter-dependence of this R&D-active sector and the universities and science councils been evaluated. This is a major gap in the total understanding of knowledge infrastructure in the NSI, given the important role that the private sector and SOEs play in making the NSI competitive. The gap should be filled by a comprehensive study, not only to gain a full understanding of the contribution of business and industry to the knowledge economy, but also to conceptualise ways in which this capacity, in conjunction with that vested in the public sector, can be mobilised to explore opportunities for innovation that have not previously been evident.

5.2.15 Recommendations

Recommendation 23: To address the growth targeted by government in national R&D (GERD) in relation to GDP, driven to a very significant extent by increased public sector investment, the Committee recommends that **the existing infrastructure needs not only to be expanded in a** commensurate manner, **but restructured** in terms of its elements to ensure a higher degree of effectiveness and efficiency in its deployment.

Recommendation 24: To this end, there is a strong case for the **establishment and step-wise roll-out of an Infrastructure Roadmap for South Africa**, probably best driven by the new NSI governance structures proposed in this report.

Recommendation 25: An appropriately constituted National Advisory Panel on Cyber-infrastructure, reporting to the proposed National Council for Research and Innovation (NCRI), would be a suitable body to deal with cyber-infrastructure at strategic and policy levels, including fast broadband, and to draw up a roadmap for integrated implementation over time.

Recommendation 26: The extent and status of **the knowledge infrastructure in the private sector and state-owned enterprises (SOEs) should be surveyed**, and the linkages evaluated between this highly R&D-active sector and the universities and science councils.

Recommendation 27: The DST-subsidised, free-online, fully indexed e-publication platform, SciELO-South Africa, set up by the Academy of Science of South Africa (ASSAf) in order to render a large part of the content of South Africa's scholarly journals visible worldwide, should be expanded and sustained.

Recommendation 28: The subsidised national licensing of e-access to high-impact, international core commercial journals should be effected following the release of the current ASSAf advisory study on this topic.

SECTION 6: MONITORING AND EVALUATION

Arising as it did from the post-apartheid policy landscape, the notion of the NSI that was introduced in the 1996 White Paper on Science and Technology was intended to be fundamentally transformative in its purpose. As argued earlier in this report, this renewal is intended to reach all dimensions of business, scientific and socio-economic activity. South Africa is a society predicated on change, and the NSI is a pre-eminent policy device geared to this end. However, the achievement of intended change is more difficult, and takes longer, than expected. Change need not always be for the good, and the world is wrestling today with the effects of perverse innovations, such as, for example, the novel financial instruments that paved the way for the current global financial crisis. Achieving virtuous patterns of change depends on the availability of top-quality information, the ability to access and interpret it, and the capacity to use the information to achieve adaptation in performance.

The Committee has already noted in the Phase One section of this Report that, "the absence of an assigned responsibility for ensuring the availability, collation, maintenance (and even analysis) of the science, technology and innovation indicators, both quantitative and qualitative, needed for monitoring and evaluation, and for planning and management" for the NSI as a whole. Although evidence is available from a number of sources for some dimensions of discreet activity in the system, there is no comprehensive synopsis available, even in conception, that reflects the desire to be able to 'see' the system in its totality, and how it might be fulfilling its function. If South Africa is to invest in the system as a fundamental strategy to advance its national purposes, then the country must have the means to review its performance.

There are some excellent windows on to selected parts of the system. For example, the 2008 **Innovation Survey** provides vital and intriguing insight into business sector innovation. This survey identifies important continuing trends, such as the relatively high innovative activity in firms but at the same time (and following international trends) the low national propensity for the acquisition of knowledge from external sources, including higher education and research councils, as noted earlier in this report. Similarly, the survey reports that investment in innovation is constrained by a lack of funds, while at the same time only a small proportion of innovating companies are accessing, or are able to access, public funds for these purposes.

The Innovation Survey notes that the pattern suggests that "it is more important for Government to create an enabling environment for innovation" than to work only through funding programmes (HSRC/DST 2011: 64). These appear to be continuing trends, reflected in earlier surveys. However, we have no sense of what further research and intervention might have been directed at these phenomena between the surveys and thus what we might have learned about the operation of the system, especially the interaction between the key players reflected in these data. **There seems as yet to be no provision for sustained research into the dynamics of the system in order to inform steerage**. As the Innovation Survey notes, "countries are still learning to understand the determinants and processes of innovation" (HSRC/DST 2011: 62). In the case of South Africa, the platform for such systemic learning has not yet been provided, and it seems South Africa is not alone in this (OECD 2009a).

Monitoring information on social innovation is also available, but from disparate sources. Intriguing survey information is available in the regular editions of Trialogue's *CSI Handbook* (its most recent 13th edition reflects 2009/2010 activity), which among other things confirms the 'scatter-shot' effect of the very considerable R5.4 billion in CSI expenditure, distributed across 12 development focus areas analysed in the report. The *Handbook* also points, however, to increasing incidences of working partnerships between corporates and non-profit and public sector collaborators, and increasing determination that CSI investment be aligned with stakeholder interests. The information provided in this resource, however, is a reflection of private sector funding of development projects, and provides little insight into the levels and destinations of social innovation funding made available through the philanthropic community.

Equally valuable insight into social development activity can be obtained from **Non-Profit Organisation (NPO)** sources. The Impumelelo Social Innovations Centre, for example, has rich information about particular projects (or portfolios of projects in some cases), often assembled into regional maps of innovation activity. These **'innovation landscapes'** have potentially powerful value for the planning and brokerage of collaborative approaches to larger innovation priorities, and provide a model for how this information (with its detailed case-study material) could be made available through a more comprehensive centre for innovation system intelligence. As it stands, South Africa does not appear to have a comprehensive or synoptic database or the analytic capacity needed to provide insight into social innovation funding or the spread of activities that it supports, despite the priority that this issue commands in the national discourse. There is a similarly fragmented picture of public service innovation, with valuable but only partial insights available from several sources (including CPSI and Impumelelo).

6.1 The Synoptic Gaze

In this chapter, the Committee make the case for a **system of specialised monitoring and evaluation (M&E)** that is structured to serve the purposes of the NSI and thus advance the broader goals intended for the system of innovation.

In arguing for a conception that brings monitoring and evaluation closer to planning, the Committee is following the observation of Miles et al. (2006: 3) that "evaluation has moved on beyond being a simple auditing of performance and is becoming an integral part of a learning-based approach to policy-making and programme formation". *Ex ante* impact assessment is increasingly *de rigueur* now for the formulation of policy instruments, as is the requirement for the up-front design of subsequent *ex post* evaluation. Similarly, contemporary notions of open innovation insist on the interactive, non-linear nature of these dynamics, where learning and adaptation are conditioned by multiple, accumulative inputs, both intentional and fortuitous. The approach to gathering and distributing intelligence about the system thus needs to understand and design these information flows in as integrated and inclusive a fashion as possible.

From the appraisal conducted in the Phase One section of this Report, and also from the discussions conducted by the Committee in Phase Two, it is apparent that the NSI does not yet occupy a firm conceptual and practical space in the critical fields of endeavour necessary for the achievement of national purposes. Given the necessary connection between policy intent and associated evaluation methodologies, it is clear that the functions of the M&E system should serve to enable both ***system-building*** **and** ***system-steerage***. The system-building function of M&E

provision needs to address existing system failures, while the capacity at the same time informs an emerging appreciation of the shape the system must take into the future.

There are a number of key respects in which the NSI still requires deliberate and well-informed attention (in the form of research and planning, policy and programmatic interventions, and monitoring and evaluation) in order to strengthen its systemic character.

6.2 System-building Priorities

The priorities for system building include:

- The achievement of broadly-shared and widely-distributed **understanding** within government, and beyond, of the nature of the NSI, its purposes, and the supportive measures that it affords
- The establishment of a **governance** architecture that reflects the systemic nature of the NSI and the imperative to achieve common vision and coordinated activities among the full range of stakeholders who are key players in the system
- The development of specific system-level **strategies** for innovation that address and strengthen the role of innovation in growing and diversifying sustainable business and industry, in strengthening the provision of public services, and in addressing poverty and exclusion (acknowledging that these spheres of activity are related and inter-connected)
- The establishment of **funding** measures suited to each of these fields of activity (such as venture capital of various kinds, tax incentives, innovation funds, etc.)
- The provision of **brokerage** services and **partnering skills** needed for cross-boundary collaboration and technology transfer between actors in the system
- The development of strategies designed to promote the **dissemination** of innovation, including the capacity in organisations to identify technologies and good practice elsewhere for adaptation into local contexts
- The launch of a sustained campaign to **popularise innovation** across the country as a whole, cultivating it as an admired national disposition and personal aspiration, and an imperative for a sustainable future

Each of these activities has proved persistent areas of need and, in some cases, persistent areas of system failure in spite of repeated efforts to the contrary. It is clear that dedicated measures, supported by top-quality research and evaluation, are needed to achieve this systemic character.

It is for this reason that special provision should now be made for the establishment of a specialist research and evaluation capacity directed at NSI system-building. The Committee believes that this capacity should be distinct from the existing central planning and evaluation capabilities, such as the National Planning Commission and the Department of Performance

Monitoring and Evaluation,[9] whose responsibilities – although importantly linked – are more comprehensively deployed across government activities and are thus less able to drive specialist sub-system development, as is clearly needed in the case of the NSI. In this regard, the Committee is following various **successful models overseas** (e.g. Sweden, Finland, Ireland and the UK), where specialist capacities have been assembled for monitoring the trajectory of national innovation systems (OECD 2009a: 76–77). Having said this, approaching the goal of "a unified national evaluation system as a way to understand the overall progress of the innovation system" (OECD 2009a: 75) must be done with South Africa's distinct purposes and contextual conditions in mind.

6.3 M&E System Purposes

In sketching out the dimensions and qualities that an M&E system should adopt, the considerable complexity should be acknowledged of trying to achieve a **mapping of innovation activity** and **understanding the determinants** that might encourage it in causal, or even associative, terms. While *ex ante* methodologies seek to lower the risks inherent in policy-making choices and to inform judgement more clearly in priority-setting exercises, experience shows that the directions that the future takes tend to resist close prediction.

> Maharajh (2011) cites a note from John Kay, a visiting professor at the London School of Economics and a columnist for the *Financial Times*, that provides a cautionary note about the boundaries of possibility inherent in a foresight exercise: "If you were in a government department pondering the future of the computer industry in the 1970s, you would naturally have turned to IBM for thoughtful experts and presentations. You would not have consulted Bill Gates or Steve Jobs, who were barely out of school, or Michael Dell, who was barely in it. But IBM did not know the future of the industry. If it had known, it would – sensibly – have tried to prevent it. The interests of the industry and of consumers were not only different from those of the dominant business: they were diametrically opposed" (Kay 2011: 10–11).

Nevertheless, this behoves us all the more to be better equipped to read the trends in the South African environment and to be alert to the surprises that the future presents. In many cases here in South Africa, however, the trends of the future look to be unsurprising and wearingly familiar, and intelligence capacities are needed to equip the country more effectively to change these for the better.

The Committee therefore proposes that a **strong and system-wide monitoring and evaluation capacity** geared to advancing the purposes and functioning of the NSI be established. This capacity should be state-funded, and be located within the institutional architecture of state, but with an independent organisational identity that enables it to engage with the full range of sectors and actors within the NSI. The M&E facility should include the following purposes in its admittedly medium- to long-term mandate:

- **System-mapping:** What innovation activity is occurring across the various sectors, with a particular interest in those areas of activity currently under-reflected in existing measures? Private sector activity and formal R&D are best represented at present,

[9] The Committee notes with appreciation the current system of delivery agreements and implementation forums associated with the government's 12 priority outcomes, and the way the Department of Performance Monitoring and Evaluation has structured its internal functions to align with these outcomes.

although as yet inadequately understood. Innovative reforms in the public sector are more difficulty to track, although several existing avenues provide rich windows into this activity. Much more elusive are the wide variety of innovations and adaptations in communities, both urban and rural, that arise spontaneously or are supported by non-profit organisation (NPO) or CSI activity.

- **System-analysis:** What is known about the state of the enabling conditions that the Committee believes are required to release the innovative potential within the system, and how are the various actors in the system responding to these conditions? What can be learnt about how bottlenecks and constraints work to limit this potential, and how incentives are able to release it? How robust are existing theories about system dynamics, and about South Africa's contextual specificities?

- **System-building:** What intelligence can be made available to inform and equip each of the system-building measures noted earlier in this section? In addition, periodic capability reviews of key agencies in the NSI should be commissioned, and the progress in fulfilling the recommendations needs to be monitored.

- **System-steerage**: What measures are best advised to produce deliberate, desired system effects? Our national goals around sustainable, labour-absorptive growth and poverty alleviation require that we make policy and investment decisions in the directions that we believe will best prompt adaptive behaviour. How can our research and evaluation capacity best guide these planning decisions? The system-steering work will probably involve at least three levels of activity, including those producing ***projections*** (such as foresight exercises and scenario-building techniques), those informing ***policies*** (both *ex ante* and *ex post* impact assessment studies) and those informing ***programmes*** (contextual and project-specific intelligence geared to optimise a particular intervention).

- **System-evaluation:** What trends are discernible, and what is the impact of the investments in innovative and adaptive behaviour? There is wide acknowledgement of the difficulties associated with estimating systemic impact accumulating over a period of sustained investment in targeted measures, especially in elusive quality-of-life measures. The monitoring and evaluation (M&E) capacity must enable the derivation of compelling indicators and analytically powerful qualitative insights. Ultimately, the capacity is require to assemble a synoptic view of emergent patterns across the system, and the relationships that might be at work among them.

- **System-learning:** One of the founding conceptions of the system is that it is an interactive, relational system of mutually reinforcing learning and adaptation. One of the functions of the M&E capacity must be to provide a knowledge base and a communicative nexus for cognitive exchange and accumulation within the system, both within sectors and across them. This has to be done deliberately and inclusively, so as to draw on local and distributed knowledges arising from the sites of innovative activity, and to ensure the widest possible distribution of the questions, the debates and the insights that must inform the growing vitality of the system.

- **System-foresight:** The extensive investment made in Research and Technology Foresight in 1998 has not been followed up with further exercises of this kind.

6.4 Operational Considerations

The intention behind ORIP is to establish a centralised facility that should serve firstly as the repository of evaluation information on the NSI and an expert site for its distillation and distribution to inform strategy and steerage at the highest levels and more broadly.

Secondly, the agency should encourage good-practice evaluation much more widely in the system. The strength of a complex, relational and multi-actor NSI will arise from strong, localised monitoring and evaluation (M&E) capacity distributed through every part of the system, where all sites of practice are making decisions based on astute localised insight. This distributed, localised knowledge needs, however, also to be assembled centrally to inform system-wide strategic views, both for state steerage and to inform thinking throughout the system. Part of galvanising the system towards a number of national priorities is the need to keep all the players informed about what is happening, what is working and what is not. Sustaining shared commitment over time depends on the capacity for collective learning, and the ability to become a learning society.

6.5 Recommendations

Recommendation 29: The intention behind the proposal for the establishment of an Office for Research and Innovation Policy (ORIP) (see Recommendation 3) is to **establish a centralised facility to serve as a repository of evaluation information on the NSI, and an expert site for its distillation and distribution to inform strategy and steerage at the highest levels and more broadly.**

Secondly, the agency should encourage good-practice evaluation much more widely in the system than is presently the case. The strength of a complex, relational and multi-actor NSI will arise from strong M&E capacity distributed through every part of the system, where all sites of practice are making decisions based on astute localised insight. This distributed, localised knowledge needs also to be assembled centrally to inform system-wide strategic views, both for state steerage and to inform thinking throughout the system. Part of galvanising the system towards a number of national priorities is the need to keep all the players informed about what is happening, what is working and what is not. Sustaining shared commitment over time depends on the capacity for collective learning, and the ability to become a learning society.

Recommendation 30: The Committee recommends that the mandate of the proposed Office for Research and Innovation Policy (ORIP) must include systematic monitoring and evaluation for the entire NSI, as outlined above. **The approach should be based on the different elements outlined above, namely system-mapping, analysis, building, steerage, evaluation, learning and foresight.** This would include:

- Provision of **the research and intelligence needed for the functioning of the proposed National Council on Research and Innovation**, from which ORIP would receive its strategic mandate and its systemic authority.
- **Provision of the research and intelligence needed for the policy-making and regulatory functioning of the DST and the proposed three policy-incubating nexuses focused**

respectively on higher education, the business sphere and social innovation (see Recommendation 5).

- **Design the range of instruments and methodologies** needed to fulfil the systemic functions outlined above, and contract and outsource those that ORIP cannot practically undertake itself. Among other things, consideration should be given to the future location of the Centre for Science, Technology and Innovation Indicators (CeSTII), support for and cooperation with CREST's SA Knowledgebase, and functional linkages with the Higher Education Information Management System (HEMIS) and the intended Research Information Management System (RIMS).

- **Oversight of the follow-through on review reports** of public research organisations and other NSI-related institutions.

- **Oversight of a policy that all major research, development and innovation projects attracting significant levels of state funding (above an amount to be determined by the DST from time to time) should be subject to statutory evaluation**, the results of which should be publicly available through ORIP.

- **Maintenance of a system whereby publicly funded databases relevant to the national R&D system make their data available to ORIP** (and thus to the public) through appropriate data access protocols.

- **Extraction of the optimal meta-analytic value from all NSI-related surveys, evaluations and indicator studies in order to inform the strategies and purposes of the NSI.**

Recommendation 31: The Committee recommends that the role of the Academy of Science of South Africa (ASSAf) should be strengthened and broadened to provide independent evidence-based advice on key issues relevant to the NSI. These might come in various formats such as commentaries on policies or draft legislation; full consensus studies; facilitated, forum-type conferences and workshops; and other deep investigations.

Recommendation 32: A thorough investigation of data collection and interpretation related to the NSI is urgently needed. Particular considerations in this regard include:

- The NCRI and national government priorities relating to social development and social innovation must be included within the range of instruments and indicators deployed by ORIP. In addition, ORIP should seek to recruit NGOs and company corporate social responsibility directors in a sustainable network of information-gathering and analysis.

- The Committee recommends that an **annual summative review of the outputs** of all the science councils and other public research or S&T-based technical service organisations be considered. The annual summative CHE review of higher education should include the key indicators selected by ORIP for monitoring and evaluation of the system as a whole. The annual report on higher education research outputs produced by the DHET should be expanded after detailed consultation among stakeholders, and made public.

- **The accuracy of the official figures for technology balance of payments should be subjected to scrutiny.**

Recommendation 33: The **annual Science and Technology Activities (STA) Report** compiled by the DST should be **linked to the new prospective research, innovation and development cluster budget** for the year in question, to enhance accountability and to provide a valuable complement to the National R&D Survey for the same year. This should be associated with a greater degree of linkage in that survey to contexts and policy outcomes.

Recommendation 34: Ten years after the most extensive exercise of its kind in this country, attention must again be given to **foresight studies**, as well as carefully designed social fabric studies as a basis for effective social innovation.

SECTION 7: FINANCING THE SYSTEM

This section examines how the various dimensions of South Africa's complex national system of innovation should be resourced to facilitate the further evolution of the resource- and efficiency-driven South African economy into one where high-level knowledge and skills are added to the system as powerful and creative new drivers.

The Committee firmly believes that such an evolution is absolutely necessary so that the country can make its living in the future.

This is because the review of the available data shows clearly that the NSI in South Africa is now generally in stasis, heavily stabilised and constrained within itself, and can only be moved to a different state by becoming very much more of a knowledge economy.

The biggest constraints (as shown elsewhere in this report) are the stuttering pipeline of trained and knowledgeable people, at all levels; the inadequate investment in the existing research teams; not keeping up with infrastructure requirements; and failing to incentivise private investment in innovation, both within and from outside the country.

Changing the trajectory of the NSI in a sustainably upward direction will be achievable only by concerted interventions, seeking synergies and forms of momentum that can disrupt the considerable inertia in the system and move it to a new, better and more sustainable position. Many such interventions have been discussed in other sections of this report. This section deals with financing the system in a new and more purposeful manner.

7.1 A Recent Macro-view

It is useful to quote some highly relevant sections from a recent draft strategy issued by the DST (2011b), entitled *Enhancing the NSI to support growth and development: a strategy to increase R&D investment in South Africa*:

> The 2008/09 National R&D Survey indicates that South Africa has maintained a steady growth in R&D expenditure over the past decade, with GERD growing from about R4 billion in 1997/98, to about R21 billion in 2008/09. The ratio of GERD as a percentage of GDP has also expanded over this period, indicating the growing role of R&D within the economy. From 2007/08, however, there was a decline in GERD as a percentage of GDP for the second year in succession, from 0.93 per cent in 2007/08 to 0.92 per cent in 2008/09 as illustrated in Figure 4 and Table 1. The 1% target remains elusive.
>
> The decline in GERD as a percentage of GDP is an indication that R&D investments have grown at a lower rate than growth in GDP. Starting in 2007/08, the nominal increases in

GERD have been slower than the increases in nominal GDP. Events leading to the economic crisis may have played a role in influencing R&D investment decisions within the private sector. Globally, some companies were scaling down, postponing or cancelling their R&D and innovation investments due to shrinking cash flows.

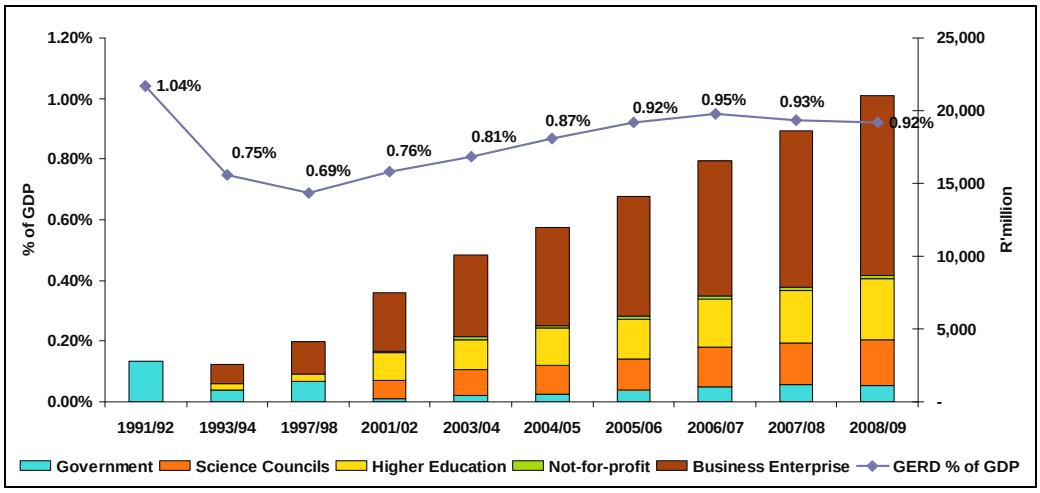


Figure 4: Performance of R&D in South Africa (National R&D Surveys 1991–2008)

Table 1: Selected data on trends in R&D expenditure

Sector	1997/98 (R)	2001/02 (R)	2005/06 (R)	2006/07 (R)	2007/08 (R)	2008/09 (R)
Business enterprise	2 216 000	4 023 576	8 243 776	9 243 165	10 738 456	12 332 012
Government	1 380 000	203 110	844 640	1 021 355	1 154 399	1 139 676
Higher education	496 000	1 896 156	2 732 215	3 298 808	3 621 862	4 191 366
Not-for-profit	11 000	70 778	226 514	212 538	223 202	240 649
Science councils	-	1 294 454	2 102 094	2 744 718	2 886 094	3 137 343
Gross Expenditure on R&D	4 103 000	7 488 074	14 149 239	16 520 584	18 624 013	21 041 046
% of GDP	0.69%	0.76%	0.92%	0.95%	0.93%	0.92%

The Committee applauds the government's intention to promote the increase in the **R&D intensity (GERD)** of the country to the ambitious target of 1.5% of GDP within a few years (specifically 2014); this target is obviously dependent on the actual growth of GDP over that period. For example, the above-quoted DST document states, "South Africa will need to double-up on its 2008 levels of GERD (of R21 billion) to between R41 billion and R46 billion by 2014 if it is to reach the 1.5 per cent GERD/GDP target. Ideally, GERD should grow between 16 and 20 per cent annually for the next three years." These figures are based on assumptions of GDP growth of 5–6% per annum, but most indications are that the growth rates will in fact be somewhat below these figures, reducing the (imposing) estimates of GERD required to attain the 1.5% of GDP target.

In any case, the increases required in national GERD are such that (i) the case for making them will have to be very strong in the face of huge competing demands, and (ii) the investments will have to be so structured that they achieve the objectives of making them, both effectively and efficiently. It is also obvious that such increased investment is a product of both the public and private sectors.

The Committee's report as a whole strongly supports the DST's case for much-increased investment in GERD. The Committee emphasises throughout, however, that only a **well-planned and concerted approach**, based on thorough understanding of the causes of inertia, will render such an investment as effective as desired.

This section seeks to suggest an optimal structure for the increased investment in financial terms.

7.2 2008/09 National Survey of Research and Experimental Development

The National R&D Survey already cited provides a useful point of departure in comparing current, relevant financing flows in the 'whole' NSI; this section provides necessarily summarised data from the survey in order conveniently to illustrate the Committee's thinking and recommendations:

- Overall, just under 50 million citizens, of whom 13.7 million are employed (10.7 million in industry), have generated a GDP of R2.3 trillion (the industry share is R2.15 trillion). The gross expenditure on R&D was R21.04 billion (0.92% of GDP), involving efforts by about 19 400 full-time equivalent (FTE) researcher performers (if doctoral students and postdoctoral fellows are included, the headcount is nearly 40 000).

- Total R&D expenditure by each of the five categories was: business R12.3 billion (58.6 %), government R1.14 billion (5.4%), higher education R4.2 billion (20%), NGOs R240 million (1%) and science councils R3.14 billion (15%)

- Basic research accounted for about 20% of the total, applied research 33%, and experimental development 46%; while 16% was spent on capital and 84% on operational costs, about half of this on labour.

- Funds were sourced in the system by the combined five categories as 53% own resources, 30% from government, 5% from other sources within South Africa, while 11.5% was of foreign origin

- More than 87% was spent overall in the natural sciences, engineering and technology fields (24.4% in engineering, 15% in health and 13% in computers/communications), and 12.5% in the social sciences and humanities.

Within **business/industry**, the relevant data were as follows:

- Two-thirds of the total of R12.3 billion funds expended was sourced from within, 20% from government, and 11.3% from abroad

- By industrial classification, R&D spending was greatest in manufacturing (39%, of which nearly half was in chemicals, oil and coal, and pharmaceuticals), financial intermediation (27.5%), electricity, gas and water supplies (19%) and mining (5%)

- The personnel deployed comprised 6100 FTEs as researchers (8560 headcount), 3800 FTEs as technicians (5584 headcount), and 2500 FTEs as 'others' (4451 headcount), totalling 12 500 FTE persons (18 591 headcount).

The **government sector** comprises national, provincial and local government departments, government research institutes and museums. Its spending on R&D was as follows:

- The expenditure of R1.14 billion was divided into national (R290 million) and provincial levels (R230 million), institutes (R580 million), as well as museums (R41 million).

- Half was spent on applied research, and the sources were own funds (65%), other government funds (28.5%) and foreign funds (5%); only 2000 FTE staff were involved.

- The spending pattern by field, interestingly from the point of view of social innovation (see Section 4 of the Phase Two report: The enabling environment for innovation in the private and social sectors), was 18.5% on social sciences, 18.5% on health, 17% on agriculture, 11% on earth sciences, 10% on biological sciences, and only 2.5% on engineering.

The **higher education institutions' (HEIs)** expenditure on R&D was broadly as follows:

- Of the total R&D expenditure of R4.2 billion, R3.9 billion (93%) was spent on R&D by universities, and only R300 million by universities of technology; the mix was 47% on basic research, 35% on applied research, and 18% on experimental development.

- The sources of funds were own resources 47%, foreign 10%, government agencies 16%, science councils and business/industry 11% each, and only 1.1% as individual donations.

- The distribution among research fields was 70% in the natural sciences, engineering and technology (21.5% in health, 10.6% in engineering, 7% and 5% respectively in biological and agricultural sciences, and under 10% for the grouped physical, chemical and earth sciences), and 30% in the social sciences and the humanities (20% and 10% respectively).

- The personnel figures were 3643 FTE researchers (out of a headcount of over 16 000), 541 FTE technicians (out of a headcount of 2054) and 674 FTE other staff (out of a headcount of 1856); there were 627 postdoctoral fellows, 10 376 doctoral students, and 35 524 masters students.

The **not-for-profit (or NGO) sector** was too small to be summarised here (R240 million). Most of its funding was foreign in origin, and most of it was spent on the social sciences.

The **science councils**, with 25% less R&D expenditure than higher education, showed a pattern of relevant data contrasting with that of higher education:

- The type of R&D was 25% basic, 44% applied and 31% experimental development.

- Government-derived funds accounted for 71% of the total expenditure of R3.14 billion (three-fifths of this sourced as grants and the rest as contracts), business/industry for only 4.4%, foreign sources 12.5%, and own sources 12%.

- The spread of funding over fields was overwhelmingly in favour of the natural sciences, engineering and technology (92%), with engineering at 23.4%, agriculture at 19%, health

at 12.5%, biological sciences at 11%, and physical, chemical and earth sciences at about 10%.

- The headcounts (which were close to the FTEs) were researchers 2650, technicians 1300, and other staff 1650.
- The distribution of expenditure on R&D among the major science councils was R1.4 billion for the CSIR, R536 million for the ARC, about R390 million each for both Mintek and the MRC, R167 million for the NRF (national facilities) and R94 million for the Council for Geoscience.

Returning to the overall picture, it is important to mention that comparison of the 2008–2009 data with those for 2007–2008 revealed an increase in total 'real' expenditure of only 1.3%, while the total number of researchers and R&D personnel generally was static, and actually fell when expressed as a percentage of the total employment in the country to only 1.4 researchers per 1000 persons employed.

These headline figures, and much else described in other parts of this report, are the basis for the Committee's conclusion that the NSI in South Africa is generally in stasis, heavily stabilised and constrained within itself.

7.3 Higher Education Institutions

The general situation of the HEIs illustrates the problem very well. They derive their revenue from three streams: government subsidies mostly determined by a policy-driven formula, self-set student fees, and a third stream acquired through research grants and contracts from both government agencies or business/industry, private donations from within and outside the country, and mobilisation of revenue from a variety of owned assets.

The autonomy enjoyed by university councils and executive management under the Higher Education Act (Act No. 101 of 1997) means that the ways in which the complex and highly inter-dependent functions of teaching, research and extension/outreach are set up and sustained are generally **at the discretion of the institution itself**, within its available means. If the leadership wants the institution to be research-led (as many do), undergraduate programmes will reflect the aspiration to attract able students, will infuse a spirit of enquiry in diverse ways, and permit the harvesting of a substantial fraction of the graduates (mixed with some attracted from other institutions) into active and productive postgraduate programmes that are often organised as 'virtuous' assemblies of established researchers who also teach, developing researchers at various levels, and support staff, sustained in well-equipped facilities by a mix of substantial, mostly but not entirely external grants, and recognised for promotional purposes as centres, units, research chairs or institutes.

In a very general way, the subsidies made to HEIs by government to date have been based on the premise that the funds concerned, together with fees and third stream income, will be used to set up and sustain the entire infrastructure of facilities and systems necessary both for teaching/training and for the performance of R&D (i.e. the **overheads of research activity are**

assumed to be covered in this way, and are not included in any further government-derived agency grants awarded for research projects). (There has long been a kind of quiet dispute between business/industry as to whether the payment of corporate taxes is enough to justify a refusal to include overheads in contracts with public universities – most firms do in fact pay overheads, but at a rate well below the real additional costs, in a compromise approach.)

The state also regards developing capacity for research (i.e. growing new timber, as part of the assumed general overhead cover. The teaching/training functions of research-active HEIs cannot thus be separated from the research functions, and recommendations designed to increase R&D at HEIs must take into account the basic **design of the resourcing model** as well as the consequences for the rest of the system.

One can now examine the implications of setting out at HEIs to increase the volume of high-quality human capital generation for the NSI (in the form of greater numbers of well-trained honours, masters and doctoral graduates as well as postdoctoral fellows, drawn from the talent of the whole population) as well as that of research outputs (such as high-impact peer-reviewed articles and scholarly books), commercially exploitable patents and useful innovations generally.

Essentially, many of the required concerted interventions have already been outlined in Section 5 of the Phase Two section of this report: Human capital and knowledge infrastructure. Many of these will require expenditure of funds held by HEIs or granted to them by government agencies and/or business. The following systemic investments can be added to these:

- Reorganising a much better-resourced external government agency system to focus primarily on the purposeful and adequate resourcing of the best-performing, multiple-output research groups
- Providing (much-increased) quanta of such group support, appropriately designed in terms of operational, capital and human resource provision, at various levels such as groups (including most of the national Research Chairs [SARChI] or institutional equivalents), units (some of the SARChI chairs and equivalent), multi-project centres (such as the national Centres of Excellence), and institutes (with multiple principal investigators, projects, and expanded, quasi-autonomous organisational models)
- Improving infrastructure (as outlined in Section 5 of the Phase Two report: Human capital and knowledge infrastructure)
- Enhancing the interaction between business/industry and HEIs by strengthening and widening the incentive schemes operated by the dti and TIA/DST, especially in the form of the so-called triple- and quadruple-helix relationship and in Centres of Competence
- Expanding further foreign grant-making for (mostly internationally collaborative) work at South African HEIs, through strengthening the links with other countries or regional blocks that are especially productive in this way
- Progressively shifting the overall balance between basic, applied and experimental development research, from just under half on basic research in the direction of about two-thirds of expenditure being devoted to the latter two categories, as was done with success in Ireland under similar national conditions

- Facilitating and optimising, through appropriate legislation, regulation and administrative practice, the potential of local HEIs to recruit high-level staff from other countries, and to maximise their impact.

To go back to the above summaries of the main resource flows in the NSI, the Committee is arguing for measures that would increase R&D expenditure in HEIs by 2014, in broadly the following indicative way, bearing in mind that the mix of R&D that would be found if GERD/GDP reached 1.5% might not continue to reflect the current pattern:

- R5.9 billion (increased from the current R4.2 billion) to be spent on R&D by universities, and R600 million (now R300 million) by universities of technology, giving a total of R6.5 billion per annum.

- The increased expenditures come from an altered pattern of funding, changing so that funding of R&D would be 37.5% from own resources (now 47%), 12.5% from foreign sources (now 10%), 30% from government departments or agencies such as the NRF, the dti, TIA and the MRC) (now 16%), 14% from business/industry as contracts (now 11%), 4% from science councils (now 11%) and 2% from individual or corporate donations (now only 1%).

- The target mix would be 40% on basic research (now 47%) and 40% on applied research (now 35%), with 20% on experimental development (now 18%).

- The distribution among research fields would be 80% for natural sciences, engineering and technology (20% for health, 20% for engineering, 12.5% for each of the biological and agricultural sciences, and 15% for the grouped physical, chemical and earth sciences) and 20% in the social sciences and the humanities. This would reflect the emphasis on applied sciences and experimental development.

- A major recruitment drive, oriented to achieve the research field balance as above, would take the headcount from the present 16 000 to 24 000. The personnel figures would be 5000 FTE researchers (out of a total headcount of over 24 000) (presently 3643 out of a headcount of over 16 000), 1000 FTE technicians (out of a headcount of 4000) (presently 541 out of a headcount of 2054), and 500 FTE other staff (out of a headcount of 1500) (presently 674 out of a headcount of 1856).

- There would be 1200 postdoctoral fellows (now 627), 15 000 doctoral students (now 10 376), and 60 000 masters students (half of them in research specialisation(see Section 5 of the Phase Two report: Human capital and knowledge infrastructure) (presently 35 524).

7.4 Science Councils

The question of 'new target' resourcing flows depends largely on what the individual and grouped mandates of the government-owned science councils should be in future (see Section 3 of the Phase Two part of this report: Governance of the NSI). Suffice it to say in this section that the competitive advantage arising from the marked systemic economies of scale, the multiple beneficial outputs of HEI-based R&D, the constant entry of talented newcomers, the richness of the multiple-discipline environment, and the independence of the general mind-set, makes an unanswerable case for funding and performing at HEIs a very large percentage of the total national R&D that is not performed within business enterprises.

If the arguments made in Section 3 for the revision of the **mandates of science councils** are accepted, these organisations would variably be special purpose vehicles of government or of a sector (or sectors) of government, designed and funded to perform operational R&D directly linked to government functions and especially service delivery, as well as R&D that is not easily or optimally done at HEIs (whether for reasons of justified secrecy; or continuing linkage to an indefinitely required scientific/technical public service; or based on a unique facility in terms of cost and scale; or simply, and probably temporarily, to supply a skills-set that no HEI [yet] possesses; or for other valid reasons).

Funding implications would attend a decision to move into the science councils many of the **scientific and technical services** that are currently housed in government departments, which would be much more effective and innovative if they were incorporated into a relevant science council. This would also apply if most or all of the **national research facilities** currently operated by the NRF were relocated to other bodies (see Section 3 of the Phase Two report: Governance of the NSI).

The weakness of the existing policy framework governing the science councils and the need for a new and clearer mandate for the organisation and financing of government R&D and technical services, extends the motivation for the Committee's proposals that a new National Council for Research and Innovation, supported by a new Office of Research and Innovation Policy be responsible for establishing coherent cross-system policy and for coordinating planning and (public) funding within the entire NSI.

The Committee recognises that its suggestion that the science council system be re-formulated and re-organised at a fundamental level means that it will be more difficult to indicate the kinds of target R&D expenditures that could be envisioned in the future. The following are accordingly indicative figures for 2014:

- The type of R&D would be 10% basic, 45% applied and 45% experimental development (now respectively 25%, 44% and 31%).
- Government would account for 75% of the funding used for a total expenditure of R4 billion (half of this as grants, and the other half as contracts), business/industry for 15%, foreign sources 5%, and own sources 5% (now respectively 71%, 4.4%, 12.5% and 12%).
- The spread of funding over fields would be overwhelmingly in favour of the natural sciences, engineering and technology, with engineering, agriculture and health at 20% each, physical, chemical and earth sciences at about 10% each, biological sciences at 5%, and social sciences at 5%.
- The distribution of expenditure on R&D among the major science councils would be revised to match their new R&D mandates and continuous functions and services.

7.5 Business/Industry

Private business/industry is the most important source of finance for, and performer of R&D, and a key strategic partner for government to engage with in promoting R&D investment in the country. The sector consists of local businesses, including small, medium and large enterprises,

foreign-owned companies in South Africa and other foreign R&D-intensive companies that invest in South Africa in a variety of other ways.

Government has little direct control over the private sector in respect of self-driven R&D, but plays a critical role in creating favourable **framework conditions** for product and process innovation, as well as steering to support mainstream policies and attain national objectives.

Government obviously exerts much more control over **state-owned enterprises**, several of which are major performers of R&D, both here and elsewhere, which accounts for the 20% of total business R&D expenditure sourced from government. Eskom, Denel and Transnet report to the Department of Public Enterprises, and from time to time receive additional funds when they face budget shortages; such injections might go toward product innovation (as in the case of the now-abandoned Pebble Bed Modular Reactor programme). Increasing R&D in this sector is relatively simple if the will to do so is present and the required framework conditions are favourable.

State-owned enterprises have considerable potential for energising innovation through their large-scale procurement activity and through international linkages. They are also extensively involved in technology transfer, with attendant opportunities for local adaptive innovation.

The contributions that government could, and should, make to enable the emergence of a substantial high-capacity workforce in the country has already been discussed, together with the kind of R&D expertise that should be available at HEIs and science councils for possible partnerships with industry, in effect the outsourcing of some or most of the R&D needed by firms for their business/industrial innovation. This can, and should, be energetically complemented by a varied set of incentive schemes carefully designed to achieve high take-up in areas considered critical to national economic and social development, and to succeed wherever possible in complete commercialisation of the innovative products and/or processes involved.

It is deeply disturbing that business/industry-funded R&D in the entire public sector has fallen from 19% in 1997 to about 10% in 2007.

The extensive array of **corporate social investment** activities contains little that could be said to contribute to public sector R&D or the capacity for it.

Both of these phenomena must be addressed as a matter of urgency; this will only happen if business/industry is drawn closely into the design of the necessary instruments and arrangements.

One such instrument is the so-called **triple helix** between government/science councils, HEIs and business/industry; **quadruple helix** formation takes place when civil society also becomes directly involved. The Committee regards it as extremely important that every effort is made to ensure

the smooth initiation and sustainable operation of such complex partnerships so that the decline in business/industry funding in the public sector can be reversed. The submission by HESA rightly points out the need for seamless funding arrangements in multi-helix innovation strategies, both along innovation chains and over time in each enterprise.

As reviewed by Kahn (2011b), the current stable of **incentive schemes** run by the dti and TIA/DST is investing about R600 million of government money in innovation projects in South African business/industry, most of it actually spent in HEIs and science councils. The tax benefit for business R&D activity that meets set criteria is being taken up increasingly despite administrative problems. The tax expenditure or tax revenue forgone due to the R&D tax incentives is estimated to be just over R1 billion for the period 2005/06 to 2008/09. The DST estimates an amount of R632 million for the year 2009/10 (DST 2011: 7d).

These generally successful schemes should be increased in size, scope and effectiveness.

The incentive schemes are additional to large-scale **government financing of private sector innovation projects**, which flows through a number of routes, including the Industrial Development Corporation, Land Bank, Public Investment Corporation and National Empowerment Fund. These funding flows need to be better documented, and integrated, in government innovation-related reporting.

SPII and THRIP are among a number of smaller funding-for-purpose schemes that **the dti** has developed over the years. These include the Enterprise Investment Programme, Black Business Supplier Development Programme, Critical Infrastructure Programme, Business Process Outsourcing and Offshoring, the Sector Specific Assistance Scheme and the Cooperative Incentive Scheme. A second dti thrust is the Seda Technology Programme. This brings together the functions of technology transfer and various technology incubators covering stainless steel, platinum, aluminium, base metals, furniture, medical devices, biotechnology, software, essential oils, bio-diesel and the automotive industries. Other dti schemes are directed toward export promotion, attracting foreign direct investment and the Coega Industrial Development Zone.

The innovation-targeted **SPII** is administered by the IDC (under the Economic Development Department since 2009) and consists of two broad schemes: (i) The Matching Scheme (providing maximum grants of R1.5 million), targeting small- and medium-sized companies and the Product Process Development Scheme, targeting small enterprises, and (ii) the Partnership Scheme which makes grants larger than R1.5 million and is open to all companies.

THRIP is managed by the National Research Foundation (NRF) on behalf of the dti. It is a collaborative intervention across industry, universities and science councils that seeks to increase the number and quality of skilled people in the development and management of technology; promote interaction among researchers and technology managers in industry, HEIs and science councils, with the aim of developing skills, technology transfer and commercialisation of research; stimulate industry and government to increase investment in research, technology development, technology diffusion and the promotion of innovation; and promote large thematic collaborative

research and development projects in priority areas of the dti. Industry and the dti share the costs of THRIP projects on a R2 to R1 basis, but dti support may be doubled if a project supports certain THRIP priorities. During the 2008/09 financial year, 240 projects received R138.9 million from the dti, while industry provided R227.5 million. THRIP activities took place at 18 universities, the ARC, CSIR and Mintek. Of these combined funds, 92% went to universities, as a source of funds close to 10% of HERD (and indeed some 20% of non-labour costs).

The **Innovation Fund**, originally operated by the NRF for the DST, was mandated to promote technological innovation by investing in late-stage research and development, intellectual property protection, and commercialisation of novel and inventive South African technologies. The operation of the Innovation Fund has been accompanied by its own innovations, such as institutional development involving staff capacity in intellectual property management, which laid the basis for the establishment of what is now the National Intellectual Property Management office (NIPMO), as well as the IPR capability of the new TIA. Other innovations were the Commercialisation Manager Development Programme and the National Innovation Competition.

The 2001 **Biotechnology R&D Strategy** noted the successes of South African science and firms in exploiting first- and second-generation biotechnologies, but lamented an underlying market failure in that the country had failed to extract value from the third-generation biotechnologies based on genetics and genomic sciences. Regional centres (BRICs) were established as nuclei for the development of biotechnology platforms, from which a range of businesses offering new products and services could be developed. The four BRICs – Cape Biotech, Plantbio, Biopad and Lifelab – were incorporated into TIA in April 2010. Prior to that they made 128 investments with a cumulative total of R980 million split R277m, R167m, R270m and R265m respectively between the four BRICs; these investments comprised grants (with royalty conditionality), loans and equity stakes.

Venture capital for innovation is actually readily available in South Africa, but the total amount invested is very small (Kahn 2011b); it appears that certain tax and exchange control regulations impair the ability of fund managers to create value. The flow of private funds into innovation depends critically on further expansion of the number of capable operators in this area, and the stimulation of risk appetite among wealthy individuals who are willing to commit part of their means in order to realise rich returns in a sufficient proportion of their ventures.

Both the **Innovation Survey** of 2005, covering the period 2002–2004, and the more recent Innovation Survey of 2008, covering the period 2005–2007 (DST/HSRC 2009, 2011) yielded data that suggested a high degree of innovation in South African business enterprises (comparable with that of many OECD member states), much of it generated locally, and with a significant impact on profitability. Total expenditure on innovation was estimated at about 3% of the total turnover.

The Innovation Survey population collectively considered that the level of public funding of business innovation activity was low, and suggested also a low incidence of innovation-related information coming from universities (5%) and government research performers (3%), as well as a low overall level of patent registration. The direct annual government input of R600 million in

business R&D (although effectively outsourced to HEIs and science councils), plus the tax forgone through R&D claims of R600 million, amounts to a total of R1.2 billion contributed by government in addition to the total business R&D spend of R12.3 billion (i.e. the level of public funding of business R&D is actually about 10%). That this was perceived as low by the survey population is interesting and clearly requires further elaboration (perhaps in the next Innovation Survey).

The role of **foreign firms** in the South African economy has increased considerably in the last decade, with FDI rising from 1% of GDP in 2003 to about 4% in 2009. Regrettably, most of the investment is in equity purchases or share portfolios rather than in 'green field' investments in innovative industry. It is clear that everything possible must be done for South Africa to become the preferred destination on the African continent for R&D-related foreign direct investment. Among the ingredients of a determined push in this direction would be (i) strong, research-intensive HEIs; (ii) a critical mass of highly skilled people; (iii) a much higher proportion of research workers in the labour force; and (iv) an appropriately designed and operated regulatory environment. All these are advocated in this report.

The country also has a widening **technology balance of payments**; domestic demand should increasingly be met through domestic capacity, as a matter of some urgency.

The Committee believes that the decisive move towards an economy driven by knowledge to a much greater extent than at present, will require in respect of the business sector:

- Much higher R&D expenditure by business/industry, probably as much as 50% more than at present
- A greater degree of partnership between business/industry, and HEIs and science councils, representing the outsourcing rather than the performance of part or all of the R&D concerned, preferably in well-regulated and well-facilitated triple- or quadruple-helix arrangements;
- Expansion of the incentive schemes offered by the dti and TIA/DST, both in total amounts applied and in the range of enterprises serviced in this way
- Assisting more purposely the realisation of innovative capacity in small and medium-sized businesses
- Enhancing the national capacity to transfer and adapt new technologies as much as the capacity to create new ones
- Facilitating and optimising through appropriate legislation, regulation and administrative practice the potential of local firms to recruit high-level staff from other countries, and to maximise their impact
- Energetically promoting foreign direct investment so that multi-national companies carry out globally applicable R&D in this country rather than elsewhere
- Mobilising the skills of business to enhance social innovation and improved service delivery in the public sector

- Expanding the venture capital industry as well as the application of corporate social investment in achieving innovation in various different ways.

The Committee's projection of the R&D expenditure data for business/industry would indicatively be as follows in 2014:

- More than 70% of the total of R18 billion expended on R&D would be sourced from within business, 15% from government (state-owned enterprises) and 15% from abroad.
- More than R1 billion would be provided to the sector by government through incentive schemes, for spending on R&D actually performed in HEIs and science councils; the tax forgone through take-up of the R&D tax benefit would be about R2 billion.
- By industrial classification, R&D spending would be greatest in manufacturing (40%), financial intermediation (15%), energy generation (15%), essential infrastructure (20%) and mining (10%).
- Personnel deployed would comprise 10 000 FTEs as researchers, 6 000 FTEs as technicians, and 2 500 FTEs as 'others', totalling 18 500 FTE persons.

Space precludes a similar treatment of the small not-for-profit sector.

7.6 Government Sector

Many of the suggestions made in the above sections on HEIs and science councils make it difficult to model the fifth sector covered in the annual National R&D Survey, namely the government sector, which is rather heterogeneous, but potentially highly significant.

It is not widely recognised that innovation in the government sector is a high priority in a knowledge economy.

In this context, it is useful to add information from the DST's annual reporting on National Science and Technology Expenditure to that already cited above from the annual National R&D Survey. The Expenditure Report was meant (after the placement of the majority of public research organisations under, or within sectoral departments in 2004 through the New Strategic Management Model) to be used for the generation of a single government S&T expenditure plan covering and integrating all DST and sectoral R&D plans. In the words of the New Strategic Management Model, the post hoc report was intended to "guide the clusters and government as a whole on the deployment of resources … while retaining absolute accountability in the relevant departments".

The Expenditure Reports collate expenditure in three different categories across the large number (25 out of 34) of departments with significant Science and Technology Activities (STAs). The STA categories are Scientific and Technological Innovation (STI, about 63%), Scientific and Technological Education and Training (STET, 20%) and Scientific and Technological Services (STS, 17%). The assistance of the National Treasury was obtained to mine the relevant information from its annual Estimates of National Expenditure (ENE) in respect of the departments concerned, supplemented by questionnaire-derived information and direct consultations with departments.

The Committee had access to four such successive reports, which appear to provide the beginnings of an informative cross-system view of government S&T expenditures. Closer inspection revealed, however, that the highly significant contribution to national STAs (STI and STET) of the Higher Education Branch of the former Department of Education (now the Department of Higher Education and Training) is either not reflected in the reports, or is grossly under-estimated, depending on how the activities of HEIs are classified. Some high figures that are reflected in the reports are problematic, such as, for example, the more than R2 billion attributed to STET of the Department of Health, which represents a questionable set of data in that the large sums earmarked for education and training in academic hospitals universities are not spent exclusively, or even extensively, on real STAs. It seems that the inclusion of such STET expenditure in the STA system is misleading, especially if the much more well-defined STET activities of the DHET are under-estimated.

The Committee notes with approval the intention of the DST to encourage improvements in expenditure classifications within the Basic Accounting System of the National Treasury for greater accuracy in the STA reporting system; it is imperative that the reports be brought to the point where they can permit the generation of a prospective national S&T expenditure plan as originally envisaged.

A matter that does deserve attention is the reportedly **low expenditure of many central line departments of government on Science and Technology Activities (STA**), which suggests that problems encountered in service delivery or policy implementation are not being innovatively addressed. This is hardly good practice in a knowledge economy context, and perhaps requires a smoothly operating channel for necessary contracted work to be done by science councils (or HEIs, as the case may be) – a case can probably be made for a kind of THRIP-type mediation in such contracting processes, offered by a suitably situated and resourced agency, perhaps (as for THRIP), the NRF.

The generation of successive annual reports has not to the knowledge of the Committee led to the generation of a prospective **National S&T Expenditure Plan**, the beneficial results of which might be expected to include direct examination of the R&D and innovation requirements of central line departments, and assistance to them in establishing the necessary client–customer relationships.

The Committee has proposed that some existing activities in line departments might be shifted to science councils or even HEIs (scientific and technical services, government research institutes, etc.). Such a shift would also allow greater focus on the more general but no less real service delivery-related needs of the departments concerned.

Government departments involved in development activity and service delivery are presently poor initiators and supporters of innovation in their areas of responsibility, and are prime candidates for a much expanded programme of steered and assisted social innovation along the lines suggested in Section 4 of the Phase Two part of this report: The enabling environment for innovation in the private and social sectors. The financing of these newly focused activities would depend on the organisational arrangements, the wide participation of sponsoring and/or

partnering companies, the interplay between different levels of government, and the way in which the developmental state is re-envisaged by government in the next few years.

7.7 Recommendations

Recommendation 35: Public resourcing of R&D conducted at HEIs should be significantly increased, with a focus on the best-performing, multiple-output research groups, the extension of the system of Research Chairs and Centres of Excellence to Research Institutes, and the provision of improved infrastructure. Furthermore, consideration should be given to the subsidisation of national licences for high-impact commercial journals and the free-online e-publishing platform, SciELO-South Africa, for high-quality local journals.

Recommendation 36: The public funding of the science councils should be adjusted to match their newly formulated individual and collective mandates.

Recommendation 37: Business/industry should be encouraged and incentivised to increase its R&D expenditure, probably as much as 50% more than at present, through much more pervasive triple and quadruple helix formation with government/science councils and the HEIs, and involving extensive outsourcing of the R&D required for business innovation.

Recommendation 38: The incentive schemes offered by the dti and TIA/DST should be expanded, both in the total amounts applied and in the range of enterprises serviced in this way, with a special focus on the realisation of innovative capacity in small and medium-sized businesses.

Recommendation 39: Everything possible must be done for South Africa to become the preferred destination on the African continent for R&D-related foreign direct investment (FDI).

Recommendation 40: The potential of local firms, HEIs and science councils to recruit high-level staff from other countries should be facilitated and optimised through appropriate legislation, regulation and administrative practice.

Recommendation 41: Measures should be devised to encourage government departments to improve service delivery through research, development and innovation, including the effective use of the annual survey of government expenditure on science and technology activities, to draw up prospective expenditure plans annually for such activities.

SECTION 8: CONCLUSION

In July 2010, the Minister laid out the terms of reference for the Ministerial Review Committee to conduct a review of the science, technology and innovation landscape in South Africa. The Committee comprised nine experts drawn from higher education, business and innovation policy, who served through sessional and other engagements.

The Committee's report speaks to the mandate that the Committee should sketch out what the research and innovation system should look like ten to thirty years hence. The work of the Committee complements other synoptic views, notably that of the National Planning Commission that was published on 11 November 2011.

The starting point for the review was to perform a high-level diagnostic assessment of the science, technology and innovation landscape, its strengths and weaknesses, and the role of government and the private sector, as well as to offer an assessment of the 2007 OECD review and its recommendations. This was to form the basis for further desk studies, informed by interviews with key players, which would lead to recommendations on governance and structure, the necessary inputs of skilled personnel and funds, the capacity to monitor and evaluate the priorities of national development, and the shift towards a knowledge economy.

The Committee took note of the Diagnostic Report of the National Planning Commission as a clear indication of a 'national crisis' in the country's ability to map a pathway to an inclusively prosperous future for its people. Together with other prevailing signs and symptoms in relation to the economy, the 'wake-up call' is loud and clear. The Committee firmly believes that knowledge application and innovation, added as a diversifying and amplifying stimulus to the country's existing resource- and efficiency-based economic system, are crucial to the ability to achieve national goals in what amounts to crisis conditions. It is therefore necessary to accord top priority to the issues dealt with in this report.

To this end, the Committee adopted an inclusive view of innovation as being the capacity to generate, acquire and apply knowledge to advance economic and social purposes. This implies that innovation is an imperative at the core of the country's transformative project. It must address all corners of the economy, it must include all social actors, and it must provide for inclusive and sustainable futures.

The Committee looked at case studies where the achievement of the necessary coherence, alignment and investment in an NSI had arisen as a consequence of a sharp and commonly held perception of a 'crisis' that must be confronted as a national emergency. These demand signals may act as focusing devices needed for the achievement of coherence, of both purpose and effect, in a system of innovation.

The Committee's discussions offered a glimpse of the future through a plausible scenario in which well-being and the quality of life show significant measurable gains, with absolute poverty being halved and morbidity being slashed. Attaining these goals requires a well-functioning and inclusive research and innovation system, and this in turn pivots on appropriate governance structures.

The analysis pointed to an as-yet sub-optimal set of governance arrangements. Drawing upon national evaluations and comparative studies, the Committee has suggested the structural changes needed for the system to respond better to demand, to attain internal alignment among the major actors, and to enjoy the benefits of policy learning. In so doing, the Committee does not claim novelty. The two core recommendations – to introduce a high-level coordinating body and to reform NACI – have previously appeared in one form or another, yet they have failed to gain traction.

This failure arises, the Committee believes, because South Africa has yet to fully mobilise political leadership and authority adequately behind the promise that the idea of the NSI holds. For the research and innovation system to reach its potential in addressing the twin problems of competitiveness and poverty, which the Committee has termed the Janus Mission, the inception of a National Council on Research and Innovation is recommended to set the agenda and make the call on high-level prioritisation. The second recommendation is the establishment of a unitary Research and Innovation Vote should be established, to function as a macro-coordinating mechanism to ensure that the country's public researchers in all public research-performing institutions are adequately supported. The third recommendation is that NACI should be reconfigured as the Office for Research and Innovation Policy. The fourth key recommendation is to establish Industrial Research and Innovation Funds, whose revenue derives from the existing mineral royalty stream, and which would serve to articulate industry needs for research towards innovation and other innovation activities. The science councils bring with them considerable legacy expertise, but in general have yet to engage strongly with the war on poverty or sufficiently with the expressed needs of established and emergent industry. For this reason, the Committee called for a systematic review of their entire range of offerings, aimed at achieving greater alignment between their activities and the priorities of the NSI. The Committee has also noted shortcomings in the framework conditions that impact upon the research investment climate.

The private sector is the engine for economic growth and value addition. While South Africa's leading companies have expanded abroad, there has been only limited expansion and diversification at home. One of the paradoxes that was noted was the high propensity to innovate alongside the low propensity to patent, despite a long tradition of patent activity, albeit at modest levels. The Committee took note of the Harvard Group's suggestions that agriculture, chemical, machinery and equipment, and pharmaceuticals could become stronger exporting sectors, linking these to scientific expertise and patenting activity. For this to happen, it is crucial that business become integrated into the agenda-setting and prioritisation processes, and that a relationship of far greater trust is built between government, business and organised labour. The achievement of such informed dialogue rests upon the availability of skilled government technocrats with work experience in large firms and small, medium and micro enterprises (SMMEs), and other brokerage agents that might be available in higher education or civil society. However, it also rests on the capacity for far-sighted leadership in the public, private and civil sectors, able to rise above parochial and sectional interests in the pursuit of shared futures.

The awareness of the social dimensions in all technological activity has informed The Committee's deliberations. Technology impacts both positively and negatively on peoples' lives; people in turn shape the uses of technology in similar ways.

It is the considered view of the Committee that the research and innovation system is key to a 'better life for all'. To this end, considerable renewal of the country's knowledge base (in all its forms) is needed, with attendant fiscal implications at a time of fierce competition for resources. The justification for an investment in a resurgent NSI is that it should ultimately deepen the impact of human and budgetary resources. Research and innovation have previously delivered in responses to the demands of the day. The imperative now is to lay the foundations of a new contract between the research and innovation system and society at large. The new contract, with Janus as its logo, is predicated upon a participatory articulation of economic and social needs, and their fulfilment through innovation activities. As such, the research and innovation system needs to be advanced as a values-driven and deeply embedded part of society, championed by compelling and inclusive leadership.

BIBLIOGRAPHY

Abrahams, L. and Pogue, T. (2010) Innovation System and Inequality: The experience of South Africa in the Strategic Management of Innovation. Research Group paper series No.3.

Albuquerque, E. (2003) *Immature Systems of Innovation: Introductory Notes about a Comparison between South Africa, India, Mexico and Brazil based on Science and Technology Statistics*. Discussion paper No. 221. Belo Hirozonte: CEDEPLAR/FACE/IFMG; ASGISA.

Arnold, E. (2011) Presentation to Ministerial Review Committee on the Science, Technology and Innovation Landscape in South Africa on 20 October 2011.

Arnold, E. and Kuhlmann, S. (2001) *RCN in the Norwegian Research and Innovation System*, Background Report No. 12 in the Evaluation of the Research Council of Norway, Oslo: Royal Norwegian Ministry for Education, Research and Church Affairs.

Arnold, E., Brown N., Eriksson A., Jansson T., Muscio A., Nählinder, J. and Zaman, R. (2006) *The Role of Industrial Research Institutes in the National Innovation System*. Technopolis report to VINNOVA.

ASSAf (2004) *Promoting S&T Capacities in the 21st Century: From Policy to Reality.* Pretoria: Academy of Science of South Africa.

ASSAf (2006) *Research Publishing in South Africa.* Pretoria: Academy of Science of South Africa.

ASSAf (2009) *The State of Science in South Africa.* Pretoria: ASSAf.

ASSAf (2010a) *The PhD Study: An evidence-based study on how to meet the demands for high-level skills in an emerging economy*. Pretoria: Academy of Science of South Africa.

ASSAf (2010b) *The PhD Study: An Evidence-based Study on How to Meet the Demands for High-Level Skills in an Emerging Economy.* Pretoria: Academy of Science of South Africa.

Australian Government (2011) *Venturous Australia: Building Strength in Innovation*. Canberra: Government of Australia.

Bitard, P. and Edquist, C. (2008) *The Paradox of High R&D Input and Low Innovation Output: Sweden.* CIRCLE paper no. 2008/14. Lund: University of Lund.

Blankley, W. and Kahn, M.J. (2005). '*The history of research and experimental development (R&D) measurement in South Africa and some current trends', South African Journal of Science*, 101(3/4): 151–156.

BLSA (Business Leadership South Africa) (2010). A private sector perspective of the current reality and future state of the national Department of Science and Technology. Paper prepared for the Ministerial Review Committee on the Science, Technology and Innovation Landscape in South Africa.

Botha, A.P. and Von Gruenewaldt, G. (2006). *A Study on the Required Physical Infrastructure to Attain the Vision of the NSI.* Pretoria: NACI.

CDE (Centre for Development Enterprise) (2011) *Value in the classroom: The Quantity and Quality of South Africa's Teachers*. September 2011.

Cohen, W.M. and Levinthal, D.A. (1990) 'Absorptive capacity: A new perspective on learning and innovation', *Administrative Science Quarterly*, 35(1): 128–152.

Cousins, B. (2011) Rural innovation systems. Paper prepared for the Ministerial Review Committee on the Science, Technology and Innovation Landscape in South Africa.

DACST (1996) White Paper on Science and Technology: Preparing for the 21st Century. Pretoria: Department of Arts, Culture, Science and Technology.

DACST (2001). South African National Biotechnology Strategy. Pretoria: Department of Arts, Culture, Science and Technology.

DST (2002) South Africa's National Research and Development Strategy. Pretoria: Department of Science and Technology.

DST (2007): Ten-Year Innovation Plan for South Africa 2008-2018. Pretoria: Department of Science and Technology.

DST (2004) *Memorandum: The New Strategic Management Model for the public Science and Technology Institutions.* Pretoria: Department of Science and Technology.

DST (2007) *Ten Year Innovation Plan 2008-2018*. Pretoria, DST. Pretoria: Department of Science and Technology.

DST (2008) *South African Innovation Survey 2008.* Pretoria: Department of Science and Technology.

DST (2009a) *Report on the R&D Tax incentive.* Pretoria: Department of Science and Technology. Pretoria: Department of Science and Technology.

DST (2009b). *Report on the R&D Tax incentive.* Pretoria. Department of Science and Technology.

DST (2010a) *Analysis of the resource requirements for high-level human capital for the national system of innovation Submission to the National Treasury.* Pretoria: Department of Science and Technology.

DST (2010c) *Ministerial Review Committee on the Science, Technology and Innovation Landscape in South Africa: Phase One Report. November 2010.* Pretoria: Department of Science and Technology.

DST (2010d) *Report on Publicly-funded Scientific and Technological Activities 2008-2009*. Pretoria: Department of Science and Technology.

DST (2011a) *Analysis of the Resource Requirements for high-level Human Capital for the NSI: 2011–2013 MTEF Submission to National Treasury.* Pretoria: Department of Science and Technology.

DST (2011b) *Enhancing the NSI to Support Growth and Development: A Strategy to increase R&D Investment in South Africa'.* Draft 1.0. Pretoria: Department of Science and Technology.

DST (2011c) *Strategic Plan for the Fiscal Years 2011–2016.* Pretoria: Department of Science and Technology.

DST (2011d) Report on the Research and Development Tax Incentive Programme 2009/10. Annual Report to Parliament. Pretoria: DST.

DST/HSRC (2009) *National Survey of Research and Experimental Development in South Africa: Main Results 2002–2004.* Pretoria: Department of Science and Technology/Human Science Research Council.

DST/HSRC (2011) *National Survey of Research and Experimental Development in South Africa: Main Results 2005–2007.* Pretoria: Department of Science and Technology/Human Science Research Council.

dti (2011) *Industrial Policy Action Plan 2.* Pretoria: Department of Trade and Industry.

EC (2002) *Innovation Tomorrow*. Innovation policy study survey commissioned by DG Enterprise, Innovation Directorate EUR Report No. 17502. Brussels: European Commission.

EC (2009) *INNO-Policy TrendChart: Innovation Policy Progress Report, Brazil.* Brussels: European Commission.

ECA (2011) *Economic Report on Africa 2011.* Addis Ababa: Economic Commission for Africa.

Economist (2010) 'Social innovation: let's hear those ideas'. 12 August 2010, print edition.

EDD (2010) *The New Growth Path*. Pretoria: Economic Development Department.

Edler, J. and Kuhlmann, S. (2008) 'Coordination within fragmentation: governance in knowledge policy in the German federal system', *Science & Public Policy*, 35(4): 265–276.

Edquist, C. (2009) 'The Swedish paradox'. Presentation at the Swedish Parliament.

Edwards, L. and Alves, P. (2005) South Africa's Export Performance: Determinants of Export Supply. Africa Series Working Paper No. 95. School of Economics, University of Cape Town.

Ejermo, K. (2006) *The Swedish Paradox*. CIRCLE Paper No. 2006/01. Lund: University of Lund.

EMBO (2003) *Research and Education in Resource-constrained Countries.* Heidelberg: European Molecular Biology Organisation.

EU (European Union) (2009) Country Report: Brazil.
http://erawatch.jrc.ec.europa.eu/erawatch/opencms/information/country_pages/br/

EU (European Union) (2010) Study on Social Innovation. Paper prepared by the Social Innovation eXchange (SIX) and the Young Foundation for the Bureau of European Policy Advisors.

Fine, B. and Rustomjee, Z. (1996) *The Political Economy of South Africa. from Minerals Energy Complex to Industrialization.* Johannesburg: Wits University Press.

Freund, B. (2007) 'South Africa: The end of apartheid and the emergence of the 'BEE elite', *Review of African Political Economy*, 34(114): 661–678.

Gardner, C. (2008) *The New Invisible College: Science for Development*. Washington: Brookings Institution.

Gupta, A.K. (2012) 'Innovations by the poor for the poor', *International Journal of Technological Learning, Innovation and Development*, 5(1/2): 28–39.

Hausmann, R. (2007). *Final Recommendations of the International Panel on Growth.* Pretoria: National Treasury.

Hausmann, R. and Klinger, B. (2006) *South Africa's Export Predicament*. Working paper. Cambridge, MA: Harvard Kennedy School.

Henry, T. (2011) *The Wise Company's View on Social Investment*. Tshikululu Corporate Social Investment Management Agency.

HESA (Higher Education South Africa) (2011) Forum of Research DVCs. Input on the STI landscape to the Ministerial Review Committee on the Science, Technology and Innovation Landscape in South Africa.

Hobsbawm, E. (1962) *Age of Revolution.* London: Weidenfeld and Nicholson.

Innes, D. (1984) *Anglo American and the Rise of South Africa*. London: Heinemann.

IAC (InterAcademy Council) (2004) *Inventing a Better Future: A Strategy for Building Worldwide Capacities for Science and Technology.*

IDRC (1993) Towards a science and technology policy for a democratic South Africa. Mission Report. Ottawa: International Development Research Centre.

Kahn, M.J (2005) 'A class act: Mathematics as filter of equity in South Africa's schools', *Perspectives in Education*, 23(3): 139–148.

Kahn, M.J. (2007) South Africa's System of Innovation. Presentation at the COFISA Conference, Innovation Hub, Pretoria, 7 June 2007.

Kahn, M.J. (2010) 'A bibliometric analysis of South Africa's scientific outputs – some trends and implication', *South African Journal of Science,* 107(1/2).

Kahn, M.J. (2011a) Governance. Paper prepared for the Ministerial Review Committee on the Science, Technology and Innovation Landscape in South Africa.

Kahn, M.J. (2011b) Financing of Innovation Activities: Paper prepared for the Ministerial Review Committee on the Science, Technology and Innovation Landscape in South Africa.

Kaplan, D.A. 2011. Paper prepared for the Ministerial Review Committee on the Science, Technology and Innovation Landscape in South Africa.

Karuri-Sebina, G. (2010). Conceptualising the township innovation system: eKasi and the Neighbourhood Development Partnership Grant. Paper presented at the Innovation for Development: Frontiers of Research, Policy and Practice Symposium. University of the Witwatersrand.

Karuri-Sebina, G. (2011). Towards an inclusive national system of innovation. Paper prepared for the Ministerial Review Committee on the Science, Technology and Innovation Landscape in South Africa.

Kay, J. (2011) 'What is innovation?', In Tilford, S. and Philip W. (Eds) *Innovation: How Europe can Take off*. London: Centre for European Reform.

Kim, L. (1997) *From Imitation to Innovation. The Dynamics of Korea's Technological Learning.* Boston: Harvard University Press.

Koch, C. (2008) 'The superministry approach', *Science and Public Policy*, 35(4): 253–264.

Lawless, A. (2005) *Numbers and Needs: Addressing the Imbalances in the Civil Engineering Profession*. Midrand: SAICE.

Letseka, M., Cosser, M. Breier, M. and Visser, M. (2010) *Student Retention and Graduate Destination. Higher Education And Labour Market Access And Success.* Cape Town: HSRC Press.

Maharajh, R. (2011) *Science, Technology and Innovation in South Africa and the Quest for Economic Expansion, Social Inclusion and Sustainable Development*. Paper on Planning, Monitoring, Evaluation and Learning for Innovation.

Marcelle, G. (2011) Private Sector Perspectives on Innovation. Paper prepared for the Ministerial Review Committee on the Science, Technology and Innovation Landscape in South Africa.

Meiring Naude, S. and Brown, A.C. (1977) 'The growth of scientific institutions in South Africa', In Brown, A.C. (Ed) *A History of Scientific Endeavour in South Africa.* Cape Town: Royal Society of South Africa.

Miles, I., Cunningham. P., Cox, D., Crowe, C. Malik, K. and Jaso, M. (2006) *Smart Innovation: A Practical Guide to Evaluating Innovation Programmes.* A Study for DG Enterprise and Industry. Brussels: European Commission.

Motala, E. (1994) The employment composition and affirmative action programmes of the science councils in South Africa, University of Durban-Westville Macro-education Policy Unit, Durban (Mimeo).

Murray, R., Caulier-Grice, J. and Mulgan, G. (2010) *The Open Book of Social Innovation*. London: Young Foundation.

NACI (2006a) *The South African National System of Innovation: Structures, Policies and Performance. Background Report to the OECD Country Review of South Africa's National System of Innovation.* Pretoria: National Advisory Council on Innovation.

NACI (2006b) *The South African National System of Innovation: Structures, Policies and Performance. Background Report to the OECD Country Review of South Africa's National System of Innovation*. Pretoria: National Advisory Council on Innovation.

NACI (2007) *Human Capital and the South African Knowledgebase*. Pretoria: National Advisory Council on Innovation.

NACI (2008) *NACI Response to the 2008 External Review*. Pretoria: National Advisory Council on Innovation.

NACI (2010) Status of Government's poverty reduction programmes: focus on DST's social impact programme. Draft report. Pretoria: National Advisory Council on Innovation.

NPC (National Planning Commission) (2011a) Diagnostic Report. Pretoria: Office of the President.

NPC (National Planning Commission) (2011b) National Development Plan. Pretoria: Office of the President.

NRF (2011) *SETI Review of the NRF 2010*. Pretoria: National Research Foundation.

NSFAS (National Student Financial Aid Scheme) (2010) Balintulo review.

OECD (1997) Oslo Manual: *Guidelines for Conducting Innovation Surveys* (2nd edition). Paris: Organisation for Economic Cooperation and Development.

OECD (2005a) *Innovation Policy and Performance*: A cross-country comparison. Paris: Organisation for Economic Cooperation and Development.

OECD (2005b) *Governance of Innovation Systems* Volume I, Synthesis Report. Paris: Organisation for Economic Cooperation and Development.

OECD (2005c) Oslo Manual: *Guidelines for Conducting Innovation Surveys* (3rd edition). Paris: Organisation for Economic Cooperation and Development.

OECD (2007) *Review of South Africa's Innovation Policy*. Paris: Organisation for Economic Cooperation and Development.

OECD (2008) *Reviews of Innovation Policy: Norway*. Paris: Organisation for Economic Cooperation and Development.

OECD (2009a) Chile's National Innovation Council for Competitiveness: Interim Assessment and Outlook. Paris: Organisation for Economic Cooperation and Development.

OECD (2009b) *OECD Reviews of Innovation Policy: Korea*. Paris: Organisation for Economic Cooperation and Development.

OECD (2010) *Main Science and Technology Indicators.* Paris: Organisation for Economic Cooperation and Development.

OECD (2011) *Fostering Innovation to Address Social Challenges*. Paris: Organisation for Economic Cooperation and Development.

Perez, C. (2002) *Technological Revolution and Financial Capital: The Dynamics of Bubbles and Golden Ages.* Cheltenham: Edward Elgar.

Perez, C. (2007). 'Two realities, two policies', In Casas, R., Fuentes, C. and Vera-Cruz, A. (Eds) *Acumulacion de Capacidades Tecnologicas, Aprendizaje y Cooperacion en la Esfera Global y Local* [Accumulation of Technological Capacities, ... Studies on Technology Innovation]. Estudios sobre la innovatión technológica. Universidad Autonóma Metropolitana, Adiat, Miguel Angel Porrúa.

Petersen, F. (2011) Specialist Report on Social Innovation and Sustainability. Paper prepared for the Ministerial Review Committee on the Science, Technology and Innovation Landscape in South Africa.

Pouris, A. (2006). 'The international performance of South African academic institutions: A citation assessment', *Higher Education,* 54(4): 501–509.

Pouris, A. (2009) 'Quantitative assessment of South Africa's inventive outputs: International patent analysis', *South African Journal of Industrial Engineering.* 20(1): 13–29.

Ramphele, M. (2010) Guest foreword. *The CSI Handbook* (13th edition). Cape Town: Trialogue.

Routti, M. (2007) Finland's Knowledge Economy. PowerPoint presentation to the Department of Science and Technology.

Royal Society (2011) *Knowledge, Nations and Networks. Global Scientific Collaboration in the 21st Century.* London: Royal Society

Segal, N. (2011) Leveraging long-term economic benefit from distinctive technological capability: dry-cooling of power stations in South Africa. Paper prepared for the Ministerial Review Committee on the Science, Technology and Innovation Landscape in South Africa.

Spicer, M. and Godsell, B. (2010) *South Africa as a Developed Country: Some Ideas from Business Leadership*. Johannesburg: Business Leadership South Africa.

Stumpf, R. (2011) An approach to human capacity development for science, technology and innovation. Paper prepared for the Ministerial Review Committee on the Science, Technology and Innovation Landscape in South Africa.

Taloustieto, O. (2009) *Evaluation of the Finnish National Innovation System*. Helsinki: Helsinki University Press.

Trialogue (2010) *The CSI Handbook* (13th edition). Kenilworth: Trialogue.

UNESCO (1980) *Manual for Statistics on Scientific and Technological Activities.* Paris: United Nations Educational, Scientific and Cultural Organisation, Division of Statistics on Science and Technology, Office of Statistics.

UNESCO (2009) Country Report: the Science and Technology System in Malaysia. Paris: United Nations Educational, Scientific and Cultural Organisation.

Van den Heever, A. (2011) Internalising innovation within the social security system. Paper prepared for the Ministerial Review Committee on the Science, Technology and Innovation Landscape in South Africa.

Von Holdt, K. (2010) *The South African Post-Apartheid Bureaucracy: Inner Workings, Contradictory Rationales and the Developmental State*. Pretoria: HSRC Press.

Walwyn, D. and Scholes, B. (2006) 'The impact of a mixed income model on the South African CSIR: A recipe for success or disaster', *South African Journal of Science,* 102: 239–243.

Ward, E. (2011) *The World in 2050.* London: HSBC Bank.

WEF (2010) *Global Competitiveness Report 2010–2011.* Geneva: World Economic Forum.

Wheatcroft, G. (1985) *The Randlords*. New York: Atheneum.

World Bank (2000) *Higher Education in Developing Countries: Perils and Promise.* Washington, DC: World Bank.

World Bank (2006a) *Finland as a Knowledge Economy*. Washington, DC: World Bank.

World Bank (2006b) *Korea as a Knowledge Economy.* Washington, DC: World Bank.

World Bank (2007a) 'A decade of measuring the quality of governance', *Governance Matters 2007*. Washington, DC: World Bank.

World Bank (2007b) *Malaysia and the Knowledge Economy*. Washington, DC: World Bank.

APPENDIX 1: LIST OF ACRONYMS

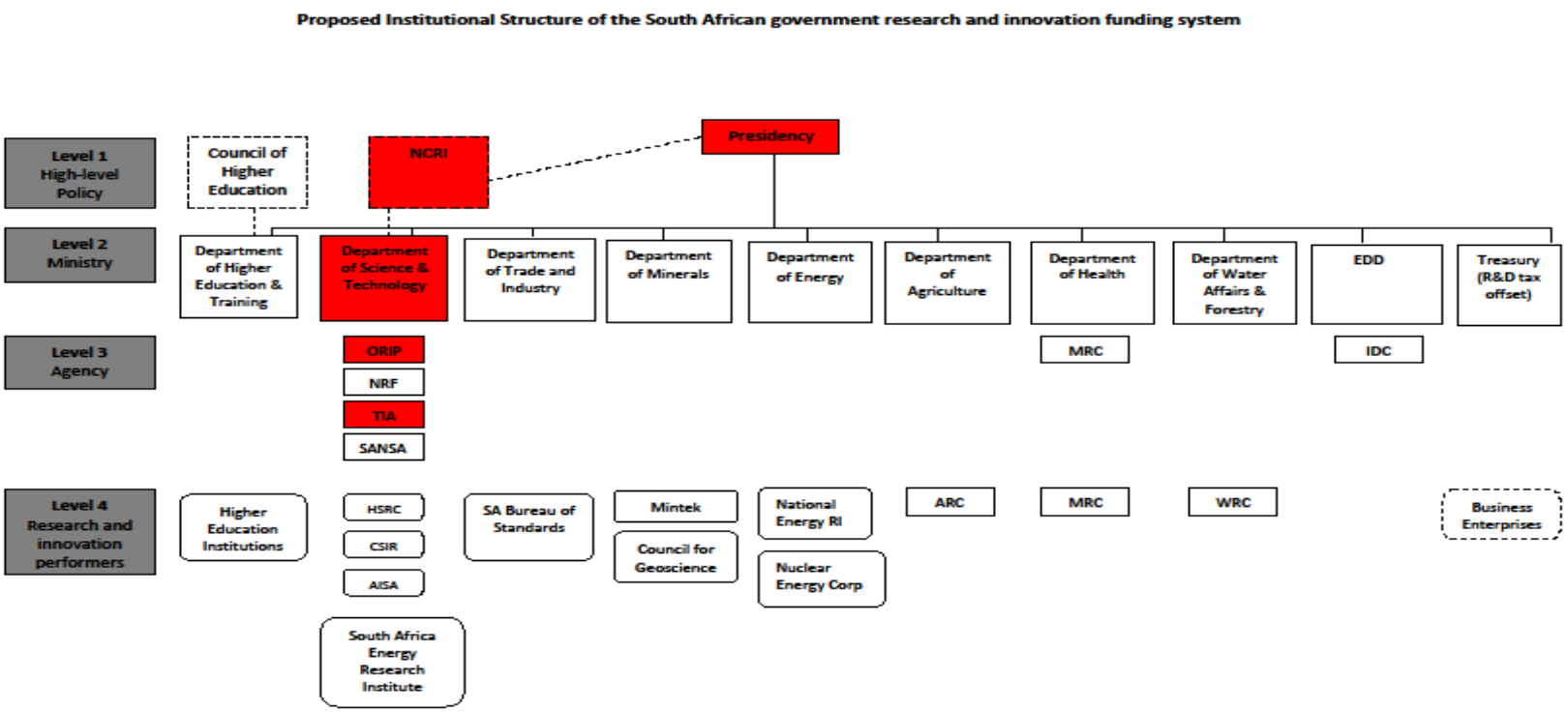
AIDP	Automotive Industry Development Programme
AIDS	Acquired immune deficiency virus
AISA	Africa Institute of South Africa
AMS	Advanced Manufacturing Technology Strategy
ANC	African National Congress
ARC	Agricultural Research Council
ASGISA	Accelerated and Shared Growth Initiative for South Africa
ASSAf	Academy of Science of South Africa
BBBEE	Broad-based black economic empowerment
BERD	Business expenditure on R&D
BLSA	Business Leadership South Africa
BRIC countries	Brazil, Russia, India, China
BRIC	Biotechnology Regional Innovation Centre
BSC	Balanced Scorecard
BTech	Bachelor of Technology
CBO	Community-based organisation
CDE	Centre for Development Enterprise
CEO	Chief executive officer
CERN	European Organisation for Nuclear Research (*Organisation Européenne pour la Recherche Nucléaire*)
CeSTII	Centre for Science, Technology and Innovation Indicators
CHE	Council on Higher Education
CIPC	Companies and Intellectual Properties Commission
COFISA	Cooperative Financial Institute of South Africa
COHORT	Committee of Heads of Organisations of Research and Technology
CREST	Centre for Research on Evaluation, Science and Technology, Stellenbosch University
CSI	Corporate social investment
CSIR	Council for Scientific and Industrial Research
CSIRO	Commonwealth Scientific and Industrial Research Organisation's
CV	Curriculum vitae
DACST	Department of Arts, Culture, Science and Technology
DEEM	Design, engineering, entrepreneurship and management
DG	Director-General
DHET	Department of Higher Education and Training
DNA	Deoxyribonucleic acid
DoE	Department of Education (until 2009)
DoE	Department of Energy (since 2009)
DoH	Department of Health
DMR	Department of Mineral Resources
DPE	Department of Public Enterprises
DRDLR	Department of Rural Development and Land Reform
DRAM	Dynamic random-access memory
DSD	Department of Social Development
dti	Department of Trade and Industry
DVC	Deputy Vice-Chancellor
EDD	Economic Development Department
FDI	Foreign direct investment

FRD	Foundation for Research Development
FTE	Full-time equivalent
FTSE	FTSE Group
GERD	Gross domestic expenditure on R&D
HCD	Human capital development
HEI	Higher education institution
HEMIS	Higher Education Management Information System
HEQC	Higher Education Quality Committee
HEQF	Higher Education Qualifications Framework
HESA	Higher Education South Africa
HET	Higher education and training
HIV	Human immunodeficiency syndrome
HSRC	Human Sciences Research Council
ICSU	International Council for Science
ICT	Information and communication technology
ID	Identity
IDC	Industrial Development Corporation
IDRC	International Development Research Centre
IP	Intellectual property
IPAP	Industrial Policy Action Plan
IPR	Intellectual property rights
ISI	Institute for Scientific Information
iThemba LABS	iThemba Laboratory for Accelerator-based Science
JET	Joint Education Trust
JINR	Joint Institute for Nuclear Research
JSE	Johannesburg Securities Exchange
KAT	Karoo Array Telescope
KPI	Key performance indicators
M&E	Monitoring and evaluation
MCOST	Ministers' Committee on Science and Technology
MDG	Millennium Development Goals
MDM	Mass Democratic Movement
Mintek	Council for Mineral Technology
MIS	Management information system
MoU	Memorandum of understanding
MP	Member of Parliament
MRC	Medical Research Council
MTEF	Medium-Term Expenditure Framework
NACI	National Advisory Council on Innovation
NARS	National Agricultural Research System
NASA	National Aeronautics and Space Administration
NCRI	National Council on Research and Innovation (proposed)
NECSA	South African Nuclear Energy Corporation
NEP	National Equipment Programme
NEPAD	New Partnership for Africa's Development
NGO	Non-governmental organisation
NIFU-STEP	Nordic Institute for Studies in Innovation, Research and Education - Centre for Innovation Research
NIPMO	National Intellectual Property Management Office
NNEP	National Nanotechnology Equipment Programme
NPC	National Planning Commission
NPO	Non-profit organisation
NQF	National Qualifications Framework

NRDS	National Research and Development Strategy
NREN	National Research and Education Network
NRF	National Research Foundation
NRTF	National Research and Technology Foresight
NSF	National Skills Fund
NSI	National System of Innovation
NSMM	New Strategic Management Model
NSTF	National Science and Technology Forum
OECD	Organisation for Economic Cooperation and Development
OEM	Original equipment manufacturer
ORIP	Office for Research and Innovation Policy (proposed)
PBMR	Pebble Bed Modular Reactor
PhD	Doctor of Philosophy
PIC	Public Investment Corporation
PRO	Public research organisations
R&D	Research and development (sometimes Research and experimental development)
R&I	Research and innovation
RIMS	Research Information Management System
S&T	Science and technology
SA	South Africa/ South African
SAASTA	South African Agency for Science and Technology Advancement
SADC	Southern African Development Community
SAIMR	South African Institute for Medical Research
SALT	Southern African Large Telescope
SANBI	South African National Biodiversity Institute
SANReN	South African National Research Network
SAPSE	South African Post-Secondary Education
SANSA	South African National Space Agency
SARChI	South African Research Chairs Initiative
SARIMA	Southern African Research an d Innovation Management Association
SARS	South African Revenue Service
SAYAS	South African Young Academy of Science
SCiELO	Scientific Electronic Library Online
SET	Science, engineering and technology
SETI	Science, engineering and technology institutions
SKA	Square Kilometre Array
SME	Small and medium enterprises
SOE	State-owned enterprises
SPII	Support Programme for Industrial Innovation
SRIP	Strategic Research Infrastructure Programme
STA	Science and Technology Activities
STEM	Science, technology, engineering and mathematics
STET	Scientific and Technological Education and Training
STI	Scientific and Technological Innovation
STS	Scientific and Technological Services
TB	Tuberculosis
TBOP	Technology Balance of Payments
TENET	Tertiary Education and Research Network of South Africa
THRIP	Technology and Human Resources for Industry Programme
TIA	Technology Innovation Agency
TIPTOP	Technology Innovation Programme for the Transfer of People
TNC	Transnational corporation

TYIP	Ten-Year Innovation Plan
UK	United Kingdom
UNESCO	United Nations Educational, Scientific and Cultural Organisation
USPTO	United States Patent and Trademark Office
VDU	Visual display unit
WoK	Thomson-Reuters Web of Knowledge
WRC	Water Research Commission
US	United States of America
VP	Vice President

APPENDIX 2: ORGANOGRAMS OF THE PROPOSED INSTITUTIONAL STRUCTURE FOR THE SOUTH AFRICAN NSI



Proposed 'Functional Organogram' for the NSI

[Note: red = new proposal]