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.

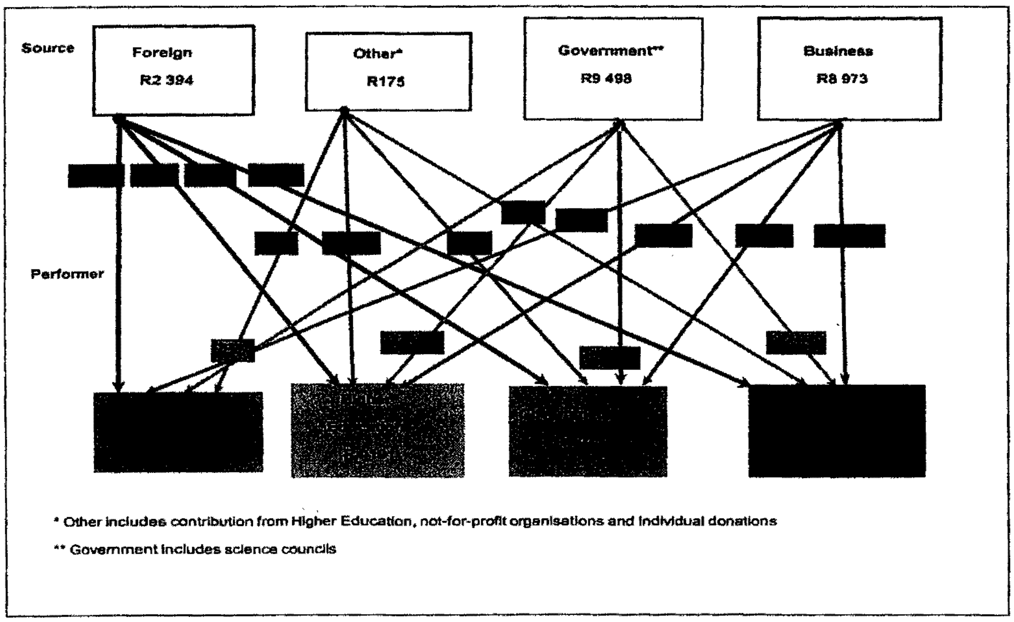

Figure 1: Major flows of funding for R&D, 2008/09 (R' millions)

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).