SOUTH AFRICA'S NATIONAL RESEARCH AND DEVELOPMENT STRATEGY

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THE CONTEXT FOR THE NATIONAL R&D STRATEGY

"Critical in this regard (wealth creation in the context of globalisation) is the matter of human resource development. We have to exert maximum effort to train the necessary numbers of our people in all the fields required for the development, running and management of modern economies. This, again, must be a national effort in which we should consider the necessary expenditures not as a cost but as an investment in our future.

Secondly, we have to ensure that as many of our people as possible master modern technologies and integrate them in their social activities, including education, delivery of services and economic activity. This relates in particular to communication and information technology.

Thirdly, we have to devote the necessary resources to scientific and technological research and development, including biotechnology. We must further encourage innovation among our people and ensure that we introduce new developments into our productive activities.

Fourthly, while ensuring that we continue to develop a balanced economy, we must also identify and develop the lead sectors that will help us further to expand the base for creation of wealth and give us the possibility to compete successfully within the dynamic world economy."

President Thabo Mbeki
January 2002

MESSAGE FROM THE MINISTER OF ARTS, CULTURE, SCIENCE AND TECHNOLOGY, THE HONOURABLE DR BEN NGUBANE

Science and technology is critical to the future of South Africa. Government recognises the key role it plays in providing an enabling environment for innovation and research and in building the human capital that we require for the future knowledge economy. Since the publication of the White Paper in 1996, there have been important changes in our system of innovation. Institutions and their programmes are better aligned to our National needs. The Innovation Fund has created stronger innovation networks, and programmes such as the GODISA Innovation and Incubator Programme and the Tsumisano Technology Stations Programme have begun to strengthen technology diffusion and harness the entrepreneurship of the Science and Technology community.

However, these positive steps forward revealed that there are new sets of challenges facing us, to which we must respond. Innovation is not the same as research and development. Innovation is the key process by which products, processes and services are created, and by which businesses generate jobs and wealth. In addition, in the social sphere, effective innovation has a direct impact on the reduction of poverty and the improvement of the quality of life of our people. It is critical, therefore, to increase the rate and quality of innovation in South Africa.

Innovation needs people – well-trained, effective scientists, engineers and technologists. There is increasing evidence that our progress in producing scientists, engineers and technologists is not yet satisfactory. We therefore need a number of interventions to strengthen the transformation of our science and technology capacity to achieve increased numbers of people working in key fields that are of importance to the future.

In this regard, it is critical that government develops a strategic view of all actors, stakeholders and participants of the National System of Innovation through a single responsible department . This will allow better governance, more effective resource allocation and better outcomes in the short, medium and long term.

The publication of this strategy represents a milestone for the National System of Innovation in South Africa. It coincides with the establishment of the Department of Science and Technology, which will be charged with giving effect to this strategy. However, a more effective innovation system is a partnership developed between all institutions involved in creating new knowledge, producing innovations and diffusing them to the benefit of the people of South Africa and our region. Therefore, I encourage positive and proactive engagement with this strategy in order to rapidly and effectively implement its key programmes.

Therefore, it is with great pleasure that I present to you the National R&D Strategy.

MESSAGE FROM THE DEPUTY MINISTER OF THE DEPARTMENT OF ARTS, CULTURE, SCIENCE AND TECHNOLOGY, THE HONOURABLE BRIGITTE MABANDLA

Science and technology are critical to the process of sustainable development. There is increasing evidence that the existing policy frameworks for development have significantly underestimated the importance of science and technology and, as a result, development policies have not led to sustainable outcomes, or improved the quality of life for the most marginalised people of the developing world.

There is also evidence that women and people from previously disadvantaged communities have not benefited sufficiently in terms of access to, and participation in, science, engineering and technology in South Africa as yet. The National Research and Development Strategy addresses these issues while at the same time sharpening our focus on areas of research and innovation that are directly relevant to South Africa and the region.

South Africa undertakes about 0,5% of global research. This requires us to strengthen our connectedness to global research networks and to ensure that we develop networks and centres of excellence in the SADC and across the continent. In addition, we need to ensure that we properly protect our intellectual property and indigenous knowledge, and conserve South Africa's unique biodiversity. As you give consideration to this strategy, you will note increased focus in all the above-mentioned areas.

It is critical to recognise that addressing these areas effectively will require new partnerships and new commitments from the science, engineering and technology community. The strategy explicitly recognises the importance of all stakeholders having a positive view of the value of science and technology on their lives and for our common future.

I therefore join the Minister in encouraging you to work effectively in the development of a stronger system of innovation in South Africa and the region.

FOREWORD BY THE DIRECTOR-GENERAL OF THE DEPARTMENT OF SCIENCE AND TECHNOLOGY, DR ROB ADAM

In July 2002, the Cabinet considered and approved this National R&D Strategy. The R&D Strategy as reflected in this document therefore represents the way forward for publicly financed science and technology and for creating an enabling environment for the National System of Innovation as a whole. The strategy operates at the level of major interventions and, therefore, it will lead to a wide range and variety of more detailed implementation activities. Organisations and groups are invited to approach the Department of Science and Technology or its agencies if they wish to participate in specific strategy initiatives or contribute to the detailed implementation phases. The Department will make every effort to align such approaches with existing processes and, where necessary, establish new ones to achieve the objectives of the National R&D Strategy.

The strategy embraces a number of initiatives, such as the National Biotechnology Strategy, which are already in progress. In addition, the strategy is designed to utilise existing institutions, where possible, to strengthen the system of innovation. This will have the positive benefit of allowing positive short-term outcomes to be realised. It is important to recognise that this is a strategy and not a policy. The White Paper on Science and Technology published in September 1996 remains a robust and effective framework from a policy perspective. This strategy operates in the context of that policy to strengthen key elements of our system of innovation that have been identified as needing particular attention and focus. It is possible, therefore, that some actors in the system of innovation will not "find" themselves in this document, but this should not be a cause for concern. Strategies by their nature are intended to provide focus and deliver particular outcomes. The system as a whole has made very positive progress in the past few years, and therefore not all elements require the same degree of attention.

However, this is not a piecemeal strategy, and will influence, over time, the vast majority of actors in our system of innovation. It will therefore be valuable for all institutions and participants in the system to give consideration to this strategy, and to indicate it can best be implemented and enhanced. The Department of Science and Technology, with its partners in Government, the Science Councils, higher education and the private sector, faces the challenge of delivering increased economic growth and improved quality of life as the two key outcomes addressed by this strategy.

We offer this Strategy for your detailed consideration and invite you to participate and contribute to the processes already in place or to be created, which will give full expression to its implementation.

South Africa’s National R&D Strategy

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LIST OF ABBREVIATIONS AND ACRONYMS

ARC	Agricultural Research Council
BEE	Black Economic Empowerment/Enterprises
CITI	The Cape Information Technology Initiative
CSIR	Council for Scientific and Industrial Research
CSIR	Council for Scientific and Industrial Research
DACST	Department of Arts, Culture, Science and Technology (until July 2002)
DEAT	Department of Environmental Affairs and Tourism
DFA	Department of Foreign Affairs
DoD	Department of Defence
DoE	Department of Defence
DTI	Department of Trade and Industry
DWAF	Department of Water Affairs and Forestry
ENHR	Essential National Health Research
GDP	Gross Domestic Product
HSRC	Human Science Research Council
MRC	Medical Research Council
NDA	National Department of Agriculture
NEPAD	New Partnership for African Development
NRF	National Research Foundation
NSI	National System of Innovation
OECD	Organisation for Economic Cooperation and Development
PII	Partnership in Industrial Innovation
R&D	Research and development – two key processes of developing and applying new knowledge
S&T	Science and technology – the two key domains of knowledge that underpin innovation
SET	Science, Engineering and Technology (usually in the context of human resources)
SPII	Support programme for Industrial Innovation
TRHIP	Technology for Human Resources in Industry
TRIPS	Trade Related Intellectual Property
USA	Unites States of America
USSR	Union of Soviet Socialist Republics
WIPO	World Intellectual Property Organisation

EXECUTIVE SUMMARY

Following the January 2002 Lekgotla, Cabinet directed the Minister of Arts, Culture, Science and Technology to produce a National Research and Development (R&D) Strategy. This R&D Strategy will be a key enabler of economic growth and articulate with other strategies, such as the Human Resource Development Strategy, the Integrated Manufacturing Strategy and the Strategic Plan for South African Agriculture.

Important recent and historical factors that need to be taken into account in the development of a new National R&D Strategy are:

- The termination of key technology missions (such as military dominance in the subcontinent and energy self-sufficiency) by the previous government between 1990 and 1994. This resulted in a drop in national R&D spending from 1,1% in 1990 to 0,7% of Gross Domestic Product (GDP) in 1994**. This reduction happened at a time when the National System of Innovation needed to expand to cope with the needs of 40 million people as opposed to a mere 5 - 6 million.**
- Strategic considerations, from human, economic and security perspectives. Adequate responses to new diseases and to old forms of new diseases, whether these diseases affect humans or animals, need to be informed by local research programmes. From a security perspective, even being a smart buyer of rapidly developing technology rather than a developer requires a critical mass of local scientists doing research in relevant areas. The S&T capacity of the country is running as fast as it can, but is still losing ground.
- Human Resources. Our human resources for science and technology are not being adequately renewed. An overwhelmingly white, male and aging scientific population is not being replaced by younger groupings more representative of our demographics.
- A complex set of factors driven largely by globalisation has resulted in reduced levels of both investment and performance by the South African private sector in R&D. This could result in a loss of local control of the developing knowledge base that underpins the success of our most competitive companies.
- Inadequate intellectual property legislation and infrastructure. New developments in biotechnology have increased our vulnerability with respect to the exploitation of our biodiversity, and inventions and innovations from publicly financed research is not effectively protected and managed.
- Fragmented governance structures. Although research institutions have been reviewed and key performance indicators put in place, the roles of different departments in governance and in setting output targets for government research institutions is not clear or synergistic. From

a budget perspective there is no holistic view of science and technology spending by government.

The new R&D Strategy is indicator based and rests on three pillars:

- Innovation
- Science, engineering and technology (SET) human resources and transformation
- Creating an effective government S&T system

The innovation "pillar" involves the establishment and funding of a range of technology missions that are critical to promote economic and social development. These include the two key technology platforms of the modern age, namely *biotechnology* and *information technology*. Two additional missions are *technology for manufacturing* and *technology to leverage knowledge and technology from, and add value to, our natural resources sectors.* Finally, we will establish a mission, *technology for poverty reduction*, to address one of the scourges of our age. This portfolio of missions needs to be managed in a coherent and integrated fashion. This will require strategic and operational functions to manage and resource technological innovation. These functions are to be developed initially within the Department of Science and Technology, which may potentially lead to the formation of a dedicated institution, the Foundation for Technological Innovation. This function will operate as a knowledge-based financing agency concentrating on innovation within each of the technology missions. It will fund innovation across the public and private sectors, and across the value chain from concept to market–though, with a key focus on high-cost development and market acceptance stages through commercialisation, incubation and diffusion.

Our approach to human resource development is rooted in the need, on the one hand, to radically increase the number of women and people from previously disadvantaged communities entering the sciences and remaining there and, on the other hand, a strategy to maximise the pursuit of excellence in global terms. Public Understanding of Science programmes can succeed in increasing these numbers only if young people can see fulfilling and remunerative careers ahead of them. During the 1970s and 1980s such careers were plentiful as a result of the key technology missions of the day – though focused, in South Africa, on one privileged community. Thus, the human resources pillar is critically linked to the innovation pillar. Around the world the time-tested way to produce high-quality creative scientists capable of transferring from one discipline to another is to focus on excellence. One way to achieve national excellence is to focus our basic science on areas where we are most likely to succeed because of important natural or knowledge advantages. In South Africa, such areas include astronomy, human palaeontology and indigenous knowledge. The key institution, in the context of this strategy, for promoting science, is the National Research Foundation, which is linked to the higher education sector through the National Plan for Higher Education

Although realignments of functions within government took place in 1994, key governance and institutional responsibilities in the National System of Innovation largely remained frozen. The third pillar of the new R&D Strategy addresses this issue by:

- Creating a clear distinction between the roles of line departments (such as Agriculture and Health) that deliver to specific sectors, and the Department of Science and Technology, which should play an integrative role.
- Ensuring that international best practice with respect to government funding of science and technology, namely the well-articulated functions of basic research (knowledge generation), innovation (new businesses, products and services) and venture capital, is observed.

The role of the Department of Science and Technology will be to coordinate a coherent performance management system for all government-owned laboratories and to have direct responsibility for five cross-cutting institutions, namely the National Research Foundation, the function currently represented by FEST (shortly to become the Institute for the Promotion of Science), the functions represented by the proposed Foundation for Technological Innovation, the Council for Scientific and Industrial Research and the Human Sciences Research Council. Line departments would have the responsibility to set research goals and budgets for institutions reporting to them. Basic research is a key shared function of the Department of Science and Technology and the Department of Education. Line departments will be involved in innovation in collaboration with the Department of Science and Technology.

Venture capital stimulation and fiscal incentives to encourage and enhance private sector participation will be the responsibility of the Department of Trade and Industry and its agency, the Industrial Development Corporation.

Across the world, in response to the increasing rates of knowledge production, dissemination and application, the shortening of product life cycles and the increasing competition for human resources, many countries are increasing their national investment in research and development. The OECD average across public and private sectors is 2,15% of GDP and countries such as Finland and Korea spend far more. South Africa's current level of 0,7% is significantly lower than it should be to ensure national competitiveness in years to come. This fact is emphasised every year in the *World Competitiveness Report*.

Accordingly, this new R&D Strategy depends on doubling government investment in science and technology over the next three years, with more gradual increases thereafter. This would raise the national investment to somewhat over 1%, not yet as large as many of our competitors, but enough to signal an appropriate, comprehensive and sustainable strategy for the knowledge economy, South Africa's current research community and the new generation that will be required to achieve our goals.

1. INTRODUCTION

1.1 Background to the R&D Strategy

Between 1990 and 1994, the strong missions for technology developed by the National Party government (e.g. military dominance in the subcontinent, energy self-sufficiency, etc.) were systematically stripped off. The percentage of the South African gross national product spent on research and development declined from 1,1% in 1990 to its current level of about 0,7%. The basic platform of competence in manufacturing technology, agriculture, mining and minerals research and fundamental sciences at the universities remained in place. However, the areas of high investment, which sustained critical mass in the past, were gone by 1994. In addition, the acceleration of corporate restructuring in the face of globalisation has significantly reduced the attraction for South African firms of undertaking bold innovation missions from within the private sector. There is evidence that the private sector, with the exception of SASOL and some innovative small firms, is disinvesting from R&D at an alarming rate. The process of privatisation may also pose risks to the national R&D capacity if national research needs are not taken into account (an important example in this respect is energy research).

The new government faced challenges in basic development. Having focused on the future for so long in the struggle, we now had to deal with the urgent service delivery needs of the present. Not surprisingly, the new funding scenarios required re-direction of the remaining technology competencies towards missions emphasising quality of life and economic competitiveness. However, the emphasis was on reprioritisation rather than the funding of new missions. Within this policy space, the White Paper on Science and Technology approved by Cabinet in 1996, established a policy framework for science and technology in South Africa based on the concept of a National System of Innovation (NSI).

In the NSI framework “Innovation” is defined as the introduction into a market (economic or social) of new or improved products and services. The NSI itself can be thought of as a set of functioning institutions, organisations and policies that interact constructively in the pursuit of a common set of social and economic goals and objectives, and that use the introduction of innovations as the key promoter of change. The idea of “innovation pull” as opposed to “science push” was already well developed in OECD policy forums and championed in the European Union by former French Prime Minister Edith Cresson. However, South Africa was the first country to adopt such a framework as its national policy. Many other countries have subsequently followed suit.

Despite having achieved recognition as trail blazing in international technology policy circles, South Africa’s national policy on science and technology has struggled to make an impact on broader debates and processes in the economy and society. This has been largely for three reasons:

1. The governance structures in the science and technology system are extremely complex and are therefore resistant to strategic intervention by a single agent.
2. The development agenda has tended to focus on the alleviation of immediate problems rather than on building platforms to deal with development in the longer term.
3. The economic debate has only recently progressed beyond discussing the control of macro-economic parameters, to recognition of the importance of micro and meso-economic factors such as research, training and entrepreneurship.

Notwithstanding significant changes in South Africa and in the rest of the world, the framework of a National System of Innovation seems as compelling as it did six years ago. It has become clear that economic growth depends on effective sectoral and cluster strategies (in agriculture, manufacturing, telecommunications, etc.), on infrastructure (electricity, transport) and on key enablers (human resources, research and development).

In the light of this and critical evaluation of quantitative R&D indicators, several factors emerged that led to a fundamental re-examination of innovation and of research and development in South Africa. These factors were set down in the paper *"The development of a research and development strategy for South Africa"*, which was presented by the Economic Cluster to the January 2002 Cabinet Lekgotla. This paper outlines six key weaknesses in which major interventions need to be made to enable the White Paper vision to be sustained. (Attachment 1)

2. KEY WEAKNESSES TO BE ADDRESSED IN THE R&D STRATEGY

2.1 Appropriate Funding of the National System of Innovation

Current South African total (public and private sector) expenditure on R&D amounts to approximately 0,7% (government 0,29%) of GDP whereas the average OECD country expenditure is 2,15% of GDP. Finland, for example, with an economy the same size as South Africa, spends 3, 5% (government 1%).

2.2 Strategic considerations

Given the very rapid development of key technology areas today, we will expose ourselves to insurmountable security risks if we do not commit to maintaining and developing competencies across the system (universities, research councils, private sector, etc.) in critical strategic areas.

2.3 Human Resources

Our human resources in science and technology are not being adequately developed and renewed; we have an aging and shrinking scientific population. The key indicators show that black and women scientists, technologists and engineers are not entering the academic ranks and that the key research infrastructure is composed of people who will soon retire. In 1990, the percentage of scientific publications produced by researchers 50 years of age and older was 18% (one in five), but by 1998 this figure had increased, alarmingly, to 45% (one in two). Over the same period the percentage of publications by black scientists rose only very slightly, from 3,5% to 8% (less than one in ten). Participation by women has not changed over the 1990s, with publication output being about 10% of the total. Currently, there is less than one researcher for every thousand members of the workforce, as compared with five in Australia and ten in Japan. Given that “technology walks on two legs”, the “frozen demographics” prevalent in our National System of Innovation represents a critical state of affairs.

2.4 Declining research and development in the private sector

Research and development undertaken by large South African companies has shown a significant, measurable decline in the past four years. Global statistics show that the real determinant of technology-driven economic development is a sustained high level of research and innovation by the indigenous private sector, by firms of all sizes. The current drive towards restructuring of large companies in the face of global economic forces has serious national consequences in the area of technology. The ongoing inability to stimulate world-class innovation will relegate the economy to, at best, “follower” status and transfer of mature technologies (rather than cutting-edge technology innovation). This will not support our new manufacturing strategy or permit us to achieve above-average growth rates.

2.5 Intellectual property

New technologies have created new challenges with regard to intellectual property. This is particularly true for biotechnology and its relation with local biodiversity and indigenous knowledge. International thinking on legislation is as fluid and fast moving as the new technologies themselves. We need to develop competencies as a matter of urgency or face exploitation and marginalisation with respect to our own resources. A clear approach to intellectual property that arises from publicly financed research is required.

2.6 The fragmentation of government science and technology

The fragmented management, frozen institutional arrangements and funding structures for government-led science and technology does not provide the right platform for leadership and strategic response in this domain. A range of technology-intensive institutions and programmes are currently being driven by different government departments with very little coordination in strategy or sharing of learning.

3. THE STRATEGIC OBJECTIVES

The objective of this strategy is to address these weaknesses in a profound but practical way. In particular, the approach is to apply internationally well-tested principles and systems that are adjusted to local realities and requirements. The strategy must be able to give expression to our national goals of economic development and improvement of quality of life for all citizens.

The three operational strategic objectives, which will be elaborated on in Chapters 5, 6, and 7, respectively, are:

3.1 Achieving mastery of technological change in our economy and society (Innovation)

Economic growth and wealth creation are based on innovation. Without the establishment of new technology missions aligned to quality of life goals and economic and industrial strategies, we will not be able to make progress towards a knowledge economy. A dedicated agency function to facilitate innovation is proposed. This agency function will finance these technology missions, and link to other innovation financing instruments, technology and business incubation, and technology transfer and diffusion activities. All relevant institutions, the private sector, research organisations, venture capital and the universities will be mobilised to deliver innovation through the technology missions. The achievement of coherence in the area of innovation is critical to strategic success.

3.2 Increasing investment in South Africa's science base (Human Capital and Transformation)

As indicated in section 2.3, South Africa is suffering from "frozen demographics" in the science, engineering and technology workforce, both with respect to race and gender. A winning human resource strategy will require new approaches and investments on both supply and demand sides. On the one hand, a highly targeted approach towards increasing excellence in mathematics and the sciences among black matriculants and young women is a critical requirement. On the other hand, new Centres of Excellence must be established in order to draw young people towards careers in scientific research and to ensure that such careers are sustainable.

3.3 Creating an effective government science and technology system (Alignment and Delivery)

The new strategy embodies a clear operational distinction between the integrative department responsible for the “global” management of science and technology across government and line departments with sector strategies that necessarily involve research and development. The integrative Department of Science and Technology will be responsible for a regulatory framework affecting all institutions with research and development as a primary mandate, whereas the line departments will set objectives and budgets for these institutions within this framework. In addition, the major cross-cutting funding agencies for research and development and innovation will reside under the Department of Science and Technology, as will state-owned laboratories and research organisations with mandates cutting across the responsibilities of many line departments.

4. STRATEGIC CONTEXT

4.1 Universal properties of healthy national systems of innovation

The new R&D strategy is based on the National System of Innovation (NSI) adopted in the White Paper on Science and Technology. To this is added a logical indicator framework for short and long-term performance measurement of the S&T system.

The variations between different countries' systems of innovation are profound. For example, Australia has a well-developed system of heavily subsidised government laboratories that focus on adding value to key primary products in the mining and agricultural sectors. Finland, by contrast, emphasises funding instruments that promote research collaboration within and between the higher education and business sectors – but with a strong emphasis on both human capital and focus areas for industrial innovation. Chile appears to be moving away from a mixed system of government laboratories and universities towards something more like the Finnish model. South Africa has a mixed NSI, with roughly equal research and development performed by the private sector, higher education and government. The private sector and government sector each finance about 50% of total spending.

Despite the marked variations between systems of innovation, key functions are present in robust national systems of innovation that are common to all such countries, spanning the value chain from research to product and the full range of institutions from academia, to high technology start-ups and large enterprises.

Good systems of innovation have two significant high-level goals, namely:

- *Quality of life*
- *Growth and wealth creation*

These goals are served by three key processes:

- *Business performance*
- *Technical progress (innovation and improvement)*
- *Effective and growing Science, Engineering and Technology (SET) human capital*

Sustaining these intermediate processes and objectives are the fundamental activities related to the acquisition, generation and application of knowledge, namely:

- *Imported know-how*
- *Current R&D capacity*
- *Future R&D capacity.*

Figure 1: From capacity to outcomes - how R&D impacts economic growth and quality of life.

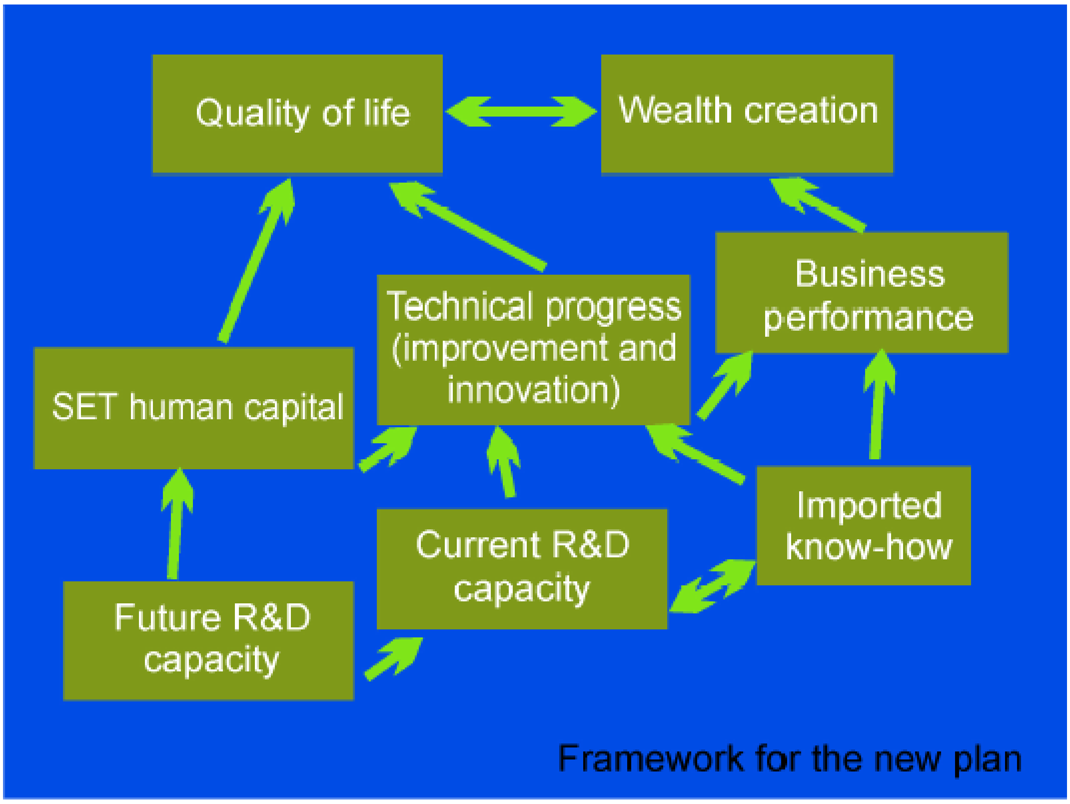
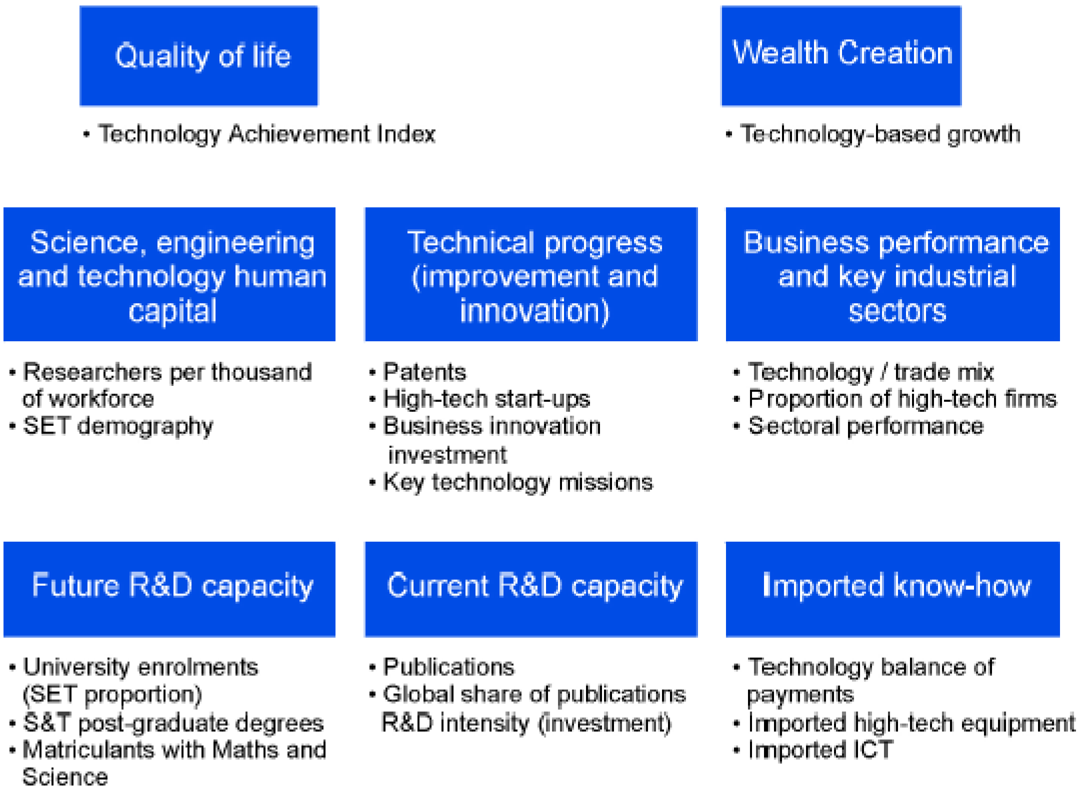


Figure 2: Key indicators that show performance of the S&T system at a macro level and are the basis of long-term planning for the National System of Innovation and its key functions.



A diagram depicting this framework and showing the most important relationships between its elements appears in Figure 1. Modern economies require all these elements to be present and growing. This framework is a representation of the National System of Innovation (NSI). The two major outcomes required from R&D and innovation are increased wealth and quality of life. There is incontestable evidence that this process requires ongoing public sector investment. At least 30% of R&D spending in large integrated developed economies (population >60 million) is made by the government – usually of the order of 0,4 to 0,5% of GDP. In effective smaller nations, government participation in non-defence R&D is higher (typically 0,6 to 0,75% of GDP). Some knowledge-based economies have government spending of closer to 1% of GDP.

This spending creates future R&D capacity and partially sustains SET human capital and the current R&D capacity of the economy. The major functions of the SET human resources and R&D are to drive improvement and innovation in the economy (as well as being involved in smart adoption of imported know-how).

Improvement and innovation directly impact quality of life (for instance in the health care sector) and business performance (e.g. through new products and processes). In developed countries more than 50% of economic growth is attributable to technical progress.

From a financing perspective, governments can target their investments in three focus areas to achieve the desired outcomes:

- The creation of a critical mass of SET human capital and a corps of researchers and future researchers;
- The stimulation and enhancement of innovation and improvement (technical progress) based on new technology and innovation missions and imported know-how; and
- The stimulation of enhanced entrepreneurship and enterprise development through targeted creation of venture capital and provision of fiscal incentives for private sector R&D.

4.2 Indicators measure progress and permit comparisons

There are key indicators that show the health of national systems of innovation. This is shown diagrammatically in Figure 2. Such indicators are a reliable way of measuring progress of short, medium and long-term plans within an agreed strategy.

Some of the indicators are leading indicators – they give an impression of the future health of the system – such as the number and proportion of SET postgraduate students at universities. Others are lagging indicators such as the “knowledge contribution” to economic growth.

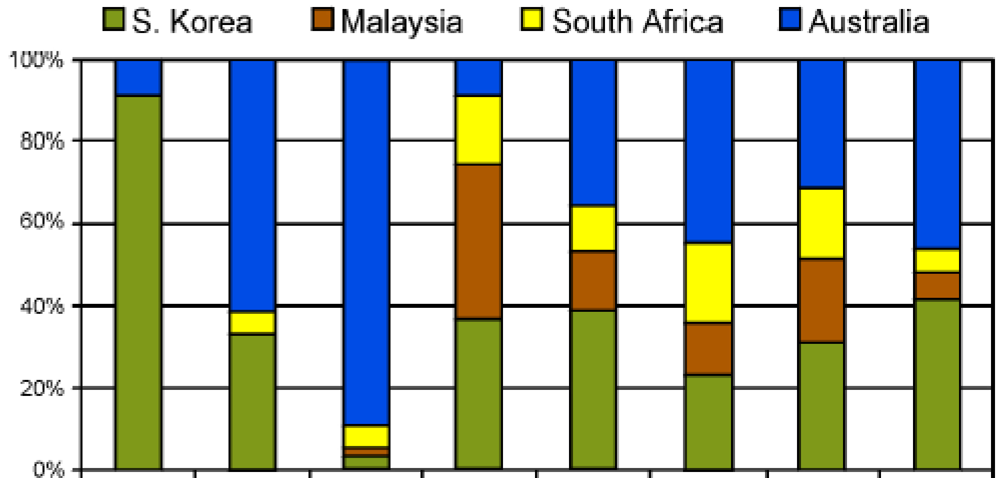
The use of such indicators allows long-term planning and tracking of the progress of the system as well as benchmarking against the performance of other countries. A comparison between four countries has been made using the UNDP Technology Achievement Index, Human Development Report 2001 and against a basket of other indicators (Figures 3 and 4).

The three countries, Australia, South Korea and Malaysia, have very different but well-articulated technology strategies. Australia's approach is to use research, knowledge and information technology to add value to its resource-based economy. South Korea is focused on advanced manufacturing and on creating a knowledge base for industrial innovation. The high levels of educational and post-graduate research and patent spending by Korea differentiate this strategy from all the others. Malaysia has opted to be a fast follower and has concentrated on importation of know-how through Foreign Direct Investment. Malaysia, therefore, pays less attention to research and patenting than it does to effective technology transfer and the broadening of scientific literacy in the general population. While this strategy paid evident dividends in the short term, it has recently been unable to maintain the high growth rates seen previously.

Apart from providing insights into the differences of approach and progress of Australia, Korea and Malaysia, the comparison signals that South Africa has much more to do in the development of human capital and needs to stimulate higher levels of R&D and innovation spending to achieve the type of economic progress currently evident (after long-term investment) in Korea. The comparison of these strategies also indicates that the fast-follower route chosen by Malaysia is not open to South Africa. Malaysia and South Africa have similar levels of GDP per capita, but Malaysia has not established the same level of human capital to date. South Africa therefore cannot adopt a strategy similar to Malaysia but rather has to push for a more knowledge-intensive strategy (in line with the Integrated Manufacturing Strategy and the National HRD Strategy).

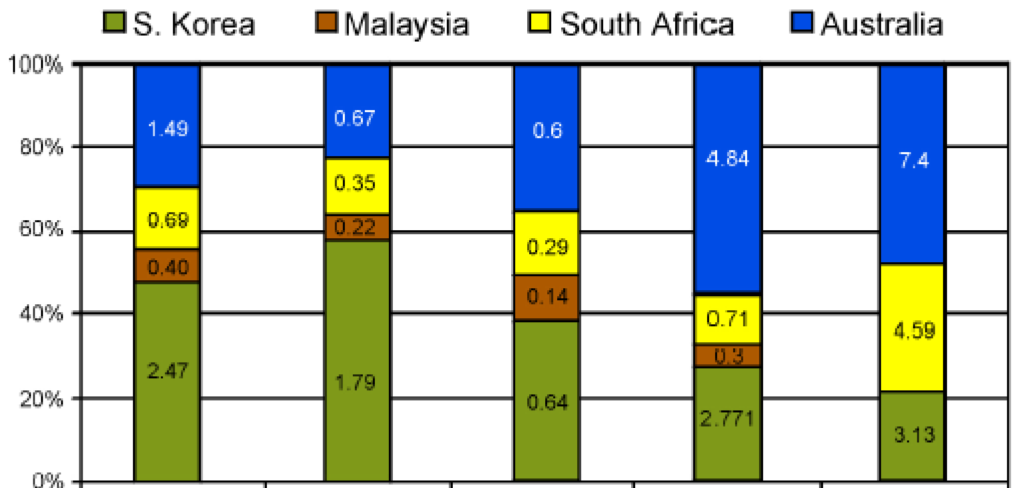
South Africa has a stronger high and medium-technology export profile than Australia, but also has a strong natural resources base. South Africa can therefore adopt a strategic approach that capitalises on the established natural resources base while actively pursuing stronger manufacturing, information technology and biotechnology strategies, more in line with the approach adopted by Korea.

Figure 3: Technology Achievement Index. The graph shows the indicators normalised relative to each other, the indicative figures from the UNDP Report for 2001: *Technology and development.*



	Patents	Royalties/ Licenses	Internet Hosts	High/Med Tech Exports	Telephones	Elec Cons	Years of schooling	Tertiary science enrolment
Australia	75	18.2	125.9	16.2	862	8717	10.9	25.3
South Africa	2.5	1.7	8.4	30.2	270	3832	6.1	3.4
Malaysia	0	0	2.4	67.4	340	2554	6.8	3.3
S. Korea	779	9.8	4.8	66.7	938	4497	10.8	23.2

Figure 4: Benchmarking of key indices gives insight into national strategies (de facto) for R&D. (*R&D intensity* is the % of GDP spent on R&D, *Business R&D intensity* is the % spent by the private sector, *Civilian R&D* is the % GDP spent on non-defence research by government, *Researchers per 1000* of workforce is a measure of human capital, and *Citations per article* is a sign of quality input to the global public good research community.)



	R&D Intensity	Business R&D Intensity	Government Civillian R&D	Researchers /1000	Citations per article
Australia	1.49	0.67	0.6	4.84	7.4
South Africa	0.69	0.35	0.29	0.71	4.59
Malaysia	0.40	0.22	0.14	0.3	
S. Korea	2.47	1.79	0.64	2.771	3.13

However, as attractive as this flexible option is, South Africa has massive challenges in the human resources domain.

As will be indicated in more detail in Chapter 6, South Africa has an aging, predominantly white male, scientific and engineering workforce. The evidence is clear that there are currently insufficient new entrants, including women, to undergraduate and postgraduate SET ranks. These "frozen demographics" represent a significant, shared challenge for all science and technology based government departments and, most particularly, for the Department of Science and Technology, the Department of Education and the Department of Labour.

In order to develop a robust, effective strategy, it is necessary to track indicators of the "health" of the science, technology and innovation systems through time and to set objectives for the future. In setting these objectives, attention has been given to the factors outlined above. It is critical to note that achieving the progress intended requires that the National R&D Strategy be a cross-cutting and integrated activity. The indicators are given for the enablers and the investment and outcomes of the strategy up to 2012, with 1990 as a base year where data is available in Tables 1 and 2.

Table 1: Research and Technology enablers

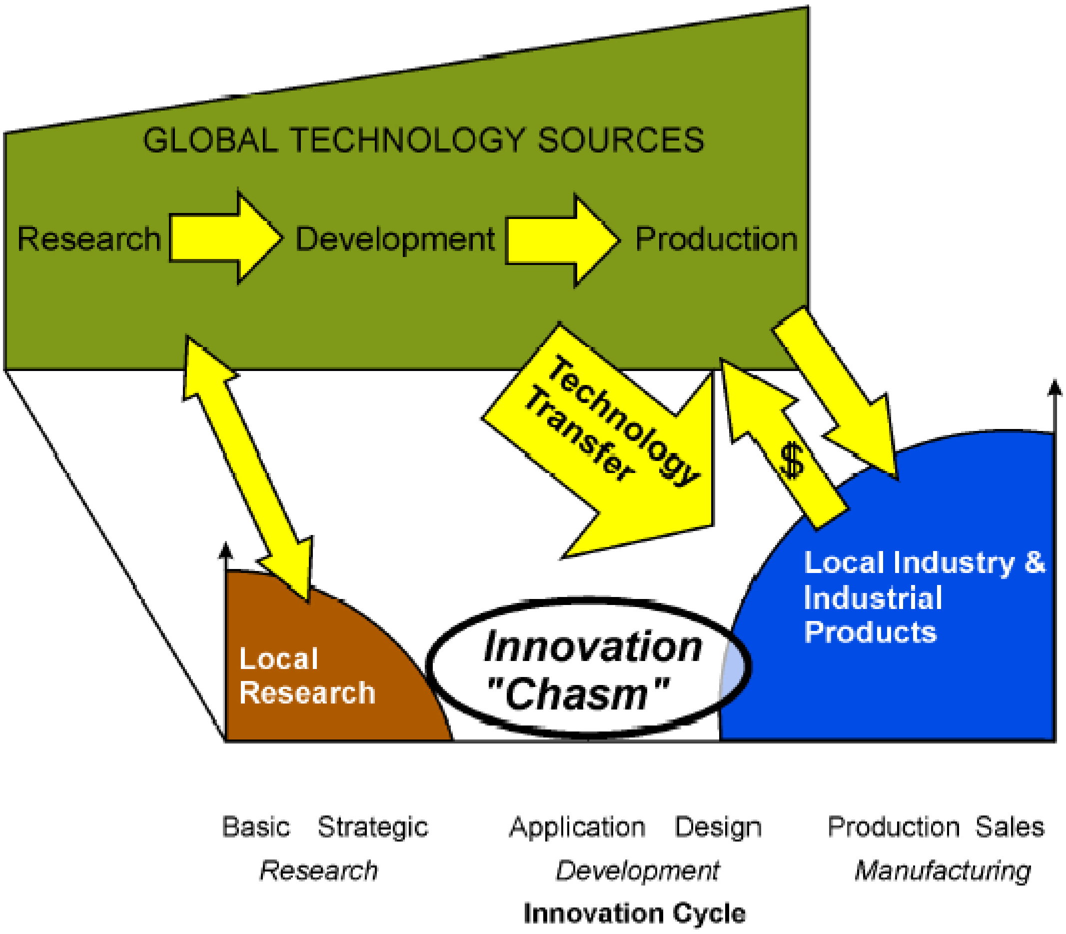
Indicator/*Target*	**1990**	**Current**	***2012***
Matriculants with university exemptions in Maths and Science	Not available	3,4%	***7,5%***
Proportion of SET tertiary students (% of all tertiary students)	20%	27%	***30%***
SET students (% of total age cohort)	6%	3.4%	***12%***
Global share of research outputs	0.8%	0,5%	***0,7%***
Number of SET practitioners per 10 000 of workforce	Not available	7	***11***

Table 2: Investment and Outcomes

Indicator/*Target*	**1990**	**Current**	***2012***
Economic growth attributable to technical progress	n/a	10%	***25-30%***
High and medium-tech exports	n/a	30%	***40%***
Number of SA originated US patents	100	100	***>200***
Government civilian R&D as a proportion of GDP	0,36% estimate	0,29%	***0,6%***
Government R&D expenditure/GDP	0,48%	0,36%	***0,66%***
Intellectual property net cost to SA (copyright and royalties)	R200 m	R800 m	***Improve ratio***
Internet hosts per 1 000 people	0	8.4	***64***
Telephone density per 1 000 people	87	270	***700***

Tables 1 and 2 show the indicator levels for South Africa 10 years ago, currently and the planned (preferred) position in 10 years' time. As indicated, the setting of targets is not a mechanistic process. It should result in a concerted series of action plans to address the challenges. It will require coordination and integrated planning with other government departments where their competences directly impact the National System of Innovation.

Figure 5: Diagramatic representation of the innovation chasm.



4.3 The Innovation "Chasm"

A stronger distinction needs to be made between human capital formation and technological innovation activities. Because these key functions have not been sufficiently defined, the innovation gap that exists between the knowledge generators and the market is never addressed strategically. This is shown diagrammatically in Figure 5.

Tactical attempts to close the "innovation chasm" focus mainly or exclusively on connecting the human capital function (universities and technikons) more and more closely with the market. While this seems logical initially, it drives the academic system towards short-term, incremental problem solving and consulting. The resulting downgrading of academic research (relative to greener pastures elsewhere) precipitates teaching overload for existing staff, fewer postgraduates with broad research experience, and "privatisation" of knowledge. It generates an endless search for "efficiencies" in an under-financed system.

The need to deal with the frozen demographics of our human resources, while simultaneously developing appropriate mechanisms to bridge the innovation chasm, represents the greatest challenge to S&T policy in South Africa. The situation is exacerbated by the fact that the historical government technology missions (energy self-sufficiency, defence and national food security) were inappropriate in the context of the new democracy and the private sector research missions (such as in mining and minerals) have shrunk in the face of globalisation. However, no formal mechanism of introducing new technology missions has been available until now.

4.4 Science Engineering and Technology (SET) Human Capital

Inevitably, the large science countries (e.g. US, UK, Germany, France) attract the best scientists as their governments are prepared to bear a high proportion of university-based research costs. Smaller, poorly financed systems cannot compete against this spending, but there is good evidence that well-financed research at universities and research organisations in small countries can develop and retain an excellent talent pool.

South Africa undertakes about 0,5% of global research. Given the high rate of knowledge development, it is imperative to connect more effectively with the global knowledge system. We have entered into a significant number of S&T bilateral agreements and we have an agreement with the EU that facilitates our participation in their framework programmes. It is in the nature of global research that South African scientists will be more likely to remain here if they can easily connect with their peers, and be linked to the most excellent global research nodes. In addition, since we have a small system, it will increasingly be necessary to use international reviewers of our science-based programmes (already the norm in most Nordic countries). This has the positive result of making South Africa's science more visible and accessible to the world's best researchers. Global R&D connectedness is essential for young researchers who enter the science system and must compete (and collaborate) with the best in the world.

Experience in other countries has shown that the greater involvement of people from previously excluded sectors of the community cannot be left to chance or just market forces. Special programmes for the promotion of women in science are required. The Department of Science and Technology is therefore establishing a Reference Group consisting of stakeholders and representatives of organisations with interest in the progress of women in science, to monitor and advise the Department of Science and Technology on relevant issues. The NRF has also developed an R&D capacity-building programme for the disadvantaged communities that will have to be strengthened. There is a special need in all these areas for enhanced contributions by the social sciences to delineate the problems that we face, and provide specific proposals for interventions that would strengthen our ability to respond.

Particular interventions will be required to ensure that the number of women and black entrants increases. This will require interventions in the school system, including increased support for activities in mathematics, science and computing outside school hours. In addition, there is a critical need to make science attractive, accessible and relevant through media, public engagement and promotional programmes.

There is a demonstrated need to connect South Africa's scientists and engineers with Africa. The networks of scientists, engineers and innovators who will underpin NEPAD and other key programmes on the continent need new resources. EU Framework R&D spending is a small fraction of total EU R&D spending (about 2%), but this financing is used to consciously develop networks throughout the European Research Area. We should do the same for the SADC and African research communities.

This requires a strong governance model, clear articulation of human capital and innovation functions, and proper allocation of resources to the associated strategies and instruments.

Within this strategic context the operational strategies are presented in Chapters 5, 6, and 7.

5. INNOVATION

As stated in Chapter 3, the National R&D Strategy requires the achievement of three core objectives:

- Enhanced Innovation
- SET human resources and transformation
- An effective government science and technology system and infrastructure

This chapter deals with innovation; Chapter 6 deals with science, engineering and technology (SET) human resources and transformation, and Chapter 7 deals with the creation and strengthening of the government S&T system and infrastructure. Attention is then given in Chapter 8 to the financing of the National R&D Strategy in order to achieve the objectives.

5.1 Current reality

Innovation (the process by which new products and services enter the market and the creation of new businesses) is the engine of economic growth and wealth creation. Government plays a key role in innovation by resourcing the process of technology development, in the phases before firms are prepared to take risks. It does this by targeting resources on key areas of high potential and ensuring that there are sufficient financing, networking and institutional arrangements in place to deliver value from the investments.

South Africa currently suffers from an “Innovation Chasm”, as discussed in the previous chapter. Notwithstanding high proportions of private sector participation in some tertiary institutions and in research councils, economic growth based on local innovation is low. The focus of activities is on human resource development and incremental research.

Most global economic growth of the past 40 years has been underpinned by technology and innovation missions. Well-known examples are the space programmes in the USA, the former USSR, and Europe, the targeted approach to eradicate smallpox by the World Health Organisation, and the green revolution in India. Some “pure science” missions, like the high-energy physics facility, led to World Wide Web technology becoming pervasive. Korea has had technology missions to dominate sectors such as consumer electronics. Often successful missions are “captured” by particular companies or clusters that become global players. Examples are Nokia for Finland, Intel for the USA (which started with a government-supported venture capital scheme), SASOL in South Africa, the jewellery and fashion clusters in Italy, composed of hundreds of small and medium firms, and Samsung for South Korea.

Such missions are significant targeted investments to achieve parity or dominance within key technology fields or industrial domains. Technology and innovation missions have a galvanising effect on industry and the research community as they provide a rationale to focus effort, attract new people and investment, and develop new technologies.

In many areas where South Africa is currently competitive, we do not have a capacity for local innovation and are dependent on imported know-how. This is not problematic in the short term. However, countries that make strategic innovation investments (develop missions) will inevitably attract new foreign direct investment and will eventually secure or supplant our current productive capacity.

South Africa has a limited capacity at present to respond to new areas of technology that are regarded as critical in the global economy, such as ICT and biotechnology. Our ability to respond is not simply dependent on having the technological capacity available. There is a particular need to mobilise the social sciences to develop far more holistic understandings and interventions to increase the rate of innovation in our society. The role of the social sciences is often underestimated, and it is therefore necessary to develop specific capacities in the social sciences to understand and strengthen our system of innovation.

At the institutional level, we have no integrated capacity to address innovation systematically. Many governments with S&T systems of similar size to ours have created specific institutions to address innovation missions and provide innovation support. Such institutions have an excellent track record in the stimulation of new industries, and provide the basis for strengthening existing industries – through injection of new technologies and knowledge.

5.2 Strategic initiatives

In order to make the innovation function coherent, a number of initiatives will have to be taken. The key structural intervention would be the establishment of a core agency function to support the government in stimulating and intensifying technological innovation. This function could be initiated in the Department of Science and Technology and developed to the point where its ultimate institutional form could be finalised. For convenience, this function, in its early stages and in its final form is to be called the Foundation for Technological Innovation (FTI), to distinguish it from the core human resource function, which is vested mainly in the National Research Foundation.

The FTI would create conditions for, and finance, technology missions to address key imperatives, sectors and new investment areas that will impact quality of life and economic growth. Such missions have underpinned the post-Cold War success of many nations that invested resources not just in R&D but also in bridging the innovation chasm.

There are a number of financing instruments (the Innovation Fund, SPII, and PII, for example) and technology diffusion and transfer programmes (Tsumisano, GODISA and NAMAC, among others) that would benefit from a clearer single point of strategic direction. There would need to be a review of each of these and their relationship to each other in order to strengthen their contribution to innovation.

There are also provincial initiatives that would benefit from an ability to share learning and experience to enhance programme performance (the Innovation Hub and CITI, for example). Technology access for SMMEs and some BEEs can be problematic when local technology sources are not available. Many countries with small systems of innovation provide resources for technology sourcing by such firms. A programme to undertake these types of technology sourcing is proposed.

Some countries have specific programmes to provide grants for certain R&D equipment in firms or to provide special financial support for procurement. It would be necessary to investigate whether such an approach would have merit in South Africa.

5.3 Functions of the Foundation for Technological Innovation

As indicated above, these functions will be initiated within the Department of Science and Technology and further research and investigation will be undertaken to determine the most optimal ultimate institutional form. For convenience, the functions are termed the Foundation for Technological Innovation.

The key attributes of the FTI would be to:

- Establish capacity to identify, coordinate and finance the new technology and innovation missions for South Africa. As outlined in the Introduction (section 1.1), the key South African technology missions were removed by the former government between 1990 and 1994. The nature of the new missions will be elaborated on in subsequent sections of this chapter.
- Draw together and integrate the management of disparate innovation, incubation and diffusion initiatives in South Africa [the Innovation Fund, Support Programme for Industrial innovation (SPII), PII, GODISA (the Department of Science and Technology/DTI Incubator Programme), Tsumisano (the Technology Stations Programme), among others].
- Create and synergise innovation activities linked to universities and research organisations.

- Develop the national capacity to manage intellectual property (especially intellectual property derived from publicly financed research).
- Strengthen initiatives for the commercialisation of intellectual property.
- Establish programmes for small and BEE businesses to source technology internationally when not available locally.

The FTI would not itself undertake innovation activities – such as later stage research and development, product development, business incubation and so on - but would finance and provide foresight and other direction-setting capabilities for these activities.

Organisations globally that undertake the functions of the FTI actively create capacity for ongoing involvement of the private sector in driving the core technology missions that are adopted. In this way, a positive and synergistic relationship is developed with much stronger mutual commitment to innovation goals.

The agency function would be strongly driven by government policies and initiatives. The FTI will require a strong capacity in S&T management and the management of technological innovation. It would need to have a distinctive identity.

5.4 New Technology and Innovation Missions for the S&T System

The primary transition of the science and technology system in South Africa involved the downscaling of the apartheid era missions (which had been focused on issues such as energy, self-sufficiency, offensive and defensive armament capabilities, and a nuclear programme, among others). Over and above this, the forces of globalisation have reduced the propensity of South African firms to engage in the large-scale innovation that characterised earlier decades.

Further, as indicated above, the total capacity of the system is about one-third to one-half the size that it should be to form the basis of a competitive knowledge-based economy for South Africa in the medium to long term. There are serious concerns with the downsizing of private sector research, our ability to manage national risks, and fully capitalise and contribute to science and technology international relations for NEPAD and the developed world. Policy and strategy processes that, inform the selection of new missions include:

- The National Research and Technology Audit (1997)
- The review of the science and technology institutions in South Africa (1998)
- The National Research and Technology Foresight (1999)
- The NACI/NSTF report: Growth & Innovation (2000)
- The Integrated Sustainable Rural Development Strategy (2000)
- The National Biotechnology Strategy (2001)

- Visits to Cuba and Finland by South African technology policy delegations (2001)
- The Strategic Plan for South African Agriculture (2001)
- The Department of Trade and Industry Integrated Manufacturing Strategy (2002)
- The National Plan for Higher Education (2002)
- The current “technology road-mapping” initiative, which seeks to define far more accurately the technological investment required to stay competitive in key product markets (ongoing).

5.5 Core functions of technology and innovation missions

The key objective of technology and innovation missions is acceleration of economic growth and the creation of wealth on a sustainable basis, and the improvement of the quality of life of South Africans. Such missions create conditions for accelerated innovation based on technology. Not all technology and innovation missions do this in the same way. In some cases, the technologies already exist and the focus is on cost-reduction, demonstration and enhanced adoption in new settings. In other cases, the technologies are new or undergoing intense change, and technological mastery by industry and academia becomes crucial to innovation. Different missions therefore have different mixes of activity to achieve their objectives. In the post-Cold War era, successful economic strategies are closely aligned with government investment in innovation.

Innovation requires targeting and resources. The later stages of innovation (scale-up, product introduction, process engineering, and new plant trials) are expensive and remain technologically risky. The rewards for the successful nations are great.

Innovation missions have an impact on human resource development but, increasingly, innovation missions assume that the necessary human resources are being produced by the higher education system (see human resources and transformation below). The focus is on key technological innovation, demonstration of technology, incubation of new businesses and enhanced networks of knowledge workers, and firms involved in technological innovation.

South African organisations currently have little opportunity or resources for quantum innovation. But there is evidence of good technologies that are lost or not commercialised because of a lack of innovation resources. In addition, there is a need for an enhanced role for the social sciences in understanding and providing strategies to enhance the rate of innovation. This includes issues such as the adoption of advantageous innovations by marginalised communities, institutional transformation and structural innovations, as well as the process of technological innovation itself.

The technology and innovation missions, in order to be successful, should meet objective criteria relating to the outcomes expected from them. These outcomes are:

- Improvement in quality of life through enhanced adoption of positive innovations.
- The ability to generate wealth and employment based on enhanced adoption of imported know-how, an increased rate of innovation and improvement, and the incubation and establishment of new enterprises.
- An increase in technological support to existing firms in the target domain.
- Increases in the number of science, engineering and technology human resources.
- Levels of, and increases in, foreign direct investment.
- Real increases in private sector R&D spending.
- South African controlled global intellectual property licenses.

Identification of technology and innovation missions is not an academic process, nor is it comprehensive with respect to all economic activity or all social challenges. These missions are identified in order to have high impact on quality of life issues and opportunities for wealth creation. Four domains have been selected for further development, based on the strategies outlined above and a review of the capacity of the National System of Innovation to respond.

The current formulation of missions is:

- Poverty reduction (focus on demonstration and diffusion of technologies to impact quality of life and enhance delivery)
- Key technology platforms (focus on knowledge intensive new industries):
  - National Biotechnology Strategy
  - ICT
- Advanced Manufacturing (linkages to the Integrated Manufacturing Strategy)
- Leveraging resource-based industries and developing new knowledge based industries from them (mobilising the power of existing sectors)

5.6 Science and technology for poverty reduction

South Africa and the region face the considerable challenges of poverty. In addition, it is women in the rural areas that shoulder the major part of the burden. As the development of NEPAD and the negotiating position for the WSSD have indicated, technology has a key role to play in poverty alleviation. In order for sustainable development to take place, rural and urban communities should have access to innovations that accelerate development and provide new and more effective solutions than those utilised previously. It is important that women play a key role in these processes. New innovations are not readily used to address poverty. Procurement processes are inherently conservative, thus people need to be assured that new approaches will have benefits since most technologists underestimate the social processes that are required for new technology adoption.

There are developments in the provision of health and education that could become significant social innovations if piloted on a wide enough scale and adopted by communities which themselves participate in the process of innovation.

In South Africa, HIV/AIDS and other communicable diseases pose a massive threat to development. At the household level such diseases reduce income, savings, and the time available to families for economic activities.

The enhanced development of R&D strategies that would mitigate against the devastation caused by these diseases should be holistic and deal with a range of issues. The following issues, although not exhaustive, should form the core of the effort.

- Understanding the social impact of disease
- Creating an environment and technologies to reduce the effect of poverty on the spread of disease.
- Developing care and support strategies
- Understanding the challenges in providing access to prevention and care measures
- Developing innovative preventative strategies
- Developing novel therapeutic regimes, including the utilisation of indigenous knowledge
- Developing preventive and therapeutic HIV/AIDS vaccines
- Creating a viable vaccine manufacturing industry

In addition, appropriate forms of telemedicine could assist in transforming rural health care provision.

Education can be massively enhanced by delivering content via the Internet (and finding effective strategies for provision of this service to the poor). Technologies like e-mail, once the infrastructure is in place, are inherently cheaper than the postal service. Many countries are undertaking extensive trials and technology roll-outs. They have a positive impact on the cost and affordability of telephony, as a wider range of services are available, and on learning and communication.

In addition, there are new methods of providing services to farmers for agricultural extension, and knowledge of prices and markets, which reduce dependency on some current marketing channels.

Many areas in South Africa have patterns of settlement and conditions that make them unattractive for classical extension of the electricity grid. This reality has been somewhat submerged in the present phase of electricity roll-out nationally. There is a need to develop local small-scale grid capabilities and household-level energy systems that are affordable, and widely known.

There are many indications that indigenous knowledge can play a role in poverty reduction, firstly by the appropriate provision of support for innovators, and by the integration of the indigenous knowledge system with the scientific knowledge system to produce new products and services. Some piloting has occurred in this regard and there should be focus on this domain within this technology mission.

The mission to reduce the impact of poverty needs to deal with the causes of poverty and the impact of poverty on women and the disabled, since they carry the greater burden. Innovative technologies need to be harnessed to positively impact on their daily lives.

South Africa's priorities in the WSSD are strongly informed by the need to reduce poverty and provide a new paradigm for development. These are:

- Water and sanitation
- Food security and agriculture
- Education
- Health
- Technology
- Energy

There is a strong convergence between WSSD and NEPAD priorities. The increased recognition of the crucial role of technology in poverty reduction and sustainable development must be understood in terms of the creation of human capital (see centres of excellence below) and the effective deployment of solutions through this technology mission.

5.7 New technology platforms

South Africa cannot ignore two major technology developments taking place globally. These are ICT and biotechnology. The importance of biotechnology and its potential impact has been described in the National Biotechnology Strategy. Operational planning is already underway. The publication of the Strategy has galvanised a number of provincial initiatives and the promised investment is now required. The management of this new platform will be transferred to the Foundation for Technological Innovation when it is formed.

ICT seems to be pervasive in the country. However, it is clear that the vast majority of ICT investment is in imported technologies (to the level of some 98%). South Africa does not have a strong R&D capacity in ICT and where there is significant innovation potential results have been patchy. It is therefore necessary to invest in a number of ICT domains that have unique characteristics that would favour local development and globalisation. Although the detailed investigation of potential areas is incomplete, the following are examples that would be invaluable to South Africa and other parts of the developing world:

- Automatic language translation technologies.
- Low-cost telephone and e-mail integration (reduced cost of postal service, text-based distance education, management information, voice/text-based government services and simple banking transactions).
- Low-cost integration of satellite telephony and the Internet (enhanced distance education services, e-government, local weather prediction, agricultural services, banking services, telemedicine).
- Robust distributed computing services (offsets high cost of high bandwidth connectivity).
- Open-source software initiatives (especially for education and low-cost government services, has positive impact on closed-system pricing).
- Participation in high bandwidth global experiments by higher education institutions and linking SADC higher education institutions in a single large-scale wide area network.
- Participation in developing country initiatives to reduce the cost of basic computer hardware (for example the Simputer in India).

The second "plank" of the ICT platform would be intensification of ICT use in resource-based industries and manufacturing. In this domain there is likely to be a more intensive use of imported know-how, but the ability to integrate and improve ICT use in these existing industries is critical to their development.

The third "plank" of the ICT strategy would be the use of earth observation (satellite and aerial) data to support government, industry and SADC in key areas such as:
Disaster prevention, monitoring and remediation
Mapping and GIS services
Agriculture services
Land-use and urban development services, among others

The use of satellites for communication has somewhat masked the constellation of satellites that generate information about the surface of the earth and the oceans. In addition, there is increasing use of digitised aerial photographic imagery for election planning, power grid extension, urban settlement development, mapping and so forth. The high cost of acquisition is not currently offset by effective and coherent reuse of images, or their effective management. Government service provision would be significantly enhanced if an innovation strategy, linked to other e-government strategies, were put in place for this resource.

5.8 Technology for advanced manufacturing

Knowledge intensity is having a direct impact on the advanced sectors of the manufacturing industry, and many of these industries, such as the automotive industry, are establishing integrated value chains as described by the Department of Trade and Industry's most recent strategy document. These global industries assume levels of technological integration (such as in design, quality control and inventory management) that are not yet the norm in South Africa. Countries that make the necessary proactive investments will benefit with an increasing share of the knowledge-intensive aspects of automotive production in the future.

In the chemical and pharmaceutical industries there are also key points of investment that are not immediately obvious: molecular modelling, taxonomy (scientific description of plants, animals and other living things), large-scale management of sterile systems, smart catalysis and so on. Targeting these areas and developing solutions increases the attractiveness of South Africa as an investment destination, increases the ability to market intellectual property globally and enhances the ability to dominate key niches for the future (deep mining machinery, right-hand drive automobile production, new generations of biopharmaceuticals and so on).

5.9 Technology and knowledge for and from resource-based industries

These industries: agriculture, fishing and forestry, mining and minerals, and energy production, remain critical to South Africa. The agricultural sector and other renewable resource sectors, and mining and minerals, have existing capabilities that make them attractive springboards for further development. However, as indicated in the Department of Trade and Industry's Integrated Manufacturing Strategy, previous strategic options (dependence on raw materials, cheap labour, proprietary production technology and privileged access to markets) are not sustainable. Increasingly, highly trained human resources, continuous improvement, technological innovation and smart acquisition of know-how will become the major differentiators. This requires an increase in the knowledge intensity of the resource-based sectors. A strategy of this type underpinned a large part of the Finnish employment revival in the mid-1990s that complemented the new IT markets they captured.

South Africa continues to show good rates of invention and creativity in the resource-based sectors. However, in many cases the changes in the structure of our large companies and their reduced R&D and innovation budgets leaves many of these technologies to be developed elsewhere (sometimes retaining a South African partnership component). Sometimes the technologies find small local niches and never reach their full potential.

These industries also have potential to break out of the commodity pricing cycle by adding value in new ways, linking to new markets and by changing or enhancing the integration of logistics for export market penetration. All of these areas are ripe for technological and institutional innovation.

5.10 Strengthened programmes to support innovation

The Innovation Fund has not had the rate of growth intended. New financing will be required to put this back on track. With the establishment of technology missions in specific areas the Innovation Fund will play a crucial role nearer to the market (in the specific development of product or service concepts). In addition, the Innovation Fund will develop capacity to finance engineering and science students, while still at university, to develop research concepts into prototype products. This approach is used in institutions like MIT in the US and widely in countries like Finland to make research outputs more attractive to venture capitalists. The incremental costs are small, but the rate of new company creation increases.

It is critical to establish a programme to secure IP from appropriate publicly financed research that meets certain criteria. The ability to secure intellectual property often competes (in budget terms) with other costs such as salaries. This needs to be recognised and specific financing provided to secure important inventions and designs.

The current pilot and roll-out programmes for technology diffusion and business incubation need to be strengthened. The GODISA and Tsumisano programmes have shown good early promise, but are funded partly from ODA. Action must be taken to link such programmes, and SPII, and PII and the Manufacturing Advisory Centres into a more holistic programme of innovation support. Without such action, potential innovators and entrepreneurs have to make large investments of their scarce time, just to understand the different programmes. Without proper integration, each programme develops its own criteria and method, without the ability to learn from others and effectively channel resources to the best opportunities.

A number of these programmes are already developing some track record and they can therefore be strengthened to increase their scope and impact. There are also provincial initiatives that would benefit from an ability to share learning and experience to enhance programme performance (the Innovation Hub and CITI, for example).

Technology access for SMMEs and some BEEs can be problematic when local technology sources are not available. Many countries with small systems of innovation provide resources for technology sourcing by such firms. A programme to undertake these types of technology sourcing is proposed.

Some countries have specific programmes to provide grants for certain R&D equipment in firms or to provide special financial support for procurement. It would be necessary to investigate whether such an approach would have merit in South Africa.

5.11 Strategic linkages

5.11.1 Responding to the Integrated Manufacturing Strategy of the Department of Trade and Industry

"Accelerating Growth and Development: The Contribution of the Integrated Manufacturing Strategy" was recently launched by the Department of Trade and Industry. It clearly articulates the need to "build on a platform of infrastructure and logistics, competitive input prices, skills, technology and innovation, partnerships, efficient regulation and effective government offerings." The strategy indicates that: "At the core of the accelerated trajectory is knowledge intensity, which means utilizing and developing the knowledge and skills of our people in order to integrate ICTs, technology, innovation and knowledge intensive services into the functioning of the economy as a whole."

There is therefore considerable synergy between the National R&D Strategy and the Integrated Manufacturing Strategy. As indicated: "It is essential to develop a domestic capacity for science, technology development and advanced skill development (pg 16)". Specific reference is made to this strategy:" A new technology, innovation and research and development (R&D) strategy proposes a number of measures that government will take in this regard, including the provision of an enabling institutional environment for R&D, as well as developing South Africa's technological capacity in strategic areas such as biotechnology."

The identified areas of the Integrated Manufacturing Strategy require targeted innovation initiatives. Apart from the initiatives in biotechnology and ICT, which will impact the key identified sectors, and the need to ensure good linkages in less technologically intensive domains, the advanced sectors of our manufacturing industries need ongoing investment to reduce dependence on imported technology. This would include areas such as the automotive and transport sectors, the chemical industry and the machine, plant and equipment sector that supports the mining industry. A second leg of the response is in specific innovation support for the resource-based sectors of the economy, including agro-processing and metals and minerals.

5.11.2 The Strategic Plan for South African Agriculture

The strategic plan for South African agriculture has a significant focus on knowledge and innovation. At present, agricultural research is undertaken both at provincial and national level and there is a recognised need to have clear articulation between these two domains as this is an area that has a clean line department requirement. However, the overlaps of agriculture with indigenous knowledge, biotechnology, earth observation and aspects like logistics, require an integrative approach. The need to increase investment in agricultural research as a sectoral research strategy supports the conclusions of the strategic analysis presented here.

The proposed National Agricultural Research System therefore anticipates (and represents) a leadership initiative that is fully congruent with the National R&D Strategy.

6. HUMAN CAPITAL AND TRANSFORMATION IN SCIENCE, ENGINEERING AND TECHNOLOGY

6.1 Global trends in the migration of scientists

Science today is a highly globalised activity. Even in advanced economies (e.g. Germany, Canada), policy analysts express concern that the best scientists are being drawn towards the highly dynamic United States system. To counteract this trend the affected countries are attempting a range of interventions, for example, Canada has set aside funds for the creation of two thousand university chairs in science and engineering over the next five years. Both France and Germany are in the process of radically overhauling their legislation and practices to promote science-industry linkages in line with the United States' highly successful Bayh-Dole Act. In South Africa, recent studies show attrition rates for researchers of approximately 11% per annum from government laboratories and 15% per annum from universities. Of those who leave employment, some 5% of the government laboratory scientists and about 22% of the academics emigrate.

The recent offshore listings of several large technology-intensive South African companies pose awkward questions regarding the retention of strategic skills in our country. Already there is a tendency for these companies to source research outside South Africa. Clearly, they do this for economic reasons, but South Africa needs to develop an effective response to what, in many cases, may be the loss of strategic control over companies originally built on South African knowledge capital. The end game here revolves around being relegated to a sales outlet in contradistinction to developing as a centre of innovation.

6.2 Support of knowledge generation through basic science

There are two basic principles underpinning government support for scientific programmes in any country:

- The programme could potentially contribute towards addressing social or economic goals
- The programme is potentially world class and could contribute to leading-edge global knowledge

Increasingly, particularly in developed countries, these principles tend to overlap. Fiercer competition due to globalisation and the rapid growth of information technology and of biotechnology have led to the shortening of the innovation cycle. The new global economy is more dependent on knowledge than ever before and it is obviously *new* knowledge that delivers competitive advantage. How should developing countries position themselves with respect to the knowledge economy, which depends critically on the national research portfolio and on linkages between this portfolio and the National System of Innovation?

Clearly, the technology missions described in Chapter 5 are motivated by the desire to meet key national economic and social objectives. This is the “market principle” that drives national systems of innovation. To complement this, global best practice recommends that the best way to generate human resources is to focus on excellence, on being simply the best on a competitive international stage. In a country such as South Africa, what strategies are there to optimise the chances for our scientists to succeed? How can we improve participation by women and other previously disadvantaged groups? Clearly, with limited resources, our best chances of success will depend on our ability to focus on our potential strengths while staying well connected to international research. Areas of scientific focus can be developed in the following ways:

- **Scientific areas where there is an obvious geographical advantage.** In the case of South Africa there are several of these that stand out. Examples are:

    - Astronomy (we have good access to the Southern skies and the engineering capability to build telescopes locally)
    - Human palaeontology (we have excellent sites in the Krugersdorp region dating from shortly after the bifurcation between apes and humans occurred)
    - Biodiversity (the Cape Floral Kingdom is the most diverse of the seven floral kingdoms)
    - Antarctic research (South Africa is the only African country with a presence on the Antarctic continent)

    Other examples of possible phenomena or systems on which it has been or would be possible to base good science include the Kaapvaal Kraton (geology) and the South Atlantic Magnetic Anomaly (geomagnetism and space science).

- **Scientific areas where there is an obvious knowledge advantage.** Important South African examples are:
    - Indigenous knowledge (clearly the collective inherited and evolving knowledge systems of indigenous communities constitute a competitive advantage).
    - Technology for deep mining (geological conditions and economic imperatives have pushed South Africa to the forefront).

Figure 6: Ageing scientists. Publication data indicates serious problems for the future.

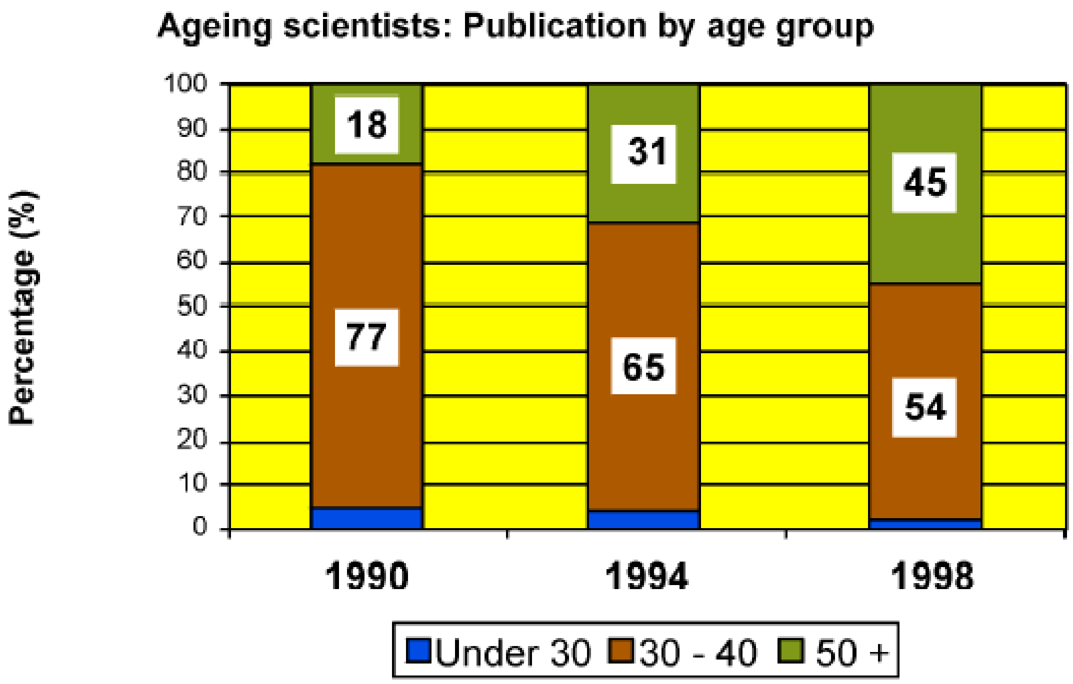
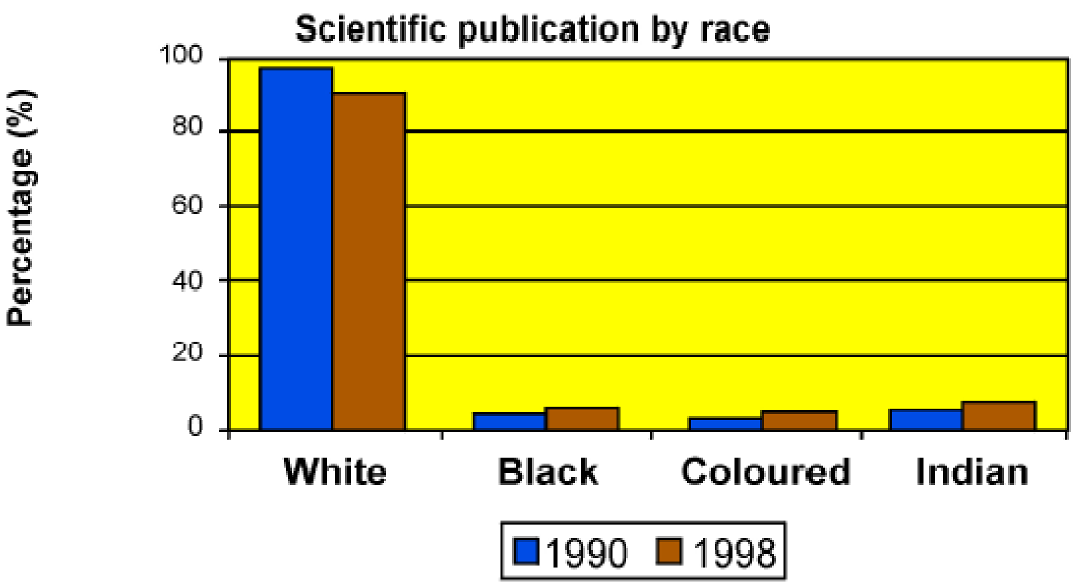


Figure 7: Limited progress with the representativity of the research and development community.



- The high incidence of diseases of poverty has placed the South African medical research community at the cutting edge of technology development in these areas.
- Microsatellite engineering (although large multinational consortia now dominate the communication satellite market, South Africa has retained a niche competence in microsatellites deriving from a fusion of defence spin-offs and university research).
- The African integrated approach to HIV/AIDS vaccine development.
- Encryption technology (spin-offs from State investment in the defence sector have generated significant foreign exchange recently).
- Fluorine technology (high entry barriers mean that the competence developed in the uranium enrichment programme could be turned to South Africa’s advantage).

The examples given are intended to be illustrative rather than exhaustive. They illustrate a way of looking at science that attempts to prioritise in terms of likely outcomes, moderated by what is deemed necessary in terms of national competitiveness in the broadest sense of that term.

Despite the fact that the motivations of individual scientists are generally fired by intellectual curiosity rather than by the weighing of potential outcomes, it is necessary for decisions to be made unsentimentally. Not to prioritise in a way that attempts to optimise impact is irresponsible and potentially wasteful. The public and their elected decision makers respond positively to success. It is a sound strategy for scientists, science administrators and policy specialists to develop a common approach towards maximising the chances for success.

6.3 The need for a new generation of scientists

Our human resources in science and technology are not being adequately renewed. We have an ageing scientific population – currently about 50% of scientific output is due to scientists over the age of 50, as opposed to a mere 18% in 1990 – see figure 6. In the private sector there has been a 16% drop in the number of researchers over the past four years. Currently, there is less than one researcher for every thousand members of the workforce, as compared with five in Australia and ten in Japan. Although there has been some progress in developing black managers in the science and technology system (up from 4% in 1994 to 30% today), there are far too few black researchers. The percentage of our scientific publications authored by black scientists rose from 3,5% in 1990 to only 8% in 1998 (Figure 7). The figures for publication participation rates by women have not improved over the last decade. Women produce less than 15% of publications. These areas clearly require strategic attention.

The remedy for this disastrous state of affairs depends on:

- Increasing the number of matriculants, particularly the number of black matriculants and young women, with appropriate passes in Mathematics and Science.

- Being able to attract these matriculants into degree courses in the sciences and engineering disciplines.
- Increasing post-graduate participation in SET.

A well-balanced human resource development approach for SET will, from a gender perspective, require:

- A clearly defined gender perspective.
- Disaggregated statistics on women to be included.
- Previously marginalised groups (including women) must be attracted via targeted programmes.
- Centres of excellence must include a strong gender-inclusive policy.
- Current policies for women entering science are fragmented and need to be consolidated into a programme of empowerment for women.
- Policy for development of women in science that is not punitive in respect of career development.

Various initiatives in the Department of Education to promote Mathematics and Science (such as the 100 Schools Project) have recently taken off. Nevertheless, very innovative programmes are necessary if we are to move far beyond the current 3 000 black matriculants with passes in higher grade Mathematics. In addition, considerable attention must be given to increasing the number of girls taking mathematics, science and computing subjects through their school careers and having in place enabling mechanisms for women to enter tertiary studies in science, engineering and technology.

This issue has become so pressing that it will be necessary to increase "out-of-school" programmes to support mathematics, science and computer education. A number of pilot programmes, run by dedicated volunteers in many cases, have shown excellent results. In addition, specific consideration should be given to incentivising schools to produce more black and more female Mathematics and Science matriculants at the higher grade. For example, private schools that successfully produce higher-grade Mathematics and Science matriculants from designated groups could be retrospectively paid the equivalent of the education subsidy.

Flagship projects such as the Southern African Large Telescope and the Pebble Bed Modular Reactor can be very effective in generating a sense of excitement about science in young people. The National Research Foundation is establishing mentoring schemes and funding increasing numbers of black postgraduates. However, opportunities need to be maintained across the span of a career. It does not help much if high proportions of young scientists move into non-scientific careers soon after graduating. This trend can partly be attributed to the high levels of mobility generally among young black professionals in South Africa. Regardless of its causes, it can only be counteracted by significant national commitment to a national research and development programme.

In other words, to attract young people to science and engineering it is necessary to communicate very clearly that these disciplines have a future and that those who enter them are likely to have fulfilling and relatively prosperous careers. In the 1970s and 1980s, this level of confidence in South Africa's scientific future existed (albeit for a small group) and it was tied very closely to the various technology missions promoted by the government of the day. These included technology to support military dominance in the subcontinent, energy self-sufficiency and other key strategic thrusts. We believe our ability to attract young people to careers in science and technology will depend on our adoption of new technology mission that are, designed for a democratic, inclusive South Africa in the context of our governmental obligations through SADC, NEPAD and the EU.

The formation of the Women's Reference Group in Science and Technology will strengthen women-led initiatives in all phases of participation in science and technology, from school to career achievement. This reference group, which will report to the Deputy Minister of Arts, Culture Science and Technology, will complement and strengthen the activities of the National Advisory Council on Innovation with respect to gender issues in our science national system of innovation.

Consideration must be given to a specific programme to retain productive science and engineering educators and mentors in tertiary education, provided that they attract and develop young black and female students into postgraduate research.

6.4 The need to focus on Centres and Networks of Excellence

It is possible for outposts of scientific excellence, which depend on an individual, highly rated scientist and his or her group, to flourish for limited periods of time. However, a more sustainable strategy is to create (or to nurture, should they already exist) "Centres and networks of Excellence" in science and technology, including the social sciences. Such Centres and Networks of Excellence:

- Should have the critical mass to generate sufficient high-quality research to make an impact on the global stage.
- Are more likely to succeed if they are focused and chosen to support technology missions or key advantages for South Africa.
- Must focus strongly on human resource development and on popularising science.
- Are more likely to succeed if they establish or promote networks of excellence across the African continent.

Examples of Centres and Networks of Excellence (currently established or being actively developed) are:

- The National Laser Centre in Pretoria (which is twinned with a similar centre in Senegal).
- The Southern African Large Telescope in the Northern Cape, which is complemented by the world-class cosmic ray telescope (the HESS telescope), under construction in Namibia.
- An integrated approach to developing palaeontology research.
- The AUTek programme coordinated by Mintek is a virtual centre of excellence in novel uses for gold with the intention of strengthening high value added uses and increasing the volume of gold sold.
- The Deepmine programme (which operated in a virtual mode), which developed people and technologies to address the challenges of very deep mines.
- The Sahara Programme of the HSRC, which is looking at social aspects of HIV/AIDS and providing a platform for interventions in this critical domain.

However, these efforts need to be strengthened considerably to create credible standing and human resource development in key areas such as nanotechnology, bio informatics, water-borne diseases, and light metal technology, among many others. Centres and Networks of Excellence must be developed to focus on key missions that impact on women and HIV/AIDS.

The establishment of such Centres and Networks of Excellence forms part of the science and technology theme of NEPAD and SADC, and complements the technology missions that will enhance the process of innovation.

6.5 Strengthening International S&T networks and connections

Science is global in reach and scope. It is critical, if we wish to retain top-class scientists in South Africa, that they are well connected to global research. It is also imperative that we tap into international human and financial resources to address South African research. It is also necessary to invest in the development of continental research networks to ensure that African scientists develop effective collaborations across the continent.

6.5.1 Global S&T linkages

The advancement of science is based on a system of peer review and common exploration of issues through conferences and seminars and exchange of scientists through post-doctoral research fellowships and sabbaticals. Increasingly small countries, such as the Nordic countries, insist that all scientific programmes be subjected to international review. In addition, increasingly, countries with small science systems use peer-reviewed publications as a basis for assessing post-graduate programmes (such as Masters or PhD) in preference to the thesis that is still commonly used in South Africa. It is essential, therefore, for South Africa and the South African research community to be connected globally.

At the national level, South Africa now has nearly 30 bi-national science and technology agreements (compared to a handful in 1994). If South Africa is to service these agreements in a meaningful way, structured action plans and well-defined activities must be linked to these agreements. Up to now, the servicing of these agreements has been largely ad hoc and our performance patchy. It is therefore necessary to develop a strategic capacity to engage in this area.

At the multi-lateral level, South Africa has a research agreement with the European Union and observer status at the OECD Committee for Science and Technology Policy. The EU agreement allows us to participate in the European research and development framework. This creates unique opportunities to link South Africa (and SADC) with the networks of research in Europe. As we support stronger participation in these frameworks, with a focus on groups such as women and researchers from previously disadvantaged groups, we strengthen the likelihood of South African researchers remaining in South Africa, since they will not feel the pressure of being “excluded” from global research networks. It is critical, therefore, that we strategically support our global science initiatives far more actively than we have done in the past. Our relationship with the OECD has been enormously productive from a policy and strategy perspective and a number of the analyses that underpin the current National R&D Strategy development can be attributed to insights gained through this key relationship.

6.5.2 African S&T linkages

South Africa is one of the key countries on the continent from a science and technology perspective. Therefore, it is essential that in science and, more importantly, in technology and innovation, we are able to contribute to SADC, NEPAD and the African Union more broadly. It is also important that we properly resource these initiatives and create conditions that are attractive for scientists, engineers and technologists to develop appropriate networks with their counterparts in Africa.

Networks of this type in Africa are comparatively recent and need to be proactively managed. Both WSSD and NEPAD technology strategies require the establishment of regional and national Centres of Excellence in science and technology (or the strengthening of existing centres). It is not possible to undertake these activities without increasing the mobility of scientists, stimulating through conferences, seminars and workshops, stronger inter-institutional relationships and directing resources towards programmes that would specifically enhance technological cooperation, technology transfer and diffusion, and African capacities to innovate in specific focus areas such as health, water and sanitation, agriculture and food security, energy and education. In designing these programmes particular attention must be given to participation by women researchers and students

6.5.3 Attracting talent to South Africa

It will not be possible to give effect to this plan without stimulating researchers from the rest of the world to come to South Africa to participate in the process of creating human capital. It will therefore be necessary to have very effective processes to ensure that attractive candidates are able to secure the necessary permission to work in South Africa. This will require specific joint planning between the Department of Science and Technology, the Department of Home Affairs and the Department of Education to ensure that effective measures are in place.

6.6 Connection with other government strategies

6.6.1 The Human Resource Development Strategy

In the year 2001 government adopted a human resource development strategy (promoted principally by the Ministers of Education and Labour) based on four pillars:

- <u>General education</u>, meaning compulsory schooling, early childhood development and adult basic education and training.
- <u>Supply-side education</u>, meaning further education and training and higher education.
- <u>The demand side</u>, meaning the integration of employer requirements into formal education programmes in a systematic way.
- <u>The National System of Innovation</u>, meaning the close articulation of research in the higher education sector with the innovation requirements of the economy and society.

The HRD strategy is indicator based, and the research and development indicators match those put forward in this strategy. Furthermore, the new targeted approach for research funding in higher education is in the spirit of this R&D Strategy, which seeks to leverage scholarship and academic creativity in a focused way.

6.6.2 The National Plan for Higher Education

The intention to strengthen the R&D capacity at tertiary institutions is in line with the National Plan for Higher Education. The more outcome-oriented approach to the funding formula for tertiary R&D will work in synergy with the focus on centres of excellence to make research careers more attractive.

In addition, the differentiation of the innovation process from the HRD process will allow the linkage of technikons to small enterprise development and product development (the GODISA and Tsumisano programmes are cases in point) to be strengthened.

7. CREATING AN EFFECTIVE GOVERNMENT SCIENCE AND TECHNOLOGY SYSTEM

7.1 The current situation

In 1994, the new government inherited a somewhat chaotic governance system for the science and technology portfolio. Although the Department of Science and Technology has outlined a profound framework in terms of the National System of Innovation concept, the implementation of changes required to effect this framework has not progressed much beyond the institutional level. Institutional reviews, although searching, have focused on efficiency, accountability and alignment of individual institutions with national policy rather than dealing with the total capacity and effectiveness of the system. They stopped short of making bold recommendations to address systemic fragmentation. To a significant extent this has been as a result of unwillingness to confront contradictions in and between departmental mandates established in a different political era.

Within the "government" sector are four types of institution involved in research and development, namely:

- State-owned corporations
- Science councils (performers and funding agencies)
- Universities and technikons
- Domain-specific research organisations/capacities within the Public Service

The State-owned corporations (Denel, Eskom, NECSA, Telkom, Transnet, Safcol, etc.) have Boards that are appointed by various Ministers, although the lead Minister for such corporations is the Minister for Public Enterprises. The same goes for the so-called Science Councils (which are broadly defined as the institutions that receive their core budgets through the allocation mechanisms of the Science Vote. From a governance perspective:

- The Boards of Mintek and the Council for Geoscience are appointed by the Minister of Minerals and Energy.
- The Boards of the CSIR and SABS are appointed by the Minister of Trade and Industry.
- The Board of the Medical Research Council is appointed by the Minister of Health.
- The Board of the Agricultural Research Council is appointed by the Minister of Agriculture.

The Minister supposedly responsible for science and technology in government, namely the Minister for Arts, Culture, Science and Technology, has line responsibility for two Science Councils, namely the National Research Foundation and the Human Sciences Research Council. The Minister of Education has line responsibility for universities and technikons.

The various domain-specific organisations (e.g. Water Research Commission, National Botanical Institute, National Institute for Virology) are either embedded within government line departments or have a statutory connection with such departments. There are also, for instance, agricultural research capacities at provincial level.

This institutional governance fragmentation is mirrored in a fragmented budgeting and reporting system. At present, for instance, the Science Vote that is constructed by the Department of Science and Technology includes the Medical Research Council, which is an organisation that reports to the Department of Health, but not the National Institute of Virology, which is part of the Department of Health. Similarly, the science vote addresses Mintek and the Council for Geosciences (which report to the DME), but the Safety in Mining Research Advisory Committee, energy research and the nuclear technology capabilities of NECSA (which are also responsible to the DME), are not made visible to the Department of Science and Technology in a structured way. These examples, of course, can be multiplied across our system. All institutions funded through the Science Vote report within a common set of agreed key performance indicators. These were developed on a consultative basis, mandated by the National Advisory Council on Innovation and the Department of Science and Technology. Science and technology institutions that are not part of the Science Vote have a range of different performance relationships with their line departments.

To make progress towards better alignment and delivery it is essential to create an enabling framework at national level. This will allow integrative research and development planning that:

- Reflects the cross-cutting issues facing government as a whole.
- Addresses the specific, sector-oriented R&D planning of national line departments.
- Leverages provincial initiatives and capacities.
- Generates enhanced innovation and human resource development

An improved system of governance would need to incorporate the features described in above.

7.2 Alignment with the policy objectives of government

The size, shape and content of the system of government-owned and funded science and technology institutions and programmes must be aligned with the economic and social development strategies of government. In particular, programmes must articulate with the key technology missions described in Chapter 5. Although the details of scientific research programmes are best left to scientists and research mangers themselves, government needs to regularly review the research landscape and institutions in terms of desired outputs, outcomes and impacts. For example, it may be that research into new technologies (e.g. biotechnology, information technology) requires new institutional arrangements or that mature programmes need to be privatised or phased out. New strategies such as the Integrated Manufacturing Strategy of the Department of Trade and Industry require research and development responses. The restructuring of higher education has implications for the research output of universities and technikons. An integrated mechanism for developing technology strategies and investments needs to be established within the medium-term strategic and expenditure frameworks.

It is often said that governments are bad at choosing research priorities. This is less a criticism of the acumen of government officials than conceding that detailed planning can never capture the quicksilver nature of innovation. Technology foresight studies have become the norm rather than the exception over the past decade in developed countries. Japan has a regular five-year cycle and the United Kingdom is busy with its second exercise. Increasing interest is being shown in non-OECD countries too, with South Africa and Thailand taking the lead. The methodology underpinning these studies involves creating a shared vision among decision makers and within key sectors regarding the threats and opportunities likely to be faced in the future and how to respond to these in terms of broad portfolio planning. Foresight does not pretend to forecast the details of actual technologies.

The purpose of government funding to technology-intensive institutions needs to be addressed as well. Many institutions earn up to 50% and more from research and service contracts with the private sector, government departments and international agencies. These additional funds certainly enable:

- The employment of a larger research workforce than would otherwise be the case.
- The alignment of research with market needs.

However, there is a danger of the emphasis moving entirely to the provision of technology integration, extension and consulting services, as opposed to strategic research that is in the long-term national interest. Several institutions have already travelled too far down this road. Nevertheless, to require them to focus once again on more fundamental and strategic research would require either more funding from the state (to compensate for contract work sacrificed) or a significant contraction in the workforce and scope of operations. The responses are outlined and addressed in Chapter 8, where financing is discussed, but they will need to be spelled out for each institution funded within the MTEF when the national R&D plan is constructed.

7.3 Mandates and responsibilities of different government departments

There needs to be a clear allocation of responsibilities between different government departments and institutions regarding both funding and performance in the National System of Innovation. Around the world, there is a bewildering array of institutional and governance arrangements for state-funded science and technology programmes. This diversity exists both at government and institutional levels. In some countries (e.g. the People's Republic of China) there is a stand-alone Ministry of Science and Technology. In Finland, the function is shared between the Ministries of Higher Education and Trade and Industry, and mediated by a Cabinet-level Council chaired by the Head of State. In many former British colonies (e.g. South Africa, India, Australia, Canada), one finds a well-developed system of state laboratories dominated by a CSIR-type institution. In many European countries (e.g. Finland) and Latin American countries (e.g. Chile), state laboratories play a much less significant role and the emphasis is on stimulating university-based research, private sector innovation and the links between programmes in both these sectors. In general, however, all effective national systems of innovation are serviced by the following three functions:

- A programme for the funding of fundamental research mainly to develop human capital and new knowledge.
- A programme to promote innovation, technological development and diffusion (mainly oriented to the market).
- A programme (often incorporating venture capital) to promote the commercialisation of research results (oriented to higher economic growth rates).

It is our view that it is imperative to establish clear mandates and responsibilities within government regarding these functions and to ensure that they are adequately funded and effectively carried out. The detailed morphology of the system of institutions responsible for conducting research and development, although in need of review from time to time, is of lesser importance. Accordingly, we make recommendations regarding the governance of the state-funded elements of the National System of Innovation.

7.4 Research and development across government

Government needs an integrated R&D plan and consistent performance measurement in order to meet the requirements relating to the optimisation of government's investment in research and development. To make this effective:

7.4.1 Government will publish and annually update a three-year R&D Plan "in sync" with the MTEF, capturing its R&D vision as well as key targets and investments. The R&D Plan will capture the programmes of each department, including the targets expected of parastatal institutions and the "return on investment" expected from transfer payments. The drafting of this plan would be the responsibility of the Department of Science and Technology and would be placed before Parliament on an annual basis.

7.4.2 The basic risk management assessment for technology, the national foresight capacity and the integration of individual budgets to produce an aggregate national research and development budget will be the responsibility of the Department of Science and Technology.

7.4.3 A standard governance/reporting framework for all institutions with a strong R&D mandate must be developed by the Department of Science and Technology for consideration by Cabinet. This framework, to be administered by the Department of Science and Technology, would apply regardless of whether such institutions are in the higher education sector, the "parastatal" sector (science councils and other statutory bodies) or are embedded in government departments.

7.4.4 The respective line departments will set R&D goals and budgets for institutions reporting to them, within the standard framework described above. The budgets would specify the funds allocated to self-directed strategic research within the broad mandate of the institution and the proportion allocated to service work for the relevant line department. In this regard, each line department will have an R&D plan that forms part of the National R&D Plan.

7.4.5 In order to ensure effective integration and predictable financing and coherence, the Department of Science and Technology would assemble all inputs into a Science and Technology Budget, and through this instrument advise Treasury, the Cabinet and Parliament of the important dynamics in the system. The Department of Science and Technology would also advise other departments of risks associated with funding and outputs from institutions within the system.

7.5 Responsibilities for technology functions across government

To meet the requirements relating to the division of responsibilities for administering government's investment in research and development, attention needs to be given to the relationships between institutions and departments within the system.

Regarding government funding functions in the National System of Innovation (see above), the following broad responsibilities exist at present:

- Basic and thematic research is funded by the Department of Science and Technology via the National Research Foundation and by the DoE in terms of formula-based research funding to higher education institutions. Other departments such as the DoH also play a role through the MRC and the ENHR frameworks.
- Innovation and technology development and diffusion funding is widely spread across government, with the DTI, the Department of Science and Technology, NDA, Defence, the DME, DWAF, DEAT, Health and several other departments all playing a role.

- Industry sector strategies and venture capital programmes are largely the responsibility of the DTI, although other departments do play subsidiary roles.

Broadly, this delineation of responsibilities is not inappropriate. Research, whether in mathematics or biochemistry, has a common set of performance indicators and resource needs. However, the development of technology requires sector or cluster focus. This is reflected in the diversity of “ownership” by line departments. There is convergence again, however, in the domain of industrial policy where common principles, such as those underpinning public/private partnerships or return on investment exist. This indicates that the DTI should take responsibility for venture capital programmes or tax treatment of private sector R&D.

Although the broad morphology of our system with respect to the three key functions is sound, we believe that a certain degree of realignment is necessary. Generally speaking, the various state laboratories and funding agencies can be separated into two types, namely those of a highly sector-specific nature and those that are multi-sectoral in nature. Examples of sector-specific laboratories are Mintek and the National Institute of Virology. Sector-specific funding agencies include the Water Research Commission and the Safety in Mines Research Advisory Committee. Currently, the key multi-sectoral funding agency is the National Research Foundation and the proposed Foundation for Technological Innovation would also fall into this category when it is established. The key multi-sectoral research laboratories are the Council for Scientific and Industrial Research (CSIR) and the Human Sciences Research Council (HSRC).

It is recommended here that all sector-specific institutions are best placed in close proximity to line departments with the primary responsibility for the relevant sector. It may be that the reassignment of some institutions from one department to another would optimise their contributions (e.g. the Africa Institute of South Africa would potentially be better located with the DFA than with the Department of Science and Technology). The principle of sectoral alignment within a common R&D framework is well established.

How should this strategy address the multi-sectoral institutions? One potential route would be unbundling, where, say, different divisions in the CSIR, HSRC and NRF would be assigned to line departments (Defencetek to the DoD, Environmentek to the DEAT, etc). In our view, this would not be a good option. The corporate management in all these organisations currently add significant value. In addition, international attempts at “unbundling” integrated research organisations have not achieved the desired results. Unbundling would seem to fly in the face of the new trend towards large-scale inter and trans-disciplinary research.

The association of the CSIR, which is the primary government laboratory, with the DTI rather than with the department responsible for science and technology is clearly an anachronism that pre-dates the formation of the Department of Science and Technology and needs to be addressed. This is particularly evident given that only one division of the CSIR, M&MTek (Materials and Manufacturing Technology), aligns uniquely with the core business of the DTI. It is therefore proposed that all multi-sectoral institutions report to the Department of Science and Technology and that sector-specific institutions currently reporting to the Department of Science and Technology be transferred to appropriate line departments.

7.6 Intellectual property

7.6.1 Current Issues

South African inventors with priority registration in the South African Patent Office secure around 100 United States patents per year. This represents 2,5 patents per million of population per annum. This number is low in comparison to the developed world. Countries like Japan secure some 776 patents per million of population per annum. The differences in patent rates between the developed and the developing world represents one of the greatest “divides” of the knowledge age. Since patents represent (with copyright), one of the strongest forms of “intangible value”, this is evidence of a major weakness in South Africa’s ability to become a knowledge economy.

The global debate on intellectual property has changed very substantially since the Trade Related Intellectual Property (TRIPS) agreements came into force. In addition, the Convention on Biodiversity has formally linked indigenous knowledge and benefit sharing to the notion of intellectual property rights. The protection of plant varieties utilising patents or sui generis legislation (specific legal frameworks in individual countries) is currently under review by the World Intellectual Property Organisation (WIPO). In addition, WIPO has created a negotiating forum relating to traditional knowledge and folklore.

These policy debates and frameworks do not represent the sole dynamic in this domain. Since the enactment of the Bayh-Dole Act in the United States in the mid-eighties, there have been fundamental changes in the way publicly financed research is utilised by institutions to create economic value and to stimulate high-tech business development.

At present, South Africa has no formal policy framework for intellectual property protection of publicly financed research. One of the consequences of this is considerable uncertainty (among institutions and individuals) about intellectual property rights and their management, particularly when the research is publicly financed. Benefit sharing, the cost of patenting, the sale of intellectual property rights outside of South Africa, the quality of licensing agreements, and the professional management of intellectual property protection in universities and research councils are important issues. The following actions/processes are already in place in government:

- A policy framework has been constructed relating to indigenous knowledge and draft legislation is in an advanced stage of development.
- This indigenous knowledge process is articulated with the negotiations on the Convention on Biological Diversity, which is managed by the Department of Environment Affairs and Tourism.
- Government is engaged in WIPO negotiations on issues related to indigenous knowledge, biodiversity and publicly financed research.
- A working group of government departments impacted by, or relevant to, indigenous knowledge and intellectual property issues meets on a regular basis to respond to changes in this dynamic domain.

7.6.2 Initiatives and interventions

At present, there is little appreciation for the value of intellectual property as an instrument of wealth creation in South Africa. A number of firms have good intellectual property offices but universities and Science Councils have not created a strong intellectual property framework. The rights of government, financing institutions, performing institutions and their staff are not defined. There is an urgent need for the creation of a proper framework and enabling legislation for the management of intellectual property arising from publicly financed research. This will define the "playing field" for publicly financed research and research that is undertaken in parastatal institutions.

An approach should have the following attributes:

- It should be legislated.
- It should draw on the enabling frameworks of global best practice.
- It should not place South African institutions at a disadvantage relative to international practice.
- It should create a context for benefit sharing by inventors and innovators.
- The obligation of institutions to protect intellectual property developed from publicly financed research should be established.
- The right of the state to acquire the right to use such IP in the public interest should be established.
- An acceptable framework for the sale of rights should be established, including the conditions under which the rights can be acquired internationally.

- Powers should be granted to make regulations in respect of recognition of inventors, designers and authors who develop intellectual property when financed with public funds in respect of benefit sharing by institutions.
- Institutional practices in respect of benefit sharing, invention disclosure and minimum standards for institutional intellectual property management should be standardised.

Considerable experience has been developed internationally at institutions such as universities and research organisations. As the process of legislation is initiated, it would be critically important to draw on this accumulated experience to guide South African institutions on best practice.

A dedicated fund to finance the securing of intellectual property rights resulting from publicly financed research and development, when this is in the national interest, should be established. The management of this fund should become one of the activities of the Foundation for Technological Innovation.

The current policy position of the World Intellectual Property Organisation (WIPO) is that patenting is not expensive. This is simply not true for most of the organisations in the developing world. Patent costs are high and staff costs for intellectual property offices in universities and research organisations continue to increase. For example, a good medium-sized intellectual property office in a United States university would typically be staffed with around 15 people with skills in technology assessment, patenting and commercialisation.

Patent expenditures compete directly with human resource budgets. Under these conditions, few institutions have the long-term strategic commitment to securing IP. On the flip-side, if patenting is seen as a virtue in its own right rather than as a strategy that leads to economic growth, patenting can increase dramatically but the quality of the patents can be poor and their economic value dubious.

Given the poor state of intellectual property protection there is a need to reduce the financial barriers experienced by institutions when they secure intellectual property from publicly financed research. The policy approach will have to be robust to ensure that institutions remain accountable for the IP, while at the same time proactively seeking to commercialise it.

A related goal of the policy would be to signal to WIPO our increasing discomfort about the cost and inaccessibility of the global intellectual property regime to publicly financed educational and research institutions in the developing world.

A national database of intellectual property that arises from publicly financed research is an important management tool to measure the current and future performance of the system. It is proposed that the Department of Science and Technology take responsibility for the development of such a database.

7.7 Private sector interventions

7.7.1 Fiscal incentives for private sector R&D

The DTI has been investigating the potential for complementing the current fiscal grant systems (such as THRIP) to include tax incentives. Analysis of National Systems of Innovation indicates that tax incentives have become much more important in stimulating private sector research than was the case five years ago when the White Paper on Science and Technology was published. Fiscal incentives fall into two categories: direct grants and tax incentives.

Where government has clear goals that are not being addressed via the market and/or significant specific spillover effects can be identified, direct grants are advantageous. In addition, where a major thrust of policy is to enhance the competitive position of the business sector in general, through the commercialisation of new products and production processes, tax incentives are appropriate. Globalisation is increasing the pressure for policies that will enhance the competitive position of local firms. This is the major factor underlying the increasing use by many countries of tax incentives to enhance business sector R&D. The same imperatives face South Africa in the context of globalisation.

Most OECD countries provide tax incentives in respect of business R&D activities. The general practice is to allow a full write-off of current R&D expenditures and accelerated depreciation allowances for capital investments related to R&D – machinery and equipment and buildings. A significant and growing number of the newly industrialised countries have similar practices. Mexico, for example, allows for 100 per cent of current R&D costs to be deducted in the year in which they are incurred. Machinery and equipment can be written off at 35% per annum and buildings at 5%.

Table 8: Tax treatment of R&D by selected countries

Country	ATC	B-index	Tax Credits	CIT
Spain	--	0,660	Yes	35,00
Canada	0,507	0,787	Yes	35,60
USA	0,521	0,879	Yes	40,75
Australia	0,570	0,890	Yes	36,00
Korea	0,635	0,918	Yes	30,80
Mexico	0,640	0,969	Yes	34,00
South Africa	0,627	1,010	No	37,80
Japan	0,525	1,010	Yes	48,00
Italy	0,647	1,027	No	37,00
Germany	0,456	1,051	No	56,60

ATC: After Tax Costs

B-Index: A measure of the effectiveness of a tax incentive (small values are "good")

CIT: Corporate Income Tax Rate

Singapore allows double tax deductions for a number of R&D expenditures. Korea allows all current R&D expenditure to be deducted in the year incurred. All capital expenditure is depreciated at 20% per annum straight line. Taiwan also has a system of tax credits for R&D.

The table shows a comparison of the tax treatment by a number of countries. The After-Tax Costs (ATC), the B-index (a measure of the effectiveness of the incentive – smaller figures are more attractive) are compared. CIT is the Corporate Income Tax Rate. The table indicates the relatively unfavourable position of South Africa with respect to tax incentives. This has an impact on local companies' cost of doing R&D and is a disincentive to multinational companies placing R&D facilities in South Africa.

It is proposed that the DTI be given a mandate in consultation with SARS and the Treasury to pursue the development of tax incentives to strengthen the attractiveness and affordability of R&D in the South African setting relative to countries with which we trade and compete.

7.7.2 Provincial Innovation Initiatives

A positive development over the past few years has been increased involvement of provincial governments in creation of infrastructure for innovation. A number of these initiatives already benefit from the Department of Science and Technology and DTI programmes (such as the GODISA incubator programme). There is a need to ensure proper coherence of the initiatives at national level. This role can be undertaken by the proposed Foundation for Technological Innovation as part of its function to support and facilitate innovation. In addition, proactive measures in provinces that do not have existing innovation infrastructure and support mechanisms are required.

7.7.3 Financing for global technology sourcing

Many small, developed economies have active programmes to support technology sourcing. Given that South Africa’s system of innovation represents less than 1% of global innovation activity, there will always be a rich source of new technologies that should be accessible to our firms. Large firms generally have good capacities to source technology globally, but small firms find this more difficult and it is likely that some BEE firms will have limited global networks for technology sourcing. In addition, there are emerging economies that have good technological capacities but limited trade with South Africa at present. There is therefore a need to have a dedicated fund for global technology sourcing. This should be available to small and medium firms and should also create the capacity to have targeted technology exhibitions/roadshows in South Africa where there are general opportunities to expose South African firms to new sources of technology.

7.7.4 Venture Capital

There has been considerable movement in this area over the past few years. The DTI has played a leading role in stimulating this positive environment. There is still a need for a greater availability of angel investors, and it is expected that the market will develop with time. There is a more specific need for seed and early-stage venture capital for high-technology businesses and the Department of Science and Technology will engage with the DTI to develop this domain.

8. FINANCE

A key conclusion of the strategic analysis of the condition of R&D in South Africa is that the system was built for 5 – 8 million people and now has to grow and develop to serve all South Africans. The system is working hard (as the reviews of its performance have indicated) but it is going backwards (as this strategic review has demonstrated). South Africa cannot afford to lose its R&D capacity. Indeed, it needs to increase its capacity and effectiveness.

This strategy proposes a structured and phased approach to funding the strategies presented above.

The model does not include government expenditures of S&T that are not part of the current science vote. This would require a second stage of planning to identify the expenditures across all government departments. The increases in expenditure required are real increases based on this strategic analyses and not “paper increases” from consolidation of government spending. In addition, baseline adjustments need to address the ongoing loss of key staff from a number of institutions.

The following assumptions underpin the financial model:

- The strategic analysis and the strategy presented here require a significant increase (at least double) in government research, development and innovation funding over 3 - 4 years.
- The performance of the strategy should be measurable with clear indicators that are locally relevant and internationally comparable.
- Government financing should be linked to the strategy and should not only enlarge existing institutions' core budgets.
- The model should take account of the need to develop capacity to plan for, and use, resources for new and strengthened current programmes.
- Planning should take account of all current government strategic focus areas and should build a robust interaction and synergy with these initiatives.
- The three core operational objectives should have clear financing objectives based on the current Science Vote (for comparative purposes), but move beyond it to a more holistic government S&T budget framework (to ensure the proper financing of the strategy).
- The financing structure should give more accountability to line departments for R&D plans and institutional financing while retaining the integrative structure of the Science Vote.

Figure 8: Increased financing to achieve innovation and human capital objectives.

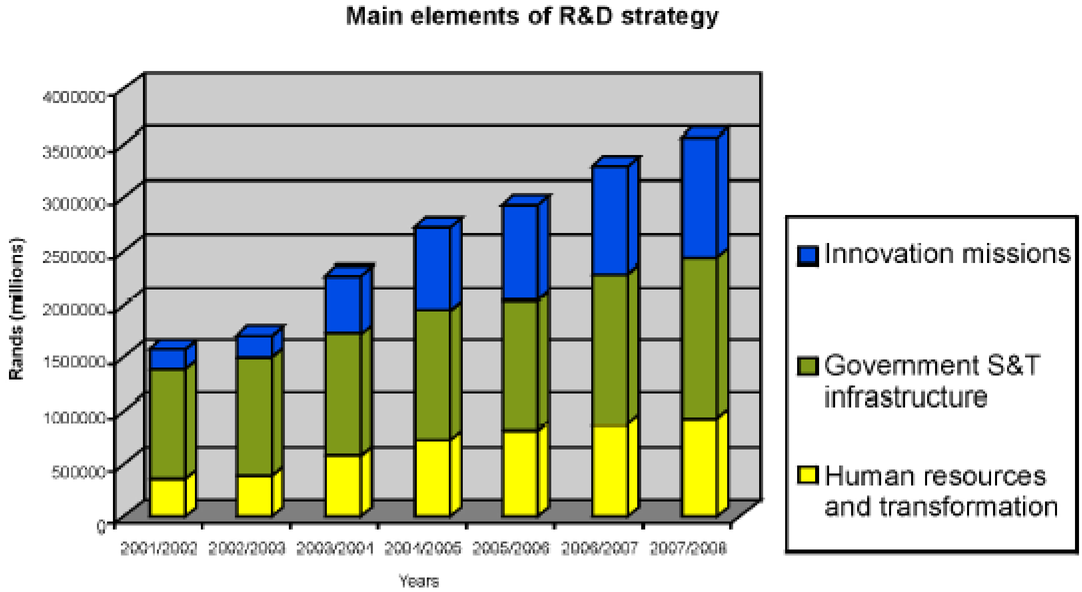


Figure 9: Shift of system balance.

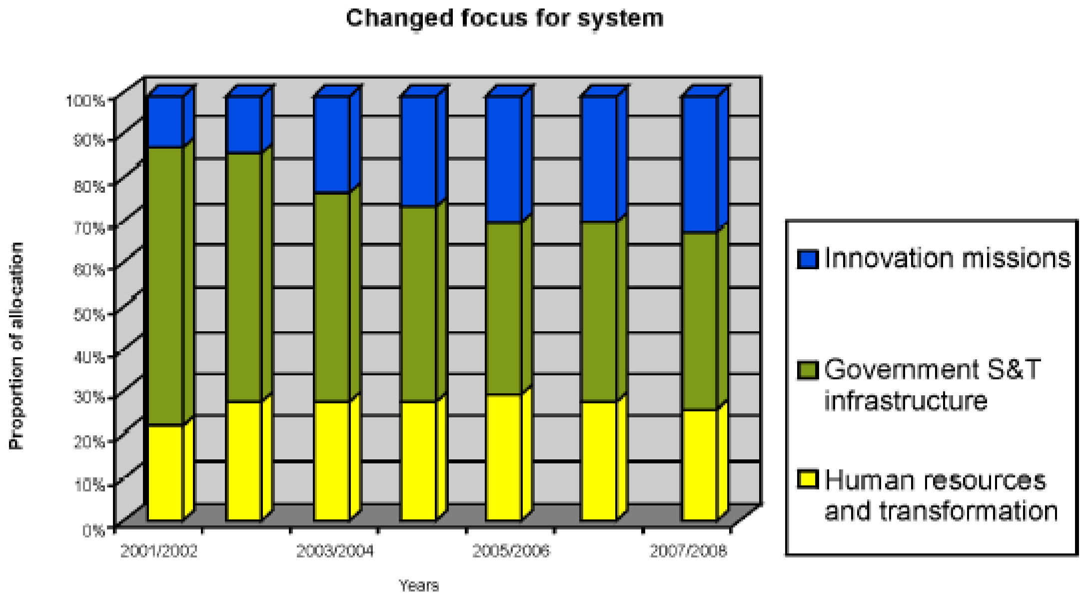


Figure 8 shows the increased finance needed to achieve the strategy. The new resources are dominantly dedicated to the human capital and transformation aspects of the strategy and the innovation financing, which is intended to create a mostly new function within the system of innovation. The phasing is intended to indicate the rate at which the system can respond to new inputs. This has been demonstrated over recent years by increases in, for instance, the MRC financing, which led to positive growth in both public financing and contract income. The phasing and implementation will be monitored by the Department of Science and Technology to ensure optimal and effective use of resources to achieve the strategy.

Figure 9 shows how the balance of the system shifts through time to have a far stronger focus on innovation. The proper management of innovation has a positive effect on the outcomes generated from the system, by focusing on near market activities with high potential to leverage private sector participation.

To achieve positive movements of indicators (strategic performance), practical programmes and initiatives will result from this strategy. The new financial requirements in the third year (following reasonable vamping up of programmes) are indicated. These are summarised below.

8.1 Innovation

8.1.1 Technology missions

This funding is for the technology missions described in Chapter 5. The targeting of these funds is for activities that take place after research and laboratory development phases of the innovation cycle. The levels of financing per programme/project are typically high relative to academic research and development. The financing requirements will form the core budget of the Foundation for Technological Innovation, which would also develop an operational budget for each of the programme areas and their support structures:

- Technology and innovation for poverty reduction (R150 million)
- Technology and innovation for advanced manufacturing and logistics (R125 million)
- Technology and knowledge to leverage resource-based industries (R90 million)
- New technology platforms for South Africa (R300 million):
  - ICT
  - Biotechnology

8.1.2 Travel grant programme

A committed fund for global technology sourcing for SMMEs and BEE companies when the technologies are not available in South Africa, (R60 million).

8.1.3 Intellectual Property Fund

The current expectation is that this fund will be a programme within the Innovation Fund and it will secure its financing from the Innovation Fund structures based on a full needs analysis.

8.1.4 Strengthen Innovation Fund

The Innovation Fund has not had the rate of growth intended in the original policy development. New financing will be required to put this back on track and be able to create capacity to establish the programme to secure IP from key publicly financed research that meets the criteria. The new financing required in the third year is R50 million.

8.1.5 Strengthen technology diffusion (GODISA, TSUMISANO)

These programmes are already developing a good track record and they can therefore be strengthened to increase their scope and impact. This requires additional financing over and above the current levels and links strongly to the required differentiation of the technikons from the university structures as contained in the National Plan for Higher Education.

8.2 Human resources and transformation

The financing of the creation of human capital is critical to the achievement of quality of life and wealth creation. Many of the technologies that we must achieve mastery of require high-level science and technology skills for innovation and research and development in industry, research laboratories and academia. In addition, we need to ensure that there are people who have mastered these technologies educating the next generation of researchers and innovators.

The programmes defined below are new requirements or programme extensions, based on the strategic review and strategy development that will provide a way out of the frozen demographics and aging profile of the current research capacity in South Africa.

- **Centres of excellence**

  Individual research grants whether open or in directed themes have been shown globally to be limited in creating long-term research capacity and most developed countries now have strong programmes to establish Centres of Excellence This has usually been done with new financing and there is a similar requirement in South Africa. The NRF has actively investigated global best practice and is able to create the necessary infrastructure. After three years, the funding required for this programme will be R150 million, starting with R50 million in the first year.

- **NEPAD/SADC Networks and Collaboration**
  There is a need to create specific capacity to meet our obligations to the SADC and NEPAD. At present contacts and networking is ad hoc and not sustainable for many institutions because of resource constraints. Three types of financing are required: network/programme development, programme financing and institutional support, to initiate activities in other countries. This programme will require R41 million of new finance in the third year.

- **Global science networks and collaboration**
  South Africa performs about 0,5% of global research. It is critical to stay connected to the other 99,5% of global science, research and development. In addition, these networks provide training and exchange opportunities that are critical for the new cohort of black and women researchers who will enter the science and technology system. This financing will also be used to support South African institutional participation in EU and bilateral programmes. After the third year the new finance requirement will be R42 million.

- **Science and technology equipment**
  New financing for large R&D equipment was requested a number of years ago. A small allocation (R14 million) was given for this purpose. Although the Department of Science and Technology has introduced stringent conditions for these equipment grants (large equipment, multi-institutional support, high potential for training and research, and use in a limited set of focus areas) the scheme is heavily over-subscribed. It is necessary to significantly increase this programme, as most equipment is sourced overseas (usually purchased in Dollars or Euros), equipment is a critical success factor in both biotechnology and ICT research as well as the chemical and physical sciences, and the ability of our scientists to be excellent globally is linked to quality of equipment. After the third year R90 million will be required, but this programme can be fast-tracked, based on our current experience, and therefore R60 million is required in the first year.

- **Science Focus Areas**
  Currently, large-scale science in South Africa is facilities based and largely located in the National Research Foundation. There is a need to derive far greater science promotion to attract learners into science and technology through our large public science programmes. This needs a more thematic and less institutional structure and identification. Five areas have been identified for long-term action. The new financing over and above current financing is indicated for the third year of this strategy:

Astronomy and Earth Observation	R6 million
Indigenous knowledge	R5 million
Bioscience/bio-resources	R15 million

Paleo-world	R20 million
Antarctic, Islands and Oceans	R44 million
Total New Financing	R100 million

These themes are not intended to exclude other disciplines and existing facilities, but to use South Africa's geographical and specific knowledge advantages on a sustainable basis to create global appreciation for South African science (given that we undertake only 0,5% of global research and development).

In addition to these focus areas, there is a need to massify a number of public understanding and engagement activities using the Institute for the Promotion of Science and similar structures. The programme massification would include out-of-school maths and science programmes to increase the number of matriculants achieving university entrance in Mathematics and Science (particularly women and other previously disadvantaged groups) and enhanced use of the media to promote mathematics, science and computing subject choices among learners. This programme would cost R30 million in year three.

8.3 Creating an effective government science and technology system

- **Core financing for Research Councils**

At present, a number of Councils require increases in core financing to assist with transformation, renewal of their research infrastructure and related issues. Because of the maturity of these institutions and their increasing levels of contract funding this requires only marginal increases over and above the expected 3% increase in MTEF financing for normal expenditure. This will require ongoing new financing to support the strategy. In addition, the future increases are intended to provide flexibility in adjusting the total portfolio in consultation with line departments. Recent discussions with the Department of Agriculture confirmed the requirement to separate the financing of key public resources required by that department from the core grant for strategic research. This needs to be incorporated into the Science Vote in the short term.

However, inadequate attention has been paid to pressures on all Councils with respect to adjustments for human resource costs, and pre-emptive action is required to address this. For instance, a number of Councils are significantly increasing their contract earnings but are not able to make proper provision for salary increases and indeed sometimes retrench or lose key staff during phases of growth. Analysis indicates that insufficient new resources are available in core financing for key national public good research and collections (gene-banks, earth observation digital resources, core collections, agricultural disease management and so on, that cannot be financed by clients).

- **National Risk Management and Foresight**

  All nations are facing risks that have considerable impact on the economy (related to poor foresight in science and technology) and quality of life (related to poor disaster prediction). The Department of Science and Technology has had limited ability to support government and other stakeholders in this domain. This is because the pilot phases of foresight projects were funded by donors and have not been mainstreamed in the activities of the Department – this clearly must be addressed. In the disaster management arena, there is a need to have resources to purchase services from tertiary institutions and research councils on an emergency basis to support government in responding in the very short term (much shorter than the budget cycle). In periods when no explicit responses are required, proactive science-based disaster investigations, modelling and prediction will be undertaken in partnership with line departments and other stakeholders. This function needs to operate on a network basis and the financing required will not be used to increase the Department of Science and Technology's headcount, except to manage the activities. In the third year, the financial requirement for this new activity will be R60 million (R20 million in the first year) with an approximate split of 50% foresight/technology road-mapping and technology assessment, and 50% for science-based disaster prediction and intervention.

9. CONCLUSION

The national R&D Strategy is located within the full set of functions of a National System of Innovation (NSI) and is strongly based on a well-established set of indicators that have international credibility. The systemic robustness of the NSI approach needs to connect with the knowledge economy in the choice of clear, content-specific technology missions. The R&D Strategy offers a clear, sustainable and bold way forward for our country to address the key problems of:

- National competitiveness in a rapidly changing and increasingly knowledge-dependent international environment.;
- Improved quality of life, especially the reduction of poverty, for South Africans.

In particular, the three pillars of Enhanced Innovation, Transformed Human Resources and Government Leadership are combined to yield a strong foundation for future growth and development.

Countries such as newly industrialized South Korea, natural resources oriented Chile and Australia, high technology fast-follower Malaysia and research and development intensive Finland all made clear technology development choices within an overall national development framework. These choices have, to a large extent, facilitated their rapid progress towards prosperity. This South African Research and Development Strategy, which depends critically on the right investments being made to underpin its ambitions, will do the same for our country.