2015

Space Science and Technology Economy

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Department of Economic

Development and Tourism

Northern Cape

1. Intro

Science is defined as a system of acquiring knowledge based on the scientific method, as well as the organized body of knowledge gained through such research. Technology on the other hand, is a broad concept that deals with a species' usage and knowledge of tools and crafts, and how it affects a species' ability to control and adapt to its environment. Simply put, technology is the practical application of science. The goal of technology is to create products that solve problems and improve human life.

Space science and technology phenomenon entails usage of various fields of science to explore space, and application of these scientific innovations or advances in new products and processes. Governments and private investors globally have begun to give the space sector much more attention in seeking new sources of economic growth. There is global consensus on the ability of the space sector to create, distribute and exploit knowledge. Hence the sector has become a major source of competitive advantage, wealth creation and improvements in the quality of life.

South African National Space Agency (SANSA) acknowledges that the space sector plays an increasingly pivotal role in the functioning of modern societies and their economic development. This it cites is because the use of satellite technology gives rise to new applications, uses and markets. In this regard, SANSA anticipates that influence of science and technology on our daily existence is likely to surge for years to come,

This report discusses the existence and extent of space science and technology in the country as well as the Northern Cape, whilst also reciting the international players in the space arena.

2. Space Science and Technology in South Africa

As modern societies placed more emphasis on the space sector, South Africa's space landscape vision similarly transitioned from a resource and commodity based towards a knowledge-based economy. Essentially, production and dissemination of knowledge was envisioned to lead to economic benefits towards enriching all fields of human endeavour. Firstly, some legislative, policy and regulatory reforms implemented towards advancing this vision for SA space science and technology post 1994[1] are discussed.

2.1 Legislative, Policy and Regulatory Developments

The first legislative milestone in 1995 was the amendment of the Space Affairs Act first passed in 1993 as the primary instrument governing the regulation of both governmental and non-governmental space related activities. In terms of this Act, the Department of Trade and Industry (DTI) is mandated to oversee and regulate the space industry. Inherent in its role to promote industrial development, investment, competitiveness and employment creation, the DTI was tasked to shape the space programme in the country through regulatory functions.

[1] The transition from apartheid to democratic government.

A crucial legislative development was the passing of the White Paper on Science and Technology in 1996 as a response to the global knowledge economy and competitive pressures on South African economy due to global forces. As a founding document for the notion of a national system of innovation ((herein referred to as the NSI[2]), the White Paper laid out the most complete description of the vision of the country that uses innovation for economic competitiveness, national development and service delivery.

Following the passing of the White Paper, the National Research and Technology Foresight (NRTF) initiative or exercise was undertaken between 1997 and 1999. The NRTF was intended to "put real content into the NSI thereby developing a framework of goals within which SA technology goals can be shaped. The main legacy of the exercise was the entrainment of a large number of participants in the national science and technology policy making and development agenda.

The White Paper clearly described institutions to be established in order to promote the development of a well-functioning NSI. In 2002, government took an important measure to separate the Department of Arts, Culture and Science into two departments, one of which is the Department of Science and Technology (herein referred to as the DST). DST was charged with the mandate to develop, coordinate and manage the NSI through playing a leading role in the implementation of space science and technology activities towards transforming the national space landscape.

The DST had a concern that the NSI was not taking shape as expected, in response to which the National Research and Development Strategy (herein referred to as the NRDS was developed in 2002. NRDS aimed at creating an enabling environment for the NSI. The strategy was thus designed to strengthen the NSI through identifying these key elements of the NSI in need of particular attention and focus.

The NRDS focused on the perceived weaknesses of the NSI identifies at the time such as inadequate funding, lack in growth of high-level science and technology personnel, absence of a new policy framework for intellectual property and the general fragmentation of science and technology activity. A warning sign for the NRDS was the public sector segment of the overall NSI, and as such the strategy advocated for performance and responses in three key areas which are enhanced innovation; providing science, engineering and technology human resource and transformation; and creating an effective government and science technology system.

Amongst other initiatives proposed by the NRDS, the most significant included the need for establishment of a foundation for technological innovation, initiation of five science and technology missions, radical increase in skilled human capital for a knowledge economy and annual draw up of a three year R&D plan for the whole country.

[2] White Paper conceptualises the NSI as a "set of functioning institutions, organisations and policies which interact constructively in the pursuit of common set of social and economic goals and objectives.

Despite the legislative, policy and regulatory reforms implemented and the initiatives undertaken since 1996 to either deepen the NSI definition and content or modify the architecture of the governance and implementation arrangements of the NSI, it became apparent to the DST that the vision of the White Paper had unfortunately not been adopted widely enough in the range of government departments to achieve the intended pervasive impact.

Amongst the concerns were resourcing plan for the NSI, absence of a clear DST focus on business, lack of effectiveness of means to a well-coordinated as opposed to the fragmented and diverse NSI. Consequently, in 2006, the DST commissioned the OECD to review the NSI as means to track progress on the South African space landscape particularly to determine if the country was well underway towards its vision for a knowledge based economy.

Amongst others, the most crucial findings published in 2007 as impeding the functioning of the NSI were, firstly, the serious deficit in high-order skills particularly in the area of design, engineering, entrepreneurship and management. OECD cited that the levels of innovation required in the economy would only be possible if there was a considerable expansion of university research, particularly to provide the necessary research capable human resources at all levels of qualification.

Secondly, the NSI insufficiently supported the transition from strong reliance on resource and commodity based economy to one that would be characterised by value-adding and knowledge intense activities. OECD cited that the national science and technology system was relatively strong but had been structured to meet the needs of an apartheid previous order. Thus rendering the NSI contribution to poverty reduction and wider inclusion in the mainstream economy inadequate.

Thirdly, the concept of a national system of innovation had limited currency, both in terms of the extent to which it was understood and absorbed into the strategies of key actors. The importance of R&D was found to be well understood and supported. However, the notion of innovation was poorly understood in all dimensions, including technical, economic and social. Lastly, business was insufficiently involved in building the NSI at the levels of both large and small firms.

In response to the OECD review, the DST released a formal documentary called the Ten Year Innovation Plan (herein referred to as the TYIP). The TYIP was developed in 2008 on the foundation of the NSI, to advance government's broad socioeconomic mandate, particularly the need to accelerate and sustain economic growth.

The plan was developed in recognition of the tremendous gap between SA and knowledge driven economies. As a result, whilst it emphasised innovation it also stressed that South Africa's prospects for improved competitiveness and economic growth rely to a great degree on the extent that science and technology play a driving role in enhancing productivity, economic growth and socioeconomic development.

The plan described a future in which South African innovations in science and technology would combat the negative effects of climate change; fight crime; produce drugs to combat diseases; develop sustainable energy solutions; introduce drought-tolerant and disease resistant crops; devise intelligent materials and manufacturing processes; revolutionise communications and change the work the country does and the way it does it. These were the five grand challenge areas central to the plan.

In line with the need for governance and institutional architecture of the NSI system as proposed by the NRDS as well as the concerns of the OECD, the Technology Innovation Agency (TIA) was established in 2008 with the objective of developing, stimulating, intensifying and exploiting technological innovations in order to improve economic growth and the quality of life of all South Africans.

TIA's core business objective is to support the development and commercialisation of competitive technology-based services and products. The Agency primarily uses South Africa's science and technology base to develop new industries, create sustainable jobs and help diversify the economy. It invests in the following technology sectors: Advanced Manufacturing, Agriculture, Industrial Biotechnology, Health, Mining, Energy and ICT.

As means of addressing the challenges of lack of coordination in the country on space science and technology initiatives, a key regulatory milestone in 2008, was the development of the national space strategy as an implementation framework for a national space programme. The institutional arrangement deemed necessary for its implementation was the establishment of the South African National Space Agency (SANSA) which Cabinet had already approved in 2006.

SANSA was then established in 2008 to coordinate and integrate national space science and technology programmes and conduct long term planning for the implementation of space related activities in the country for the benefit of all citizens.

The main objectives of this agency are to promote the peaceful use of outer space; support the creation of an environment conducive to industrial development in space technologies; foster research in astronomy, earth observation, communication, navigation and space physics; advance scientific, engineering and technological competencies and capabilities through human development and outreach programmes as well as foster international co-operation in space related activities.

The main challenge encountered in the national space science and technology initiatives was that the TYIP was already in the process of development prior the findings of the OECD. As such, there were weaknesses found in the OECD that were not addressed by the TYIP. This is why again in July 2010, the Minister of Science and Technology commissioned a Ministerial Committee to review the science, technology and innovation landscape in the country.

The review needed to particularly focus on the readiness of the SA science and technology landscape to meet the needs of South Africa, the degree to which the country was optimally utilising its existing strengths and whether SA was well positioned to respond to the global changes.

The Ministerial Committee established that the vision towards a knowledge based economy was not adopted widely enough across the range of departments to achieve the intended impact. Another finding of the Committee was that the role of business was inadequately included in the conception and coordination of the NSI and much attention needed to be given in particular to the growth of small and medium enterprises.

This challenge meant that the efforts of the country insufficiently supported the transition from strong reliance on a resource and commodity based economy to one characterised by value-adding and knowledge-intensive activities, thus implicating on the key government priorities of employment creation and poverty alleviation.

The Ministerial Committee also established the shortfall in human capital development as another key weakness of the NSI. This is because availability of highly skilled individuals is a vital condition for the framework. The inadequacies of the schooling and education system being widely acknowledged, the Committee cited the concerns on the consequent shortages of well-equipped school-leavers, artisans and technicians. It also mentioned the need for deeper insights into quantity of postgraduates, the production and retention of academics, researchers and science council staff in public sector.

The Committee stated adequate knowledge infrastructure as a crucial condition for a well-functioning NSI. The finding was that public research system was seriously undercapitalised. In other words there was insufficient institutional support in the form of universities, vocational colleges and state laboratories with equipment for research and utilities like reliable energy supply, communications and transport and especially ICTs like broadband and computing power.

The imperative for South Africa's NSI continues to inform and be enshrined in high-level policy documents, most recently being the National Development Plan (herein referred to as the NDP) developed in 2012. NDP also carries the vison for a knowledge based economy. It highlights science and technology as one of the key drivers of development.

Amongst other aspects the NDP envisions for the research and innovation systems, is the need to develop world class centres and programmes within both the NSI and the higher education sector. Most importantly, government must create an investment climate that encourages the private sector to compete locally and globally with innovative products, services and technologies.

The NDP acknowledges that developments in science and technology are fundamentally altering the way people live, connect, communicate and transact, with profound effects on economic development. One reason the NDP cites science and technology as key to development, is that technological and scientific revolutions underpin economic advances, improvements in health systems, education and infrastructure.

The NDP not only mentions science and technology as key for development, but scientific knowledge and literature. The importance of scientific knowledge and literacy are reflected in the statement that the "extent to which developing economies emerge as economic powerhouses depends on their ability to grasp and apply insights from science and technology and use them creatively".

The NDP focuses on the application of science and technology in national development, whilst also making reference to the corollary of their effective application (the importance of science literacy). In this regard, the NDP states that the country (along with other developing countries) should invest in education for youth and ensure that knowledge is shared as widely as possible across societies.

2.2 Developments in the SA Space Arena

South Africa has a rich history of involvement in space science and technology. This section of the report provides an overview of the developments in the South African space arena since 1957 to the latest investments in 2013. This is in order to show the existence and extent of space science and technology in the country, in addition to the legislative, policy and regulatory reforms already discussed in Section 2.1 above.

The evolution of space capabilities in countries follows a pattern. Stage 1 includes purchasing satellites from space faring nations (merely technology transfer), Stage 2 involves establishment of satellite development facilities in the emerging space nations and Stage 3 are countries capable of developing their space systems independently. The discussions to follow on the developments in the national space arena will reveal the stage within which South Africa currently stands.

2.2.1 Space Activities in the Historic Era

Between 1950s and 1970s it can be said that South African involvement in space activities was on a small scale. During this era, it can be said that South Africa was in Stage 1 as the focus was purchasing satellites often with participation of scientists and engineers in the development and construction.

During the late 1950s and early 1960s, the country participated in the early '***Moonwatch'*** programme to observe the orbits of numerous Soviet and American satellites. The satellites were tracked by South Africans to determine upper atmosphere effects on orbits and as such these satellite tracking activities continued up until the 1970s.

In the early 1960s, NASA established one of its ***Deep Space Network stations*** in Haartebeethoek. This station supported a number of the early robotic missions to the Moon as well as some of the later human landings on the Moon in the Apollo era. In 1974 this station ceased to operate as a NASA Deep Space Network station and it was transferred to the South African government. The facility became Haartebeesthoek Radio Astronomy Observatory, the national facility for radio astronomy.

In the late 1980s South Africa established a military space programme to build a reconnaissance satellite and launch vehicle. To support this programme, a satellite integration facility was established in Grabouw near Cape Town and a launch facility was established at Arniston on the Cape south coast. With the break-up of the Soviet Union in December 1991, the geopolitical situation in the subcontinent changed.

With the peaceful transition to a fully representative democratic government in the country, the reasons for establishment of a military space programme largely disappeared. This programme was terminated in the 1990s after a failed attempt to commercialise the satellite under the name ***Greensat***. Despite the termination of this first space programme before operational satellites were produced, the infrastructure that was established for satellite integration and testing remains in existence.

In 1995 South Africa became an adherent to the ***Missile Technology Control Regime*** (MTCR) and abandoned all work on the development of launch vehicles. The former integration facility at Grabouw was taken over by the Department Of Communications and became Institute for Satellite and Software Applications. The Overberg test range in Arniston has continued to be used as a test flight facility, although not for rocket research.

Again in 1999, space activities in the country entered a spotlight with the launch of ***Sunsat***, built by the Faculty and students of the electrical engineering department of the Stellenbosch University. This was a 64kg micro-satellite with a small imager, a packet of radio communications payload, magnetometer, GPS array and a retro-reflector array. The primary mission objectives were imaging, worldwide store-and forward email communications, and satellite engineering research. Secondary mission objectives were studies of the Earth's magnetic field, gravity field, atmosphere and ionosphere plus inter-comparison of GPS and SLR precision orbits.

2.2.2. Space Infrastructure in the historic era

On the infrastructure front, South Africa's first developments date back to the early 1970s. Infrastructure to support ground based astronomy and space physics was developed in this period. Research facilities for space science include the South African Observatory for optical/infrared astronomy, the Haartebeesthoek Radio Astronomy Observatory for radio astronomy and space geodesy, the Hermanus Magnetic Observatory for geomagnetism and space physics and the South African research base in Antarctica. Several universities conduct research programmes in the space sciences and provide undergraduate and postgraduate level training in the sphere.

Satellite tracking capabilities were established in 1975 at the Haartebeesthoek Radio Astronomy Observatory. This facility provides commercial telemetry, tracking and command services to a host of international operators and launch providers. This facility is also the premier ground facility in the subcontinent, with a footprint extending as far north as Luanda on the west coast and Dar es Salaam on the east coast of Africa.

2.2.3 Space developments in the 2000-2006 Era

In a marked contrast to the discussed historic era, the period following 2000 had marked acceleration of activity in the space science and technology landscape of the country. Mostly, this period has seen marked investment in the national space infrastructure for space science and technology.

In 2000, the intention to construct the South African Large Telescope (SALT), the largest single optical telescope for optical astronomy in Southern Hemisphere was announced. SALT was an international project led by the country with institutional partners in Germany, India, Poland, New Zealand, the United Kingdom and the United States. SALT was later inaugurated in 2005.

The construction and operation of Sunsat created a university based team with direct experience of satellite engineering and satellite operations. In 2002 a company SunSpace was established around a core team of four members of the Sunsat project to commercialise and further develop the technology base established with Sunsat. This marked the birth of an indigenous micro-satellite industry in the country. In a few years since its establishment, Sunsat has managed to develop a range of capabilities and services.

In 2004, South Africa became a minor partner through the University of North West, in the High Energy Stereoscopic System (HESS) located in Namibia. HESS is a system of imaging atmospheric Cherenkov telescopes for investigating cosmic rays. The instrument allows astronomers to explore gamma ray sources with the intensities at a level of a few thousandths of the flux of the Crab nebula.

Large scale international facilities such as SALT and HESS were attracted to the region firstly because of the excellent climatic conditions for astronomy. Secondly, because South Africa is a politically stable region. And lastly, the country has an adequate infrastructure and industrial base to support such hi-tech ventures.

In 2005 a new satellite programme called Sumbandila was announced by DST. The University of Stellenbosch was appointed as the implementing institution for the 84kg microsatellite programme. Sumbandila is a technology demonstrator with a main optical remote sensing payload and several secondary experimental payloads. The primary objective of this satellite project is capacity building in all aspects of a space programme with emphasis in the technical, regulatory, operational and applications development areas.

2.2.4 Space Activities post 2006 Era

Following the SALT and HESS international facilities, South African government realised that conditions in the country were right to promote the attractiveness of the southern African region as a hub for large scale astronomy projects. The critical reason for this interest was that, in addition to the scientific benefits of such projects, they also provide lucrative opportunities for local industry. The latest developments in the country's science landscape are the investments in the Square Kilometre Array (SKA) and the Karoo Array Telescope (Meerkat) radio telescopes located in the Northern Cape Province.

The SKA is an international effort to build the world's largest and most sensitive radio telescope. The SKA project includes a precursor telescope, the Meerkat. Meerkat will be the world's largest telescope in its own right, designed to be most sensitive in the Southern Hemisphere on completion. Meerkat program will develop and test many of technologies required of the SKA, including one piece reflectors, single pixel wide band receiver and cryogenic systems.

3. Northern Cape Developments

South Africa can be said to have excellent climatic conditions for astronomy, and as such the SKA project aligns with this desirable location as well as the county's strategic policy goals of developing an innovative economy and workforce. The Karoo area in the Northern Cape, where the SKA is to be situated, is very dry with few clouds, and its remote location and surrounding hills minimise signal interference thus making it the best location for the SKA.

This project is envisaged to act as a catalyst for science, technology and engineering business opportunities, jobs and innovation; and to actually put Africa on the map as the world 'big data' and analytics hub. Because of the unprecedented data connectivity as well as the technology and engineering needs, the SKA project will result in significant local skills development, revolutionise science and technology research, and enable innovative new businesses and employment in science, technology and engineering fields.

4. International Space

The international space landscape differentiates between three groups of nations, the advanced, intermediate and emerging space nations. What often distinguishes these nations is the capabilities in terms of developing, building, operating and launching space programmes, and general access to space.

The global space landscape is dominated by a major few actors namely the United States, Europe, Russia and Japan, all of which fall within the group of advanced space faring nations. All the countries in this group have end-to-end capability to develop, build, launch and operate space systems of varying degrees of sophistication. These are the first countries that developed planetary exploration and human spaceflight capabilities. India and China, with their human spaceflights and exploration programmes are joining this exclusive club of advanced nations.

The second group is the intermediate space nations, which have considerable but not yet comprehensive space capabilities. These nations have the means to design and develop satellites with reliance on other countries for critical subsystems or components and for access to space. It is not uncommon for countries in this group to pursue research and development activities relating to launch vehicles. This group includes countries such as Brazil and the Republic of Korea.

The third group is what is called emerging space nations. Countries in this group have nascent national space programmes to develop earth observation or scientific satellites. The development activities take place in public sector research laboratories. These countries have significant reliance on the other two groups (advance and intermediate) space nations for access to technology and know-how. South Africa falls within this group, as well as countries like Algeria, Nigeria, Egypt, Malaysia and Pakistan.

Interestingly, countries with strong international cooperation in space activities prefer national space agencies' model for a national organisational structure to deal with space activities such as a Ministerial department, inter-departmental Committee and so on. It is comforting to note that South Africa is well in line with the global space trends, despite it being in the emerging space nations group.

Whilst South Africa has largely been a net importer of space technologies in spite of the satellites built towards the envisioned space science and technology landscape as discussed in Section 2.2 of the report, its role in the global space arena cannot be disregarded.

For instance, South Africa is a member of the United Nations Committee on the Peaceful Uses of Outer Space, whose mandate is to promote international cooperation in peaceful uses of outer space. The country is also a member of the Group on Earth Observations, which coordinates international efforts to build a system for monitoring and forecasting changes in the global environment by weaving together information.

5. Synthesis

Whilst the country was clear of its vision to transition from a resource and commodity based economy towards a knowledge-based economy, initial efforts undertaken would no way achieve this intended vision. Firstly, there was no coordination of South African space science and technology activities prior 2003, which resulted in duplication of efforts and facilities.

Secondly, the concept of a national system of innovation had limited currency, both in terms of the extent to which it was understood and absorbed into the strategies of key actors. The notion of innovation was poorly understood in all dimensions, including technical, economic and social.

Thirdly, the minor/insufficient role played by business in conception and coordination of the national system of innovation particularly the much needed attention to growth of small and medium enterprises was a weakness. Also, whilst the importance of R&D was found to be well understood and supported it was inadequately funded to warrant the vision of the country on space science and technology.

The government initiatives undertaken from 2003 were key in addressing these challenges and began to modify the architecture of the governance and implementation arrangements of the space science and technology vision. Beginning with the establishment of the DST with a clear mandate to play a leading role in the implementation of space science and technology activities in the country.

Furthermore, was the establishment of the SANSA to implement the wide array of our national priorities specifically relating to socio-economic development. The three implementation areas of the SANSA are Environment and resource management, Health, Safety and security as well as Innovation and economic growth. Hence the agency supports initiatives in research and development, advanced manufacturing and industrial development.

Establishment of SANSA was not only strategic as it served to address some of the weaknesses identified by the OECD review. The notion of a national agency on space programme is moreover a key model adhered to by advanced international space players. Hence establishment of the SANSA paved a way for the country in terms of use of global space and the necessary co-operation in space related activities, amongst others. The SANSA

Significant efforts have been made to build public support for space science and technology. This has been done through a sponsorship of space-related public outreach activities such as World Space Week. There is also a Space Portal established to support policy discussions, communicate importance of space to the general public. The portal is also used to advertise study and work opportunities, space conferences and so on.

Other efforts include initiatives to not only improve coordination of government funded space science and technology activities in the country. But to also support accelerated growth in the South African space arena and greater utilisation of space technology for national development. The SKA is one such initiative.

Referring to the three stages followed by countries in evolution of space capabilities, the SKA has presented South Africa with an opportunity to transition from Stage 1 to Stage 2. SKA presents our country with the opportunity of operational and space skills transfer and not merely the technology transfer. Through the SKA, South Africa will identify areas of autonomous capability and steer industrial development accordingly.

An area of concern still, is the minor role played by business on the space science and technology landscape in the country. For instance, Sunspace which built both Sunsat and Sumbandila satellites remained the only SA's satellite manufacturer until 2011. More needs to be done by government to create an enabling environment to support better participation of private role players.

6. Conclusion

South Africa's space science and technology landscape has in the main been dominated by legislative, policy and regulatory reforms. Whilst the vision is clearly spelled out to transition from a resource/commodity based towards a knowledge economy, much still needs to happen. Particularly, in the commercial space activities which has largely been dominated by government. Challenges such as inadequate funding of R&D, lack of required human capacity, inadequate education system to produce scientists and engineers, constrain the government from making strides towards reaching its vision of a knowledge based economy. But poor role played by the private sector needs the most urgent attention. More so, given that commercial space activities are the most dominating in the international leading space nations.

7. References

i. DACST (1996) White Paper on Science and Technology: Preparing for the 21st Century. Pretoria.

ii. DST (2002) South Africa's National Research and Development Strategy. Pretoria: Department of Science and Technology.

iii. DST (2007): Ten-Year Innovation Plan for South Africa 2008-2018. Pretoria: Department of Science and Technology.

iv. OECD (2007) Review of South Africa's Innovation Policy. Paris: Organisation for Economic Cooperation and Development.

v. DST (2010): National Space Strategy Pretoria: Department of Science and Technology

vi. DST (2010c) Ministerial Review Committee on the Science, Technology and Innovation Landscape in South Africa: Phase One Report. November 2010. Pretoria: Department of Science and Technology.

vii. NPC (National Planning Commission) (2011b) National Development Plan. Pretoria: Office of the President.