Strategic Management of Innovation and Entrepreneurial Framework applied to the South African Nanotechnology Flagship Projects

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ABSTRACT

This study considers four South African nanotechnology flagship projects and evaluates them using the Strategic Management of Innovation and entrepreneurial framework. The flagship projects span a variety of focus areas which include beneficiation of strong materials (platinum group materials), viral therapeutics (HIV, Hepatitis), development of 1D nano-structures for nano electronics and fuel cell development.

The study found that although projects were at the early stage and therefore dominated by research activities, they were not well aligned to later effectively capture value and take advantage of the existing innovation ecosystem. A number of recommendations were put forward emanating from the gap analysis studies.

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This thesis is dedicated to my kids Mlibo and Qhayiya Hillie for the year they spent without their father at home. My thoughts were with you all the time.

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Chapter 1: University Research Commercialization

Overview

Capturing value through commercialization of public research is a daunting task. The accumulation of tacit knowledge and the culture of entrepreneurship are among the most critical resources to create wealth from research and subsequent technology innovation. This process cannot take place inside the university and instead has to be complemented by an external environment that is conducive to innovation. Wealth creation can be facilitated either through the creation of a new business entity, the establishment of a new venture within an existing company or licensing the intellectual property. Hindle et al., [1] presented a number of models that define the entrepreneurial opportunity and capacity as essential elements in the interaction between all types of tacit knowledge, which also derive from interactions between the institutions, organizational culture and the external business environment. The type of tacit knowledge in this regard refers to technological, managerial, risk management and financial.

The role of the University

The traditional university is an educational institution that grants degrees in a variety of subjects as well as conducting original scientific research. The new university is a combination of teaching and research, applied and basic, entrepreneurial and scholastic. It is now seen as the cost effective, creative inventor and transfer agent for both knowledge generation and technology. In a knowledge-based economy the university plays a critical role as both the human capital provider and a spring board for new companies. Etzkowitz et al., [2] refers to this university as an entrepreneurial university that includes economic development in addition to research and teaching. The university assumes a role that facilitates the interconnection of three institutional domains; public, private and academic at different levels of innovation. In his address to the Massachusetts life Sciences summit meeting in in September 2003, Dr. Lawrence Summers, the then president of Harvard University refereed to John Kenneth Galbrith observation that universities in the 21st century economy will be what banks were in the 20th century economy [3]. Massachusetts Institute of Technology (MIT) has about 4000 spin-offs with 150 new firms spun out by its graduate students and faculty each year, is unusually successful and its importance is obvious in the regional economic development [4].

In formulating policies to develop new technology based ventures the universities are faced with two options; either to encourage faculty members to take up the innovation process or to encourage surrogate entrepreneurs to assume the leadership role. In a survey conducted at 57 UK universities, Franklin et al., [5], concluded that these two approaches are not mutual exclusive and should not be viewed as such. It suggested that the unification of the two approaches together with the appropriate venture capital is an important recipe for success in establishing successful new technology ventures.

In South Africa the institutions of higher learning that were positioned to facilitate enterprise spin-off were technikons, a word derived from the Greek word "tecnike" that refers to technique or technology [6]. The technikons set in an intermediate position between a technical college, whose responsibility was to offer theoretical aspect of apprentice education, and the university. The technikon had a tier system offering a diploma over three years mainly in technical subjects. The student had to spend half that time at the technikon for the theoretical part and the rest at the relevant industry for experiential learning. This system facilitated a strong collaboration between academia and industry and was successful in developing new technologies.

Some of these technikons have since been merged with traditional universities in the new political dispensation in an attempt to transform higher education.

With the emerging or consideration of the 'entrepreneurial' universities, there are those who are opponents to this notion fearing that it will change the academic mission from dissemination to capitalization of knowledge.

A special kind of an academic

It takes a special kind of researcher to pursue the path of conducting research aimed at the market place. A number of academics feel that science should not be interfered with by bringing in business. In contrast, Dr Robert Langer an Institutional professor at MIT and a prolific inventor offers a different point of view; he thinks that there are enormous benefits in the interaction of science with companies. He is quoted saying that what excites him is that one can use science a tool to create things that can change the world [3]. (See Appendix 2 for a recent interview with Dr Robert Langer).

Siegel et al., [7] presents the vague side of academic entrepreneurs who engage in informal technology transfer mechanisms that facilitate the flow of technology knowledge through informal communication processes. These academics they claim are not disclosing their inventions to the university but use informal technology transfer through; transfer of commercial technology, joint publication with industry scientists and industrial consultation. Murray et al.,

[8] noted gender disparities on the supply side of commercializing science and that these are highest at the most prestigious institutions. They have also reported that at faculty level woman are less likely to disclose inventions than men.

The academic network is also crucial to complement the capabilities of the institutional researcher to bring about the scientific solution since the solutions to the problems are most likely to require an inter-disciplinary approach. Some of the collaborators bring with them social capital [9] in addition to the human capital. You should have people with passion to take science to the society and change the world.

Research agenda

The science systems are seen to be transforming towards the production of relevant knowledge. In the main there is an emerging new way of knowledge production which is becoming more dominant introduced by Michael Gibbons and colleagues more than a decade ago. Hessels et al., [10] reflected on the Gibbons-Nowotny notion of "Mode 2 knowledge production" and made a bold attempt to follow its reception through scientific literature review and compared it with seven alternative diagnoses of changing science systems. The characteristics of mode 1, traditional knowledge generation mode, and Mode 2 are presented for comparison in table 1.

Table 1

Mode 1	Mode 2
Academic context	Context of application
Disciplinary	Trans-disciplinary

Homogeneity	Heterogeneity
Autonomy	Reflexivity/social accountability
Traditional quality control (peer review)	Novel quality control

The main proposition of the Mode 2 is of a knowledge production system that is socially based rather than residing in universities, government institutions and industrial research laboratories. It is to supplement the traditional knowledge generation, mode 1, rather than to replace it. Mode 2 has attracted its fair share of critics who feel that it is more a political ideology that a descriptive theory. The opponents fear that the lack of empirical data is dangerous as it gives an impression that the present system needs to be changed; they think it is a prescriptive rather than descriptive theory [10]. Another argument is that disinterested basic research is the fundamental and only path to later technological innovation and useful applied knowledge [11]

The separation between basic and applied research is complex and there is a lack of clarity. Stokes [12] concludes that the dichotomy between basic and applied and the linear thinking about research is misplaced and maintains that the interest for understanding the fundamentals of science and the effort to derive application should not be separated.

External environment

The external environment also plays a major role in successful commercializing of university research as it provides the impetus for university-industry partnerships. Close proximity and a well-coordinated effort to link the university, industry and local entrepreneurs can result in the founding of an entrepreneurial ecosystem. An ecosystem offers mechanisms to move ideas from the university into the start-ups and established firms through negotiated intellectual property (IP) contracts. Integrating academic research labs into the entrepreneurial ecosystem is a long-term but critical challenge for nations, large corporations and entrepreneurs [13].

Funding

Funding is very important to any research endeavor and should be available as of where and when it is needed. This is due to the fact that research by nature is unpredictable and may occasionally require additional resources at any given time. Consumables and the supporting infrastructure may require replenishing and upgrading, respectively. In this regard the lead investigator has to constantly raise funds to support the research activities. They have to sell the prospective outcomes of the research to a much eager industrial partner. There is a usual risk of misunderstanding of expectations in this process since the scientist are not trained in selling, they either sell low which deters the industrial partner or oversell which brings unreasonable expectations. The successful researchers use their social capital and the record of previous successful projects, the latter acts as a signaling mechanism to the funders and increase the chances of the researcher to be funded.

Challenges

It still remains difficult to capture the value created in the projects from the university laboratories. This problem has many facets which include a defining plan, a choice of model to capture value and required internal and external appropriate assets and capabilities.

Study Objectives

This study will attempt to reconcile the objectives of the nanotechnology flagship projects with the entrepreneurial strategic framework to maximize value capture. Four South African flagship projects were evaluated in regards to the assets, capabilities and external networks. The results will be matched against the strategic framework to perform a gap analysis. The result of this study are expected to expose critical gaps and contribute towards the understanding of the process that informs the successfully commercialization of science, especially the emerging technologies..

Scope and thesis layout

The thesis will investigate four flagship projects from South Africa which are in different disciplines with nanotechnology as the underlying enabler. These projects were funded for three year by the time we conducted the survey to establish where they are and where they would like to be.

The thesis begins with a literature review of university research commercialization leading to leading to technology innovation.

Chapter 2 will give an overview of nanotechnology worldwide highlighting the various initiatives by regions and countries. It will also share information on initiatives which are directed to responsible nanotechnology research and risk mitigation amongst others

Chapter 3 will share the development of South Africa National Nanotechnology Strategy (NNS) leading to the funding of the flagship projects as part of the roll out of the ten year implementation plan.

Chapter 4 will present the MIT entrepreneurial strategic framework with respect to its three main components of value creation, value capture and defining plan. This defining strategic plan will put emphasis on the internal assets or capabilities and the external networks as resources of the project.

Chapter 5 will capture the questionnaire responses and match them against strategic framework for gap analysis studies.

Chapter 6 will present the conclusion of this study and put forward recommendations that will advise the model of using the nanotechnology flagship projects to deliver on their objectives.

Chapter 2: Nanotechnology A brief History

The three quotes below chronologically presents the evolution of nanotechnology from an idea in an American Physics Society meeting at Caltech in December 1959, followed by the worldwide market projections of a $1 trillion market in 2015 almost 40 years after the famous lecture. In 2005 at the event of the launch of the South African Nanotechnology Strategy nanotechnology held promise to remedy social ills of underdevelopment as stated by the Minister of Science and Technology.

> *"The principles of physics, as far as I can see, do not speak against the possibility of maneuvering things atom by atom. It is not an attempt to violate any laws; it is something, in principle, that can be done; but in practice, it has not been done because we are too big".* — Richard Feynman, Nobel Prize winner in Physics, 1959

> *"Nanoscale science and engineering will lead to better understanding of nature; advances in fundamental research and education; and significant changes in industrial manufacturing, the economy, healthcare and environment management and sustainability. Example of the promise of nanotechnology, with projected total worldwide market size of over $1 Trillion dollar in 10 to 15 years"* Mihial C. Rocco and William Sims Bainbridge, 2001

> *"As Government moves the frontiers of poverty and underdevelopment in the Second Decade of Liberation, the Nanotechnology Strategy moves us even closer to the realization of a knowledge-based economy".*- South African Minister of Science and Technology Dr Mosibudi Mangena, 2005.

International Standard Organization ISO (TC229) defines nanotechnology as either; *Understanding and control of matter and processes at the nanoscale, typically, but not exclusively, below 100 nonametres in one or more dimensions where the onset of size-dependent phenomena usually enables novel applications,* **or** *utilizing the properties of nanoscale materials that differ from the properties of individual atoms, molecules, and bulk matter, to create improved materials, devices, and systems that exploit these new properties*, or both [14].

Emerging technologies including nanotechnologies hold a promise to offer a variety of solutions across the board. Nanotechnologies possess a huge potential to deliver breakthrough solutions in areas like health, energy, water purification, advanced manufacturing, electronics (spintronics) to name a few, but there are also areas of concern relating to responsible research, regulation and safety, health and environmental issues that need to be mitigated for these promises to be appreciably realized in a sustainable manner. This chapter presents the brief history of nanotechnology as it evolved to be a force to be reckoned with from almost two decades ago when research started in earnest in nanoscale science.

Front runners

Switzerland was among the first countries to focus on the application of nanotechnology at the initial stage and is one of the fastest growing countries in this regard. It was one of the highest funding countries in the world per capita and they were pioneers and still maintain the forefront in developing high end characterization techniques, e.g. Scanning Tunneling Microscope (STM) [15], which revolutionized nanoscale research. The Swiss government also initiated a ToPNano21 program which ran from 2000 to 2003 in an effort to stimulate and exploit nanotechnology and support small, medium enterprises. ToPNano21 funded more than 200 projects aimed at the development of new nanotechnologies and founding of new companies. The strategy evolved and is continued through the Swiss Innovation Centre [16].

The National Nanotechnology Initiative (NNI) of the United States of America provided an impetus to other countries and regions in the world due to its sheer size and the endorsement from the highest office in the land (US President Bill Clinton announces plans to create and fund the National Nanotechnology Initiative, 2000). The NNI past, present and future is still guided by three reasons which are to 1) fill the major gap in fundamental knowledge of matter, 2) that nanoscale phenomena holds the promise of fundamentally new applications and 3) for the interest in the beginning of industrial prototyping and commercialization fuelled by appetites of governments around the world to develop nanotechnology as rapid as possible [17].

United Kingdom's vision for nanotechnology is to benefit the economy and consumers from the development of nanotechnologies through government's support of innovation and promotion of the use of these emerging and enabling technologies in a safe, responsible and sustainable way reflecting the needs of the public, industry and academia [18]. In this regard the government has focused on the following areas; business, innovation and industry, environmental, health and safety research, regulation and the wider world, which forms the basis of its strategy.

Other leading countries like Japan, Germany, Taiwan and South Korea have pursued their interests in nanotechnology form strong material research in Japan, National Institute for Material Science, the consolidated nanoscale research activities in Germany, Max-Planck Institutes, semiconductor nano-fabrication in Taiwan, and application in electronics and display technology in South Korea. The emerging powers that include China, Russia, India and Brazil have also joined the band wagon and are heavily investing in both fundamental research and infrastructure in nanotechnology. Countries like South Africa, Argentina, Mexico and others still require developing human capital in nanoscale science and characterization infrastructure.

EU Framework programs on nanotechnology

On the 12th May 2004, the European Commission (EC) adopted the Communication "Towards a European Strategy for Nanotechnology" COM (2004) 338. It aimed to bring the discussion on nanoscience and nanotechnology to an institutional level and proposed an integrated and responsible strategy for Europe. The subsequent action plan for Europe 2005-2009 (COM 2005) 243 was adopted in 2005 and defined a series of articulated and interconnected actions for the immediate implementation of a safe, integrated and responsible strategy for nanoscience and nanotechnologies. The EC sees international co-operation as essential for the development of nanotechnology, where scientific and technical challenges are huge and a wider critical mass is beneficial. This is shown by the co-operations that the EU has with Africa, Australia, North America, Eastern Europe and Latin America through the framework programs [19].

United Nations

In the ethics and politics of nanotechnology UNESCO interrogates the ethical issues in relation to nanotechnology that should be identified and analyzed so that the general public, specialized groups and decision-makers can be made aware of the implications of the new technology [20]. ICS-UNIDO is an international technology center of the United Nations Industrial Development Organization, created to promote capacity building of countries. It has embedded nanotechnology in its thematic fields that seek to transfer scientific knowledge through advanced training; support of scientific communities and individual scientists and technologists in developing countries and economies in transition with the aim to prevent the nano-divide. The UN food and agricultural organization (FAO) is considering new emerging applications of nanotechnologies in food and agriculture whilst the World Health Organization (WHO) intends to address occupational risks of nanomaterials.

Organization of Economic Cooperation and Development (OECD)

The OECD embarked on a campaign aimed to foster the responsible development of nanotechnology [21]. OECD believes in the potential of nanotechnologies to present benefits in energy, healthcare, food and agriculture, information and communication, water treatment and pollution remediation. It calls on policy makers and other stakeholders to identify and adapt internationally accepted risk assessment methodologies and appropriate scientific principles and technical requirements for responsible development of nanotechnologies.

Commercial value

In 2009 the nanotechnology worldwide market was at the quarter of a trillion US dollars of which $91 billion dollars was due to the nanoscale incorporated products in the USA [22]. The $1 trillion dollar promise that was predicted for 2015 might not be realized but there should be no panic since this depends on what we measure. Nanotechnology is touted as an enabling technology; this means that the market will be populated by devices that have embedded nanotechnologies than whole nanotechnology devices. If we consider the former as in the memory storage gadgets like the iPods, the Random Access Memory (RAM) in our computers etc., then nanotechnology market is approaching the predicted market value [23].

Regulation

The USA Food and Drug Agency (FDA) issued draft guidance on considering whether a FDA-regulated product contains nanomaterials or otherwise involves the use of nanotechnology. This issuance of the guidance was seen as the first step toward providing regulatory clarity on FDA's approach to nanotechnology [24]. ObservatoryNANO project is an evolving document, to keep pace with changes in the regulatory landscape and the governance more broadly. It provides in–depth information that includes detailed description of regulatory actions undertaken in the most relevant application areas of nanotechnologies in more than 15 countries worldwide. It reports on initiatives related to voluntary measures, standards and international cooperation and offers additional information on the most relevant recent developments [25]. There are other initiatives to regulate nanotechnology which are not listed here that also involve multi stakeholder forums. These efforts consider individual countries and regions by design since it is difficult to achieve universal regulation, but moves towards convergence are gaining ground.

Recognition

Nanotechnology and its associated discoveries have had a fair share of Nobel Prizes in science. Amongst others is the 1986 physics prize, the other half was jointly given to Gerd Binnig and Heinrich Rohrer for their design of the scanning tunneling microscope (STM) which revolutionized characterization and manipulation of materials at atomic level and the 1996 chemistry prize awarded jointly to Robert F. Curl Jr., Sir Harold W. Kroto and Richard E. Smalley for their discovery of fullerenes which are together with the allotropy (carbon nanotubes) became a topical issue in nanotechnology. The physics prize that actually mentioned nanotechnology was the 2007 physics prize awarded jointly to Albert Fert and Peter Grünberg for the discovery of Giant Magnetoresistance; it is an electron spin enabled technology behind far larger stores on the memory chips in digital cameras, smaller mobile phones which are among the readily visible consumer benefits that have already appeared on the market place. The latest was the 2010 physics prize awarded to Andre Geim and Konstantin Novoselov for groundbreaking experiments regarding the two-dimensional material, grapheme. Nanoscience and nanotechnology are poised to still collect a number of accolades with groundbreaking discoveries yet to be made.

Developing world

In 2005 the representatives of Brazil, India and South Africa met in South Africa in a meeting that was sanctioned by the department of Science and technology to forge a collaboration that would have the three countries working together in a concerted effort to solve similar societal problems using nanotechnology. The IBSA nanotechnology group was established and its activities focused on the areas of advanced materials for sensing, energy, water purification and drug delivery.

Chapter 3: Background of South African Nanotechnology

Introduction

1994 ushered a new dispensation in South Africa followed by the new constitution based on the Bill of rights and the principles of the freedom Charter [26], which was adopted in 1997. The era after the advent of democracy was characterized by a lot of changes and democratic processes to transform the country. Implementation of new policy frameworks were a priority and one of them led to the development of a white paper in Science and technology [27] to map out South Africa vision of science and technology for the 21st century. This paper culminated in a South African national research and development strategy [28].

The South African Research and Development Strategy

The national research and developmental (NR&D) strategy was based on the consideration of historical factors including the respective drop in research and development (R&D) spending between 1990 and 1994 from 1% to 0.7%, the entire science and technology (S&T) capacity of the country which was losing ground with a security threat based on not only being capable of developing our own technology but vulnerable as smart technology buyers, depletion of science, engineering and technology (SET) expertise, declining research activities in private sector, globalization, weak intellectual property protection and fragmented government structures [28].

The new strategy was based on three pillars i.e. Innovation, transforming SET human resources and creating an effective government S&T system.

South African Nanotechnology initiative

In 2002 the South African S&T stakeholders including SET professionals, business, government and NGOs met and found the South African Nanotechnology initiative (SANi) [29] in anticipation of the call of the Europe Commission (EC) framework project in nanotechnology [19] since South Africa was accorded a participatory status in the call. SANi is a multi-stakeholder body that was meant to strategically position the South African response to this call and it still enjoys a huge support across the R&D landscape. Other SANi's activities were to generate awareness in nanotechnology at all levels, create a database and maintain a webpage, and to provide assessment of the impact of participation by the South African researchers in the EC framework program.

The role of SANi evolved in 2004 as it was subsequently commissioned to lead a process to develop the South African National Nanotechnology Strategy (NNS) that is aligned to the objectives of the NR&D strategy. SANi gathered a number of national and international experts in academia, business, labor and all interested stakeholders spanning the innovation system, and guided by the Department of Science and Technology (DST) developed the NNS which was launched in May 2005 exactly three years from the founding of SANi. Nanoscience and nanotechnology were also perceived to be sexy subjects to attract young talent to revitalize S&T and put an attempt to adequately renew the required Human Capital (HC).

National Nanotechnology Strategy

The main objectives of the NNS are to [30]:

- Support long-term nanoscience research that will lead to the fundamental understanding of the design, synthesis, characterization, modeling and fabrication for nanomaterials.
- Support the creation of new and novel devices for application in various areas.
- Develop the required resources human and supporting infrastructure to allow the development
- Stimulate new developments in technology missions such as advanced materials for advanced manufacturing, Nano-bio materials for biotechnology, precious metal-based nanoparticles for resource-based industries, and advanced materials for information and communication technologies.

The NNS identified and grouped water, health, chemical and bio-processing, mining and minerals, and advanced materials and manufacturing as six focus areas that South Africa could generate most benefits.

The adoption and launch of the strategy was followed by the implementation of a ten year roll out plan to operationalize the strategy [31].

Nanotechnology Implementation plan

The implementation plan is categorized by programs and projects [31]. Its priority is to build capacity in both human capital and infrastructure for critical mass. The first program to be realized was the National Nanotechnology Equipment Program (NNEP) hosted by the National Research Foundation [32] to facilitate infrastructure development. Institutions of higher learning were encouraged to apply for characterization techniques to support their nanoscience research through this funding instrument. This was followed by the establishment of two Nanotechnology

Innovation Centers DST/CSIR NICs [33, 34] which were meant to host and maintain high end characterization equipment and to pursue nanotechnology innovation. Another form of intervention to build human capital was the research chairs initiative, which created nanotechnology research chairs at institutions of higher learning that are dedicated to train students in nanoscale science led by prominent leaders in this field.

In an effort to demonstrate the benefits of nanotechnology the DST proposed through the NRF a call for nanotechnology flagship projects.

Nanotechnology Flagship Projects

Nanotechnology flagship projects are defined as research projects in the field of Nanoscience and technology, with a definite end product or service to demonstrate the benefits of this technology [30]. As part of the implementation plan the flagship projects seek to showcase nanotechnology benefits with tangible products or processes. These projects are fundamentally different to the normal sponsored research projects which only serve to generate knowledge and build competency and capacity at the institutions of higher learning. The nanotechnology flagship projects required tangible products as outcomes and were in areas that are prioritized in the NNS. In addition, nanotechnology flagship projects are not seen only in the context of the National Nanotechnology Strategy, but are meant to contribute to other relevant national initiatives such as the grand challenges contained in the 10-year innovation plan.

The Grand Challenges

The grand challenges were informed by the cabinet's 10-year innovation plan [35]. The grand challenges are to ensure that government investments are effective to strengthen the National Systems of Innovation (NIS) and are also on trek to yield socioeconomic benefits. The grand challenges address an array of social, economic, political, scientific, and technological benefits. They are designed to stimulate multidisciplinary thinking and to challenge the country's researchers to answer existing questions, create new disciplines and develop new technologies

The grand challenge areas are [35]:

- The "Farmer to Pharma" value chain to strengthen the bio-economy – over the next decade South Africa must become a world leader in biotechnology and the pharmaceuticals, based on the nation's indigenous resources and expanding knowledge base.
- Space science and technology – South Africa should become a key contributor to global space science and technology, with a National Space Agency, a growing satellite industry, and a range of innovations in space sciences, earth observation, communications, navigation and engineering.
- Energy security – the race is on for safe, clean, affordable and reliable energy supply, and South Africa must meet its medium-term energy supply requirements while innovating for the long term in clean coal technologies, nuclear energy, renewable energy and the promise of the "hydrogen economy".
- Global change science with a focus on climate change – South Africa's geographic position enables us to play a leading role in climate change science.

- Human and social dynamics – as a leading voice among developing countries, South Africa should contribute to a greater global understanding of shifting social dynamics, and the role of science in stimulating growth and development.

The Nanotechnology implementation plan is not a static document by design as it is constantly seeking to respond to national priorities to maximize impact in a concerted effort with other key stakeholder and initiatives in the NSI, to apply nanotechnology as an enabling technology to achieve the set of goals.

Chapter 4: Entrepreneurial Strategic Framework

Do entrepreneurs really need a strategy?

Entrepreneurship and strategy had been always difficult to reconcile due to the sporadic nature and high risk associated to the uncertainty of entrepreneurial ventures. The entrepreneurial strategy is a combination of plans and activities that in the main to capture value that was created from a hypothesized idea that presented the opportunity for value creation.

Below are set of arguments that articulate the disadvantages of an effort to create and capture value without the strategy. These bullets were extracted for Prof Murray's lecture notes on Strategic Management of Innovation and Entrepreneurship (SMIE) [13].

- Without a strategy it is hard to specify the opportunity you are seeking
- Without a strategy it is hard to make CHOICES when you have to use resources
- Without a strategy it is hard to know what NOT to do
- Without a strategy it is hard to interpret new information
- Without a strategy it is hard to know when to STOP

The MIT Entrepreneurial strategic framework is depicted in figure 1 below. This framework defines the entrepreneurial opportunity, the entrepreneurial defining model and strategy to take advantage of the opportunity and the plan to capture the value. The components of this framework will be discussed in detail in this chapter with the content that is based on the lectures by Prof F.E. Murray [36] during the MIT Sloan SMIE week 2011 unless stated otherwise.

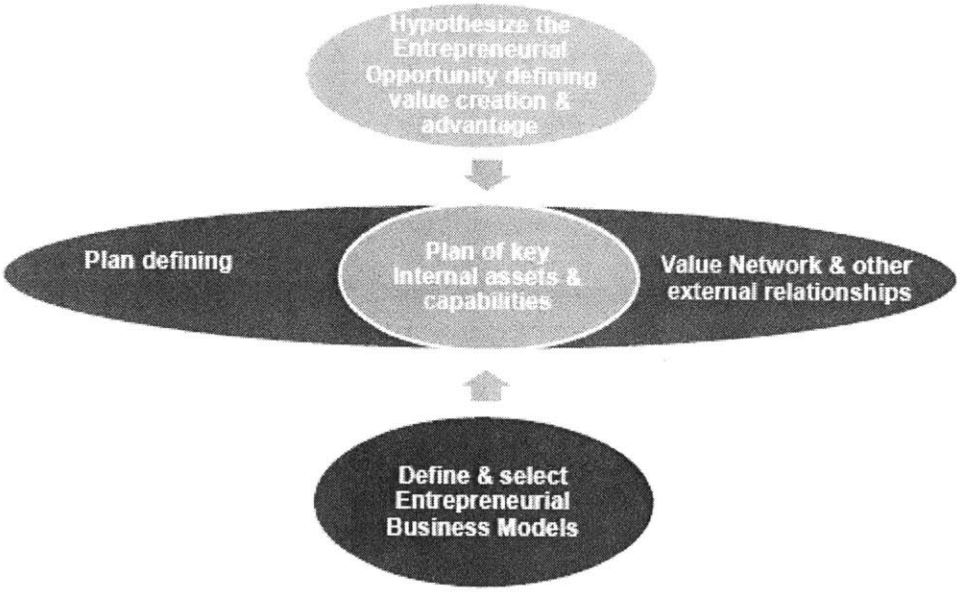

Figure 1, the framework that defines the entrepreneurial strategy

Value Creation

The first component is about the opportunity defining the value creation from the hypothesis. It is the statement that defines the nature of the solution to a problem. The solution can be technology of service that has a potential to solve the existing problem. In formulating this hypothesis key questions relating to the solution have to be asked. These questions include, why does the solution matter and to whom it matters and what are the alternatives in the market. If there are alternatives that are already in the market, the source of value creation has to be established and so is the determination of the source of advantage which could be the intellectual property, its uniqueness and the low cost.

Value Capture

There are many possible models to capture value from a given opportunity each with characteristic business plan. Once one is selected as entrepreneurial strategy it should be adhered to till the end as it is costly to hop around strategies. This component of the framework defines the different possible models through which the opportunity can be pursued to leverage and build competitive advantage and capture value, as determined by different levels of control and construction of value chains. The models include intellectual property licensing, establishment of a startup and a partnership with an established company. The key advantages and disadvantages of each regarding control, financing and collateral resources and infrastructure are listed in the table below.

Table 1

	IP licensing	Startup	Partnership
Advantages	1. The company finances the go to market phase 2. Depending on the terms, might ride on the succeed of the company that bought the license	1. Total control 2. Opportunity to grow 3. Determine your own exit strategy	1. Depending on the allocation of the decision 2. Utilize the resources and infrastructure to quickly move the technology to the

	3. Risk is diversified		market 3. Flexibility
Disadvantages	1. No Control 2. Success of the technology depends on the company, especially if it was an exclusive license	1. Bear all the risks 2. No established infrastructure 3. Tight budget no room for experimentation	1. Partial loss of control 2. Uncertainty due to less commitment by the partner

Defining Plan of the strategy

This part defines the strategic business plan which is the backbone of the framework. The business plan includes objectives, scope, internal assets or capabilities and the external relationships that will most effectively allow you to pursue the opportunity through a selected model. The objective is where the business or project has to be, the solution. How the objective is going to be pursued defines the scope or what will be done or researched. The competitive advantage is defined by the assets or capabilities that form the resources of the project. These also include external networks that certainly complement the in-house resources to capture the value created by the solution. The external academic scientists can contribute social capital in addition to their human capital facilitating the transfer of tacit knowledge and signaling [9].

Different strategic business plans have distinctive financing implications for financing, capital requirements and cash flows amongst other things. Although it is recommended to perform iterative experimentation, flexible to test which model to use, once the model is chosen an irreversible commitment to the model has to be made since it is costly to shift to a new model.

In the next section this model is going to be utilized to perform gap analysis studies to evaluate the nanotechnology flagship projects aimed at delivering tangible products in South Africa.

Chapter 5: Results and Discussions

Introduction

In this chapter the responses to the questionnaire (Appendix 1) are presented. The questionnaire focused on internal assets and capabilities together with the external networks to support the project. The responses will be tabulated and arranged according to the three main questions posed in the questionnaire. The questions posed were; where are you, where would you want to be and what are the barriers to achieving objectives.

The four nanotechnology flagship projects focus areas were in beneficiation of strong materials (platinum group materials), viral therapeutics (HIV, Hepatitis), development of 1D nano-structures for fast nano electronics and fuel cell development. One of the projects had five partner universities, one was based at the Council for Scientific and Industrial Research (CSIR), one had a short-term industrial partner and one had a contract with overseas facilities. This sample provided a good spread of focus areas, assets and capabilities to give credibility to the study.

Responses to the questionnaires

Where were the projects initially?

Funding and the year of commencement of the project are tabled below in Table 1 below.

Table 1

Project	Initial Funding	Main source of funding	Level of funding to date
1	2008	NRF/DST, EC FP6, Innovation Fund	Almost all public
2	2008	NRF/DST	65% NRF/DST, 30% CSIR, 5% University
3	2008	NRF/DST	100% public shared among 5 universities
4	2008	NRF/DST, University, CRIR/NLC	100% public form the three institutions

Table 2 below tabulates the Human resources of the project.

Table 2

Project	No of people	FET	How many PhDs	Academic Collaborators	Industrial collaborators
1	10	10	3	4	0
2	10	10	5	5	0
3	35	8 students in other institutions,	6 overall, 3 in the lab and 3 in	5	0

		12 students in the laboratory including, 3 Post docs	collaborators		
4	6	6	1	2	1 (short time)

Table 3 presents the laboratory assets internally and those that could be accessed externally.

Table 3

Project	Internal	External access
1	A well-funded molecular biology lab	Electron Microscopy Animal services
2	Electrochemistry Equipment	HRTEM, XPS
3	ICP-OES, Quantachrome, GPES in process	XRF, HRTEM (plus SEM, TED EDS, EELS etc.), FRIT, GC
4	Nano-scale Transport Physics Laboratory, AFM, Laser Ablation facilities Hot Filament CVD and a clean room	Raman Spectrometer, X-ray diffractometer

The specific project required deliverables according to the Principal Investigators (PIs) are listed as follows and highlight the diversity of possible deliverables as well as the gap between stated deliverables and commercial application:

Project 1:

Lipoplex nanoparticle vectors that are capable of delivering hepatitis B virus silencing sequences to the liver.

Project 2:

Publications, conferences, HCD (number of students trained)

Project 3:

In the proposal we estimated the following but asked for a much higher budget than what was allocated.

Publications: the experimental results will contribute to the current scientific literature on NSA design and fabrication. At least 5 publications per annum are envisaged.

Conference proceedings: At least 3 conference proceedings per annum

Patents: Materials with advanced performance or potential applications will be identified and reported. Novel materials with commercial potential will be protected by registration of patents. It is expected that at least 2 patents will be prepared.

Students:

2 BSc (Hons) graduates 2008

2 BSc (Hons) graduates 2009

2 BSc (Hons) graduates 2010

5 MSc graduate in 2009

3PhD students should be in completion by 2010/graduation 2011

Project 4:

Manufacturing advanced 1D wires and SL exclusive for nano-electronics: Synthesis of 1D NWs/NTs by using chemical vapor deposition (CVD) and pulsed (excimer) laser ablation to fabricate of electronic devices directly on lithographically patterned substrates. The materials will be grown are carbon nanotubes (CNTs) & doped NWs of Si, Ge, Si-Ge.

Developing 1D nano-electronics & spintronics: Patterned substrates made by will be used for deposition of arrays of aligned 1D NWs/NTs whose galvanometric properties [resistivity, magneto-resistance (MR) & magnetic transport] close to milli K & at a high magnetic field will be studied to establish high level of electron phase coherence through resonant tunnelling and ballistic transport. For spintronics devices transition metal doped NWs will be deposited on ferromagnetic electrodes to study MR.

Table 4 below presents the Intellectual Property (IP) generated in the lab.

Table 4

Project	IP	Owner	Licensed	Start-up plan
1	Yes	University	Not yet	To form a start up
2	None	N/A	N/A	None
3	Yes	University	In process	No
4	Not yet	No comment	No comment	Plans to form a start-up

The scope of activities inside and outside the laboratory is tabled to determine the level of the project development by looking at the split of activities. The scope is presented in table 5 below.

.Table 5

Project	Research %	Developmental %	Technology demonstrator %
1	80	20 (including pre-clinical)	0
2	90	10	0
3	95	5 Budget is too low for this	0
4	75	20	5

The next section maps out where the PIs would want to be eventually.

Table 6 tabulates the PIs developmental plan regarding the project deliverables.

Table 6

Project	Proof of concept	Complete device	Technology demonstrator	Elaboration of involvement
1	In the lab	Outside with collaborators	Outside with outsiders	As a consultant to

				both large companies and start-ups
2	Still to be realized	In the lab with outside collaboration	In the lab with the outside collaboration	Consultant
3	Achieved several proof of concept at each partnering university	Completed devices in 2 partnering institutions	Impossible on budget	Not within the scope of an academic role
4	Establishing electronic properties of nano-materials	To design devices based on carbon	Development of nano-electronic devices in the lab using electron beam lithography	After the successful development of the devices we shall think of forming a company

Table 7 tabulates the available set of skills internally presented together with the required skills and other assets in the PIs laboratory

Table 7

Project	Current-available Skills	Required skills	Required facility collaborator	Required skills contract
1	3 Post docs, 6 PhD, 5 MSc	More Post docs in Biology and biologically applied synthetic organic chemistry	Both High end (e.g. in vivo imaging capabilities) and work horse	None
2	1 post doc, 4 PhD, 2 MSc	Chemistry, Electrochemistry, Physics, Materials, Electronics/mechatronics	High end	None
3	3 Post docs, 8 PhD, 10 MSc, 3 Honours, 2 in-service trainees, 2 admin officers, 1 technician	Our team is very diverse	Rely on outside regional facilities which cost a lot to access. Not interested in running in-house characterization	None
4	1 Post doc, 2	2 PhDs, 2 MSc, 3 Post	Cry-free	None

	PhDs, 3 MSc, 2 undergraduates, 1 senior technician	Docs and 1 full time technician	dilution fridge	

External skills and assets to support the project are shown in table 8 below.

Table 8

Project	Academic Collaborators	Industrial collaborators	Facilities with collaborators	Contract facilities
1	3-4 collaborators are mainly in synthetic organic chemist	None	Organic Chemistry Synthesis capabilities of 3-4 collaborators	Collaborations with universities and overseas government agencies (e.g. French INSERM, Medical Research Instate)
2	Electrochemical skills, 3 international collaborators	Industries are impatient with R&D	XPS, HRTEM, FESEM	None
3	Diverse skills in	THRIP* partners	Yes	Not on this

	association to the project	are not interested in nanotechnology at present		project
4	Need collaborators in Spintronics	Require an Industrial partner working in device fabrication	High field magnetic transport measurements	Device fabrication (transistors)

*Technology and Human Resources for Industry Programme (THRIP) aims to boost South African industry by supporting research and technology.

This section will present the barriers that the PIs encounter as they pursue their project.

Table 9 below refers to the funding cycle of the project and the operational space of the IPs.

Table 9

Project	Is 3 year enough	Suggested time	Space to operate	What would you opt for
1	No	Renewable grant applications	Yes	Different space in the long term
2	No	15 year plan	No clean room	Larger space
3	No	5 years	Enough lab, no clean rooms, no	Yes, UWC is developing a

			controlled atmosphere facilities	chemical sciences block
4	No	6 years	No space for device fabrication and synthesis	Need to construct a larger clean room

Table 10 shows the comments made by the PIs on finances and human capital as impediments to the project progress.

Table 10

Project	Capital requirements	Cash flow requirements	Human Capital	Mentoring/Industrial experience
1	R1-2million	Running expenses are high, long term secure funding would create confidence.	More bursary support for postgraduate and Post-doctoral fellows	Involvement with industry through internship programs. 1 PhD from the lab had 3 month internship at Novartis in Basel, Switzerland
2	More grants required	Important	Important	Crucial
3	Yes	Yes	Yes	Not relevant yet

4	Not enough to construct the proposed cleanroom	No money to support students	Need to expand the research group	Need this experience to test devices developed in the lab before commercialization

The PIs personal thoughts about commercialization options

This part of the questionnaire was deigned to get the opinions of the PIs on which type of vehicle they would use to capture value form their research. Three options were given that were; Intellectual property, establishing a Start-up and Industrial partner. The responses will be presented verbatim under each option.

General overall comment verbatim:

Project 1:

No overall general comment

Project 2:

No overall general comment

Project 3:

"As academics it is not within our ambit or skill set to become entrepreneurs or businessmen. Our job is to teach, train and mentor students and generate new knowledge. It is a total nonsense for the DST/government to expect educational institutions to become business roll out units. Our core competencies and primary goal should be to develop qualified/skilled people and develop new knowledge. IP protection is costly and requires a huge amount of effort to finalize– unless there is a great deal more support (financially and personnel) for academics who are generating new knowledge, a huge amount of new knowledge becomes public too soon and cannot be patented in time. Students, especially at PhD level have to publish. Patenting takes too long and diverts them from their studies excessively and academics do not have the free time to dedicate to this task due to the high workload they already carry. Because there is not sufficient technical knowledge amongst the Innovation Office staff they require the academic and students to provide script for them for the patenting. This is time consuming and laborious. For the new knowledge or proof of concept studies and small prototypes generated during the student training to become viable it would be necessary to partner firstly with a well-funded and skilled Innovation office to protect the idea, then they need to partner with a decently funded incubator system with competent engineering and development staff who could then support the qualified students once they graduate to further develop the concept and this system would then need to link into venture capital and business enterprises who are willing to risk investing into full demonstration development of the prototype. Only then could one talk about carrying the product to market. Perhaps if the financial burden was properly considered, the DST would leave this to the business world".

Project 4:

"For any IP related issues we have to talk to the research office in the Wits University. University new developments, be they registered IP in the form of patents, designs or trademarks, or unregistered in the form of know-how or trade secrets, are best commercially exploited by licensing to an established company in the field. This is always the first option. If, however, there is no company in the field in which the new development was made, and there is good IP to be exploited, the University may be motivated to support the set-up of a spin-off company. The University would then, as the owner of University generated IP, license the spin-off company, and also may take some equity in the company".

IP licensing

a) How are you or would want to be involved?

Project 1:

"We would like to perform the basic applied research and generate intellectual property that can be licensed out to industry partners. We would however like to be involved through a consultancy process or through establishing a spin out company that could manage the IP. Realistically, as an academic research entity we do not have the human resources, inclination or material wherewithal to take the work beyond basic preclinical development".

Project 2:

"Yes, IP licensing is better for me".

Project 3:

"Licensing fees or inventor buy out? Don't know the modalities"

Project 4:

"Although I would take a leading role in forming the spin-off company I do not like to be the chief of the company. I prefer to work as a consultant to the head of the proposed company".

Start-up

a) Would you want to be part of ownership? How else would you want to be involved? How would you prefer your students to be involved?

Project 1:

"Involvement in the establishment of a start-up company that would own the intellectual property would be ideal. This company would then be the interface with the industry partners. The shareholders of the company may be the university, the founders and industry partners as well as other parties who may contribute to the venture".

Project 2:

"My students and I would like to be part of the owners"

Project 3:

"Only to the extent of a % of the profits made from the IP/licensing fee. Or in terms of consultancy fees. I guess students could decide for themselves if they wanted to be involved once they graduate. I think it is premature for them to be involved during their PG studies".

Project 4:

"My postdoc or senior students can be in charge of the spin-off company. I as the academic researcher may have some equity in the Company, but will receive my rewards through the license that the University grants to the spin-off (will be an exclusive license for a number of years, then reducing to a non-exclusive license should the spin-off company not perform up to expectations)".

Industrial Partner

a) Is this your preferred route to impact? If so why?

Project 1:

"Yes, because the industry partners in the pharmaceutical business have the necessary human, material and financial resources to take the technology to a stage of clinical testing".

Project 2:

"Industrial partners are likely to provide real experience (market needs, etc.)".

Project 3:

"No"

Project 4:

"We would like to have a partnership with Detek (Pretoria) since they are expert in semi-conductor device testing".

b) How easy is it for you to find partners?

Project 1:

"This should depend on the quality of the technology that is being developed. We believe that our technology has original and very useful aspects that should be interesting to industry partners. It will of course be imperative to demonstrate this conclusively with watertight science to back up the claims of the technology. Our requested extension of the tenure of the grant is intended to enable this".

Project 2:

"Difficult!"

Project 3:

"Impossible – no time"

Project 4:

"There is very limited number of industry available in RSA".

c) What will they contribute to this project? (Money, skills, market knowledge....)

***Project 1*:**

"Their contribution will be through the providing of resources necessary to take the technology beyond a stage of preclinical assessment to use in patients. This will involve clinical assessments, toxicology and business development".

***Project 2*:**

"Money"

***Project 3*:**

"All of the above - also see previous comments".

***Project 4*:**

"Testing of devices and packaging".

d) What terms and conditions would you prefer?

***Project 1*:**

"A royalty on returns from the use of the technology. A lump sum payment for the IP would be a second choice".

Project 2:

"I am happy with any acceptable terms/conditions provided everyone's input is recognized and properly rewarded".

Project 3:

"The generators of the idea/concepts should be rewarded in the outcome".

Project 4:

"Equal share of the product".

e) What makes this challenging?

Project 1:

"The greatest challenge for us it to make the technology innovative, safe, and applicable to treating a variety of diseases and interesting to large industrial partners".

Project 2:

"Industries are impatient with R&D, they want quick money!"

Project 3:

"Lack of time, money, personnel, skills and primary duties and responsibilities to primary employer. The DST is day dreaming when they expect the academic staff or institution to handle product development to market within the typical budget allocation and the scope of an academic research environment. In our institution there is NO budget allocation to assist with PG research.

The PI has to bring in all funding for PG student support and post graduate research. This is already a huge task considering the VERY onerous business of applying for funds and securing them which are two different things entirely. Most of my time is taken up in hunting for funds to keep my students' research going and then filling out hugely complex reports to the funders for minimal grants– I do not have any time left to think about product development".

Project 4:

"Sometime it is not so easy, since partner may not find a large profit from the work".

Discussion

The responses to the questionnaire were discussed in the context of the entrepreneurial framework that was presented in the previous chapter. This systematic approach is meant to compare the responses to the framework to expose gaps. The discussions will therefore commence with the creation of the opportunity, the strategy defining the plan and the value capture.

Value creation

In this regard since all these projects were funded, the focus will not be too much on the details of the specific idea but a general comment would be made referring to the flagship framework document. It is unequivocal stated that:

"The primary objective of the Nanotechnology Flagship Programme (NFP) is to help demonstrate the benefits of nanotechnology within a reasonable short period of time. As such projects supported under this programme will be expected to have, as their end goal, tangible products. The support of any project will be based on the probability of it yielding tangible products" [36].

It is on the substance of this paragraph that we will base our analysis and especially assuming that since these projects were funded, the projects had a high probability of yielding tangible products.

Two of these projects had generated intellectual property (IP) which were owned by the university, the licensing of the IP were yet to be realized in both instances. The split of activities which reflects the level of development was that beyond 75 % of the work was still conducted as basic research and up to 20% on the development of product or technology. One project that had a short-term industrial partner had spent 5% on technology demonstrator.

All the projects started in 2008 and were mainly funded by the Department of Science and technology/ national Research Foundation (DST/NRF) grants under the NFP. Some universities complemented the grant which is usually expected as a show of support to the project by the University.

Defining Plan of the Strategy

This section is more important in this study as it deals with the assets, capabilities as external networking to resource the plan. These issues have a significant role especially with University research commercialization due to the fact that the technology development is usually at the laboratory level and research was still the major activity as shown by the split in Table 5. At this level human capital is critical inside and outside the laboratory to augment ant complement existing skills. Some of the external collaborators not only bring their expertise to the project but also offer assurance due to their social capital [9]. The interest in the project by these luminaries makes it favorable for extra funding and attractive to young talent.

These projects have good number of post graduate students who are being trained in nanotechnology to build human capacity. As an overarching requirement from the NR&D strategy, government supported projects had to have human capital especially from Historic Disadvantaged Individuals (HDI) as one of the expected outputs. All the projects were doing well in this regard, Table 2, and all had a fair number of collaborators. In all these projects there was an obvious lack of industrial collaborators, except one project that had an industrial collaborator for a short term. The reason for the lack of industrial collaborators can be deduced from the feedback on the required deliverables for each project. All the projects except one put emphasis on publications, conference and Human Capital Development (HCD). These projects were still on the research stage and since these are the views of the PIs it is unlikely that this would change. Although all the PIs realized the benefits of having an industrial partner they encounter difficulties in finding them. This was also expressed in their responses on how easy is it to find industrial partner. Even though one PI had confidence that with good science backing the claims of the technology they could have industrial partners interested, the rest thought that it was difficult to an extent of being impossible to find an industrial partner.

The skills set in table 7 on current and required skills still disregards any expertise beyond science disciplines. The required skills for all the projects included biology, synthetic organic chemistry, physics, material science, electronics, mechatronics and electrochemistry at post graduate level. The PIs made no mention of complementary skills like marketing, fund raising and other business skills. This might be due to the stages of the projects, which were still at the fundamental research level.

The responses in external skills and assets to support the project all seemed to be struggling with industrial partners. There were sentiments that industry was impatient with research and development and that nanotechnology was not in their core business of most of the industries.

All the PIs felt that the funding cycle was short and suggested a period that will last beyond five years. Most of the demands on space were particularly on the clean room. Clean rooms of different classifications are a necessity for device fabrication and some sensitive nanoscale science research since dust or any other contaminant could have drastic effects on the outcomes of the experience. The clean rooms were in the wish list of almost all.

There was also a unanimous need for cash flow to support students and the running of the laboratory.

Emanating from the responses was that the projects were on the right track if they were just meant to generate knew knowledge, publish results and graduate students. However, if these projects were required to produce tangible products the external environment had to be better utilized linking the projects with industrial partners and engaging diverse expertise form the entire innovation ecosystem.

Value Capture

The choice of an appropriate vehicle to capture value was not clear although almost all the PIs were interested in being part of all the commercialization options. It was also clear that most of the projects were at early stages for PIs to consider these options although they had opinions in all. There was less evidence to the fact that these options were being pursued in earnest.

Conclusions

After three years of funding most of the nanotechnology flagship projects not showing any signs that they will adequately meet their goals. There was less undertaking though to configure these projects for the desired outputs and the proposals evaluated and funded using the general model applied to knowledge generation research projects.

The gaps that are obvious when matched against the framework were:

- A lack of university in the internal capabilities of skills to inform the laboratory activities of the market outside the laboratory. These capabilities or skill include but not limited to marketing, risk finance, sales etc.
- There was less or no interaction all together with industry. This meant that the projects could not benefit from mentoring and industrial experience.
- Although all the projects were in the early stages of development, they all had not defined the strategy to capture value.
- All either did not have a plan or had no interactions with the innovation ecosystem

Recommendations

- The valuation of the proposal should define entrepreneurial opportunity and knowledge capacity. Knowledge in this regard referring to technological, managerial, market, risk management and industry.
- Interaction between institutions in the NSI to take advantage of the existing innovation ecosystem. Some of the required skill base resides in these institutions, for example Technology Innovation Agency (TIA), Innovation Hub (IH) etc.

- Introducing surrogate entrepreneurs to assume leadership role of go to market working closely with the PI.
- Long term funding outlook with cycles that are linked with project progress evaluations.

In general, nanotechnology flagship projects require an enabling strategy that is more inclusive in their formation. This strategy should inform the appropriate skills to create value, proper resources and capabilities and entrepreneurial vehicles to take these products to the market to capture value.

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APPENDIX 1

Questionnaire

Dear Investigator

Thank you for taking the time to complete this survey. We are interested in getting your feedback on the barriers and opportunities that you have faced as you aim to take your research ideas forward and ensure that they are translated to reach their full commercial (and/or social) potential.

For the purposes of this survey we ask you to consider a recent project that you believe not only had scientific potential but also the potential for commercial value. In this regard think about your Nano Flagship project.

Where are you?

When did this project first receive funding? When did you start the project?

What was the main source of funding? (Please identify the two largest named sourced e.g. specific agency or company)

What level of funding have you received to date? How did it breakdown (public, private, other) on a percentage basis

What additional resources did you have available to you in your lab when you started the project

(a) Human Capital –
   a. How many people were in your lab overall?
   b. How many people were on the project (in FTEs)?
   c. How many PhDs?
   d. How many academic collaborators
   e. How many industry collaborators

(b) Lab Assets

a. What equipment do you have?

b. What equipment do you have access to elsewhere in your university?

What were the required deliverables as noted in the funding or grant application?

Have you generated IP yet? If so to whom does it belong? Has it been licensed? If not, is it going to generate IP?

Have you formed a start-up company to pursue the idea? Has anyone else?

So far, how have the scope of activities broken down - % split

a) Research

b) Developing technology

c) Technology demonstration/Clinical trials

Where do you hope to be eventually? (Within the lab, outside the lab but with your involvement, outside the lab in the hands of others)

a) Proof of concept

- in the lab/outside with your involvement/others outside

b) Complete device/process

- in the lab/outside with your involvement/others outside

c) Technology demonstrator/Clinical trials

- in the lab/outside with your involvement/others outside

When you describe "with your involvement" can you elaborate

- as company founder, as a consultant to a start-up, as consultant to a large company

What are your current-available and future-required skills and other assets inside your lab?

a. How big is your team and level of skills (Post Docs, PhD, MSc etc.) - # by skill

b. What are the skills that are required (Post Docs, PhD, MSc etc) # by skill, and in what fields (e.g. Physics, biology, materials science, marketing) – categories

c. What is the level of in-house facilities and what is required (High end, work horse?)

What external skills do you currently tap into for this project?

a) Collaborators – how many, what complementary skills that you can outsource
- With other academics

- With industry

b) Facilities from outside (do you do some experiments outside)

With collaborators

With contract research orgs

What are the barriers to achieving your objectives?

Time

a) Is present three years funding cycle enough?

b) What would you suggest?

Space

a) Do you have enough space to operate (what do you have now, labs, clean rooms, etc.)

b) Would you opt for a different space and environment (larger space, incubator, etc..)

Financing

a) Capital requirements – more grants?

b) Cash flow

c) Other funding

Human capital

Mentoring/Industry experience

As a principal investigator: Select entrepreneurial business model that you think would be suitable for your product to be carried to market. (Please share your thoughts)

IP licensing

a) How are you or would want to be involved?

Start up

a) Would you want to be part of ownership? How else would you want to be involved? How would you prefer your students to be involved?

Industrial Partner

a) Is this your preferred route to impact? If so why?

b) How easy is it for you to find partners?

c) What will they contribute to this project? (Money, skills, market knowledge….)

d) What terms and conditions would you prefer?

e) What makes this challenging?

Appendix 2

Interview with Professor Robert Langer, David H. Koch Institute Professor at MIT and one of the prolific inventors the world has ever seen at the Langer Lab, MIT.

Thembela Hillie (TH): What kind of scientist is required to do what you do?

Robert Langer (RL): It can be any kind of scientist; it is more of an attitude. It is more the type of person.

TH: What drives you?

RL: It is to make the difference in the world through creating products and technologies. That is what motivates me.

TH: What is the role of the institution?

RL: I do not think there is a single task that the university should do. Yes they should do research and teach but I also think if the university wants to do things beyond research that is a positive. I don't think it is a requirement but a positive. To foster that role the country needs laws, patent laws and incentives for people to invest. The university itself needs a good technology transfer program and it should provide some funds for places like the Deshpande Centre here at MIT as an example, and the 100k competition. The university should create some opportunities for these things to happen.

TH: What kind of environment is required?

RL: MIT is a good example of the environment. Stanford is too. I think it is an environment of doing science and doing research but also having business schools like Sloan, having entrepreneurship programs, and a community that spins out companies. The Boston area is a terrific example of what one can do. 34 years ago it looked like a slum. Now it has hundreds of companies. A concentration of people in an environment that fosters innovation helps. There are many aspects to it; there is the university, the investment community and the legal and patent community all working together trying to create innovation.

TH: When is the right time to start involving other expertise and capabilities in your particular research?

RL: It varies with the area. In medicine, you should have done quite a bit of initial work before starting a company. You want to prove your concept in animals, you want to have a scientific paper published if not several, and you want to have real good patents. These are some of the things you want to do. You should be fairly far advanced.

TH: On funding, how do you secure funding for all the required phases?

RL: The government and the investment community can help. The government needs to feel that it is an important thing. We have been fortunate to have NIH and NSF help. I also think they have to create laws that bring incentives to the investors to make investments. For example, capital gains, if you do an investment you get taxed less. There could be other breaks to incentivize people to want to invest.

TH: What is your opinion on the developing countries looking at the opportunities to use emerging technologies for development?

RL: I think that is key. I think it is very important for them to do that. For a lot of good reasons I think it is good for the country itself and good for the countries economics. It is the good thing to do.

TH: Prof thank you very much for your time, it is highly appreciated.

RL: Sure my pleasure. If you need anything let me know.