The Essentials of
Science, Technology and Innovation Policy

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For Colleagues and Smart Partners Who are Committed to Improving Technology Management Practices

TUN DR MAHATHIR MOHAMAD

MESSAGE

When on 28 February 1991, I presented the paper *Malaysia: The Way Forward* to the then Malaysian Business Council, I suggested the idea that Malaysia should be a developed nation by the year 2020. That was later acclaimed as Vision 2020. To become a developed nation in our own mould by 2020, I had spelled out nine challenges[1] to be overcome. Two of these have relevance to this book—The Essentials of STI Policy.

Challenge No. 6: …*establishing a scientific and progressive society, a society that is innovative and forward looking, one that is not only a consumer of technology but also a contributor to the scientific and technological civilization of the future.* This is what Tan Sri Omar has called Policy for STI.

Challenge No. 9: …*establishing a prosperous society, with an economy that is fully competitive, dynamic, robust and resilient.* I know fully well that this is not possible without a strong STI capability. This is what I believe Tan Sri Omar referred to as STI for Policy.

Tan Sri Omar has emphasized STI for Policy as a compelling reason for Government to devote time and resources to establishing a Policy for STI. I believe this is a valid argument. In my time I have myself devoted much effort in strengthening the STI infrastructure and resources in the conviction that STI is a driver for economic growth. I must have, I suspect, caused some discomfort to some of my scientific personnel for being hands-on in pursuing some projects related to STI.

The crucial role of STI in economic growth is abundantly demonstrated by Malaysia's neighbours to the east—Japan and South Korea. Japan in its time, and even now, is an economic giant and South Korea is in economic ascendency. But both countries have little by way of natural resources. They have however promoted, developed, nurtured and strengthened their human resource, infrastructure, funding and management of STI so that it now is the driver of their economies. This fact should not be lost on the leaders of all developing countries. Attention to STI policy matters in national development planning must be championed from the very top. By pointing out the key elements that require attention, The Essentials of STI Policy will help make easier the task of championing this factor in development.

DR MAHATHIR MOHAMAD
15 February 2013

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FOREWORD

The Academy of Sciences Malaysia (ASM) and Malaysian Industry-Government Group for High Technology (MIGHT) have been waiting for a long time for Tan Sri Omar, our founding President and Senior Fellow, and founding Joint Chairman, respectively, to put down on paper his thoughts on STI policy and related matters, based on his long experience as Science Adviser to our fourth Prime Minister, Tun Dr Mahathir Mohamad. This book on the Essentials of STI Policy is what the doctor ordered. It is not a chronicle of his time as Science Adviser (although that would have been interesting reading in itself!) but rather a distillation of the issues that must be considered in the formulation of a National STI Policy.

An important factor in moving the national STI agenda is the presence of a strong champion. We have been fortunate in Malaysia in having Tun Dr Mahathir as the supreme champion for STI. Many institutions and processes were put in place when Tun Dr Mahathir was Prime Minister of Malaysia. The momentum that has been built must not be lost. Unless STI continues to be emphasized in national development planning and bold steps taken to strengthen it, we may not achieve the targets we have set for ourselves in our agenda for national development.

In this context the strengthening of the STI governance system is critical. Tan Sri Omar has given an example how this might be organized. To move the STI agenda, apart from the need for a supreme champion, the governance structure for STI must ensure appropriate authority across all sectors of government. This is because STI cuts across all government ministries and this in turn, must link effectively with the private sector. Fragmentation of policy bodies for the different components of the STI landscape must be urgently addressed, consolidated and harmonized.

The Essentials of STI Policy is a valuable addition to the literature on STI I believe it will prove to be a useful practical guide to the formulation of STI policy, particularly for countries in the developing world. Of course, it must be customized to suit local context but the key elements which are clearly spelt out in this book must be given serious consideration and incorporated into the STI Policy.

TAN SRI DR AHMAD TAJUDDIN ALI
President, Academy of Sciences Malaysia
and
Joint-Chairman, Malaysian Industry-Government Group for High Technology

FOREWORD

The Commonwealth Partnership for Technology Management (CTPM) colleagues in the Smart Partnership Movement and myself are very proud and honoured to be part of the unique evolution of the STI Policy framework in Malaysia, since the late 1980s, under the guidance of Tun Dr Mahathir Mohamad as Prime Minister and in the implementation of which, our Chairman Tan Sri Omar, as his Science Adviser, was very much involved.

The wisdom accumulated over more than 16 years through sharing the evolution of Malaysia's STI policy framework is synthesized in a unique way by Tan Sri Omar in this book – the Essentials of STI Policy. For the CPTM members and Smart Partners, this book is especially significant because it is derived from his real-time experience in the Office of the Science Adviser, Prime Minister's Department, Malaysia, and therefore it has the highest degree of authenticity as well as authority, legitimacy and credibility.

Malaysia witnessed rapid development under the leadership of Tun Dr Mahathir who is acclaimed as "the Father of Industrialisation" and champion of STI, his effort complementing the emphasis in agricultural development of his predecessors. The country's technology management principles and practice framework described in the book revealed the many STI initiatives introduced during his premiership with Tan Sri Omar as his Science Adviser. Most of the STI initiatives were implemented through collaboration among Malaysian government agencies, businesses and professionals, as well as with non-Malaysian partners. This collaboration was based on a new networking approach referred to as Smart Partnership, which became the main ethos and practice of CPTM members in the Commonwealth and beyond. In this book, Tan Sri Omar has emphasized Smart Partnership as the preferred mode of implementing STI policy initiatives.

In my view, technology could be looked at as having three meanings: technology as a means to fulfill a human purpose, technology as assemblage of practices

and components and technology as the entire collection of devices and engineering practices available in a given context. Therefore, Tan Sri Omar's Technology Management framework is based on "technology inclusiveness", which refers to policy frameworks and approaches for using innovation to foster "inclusive growth", not only strong growth, but "resilient growth", "smart growth". This approach requires synchronization through dialogues, joined up thinking and action, towards a common Vision, with measures to support new entrants with riskier projects in advanced materials (such as composites), nanotechnology, information and communication technologies, high performance computers, synthetic biology and virtual manufacturing.

Since 1995, CPTM became the platform for Tan Sri Omar to put forward his ideas and the CPTM's members provided him a sounding board. This was possible because CPTM members themselves had their own hands-on experience in STI policy matters and their implementation. This interaction has been mutually enriching, sustainable and very smart. This book is therefore rich in practical pointers for STI policy formulation and implementation. CPTM thanks Tan Sri Omar for putting in a nutshell the Essentials of STI Policy for the benefit of its members in the Commonwealth and beyond.

On Behalf of CPTM Smart Partners Colleagues

DATUK DR MIHAELA Y. SMITH
CPTM Chief Executive and Joint Dialogue Convener, Smart Partnership Movement

ISTIC

FOREWORD

Tan Sri Omar and I started the journey together to establish the Academy of Sciences Malaysia (ASM) in 1991. When ASM was officially established under the Academy of Sciences Malaysia Act in 1995, He was founding President and I was founding Secretary-General. Together we nurtured ASM holding firm to ASM's mission statement "the pursuit, encouragement and enhancement of excellence in the field of science, engineering and technology for the development of the nation and the benefit of mankind". With his vast expertise and experience in the formulation and implementation of science and technology policy in Malaysia, it was not surprising that ASM's primary focus was "Science Advice to Government".

When the International Science, Technology and Innovation Centre for South-South Cooperation under the Auspices of UNESCO (ISTIC) was launched in Kuala Lumpur on 22 May 2008, Tan Sri Omar, then the President of the Malaysian University of Science and Technology (MUST), immediately offered to anchor the Science, Technology and Innovation (STI) Policy Agenda of ISTIC. ISTIC subsequently established the STIP Unit under Tan Sri Omar to offer advice and guidance to policy makers from G77 countries. It was ISTIC's ambition that the STIP Unit would be able to offer practical assistance to UNESCO in the formulation of national STI policies for UNESCO member states. This has not come to pass. Nevertheless, on behalf of ISTIC, Tan Sri Omar did travel to Mongolia and Sudan to participate in workshops to review their national STI policies formulated by UNESCO.

The annual ISTIC STI Policy workshops for high level STI policy makers in Kuala Lumpur under Tan Sri Omar have been very popular for participants from G77 countries. The participants have found the Malaysian STI policy template, which is also that of Tan Sri Omar, very focused and doable. In sharing Malaysian STI policy experience with them, we open it for examination, warts and all. We have also in these workshops examined national STI policy implications for industry, whose engagement has often been neglected and which Tan Sri Omar has persistently championed. The most innovative aspect has been the grouping of participants to analyse and provide STI policy advice to particular developing countries during the workshops. ISTIC has promised these enthusiastic STI "consultants" that ISTIC will organize "consultancy" missions for them to designated developing countries under Tan Sri Omar.

I was fortunate to have been appointed by then UN Secretary-General Kofi Annan as Co-Chair of the UN Millennium Project "Science, Technology and Innovation" Task Force under Professor Jeffrey Sachs, his Special Advisor for the Millennium Development Goals (MDG). In the STI Task Force Report "Innovation: Applying Knowledge in Development", the Science Advice and Science Governance recommendations were based on the work of Tan Sri Omar during his tenure as Science Advisor to Malaysian Prime Minister Tun Dr Mahathir Mohamad. I am pleased to see the UN Millennium Project STI Task Force Report in the Bibliography.

ISTIC look forward to this book "The Essentials of Science, Technology and Innovation Policy" being the basic reference publication for all future ISTIC STI Policy training programmes.

Dato Ir. Lee Yee Cheong,
Chairman, ISTIC Governing Board.

PREFACE

This book started as The Five Templates of Science, Technology and Innovation Policy which I wrote as a contribution to my biography which is been written by Dr Ahmad Ibrahim, Chief Executive Officer of the Academy of Sciences Malaysia (ASM).

What prompted me to write The Essentials of Science, Technology and Innovation (STI) Policy, the longer version, was firstly because of the discussion and consultation in 2012 on Malaysia's Third STI Policy in which I was deeply involved. The more one deliberated on this topic the more one got the sense of déjà vu. Many of the ideas, concepts or proposals coming out of the deliberations have been discussed and argued about and even articulated in the earlier two science policies.

Secondly, the younger generation in Malaysia coming on the STI Policy scene is not aware of what had happened before and what had gone into previous policy documents. They are very much aware, however, of the writings of international experts on the subjects of science policy.

I am not claiming ownership of all the ideas presented in this book. Many have been picked up from public domain documents but have been dissected, expanded, modified and rearticulated and implemented after various interactions with colleagues both in Malaysia and abroad. These interactions included the Annual Scientific Conferences of The Islamic World Academy of Sciences, the Smart Partnership International Dialogues in Malaysia and Africa and Think-Tanking Sessions at the Commonwealth Partnership for Technology Management's (CPTM's) Smart Partnership Hub in London, as well as many seminars and workshops organized by the Academy of Sciences Malaysia, the Malaysian Industry-Government Group for High Technology (MIGHT) and the International Science, Technology and Innovation Centre (ISTIC), Kuala Lumpur.

The interaction with CPTM network members I consider as especially valuable. CPTM is an organization originating from the now defunct Commonwealth Science Council. It deals

with issues in STI for development in the emerging economies focusing on technology management best practice as an agent for change, and national vision as a starting point for action on socio-economic transformation. Many networking members of CPTM have hands-on experience in dealing with STI issues and strategies and their implementation.

I quote from Ahmad Ibrahim, "His experience (Omar's) in STI Policy in Malaysia was shared with colleagues in the Commonwealth through his work with CPTM and his active participations in the Smart Partnership International Dialogues which are co-organised by CPTM. Through the Dialogues which promote learning through sharing as well as through his involvement in other international organizations, Omar has been able to increase his grasp of the main requirement of STI Policy thus making him more effective in his work (as Science Advisor). This has resulted in continuing improvement of the STI infrastructure in Malaysia and more learning and sharing with colleagues in the CPTM network".

Both Malaysian and other countries' examples are used to illustrate the various components and elements of the STI policy described in the book.

I hope this book is useful as a practical guide to writing an STI Policy embodying the essential elements without the trimmings of lengthy academic analysis and argument which can be added if required, according to the flavour of the month. The "Essentials of STI Policy" is also aimed at emphasizing the role of STI as a major enabler of national development, and therefore the importance of STI policy as an integral part of national development policy, so as to be meaningful to development policy makers rather than just preaching to the converted, namely the scientific community.

ACKNOWLEDGEMENTS

I owe a debt of gratitude to Dr Ahmad Ibrahim of ASM who persuaded me to put my thoughts on STI Policy and related matters on paper for my Biography he is writing entitled *"From Science to Science Policy—One Man's Passionate Journey"*. The "Five Templates of STI Policy" for the Biography is expended into this book.

Valuable comments to the draft of the manuscript were received from The Hon Prof Heneri Dzinotyiweyi, Minister of Science and Technology of Zimbabwe; Dr Mustafa El Tayeb, President, Future University, Khartoum, Sudan, formerly Director, Science Policy and Sustainable Development, UNESCO, Paris; Datuk Dr Mihaela Y Smith, Chief Executive of CPTM Ltd; Mrs Catharine M. Cunningham, CPTM Companion, former member, Office of the Government Chief Science Adviser, Cabinet Office, London; Dr Ashok Jain, CPTM Companion, formerly Director of NISTADS, New Delhi, India; Dr Hassan Mshinda, Director General, Tanzanian Commission for Science and Technology, Dar es Salaam, Tanzania; and Prof Yong Hoi Sen, Senior Fellow, Academy of Sciences Malaysia. Adznir Mokhtar of Prima Consulting helped with the figures and the updates of the Technology Management Best Practice Checklist for Malaysia in Annex 1.

I thank Muhammad Fardy Md Ibrahim, Norhafiza Awang Idris, Nur Shafawaty Ahmad and Asmah Amat of the Academy of Sciences Malaysia for assistance with the manuscript.

Last but least my thanks to Tun Dr Mahathir Mohamad, Malaysia's Fourth Prime Minister. It was while working as Science Adviser in the Prime Minister's Department from July 1984 to January 2001 that I had to learn quickly what I could about STI policy and related matters in order to discharge my duties. Tun Mahathir's open mindedness and preparedness to listen made the work of the Science Adviser both challenging and fulfilling.

INTRODUCTION

A policy is a declaration of intent with legitimate justification. To be relevant an **STI Policy** cannot be a stand-alone policy. It must be an integral part, or at least in support of, the national development policy. It provides the basis for informed decision in managing an important instrument of **Socio-economic transformation**, the current idiom for the objective of national development.

There are four **critical groups of technologies** essential for socio-economic transformation:

1. Technologies for meeting basic needs such as food, water and shelter;

2. Technologies for quality of life, e.g. education, healthcare, stabilization of population size, environmental sustainability;

3. Technologies for wealth creation in support of economic growth and competitiveness; and

4. Technologies for good governance in both public and private sector.

Within the four technology groups, the needs of each nation varies according to its stage of development. These needs once identified become the **National STI Agenda**. Its is important to realise that the needs may change as circumstances change. Therefore the STI Agenda must be periodically reviewed.

Technology however cannot be considered in isolation. It is now accepted to be part of a system consisting of science, technology and innovation. The national STI agenda, which the STI policy must identify and deliver, is therefore the sum total of the sciences, technologies and innovations required to achieve socio-economic transformation. Because of this STI policy consideration now embraces the whole system.

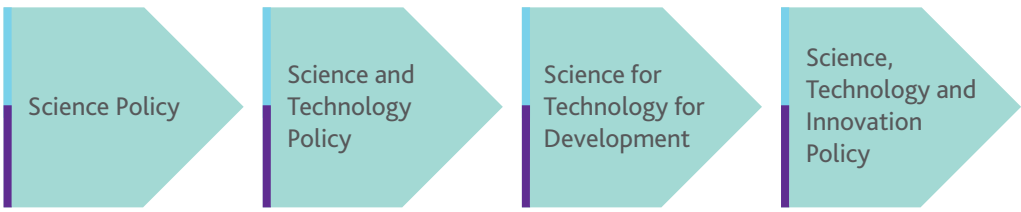

Figure 1. The evolution of science policies.

It has not always been this inclusive. The evolution of STI policy can be briefly traced thus: Initially it was just a 'science policy' emphasizing the need to do 'good science'. Then it was a Science and Technology (S&T) policy, linking knowledge (science) to its application (technology). Much later there was a move for a policy for "science for technology for development" focusing on harnessing S&T for national development. This gave rise to the concept of science for development (role of S&T in achieving development objectives) and development for science (measures to strengthen the S&T capacity).

Currently it is "science, technology and innovation (STI)" policy, implying that doing good science is not good enough. Science must translate into innovative technologies in the marketplace. In other words, STI must be an instrument of the economic transformation programme (ETP) and part of the economic system and therefore STI for Policy, and in turn STI must be strengthened so it can deliver the goods, hence a Policy for STI *(Figure 1)*.

Underpinning the STI for Policy and Policy for STI are two important parallel systems namely, the **research, development and commercialization (RD&C)** system and the **science, technology and innovation (STI)** system. RD&C was at one time referred to as research, development and engineering (RD&E). Research gives knowledge (science) and development results in technology which becomes innovation when commercialized or in anyway usefully utilized *(Figure 2)*.

Actually, central to the RD&C system is **invention** which is the result of systematic R&D or trial and error tinkering. Invention becomes **innovation** when applied or commercialized.

The story of the slow acceptance in Europe of the concept of STI and of its role in the economy and national

development is well documented (King 2006). Science was at one time considered only as part of social or education policy. Of course the situation has now completely changed. Even in education, universities are now deeply involved in STI and RD&C. The so-called third generation universities are distinguished by excellence in STI and RD&C (Wissema 2009).

STI Policy formulation must therefore be inclusive of the STI and RD&C systems and provide for the total eco-system to deliver the **National STI agenda**. Once this is done a number of sectoral policies may be formulated such as for innovation, commercialization or research funding.

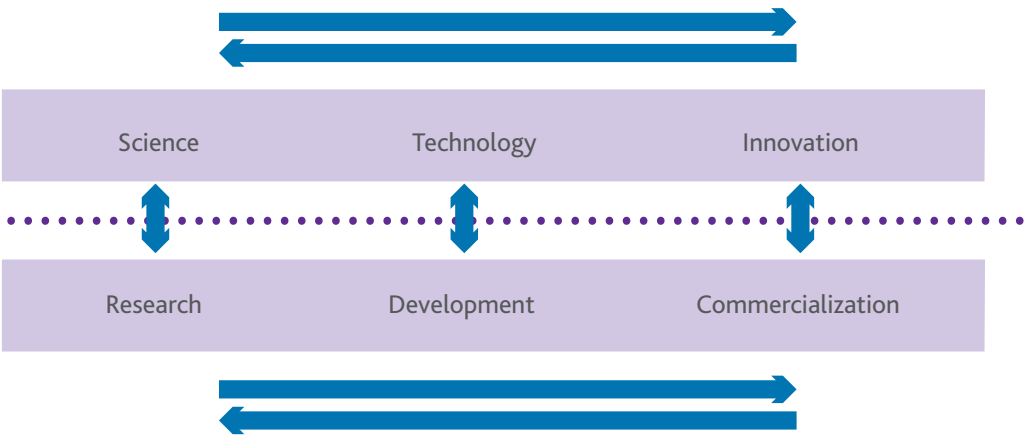

Figure 2. The STI and RD&C parallel systems.

PART 01

THE FIVE TEMPLATES OF STI POLICY

Template 1 The six components of STI policy

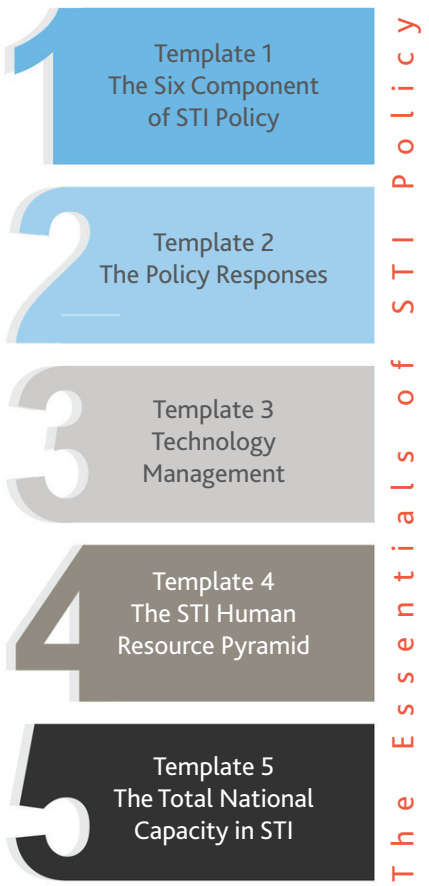

Figure 3. The five templates of STI Policy.

There are various ways of articulating an STI policy. It can be very academic and analytical in approach or concise and practical leading to a set of clear implementation strategies. However an STI policy which is an integral part, or supportive of, a national socio-economic transformation programme, must deal with the six basic components. These are **STI for Policy, Policy for STI, STI and the Private Sector, STI and the Community, International Collaboration in STI, and STI and Governance.**

STI for policy

STI for policy is the most important component and must be customized to the needs of a country's STI agenda in support of its current socio-economic transformation programme and its anticipated future needs for continued **growth and competitiveness** in the global marketplace. STI for policy must therefore deal with the national need in the context of the four major

groups of critical technologies, namely technologies for basic needs, for quality of life, for wealth creation and economic competiveness, and for good governance. The aspiration of a national transformation programme can be more ambitious but realistic when STI components are factored into the formulation process.

Policy for STI

In order to deliver the support for a nation's socio-economic transformation programme, the nation's **STI capacity and capability** must be strengthened in terms of institutions, mandates, personnel, management, funding and linkages. Measures to strengthen education and research for capacity building in the sciences relevant to the needs of policy and for public good (e.g. water, energy, biodiversity) as well as matters related to ethical issues must be part of the policy for STI.

STI and the private sector

Success in the implementation of a government economic transformation programme much depends on full commitment and participation of the private sector.

A strategy to get **private sector buy-in** is therefore crucial and will vary from country to country depending on existing public-private sector partnership framework. In situation where the private sector is innovation-recalcitrant the strategy to get buy-in must include presentation (of government's strategic direction and policy objectives), persuasion, incentivisation, legislation, active cooperation and collaboration with government entities.

STI and the community

A supportive and **science literate** community is part of the total STI ecosystem. The policy must therefore deal with issues of science enculturization which includes an appreciation of the **scientific method**. The scientific method is a logical, systematic evidence-based approach to understanding issues and solving problems in general and not just in science. An education system that includes 'science for all' and promotes **creativity, innovativeness and entrepreneurship**, i.e. a holistic human capital development must be considered. In some countries policy statement against gender discrimination in education and employment may be necessary.

International collaboration in STI

Moving the National STI agenda requires not only a close cooperation among all national stakeholders but also with **international collaborators**. There is also increasing needs for **science diplomacy** as international relation and cross border issues are becoming more complex. This is where an effective framework and mechanism of partnering is required.

STI and governance

There are two components to this namely, **Governance for STI** and **STI for Governance**. Since STI cuts across many government ministries and must

be linked to industries, consultation, coordination, collaboration and harmonization become both important and difficult. Hence, the overall governance for STI must be enhanced. Existing STI institutions and agencies must be periodically reviewed in terms of their legitimacy, authority, mandate and capacity including linkages. An inter-ministry agency must be put in place to coordinate and oversee implementation. Parliament should be a platform for debate on STI issues affecting the government, industry and the public. A **parliamentary standing committee on STI** should be established where none exists. Mechanism for international collaboration must be in place.

In some countries legislations are in place in order to strengthen the governance for STI and commit authorities to implementation strategies and programmes. In South Korea for example, some 90 laws are in force for S&T development and promotion. Some of these are listed in *Table 1*.

Similar legislations may be necessary in many countries.

Additionally, both public governance and corporate governance require enhanced technology application for increased efficiency. This is STI for Governance.

Table 1. SOME MAJOR STI LAWS — SOUTH KOREA

1. National Science and Technology Promotion Law (Law No. 1864, 1964)
2. Industrial Technology Development and Promotion Law (Law No. 2399, 1972)
3. Promotion of Engineering Services Law (Law No. 2474, 1973)
4. Promotion of Basic Scientific Research Law (Law No. 4196, 1987)
5. Special Law of Science, Technology and Innovation (Law No. 5340, 1997)
6. Dual-Use Technology Programme Facilitation Law (Law No. 5535, 1998)
7. Science and Technology Framework Law, (Law No. 6353, 2001), replacing No. 1 and No. 5 above.

Template 2 The Policy Responses

Policy responses refer to the identification of **strategic thrusts** and the formulation of **action plans** to address issues or areas of concern or to strengthen existing initiatives or overcome bottlenecks. They must be based on national issues or needs in the context of the six components of Template 1. These needs must cover those existing, those perceived and those anticipated which are to be translated into "where we are now, where do we want to go, and how do we get there" strategies and road maps. As examples the following 22 groups of policy responses may be considered:

STI for policy

1. Identification of the STI agenda to support socio-economic transformation and strengthening the capacity for RD&C in the critical technology areas of the STI agenda.
2. Enhancement of capacity for technology prospecting and technology foresight.
3. Enhancement of the support for entrepreneurship and enterprise development.
4. Enhancement of the innovation delivery process including establishment of an innovation exchange.
5. Innovative financing mechanism for commercialization of innovative technologies.
6. Strengthening public-private sector partnership.

Policy for STI

7. Enhancement of the system of science education and STI human capital development.
8. Intensifying capacity for knowledge and technology generation, acquisition and dissemination - infrastructure, people and funds.
9. Strengthening capacity building in key areas of science to support the targeted critical technologies of the STI agenda.
10. Strengthening public sector R&D capacity — priority setting, funding, management, implementation monitoring and evaluation.
11. Promotion of science ethics and smart partnership ethos and practices.

STI and the private sector

12. Mechanism to secure private sector participation and commitment to the national STI agenda.
13. Mechanism to encourage, promote and incentivize private sector involvement in RD&C and uptake of innovation.

STI and the community

14. Promotion of science literacy and the understanding of the scientific method.
15. Creation of a culture of creativity, innovativeness and entrepreneurship.
16. Promotion of a national mass (inclusive) innovation movement.

International collaboration in STI

17. Framework and mechanism for international collaboration in STI.
18. Framework for cooperation and compromise on international and cross-border issues — Science Diplomacy.

STI and governance

19. Enhancing the STI advisory system and consolidating and harmonizing the STI policy and development planning and implementation oversight mechanism.

20. Strengthening the STI implementation coordination, monitoring and evaluating structure.

21. Enacting legislation to ensure commitment to STI Policy decisions and implementation strategies and to involve Parliament in debate on STI issues of national importance.

22. Enhancing technology application in both public and corporate governance.

These policy responses must be country specific and may be more or less than the 22 examples above. Policy responses must result in policy instruments, i.e. strategies and action plans.

Template 3 Technology Management Best Practice Framework

Technology Management (TM) as defined by CPTM in 1997 is "The mechanism, processes and infrastructure needed to foster, promote, manage and sustain the development of scientific knowledge and technological innovation and related skills and expertise for the attainment and sustainability of the overall national development objectives".

Components of Technology Management Framework

Ten components that make up the Technology Management (TM) Framework as defined above, based on the experience of Malaysia, are identified as follows:

1. Political commitment;
2. Policy integration;
3. STI Advisory system;
4. STI Policy Development Planning, Implementation, Coordination, Monitoring and Evaluation;
5. Infrastructure for STI Development, Acquisition and Dissemination;
6. Funding & Management of R&D;
7. Mechanism for commercialization of Research and Technology;
8. Integrated Human Resource Development;
9. Mechanism for S&T Enculturisation; and
10. Smart Partnership and Science Ethics Principles and Practices.

It is important that political commitment is articulated and manifested.

Articulation of commitment to STI can be done in many ways, for example in national development plans. In some countries it is done through election manifestos of political parties. The most common however is in the articulation of **national visions**.

In the case of **Malaysia's Vision 2020,** two of the nine challenges to achieving its objectives of becoming a developed nation by 2020, namely challenge no. 6 and no. 9, refer to STI capacity *(Box 1)*. A number of countries in Africa, such as Botswana, Mozambique, Lesotho, Uganda, Zambia and Mauritius has a national vision.

All the national visions contain implicit or explicit reference to STI capacity, for example Botswana's Vision 2016 refers to 'a prosperous, productive and innovative nation'; Mozambique's Agenda 2025 refers to 'competitiveness and modernization of companies'; and Lesotho's Vision 2020 refers to 'economic growth, management of the environment and advancement of technology'.

It must be emphasized that articulation of political commitment must be manifested and the other nine components in the above TM list are considered as manifestations of the political commitment, to which may be added as part of policy integration, an enhanced STI Governance system. They therefore can be used as a **Technology Management Best Practice Checklist** for a country's current STI

BOX 1. THE NINE CHALLENGES OF MALAYSIA'S VISION 2020

1. Establishing a united Malaysian nation with a sense of common and shared destiny. This must be a nation at peace with itself, territorially and ethnically integrated, living in harmony and full and fair partnership, made up of one 'Bangsa Malaysia' with political loyalty and dedication to the nation.

2. Creating a psychologically liberated, secure and developed Malaysian Society with faith and confidence in itself, justifiably proud of what it is, of what it has accomplished, robust enough to face all manner of adversity. This Malaysian Society must be distinguished by the pursuit of excellence, fully aware of all its potentials, psychologically subservient to none, and respected by the peoples of other nations.

3. Fostering and developing a mature democratic society, practising a form of mature consensual, community-oriented Malaysian democracy that can be a model for many developing countries.

4. Establishing a fully moral and ethical society, whose citizens are strong in religious and spiritual values and imbued with the highest of ethical standards.

5. Establishing a matured liberal and tolerant society in which Malaysians of all colours and creeds are free to practice and profess their customs, cultures and religious beliefs and yet feeling that they belong to one nation.

6. ***Establishing a scientific and progressive society, a society that is innovative and forward-looking, one that is not only a consumer of technology but also a contributor to the scientific and technological civilisation of the future.***

7. Establishing a fully caring society and a caring culture, a social system in which society will come before self, in which the welfare of the people will revolve not around the state or the individual but around a strong and resilient family system.

8. Ensuring an economically just society. This is a society in which there is a fair and equitable distribution of the wealth of the nation, in which there is full partnership in economic progress. Such as society cannot be in place so long as there is the identification of race with economic function, and the identification of economic backwardness with race.

9. ***Establishing a prosperous society, with an economy that is fully competitive, dynamic, robust and resilient.***

(From Mahathir Mohamed 1991)

status, assessing weaknesses needing enhancement and gaps requiring new initiatives. The checklist requires regular review to ensure that the components are relevant and competent from the perspective of legitimacy, authority and capacity. Smart partnership (see Part V) is the preferred framework for cooperation/collaboration at both national and international level, while ethical principles and practices must be incalcated into the education system.

The Technology Management Best Practice Checklist for Malaysia

The complete TM Best Practice Checklist for Malaysia is appended in Annex 1 as an example. Some salient features of the checklist are briefly described below in two parts: before Independence — pre-1957 and after Independence — post-1957.

Pre-1957

What might be considered a research tradition started in Malaysia during the colonial era with the establishment of the Dunlop Research Station in 1910 and the Chemara Research Station in 1921, both by the private sector in the rubber plantation sector. At Independence in 1957, there were in the public sector the following research entities: Institute for Medical Research (IMR), established in 1901; Forest Research Institute (FRI), 1929; Rubber Research Institute (RRI), 1925; and Veterinary Research Institute (VRI); 1948. In addition there were the Mines Research Institute (MRI); and the Department of Geological Survey. In agriculture there were experimental stations (AES) in various locations in the country.

While the IMR and the VRI were originally diagnostic laboratories and the FRI and Geological Survey were for natural resource inventorying, the RRI, the MRI and the AES may be considered as the beginning of an STI tradition. These entities dealt with the sciences and technologies associated with their commodities as well as finding new ways (innovations) to improve production respectively for rubber, tin and agricultural produce especially rice.

Post-1957

The articulation of a political commitment and an overall policy for STI, however, was not made until many years after Independence. Before the articulation of Vision 2020 and its nine challenges *(Box 1)* in 1991 there was the Rukun Negara, proclaimed in August 1970, thirteen years after Independence. One of the five pillars of the Rukun Negara states: " ..... building a progressive society by harnessing modern science and technology" *(Box 2)*. In the New Economic Model announced in 2010 *(Box 3)*, there were many inferences to the need for increased STI capacity.

Despite the articulation of commitment, manifestation of that commitment by way of policy integration did not happen until the formulation of the Fifth Malaysia Plan covering the period 1986–1990. At that time STI components became part of the overall national development plan and with resource allocation provided. Since then policy integration became a norm in both long term perspective as well as the five-

BOX 2. *RUKUN NEGARA* — MALAYSIA'S NATIONAL PILLARS AND PRINCIPLES

Our Nation Malaysia is dedicated to:

- Achieving a greater unity of her people
- Maintaining a democratic way of life
- Creating a just society with equitable distribution of wealth
- Ensuring a liberal approach to her rich and diverse cultural traditions.
- **Building a progressive society by harnessing modern science and technology**

We Malaysians as one, pledge to strive to attain these goals guided by the following principles:

- Belief in God
- Loyalty to King and Country
- Supremacy of the Constitution
- The Rule of Law
- Ethical Behavior and Morallity

Source: Proclamation, Independence Day, 31 December 1970.

BOX 3. MALAYSIA's NEW ECONOMIC MODEL — ECONOMIC TRANSFORMATION PROGRAMME — THE EIGHT STRATEGIC REFORM INITIATIVES (SRI)

SRI 1 — Re-engineering the Private Sector

- Target high value added products and services
- Remove barriers and cost of doing business
- **Create eco-system for entrepreneurship and innovation**
- Encourage efficiency through healthy competition
- Promote SME growth
- Create regional champions

SRI 2 — Developing Quality Workforce an Reducing Dependency on Foreign Labour

- Increase local talent over time (education system for creative and critical thinking)
- Re-skill the existing labor force
- Retain and access global talent
- Remove labour market distortions constraining wage growth
- Reduce reliance on foreign labour

SRI 3 — Creating A Competitive Domestic Economy

- **Improve economic efficiency through competition**
- **Build Entrepreneurship**
- **Revamp seed and venture capital fund to support budding entrepreneurs**
- Remove market distortions leading to misallocation of resources

SRI 4 — Strengthening The Public Sector

- Improve decision making process
- Improve service delivery
- Reduce "friction costs"
- Provide a safety net to facilitate a smooth transition
- Strengthen public finance management

SRI 5 — Transparent and Market-Friendly Affirmative Action

- Reduce income disparity
- Create market-friendly affirmative action
- Narrow regional difference
- Encourage rewards on the basis of performance
- Promote equal and fair access to opportunities

SRI 6 — Building the Knowledge-Based and Infrastructure

- **Create an ecosystem for entrepreneurship**
- **Promote an environment of innovation**
- **Establishing stronger enabling institutions**

SRI 7 — Enhancing the Source of Growth

- Create value from first movers and other comparative advantage
- Develop greater integration between products
- Create new markets
- Build scale of industries and production networks for specialization
- **Harness innovation potential**
- Integrate real sector industries with financial services

SRI 8 — Enhancing Sustainability of Growth

- Preserve natural resources
- Leverage on comparative advantages for high value added products and services
- Meet international commitments
- **Facilitate bank lending and financing for "green investment"**
- Ensure sound public finances

Source: National Economic Advisory Council-March 2010.

year development plans. The position of STI was further strengthened by the introduction of the first Science and Technology Policy in 1986 and the second in 2003.

That is not to say, however, that before the STI policy integration was articulated there were no development in the STI landscape. As indicated in Annex 1, a good number of institutions, infrastructure and processes were put in place, many of which were initiated by or during the time of Tun Dr Mahathir Mohamad, Malaysia's fourth Prime Minister.

The STI advisory system was strengthened with the creation in 1984 of the Office of the Science Adviser and the appointment of a Science Advisor in the Prime Minister's Department. The Malaysian Industry-Government Group for High Technology (MIGHT) and Academy of Sciences Malaysia (ASM) were established in 1993 and 1995 respectively and became important sources of advice from the business and scientific community respectively. There were also in existence a number of national advisory councils, e.g. the National Council for Scientific Research and Development (NCSRD, established in 1975) and Malaysian Aerospace Council (2001), as well as international advisory bodies such as the International Advisory Panel for the Multimedia Supercorridor Project (1997), the Biotechnology International Advisory Panel (2005) and the latest, the Global Science and Innovation Advisory Council (2010). The NCSRD was replaced by the National Science and Research Council in 2011.

A number of new research entities were established, notable among which were the Malaysian Agricultural Research and Development Institute (MARDI) in 1969, the Standard and Industrial Research Institute of Malaysia (SIRIM) in 1975, Fisheries Research Institute in 1949, the Palm Oil Research Institute (PORIM) in 1979, the Malaysian Institute of Microelectronics Systems (MIMOS) in 1985, the Forest Research Institute of Malaysia (FRIM) in 1985, the Malaysian Centre for Remote Sensing (MACRES) in1998 and the most recent one, the Agro-Biotechnology Institute of Malaysia in 2006. SIRIM was the amalgamation of two existing entities, namely the Standards Institute of Malaysia and the National Institute of Scientific and Industrial Research while FRIM was the reorganisation of the old FRI into a statutory organization.

In addition a number of 'technology development' centres was also created. These differ from the research institutes in that they focus on product development and manufacturing and were established as companies. These include Composites Technology (Research) Malaysia Sdn Bhd (CTRM), Astronautic Technology Sdn Bhd (ATSB), InnoBiologics Sdn Bhd and SYMMID Sdn Bhd, respectively for composites products, microsatellites, biotechnology products and microchips design.

Higher education which was the preserve of the public sector was liberalized. In 2013 there are 55 private sector universities and universities colleges, some being campuses of foreign universities. Public sector universities have increased to 20 from the earlier five: Universiti Malaya, established in 1959 in Kuala Lumpur; Universiti Sains Malaysia, 1969; Universiti Kebangsan Malaysia, 1970; Universiti Pertanian Malaysia,1971; and Universiti Teknologi Malaysia, 1975. There are also 27 polytechnics and a number of skills development centres.

In order to promote commercialisation and enterprise development, various types of grants are made available and a number of venture capital companies established (see *Box 8*). Business incubators such as Technology Park Malaysia, Kulim High-Tech Park and Cyberjaya were also established. The latest initiatives are the development of economic growth corridors. There are five of these in various parts of the country, namely, Iskandar Malaysia, Northern Corridor Economic Region, East Coast Economic Region, Sarawak Development Corridor and Sabah Development Corridor. They each have specific industry focus such as ICT and creative industry, halal food, marine fish culture and biofuel.

It is to be noted that effort is underway to review the legitimacy, authority and capacity of the older organizations in order to ensure relevance and capacity to deliver their mandates. This review should result in institutional strengthening and identification of gaps that must be filled.

Template 4 The STI Human Resource Pyramid

In order to move the STI agenda, a total complement of people is needed. This can be referred to as the STI human resource pyramid, comprising champions at the top, down to the practitioners and implementers at the base *(Figure 4)*.

Figure 4. Moving the STI Agenda — The STI Human Resource Pyramid.

The **champions** can be individuals or institutions. In developing countries a Supreme Champion — the Head of Government — may be needed to move the STI agenda, otherwise commitments to STI may remain only rhetorical.

The **advisors** can also be either individuals or institutions. If the Head of Government is a champion, he would certainly need a personal STI advisor. The champions and advisors have to be formalized into structured entities with their own mandates.

The **popularizers** are those responsible for STI information to the general public and are essential to the STI enculturisation process.

The **planner and manager groups** must include policy makers as well as monitoring and evaluating procedures.

The full responsibilities of all the above groups are described in the section on Strategies for Implementation.

The base of the pyramid comprises the **practitioners** who are the **implementers.** For the STI and the RD&C processes to work effectively, they must include in addition to scientists and technologists, entrepreneurs, business managers, financiers and a host of other players. They are individuals in government ministries and agencies and in private sector companies and organisations.

STI is too important to be left to scientists and technologists alone.

Template 5 The Total National Capacity in STI

When appropriate policy responses, checked against the 10 Technology Management best practice framework as well as the complete STI human resource are in place then a nation can be said to have a **Total National Capacity (TNC)** in STI.
The TNC comprises:

1. A government committed to providing a comprehensive STI physical and soft-infrastructure;
2. A scientific community, ethical and competent and able to contribute to and draw from the global pool of scientific knowledge and technological know-how;
3. A private sector capable of creating wealth through the application of technology and innovation in all sectors of the economy;
4. A society that is science literate, imbued with a culture of creativity, innovativeness and entrepreneurship, the application of the scientific method; and
5. An efficient governance system enabling effective policy making, planning, implementation and public debate and international collaborations that ensures long-term commitment to STI development.

Achieving the TNC would be the ultimate objective of an STI policy and it is only with TNC that a nation's STI agenda can be achieved and the economy can be innovation driven and private sector led. The STI governance system may need to be backed by legislation.

PART 02

HOLISTIC HUMAN CAPITAL DEVELOPMENT

It has been argued that while "an inflexible, top down, standardized curriculum maybe a good answer to the industrial economy's demand for punctual, literate, diligent workers capable of following rules and procedure", an innovation economy requires different characteristics in its workforce. This can only be produced with "education systems that are curiosity-led, create high level of self-motivation and promote collaboration between learners" (Leadbeater 2006).

Then there is the idea of the five types of 'minds' which are required for the future (Garder 2007). Three of these — disciplined, synthesizing and creative- relate to the individual's intellect, and two — respectful and ethical — relate to his or her character.

The Knowledge Worker for the Innovation Economy

Taking the above into consideration, it is proposed here that the workforce for the innovation economy which is the key factor underpinning the five templates described earlier is the **knowledge worker** with the following attributes (Omar 2006).

1. Ability to provide solutions, working alone or in a group;
2. Possession of a core competency and creativity, which is enhanced by mastery of ICT;
3. Being creative, innovative and entrepreneurial;
4. High motivation; adaptable and open to learning, including self-learning and re-learning and prepared to master new skills;
5. Being a risk taker and able to work boundryless and even borderless; and
6. Work ethics based on Smart Partnership values (respect, trust, tolerance and transparency) and science ethics (professional with social, environmental, moral and ethical obligations).

Components of Holistic Human Capital

Educating and training the knowledge worker so defined would require the holistic human capital (HHC)

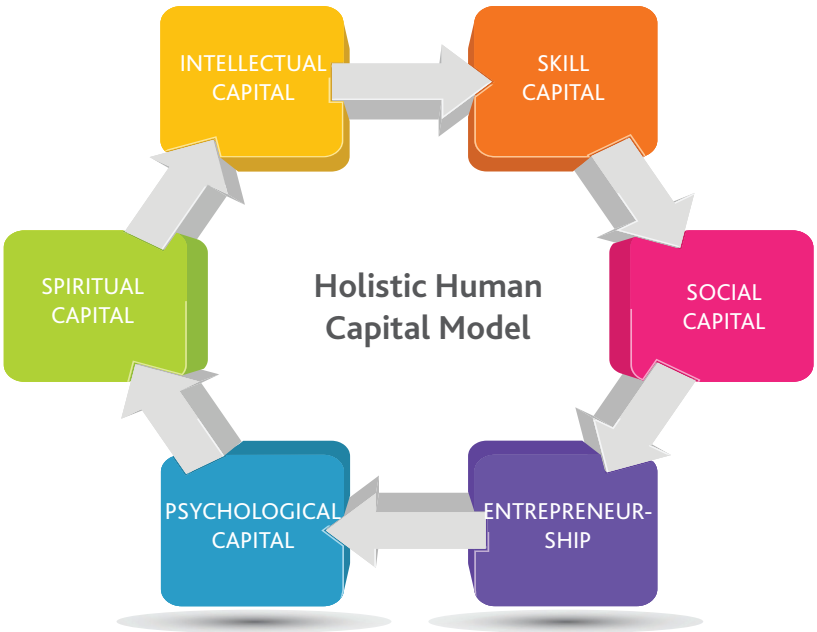

Figure 5. Components of Holistic Human Capital Model.

development approach which comprises six elements *(Figure 5)*:

1. **Intellectual Capital** — logical and strategic thought processes nurtured through formal, non formal and informal education;
2. **Skills Capital** — codified and tacit knowledge; technical skills from training or acquired through experience;
3. **Social capital** — social skills (communication, cooperativeness, networking; ability to debate and negotiate);
4. **Entrepreneurial capital** — creativity, innovativeness and entrepreneurship;
5. **Psychological capital** — commitment, passion, dedication, confidence, belief in self; and
6. **Spiritual Capital** — Ethical values and principles, right and wrong, Smart Partnership ethos and practices.

Environment for Holistic Human Capital Development

To achieve HHC development, the process must begin in the home and carried through to the workplace with conducive environment in each *(Figure 6)*.

Implementing HHC development programme would require Smart Partnership among a number of government ministries. This will enable harmonization of concept, curriculum development and implementation.

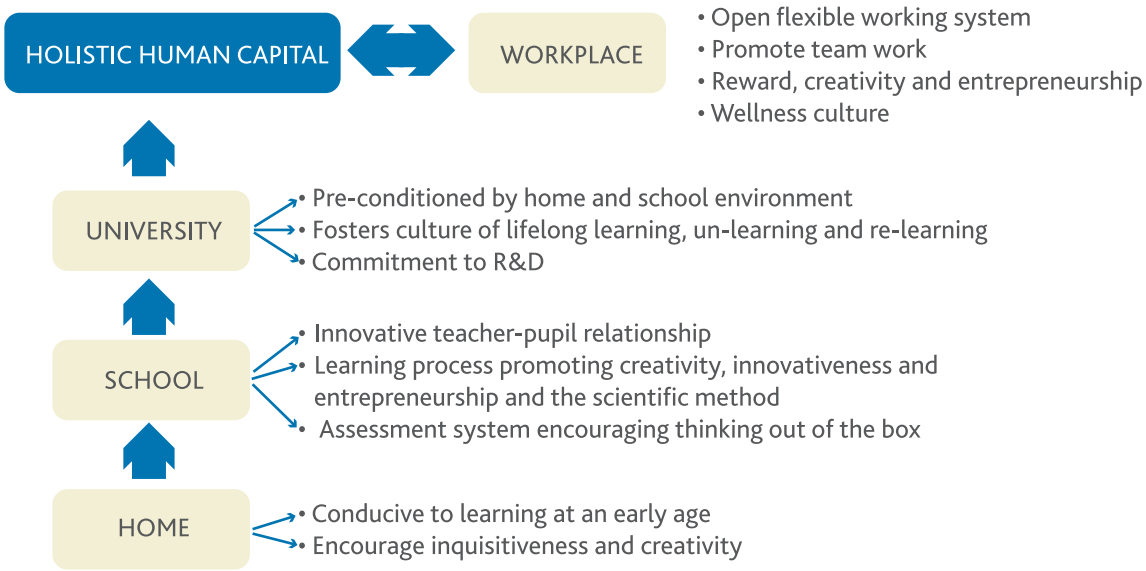

Figure 6. Environment for Holistic Human Capital Development.

PART 03

STRATEGIES FOR IMPLEMENTATION

It is not unduly difficult to write an STI policy. Getting implementation started is quite a different matter. In this section, generic approaches to the implementation of some selected elements of the STI Policy are discussed.

STI for Policy

Economic growth is always a major topic of a national development policy or a national socio-economic transformation programme. And STI is always recognized as a major means of achieving it. Where the focused key economic sectors are identified in the national development plan or in the economic transformation programme, the starting point is clear. The STI for Policy will have to identify the key enabling technologies and their supporting sciences which are critical to ensure efficiency, productivity and competitiveness of the selected economic sectors.

In the case of Malaysia for example, the current national development policy is based on the **New Economic Model (NEM)** (NEAC, 2010) whose main objectives are high income, inclusiveness and sustainability, to be achieved within the time frame of Vision 2020 through an economic transformation programme. Eight **Strategic Reform Initiatives (SRI)** *(Box 3)* and the 12 **National Key Economic Areas (NKEA)** *(Box 4)* have

BOX 4. MALAYSIA'S NEW ECONOMIC MODEL — THE 12 NATIONAL KEY ECONOMIC AREAs (NKEAs)

- Oil, Gas and Energy
- Palm Oil
- Financial Services
- Tourism
- Business Services
- Electronics and Electrical
- Wholesale and Retail
- Education
- Healthcare
- Communications Content and Infrastructure
- Agriculture
- Greater Kuala Lumpur/Klang Valley

- NKEAs = Focus economic areas receiving government prioritized support: funding, top talent and PM's attention
- EPPs = Total 131 Entry Point Projects have been identified under NKEAs.

Source: National Economic Advisory Council 2010.

been identified under the economic transformation programme.

In addition there are 131 **Entry Point Projects (EPP)**. These are pledged, planned or already initiated new investments, foreign, local or joint venture, within the NKEAs.

It is interesting to note that the recurring key words from the SRIs relate to the weaknesses or inefficiency of both government and industry in creativity, entrepreneurship, knowledge base, technology, innovation and value addition. These are clear indications of the need for increasing the capacity in STI to support the ETP and take Malaysia out of the middle income trap.

Hence, the essential STI components to support the NKEAs and the EPPs must be identified.

STI components especially the technology for wealth creation and economic competitiveness must be factored in for viability, competitiveness and sustainability of the businesses in the long term. It is important not only to identify the technologies but also the supporting sciences critical to each of the EPPs and the R&D priorities to meet the needs or to solve existing and anticipated problems. Malaysia can take a leaf from the experience of its rubber and palm oil industries which remain strong and competitive with the support of their

R&D infrastructure and the resulting technological strength.

The Four Critical Questions
Where priority areas are not identified, an approach to the harnessing of STI for economic growth would be to ask the following four Critical Questions:

Question 1. Which economic sectors are now the mainstay of the national economy, and what STI inputs are needed to sustain and to grow?

Question 2. Which economic sectors are now most at risk (because they are 'forgotten' or considered "sunset"); and what STI inputs can save and revive them?

These two questions will lead to a host of other questions which will include:

1. Where in the value chain are the sectors concerned?
2. What is the current status of STI capacity in each sector? Does it require enhancement?
3. Where is the potential for more value add — downstream or upstream?
4. What new or emerging technologies can meet the current and anticipated needs of the sectors?

Answers to those questions will identify the critical technologies and will lead to priority areas in technology development, meaning R&D, or technology acquisition, meaning technology transfer. This is the choice of the classical **make-some, buy-some** strategy *(Figure 7)*. The effort would require the participation of both public and private sectors, hence the importance of the private sector buy-in for the national STI agenda.

The identification of the critical technologies in support of current and anticipated future needs of industry must be done through **technology prospecting** and **technology foresight**. In this context prospecting is searching, identifying and acquiring existing technology that meets the requirement. Foresight refers to search for emergent technologies. While prospecting is "down to earth", there is a tendency for foresight to be an academic exercise, unless it is done for immediate industry needs in the context of reviving, sustaining or enhancing an enterprise or an industry sector.

For the make-some strategy the identification of critical technologies must be followed by capacity building and research focus in the key scientific disciplines supporting them. This must be a priority for the Policy for STI.

The buy-some choice may be considered a short term strategy while the make-some, the long term. "Buy-some" must be supported by capacity to receive. The full capacity to receive — the complete **technology transfer** — has four stages, namely (A) Aquisitive, (B) Operative, (C) Adaptive, and (D) Innovative, with a total of 17 steps *(Table 2)*. The implementation strategy must be put in place up to the Adaptive Stage even if the complete technology transfer is not the plan.

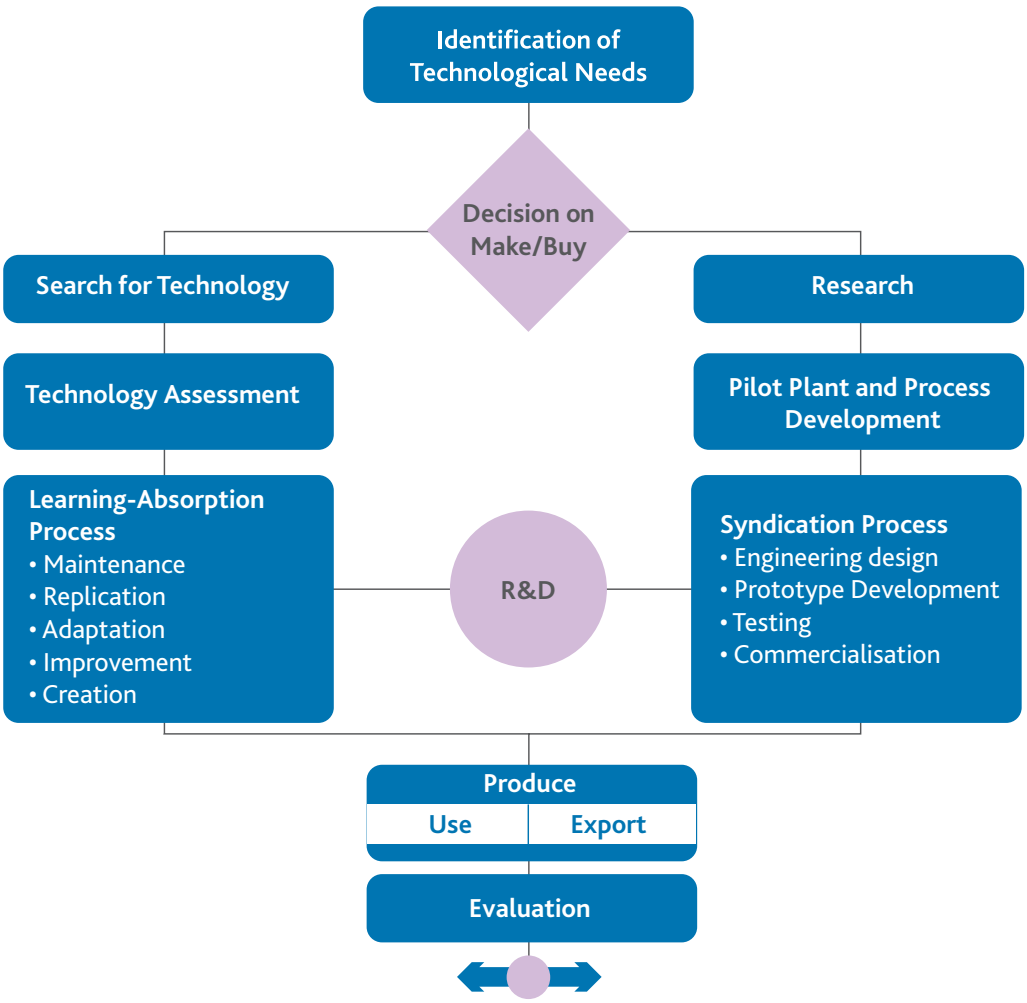

Figure 7. Schematic Reresentation of the Make-Some-and-Some Strategy.
Source: UNDP/APCTT-Technology Atlas Project, Volume 6.

TABLE 2. STAGES AND STEPS IN TECHNOLOGY TRANSFER.

A.	Acquisitive
	1. Search
	2. Assessment
	3. Negotiation
	4. Procurement
	5. Plan layout design
	6. Installation and start up
B.	Operative
	7. Process operation
	8. Maintenance
	9. Quality control
	10. Inventory control
C.	Adaptive
	11. Technology design & product imitation
	12. Minor product modification
	13. Minor process modification
D.	Innovative
	14. R&D or RD&E
	15. Radical product modification or new model design
	16. Radical process modification or new process design
	17. New invention.

Source: Kritayakirana 1989.

Question 3. Which economic sector has a big potential?

The big potential may be because of availability of raw material (agricultural or natural resource), special skill of the labour force, proximity to market, existing big demand in the domestic or international market or other factors.

An example from Malaysia in this category is composites products manufacturing. Tun Dr Mahathir, Malaysia's fourth Prime Minister, had recognized the potential of carbon composites as an industrial material and had observed that a lot of manual labour went into the manufacture of products from this material. Dr Mahathir, realizing the relative low cost of labour in Malaysia and the manual dexterity of her workforce asked his Science Advisor at that time, how could Malaysia enter this manufacturing sector. This led to the establishment of a company, Composites Technology (Research) Malaysia Sdn Bhd (CTRM), the acquisition of Eagle Aircraft Pty Ltd in Perth, Australia where Malaysian workers learn the skill of composite work. CTRM is now a major manufacturer of composites components for commercial aircraft. More than that, composites products manufacturing is now a sizeable industry in Malaysia. It is important to note that once a potential new sector is selected, the identification and development of the critical skills and STI capacity to support the sector must be initiated.

An interesting twist to the "big potential" approach is the case of South Korea where a major crisis was turned into a big opportunity. The country faced an energy crisis. In response, the government came up with a five-year development plan for green growth with the objectives of enhancing its energy security and at the same time promoting green technology as a new engine of economic growth. The Green Growths plan covering the

years 2009–2013 has an investment of USD83.6 bil or 2% of the nation's GDP.

Question 4. How does one deal with new technologies?

New technologies — biotechnology, information technology (IT), nanotechnology etc. — in the context of STI for Policy have to be treated differently from that of Policy for STI. They have to be evaluated from the perspectives of economic benefits and national capacity. In the case of IT, the possible economic benefits are listed in *Table 3*. To be more than just a consumer, a policy decision will have to be made as to which activities to target. Once done, then preparation for capacity building must be undertaken and this becomes a function of Policy for STI.

Table 3. DERIVING ECONOMIC BENEFITS FROM INFORMATION TECHNOLOGY

1. Application of IT in existing business for higher efficiency, productivity and profitability
2. System integration — providing services for IT application
3. Training in IT at various levels — executives, operators and specialists
4. IT-enabled businesses — e-commerce
5. Software and applications development
6. Hardware development
7. Hardware manufacturing — OEM and ODM

The four Critical Questions deal with STI for socio-economic transformation specifically for wealth creation or economic growth and competitiveness of industry. The other aspects, namely STI for basic needs and quality of life, must also be dealt with in a similar manner. In summary, STI for Policy is demand driven by factors outside the STI system, but must be linked to those of Policy for STI.

The big question now is who will decide and carry out the necessary tasks elucidated from the four Critical Questions. The tasks are part of the National STI agenda and require policy direction, political commitment, development planning and implementation coordination and monitoring. This will be discussed in the section on STI and Governance.

Policy for STI

This deals mainly with matters internal to the STI system such as capacity for STI development which in turn comprises infrastructure, human capital, resource allocation and linkages.

Allocations to R&D

National spending on R&D is one measure of capacity for STI development. Public sector resource allocation for R&D should be based on the following categories and consideration:

Mandatory R&D Fund

Research institutes and universities must be provided with the necessary funds to carry out their mandates. These mandates must be periodically reviewed to ensure relevance to the National STI agenda.

As for the universities, although they are now expected to embrace the RD&C culture in line with national requirement and global trend, their research role in capacity building and discovery of new knowledge must continue to be funded.

Technology Acquisition Fund
Funds should be allocated to non-research entities of government to acquire technology and innovation to improve their performance and delivery of their services. They can work in collaboration with research entities or their requirement can be outsourced to them.

This strategy also serves the purpose of increasing R&D collaborations, promote demand driven R&D and strengthen public sector R&D spending.

Contestable R&D Funds for Priority Areas
Funds should be established by the government to support R&D in priority areas identified in the national STI agenda. These funds should be made available to all research entities through a bidding process. The private sector should have access provided they work in collaboration with a government entity. This will again nurture the research collaboration culture in the country.

An example from New Zealand of a contestable fund for R&D was the Public Good Science Fund managed by the Foundation for Science, Research and Technology. With the reorganization of the NZ ministerial structure in 2012 and the creation of a "super" Ministry of Business, Innovation and Employment (MBIE), the contestable fund has been enhanced to support six priority areas: Biological Industries, Energy and Minerals, Environment, Hazards and Infrastructures, Health and Security, and High-Value Manufacturing. The fund now is managed by the Science Board of the Science and Innovation Boards of the MBIE.

The example from Malaysia of a contestable fund was the Intensification of Research in Priority Areas (IRPA) Fund introduced in 1987 during the Fifth Malaysia Plan period (1986-1990) totaling RM400mil., which was administered by the then Ministry of Science, Technology and Environment (MOSTE).

The contestable fund is now divided into the Science Fund, Innovation Fund and Technology Fund totaling RM2.99 bil. for the Ninth Malaysian Plan Period and managed by the Ministry of Science, Technology and Innovation (MOSTI). In addition there are the Fundamental Research Grant Scheme (FRGS), Exploratory/Experimental Research Grant Scheme (ERGS), Long Term Research Grant Scheme (LRGS) and the Prototype Development Grant Scheme (PDGS) totaling RM741 mil. administered by the Ministry of Higher Education (MOHE).

Management of the Public-Sector R&D Funds

The mandatory funds and the technology acquisition funds should be managed through the usual ministerial allocation and disbursement procedure.

Ideally, the contestable funds should be managed separately under an inter-sectoral, inter ministerial agency. They should be managed judiciously so as to achieve both short term and long term objectives. It would be unwise to declare the contestable funds specifically for basic or applied research. It should be problem solving or issue related. In the effort to solve a problem, research can go either way, basic or applied or both. In New Zealand this is the case and the MBIE has jurisdiction over a good number of ministries and agencies.

Infrastructure and Institutions for STI

Infrastructure and institutions are the bread and butter issues of traditional science policy. They are still a major concern of the Policy for STI. However, what needs to be said here is that institutions and the supporting infrastructure must be established to support the full activities needed to achieve the STI agenda. These institutions must be reviewed periodically for their legitimacy, authority and capacity to ensure continuing relevance and effectiveness.

STI and the Private Sector

It cannot be over emphasized the importance of the role of the private sector in developing and implementing the national STI agenda. Securing private sector involvement is therefore crucial.

Securing Private Sector Commitment to STI

An example of a mechanism to secure private sector interest and involvement in the development and implementation of the national STI agenda is an organization like the **Malaysian Industry-Government Group for High Technology (MIGHT).** Established in 1993 as a public-private sector partnership involving leading Malaysian companies and public-sector STI-related entities, MIGHT's objectives were to carry out 'Prospecting to Identify Business Opportunities for Industries, Policy Options for Government and Research Priorities for Public and Private Sector Research Institutions'. It is a not for profit company, limited by guarantee, governed by a board consisting of both public and private sectors members and jointly chaired by a representative each from the public and private sectors. The Prime Minister is the patron *(Box 5)*.

Currently MIGHT declares its objective as "serving the nation in advancing competency in High Technology through partnerships towards sustainable development", and its modus operandi and area of focus have evolved from the original mission (MIGHT 2012). But an organization like MIGHT can be the conduit for a continuous constructive engagement between the government and private sector on issues of STI for economic transformation and for securing private sector commitment and participation in the implementation of the national STI agenda.

While MIGHT brings industry and government together it does not provide funding. The United Kingdom Technology Strategy Board (UKTSB), on the other hand, actually invests in private sector projects that fall within government priority areas deemed to have big potential. The UKTSB is a non-departmental public body sponsored by the Department for Business, Innovation and Skills. It is in fact billed as the UK's national innovation agency.

Ideally industry sectors and individual firms should have their own STI agenda for their own business sustainability and competitiveness. Therefore the components of technology management best practice framework and the STI human resource pyramid must have their equivalents in both industry sectors and individual firms. To engender this culture, government linked companies (GLCs) and parastatles must take the lead. Their key performance indicators (KPI's) should include measures of STI index, which can be developed by the parties concerned. This index is to demonstrate and measure commitment to technology upgrading and uptake of innovations and especially of collaboration with local research entities.

Private Sector R&D

Commitment of the private sector to R&D can be through in-house R&D, outsourcing R&D to outside research entities or contribution to a common industry fund through a levy mechanism. The New Zealand industry research companies, such as the Logging Industry Research Organization (LIRO), are good examples of the last named. In addition to the funds from the levy, LIRO also has access to the contestable funds from the MBIE.

A generous tax rebate is usually claimable by industry for R&D expenditure in any of the three forms described above. In Malaysia the rebate is 200%.

To encourage sustained commitment to R&D in industry in New Zealand, the MBIE also provides generous research grants to companies with good track record in research.

Industry-Government STI Initiatives

There are a number of ways industry and government can cooperate in the STI area. These include cooperative research centres (CRC), research partnerships and industry-specific research centres.

Cooperative Research Centres (CRC)

The Australian CRC programme is a good example of this industry-government STI collaboration. Initiated in 1991, the CRC brings together researchers from companies in the private sector and those from universities and research institutes in the public sector to cooperate in research and in post-graduate education in certain specific areas. The CRC is run like a company, with specific objectives and pooling of resources and governed by a legal agreement.

BOX 5. MIGHT— MALAYSIAN INDUSTRY-GOVERNMENT GROUP FOR HIGH TECHNOLOGY

MIGHT is governed by a 15-member Board of Directors, headed by a Chairman, a prominent Malaysian Business personality and the Science Advisor as the Co-Chairman. The other directors are likewise captains of the Malaysian Industry and chief executives of technology-based organizations from the public sector. This high- powered private-public sector composition effectively positions MIGHT as a credible and respectable national gateway to business and technology. Membership in MIGHT is strictly by invitation only where the stringent selection criteria is based on the organisation's commitment to contribute towards the national technology business agenda. Corporate members include some of the larges public-listed firms in Malaysia with substantial overseas investments.

MIGHT strives to catapult Malaysia into truly industrial economy by carrying out the process of prospecting to identify business and investment opportunities for industry; policy options for the government and research priorities for public and private research institutions. It will mobilize and manage, joint or collective technology efforts which are beyond the resource of individual organizations.

MIGHT — Malaysian Industry-Government Group for High Technology. WHY PROSPECTING?

Prospecting is a generally a pro-active process to search for business and investment opportunities through strategic exploitation of research and technology. It entails monitoring, forecasting and assessing of what is happening nationally, regionally and globally so as to identify areas of opportunity and action.

The prospecting process brings together organizations from the public and private sector into task-oriented consultations to explore emerging technologies in order to produce integrated long term and strategic planning for both industry and government.

Prospecting may be driven by one or more of the following factors:

i. National Policy: analyse the implications and impact of national policy and strategies on industrial development;
ii. Changes in Business Environment: expand, diversify or restructure existing business activities or to exploit new market opportunities;
iii. New Developments in Technology: identify opportunities to exploit emerging technologies or synergies their uses in current business; and
iv. Externally Imposed Factors: seek opportunities in adaptation to changes such as new standards, new terms of trade, or global political realignments.

BENEFIT TO INDUSTRY

A broad spectrum of technology-driven industries would benefits from the fruits of prospecting, including those which have or are developing linkages within the international framework. The focus will not only be on manufacturing but also on other industries which will use technology for business such as construction, agriculture and the service industry.

The industry in general, and MIGHT members in particular will stand to reap substantial gains from prospecting output through:

- Early knowledge or strategic information of business and investment opportunities at home and abroad;
- Opportunity for direct interaction with key personnel in the government responsible for technology and industrial policies;
- Better understanding of opportunities through a broader and independent perspective;
- Opening for new collaborative and synergistic partnership; and
- Helping the research community to undertake relevant R&D.

MIGHT provides an effective platform and a network of domestic and international linkages for members to work in a cooperative manner to reap maximum benefits from the partnership.

On the international front, MIGHT is the Malaysian counterpart and strategic partner to the Commonwealth Partnership for Technology Management (CPTM) which has members from all 51 Commonwealth countries.

In Australia, altogether 190 CRCs have been funded and 44 are still active in 2011–2012 in Agriculture, Forestry and Fisheries, Mining, Manufacturing, and Services.

Research Partnerships

In New Zealand, the MBIE through its Science Board, supports research partnership between "research users working with research providers". Funding is provided for high-quality, long-term research programmes aimed at increasing competitiveness of industries and strengthening ties between industry and the research community. Examples of these research partnerships include: Pastoral Genomics, Kiwifruit Consortium, Ovine Automation, and New Zealand Wool Consortium.

Industry-Specific Research Centres (ISRC)

This is a joint venture between a public sector entity and industry to focus on STI requirement and human capital development for a specific industry sector. The University of Warwick's Manufacturing System Engineering group is an example for the manufacturing industry especially automotive in the UK. Some 30 major manufacturing companies contribute to the project in return for research facilities, joint research undertaking and a steady supply of trained graduates.

In Malaysia, R&D in the two major agricultural commodities — rubber and palm oil — is undertaken by industry-specific research organizations. The research is funded by a **cess** mechanism. A cess is a tax collected by the government for a specific purpose and not part of general government revenue. In the case of rubber and palm oil, cess is collected on the basis of the commodity exported and commodity produced, respectively. The cess fund from rubber export is managed by the Malaysian Rubber Board and from palm oil produced, by the Malaysian Palm Oil Board. The Boards are established by the government and membership comprises both government and industry representatives. The fund derived from cess is utilized for the development of the respective industry including for R&D. Both Boards also have access to the contestable funds for Science and Technology from the government.

Industry-funded Foundation for STI

A unique example of private sector's support for STI is the establishment of foundations by multinationals to support STI in the countries they operate. These are considered as part of their corporate social responsibility (CSR). The case in point is the establishment in 1993 of the Malaysia Toray Science Foundation (MTSF) by Toray Industries Inc of Japan and the Toray Group of Companies in Malaysia. MTSF supports STI in Malaysia through:

1. S&T Awards for outstanding achievement in R&D for young scientists;
2. S&T research grants to scientists in both public and private universities and research institutes; and

3. Science education award for creative and innovative teaching methods for science subjects in secondary schools.

Similar foundations are also established by the Toray Group in Thailand and Indonesia. Other multinational and domestic companies should emulate this practice.

The above are some examples of mechanism to encourage a research culture in industry and its participation in the national STI agenda. There are probably many others. In any case, the government would have to initiate, encourage and reward private sector investment in technology acquisition and development. An effective public sector STI governance system which involves wide consultation, must be put in place which complements the STI ecosystem.

STI and the Community

In order for STI to become truly a tool for socio-economic transformation, the community must be science literate and the scientific method must become a way of life and attitude of mind and a means of enriching the nation's welfare. This is STI enculturisation of the public at large. The process must be incorporated into the education system, for example through the 'Science for All' programme in the schools.

There must be exposure to the basic concept and principle of the scientific method at all levels of education, from the simplest to the most advanced. The method of enquiry-based or experiential learning is an excellent way of teaching the concept of the scientific approach.

In India, the ethos and practice of the scientific method is the basis of the 'scientific temper' introduced by India's first Prime Minister Jawaharlal Nehru in 1946 which is enshrined in the Constitution of India. Scientific temper extols the virtues of the scientific method and is defined simply as "an attitude which involves the application of logic and avoidance of bias or preconceived notions".

Continuous exposure to STI issues is best done through the "Populariser" channel. The popularisers (see STI Human Resource Pyramid) refers to the group of individuals or organizations that create interest in STI in the population, educate them in the major achievement in STI, and the impact of STI on their daily lives. The popularisers play a major role in STI enculturisation of the public at large.

STI-based NGOs form an important group of popularisers. Examples are professional regulatory bodies, learned societies and associations for the advancement of science. They have the capacity for reaching out to the public in addition to promoting excellence in their own scientific disciplines.

Academy of Sciences around the world usually have a mandate on popularization and enculturisation of STI. In the case of the Academy of Sciences Malaysia (ASM),

one of its four major activities relate to "promoting public awareness and understanding of the importance of STI in everyday life". The activities in this area include public lectures by invited Nobel Laureates and winners of the Mahathir Science Award; various lecture series organized with like-minded organizations such as the Petronas Science Museum (PetroSains); back to school lectures by ASM Fellows; and special publication in cooperation with a local newspaper. In addition ASM organises school science quizzes, science expositions and science camps.

The target audience for the popularisers must include the young, the public at large and special groups such as public administrators and parliamentarians. The "smart communication" channels to reach them are varied. They have to be carefully selected.

Another avenue for popularizing STI is public debate. In this respect, Parliament should be a platform for public debate on STI issues of public interest and affecting national development. For this purpose a **Parliamentary Standing Committee on STI** must be established, if there is none. And this should be part of the Public Sector Governance of STI.

Much of the work of the popularisers is done through the media. There is need therefore to promote **science journalism**. Science Museums, science centres, discovery parks and similar entities play a big role as well. They must be established to complement the effort in the popularization of STI.

Enculturisation however is not just appreciation. It must include practice. This is where a mass or **inclusive innovation movement** comes in and it must be promoted. Everyone must be thinking about doing his or her job or accomplising a routine task, more efficiently and more economically.

International Collaborations in STI

Implementing the national STI agenda is a major task that cannot be achieved by the government alone. It requires close cooperation with all national stakeholders. It would also require collaboration at the international level, with agencies of the United Nations, for example, or multinational companies. The case in Malaysia of composites products manufacturing for aircraft parts, described earlier, for example, involved collaboration between CTRM and Short Brothers of Belfast. The latter sent officials to assess the project in Perth, Australia, and seconded personnel to assist in staff training and finalization of the Eagle aircraft prototype.

An outreach mechanism is required for international advice, access to international research funding and development assistance, to R&D collaborations and for science diplomacy. Within the STI governance structure, this task must be recognized and be assigned to a specific operational entity. In Tanzania, for example the Tanzanian Commission for Science and Technology facilitates access to international funding for the nation's research community.

TABLE 4. THREE EXAMPLES OF NATIONAL SCIENCE AND TECHNOLOGY COUNCILS

Country	Year Established	Authority Level	Chairman	Membership	Mandate
USA	1993	Cabinet-level Council	The President of the USA	- Vice-President - Cabinet secretaries - Head of Agencies - Director, office of S&T Policy	- Coordinate S&T policy across all agencies of Federal government - Determine national goals for Federal investment in S&T and R&D
South Korea	2011	Under the President	The Prime Minister	- Key Ministries with S&T fort folio - Distinguished persons	- Improve efficiency and accountability of R&D projects across ministries - Policy coordination
Zambia	1997	Under the Minister of S&T and Vocational Training	Private Sector person	- Public sector agencies - Universities	- S&T Advisory and promotion - Coordination of S&T, research and innovation - Regulation of R&D - Policy advice to government - Mobilise resources for S&T

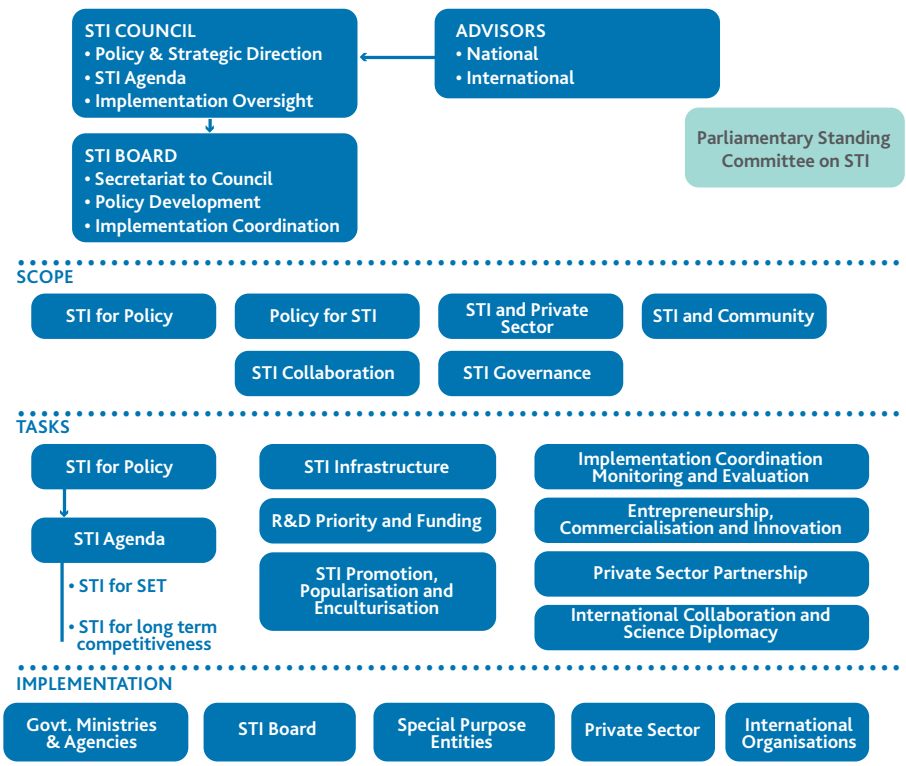

Figure 8. STI Governance Structure — Public Sector.

Another form of international collaboration is the **off-set agreement** usually attached to government procurement for big-ticket defence equipment. Although criticized by some quarters, it is a legal trade practice. Off-sets can be direct or indirect, but both can be negotiated to be utilized to strengthen national STI capacity or directly as an innovation driver in small and medium enterprises (SMEs). Again this activity must be managed well and different countries have their own off-set management systems. In Australia it is managed by the Department of Defence, in Canada by the Industrial and Regional Benefits Directorate, in Kuwait by the National Off-set Company belonging to the Ministry of Finance. In South Korea the agency is the Defence Acquisition Program Administration and in the UK, the UK Trade and Investment (UKTI) under the Minister of State for Trade, Investment and Business. In Malaysia, off-set programmes are managed by MIGHT on behalf of the Ministry of Finance.

The basis of international cooperation and collaboration must be on a win-win outcome and preferably within the context of Smart Partnership, which will be explained in Part 5.

STI and Governance

Governance for STI — Public Sector

The human resource needed to move the national STI agenda (see Template 4) consists of the **champions, advisers, popularizes, planners and managers, educators and practitioners or implementers** *(Figure 4)*. Each group has its own task and responsibility. The champions, the advisers, the planners and the managers need to be formalized into an organizational hierarchy which will constitute the main national governance structure for STI *(Figure 8)*.

The Champions —National STI Council (NSTIC)

The various champions of the national STI development are best constituted into a body such as a National STI Council chaired by the top leadership. This council is responsible for policy and strategic direction, STI agenda formulation and its implementation and coordination oversight. It should be composed of representatives of all stakeholders, public and private sectors, meet regularly to be updated on implementation progress, consulted on implementation issues, and be appraised of new development.

There are many national science and technology councils (NSTC) in both developed and developing world, with varying authority level and composition. Most of them deal with policy and implementation coordination in respect of public sector investment in R&D. Three examples are given in *Table 4*. The NSTIC proposed here has a wider mandate as indicated in *Figure 8*. It is responsible for developing the total national STI agenda. This is a model that may be more suitable for developing countries as it reduces fragmentation of policy bodies across the STI landscape. The implication is that NSTIC requires direct involvement of the

Head of Government and membership from both the public and private sectors.

The Advisers — STI Advisory System

An efficient advisory system to the council is crucial to the STI governance structure. This should consist of national advisory bodies representing the STI, the corporate and the academic sectors. The national **academy of sciences** or similar organizations should represent the STI community.

Others may be included as the situation demands. It may be desirable to also have an international advisory body, but both the national and international advisors must be guided by a set of principles which should include trust, credibility and accountability.

In many countries the Head of Government has a science advisor whose responsibility varies from country to country. He maybe part of the formal advisory system or act only as a personal adviser to the Head. In some cases he is also incorporated into the implementation mechanism as head of the secretariat supporting the Council.

The Planners and Managers — National STI Board

The planners and managers maybe grouped into a National STI Board which acts as a secretariat to the NSTIC and as a bridge between the Council and the implementing ministries and agencies and the private sector and international partners. The Board's functions are wide and should include: Policy and STI agenda development, R&D priorities and funding requirements, STI promotion and popularization, oversight of implementation coordination, monitoring and evaluation, commercialisation and innovation promotion, public-private sector partnership, and international collaboration. The implementation channels are the government ministries and agencies, private sector and international organizations and the STI Board itself. Where a vacuum exists, the Board should be empowered to establish new entities.

To be effective, the Board must be an inter-agency body under the purview of the Office of the Head of Government. It must be manned by qualified professionals in various disciplines who are capable of using tools and techniques of measurement, mapping and analysis of STI to facilitate informed decision making by the Council. The Science Advisor to the President or to the Prime Minister maybe appointed Head of the Board. It goes without saying that the Board must have adequate funds to carry out its broad mandate. The Secretariat to the South Korean National Science and Technology Council, for example, consist of 140 staff members, 45% of which are from the private sector. It manages a fund of USD13.4 bil.

The implementation coordination, monitoring and evaluation function may best be delegated to a special agency with inter-ministrial jurisdiction. Likewise management of the contestable R&D

funds for priority areas should be given to a special vehicle such as a National Research Council or a Foundation.

The total structure for the governance of STI *(Figure 8)* would need local customization. It may also need in some cases to be established by law.

Governance for STI — Private Sector
In order for companies to continue to grow and be competitive, it would require a business culture which is aware of the urgent need of continuous technology enhancement. There is need therefore for an STI governance system within firms that mirrors the STI governance system of the public sector. The firm can, for example adopt a technology management best practice framework of its own *(Table 5)*.

There must be a champion, planners and managers and implementers. At the very least one person maybe given the responsibility for the firm's STI agenda — the **Chief Technology Officer** for example. His needs can be met either through an in-house R&D capacity or be outsourced to the universities or research institutes.

In many countries there are business entities linked to or owned by the government. They can serve as role model for technology-aware enterprises. Their KPIs must include some form of measurement of commitment to STI and increasing STI capacity.

TABLE 5. TECHNOLOGY MANAGEMENT BEST PRACTICE FRAMEWORK — BUSINESS SECTOR

- Commitment to technology upgrade — appetite for innovation
- Business and Investment Policy Integration — technology upgrade as part of business development strategy
- STI Advisory System
- Business Development Planning
- STI Related Infrastructure — Mechanism for New Technology Integration
- Budget for technology acquisition and development
- Human capital development
- Public-Private Sector Coorporation — Smart Partnership Practices

PART 04

DELIVERING INNOVATION — THE LAST MILE

In the innovation economy, capacity to innovate and utilize innovation is the determinant of competitiveness. Delivering innovation is therefore a major goal of an STI policy.

Definition of Innovation

What is innovation? This is a hot topic about which much has been written. In a Google survey in 2007 a staggering 330 million references to innovation were recorded (Kao 2007). The UK-based National Endowment for Science, Technology and the Arts (NESTA 2010) alone published 16 full reports on innovation between 2006–2010. Not surprising therefore that there are so many definitions of innovation. One classical definition is "…..the successful exploitation of human creativity by the incorporation or adaptation of technologies, processes, systems and best practices for sustainable national growth and development". However there are a bewildering number of other definitions especially from the business perspective. A few examples are shown in *Box 6*.

In addition to the various definitions, innovation is also divided into technological or product innovation and soft innovation. The latter is again classified into process innovation and strategy innovation which include esthetical innovation and innovation in the creative industries. The soft innovation is also referred to as "hidden innovation". Innovation can be open or closed, systems or systemic, incremental, substantial, breakthrough and even radical. It can occur in governance, geopolitics, socio-economics issues and in strategies and alliances.

And then there is 'disruptive innovation', defined as "a product or service that takes root initially in simple applications at the bottom of a market and then relentlessly moves up market eventually replacing established competitions." This should perhaps be more correctly termed 'positive disruptive innovation' as far as the consumers are concerned.

There is also the concept of mass innovation, inclusive innovation, grassroot innovation, meaning that innovation is not the preserve of an elite group but is everyone's business.

BOX 6. DEFINITIONS OF INNOVATION

"…….innovation to bring positive change, novelty, improvement and enhancement spans methods, systems, service offerings, sales and marketing techniques, accounting and numerous aspects of understanding and caring for customers".
Barrell, Herriot and Mitchell, 1992

"Innovation is the result of creativity in R & D which can be in the form of new products, new services and productivity increases".
Omar Abdul Rahman and Yew Kam Keong, 2005

"…….the ability of individuals, companies and entire nations to continuously create their desired future. Innovation depends on harvesting knowledge from a range of disciplines besides science and technology, among them design, social science and the arts. And it is exemplified by more than just products; services, experiences and processes can be innovative as well……. Innovation flows from shifts in mind set that can generate new business models, recognize new opportunity and weave innovations throughout the fabric of society".
John Kao, 2007

"…….innovation is coming up with ideas and bringing them to life. Hatching ideas is the creative part, bringing them to life successfully in the form of a new product or service or management method is what makes a new idea an innovation".
Robert B. Tucker, 2008

"Innovation is the creation something new – a good or a service, a way to deliver goods or services, an organizational or management structure or the capture of new markets".
Fred Gault & Susanna Huttner, 2008

"Emergent Innovation is localised innovation of markets in emerging economies by industrial companies….. The MNC serves as a sponsor that coaches and finances selected local innovations project against the 'first right to buy' of successful startup economies".
Jan Verloop, 2008

"Technology can lead to an invention, a new (hitherto unknown) device, process or algorithm that has been shown to work. Not all inventions are based on scientific reasoning, many are ideas developed by trial and error. An innovation is the successful application of something new".
"An idea is nothing, an invention is something, and an innovation is the real thing".
J. E Wissema, 2009

"Innovation is about approaching your daily work and the challenges you face with an open mind and a creative can–do attitude. It's about seeking unconventional solutions to the problems on your plate. At work, it's looking at everything you do and figuring what and where you can do better, in less time, with fewer motions, in a way that adds value to both internal and external customers".
Robert B Tucker, 2010

"Innovation is a strategic change that creates value. The change can be a change in design, technology, process, thinking and mindset or any combination of these".
Azim Pawanchik and Suraya Sulaiman, 2010

"Innovation – the creation of new customer value in the marketplace with a sustainable business model for the enterprise producing it".
Dennis Tsu, (SRI International) , 2012

TABLE 6. SYNERGY BETWEEN TECHNOLOGICAL AND SOFT INNOVATIONS IN A TECHNOLOGY ENTERPRISE

Business Driver B	Technology Provider A	Business Enabler C
• Sales and marketing • Promotion, Advertising • After Sales Services • Customer Loyalty	• Products • Devices • Accessories	• Work Force • Business Processes • Cost cutting and productivity increases • Financial Management
Soft Innovation	Technological innovation	Soft Innovation
Success of A in the marketplace requires innovations in B and C.		

It is about finding ways of doing what we are doing daily better, quicker, more efficiently and more profitably.

Although both technological and soft innovations are usually required for a successful enterprise in the marketplace *(Table 6)*, our concern here is technological innovation especially in the form of new products, new algorithms, new processes or services that can meet the needs or solve the problems of socio-economic transformation, in the context of the critical technologies for basic needs, quality of life, wealth creation and economic competitiveness and good governance.

Invention, Prenovation and Innovation

Technological or product innovation begins as an **invention** which results from a systematic R&D or from a trial and error tinkering. It is only when the invention is commercialized or in any other ways fully utilized that it becomes an **innovation**. In other words innovation denotes the diffusion of products, processes or services among users either for commercial or non-commercial purposes. This is generally in agreement with the current definitions of innovation. For technological innovations, the definition can be even more exacting, for example by the US-based SRI International: " ….. the creation of new customer value in the marketplace with a sustainable business model for the enterprise producing it."

In this context therefore the word innovation is generally loosely and wrongly used. Often it is an invention looking for uptake or a prototype seeking commercialization, and therefore a pre-innovation or **prenovation** *(Figure 9)*.

Inventions resulting from trial and error tinkering are a significant source of prenovations. It is important therefore to encourage and support such activity. Around the world there are national and international **invention societies**. They regularly hold exhibitions and promote commercialization of their members'

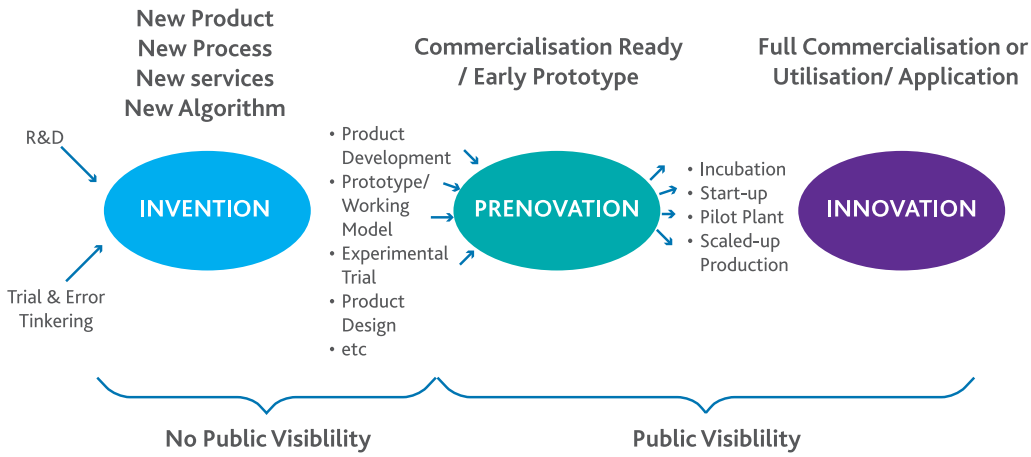

Figure 9. The invention, prenovation and innovation value chain.

inventions and prenovations. In Malaysia for example there is MINDS (Malaysian Invention and Design Society) which was established in 1987 and is a member of IFIA (International Federation of Inventors' Associations). Every year since 1989, MINDS organizes an international event — International Invention, Innovation and Technology Exhibition (ITEX) which showcases Malaysian and International inventions from individuals including school children, universities and research institutes. ITEX 2013 for example exhibited 1000 inventions from 20 countries. Many were at the prenovation stage and a good number already commercialized. Inventors are an integral part of the innovation community.

From Prenovation to Innovation — Bridging the Gap

The concept of prenovation is significant. Results from research and technology development under the STI for Policy, as well as from the universities and research institutes under the Policy for STI which are commercialization-ready, and especially after undergoing **market validation,** are all prenovations. When patented, prenovations become intellectual property (IP).

Prenovations patented or otherwise need to bridge the gap between the laboratory and the marketplace : the gap is now dramatically called 'the Valley of Death'.

Transferring a prenovation into an innovation is a complicated process requiring a large number of players and processes, i.e. a complete innovation ecosystem *(Figure 10)*, which in this case is derived from the basic concept of the ecosystem of the innovation or the knowledge-based economy *(Figure 11)*. The innovation ecosystem is actually the summation of the sub-systems of creativity, creativity in R&D, entrepreneurship and of

commercialization. Though the subsystems share a number of common components, each has its own special requirement *(Box 7)*. All these must be put in place in order to complete the last mile requirements for the delivery of innovation.

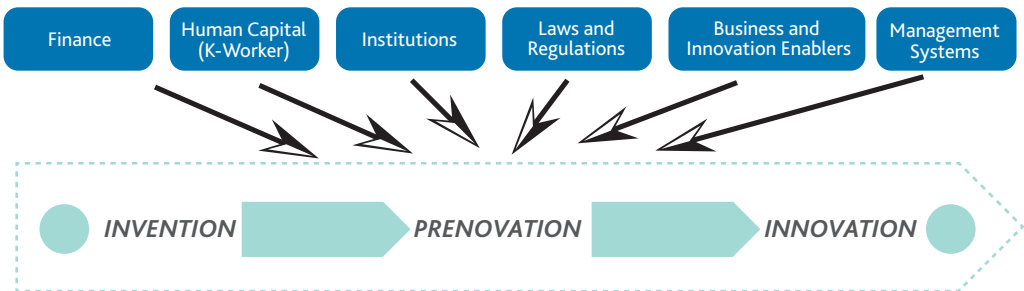

Figure 10. Bridging the gap between invention and innovation.

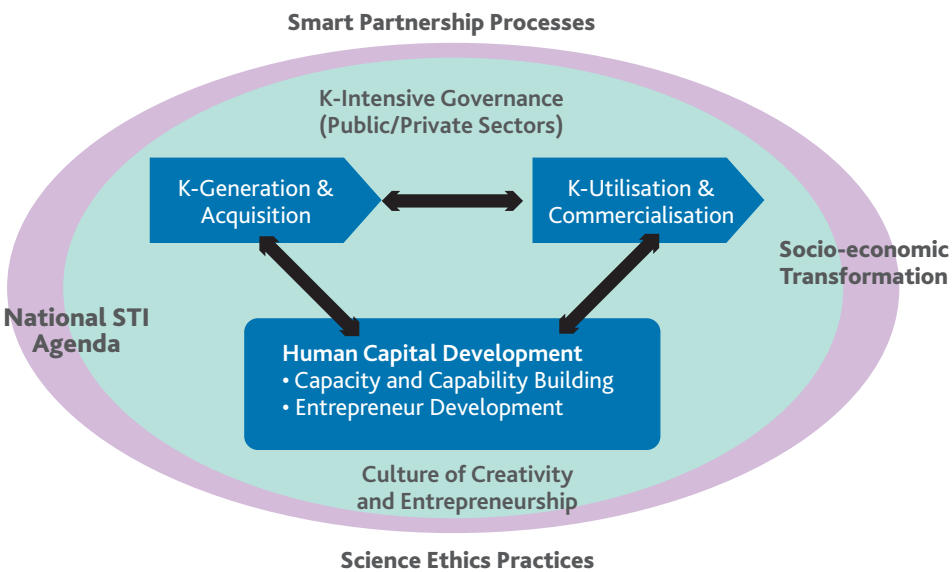

Figure 11. The basic components of the ecosystem of the knowledge-based or innovation economy.

The main components of the innovation ecosystem at the interface between prenovation and innovation include **Finance, Human Capital, Institutions, Laws and Regulations, Business and Innovation Enablers,** and **Management Systems** *(Figure 10)*.

Finance

The total funding requirement to support the RD&C value chain and to support the STI value chain comprises four stages: The ideation or Pre-R&D, the R&D, the startup or early commercialization, and the full commercialization stages (Figure 13).

BOX 7. COMPONENTS OF THE SUB SYTEMS SUPPORTING THE INNOVATION ECOSYSTEM

CREATIVITY — Action driven by curiosity and inquisitiveness, not accepting the conventional, seeking novel ways of solving problems:

- Education system and teachers training programme
- Home and school environment
- Workplace
- Team work
- Creative leadership
- Reward system.

RESEARCH and DEVELOPMENT — creativity in approach and conduct of R&D:

- Institutional legitimacy and mandate
- Authority — legal/administrative
- Capacity — people, facilities, funds, linkages
- Creative leadership
- Monitoring and evaluation system
- Reward system
- Collaboration framework.

ENTREPRENEURSHIP — Ability to recognize potential of prenovations and to develop a bankable business plan:

- Education system / creative individuals
- Sources of prenovations
- Mentoring
- Access to financing
- Business enablers
- Cultural norm – failure not a stigma
- Innovation marketplace
- Access to key customers
- Innovation space.

COMMERCIALIZATION – Success in establishing a sustainable business and in delivering value to customer and the enterprise:

- Government policy
- Entrepreneurs
- Prenovations
- Mentoring
- Venture capital
- Business enablers
- Innovation enablers
- Innovation space, science parks and technology industrial park
- Access to "key customers"
- Technology bourse.

The requirement for the first two stages is the function of the Policy for STI and of the STI and the Private Sector. The last two stages are part of the last mile and consist of pre-seed, seed (start-up), mezzanine, pre-IPO (initial public offer), IPO and expansion capital. Traditional financial institutions and private equity companies cannot be relied upon to provide all the above capital needs. The risky financial requirement (pre-seed, seed, mezzanine and pre-IPO) can only be met by special institutions — **venture capital companies (VCC)**. It is not unusual for the risky seed capital to be provided by angel investors — the so-called three Fs: family, friends and fools. Angel investors are usually high net-worth individuals who invest either in exchange for convertible debt or equity.

In mature economies VCCs abound. Even technology banks exist in order to provide financial support for technology–based companies. A VCC normally also provides mentoring for start-up companies and has a representative on the board. In developing countries the government will have to establish VCCs and give a nudge to the development of a venture capital market. It will also have to provide various kinds of grants in order to encourage technology startup companies to commercialize prenovations.

A word of caution, however. In situations where the ecosystem of invention, prenovation, commercialization and innovation is not mature, VCCs will not be able to operate effectively. There will not be enough deal flows, ie sufficient supply of quality prenovations to be commercialized, and the necessary complement of business enables may not be complete to initiate the operation of start-up companies. The operation of VCCs will have to be modified and this must be country specific.

Examples of government initiatives in Malaysia *(Box 8)* are given to illustrate the last–mile financial instruments that are required to make innovation happen. The UKTSB mentioned earlier is a good example of financial support by the public sector "to accelerate the journey between concept and commercialization".

BOX 8. FINANCING INNOVATION — THE MALAYSIAN EXAMPLES

CRADLE FUND MALAYSIA
(www.cradle.com.my)

- Cradle Investment Programme – CIP – (launched in 2003)
- CIP Catalyst
- Ideas Bank.

Conditional grants up to RM150,000 for innovative ideas and up to RM500,000 for commercialization.

CRADLE INVESTMENT PROGRAMME (CIP)
Goals:

- Generate new technology ideas and innovations from individuals, institutions of higher learning
- Create employment through technology venture development and commercialization
- Act as a catalyst for new areas of economic growth
- Address the funding gap and industry expectations between pre-seed stages of capital funding
- Create a critical mass of entrepreneurs and technopreneurs
- Build a foundation for technopreneurs to spin off their ventures to commercialization.

ICT and high-growth areas supported:

- Software and information services
- Internet: e-services, e-commerce and e-content
- Communication and networking mobile data
- High tech consumer and business products
- Electronic and semi-conductors
- Medical devices and advance materials
- Biotechnology and life sciences
- Environmental resource management and renewable energy
- Technology innovation for any industry.

CIP CATALYST
Activities Funded:

- Development of prototype
- Proofs of concept
- Business of market feasibility research
- IP (Intellectual Property) search and registration
- Surveys on concrete statistical data
- Product sampling expenses.

Services Provided:

- Monitoring of the idea development
- Mentors
- Further funding and market access support
- Coaching
- Networking opportunities
- Product and idea refinement
- Financial training
- Others.

MALAYSIAN TECHNOLOGY DEVELOPMENT CORPORATION (MTDC)
(www.mtdc.com.my)

Established in 1992:

- Promotion of commercialization of local research
- Investment in new ventures bringing new technologies from abroad
- Now an integrated venture capital solutions provider
- One-stop agency for financing — from laboratory ideas to full commercialization.

Private Equity — Funds:

- Malaysian Technology Venture One
- Malaysian Technology Venture Two
- Malaysian Technology Venture Two (Agriculture)
- Malaysian Technology Venture Three
- *Sumber Modal Satu*
- East Malaysian Growth Corporation
- Non-ICT Fund (RM1 billion)
- Life Sciences Capital Fund (USD150 million).

Services Provided:

- Nurturing and business advisory
- Capacity building
- Market research
- Strategies planning.

- Technology Incubators:

  - UPM MTDC Technology Centre — ICT Multimedia; Agro-biology
  - UKM MTDC Technology Centre — Biotechnology
  - UPM MTDC Technology Centre — Advanced Engineering; Life Sciences.

GOVERNMENT GRANTS FOR PROMOTION OF TECHNOLOGY BUSINESS
(Managed by MTDC)

- Technology Acquisition Fund (TAF) — partial grants to promote private sector effort to acquire new technology or technological improvement to production process.

GOVERNMENT GRANTS FOR PROMOTION OF TECHNOLOGY BUSINESS
(Managed by MTDC)

- Commercialization of Research and Development Fund (CRDF)
- CRDF 1 — feasibility study for commercialization of research from universities and research institutions
- CRDF 2 — commercialization of public sector R&D results via spin-off Companies (up to RM500,000)
- CRDF 3 — commercialization of public sector R&D via start-up companies (up to RM500,000)
- CRDF 4(a) — commercialization of any locally generated R&D by SMEs (up to RM4 million)
- CRDF 4(b) — commercialization of any locally generated R&D by large corporation (up to RM4 million)
- CRDF 4(c) — commercialization of any locally generated R&D by listed company (up to RM4 million).

MALAYSIAN VENTURE CAPITAL MANAGEMENT BHD (MAVCAP)
(www.mavcap.com.my)

- Incorporated in 2001 by the Malaysian Government with investment focus in the local information, communications and technology sector (ICT)
- Provides an alternative source of high-risk financing for start-ups, seed capital and early stage ventures in the ICT sector and high-growth industries
- Invests for a period of 5–8 years in seed, start-ups and early stage companies, holds a Board position and drives key management decisions. Initial investment of RM1 million – RM3 million are complemented with Mezzanine allocations valued at RM5 million – RM10 million to fund companies through to the pre-IPO stage. In later stage investments, MAVCAP typically invests between 3–5 years.

MODAL PERDANA
(www.modalperdana.com)

Established In 2001:

- Perdana Fund
- Malaysia-based; pre-IPO I high growth areas
- Flagship Capital
- Investment in China and Asean; managed by Hupomone Capital Partners Ltd
- Hi-Tech Venture capital LP (HTVC)
- Based in Silicon Valley
- Plug and Play
- Start-up incubator, based in Malaysia.

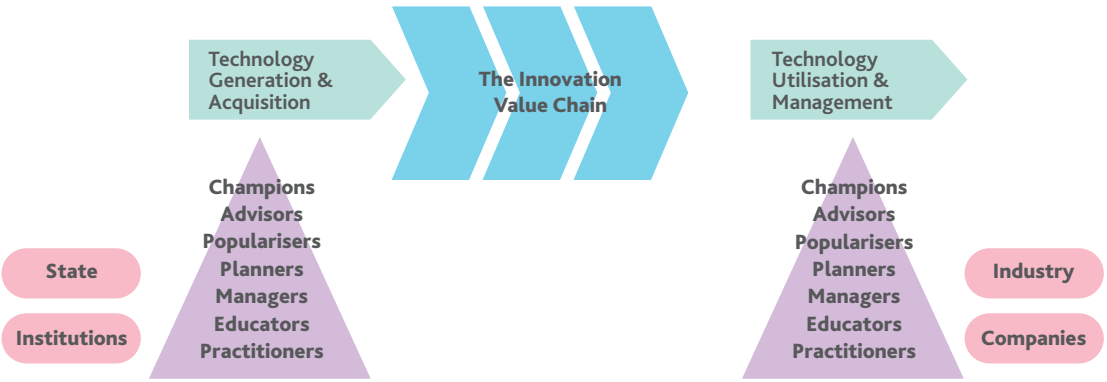

Figure 12. Complementary Innovation Framework — public and private sectors.

Human Capital

Holistic Human Capital (HHC), or other similar system (e.g. project–based learning, enquiry-based learning, experiential learning) will produce the creative, innovative and entrepreneurial leaders and workforce necessary for the innovation economy. As noted earlier, while "an inflexible, top down, standardized curriculum may be a good answer to the industrial economy's demand for punctual, literate, diligent workers, capable of following rules and procedures", an innovation economy requires creativity, innovativeness and entrepreneurialism in management and the workforce.

Institutions

A number of specialized institutions are essential to the closing of the gap between prenovation and innovation. This includes what might be called **innovation space**, starting with **ideation room** (where researchers and entrepreneurs especially netpreneurs can gather to bounce off ideas with colleagues, develop application concepts and nurture business ideas), to **plug–and-play** facilities, to **workshops** for prototype development, to **business incubators.** These can be hosted by universities, research institutes or other government entities or by private sector. **Science Parks** and **Technology Industrial Parks** are the eventual establishments in this group of institutions.

Product development must follow and conform to an appropriate quality and standards requirements so that the end products are tradable globally. Hence a **standards institute** is part of the institutional infrastructure.

There is in addition a need for intellectual property (IP) protection, patent filing and registration and for arbitration in case of disputes, all requiring institutions with

specific mandate.
The existence of a stock exchange for technology companies such as NESDAQ in the USA, will facilitate the access to the capital market by technology startups through the IPO process and subsequent fund-raising exercise. Such a stock exchange will also promote the growth of the venture capital market as it will provide the exit mechanism for venture capital companies.

Law and Regulations
Appropriate legal frameworks must be in place to protect IP, patent rights, and to simplify the registration of new businesses. Laws to provide tax incentives to encourage entrepreneurs and to encourage prenovation uptake by companies will be necessary to promote the delivery of innovation.

Business and Innovation Enablers
Business enablers are private sector entities such as law firms; business and marketing consultants, public relations, advertising, accounting and human resource (HR) firms; equipment vendors and many others. In other words a whole host of business enablers would be required to create an innovation community.

On the public sector side are innovation enablers such as a government innovation promotion agency (e.g. UKTSB, Agency Inovasi Malaysia), national innovation council and innovation foundation. Public sector research institutions may have a commercial arm for the commercialization of their research results. Universities are now

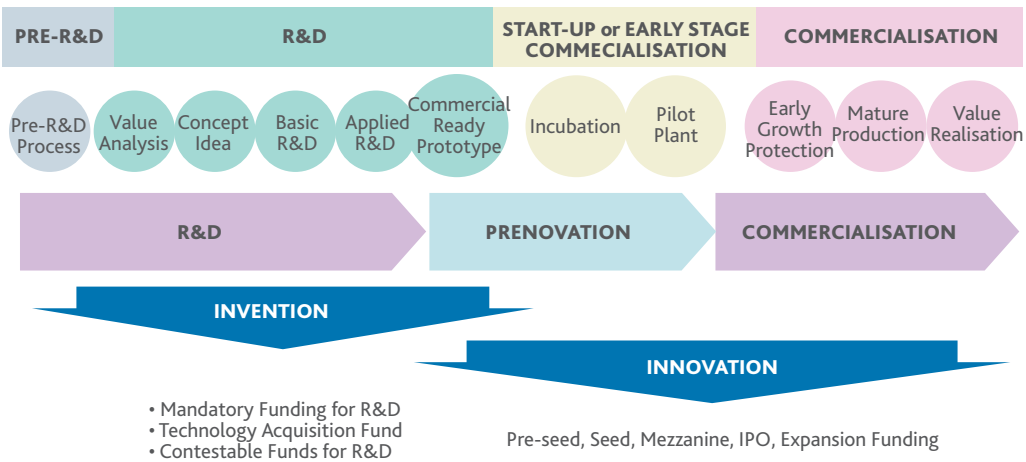

Figure 13. The linear RD&C value chain and funding requirements.

encouraged to undertake RD&C and to establish companies to promote their prenovations. At least two universities in Malaysia are already doing this and both with good track record. They are Universiti Sains Malaysia (USM) through its Innovation and Commercialization Unit in the Division of Research and Innovation; and Universiti Putra Malaysia (UPM) through UPM Innovations Sdn Bhd, a company under UPM Holdings Sdn Bhd.

Management Systems

The key principle in managing the interface between prenovation and innovation is not only to provide the various components as enumerated above, but also to facilitate the process of transference. This would mean easy access to advice, guidance, nurturing and mentoring, facilities and funds. For example, access to some type of innovation space may be free of charge or at a subsidized rate. In established innovation economy, IPs can be used as collateralized asset for obtaining financing. This is a great help to entrepreneurs.

Access to "key customers" is a major factor in the success of commercialization. Here the government has a big role to play. In many countries there are parastatles and government-linked companies (GLCs). They can become the "key customers" providing the breakthrough for new products and services coming out of the commercialization pipeline. The government can also assist in fast tracking the products into the global market place by helping in branding and promotion through its agencies abroad. In order to nudge the parastatles and GLCs to accept the role of "key customers" to new products and services, their key performance indicators (KPI) must include uptake of local prenovations and assistance in their commercialization, as well as in actual investment in RD&C.

Many of the public sector technology developers or prenovation providers (research institutes and universities) have their own information dissemination and marketing channels including on-line portals. These may not be enough to bring prenovations to potential users, especially in situations where the private sector is innovation recalcitrant. What is needed is a common portal and a physical marketplace — an **innovation-exchange** — where all the players (the technology providers, the potential users and the enablers) can be continuously engaged. The innovation exchange will then be the place where presentation and persuasion can be made and incentivisation, cooperation and collaboration can be offered.

To promote and facilitate prenovation uptake in the private sector, firms should have a technology management best practice framework of their own that mirrors the technology management best practice framework of the public sector *(Table 5)*, to ensure commitment to continuing technology upgrading. Firms should also have its own technology champion and human resource pyramid to move its own STI agenda *(Figure 12)*.

PART 05

SMART PARTNERSHIP — FRAMEWORK FOR COOPERATION IN IMPLEMENTATION

It cannot be over emphasized the importance of wide consultation in developing the national STI agenda and the necessity for cooperation and collaboration both nationally and internationally in its implementation; the government cannot carry out the task alone.

Cooperation to implement the national STI agenda is complex and multidimensional. It requires a robust and fair framework. **Smart partnership** is proposed as the preferred framework for this task. What then is smart partnership?

Smart Partnership was first elucidated at the **Langkawi International Dialogue (LID)** in 1995 as the philosophical basis of the Malaysia Incorporated concept promoted by Dr. Mahathir Mohamad,

Malaysia's fourth Prime Minister, for public-private sector partnership in national development.

Smart partnership is based on time-tested principles and values applied in the modern context. The principles are:

1. Shared vision — long-term commitment based on evolving common objective that goes beyond strategic alliance;
2. Fair and equitable outcome for all partners — a win-win situation based on prosper thy neighbour rather than 'beggar thy neighbour';

Table 7. SMART PARTNERSHIP IN PRACTICE

1. Smart Partnership for National Cohesion, Stability and Prosperrity
   i. GOVERNMENT LED
   ii. PARTNERS TO INCLUDE
   - Private Sector, Special Interest Groups, Media, Citizen Groups, Labour Unions, Religious Leaders, Professionals.

   - Shared long term vision and coordinated effort for a cohesive, stable, harmonious and prosperous society.

   iii. ISSUES:
   iv. National Vision and Nation Building
   v. National Development – Socio Economic Transformation, including STI development.
   vi. Economic Empowerment
   vii. Social Enhancement
   viii. Other Socio-economic and political issues

2. Smart Partnership for Business at the National and International Levels
   i PRIVATE SECTOR LED, GOVERNMENT ENABLED

   ii PARTNERS TO INCLUDE
   - Government, Workforce, Consumers, Investors, Foreign Partners, Media

   iii GOAL
   - Wealth Creation with equitable benefits to all partners; business with social conscience

   iv. ISSUES
   - Public-private sector dialogues
   - Education and skill development
   - Cooperate to compote
   - Technology transfer and technology management
   - National innovation system
   - Other techno-financial issues

3. Smart Partnership in a Regional or International Arena
   i. REGIONAL GROUP LED
   ii. PARTNERS TO INCLUDE
   - Governments, Special Interest Groups.
   iii. PURPOSE
   - To cooperate for empowerment in International Fora.

   iv. GOAL
   - Common stand on and participation in decision making on cross-boundary and global issues, fair and equitable participation in the global marketplace.

   v. ISSUES
   - Business globalization and trade liberalization — Role of Regulation
   - Sustainable development
   - Economic empowerment
   - Participation in the innovation economy — managing technology in open economies; cooperate to compete
   - Democracy, rule of law, human rights
   - Science diplomacy

3. Complimentarity of attributes of the partners and synergy between the formal structures and the off–formal process; and
4. Ethical commitment based on respect, trust, transparency and tolerance.

Key to Smart Partnership is dialogue and networking, i.e. a continuing constructive engagement through various means of all the stakeholders. These provide the opportunities for synchronizing perceptions which can lead to consensus on conflicting and contentious issues, for new insight into common concerns which can lead into new and innovative ways of dealing with them, and for unifying positions on shared problems which can lead to cooperative actions.

In subsequent LIDs and Smart Partnership Dialogues in Southern and East Africa jointly organized by CPTM and the host country, it became clear that Smart Partnership has wider application than national public-private sector partnership. It is applicable for all multi- stakeholders partnering

for national development, business ventures and regional and international cooperation *(Table VII* and *Box 9*). It is therefore an ideal framework for both national and international cooperation and collaborations for implementing the national STI agenda.

Dissemination of the concept and practice of smart partnership should therefore be one of the tasks of the STI Board. For this reason it has been included as part of the Governance for STI and as a component of the technology management best practice framework.

BOX 9. EXCERPTS ON SMART PARTNERSHIP

Smart Partnership is about creating limitless opportunities and wealth that is shared, that is sustainable and that allows the participants to function in the global economy. Its successful functioning depends on a "win-win" and "prosper –thy-neighbour" relationship among Partners. All the Partners, whether they be political leaders, civil servants, entrepreneurs, corporate leaders, management, labour, or people in general, play different roles according to their different circumstances, but all operate from the same set of principles. Smart Partnership is s process which unites people in growing co-prosperity.

Smart Partnership advances the philosophy and practice of "win-win" and "prosper-thy-neighbour" relationships in contrast to the "beggar-thy-neighbour practices that too often prevail in the world of international commerce. Smart Partnership is a new policy framework for Governments and Companies to do business effectively in an international context. The ethical superiority of practices based on win-win is obvious to all, but successfully applying it has historically been difficult. Smart Partnership uses a win-win philosophy as the basis of a strategy that enhances economic relationships producing outcomes that exceed those of more traditional relationships. Smart Partnership is not then, an end in itself- but a principle whose validity is derived from successful practice.

Smart Partnership is also about sharing experiences, both positive and negative and jointly benefiting from working out the solutions. The Smart Partnership in itself is not a panacea to all the socio-economic problems and is not a substitute for the spirit of enterprise and risk taking that all business activities entail. In practice Smart Partnership is complementary to the spirit of competition and enterprise.

Smart Partnership promotes a shift in emphasis from **the purely competitive to the more cooperative and a change in outlook from rigid adherence to the formal agreement to a willingness to be flexible for the sake of a continuous "common good", strengthened by strong formal relations.**

Smart Partnership is both an intellectual framework (philosophy) within which one operates but also a set of guidelines for actions under specific conditions. Conversely, Smart actions become an essential element of defining the framework and guidelines in a process of dynamic change. For instance Technology policies for Smart Partnerships have to include the ability to understand and capture the dynamics of the development process so that negotiators are continuously alert to emergent possibilities. Individual actions can manifest Smart Partnership characteristics and are a necessary but not sufficient condition for being Smart. **Smart Partnership is the process and not just the individual action.**

Smart Partners bring complementary attributes to a transaction. Without an element of complementary, identifying mutual gain could be difficult. Smart Partners also need trust. Trust must be painstakingly built up by all parties displaying fairness at all times. Smart Partners demonstrate this trust by a willingness to review and re-negotiate when the original win-win outcome becomes skewed through unforeseen developments.

Source: 'Limitless Oportunities Through Smart Partnership', CTPM, Nov. 1998, London.

SUMMARY

The Essentials of STI Policy can be summarized into four broad canvases: the **Rationale, the Requisites, the Results, and the Rewards.**

The Rationale Canvas
The justification for government support for and commitment to an STI Policy is the indispensable enabling role STI plays in national development whose objective is socio-economic transformation, and this in turn, depends on the four groups of **critical technologie**s:

i. Technologies for basic needs,
ii. Technologies for quality of life,
iii. Technologies for wealth creation and economic competitiveness; and
iv. technologies for good governance

The ability to harness the above critical technologies for socio-economic transformation depends on the Total National Capacity in STI whose components are:

- A government committed to providing a comprehensive STI physical and soft- infrastructure;
- A scientific community, ethical and competent and able to contribute to and draw from the global pool of scientific knowledge and technological know-how;
- A private sector capable of creating wealth through the application of technology and innovation in all sectors of the economy;
- A society that is science literate, imbued with a culture of creativity, innovativeness and entrepreneurship; and
- An efficient governance system enabling effective policy making, planning, implementation and public debate and international collaborations that ensures long-term commitment to STI development.

A sound STI policy is necessary to achieve the Total National Capacity in STI. Underpinning the development of Total National Capacity are two groups of enablers: the **Holistic Human Capital (HHC)** and a framework of cooperation based on Smart Partnership *(Figure 14)*.

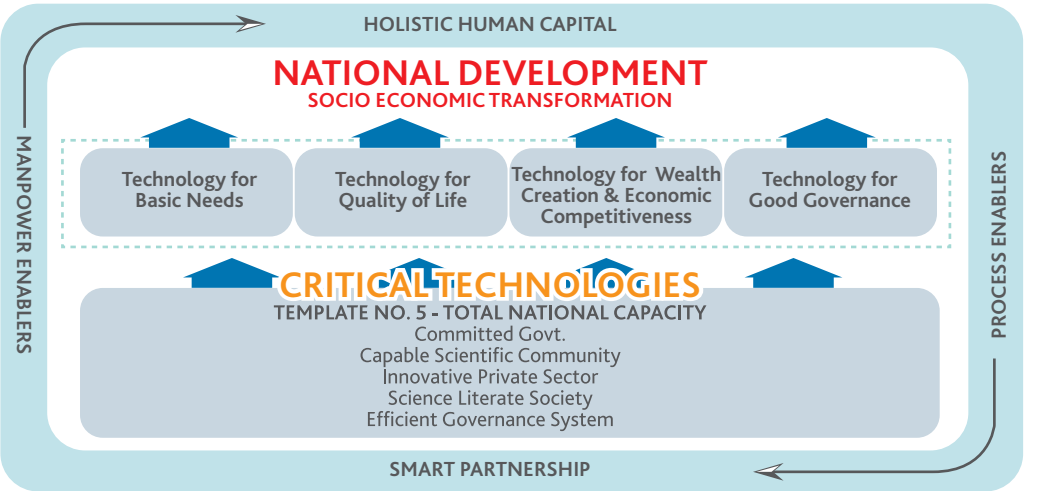

Figure 14. STI Policy
The Rationale — The Need for TNC to leverage critical technologies to achieve Socio-Economic Transformation.

The Requisites Canvas

Achieving the Total National Capacity of Template 5 requires a sound STI policy. The necessary requirements of an STI Policy are the six components of Template 1, the policy responses of Template 2, the Technology Management Best Practice Framework of Template 3 and the STI human resource pyramid of Template 4 *(Figure 15)*.

The Results Canvas

One outcome of a sound STI policy is improved connectivity and information flow between the issues and concerns of national development and their STI needs and those of economic sectors, such as manufacturing and agriculture, and the issues and concerns of STI development; in other words the harmonization of STI for Policy and Policy for STI *(Figure 16)*.

The Rewards Canvas

Understanding the STI needs of the various sectors will enable the development of a full national STI agenda, the formulation of an effective implementation strategies, management and coordination, and the emplacement of a rational STI governance system. The final achievement is the establishment of a complete and optimal national innovation system *(Figure 17)*.

Template 1
The Six Components of STI Policy

1. STI for Policy
2. Policy for STI
3. STI & Private Sector
4. STI &Community
5. International Collaboration in STI
6. STI and Governance

Template 2
The Policy Responses (Examples)

STI for Policy	• Identification of STI Agenda to support SET • Strengthening the capacity for RD&C • Enhancement of the support for entrepreneurship and enterprise development
Policy for STI	• Enhancement of the system of science education and STI human capital development • Strengthening public sector R&D capacity
STI & Private Sector	• Mechanism to secure private sector participation and commitment to national STI agenda
STI & Private Community	• Promotion of science literacy
International Collaboration in STI	• Framework for international collaboration
STI and Governance	• Consolidation of STI policy and development planning and implementation oversight

The Essentials of STI Policy

Template 3
Technology Management Best Practices Check List

1. Political Commitment
2. Policy Integration
3. STI Advisory System
4. STI Policy Development Planning, Implementation, Coordination, Monitoring and Evaluation
5. Infrastructure for STI Development
6. Funding and Management of R&D
7. Mechanism for Comm. of R&D
8. Integrated HRD
9. Mechanism for S&T Enculturisation
10. Smart Partnership

Template 4
The STI Human Resource Pyramid

Figure 15. STI Policy —The Requisites.

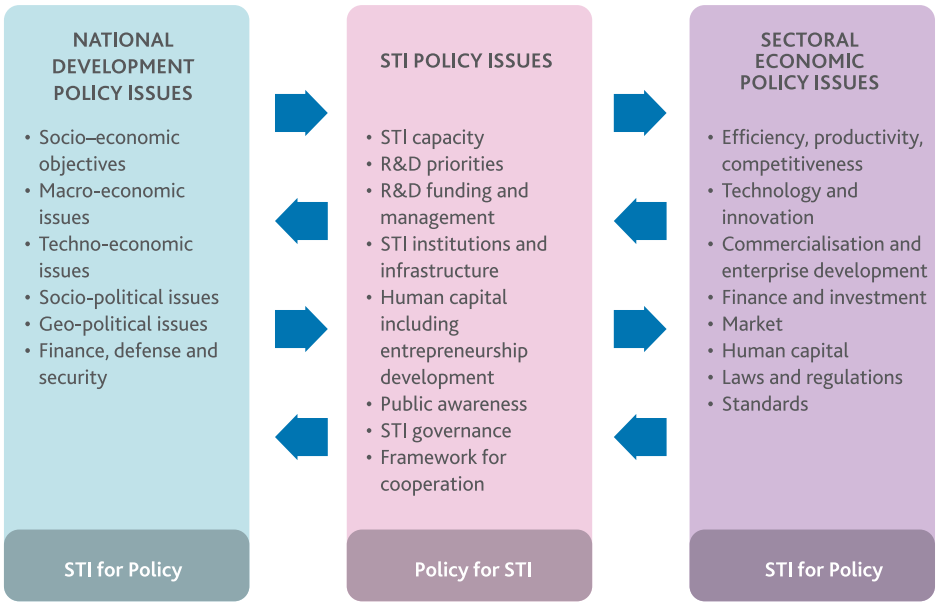

Figure 16. STI Policy — The Results.
Information flow and relationship between issues of National Development Policy, Sectoral Policies and STI Policy.

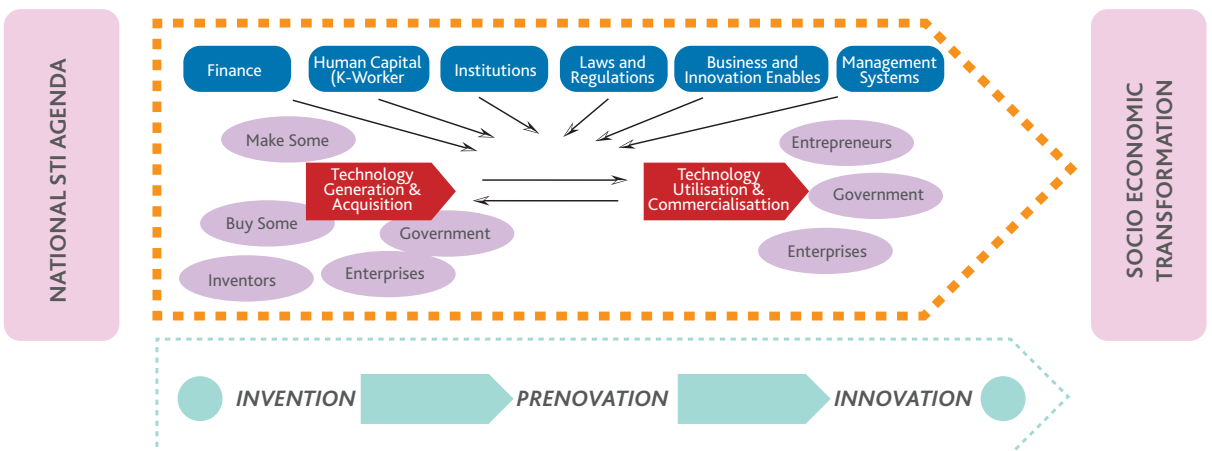

Figure 17- STI Policy — The Rewards — Towards an Optimal National Innovation System.

CONCLUSIONS

An STI policy is not just about doing "good science". Doing "good science" is not good enough. "Good science" must support a nation's socio-economic transformation programme by producing innovative technologies to meet the requirement of basic needs, quality of life, wealth creation and industrial competitiveness and good governance.

An STI policy is therefore very much about strengthening the STI apparatus and processes to support transformation. It is about establishing a sound governance system and emplacing institutions, funding, human capital and all enablers to complete the innovation ecosystem, thus facilitating the transfer of prenovations into innovations.

An STI policy should emphasise STI for Policy to gain full government acceptance that STI is a major instrument of socio-economic transformation along side economic, financial and political instruments.

It is about measures to nurture a culture of creativity, entrepreneurship and innovativeness in the community.

An STI policy is about strengthening international collaboration and enhancing public-private sector partnership and cooperation towards establishing unified strategies for transformation and the emplacement of a complementary innovation-friendly management system. It is about achieving the Total National Capacity in STI. Only then the nation's economy can be innovation driven and private sector led.

Finally, an STI policy is about action, not just rhetoric, and the achievement of transformation through STI the smart par tnership way.

ANNEX 1

TECHNOLOGY MANAGEMENT BEST PRACTICE CHECKLIST – MALAYSIA

1	Political Commitment	*Rukun Negara* (1970) *Vision 2020 (1991)* New Economic Model (2010)
2	Policy Integration	1st, 2nd, 3rd, *4th, 5th, 6th, 7th, 8th*, 9th, 10th Malaysian Plan OPP1 (1970-90), *OPP2 (1991-2000) and OPP3 (2001-2010)*, New Economic Model (2010) *K-Economy Master Plan (2000)*, Economic Transformation Programme (2010) *IMP 1(1986 -1995), IMP2 (1996-2005)* and IMP3(2006-2020) *1st Science and Technology Policy (1986), 2nd Science and Technolohy Policy (2003), APITD (1990)*
3	S&T Advisory System — Overall	National Economic Action Council, National Economic Ccouncil, National Economic Advisory Council (2009) and NDPC
	S&T Advisory System — Prime Minister's Department	*Science Adviser (1982), MIGHT (1993)*, UNIK/AIM (2010), Global Science and Innovation Advisory Council (2010)
	S&T Advisory System — National	MOSTE (1976), MOSTI (2004), NCSRD, NSRC(2010), NIC (2011) and *ASM (1994)*
	S&T Advisory System — Sectoral — HiTech	*MSC-IAP (1997), NITC (1994), Malaysian Aerospace Council (2001)*, National Green Technology and Climate Change Council (2010), Biotechnology International Advisory Panel (2005)
	S&T Advisory System — Sectoral — Traditional	Rubber, Palm Oil, Cocoa, Timber, National Kenaf and Tobacco Boards

4	**S&T Development Planning and Co-ordination**	
	National	NDPC, MOSTE (1976), *MOSTI (2004) EPU (1982)*, ICU, PEMANDU (2009), AIM (2010)
	Sectoral	*National Biotechnology Directorate, MDeC, National Nanotechnology Directorate*, Biotech Corp, *MCMC*, ECM, SPAN, SPAD
5	**S&T Infrastructure**	
	R&D Institutions	SIRIM (1975), IMR (1901),Dept of Chemistry (Merged 1946), VRI (1948), The Fisheries Research Institute (1949), MARDI (1969), Nuclear Malaysia (1972), *MIMOS (1985), FRIM(Upgraded1986), MACRES (1988), Petronas Research Institute (Corporatised 1992), National Hydraulic Research Institute of Malaysia (1995), MRB (Merged 1998),PROTON Research Centre, MPOB (Merged 2000), STRIDE (Upgraded 2001), National Space Agency (2002)*, Malaysian Institute of Pharmaceuticals and Nutraceuticals (2006), Malaysia Genome Institute (2006), Agro-Biotechnology Institute Malaysia (2006),
	Technology Development Companies	*CTRM(1990), Astronautic Technology (M) Sdn Bhd(1997), INNOBIO (2002), SYMMID,*
	Support Institutions	National Measurement Centre, *Standards Malaysia(1996)*,Malaysian Meteorological Department (1930 as a unit), *Atomic Energy Licensing Board (1984)*, ASMA, YIM, *Majlis Rekabentuk Malaysia (1993), CyberSecurity Malaysia (1997), Mynic Berhad (1987 as a division in MIMOS)*, Pusat Tenaga Malaysia
	Development Triangles and Corridors	*SIJORI (1989/1990), IMT-GT (1993), BIMP-EAGA (1994), MSC (1996)*, Iskandar, NCER, ECER, SCORE, Sabah Development Corridor (SDC)
6	**Funding and Management of R&D**	
	Funding	*IRPA*, Science Fund, TechnoFund, InnoFund, NanoFund, Fundamental Research Grant Scheme (FRGS), Long Term Research Grant Scheme (LRGS), Prototype Research Grant Scheme (PRGS), Exploratory Research Grant Scheme (ERGS)
	R&D and Management and Support	*MASTIC, PHIM*

7	**Mechanism for Commercialisation of Research and Technology**	
	VCs and Funds Providers	*MTDC (1992), MAVCAP (2001), MDV (2002),* Modal Perdana, Bank Pembangunan Malaysia
	Funds	*CRADLE, ITAF, MGS, COT, TAF, MESDAQ*, Green Technology Financing Scheme - GTFS, MAVCAP 110, MAVCAP 100, *Commercialisation of Research & Development Fund (CRDF)*, Business Growth Fund (BGF), Business Start-up Fund (BSF)
	Businee Incubators/ TechnologyParks	*TPM (1996), KHTP (1996), Cyberjaya (1997), UPM-MTDC, UKM-MTDC, FRIM-MTDC, UTM-MTDC*
8	**Integrated Human Resource Development**	
	Integration Coordination	JTR, MOHE, Talent Corp (2011)
	Public Universities and UCs	UM(1961),USM(1969), UKM(1970), UPM(1971), UTM(1975), *UIAM (1983),UUM(1984), USIM(1998), UNIMAS(1992), UMS(1994), UPSI(1998), UiTM(1999), UMT(1999), UTHM(2000), UTeM(2000), UMP(2001), UNIMPA(2001)*, UNiSZA(2005), UMK(2006), UPNM(2006)
	Private Universities and UCs	29 + 5 (BC) +21 (UC)
	Polytechnics	PUO(1969), POLISAS(1976), *POLIMAS(1984), PKB(1985), POLIKU(1988), POLIPD(1990), PKK(1996), PSA(1997), PSI(1998), PSP(1998), PMK(1999), KT(1999), PSMZA(2001), PMM(2002), PSAS(2002)*, PTSB(2002), PSIS(2003), PTSS(2003), PMS(2003), PMU(2004), PBU(2007), PJK(2007), PNS(2007), PBS(2008), PMJ(2008), PHT(2008), PSS(2008), PMKL, PMKU, PMJB
	Community Colleges	80
	Industrial Training Institutes (ILP)	JMTI, ADTEC Shah Alam, ADTEC Batu PahatADTEC Kulim, ADTEC Melaka, ADTEC Taiping , ADTEC Kemaman, ADTEC Bintulu, ADTEC Jerantut, ILP Kuala Lumpur, ILP Kuala Langat, ILP Selandar, ILP Bukit Katil, ILP Ledang , ILP Pasir Gudang, ILP Mersing , ILP Pedas, ILP Ipoh, ILP Kuantan, ILP Kangar, ILP Arumugam Pillai, ILP Perai, ILP Kepala Batas, ILP Kuala Terengganu, ILP Kota Bharu, ILP Kota Kinabalu, ILP Sandakan, ILP Labuan, ILP Kota Samarahan, ILP Miri, ILP Marang
	IKM	KKTM Rembau, KKTM Petaling Jaya, KKTM Beranang, KKTM Masjid Tanah, KKTM Ledang, KKTM Sri Gading, KKTM Balik Pulau, KKTM Kuantan, KKTM Pasir Mas, KKTM Kemaman, IKM Kuala Lumpur, IKM Jasin, IKM Johor Bahru, IKM Lumut, IKM Sungai Petani, IKM Sik, IKM Alor Setar, IKM Beseri, IKM Tan Sri Yahya Ahmad (TYSA) Pekan, IKM Besut, IKM Bintulu, IKM Kuching, IKM Kota Kinabalu

9	Mechanism for S&T Popularisation and Enculturisation	
	Mass Media	ESTI.COM, Jaring Internet Magazine (MIMOS), Symbiosis (TPM), REKA (MRM), MRM Bulletin, Cuaca Angkasa, Nuclear Regulatory Newsletter (AELB), Warta Nuklear Malaysia,
	Science Centres	Museums, *Planetarium(1989), National Science Centre (1986), Petrosains*
	Gardens/parks	Botanical, herbal, *Putrajaya Wetlands*, national parks, *KL Birdpark* (1991), *KL Butterfly Park*,
	University-based and community focussed activities	MMC, BEM, BAM, BSM, DCA, Malaysian Veterinary Council
	Professional registration and regulatory authorities	
	Learned societies; professional and scientific asssociations	MMA, IEM, PAM, BIM, ISM, Malaysian Dental Association, Veterinary Association Malaysia, Malaysian Pharmaceutical Society, Yayasan Angkasawan Malaysia, Malaysian Association of Medical Physics, Institute Physics Malaysia, Malaysian Scientific Association, Malaysian Society for Engineering & Technology, Malaysian National Computer Confederation, Persatuan Geologi Malaysia, Malaysian Society of Applied Biology, and others
10	Smart Partnership Practices — Frameweork for Co-operation / Collaboration	*Smart Partnership Dialogues, MIGHT Consultation(1994),Langkawi International Dialogue (1995, 1996, 1997, 1999, 2000, 2002, 2004, 2007, 2009, 2011), National Smart Partnership Dialogues*

Note: items in red are entities introduced during Tun Dr Mahathir's premiership.

BIBLIOGRAPHY

Arnot, C 2002, 'The Kumar at no. 10', The Guardian Education 4 June.

Academy of Sciences Malaysia 1997, 'Harnessing science and technology for the Seventh Malaysia plan', ASM, Kuala Lumpur.

Academy of Sciences Malaysia 2000, 'Popularisation of Science and Technology in Malaysia', ASM, Kuala Lumpur.

Pawanchik, A. & Sulaiman, S. 2010, Leading innovations. embedding innovation culture in Malaysian organisations, Alpha Catalyst Consulting, Kuala Lumpur.

Barrell, A, Heriot, W & Mitchell, R 1992, How to profit from innovation, Director Books, Cambridge, UK.

Christensen, C M 1997, The Innovator's Dilemma : When New Technologies Cause Great Firms to Fail, Harvard Business Press.

Commonwealth Partnership for Technology Management 1997, Leading the way to commonwealth prosperity through "Smart Partnership" in technology management, CPTM, London.

Commonwealth Partnership for Technology Management 1998, Limitless Opportunities Through Smart Partnership,CPTM, London.

Commonwealth Partnership for Technology Management 2007, 'The Gabarone Get Together on National Visions, 10–11 June 2007', CPTM, London.

Commonwealth Partnership for Technology Management 2009, The CPTM Way – Smart Partnership Dialogues for Development and Transformation, CPTM, London.

Commonwealth Secretariat 1984, Expert Group Report on Managing Technological Change – Enhancing the Benefits, Commonwealth Secretariat, London.

Cradle fund Malaysia, <www.cradle.com.my>.

Cooperative Research Centres, Programmes – Directory 2011–12; Government of Australia, Canbera.

Economic Planning Unit 2004, Handbook: Economic Instruments for Environmental Management of Malaysia, Government of Malaysia.

Howard, G 2007, Five Minds for The Future, Havard Business Review Press.

Gault, F & Huttner, S 2008, 'A Cat's Cradle for Policy', Nature, vol. 455, pp. 462–463.

Golden, WT 1990, Worldwide Science and Technology Advice, Pergamon.

Groysberg, B, McLean, AW & Nohria, N 2006, 'Are Leaders Portable?', Harvard Business Review, May 2006.

Harris, M & Halkett, R 2007, Hidden Innovation, National Endowment for Science, Technology and the Arts, London.

UNESCO-Malaysia International S&T Centre for South-South Cooperation (ISTIC), <www.istic-unesco.org>.

Kao, J 2007, Innovation Nation, Free Press (Simon & Schuster Inc.).

A, King 2006, Let the Cat Turn Around, Commonwealth Partnership for Technology Management, London.

Kritayakirana, K 1989, 'Technological Capability for Emerging Economies: A Survey of Thai Industries, in 2nd Asean Science and Technology Week, Manila.

Leadbeater, C 2006, The Ten Habits of Mass Innovation; National Endowment for Science, Technology and the Arts, London.

Mahathir Mohamad 1991, 'Malaysia the Way Forward', Center for Economic Research and Services, Malaysian Business Council, Kuala Lumpur.

Malaysian Venture Capital Management Sdn Bhd, <www.mavcap.com.my>.

Malaysia Industry-Government Group for High Technology (MIGHT) 1993, Document on the launching of MIGHT.

Malaysia Industry-Government Group for High Technology 2012, Annual Report 2011.

Malaysian Invention and Design Society (MINDS) 2012, Transformation Through Invention, A Short History of MINDS, Kuala Lumpur.

Ministry of Business, Innovation and Employment, New Zealand, <www.mbie.govt.nz>.

Ministry of Science, Technology and Environment 1996, The National Science and Technology Policy, MOSTE, Kuala Lumpur.

Ministry of Science, Technology and Environment 2003, The Second National Science and Technology Policy and Plan of Action, MOSTE, Kuala Lumpur.
Modal Perdana (Malaysia), <www.modalperdana.com>.
Malaysian Technology Development Corporation, <www.mtdc.com.my>.

Malaysian Toray Science Foundation, <www.mstf.org>.

National Institute of Science, Communication and Information Resources 2011, Scientific Temper Statement Revisited, The Palampur Declaration, Council of Scientific and Industrial Research, New Delhi.

National Economic Advisory Council 2010, New Economic Model for Malaysian, Part I, NEAC, Malaysia.

National Endowment for Science, Technology and the Arts 2010, Knowledge bank, 2nd edn, London.

New Zealand Forestry 1993, Industry Profile — NZ Logging Industry Research Organization.

Omar Abdul Rahman 1991, 'Achieving the Industrial Targets of Vision 2020 — The Science and Technology Perspective', in Proceedings of the National Seminar: Towards A Developed and Industrial Society, Understanding the Concept, Implications and Challenges of Vision 2020, Economic Planning Unit, Kuala Lumpur.

Omar Abdul Rahman 2000, 'Competitiveness in the knowledge - driven economy', A Briefing on the Proposal for A Policy Response, Office of the Science Advisor, Putrajaya.

Omar Abdul Rahman & Yew KK 2005, 'Forging Creativity, Innovation and Technopreneurship Agenda for OIC Countries', in Proceedings, 4th IAS Science Conference, Kuala Lumpur, pp. 179–189.

Omar Abdul Rahman 2006, Memo to the Minister of Higher Education on Holistic Human Capital Development.

Omar Abdul Rahman 2007, 'Managing the STI value-chain for wealth creation', in International Symposium on STI, Academy of Sciences Malaysia, Kuala Lumpur.

Omar Abdul Rahman 2010, 'Some thoughts on the STI policy considerations for the New Economic Model (NEM), ASM International Conference, wealth creation management STI - creating the environment for technology-based innovation, in ASM International Conference, Kuala Lumpur.

Omar Abdul Rahman 2011, 'Making the Third Science Policy Work', ASM Science Journal, vol. 5, no. 1, pp. 71–72.

Osterwalder, A & Pigneur 2010, Business Model Generation, Wiley.

Ridderstrale, J 2006, 'Knowledge is No Longer Power', World Business, May 2006.

Ronayne, J 1984, Science in Government, Edward Arnold, Australia.

Stads, GT, Tawang, A & Beintuma, NM 2005, Agricultural Science and Technology Indicators Country Brief.

Stahl, MJ & Dunne, EJ 1984, 'Project and Matrix Organization in Research, Development and Engineering', in Modern Management Techniques in Engineering and R&D, Van Nostrand Reinbold, New York.

Stoneman, P 2009, 'Soft Innovation - Towards a More Complete Picture of Innovative Change', National Endowment for Science, Technology and the Arts, London.

Tsu, D 2013, 'Critical Factors for Global Competitiveness', in ASM International Conference, STI for Socio Economic Transformation - Strategic Drivers for High Income Economy, Kuala Lumpur.

Tucker, RB 2008, Driving Growth Through Innovation, Berrett-Koehler Pub., San Francisco.

Tucker, RB 2010, Innovations is Everybody's Business, Innovation Resource Publication, Santa Barbara.

UK Technology Strategy Board (UKTSB), <www.innovateuk.org>.

United Nations Development Programme (UNDP) 1998, Technology Atlas, vol. 6, APCCT, Bangalore.

UN Millenium Development Project 2005, Taskforce Report "Innovation : Applying Knowledge in Development", New York.

United Nations Environmental Program (UNEP) Report 2010, Overview of The Republic of Korea's National Strategy for Green Growth.

Verloop, J 2008, 'Emergent Innovation, EMPI', J. Interdisciplinary Perspectives, vol. 2, no. 2.

Wissema, JE 2009, Towards the Third Generation University, Edward Elger, UK.

ACRONYMS

ASM – Academy of Sciences Malaysia

CPTM – Commonwealth Partnership for Technology Management

CRC – Cooperative Research Centre

COMEST – UNESCO's World Commission on the Ethics of Scientific Knowledge and Technology

COMSTECH – Ministerial Standing Committee on Scientific and Technological Cooperation of the OIC

CTRM – Composites Technology (Research) Malaysia Sdn Bhd

EPP – Entry Point Projects (Malaysia)

ETP – Economic Transformation Programme

FAFAS – Federation of Asian Scientific Academies and Societies

HHC – Holistic Human Capital

IP – Intellectual Property

IPO – Initial public offer

ISTIC – The International Centre for South-South Cooperation in Science, Technology and Innovation

KPI – Key Performance Indicator

MBIE – Ministry of Business, Innovation and Employment, New Zealand

MIGHT – Malaysian Industry-Government Group for High Technology

MIMOS – Malaysian Institute of Microelectronics Systems

MOSTI – Ministry of Science, Technology and Innovation, Malaysia

MTSF – Malaysia Toray Science Foundation

NEM – New Economic Model (Malaysia)
NESTA – National Endowment for Science, Technology and the Arts (UK)

NKEA – National Key Economic Areas (Malaysia)

NSC – National Science Center

ODM – Origal Design Manufacturer

OEM – Original Equipment Manufacturer

OIC – Organization of Islamic Cooperation

RD&C – Research, Development and Commercialisation.

RD&E – Research, Development and Engineering

SET – Socio-economic Transformation

SRI – Strategic Reform Initiative (Malaysia)

SRI International – Stanford Research Institute International, USA.

S&T – Science and Technology

STI – Science, Technology and Innovation

TM – Technology Management

TNC – Total National Capacity

TWAS – Academy of Sciences for the Developing World

UKTSB – United Kingdom Technology Strategy Board

UNCSTD – United Nations Committee on Science and Technology for Development

UNEP – United Nations Environmental Program

UPM – Universiti Putra Malaysia

VCC – Venture Capital Company

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