Sustaining
Innovation-Driven
Growth

2006 2007 2008 2009

Science & Technology

Plan 2010

Published February 2006

ISBN: 981-05-5335-8

Printed by SNP Security Printing Pte Ltd


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FOREWORD

SINGAPORE is at an exciting phase of growth as we face new challenges to sustain economic growth and prosperity. While we will continue to build on our existing strengths of an efficient workforce, clean government and world-class infrastructure, we need new strategies to differentiate ourselves and develop peaks of excellence in selected areas where we can build a sustainable comparative advantage. We should leverage on our tradition of excellence in science, mathematics and technology to grow a strong base of scientists, researchers and technologists who will provide the leadership in the next phase of knowledge- and innovation-driven growth.

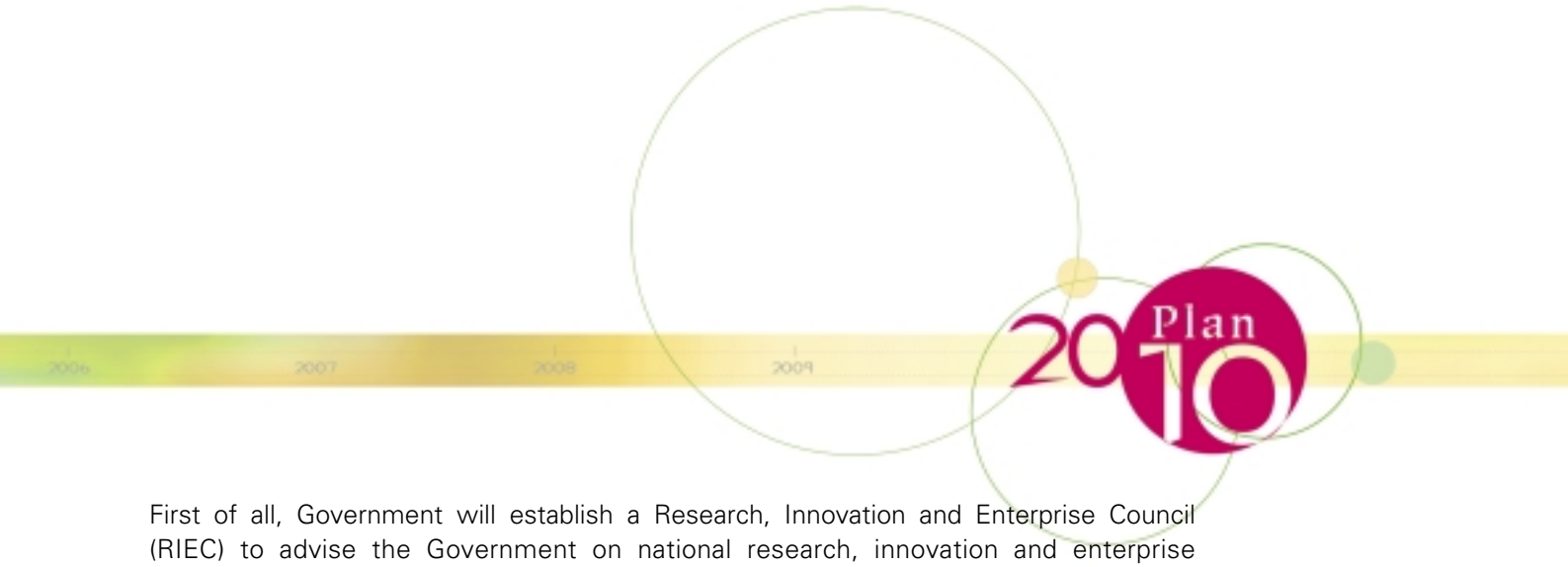
Back in 1991, the National Technology Plan was formulated to steer the development of science and technology in Singapore, with the aim of enhancing our economic competitiveness. With a funding of $2 billion over 5 years, its implementation by the National Science and Technology Board placed Singapore on the path of rapid technological growth. We have not looked back since.

Our second 5-year plan, the National Science and Technology Plan, helped to bring Singapore closer to having world-class science and technology capability; with $4 billion set aside to strengthen manpower, support for industry research and development (R&D) and indigenous R&D capability.

The current Science and Technology (S&T) Plan 2005, our third national 5-year plan, builds on the groundwork of the first two Plans. It focused on strengthening R&D capabilities in niche areas, nurturing local talent and recruiting global talent, and working with industry through technology transfer and other mechanisms. Its $6 billion budget included $4 billion to A*STAR to boost local R&D capabilities, and $2 billion to EDB to promote private sector R&D in Singapore.

Over the three national S&T plans, our Gross Expenditure on R&D (GERD) as a percentage of GDP has increased from 0.85% in 1990 to 2.25% in 2004. The number of Research Scientists and Engineers in Singapore has grown significantly, from 28 in 1990 to 87 per 10,000 labour force in 2004. We have made significant strides in building up our scientific and research manpower base; by developing home-grown talent as well as by attracting talent from abroad.

In August 2004, the Ministerial Committee on Research & Development (MCRD), chaired by then-Deputy Prime Minister Dr Tony Tan, was formed to review the R&D strategies and direction for Singapore. The MCRD, after extensive deliberations and consultations, has identified five key strategic thrusts to drive Singapore's R&D efforts. The recommendations have been approved by Government.



First of all, Government will establish a Research, Innovation and Enterprise Council (RIEC) to advise the Government on national research, innovation and enterprise strategies. The RIEC will be chaired by the Prime Minister and will comprise Cabinet Ministers, prominent captains of industry, and internationally renowned individuals from the scientific and academic community. A new department under the Prime Minister's Office, called the National Research Foundation (NRF), was formed on 1 January 2006 to support the RIEC, to implement the key strategic R&D thrusts, to provide a coherent strategic overview of R&D at the national level, and to allocate funding to longer term R&D programmes.

Government will be making significant investments in growing R&D in the next 5 years, earmarking $13.55 billion to different agencies to promote R&D. Of this, $5 billion will be allocated to the NRF for longer-term strategic programmes, $7.5 billion to the Ministry of Trade and Industry for economic-oriented R&D and related investment promotion activities, and $1.05 billion to the Ministry of Education for academic research. The goal is to achieve a GERD of 3% of GDP by 2010.

Secondly, the focus will be on identifying and developing selected R&D areas of economic importance where Singapore can be internationally competitive. This is important as we are a small country and must concentrate our limited resources to develop peaks of excellence. In general, R&D funding will be directed to selected areas where there is most potential for scientific breakthroughs to yield economic benefit for Singapore, by generating industry growth and enterprise creation. Two new areas that have been identified as having rapid growth potential are the Environmental and Water Technologies sector and the Interactive and Digital Media sector. Together with the Life Sciences sector which is a relatively new sector that has seen rapid growth since it was identified in 2000, we expect to double the jobs in these sectors to 80,000 and to triple the value added to $27 billion by 2015. The NRF will continue to identify promising new economic sectors to promote.

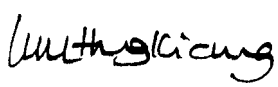
Thirdly, within the selected strategic areas, we will develop the whole spectrum of research capabilities, from basic research to build the foundation for scientific excellence, to mission-oriented research with better integration into industry. We will encourage a broad diversity of views so that scientists and researchers at the universities and public research institutions will have adequate resources to pursue new knowledge and thrive in a vibrant and challenging environment.

Fourthly, we will focus on growing the private sector share of R&D. Corporations are best placed to decide which areas of R&D to invest in, and to align R&D investments with commercial opportunities. Encouraging global R&D centres that are at the forefront of research and technological developments in their respective fields to invest in Singapore will be important. We encourage talented scientists and researchers to flow between academia, public research institutions and industry in open collaborative networks.

Lastly, we will strengthen the linkages between R&D and business. Focus will be on creating technology transfer frameworks to help push new knowledge and technologies to enterprises. We will develop stronger co-funding frameworks between industry and public education and research institutions, with the objective of leveraging on public sector resources to strengthen innovation in the private sector and to uplift technological and manpower capabilities in enterprises.

The Science and Technology Plan 2010 is the culmination of many months of extensive discussion and brainstorming by a wide cross-section of agencies, including universities, research institutions and hospitals. Some 450 researchers participated in thirteen technology scan panels set up to identify new and emerging technology areas that could enhance Singapore's competitiveness. Views were sought from eminent scientists, experts and leaders from the research community and industry, both locally and overseas. Special attention was given to ensure that the technology plans are aligned with industry development plans. The development of the Plan is made possible by the dedicated efforts of the S&T2010 Steering Committee, ably led by A*STAR and with the active and valuable contributions of many member representatives from ministries and agencies.

The Science and Technology Plan 2010 will anchor our transition into a knowledge- and innovation-driven economy. This will help to fulfil the strategic thrusts identified above, which are critical in enabling us to achieve a sustainable competitive advantage for long term growth and prosperity.



Lim Hng Kiang
Minister for Trade and Industry
Singapore

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EXECUTIVE SUMMARY

WE live in an increasingly competitive and integrated global economy. The rise of the knowledge economy and the rapid growth of large emerging economies have changed the global economic landscape dramatically bringing with it both increased growth opportunities and competition. While Singapore will continue to leverage on its existing strengths of an efficient workforce, clean government and world-class infrastructure, these will not be sufficient to sustain our competitiveness and secure our long-term growth. Singapore must leverage on innovation and R&D to transform its economy and raise it to the next level. We need to build our capabilities for research, innovation and enterprise, and develop peaks of excellence in niche areas where we can sustain an advantage.

Review of Science & Technology Plan 2005

Singapore launched its first five-year Science and Technology (S&T) plan, the National Technology Plan (NTP), in 1991. The $2 billion NTP was implemented by the then National Science and Technology Board (NSTB) with the aim of driving the development of science and technology in Singapore. In 1996, the NTP was succeeded by our second five-year S&T plan, the National Science and Technology Plan, with a $4 billion budget to strengthen Singapore's key enabling factors of manpower, support for industry R&D and indigenous R&D capability.

The S&T Plan 2005 (S&T2005) is our third national five-year plan. It built on the groundwork of the first two S&T plans and focused on strengthening R&D capabilities in niche areas, nurturing local talent and recruiting global talent, establishing a system for technology transfer, and encouraging private sector R&D.

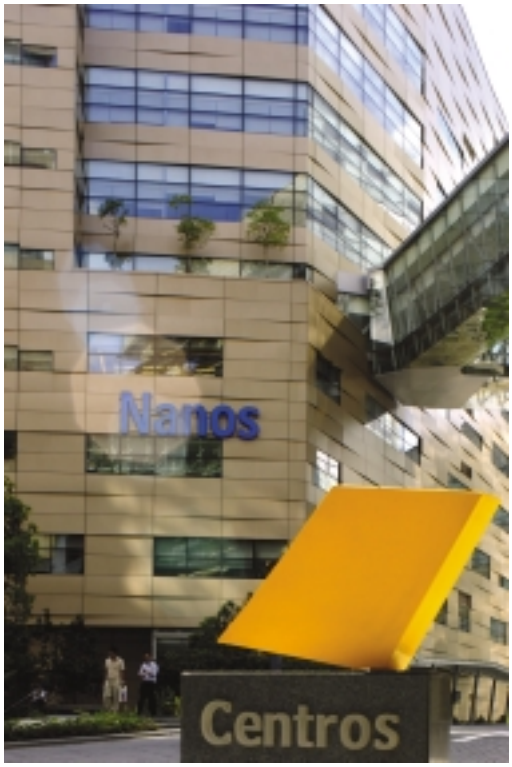
The $6 billion S&T2005 sought to develop Singapore's R&D base through the three thrusts of Human Capital Development, Intellectual Capital Development and Industrial Capital Development.

Under S&T2005, A*STAR developed our Human Capital for research and innovation through a range of scholarship and fellowship programmes targeted at young talent at various levels. It also attracted global talent, including renowned scientists and eminent researchers, to head its research institutes (RIs) and set up their research laboratories within its RIs.

Capabilities at the A*STAR RIs were streamlined and strengthened, with focus on the broad S&T areas relevant to advancing Singapore's economic goals, as part of building our Intellectual Capital. Significant efforts in the development of biomedical research capabilities at newly established RIs helped transform Singapore into a Biomedical Science hub. The base of high-quality researchers at the RIs has grown in tandem to a critical mass of research talent with the potential to carry out impactful research work of international standards. Inter-RI research collaborations were forged to tap on opportunities in multi-disciplinary research, while A*STAR's interactions with the extramural community have also intensified through its extramural grant calls.

In Industrial Capital Development, A*STAR and its RIs have stepped up international industry promotion activities with EDB, showcasing Singapore's R&D capabilities and manpower, to attract new investments to Singapore. In the biomedical sector, an integrated framework involving the two agencies has been put in place to grow the industry, and has successfully drawn several major R&D investments in the form of flagship R&D centres by global firms such as Novartis and GlaxoSmithKline. In science and engineering, A*STAR has similarly worked with EDB to attract major private R&D activities to Singapore through its strategy of holistically integrating the RIs' capabilities to meet industry needs. It has provided technical assistance and manpower to help improve the technology capabilities and global competitiveness of the local enterprises.

The opening of the Biopolis was a major milestone under S&T2005. The Biopolis offers purpose-built state-of-the-art facilities, and co-locates A*STAR's biomedical RIs and private R&D companies to foster intellectual and industrial exchange between them. The Biopolis is almost at full occupancy and Phase 2 construction to expand its capacity has commenced. The Fusionpolis, currently under construction, will be the focal point of the Infocomms and Media community.



Singapore has made good progress under S&T2005. We have improved on the various R&D indicators, notwithstanding the economic slowdown in 2001-2003, and the shock events of Sep 11 and SARS, which had affected private sector R&D spending.

Between 2000 and 2004, Singapore's Gross Expenditure on R&D (GERD) rose from 1.89% to 2.25% of GDP. Private sector share of GERD increased from 62.2% to 63.8%. The number of research scientists and engineers (RSEs) per 10,000 labour force increased significantly from 66 to 87, while the percentage of postgraduates among RSEs remained at about 47%.

From 2001 to 2005, EDB attracted $8.5 billion in total R&D investment, and created more than 6.400 RSE positions.

Economic Challenges Ahead

Since independence, Singapore has continued to sustain its economic growth by moving up the value-chain - from labour-intensive to capital-intensive and now knowledge-intensive industries - and staying ahead of competition.

Going forward, Singapore's economic strategies must keep up with the changing global economic landscape. Singapore must continue its process of upgrading and renewal to ensure that we remain competitive in a global knowledge economy. We need to develop our innovation capacity as a new, sustainable source of competitive advantage. Given our strengths in science and mathematics, Singapore is naturally positioned to excel in S&T.

To succeed, talent will be key. Singapore must become a global talent hub, attracting talent here by providing a vibrant environment and an open society that offer opportunities for communities of creative and talented people.

Strategic Directions for S&T Policy (2006 – 2010)

In August 2004, the Ministerial Committee on Research and Development (MCRD), chaired by then Deputy Prime Minister Dr Tony Tan, was formed to review Singapore's R&D strategies and direction. The MCRD visited public and private R&D institutions in Singapore, as well as a number of small but economically advanced economies to study how they organized themselves to achieve good economic growth and sustain strong S&T performance.

The MCRD concluded from its visits that Singapore needs to refocus its research and innovation agenda to keep up with international developments. Singapore must push on to transform itself into an innovation-driven economy that competes on knowledge and talent.

The MCRD identified five key strategic thrusts to guide Singapore's R&D efforts:

(i) More resources for R&D and continued high level attention on R&D;

(ii) Focus on selected areas of economic importance;

(iii) Balance of investigator-led and mission-oriented research;

(iv) Encourage more private sector R&D; and

(v) Strengthen linkages between R&D and business.

National R&D Framework

The MCRD also outlined a national R&D framework to implement the key strategic thrusts. The new Research, Innovation and Enterprise Council (RIEC), chaired by the Prime Minister, will lead the national drive to promote knowledge creation, innovation and enterprise. It will be supported by the new National Research Foundation (NRF), which will also fund longer term strategic research programmes, and provide a coherent strategic overview at the national level to coordinate the research of various Government agencies. The national R&D system (excluding defence) will be organized mainly along two tracks, with the Ministry of Trade and Industry (MTI) driving mission-oriented research through A*STAR, EDB, and SPRING, and the Ministry of Education overseeing academic, investigator-led research through the universities and polytechnics.

Enabling Technology Environment for Sustained Industry Growth

In line with the strategic thrusts, Singapore must focus on differentiating itself as a compelling investment location and achieving leadership positions in niche areas within its industry clusters. Singapore's strong manufacturing and technology base will help it to attract cutting edge R&D activities which in turn will attract and anchor higher value-added industrial activities. At the same time, Singapore will continue to pursue new growth areas, augmented by well-organized S&T efforts.

The priorities for public research over the next 5 years have been developed, and aligned to EDB's Manufacturing 2018 Plan. The priorities were identified through a planning process that involved experts and leaders from the research community and industry in Singapore and abroad, as well as key agencies and ministries. It covered wide-ranging technology scans and the assessment of future S&T infrastructure needs, among other perspectives.

Within public research, A*STAR will focus efforts and resources to build internationally competitive concentrations of R&D in areas that are most relevant to the development of key industry sectors.

The BMRC will continue to deepen the basic core capabilities of its RIs to support Singapore's growing BMS industry and to strengthen its translational competencies to bridge the gap between basic science and clinical applications. The BMRC will optimize limited resources by ensuring that bench research is driven by current and pertinent clinical needs. It will also continue to foster interactions amongst the basic and clinical scientists so as to extract the full potential of expertise available in Singapore.

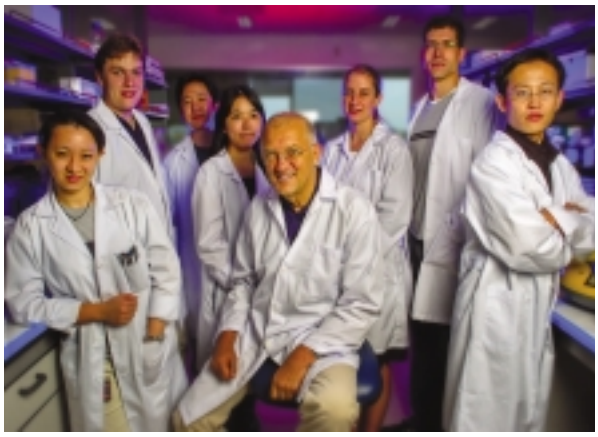
The SERC RIs will develop relevant technologies and capabilities to meet the needs of our key manufacturing industry sectors viz. Electronics, Infocomms and Media (ICM), Chemicals, and Engineering.

Developing and Managing R&D Human Capital

Talent will be the key to economic progress in the twenty-first century. In a global economy where talent flows freely between cities and countries, Singapore needs to be a global talent magnet. A ready and abundant supply of highly trained research manpower will attract knowledge-intensive industries. Investments will follow talent. Highly-trained manpower will also help our local enterprises to upgrade, move up the technology value-chain, and become more internationally competitive.

More RSEs will be needed to support the higher level of R&D activities that we aim to achieve. Educational institutions, especially at the tertiary level, will play important roles in providing a strong pipeline of high quality S&T graduates.

Within MTI, A*STAR will develop and sustain a substantial pipeline of research talent to meet industry needs. It is well-positioned to do so as its RIs conduct R&D activities to support the industry and are positioned close to the market to better understand and support industry needs. A*Star adopts a pro-foreign and pro-local talent recruitment policy. It aims to draw the best global talents to Singapore to meet its immediate needs for quality R&D manpower and to create a vibrant research community. It will also groom more of the brightest Singaporeans to pursue careers in research and assume leadership positions in the public research sector.



Building a strong base of quality local RSEs will provide stability to Singapore's human capital base and instill confidence in potential high-technology investors. In this regard, A*STAR targets to train 1,000 Singaporean PhDs. It will tap on various streams of R&D talent, through attachment, outreach, and scholarship programmes, at the Pre A-Levels, Post A-Levels and Postgraduate levels, to build its pipeline.

Promoting Private Sector R&D

Singapore must continue to intensify efforts to promote private sector R&D, as companies are better placed to decide on R&D investments. In the longer term, private sector R&D should make up two-thirds of GERD.

To raise the level of private sector R&D, Singapore must aim to anchor more flagship R&D projects and attract more multinational companies to locate corporate R&D activities in Singapore. The role of promoting industry R&D is largely driven by EDB. EDB will work closely with A*STAR RIs and the universities to promote R&D investments, so as to better engage companies at the technology level. Incentive and assistance schemes, such as the Research Incentive Scheme for Companies (RISC), will continue to support these promotion efforts.

A*STAR will expand linkages between public sector R&D and industry by directly supporting industrial innovation activities, providing/sharing R&D human capital and technical facilities, and undertaking development risks in the commercialisation of technology.

In addition, EDB will seek to attract private laboratories here to diversify our R&D sources such as from non-profit organizations, private foundations and private universities, to support long-term industry R&D growth.

Strengthening Technology Innovation Capabilities in SMEs

Strengthening technology innovation in SMEs would help to create a strong cluster of innovative enterprises that would support and hence attract higher value-added industries and private R&D activities.

SMEs hold great potential as a source of creativity and innovation. While SMEs understand the need to leverage on technology to compete in a knowledge-based economy, many of them lack the capability to absorb and deploy new technologies. The GET-Up programme was launched in 2003 to help enterprises undertake technology innovation.

Going forward, SPRING has identified three key strategies, within an SME Technology Innovation Framework, to support technology innovation in SMEs. First, SPRING will encourage SMEs to undertake technology innovation projects by raising their awareness of the importance of technology application and innovation and providing them with technology advisory and matching services. Second, SPRING will seek to enhance technological innovation capabilities in SMEs through the secondment of expert manpower, training of employees in SMEs, and partnerships with technology providers. Third, SPRING will support the development of technology infrastructure for SMEs, given SMEs' high dependence on external laboratory facilities for their technology needs.

Increasing Commercialisation of Public Research

A robust intellectual property (IP) framework offers protection for created knowledge and provides an equitable platform for such knowledge to be exploited commercially. It is a key infrastructure underpinning innovation and business growth.

Over the past years, Singapore has strengthened its IP legislation and enforcement mechanism, fostered greater IP awareness and capability development, and raised our profile in the international IP arena. The success of these efforts is reflected in Singapore's high international rankings in IP rights protection. Singapore's excellent IP regime has contributed to its attractiveness as an investment location and IP hub, and supported its efforts to increase the level of R&D in Singapore.

In particular, public research organizations (PROs) are an important source of IP which can be taken to the market to create value and wealth for Singapore. This will require PROs to view commercialisation as a core activity alongside research, with incentive and funding models that recognize the risks and time it takes to commercialise research successfully. This must be underpinned by clear policies on IP ownership, use, and exploitation. For instance, PROs can use incentive policies to encourage researchers to commercialise their research, and invest

in proper commercialisation management systems, as well as technology validation and proof-of-concept activities.

PROs also need to make available early stage funding for commercialisation. For instance, A*STAR Exploit Technologies' Commercialisation of Technology (COT) Fund was set up to bridge this funding gap. To promote the take-up of public IP, Exploit Technologies will continue efforts to promote awareness of public research technologies and the benefits of technology licensing and upgrading, in particular among local enterprises.

R&D Infrastructure

Singapore has created an attractive research collaboration environment in the Biopolis, with high quality facilities to support research and technology activities. Such an environment is important in attracting foreign companies and global talent to conduct research in Singapore.

In the same way, the Fusionpolis is being developed as the focal point for the ICM cluster as well as the physical sciences and engineering. By housing both public and private research and creating the necessary synergies between public research and industry, the Fusionpolis will be a cradle for knowledge convergence, where next generation applications are incubated and test-bedded.

Budget and Targets

Over the next 5 years, $13.55 billion will be spent on R&D to drive Singapore's transformation into an R&D and innovation-driven economy. $5 billion will go towards the NRF to fund new growth areas and strategic programmes; $1.05 billion to support MOE's drive to promote academic and investigator-led research; and $7.5 billion to support MTI in promoting mission-oriented R&D.

MTI's $7.5 billion R&D budget will be used to support the 5-year S&T Plan 2010 from 2006 to 2010. 63% will go towards supporting A*STAR's intramural and extramural research activities; 28% towards private sector R&D; 6% for talent development through various A*STAR scholarships and fellowship grants; and 3% on the development of research infrastructure.

At the national level, Singapore aims to increase GERD to 3% of GDP within the next five years, so as to close the gap with other leading innovative countries; to increase private sector R&D to two-thirds of GERD in the longer term; and to increase the research manpower to support our R&D thrusts and sustain the higher levels of R&D in Singapore.

REVIEW OF SCIENCE AND TECHNOLOGY PLAN 2005

SCIENCE & TECHNOLOGY PLANS

Singapore began a major drive to raise technological capabilities to enhance its economic competitiveness in 1991, with the set up of the then-National Science & Technology Board (NSTB) and the development of the first 5-year science and technology (S&T), the National Technology Plan (NTP, 1991-1995). The NTP, with a budget of $2 billion, led to the establishment of research institutes and centres, technical infrastructure, manpower development programmes, industry R&D grants and innovation support schemes.

The second 5-year S&T Plan, the National Science and Technology Plan (NSTP, 1996-2000), with a $4 billion budget, continued the efforts of the NTP. The current Science and Technology Plan 2005 (S&T2005, 2001-2005) is the third 5-year national S&T plan.

• S&T PLAN 2005

S&T2005 built on the groundwork of the first two S&T plans. It focused on strengthening R&D capabilities in targeted areas, nurturing local talent and recruiting global talent, and promoting industry.

S&T2005 had a $6 billion budget. Of this, $4 billion was managed by A*STAR to develop public R&D. This comprised intramural research at the A*STAR Research Institutes (RIs) and extramural research funding to other research organisations in the public sector, in particular the universities and hospitals. The remaining $2 billion was managed by EDB to co-fund industry R&D.

The plan had six key objectives:

- Nurture local talent and recruit global talent;
- Strengthen R&D capabilities in niche areas;
- Encourage private sector R&D;
- Build up institutions to prioritise and manage public R&D;
- Establish a system for technology transfer and the management of intellectual property; and
- Develop strong international relationships.

Major research initiatives introduced in S&T2005 have transformed and shaped the R&D landscape in Singapore. The 3 main thrusts of S&T2005 were:

- Human Capital Development;
- Intellectual Capital Development; and
- Industrial Capital Development.

These thrusts are centred on enhancing Singapore's talent and knowledge base to support economic growth and job creation in biomedical sciences and the physical sciences and engineering.

• Human Capital Development

A*STAR has established scholarship and fellowship schemes to train young talent at the undergraduate and post-graduate levels.

A*STAR launched the National Science Scholarships (NSS) in 2001 and the A*STAR Graduate Scholarships (AGS) in 2003, to build a pipeline of trained researchers for Singapore.

The NSS supports both undergraduate and postgraduate studies at leading overseas universities, as well as a year of attachment at the A*STAR RIs between the undergraduate and graduate programmes. A*STAR scholars return to take up R&D positions in the research institutes, and eventually flow out to industry.

A pastoral care programme has also been established to maintain close relationships and strong linkages with these scholars through their studies overseas.

Under the AGS programme, A*STAR partners top universities to jointly train researchers at the PhD-level. The AGS programme has two components. AGS (Local) is a collaboration with the National University of Singapore (NUS) and the Nanyang Technological University (NTU). Under AGS (Foreign), A*STAR has established partnerships with top overseas universities such as Imperial College London, the University of Illinois at Urbana-Champaign, Sweden's Karolinska Institutet and Scotland's University of Dundee.

A*STAR has also put in place the International Fellowship programme to provide funding support to medical doctors to train to become clinician-scientists.

A*STAR has awarded 460 scholarships and fellowships under the NSS and AGS programmes as at June 2005.

RESTRUCTURING OF A*STAR

*In 2001, the former National Science & Technology Board (NSTB) was restructured to form the Agency for Science, Technology and Research (A*STAR) to better reflect Singapore's emphasis on the creation and exploitation of intellectual capital and the training of research manpower in its transition to a Knowledge-Based Economy.*

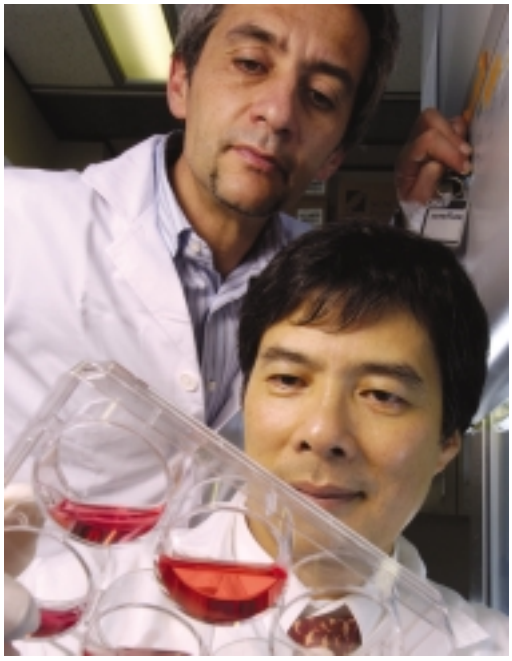
Four organisational units were established to help advance the development of Human, Intellectual and Industrial Capital:

- *Two research councils, viz. the Biomedical Research Council (BMRC) and the Science & Engineering Research Council (SERC) to support, direct and stimulate quality research in selected disciplines of science, engineering and biomedicine;*
- *A*STAR Graduate Academy (A*GA) to implement A*STAR's scholarship programmes to create and sustain a diverse and critical mass of PhD talent to meet Singapore's R&D manpower needs; and*
- *Exploit Technologies Pte Ltd, a wholly-owned subsidiary of A*STAR to manage intellectual property and technology transfer.*

The scholarship and fellowship programmes are supplemented by A*STAR's Youth Science Outreach programme. This programme was established to increase the exposure of our school students at both the primary and secondary levels to a broad range of scientific and research activities, with the aim of cultivating in them an interest in science and technology. It aims to encourage more of our bright young talent to choose R&D careers.

A*STAR has continued to attract renowned scientists and top international talent to Singapore. Some of these eminent researchers now head the A*STAR research institutes. Prof Edison Liu, formerly the Director of Clinical Research at the National Cancer Institute, National Institutes of Health in the US, is currently the Executive Director of the Genome Institute of Singapore (GIS). Prof Sir David Lane, the world-renowned discoverer of the p53 gene and professor at Dundee University, is the Executive Director of the Institute of Molecular and Cell Biology (IMCB). Prof Jackie Ying, a professor at the Massachusetts Institute of Technology, is the Executive Director of the Institute of Bioengineering and Nanotechnology (IBN). Prof Dim-Lee Kwong, a professor at the University of Texas, Austin, is the Executive Director of the Institute of Microelectronics (IME). Dr Keith Carpenter was recruited from the major chemicals company Syngenta to be the Executive Director of the Institute of Chemical and Engineering Sciences (ICES).

Other eminent scientists have been recruited to spearhead key research programmes in Singapore. Dr Sydney Brenner, Nobel Laureate and Distinguished Professor at the Salk Institute, is a member of the A*STAR Board and Chairman of the Biomedical Research Council, as well as a member of the Biomedical Sciences International Advisory Council (BMS IAC). He leads the Genetic Medicine Laboratory at the Centre for Molecular Medicine (CMM). Prof Sir George Radda, Professor and



Chairman of the Department of Physiology, Anatomy and Genetics at the University of Oxford, is a member of the BMRC Board and is an emeritus member of the BMS IAC. Sir George chairs the Singapore Bioimaging Consortium. Prof Axel Ullrich, the Director of the Department of Molecular Biology at the Max-Planck-Institute for Biochemistry in Martinsried, Germany, leads the Singapore OncoGenome Project at the CMM. Prof Lady Birgitte Lane, formerly of the University of Dundee, is a Principal Investigator at the CMM, leading a research team in epithelial cell biology.

Leading cancer geneticists, Dr Neal Copeland and Dr Nancy Jenkins, a husband-and-wife team, were recruited from the US National Cancer Institute (NCI) to IMCB to lead a research team using the mouse genome to study human diseases. Renowned Japanese cancer expert Dr Yoshiaki Ito moved to IMCB from Kyoto University, along with his team of nine researchers. They are conducting research on stomach cancer, a disease afflicting many in the region. Prof Ito also heads the NUS's Oncology Research Institute. Top chemical synthesis and chemical biology research scientist at the Scripps Research Institute, Prof Kyriacos

Costa (KC) Nicolaou was tapped on to help build Singapore's capabilities in chemicals synthesis. He directs the Chemical Synthesis Laboratory at the Biopolis.

SERC established the Visiting Investigatorship Programme to bring top scientists to Singapore to help develop new capabilities in key areas. Prof Nico De Rooij from Switzerland's University of Neuchatel is spearheading efforts in the area of MicroElectro Mechanical Systems and NanoElectro Mechanical Systems (MEMS/NEMS) at the Singapore Institute of Manufacturing Technologies (SIMTech). Prof Ananth Dodabalapur from the University of Texas at Austin is Visiting Investigator in the area of plastic electronics at the Institute of Materials Research and Engineering (IMRE). Prof Christian Joachim, of the French National Centre for Scientific Research (CNRS), has helped to establish a new research programme on atomic and molecular devices at IMRE. Prof David Srolovitz, from Princeton University, was invited by IMRE and the Institute of High Performance Computing (IHPC) to lead a project in new areas of computational materials science.

• Intellectual Capital Development

Capabilities at the A*STAR RIs have been streamlined and strengthened focusing on the broad scientific and technological areas relevant to advancing Singapore's economic development goals.

Significant efforts have been dedicated to transforming Singapore into a Biomedical Sciences hub. Research capabilities in genomics, bioinformatics, and bioengineering and nanotechnology are being developed at three newly-established RIs: the Genome Institute of Singapore, the Bioinformatics Institute, and the Institute of Bioengineering and Nanotechnology. In addition, A*STAR has established the CMM, focusing on translational research, to bridge the gap between basic science and clinical medicine.

ICES was established to add chemicals research to the spectrum of core capabilities. ICES is located in the chemicals hub on Jurong Island.

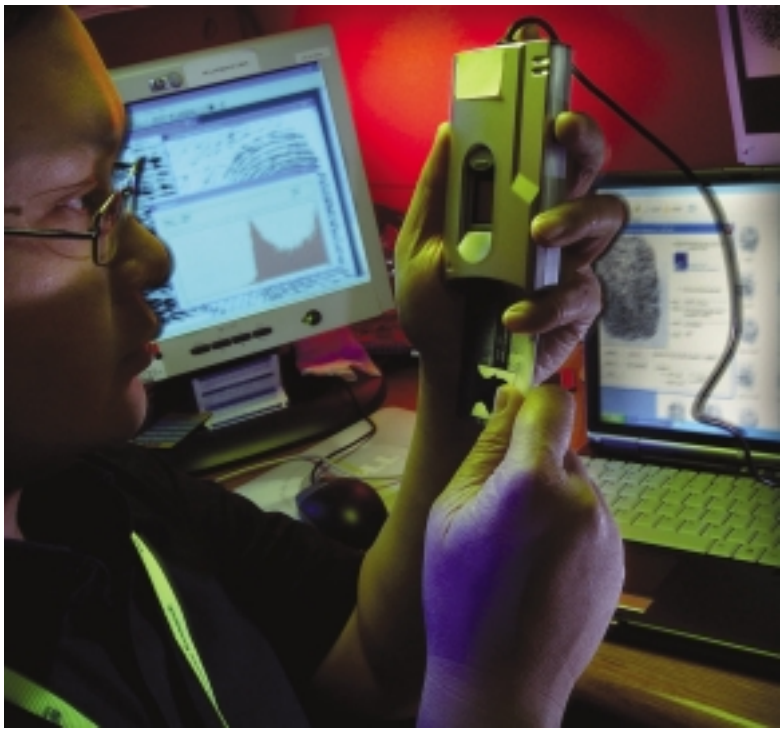
Some RIs have been restructured. The Institute of Molecular Agrobiology was reorganized so as not to overly diversify resources in research. Its biomedical-related research groups were merged with the IMCB, while its agrobiology-focused groups were spun off as the Temasek Life Science Laboratory, a non-profit organization funded by Temasek Holdings. The Institute for Infocomm Research (I^2R) was formed through the merger of Kent Ridge Digital Laboratories, the Centre for Wireless Communications, the Centre for Signal Processing and elements of NTU's Network Technology Research Centre, to harness the benefits of related research activities in Information and Communication Technology. The Institute of Microelectronics consolidated its 6- and 8-inch Deep Sub-micron Integrated Circuit facilities to better align to industry requirements. The Bioprocessing Technology Centre was upgraded to a full Institute when its research activities increased in scale and scope. The institute's Bioprocessing Manufacturing Technology Centre (BMTC) was spun off to A-Bio, a local biologics contract manufacturing company, in 2002.

A*STAR has built a critical mass of research talent at the RIs capable of carrying out impactful and internationally competitive research. From 2001 to 2005, the A*STAR RIs produced some 6,790 scientific publications in Science Citation Index and Engineering Index journals, and filed 739 patents.

In addition to managing the RIs, the two research councils have established the necessary structures and processes to fund extramural research in the wider research community. Mechanisms have been put in place to prioritise research areas, implement peer review of research proposals and coordinate activities across research institutions.

Cross-Council and inter-RI research collaborations are increasingly being forged to tap on the emerging opportunities in multi-disciplinary areas. For example, the Chemical Synthesis Laboratory in the Biopolis is an initiative that draws expertise from both BMRC and SERC RIs to build technology platforms for new drug therapies.

A*STAR's interactions with the extramural community, in particular the universities, hospitals and disease centres, have intensified. Since 2004, BMRC and the Ministry of Health's National Medical



Research Council (NMRC) have established a joint grant call for research proposals. This integrated approach will foster closer linkages across the spectrum from basic to translational and clinical research. More recently, BMRC has directed resources towards translational research to bridge the gap between laboratory research (bench) and clinical applications (bedside), and closer engagement with the hospitals and disease centres. As part of these efforts, the Clinician-Scientist Investigatorship programme was launched in 2005 to provide funding support to enable medical doctors to devote more time to translational research.

- **Industrial Capital Development**

BMRC and SERC, together with their RIs, have stepped up international industry promotion activities in collaboration with EDB to showcase Singapore's R&D capabilities and manpower.

For the Biomedical Sciences, an integrated framework involving BMRC, EDB's Biomedical Sciences Group and EDB Bio*One Capital was put in place to grow the biomedical sector by promoting investment and drawing multinational companies and start-ups to anchor their R&D activities in Singapore. Major R&D investments were successfully realized with the establishment of the Novartis Institute for Tropical Diseases, Lilly Systems Biology and GlaxoSmithKline Clinical R&D Centre. Many Biotechnology companies, such as Vanda, Paradigm and ES Cell International have also chosen to locate their R&D operations at the Biopolis.

SERC, through its strategy of integrating the RI's capabilities to meet industry needs, has worked closely with EDB to attract major private R&D activities to Singapore. Rolls-Royce, a respected and global leader in technology, is partnering a Singapore consortium of companies to set up a new venture to develop a commercially viable power system based on fuel-cell technology. Leica Geosystems, the world's largest maker of surveying and engineering equipment, set up a new plant in Singapore to conduct the design, R&D and manufacturing of sophisticated L&A equipment such as the Sprinter Electronic Level. As the result of the signing of a master R&D agreement, researchers, scientists and engineers from Mitsui, ICES and IMRE are collaborating on R&D projects to develop proprietary products, process technologies and jointly publish patents and scientific

Birds-eye-view of **Biopolis**

Biopolis offers purpose-built state-of-the-art facilities for the co-habitation of public and private research laboratories, and a plug and play environment.

papers to advance the production of key petrochemical products and nano-structured hybrid materials for new product applications respectively. ICES signed a master R&D agreement with RohMax Oil Additives, a business line of Degussa, to collaborate on research and development of lube additives. Through collaboration with IME and I^2R, Toppan Electonics Singapore, subsidiary of Toppan Printing, has developed an original RFID chip, Tesstar (trademark pending), and peripheral devices, including tags and reader/writers.

A*STAR RIs' partnerships with industry have resulted in some 750 joint projects and consortia in the last 5 years and $138 million in industry revenue.

SERC has actively helped local enterprises to improve their technological competitiveness through the Growing Enterprises with Technology Upgrade (GET-Up) Scheme. GET-Up is a multi-agency initiative jointly set up by A*STAR, EDB, IE Singapore and SPRING. Through GET-Up, SERC RIs have played a pivotal role in providing research and technological assistance and manpower to local enterprises. As of June 2005, 81 research scientists and engineers (RSEs) have been seconded to 65 companies under the Technology for Enterprise Capability Upgrading (T-Up) secondment scheme, and 27 technical advisors have been appointed to 26 companies. In addition, 54 operations and technology roadmaps have been developed for 45 companies.

The establishment of Exploit Technologies in 2002 has put in place an integrated system to manage the intellectual property and commercialise the technologies emerging from the A*STAR

ROLLS-ROYCE

Rolls-Royce first signed an MOU with A*STAR's Institute of High Performance Computing in 2002 to collaborate in joint R&D projects on engine modelling. In 2003, this agreement was extended to include other areas such as power generation and non-destructive testing. In 2004, Rolls-Royce signed a Master Agreement with A*STAR to set up an Advanced Technology Research Centre in Singapore. This was the first of its kind in Asia, and subsequently led to the signing of an agreement in 2005 with a Singaporean consortium of companies to invest US$100 million in developing a commercially viable power system based on fuel cell technology.

*"This new centre builds on our best practice for collaborative working with universities and government institutes in the UK, Europe and globally, and recognises the breadth of technical expertise and industrial focus available in the A*STAR institutes here in Singapore... The new centre is also unique as our first 'one-stop' technology centre."*

- Dr Mike Howse, Rolls-Royce Director of Engineering and Technology

RIs. To date, over 90 cutting-edge IP and technologies have been licensed to companies. Exploit Technologies has built capabilities in IP management, technology and competitive intelligence, technology commercialisation, and incubation and spin-off management. It currently manages more than 2,000 patents and patent applications. In 2003, Exploit Technologies initiated the key Commercialisation of Technology (COT) programme. COT aims to further develop promising technologies from the RIs in order to bring them closer to the market, and therefore more attractive to industry. An example is the development of a Radio Frequency Identification (RFID) Contact and Location Tracing System based on existing RFID technology know-how and expertise of researchers from I^2R.

An A*STAR patent portfolio panel has been set up. The inter-RI panel reviews A*STAR's patent portfolio and new patent applications, and aims to integrate commercialisation strategies across RIs. The panel identifies new technology areas that A*STAR RIs can collaborate on to enable more impactful commercialisation.

• Biopolis and Fusionpolis

The official opening of the Biopolis on 29 October 2003 was a major milestone. Of the seven buildings, five are occupied by the five BMRC RIs and two are occupied by private sector R&D laboratories. This co-habitation has fostered closer collaboration and intellectual exchange between public research institutions and industry.

The Biopolis offers purpose-built state-of-the-art facilities and a plug and play environment. The Biopolis Shared Facilities and the Biological Resource Centre offer scientific facilities, services and other research resources, such as DNA sequencing and media preparation.

With the capacity to house up to 2,000 researchers, Phase 1 of the Biopolis is already at close to full occupancy. The construction of Phase 2 commenced in January 2005 and is expected to be

Biopolis' Epicentre at Night

The forces of globalization have integrated the economies of the world like never before. Singapore needs to continue the process of upgrading and renewal to ensure that it remains competitive in a global knowledge economy.

completed by the end of 2006. It will provide two additional buildings for private sector laboratories.

Fusionpolis will be the focal point for the infocomms and media and physical sciences and engineering research community. It will house both the SERC RIs and private companies. The construction of the Fusionpolis is underway and due to be completed in 2007.

- **Promotion of Private Sector R&D**

EDB has promoted private sector R&D by leveraging on its R&D capability and integration with strong industry clusters to set up R&D operations in Singapore. For instance, Pratt&Whitney has set up a process development centre in Singapore that looks into repair development, while the world's largest maker of smart cards, Gemplus has chosen to locate in Singapore its first R&D centre outside of its home country, France. Hewlett Packard has also established in Singapore its first Asia Pacific Integrity Server R&D Centre. Hyflux, a local enterprise has also set up its R&D centre for Advanced Membrane Technologies, to enhance its capabilities to compete on the global market.

Attracting such R&D activities has helped to anchor associated high-end manufacturing projects, and seed new growth within our industry clusters.

Under S&T 2005 (between 2001 and 2004), EDB attracted $4.6 billion in total R&D spending, and created 2,471 RSE positions. With every dollar of RISC grant, EDB has attracted several dollars in additional R&D investment by the private sector.

• S&T 2005 Budget Commitments and Performance

Of the S&T 2005 $6 billion budget, $4.5 billion was committed as at end-2004, with another projected $1.4 billion in commitments by end-2005.

The table below summarises the progress of the key indicators.

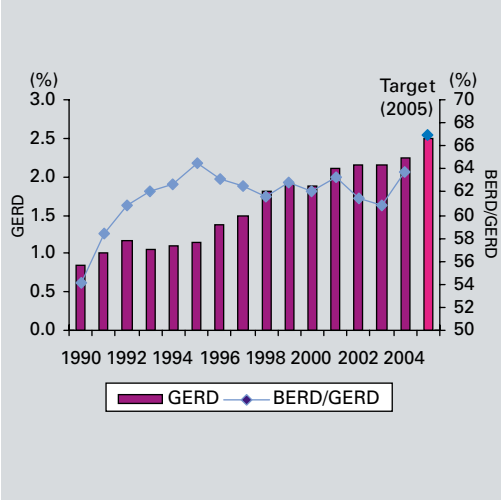
We have improved on all indicators, although the increases have been dampened by the economic slowdown in 2001-2003, coupled with the shock events (Sept 11 terrorist attacks, Bali bomb blast and SARS). Trends of GERD and RSEs are shown in Fig 1-2 and Fig 1-3.

Singapore, with its GERD at 2.25% of GDP in 2004, still lags the leading R&D-intensive countries, such as Finland, Sweden and Israel, which are at 3.49% (2003), 3.98% (2003), and 4.85% (2004) respectively (see Fig 1-4).

Fig 1-1: S&T2005 Key Indicators

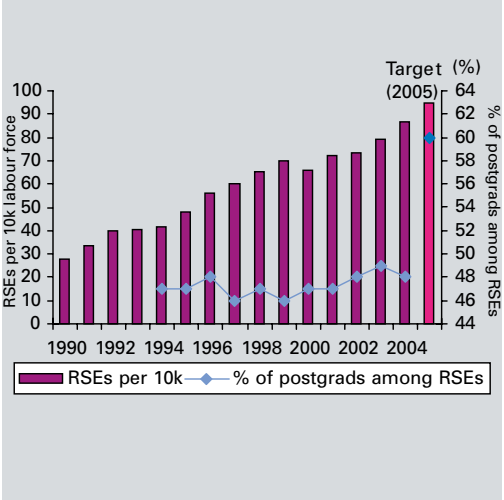
	2000 (Base)	2004 (Actual)	2005 (Target)
GERD/GDP	1.89%	2.25%	2.5%
Private sector share of GERD	62.0%	63.8%	67%
No. of RSEs per 10,000 labour force	66	87	95
% of postgraduates among RSEs	46.7%	47.4%	60%
GERD per no. of patents filed	$3.9 mil	$3.2 mil	$2.0 mil

Fig 1-2: GERD/GDP growth and Private sector share of GERD



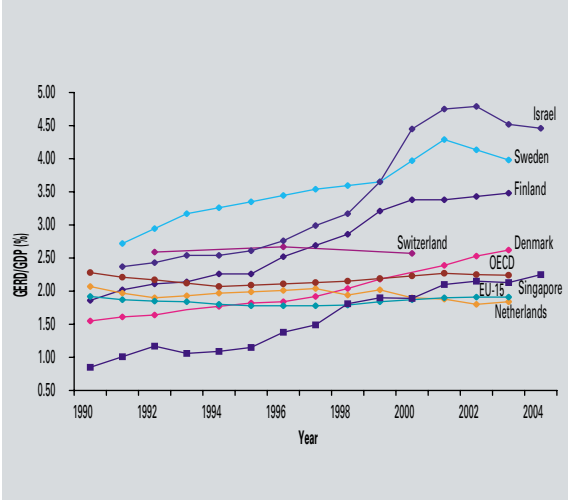
Source: National Survey of R&D in Singapore (2004)

Fig 1-3: RSEs per 10,000 labour force and proportion of postgraduates among RSEs



Source: National Survey of R&D in Singapore (2004)

Fig 1-4: GERD/GDP Ratio of various countries over time



Source: OECD Main Science and Technology Indicators (2005)

ECONOMIC CHALLENGES AHEAD

SINGAPORE TODAY

Singapore has made significant progress since its independence in 1965. Singapore embarked on its industrialization programme in the 1960s, beginning with labour-intensive industries. These industries needed workers who were literate and skilled in working machines. Focus was placed on raising standards of education, upgrading the skills of its people and increasing the number and quality of engineers, technicians and managers to support the industries.

With good infrastructure, a stable investment climate, political stability, and a disciplined and hardworking workforce, companies were attracted to invest and operate in Singapore.

As competition intensified from both developed and developing countries, Singapore moved up the technology chain so as to stay ahead. Efforts were made to attract high value industries such as electronics and chemicals, which required higher skilled workers. In 2000, Singapore moved up the value chain again with its initiative to develop the knowledge-intensive biomedical industries.

Going forward, Singapore needs to continue the process of upgrading and renewal to ensure that it remains competitive in a global knowledge economy. Singapore must find and create its comparative advantage in the changing economic landscape.

CHALLENGES AHEAD

The forces of globalisation have integrated the economies of the world to unprecedented levels. Advances in IT and communications have allowed business activities to be located and conducted from virtually anywhere in the world. The fast flow of information and technology-induced productivity gains have significantly shortened business cycles, and intensified competition between regions. As a result, countries find that comparative advantages based on efficiency and cost-competitiveness are fast-eroding.

The rapid growth of large emerging economies has changed the global economic landscape dramatically. With large domestic markets and abundant supply of low cost skilled workers, the opening up of these economies has become a powerful force shaping the global economy and investment environment. The growth of these countries has created both opportunities and challenges for the rest of the world, including Singapore.

SUSTAINING ECONOMIC GROWTH AND PROSPERITY

- **An Innovation Strategy**

Singapore ranks highly amongst the

world's most competitive nations today. Singapore was ranked the third most competitive economy by the IMD World Competitiveness Yearbook 2005 and the seventh most competitive economy by the WEF Global Competitiveness Report 2004-2005. Among the small economies (with population under 20 million), Singapore is the second most competitive.

As a small country with few natural advantages other than its geographical location, Singapore understands well the imperative to move ahead of the competition and to find new ways to sustain our competitive advantage over the longer term.

Singapore will continue to offer excellent infrastructure, stable political and investment climate, an efficient government, a strong intellectual property protection regime, and a steady supply of well-educated manpower. However, these assets will not be enough to ensure its continued prosperity.

Going forward, Singapore will need to leverage on its strengths and find new ways to differentiate itself, beyond cost-effectiveness and efficiency, and build sustainable competitive advantages. It must focus limited resources to achieve peaks of excellence in niche areas, and develop capabilities that are difficult for competitors to replicate.

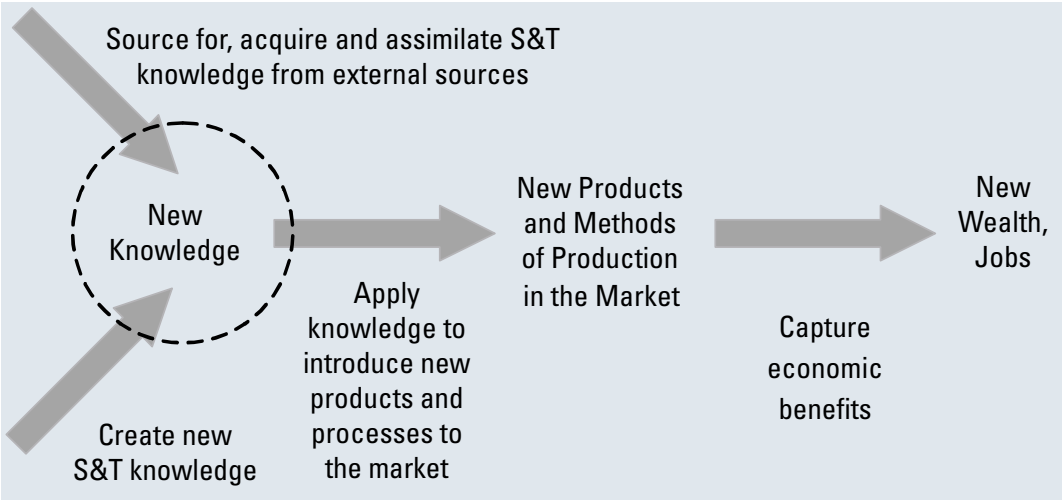
Singapore's economic strategies must address the changed economic realities and respond to the challenges to its economic competitiveness. The industrial focus must shift to knowledge- and competence-based activities, in addition to production. Singapore must develop its innovation capacity as a new, sustainable source of competitive advantage.

Indeed, many countries are focusing on building up their innovation capacity as a strategy for sustainable competitiveness. In the OECD countries, this is evident from the strong and increasing emphasis on tertiary education and research. In particular, small advanced countries like Finland and Sweden have led the innovation wave in Europe, making bold investments in research and development and putting in place structures to support the development of effective innovation systems.

- **Public Research in the Innovation System**

The public research sector is a key player in the innovation system. It acts to lower the barriers and costs to firms of engaging

Fig 2-1: Innovation capacity



in innovation and to create a facilitative environment for these activities to be undertaken effectively, efficiently and competitively. It performs this important role in the following ways:

a) Creating a source of R&D manpower with the appropriate skills, knowledge and experience – the mobility of personnel between the public research sector and the enterprise sector is key;

b) Being a collaborator in R&D, and complementing the internal knowledge and competence of enterprises, and a catalyst for the generation of knowledge-based activities in the enterprise sector through the exploitation of its inventions and discoveries; and

c) Being a sharer and provider of R&D and technical infrastructure, facilities and services; and a bridge to the global base of scientific and technological knowledge.

• Science and Technology

Science and Technology has been the prime driver of economic development in the last 2–3 centuries. Technological breakthroughs have transformed the economies of developed countries in North America, Western Europe and Japan. Countries at the forefront in harnessing technological change have continued to enjoy the highest standards of living.

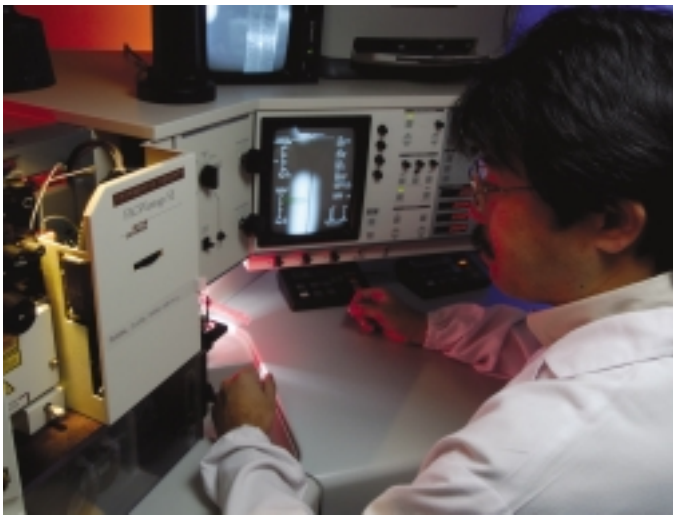
In an increasingly competitive and globalised economy, one of the keys to sustaining one's competitive advantage will be to develop superior technological capabilities and continue to create high-value new jobs that competitors cannot yet do.

Science and Technology is a natural area for Singapore to excel in, given its people's strength in the sciences and mathematics. Singapore students regularly top international competitions in Science and Mathematics. Many of its top students gravitate to science and engineering disciplines at universities, in which they excel.

This natural bent towards the sciences is encouraged by the country's education system, and provides the foundation for a society that is comfortable with science and technology, and a workforce that is able to quickly adapt and adopt new technological innovations and scientific advances.

• Talent

Talent is the economic paradigm for the twenty-first century. It will be the key to continued economic prosperity.



BOSTON-CAMBRIDGE – A TALENT HUB

The concentration of top talent in the universities and research organisations in the Boston-Cambridge- area has been the prime attractor of investments and companies. Boston-Cambridge today is a hotspot for biomedical research. Many of the world's largest pharmaceutical companies have established research activities in the area. For instance, the Swiss pharmaceutical company, Novartis relocated its global R&D headquarters to Boston-Cambridge in order to be near the major sources of scientific talent and to recruit the best researchers for its laboratories.

The critical success factor for Singapore will be its ability to become an international talent node – nurturing its own talent as well as drawing creative and talented people from all corners of the world to live and work in Singapore.

This is already happening. Successful global cities today are global talent hubs. The growth regions of Boston-Cambridge and Silicon Valley have demonstrated that investment and economic opportunities follow talent.

Talent will be Singapore's competitive advantage. To be a talent hub, Singapore must cultivate a dynamic and open society that offers economic opportunities for communities of creative and talented people. Research in particular is a highly networked activity and researchers will be attracted to communities of like-minded and creative people who can interact with, stimulate and challenge one another.

The goal is to transform Singapore into a talent magnet for scientific excellence in selected areas, which will help anchor its economy, and position Singapore as the R&D gateway to Asia. This will create a sustainable path for its long term economic growth. In tandem with the growth of knowledge industries in Singapore, more post-graduates and post-doctorates will need to be trained to support highly knowledge-intensive industries e.g. in the biomedical and pharmaceutical sectors.

STRATEGIC DIRECTIONS FOR S&T POLICY (2006 – 2010)

SCIENCE & TECHNOLOGY - KEY TO SUSTAINABLE COMPETITIVENESS

Many countries have recognised the importance of science, technology and innovation to economic growth, and are taking steps to strengthen their S&T and innovation systems.

The OECD Science, Technology and Industry (STI) Outlook 2004 outlined the commitment of OECD governments to intensify R&D activities to fuel economic growth. OECD governments have committed to increasing R&D spending, despite their tight budgets. Many countries, as well as the European Union (EU), have established explicit targets for boosting R&D expenditure, in both the public and private sectors. Increasing amounts of public money are being invested in scientific and technological fields that promise great economic and societal value, in particular, infocomm technology (ICT), biotechnology and nanotechnology. Countries, such as Denmark and the Netherlands have created special funds to finance research in priority fields.

REVIEW OF SINGAPORE'S R&D DIRECTION

The Ministerial Committee on Research and Development (MCRD), chaired by then Deputy Prime Minister Dr Tony Tan, was formed in August 2004 to review Singapore's R&D strategies and direction.

EUROPEAN LISBON TARGETS

The European Union (EU) aims to develop Europe into the most competitive and dynamic knowledge-based economy in the world by 2010. To achieve this goal, the EU aims to raise the collective level of R&D spending to 3% of GDP by 2010, of which two-thirds would be from the private sector. This is expected to have a significant impact on long-term growth and employment in Europe, creating an additional 400,000 jobs every year after 2010. In addition, the European Commission (EC) has proposed a doubling its research budget, with greater emphasis on industry-relevant research, under its ambitious European Seventh Research Framework Programme (FP7).

As part of its work, the MCRD visited various public and private R&D institutions and companies in Singapore. It also visited five small but economically advanced economies (i.e. Switzerland, Denmark, the Netherlands, Sweden and Finland) to better understand how they have successfully organized themselves to achieve good economic growth and strong science and technology performance on a sustained basis, despite their relatively small population sizes.

Singapore must push on with transforming itself into an innovation-driven economy, competing on knowledge and talent, and in so doing put itself on the path towards sustained economic growth.

The top leadership in these countries placed great importance and urgency on R&D. It was clear from the insights and information gained during MCRD's visits that Singapore has to refocus its research and innovation agenda to keep up with international developments. Singapore must push ahead with transforming itself into an innovation-driven economy, competing on knowledge and talent, and in so doing put itself on the path towards sustained economic growth.

Singapore needs to refocus its research and innovation agenda to keep up with international developments.

STRATEGIC KEY THRUSTS OF R&D

The MCRD identified five key strategic thrusts that will guide our R&D efforts over the next five years.

• THRUST 1 - MORE RESOURCES FOR R&D AND CONTINUED HIGH LEVEL ATTENTION TO R&D

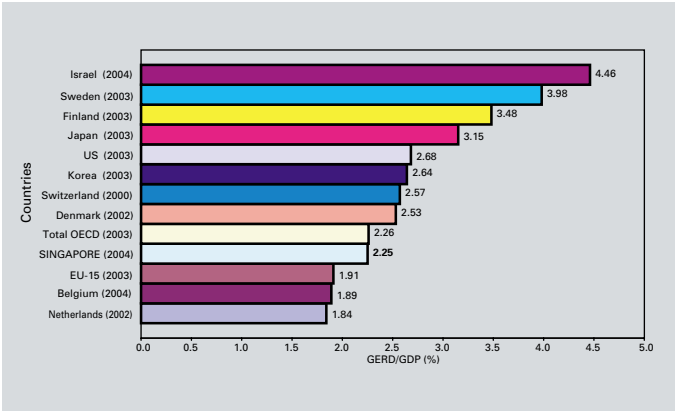
Currently, Singapore lags significantly behind other advanced countries with its GERD at only 2.25% of GDP (2004), and a smaller GDP (see Fig 3-1).

Singapore will need to intensify its R&D efforts significantly and allocate new money to this area. The need to increase funding for R&D has also been recognized by EDB's International Advisory Council.

Singapore aims to increase its expenditure on R&D to at least 3% of GDP within the next 5 years. This will be a critical investment in our future and will make a significant economic impact.

To ensure continued top-level attention on R&D, Singapore is setting up a high-level advisory council, the Research, Innovation and Enterprise Council (RIEC), chaired by the Prime Minster which will provide guidance and leadership to drive the transformation of our economy through research and innovation. The Council will be supported by a new National Research Foundation (NRF).

Fig 3-1: Comparison of GERD/GDP Ratio of Various Countries

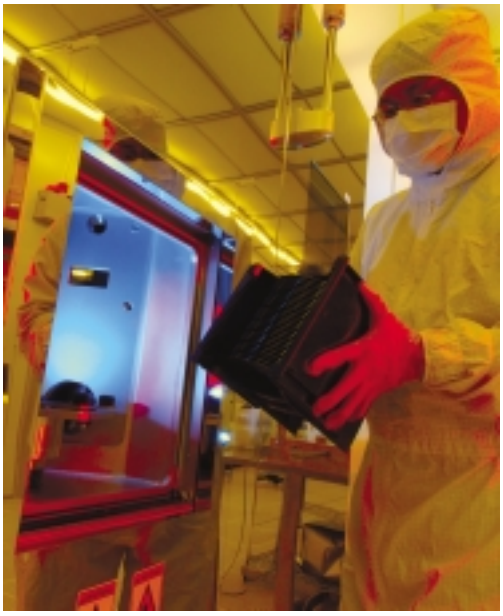


Source: OECD Main Science and Technology Indicators (2005)
National Survey of R&D in Singapore (2004)

• THRUST 2 - FOCUS ON SELECTED AREAS OF ECONOMIC IMPORTANCE

Singapore will need to concentrate its public research budget around a small number of strategic areas so as to develop a critical mass of research capabilities in industries where it can be economically competitive.

Apart from continuing to deepen its capabilities in existing manufacturing clusters such as electronics, chemicals, engineering and biomedical sciences, through continued investment in R&D and manpower development, Singapore needs



to continually look for new growth areas to sustain its economic growth over the longer term. The NRF Board has identified two new growth sectors that show good potential viz. the Environmental and Water Technologies sector and the Interactive and Digital Media sector. Ministerial-level Steering Committees have been established to drive developments in these sectors; to co-ordinate activities across agencies in the areas of industry development, research and education; and to offer guidance on policy issues that may arise.

- **THRUST 3 - BALANCE OF INVESTIGATOR-LED AND MISSION-ORIENTED RESEARCH**

Within the selected strategic areas, Singapore must be prepared to fund a broad spectrum of research, ranging from basic investigator-led research to applied research.

There will be increased support for basic research, which will build the foundation for scientific excellence. This will help to create new knowledge and attract talent to Singapore. In this connection, the existing Academic Research Fund (AcRF) under the Ministry of Education (MOE) will be expanded in scope to cover not only basic research at our universities, but also academic, investigator-led research that is broadly aligned with the long-term vision of the strategic interests of Singapore. A*STAR, under MTI, will continue to drive efforts in the area of mission-oriented industrial research.

- **THRUST 4 - ENCOURAGE EVEN MORE PRIVATE SECTOR R&D**

Increasing private R&D in Singapore is a key priority as companies are best placed to decide which areas of R&D to invest in, and align R&D investments with commercial opportunities.

"Innovation, enterprise and R&D, these are the ways to remake the economy. There are risks in this approach. We are a small country, we can't bet on every number on the table, we have to back certain positions. But we have to do this and if we succeed, we will gain a competitive edge which will put us ahead for 15 or 20 years to come; not forever, but long enough for us to make a living and to work out the next step forward and, therefore, to create jobs and prosperity for Singaporeans."

- PM Lee Hsien Loong, National Day Rally Speech 2005

Over the shorter term, the increase in private R&D expenditure will continue to be largely driven by the MNCs. Singapore's incentive packages will be reviewed to ensure their continued effectiveness in attracting global R&D centres to locate in Singapore.

More resources will be allocated for these promotion activities and to ensure that a high quality supporting framework is in place, including strong scientific and research manpower and sophisticated intellectual property protection regulations.

Importantly, an open innovation platform must be created for the research community in Singapore, so that talented research scientists and engineers can flow across academia, public research institutions, and industry in open collaborative networks.

• THRUST 5 - STRENGTHEN NEXUS BETWEEN R&D AND BUSINESS

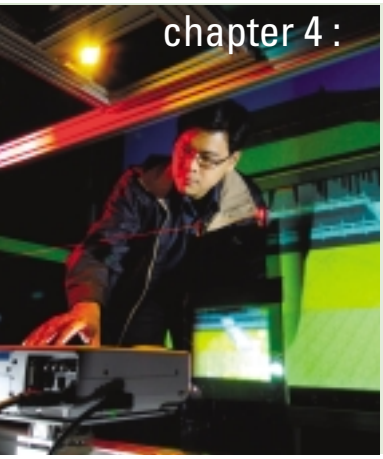
Innovation is a key preoccupation of many countries seeking to sustain competitiveness in a global economy. Even countries with long traditions of scientific excellence are recognizing the need to strengthen their innovation framework to derive greater economic value from research by strengthening the nexus between research and innovation.

Singapore needs to strengthen the nexus between its knowledge institutions and research performing agencies such as the polytechnics, universities, research institutes and industry. These agencies must improve on their ability to commercialise research results, and develop closer collaboration with industry.

Research performing agencies will need to review how to strengthen their technology transfer framework and offer more sophisticated supporting services, including access to financing, and the protection, management and marketing of innovations.

Stronger co-funding frameworks between the public and private entities would be developed, e.g. by encouraging our polytechnics to link up with industry associations to collaborate on R&D initiatives, with support from the Government.

In particular, SPRING, IE Singapore and EDB will work closely on the promotion of entrepreneurship. More attention will be focused on startups and new growth enterprises, especially those involved in identified strategic areas. These efforts will spark new growth and economic rejuvenation. Promotion of technological innovation and capabilities in Singapore's SMEs, which can complement the MNCs through the economy's cluster strategy, will continue.



NATIONAL R&D FRAMEWORK

"To transform the five key strategic thrusts [of the MCRD] from concept to reality, we need strong leadership to lead our drive towards a more dynamic research and innovative environment."

— Then-DPM Dr Tony Tan in Aug '05

The MCRD has outlined a national R&D framework to implement the strategic thrusts to drive the economic transformation of Singapore into a research-driven knowledge-intensive economy.

NATIONAL R&D FRAMEWORK

The national R&D framework is described in Fig 4-1. At the top level, the RIEC will advise Government on national research, innovation and enterprise strategies.

The national R&D system (excluding the defence sector) is organised mainly along two tracks – the Ministry of Trade and Industry will drive mission-oriented research, while the Ministry of Education will oversee academic and investigator-led research. A new National Research Foundation has been set up to fund longer term strategic programmes.

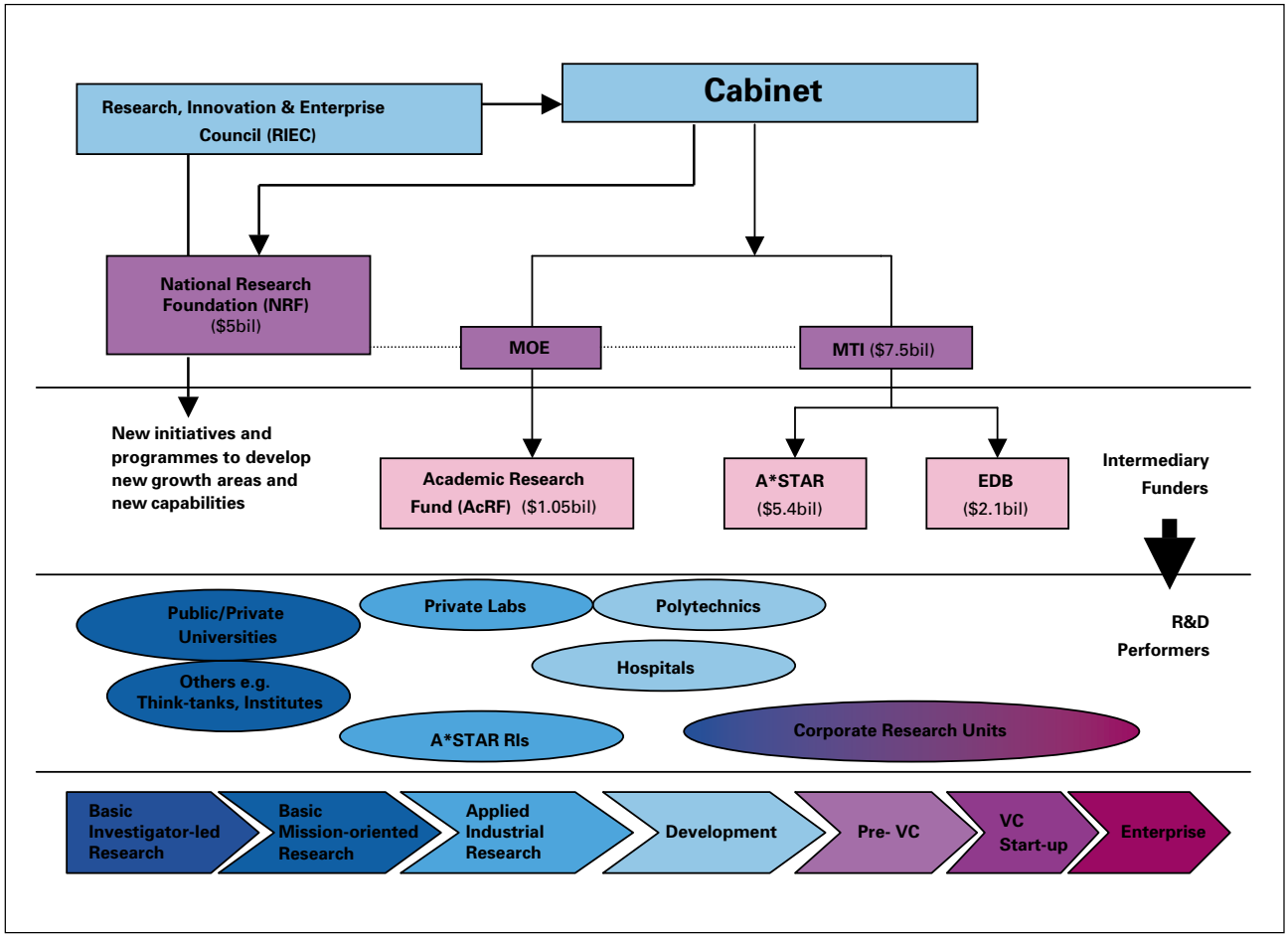
Research, Innovation and Enterprise Council (RIEC)

The RIEC will lead the national drive to promote research, innovation and enterprise, by encouraging new initiatives in knowledge creation in science and technology, and to catalyse new areas of economic growth. The Council will be chaired by the Prime Minister, and will comprise other Ministers, prominent captains of industry, and internationally renowned individuals from the scientific and academic communities. The RIEC will play an important leadership role in transforming Singapore into a knowledge-based economy, with strong supporting capabilities in R&D.

National Research Foundation (NRF)

The NRF will implement national research, innovation and enterprise strategies approved by the RIEC, and allocate funding to programmes that meet the NRF strategic objectives. It will provide Secretariat support to the RIEC. It will coordinate the research of different agencies within the larger national framework so as to provide a coherent strategic overview and direction. It will also be responsible for developing policies and plans to implement the 5 strategic thrusts of the national R&D agenda.

Fig 4-1: National R&D Framework



The **Research, Innovation and Enterprise Council** will lead the national drive to promote knowledge creation and innovation.

MTI - Mission-oriented R&D

MTI will drive mission-oriented R&D, through the close integration of the efforts of its economic agencies, A*STAR, SPRING and EDB.

• A*STAR

A*STAR's mission is to foster world-class scientific research and nurture world-class scientific talent to advance Singapore's economic goals. It plays a central role in setting the thematic priorities for public research, developing the national base of postgraduate research manpower, investing in major physical research infrastructure, and catalyzing the commercialisation of IP generated in public research.

A*STAR's research capabilities are an integral component of Singapore's industry development strategy and will support EDB's investment promotion efforts. Close integration of A*STAR's R&D with economic development objectives will strengthen our ability to attract research-intensive manufacturing projects from MNCs, deepen capabilities in existing industry clusters, and upgrade our local enterprises.

A*STAR and EDB will work together in identifying prospective technologies and key growth areas for the economy.

- **EDB**

EDB's mission is to create sustainable economic growth and business opportunities in Singapore. As part of this role, EDB promotes private sector R&D by attracting multinationals to locate R&D centres and corporate R&D activities in Singapore. EDB will also promote private sector R&D in local enterprises and start-ups.

- **SPRING**

SPRING will seek to encourage technology innovation in local enterprises, in particular SMEs, by addressing the gaps they experience in doing so. SMEs' technology innovation capabilities can be enhanced through the transfer of technology and expert management.

MOE – Academic and Investigator-led R&D

MOE will oversee and fund academic research at the tertiary institutions, as well as investigator-led research through the expanded AcRF. Its focus will be on research which is basic in nature, with longer timeframes and driven more by knowledge creation.

- **Academic Research Fund (AcRF)**

The scope of AcRF will be expanded to cover not only basic research at our universities, but also investigator-led research that is broadly aligned with the long-term vision of the strategic interests of Singapore. In particular, there should be an assured level of funding for investigator-led research over a reasonable period in order to attract world-class researchers to Singapore.

Having a more active investigator-led research climate would help to provide a fertile environment for seeding new ideas and achieving breakthroughs in new knowledge. The presence of top research talent enhances the quality and attractiveness of our graduate education programmes, and through close linkages with our universities, would help our universities achieve even higher peaks of excellence.

- **Universities/Polytechnics**

Within the universities, the focus will continue to be on faculty-led research either independently or in collaboration with other public and private sector institutions, which creates new knowledge that will form the foundation for future innovations and discoveries. In particular, there will be assured medium- to long-term support for selected areas of research which are broadly aligned with the long-term vision of the strategic interests of Singapore.

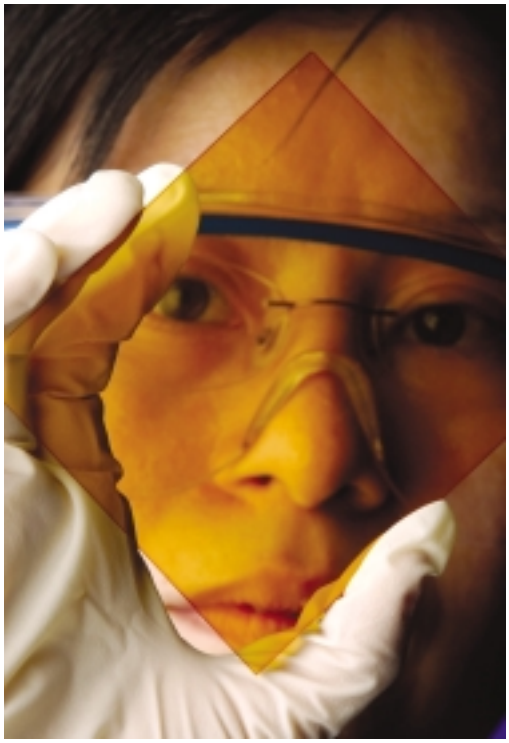
The polytechnics will focus on research which is more developmental in nature, with greater focus on strengthening the nexus between R&D and business through joint projects with industry and local enterprises. The polytechnics will play a significant role in strengthening innovation in the private sector and uplifting technological and manpower capabilities in Singapore.

COLLABORATION IN R&D

The various R&D performers in the national research landscape will need to collaborate closely. At the national level, the NRF will provide the coherent strategic overview so that the research activities of different Government agencies are coordinated within the larger national framework.

Close linkages and collaboration between research institutes, tertiary institutions, public research agencies, disease centres and hospitals will be important to facilitate a continuum of research from basic science to applied science to commercial application.

Such linkages would take different forms. A*STAR has extramural programmes where it engages the universities, public research agencies, hospitals and disease centres in joint R&D projects and thematic programmes, and in holding conferences and seminars. Collaborative efforts will cover research manpower, such as encouraging joint appointments at RIs, universities, hospitals and disease centres, having joint supervision and teaching of graduate and postgraduate students and A*STAR scholars, seconding RSEs from A*STAR RIs or polytechnics to the private sector. It is important that we facilitate an open platform that allows ideas and people to flow freely between the different players in the research landscape.



chapter 5 :

ENABLING TECHNOLOGY ENVIRONMENT FOR SUSTAINED INDUSTRY GROWTH

The priorities for public research over the next 5 years have been developed, building on EDB's Manufacturing 2018 Plan, as well as IDA's Infocomms Technology Roadmap (ITR5) and Intelligent Nation 2015 (iN2015).

The planning process involved experts and leaders from the research community and industry in Singapore and abroad, as well as the key agencies and ministries. It covered wide-ranging technology scans, assessment of future S&T infrastructure needs, RI-university linkages, IP issues, industry views and perspectives, and coordinated efforts of public sector agencies.

MANUFACTURING & SERVICES

Manufacturing and services will remain the twin engines propelling Singapore's growth in the knowledge-driven globalised economy. This dual thrust will help to ensure that the economic base is diversified and make Singapore more resilient against business cycles. It will create good jobs for Singaporeans across the skills spectrum and provide opportunities for everyone in society.

Singapore will focus on differentiating itself as a compelling investment location and achieving leadership positions in its industry clusters. This will require capabilities ranging from science and technology to creative skills and management know-how, as well as focusing on niche areas.

Singapore's strong manufacturing and technology base will help to attract cutting edge R&D activities which will in turn attract and anchor higher value-added industrial activities in the country.

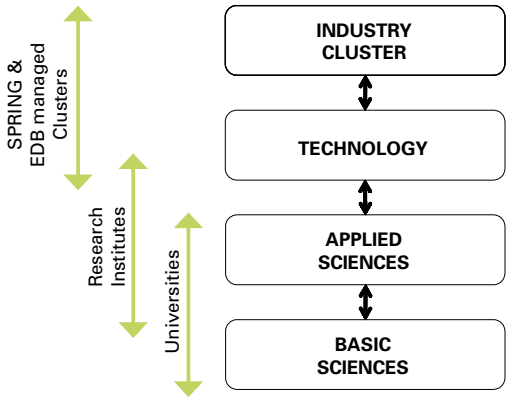
The main industry clusters in the manufacturing sector are: Electronics, Chemicals, Biomedical Sciences (BMS), Precision Engineering (PE), Transport Engineering (TE) and General Industry (GI) clusters; and in the services sector: Education, Healthcare, Infocomms & Media (ICM), Logistics, Engineering & Environmental Services (EES) and Business & Professional Services clusters.

In each of these clusters, Singapore aims to maintain its existing leadership positions, while actively pursuing new growth areas such as animation & games development, education, environmental engineering and alternative energy. At the same time, Singapore will continue to seek out new and emerging growth industries.

TECHNOLOGY PLANS

Our industry development plans are supported by corresponding technology plans. Close collaboration between the industry and the RIs and universities is needed to address the technological

Fig 5-1: Management of Knowledge from Basic & Applied Sciences to Industry



needs of major industry projects and initiatives.

EDB has identified the areas of engineering, sciences & technologies needed to reach the targeted levels of industry pre-eminence for the manufacturing and services clusters. These include focused S&T areas for each cluster, as well as broad-based technologies that cut across various clusters e.g. Computational Technology, Material Technology, Nanotechnology and Microelectronics.

Fig 5-2 highlights the set of applied sciences and broad-range technologies needed by industry clusters.

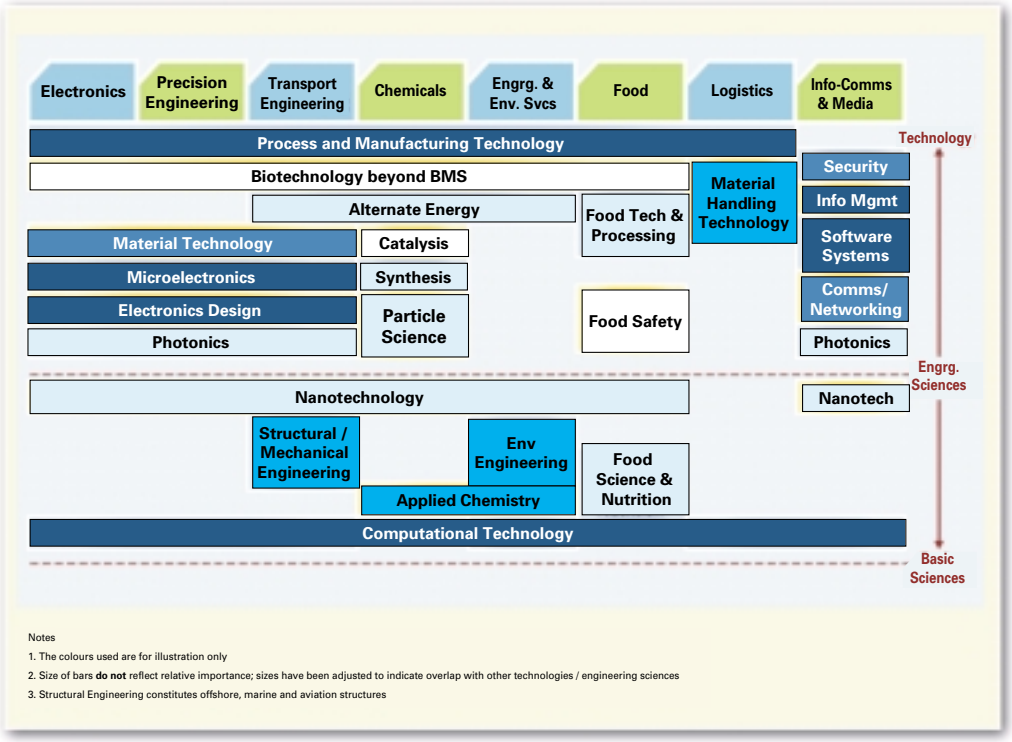
STRATEGIC PRIORITIES FOR PUBLIC RESEARCH

The strategic goals of public research at A*STAR are to:

- anchor high value-added manufacturing clusters through deepening of R&D capabilities; and
- develop new R&D-intensive growth industries.

With our small resource base, investments in public research have to be targeted in selected fields, in order to concentrate resources and focus efforts to build internationally competitive concentrations of R&D capital in selected areas. A*STAR targets the broad fields of science and technology of most relevance

Fig 5-2: Technologies Needed by Industry Clusters



to the development of the key industry sectors: Biomedical Sciences, Electronics, Infocomms & Media, Chemicals, and Engineering.

In the high value-added sectors, opportunities exist for the upstream migration or expansion of existing activities towards R&D. In particular, sectors such as the semiconductor and hard disk drive industries in Singapore are part of high R&D-intensity global industries. Trends in the off-shoring of R&D and relocation outside the triad economies of North America, Europe and Japan may also offer opportunities that we can capitalise on.

In other sectors, opportunities to create new growth industries may be generated by scientific and technological advances, e.g. in biotechnology, information technology and nanotechnology, especially in the areas of convergence of these fields.

PRIORITIES OF THE BIOMEDICAL RESEARCH COUNCIL (BMRC)

BMRC's efforts in the last 5 years have centred on establishing the infrastructure for the conduct of world-class basic biomedical R&D in Singapore. In the next 5 years, BMRC's 5 RIs will continue to deepen their basic core capabilities in the specific domains to support our growing BMS industry, to translate the outputs of basic research into clinically useful and commercially viable applications. The overall aim is to stimulate economic growth for Singapore through the advancement of human healthcare.

In optimising limited resources, BMRC will ensure that bench research is driven by current and pertinent clinical needs. To foster collaborations, BMRC will structure its translational activities as thematic strategic research programmes so as to increase the participation and partnership of the relevant research groups

Fig 5-3: Basic and Translational Research – Supporting the Biomedical Sciences Cluster

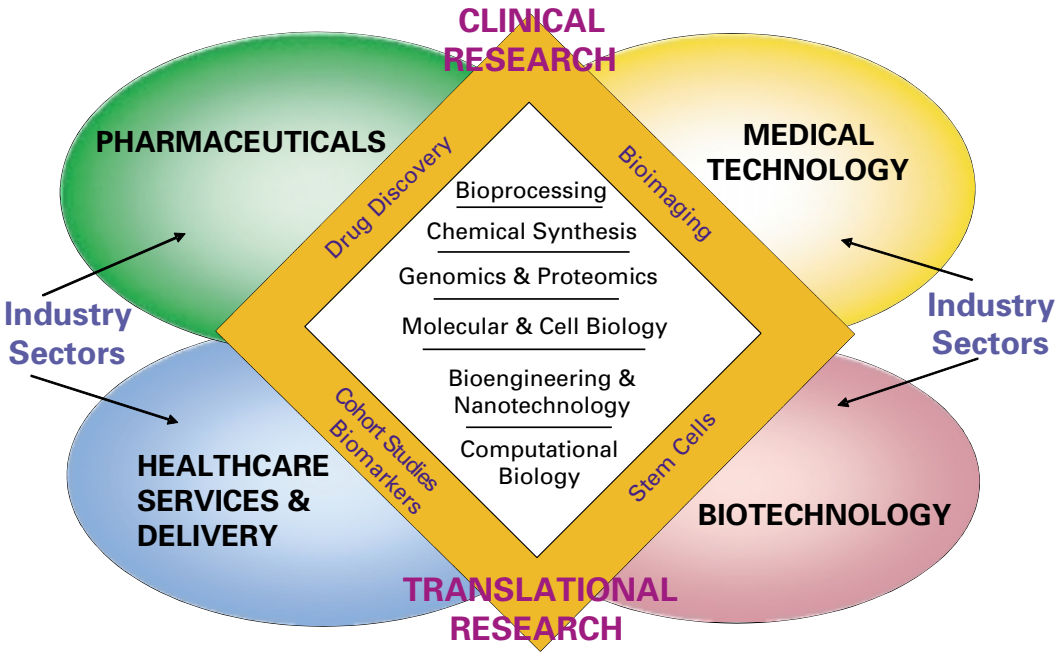


Fig 5-4: BMS Value Chain

contributing through a network towards specific needs.

5 key areas of research have been identified where Singapore could play a critical role: (i) Drug Discovery, (ii) Bioimaging, (iii) Stem Cells, (iv) Cohort Studies, and (v) Biomarkers. These translational programmes will interface with our basic biomedical core capabilities to further strengthen the BMS industry cluster (Fig 5-3).

• Deepening Basic R&D Capabilities

The BMS is a multidisciplinary field which requires the basic building blocks to ensure outputs across the entire value chain (Fig 5-4). Molecular and Cell Biology will continue to be a cornerstone to new biomedical discoveries. With the advent of new tools, novel technologies and methodologies are now being developed to elucidate the complex network of genes (Genomics) and proteins (Proteomics), bringing scientists closer to understanding the mechanisms that determine life and its regulatory processes in human, pathogens as well as carriers of infectious diseases.

With the recent explosion of gene and protein sequence and structure data, new applications of Computational Bioengineering are emerging in the area of macromolecular structure and function. In addition, bioinformatics provides a tool for the modelling of complex biological pathways. Bioprocessing as well as Bioengineering and Nanotechnology are the 2 other basic building blocks that develop capabilities in the manufacture of biological vaccines and therapeutics, and in new treatment modalities that are based on nanotechnology for drug delivery, artificial organs and implants as well as medical devices.

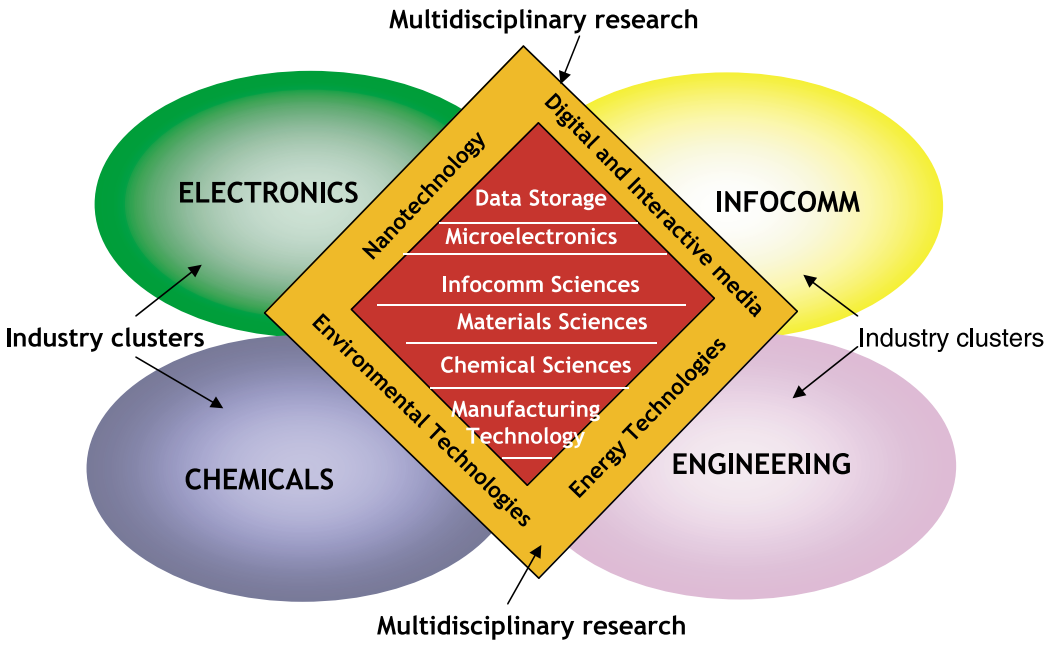
In the next 5 years, the BMRC RIs will deepen their capabilities in these basic capabilities. This will also present opportunities for interfacing with the clinical communities where new basic scientific frontiers could be exploited for clinical purposes. To this end, the BMRC will continue to foster interactions amongst the basic and clinical scientists so as to extract the full potential of expertise available in Singapore.

• Building and Strengthening Translational Competencies

BMS efforts require sustainable investments for long term gestation. Pharmaceutical MNCs are moving towards greater outsourcing of their R&D activities, and companies are becoming less willing to take on early discoveries for further development because of the need to invest significant resources. In response to this global trend where research institutions play an increasingly larger role in Drug Discovery, BMRC will set up an in-house developmental laboratory to help nurture early phase discoveries from the RIs to bring them closer to the point where they are sufficiently advanced along the drug discovery value chain for industry to take over.

In 2004, BMRC established the Centre for Molecular Medicine (CMM) to bridge the gap between basic science and clinical medicine. As a programme directed research centre, the CMM aims to bring together scientists and clinicians from RIs, universities and hospitals to serve as a platform to train a new breed of clinician-scientists. Six CMM programmes have been established so far, namely Regenerative Medicine, OnoGenomics, Epithelial Biology, Immunology, Virology and Genetic Medicine.

Fig 5-5: Supporting the Science & Engineering Clusters



PRIORITIES OF THE SCIENCE AND ENGINEERING RESEARCH COUNCIL (SERC)

SERC supports Singapore's four key manufacturing industry sectors in Electronics, ICM, Chemicals, and Engineering (Fig 5-5). SERC RIs develop relevant technologies and capabilities to meet the needs of manufacturing industries.

SERC also actively helps local enterprises improve their global competitiveness through the GET-Up Scheme. Here, SERC RIs play a pivotal role in providing technical assistance and manpower transfer to Singapore local companies. SERC will continue to invest in technological developments that will help anchor companies in Singapore and help local enterprises compete effectively in the global markets. Only with knowledge arising from deep engagement in R&D will SERC understand the technological trends needed to renew capabilities so as to help local companies take advantage of new market opportunities and growth industries.

To identify and prioritise areas for new capability development, SERC led a process of Technology Scans that engaged a large part of the local research community to conduct foresights of major social, economic, technological, and political trends over a horizon up to 2015-2020. From the scans, possible scenarios of the future needs of the industry and society are painted. Understanding these future needs will better guide SERC RIs in developing relevant competencies. The technology scans serve as inputs to SERC RIs to update their intramural programmes so as to stay relevant to the industries. They also serve to inform the broader research community on the directions of SERC's extramural programmes.

• Electronics

Data storage and semiconductors are two important sectors of Singapore's electronic cluster. Unique to these two sectors is the availability of established international technology roadmaps, which industry players rely on for a major part of their product development. SERC will strive to develop new capabilities to meet future needs of the industry as projected by these roadmaps.

SERC will also build capability in data storage and memories to maintain

Singapore's position as the data storage capital of the world. Over the medium term, the global aging population will provide opportunities for technological developments in healthcare applications. Through its multi-disciplinary Nanotechnology initiative, SERC will also develop capabilities to address the technical barrier of incumbent technologies approaching atomic limits.

• Infocomm & Media

SERC will focus on core capabilities in Infocomm & Media (ICM), in particular in Communications, Information Science and Media technologies which are key enablers of ICM. ICM capabilities are also enablers for other industries such as the electronics cluster, chemicals cluster, engineering services as well as biotechnology.

ICM will play an increasingly important role in our daily life. SERC RIs will address new opportunities in digital entertainment, digital healthcare and digital home / work environment.

• Chemicals

Singapore's chemicals industry has a large diversity of products and processes. Chemicals R&D will support platform capabilities in synthesis, catalysis, polymer and process sciences. Capability development efforts will be focused on this basic set of capabilities to provide the necessary expertise to meet industry needs and provide value-add technologies.

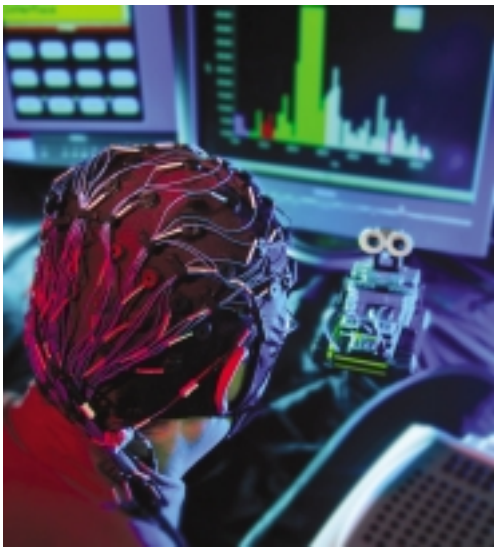
• Engineering

The engineering cluster cuts across multiple disciplines e.g. transport engineering, logistics, and environmental engineering, with expertise residing in a number of SERC RIs, the universities and polytechnics. SERC will adopt a multi-disciplinary approach involving the relevant RIs and partners in supporting these clusters.

• Inter-cluster Opportunities

The technology scans have identified new focus areas of research where Singapore has a competitive advantage. In addition, the scans identified novel interfaces between disciplines where technology breakthroughs are likely and where Singapore can build world-class expertise.

Based on these novel interfaces, integrative themes that have high potential to impact inter-cluster industry development have been identified. The aim is to explore research opportunities at the technology interfaces. Examples of these areas include Nanotechnology and Environmental and Energy Technologies. Programmes that take advantage of these inter-cluster opportunities will need to leverage on a multitude of scientific and engineering disciplines that exist in A*STAR RIs and the universities. Over the next 5 years, SERC will develop a pipeline of such capabilities across the broader research community in areas important to the Singapore economy through various programmes.



chapter 6 :

DEVELOPING AND MANAGING R&D HUMAN CAPITAL

ATTRACTING AND NURTURING R&D TALENT

Talent is the key to economic progress in the knowledge-based economy of the twenty-first century. In a global economy where talent flows freely among cities and countries, Singapore must position itself as a key node in the cross-border knowledge networks, and magnet for global talent.

As Singapore moves up the technology chain, the need for highly trained R&D talent will increase. Such talent will be needed to fuel our economic transformation, and support new and high value-add industries.

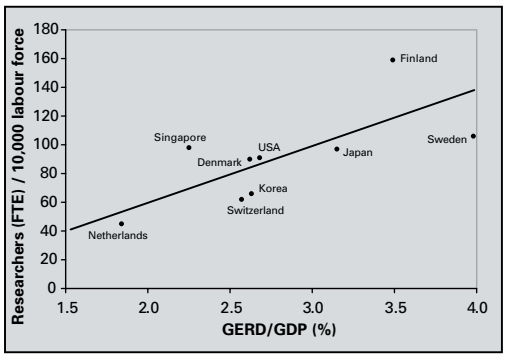
Investments will follow talent. A ready and abundant supply of highly trained research manpower will be a key factor pulling knowledge-intensive industries to Singapore, in addition to our traditional strengths of good infrastructure, a stable investment climate and political stability.

Highly trained manpower will help our local enterprises upgrade and move up the technology value-chain, thereby enabling them to become more internationally competitive.

NATIONAL EFFORTS

Between 1995 and 2003, the number of Research Scientist & Engineers (RSEs) more than doubled from 8,340 to 17,074. As Singapore targets to achieve a GERD of 3% of GDP, we will need to increase the number of RSEs to sustain the higher levels of R&D activity. (Fig 6-1 shows the upward trend when each country's number of RSEs are plotted against their GERD.)

Fig 6-1: Researchers (FTE)/10,000 labour force vs GERD/GDP



Source: OECD Main Science & Technology Indicators (2005)

Tertiary institutions will play an important role in encouraging and developing talent and interest in science and technology. Our local universities and polytechnics will continue to provide a strong pipeline of high quality graduates trained in S&T disciplines.

A*STAR'S EFFORTS

A*STAR aims to develop and sustain a strong pipeline flow of PhD talent to meet industry needs. It is well-positioned to do so, with its RIs engaged in R&D activities that support the key industry sectors. The RIs are positioned closer to industry to

Fig 6-2: A*STAR'S Key Tasks in Human Capital Development

better allow them to understand and support industry's needs. They are structured to respond more quickly to the emerging scientific and technological advances and industry developments.

A*STAR's Approach to Human Capital Development

• Pro-Foreign, Pro-Local Approach

A*STAR taps on the best in the world to meet Singapore's needs for quality R&D manpower. The new technologies and know-how brought in accelerates the development of Singapore's research capabilities. Global talent also helps to connect Singapore to the best scientists and scientific organisations internationally, strengthening our global network. It also creates a vibrant research community that puts Singapore on the world map as a key node for scientific and technological research.

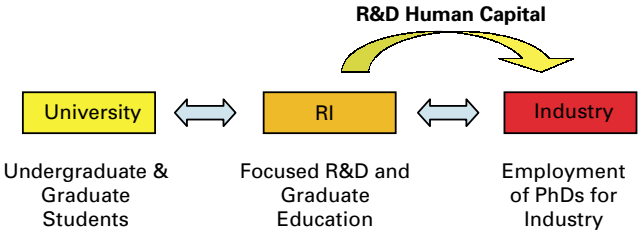
A*STAR plans to groom more of the best and brightest Singaporeans to undertake careers in research. These will help to fill position in the RIs and assume leadership positions in future.

A*STAR aims to develop a good balance of local and foreign R&D talent for sustainability over the longer-term. R&D

The **Distinguished Visitors Programme (DVP)** brings eminent scientists to Singapore, with the aim to increase the exposure of researchers and young scientific talent in Singapore to international trends and developments in scientific research, and to .build closer ties with the international scientific community.

Prof Sir George Radda (above) visited Singapore in August 2002 as part of BMRC's DVP. Since then, he has been increasingly involved in Singapore's biomedical sciences efforts. He is a member of the BMRC Board and is an emeritus member of the Biomedical Sciences International Advisory Council. Sir George is currently Professor and Chairman of the Department of Physiology, Anatomy and Genetics at the University of Oxford. Previously, he was Chief Executive of the Medical Research Council and Chairman of the National Cancer Research Institute in the UK. In 2005, Sir George was appointed Chairman of the Singapore Bioimaging Consortium.

Fig 6-3: A*STAR's Unique Position



must be anchored by a sufficient base of rooted RSEs in order to effectively retain the knowledge and R&D capital in Singapore.

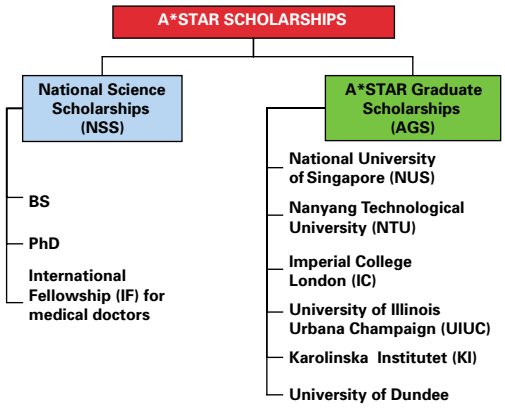
• Programmes to bring top scientists to Singapore

As part of the efforts to seed local talent, the BMRC and SERC established the Distinguished Visitors' Programme (DVP) and Visiting Investigatorship Programme (VIP) respectively.

The **Visiting Investigatorship Programme (VIP)** brings top researchers to Singapore to spearhead new research opportunities which have the potential to be developed into major research themes for Singapore.

*Prof Dim-Lee Kwong, of University of Texas, Austin, was appointed a Visiting Investigator in 2000. Through the appointment, Prof Kwong helped set up the Silicon Nano Devices Lab at the National University of Singapore. The relationship was furthered when he accepted the appointment as member and subsequently chairman of the Science Advisory Board of Institute of Microelectronics. In 2004, Prof Kwong accepted the role of Director of the IME Semiconductor Process Technology Division where he has helped consolidate research equipment for 8-inch process technology. Building on this, A*STAR has successfully interested Prof Kwong in playing a stronger role in leading microelectronics R&D in Singapore, by taking on the position of Executive Director of the Institute of Microelectronics in Jan 2005.*

Fig 6-4: A*STAR Scholarships



• Scholarship Programmes

A*STAR has established a comprehensive range of scholarship and fellowship schemes to target different segments of young talent at the undergraduate and post-graduate levels.

A*STAR launched the National Science Scholarships (NSS) in 2001 and the A*STAR Graduate Scholarships (AGS) in 2003, to build a pipeline of PhD trained researchers for Singapore.

The NSS supports both undergraduate and postgraduate studies at leading overseas universities, as well as a year of attachment at the A*STAR RIs between the undergraduate and graduate programmes. A*STAR scholars eventually return to take up R&D positions in the research institutes, and thereafter in industry. A pastoral care programme has also been established to maintain close relationships and strong linkages with the scholars through their studies.

Under AGS, A*STAR partners top universities to jointly train researchers at the PhD-level. The AGS programme has two components. AGS (Local) is a collaboration with the National University of Singapore and the Nanyang Technological University. Under AGS (Foreign), A*STAR has partnered top overseas universities such as Imperial College London, the University of Illinois at Urbana-Champaign, Sweden's Karolinska Institutet, and Scotland's University of Dundee.

SCHOLARSHIP AWARDS

Over the past 4 years (FY01-04), A*STAR has awarded 276 NSS and 110 AGS scholarships and fellowships. The scholarships have been successful in expanding the R&D talent pool in A*STAR and Singapore.

PROMOTING PRIVATE SECTOR R&D

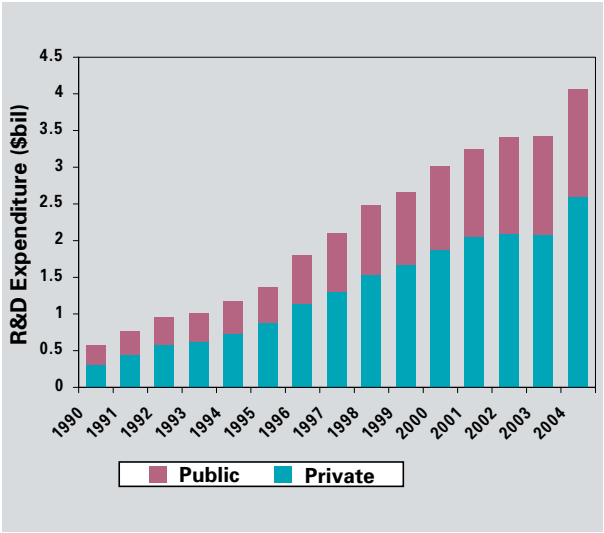
The growth in intensity of private sector R&D activities in Singapore reflects the development of the Singapore economy up the value-add chain – from low-technology labour-intensive industries in the 1960s to increasingly higher value-added and knowledge intensive ones today.

Singapore was a relatively late starter in R&D, compared to the developed countries with steep traditions in science and technology e.g. US, Switzerland, Japan.

However, we have made significant progress over the past 10-15 years (Fig 7-1), trebling our private sector R&D expenditure over this period. In 2004, private sector R&D expenditure constituted 64% of GERD and 1.43% of GDP. R&D growth was fuelled both by strong economic growth, a focus on attracting high value-added manufacturing activities, and the development of knowledge institutions, viz. universities and public research institutes.

Under the S&T Plan 2005, the target is to grow private sector R&D to two-thirds of total R&D expenditure (i.e. 1.67% of GDP) by 2005. In 2004, private sector R&D constituted 64% of GERD.

Fig 7-1: Public and Private Share of GERD



Source: National Survey of R&D in Singapore (2004)

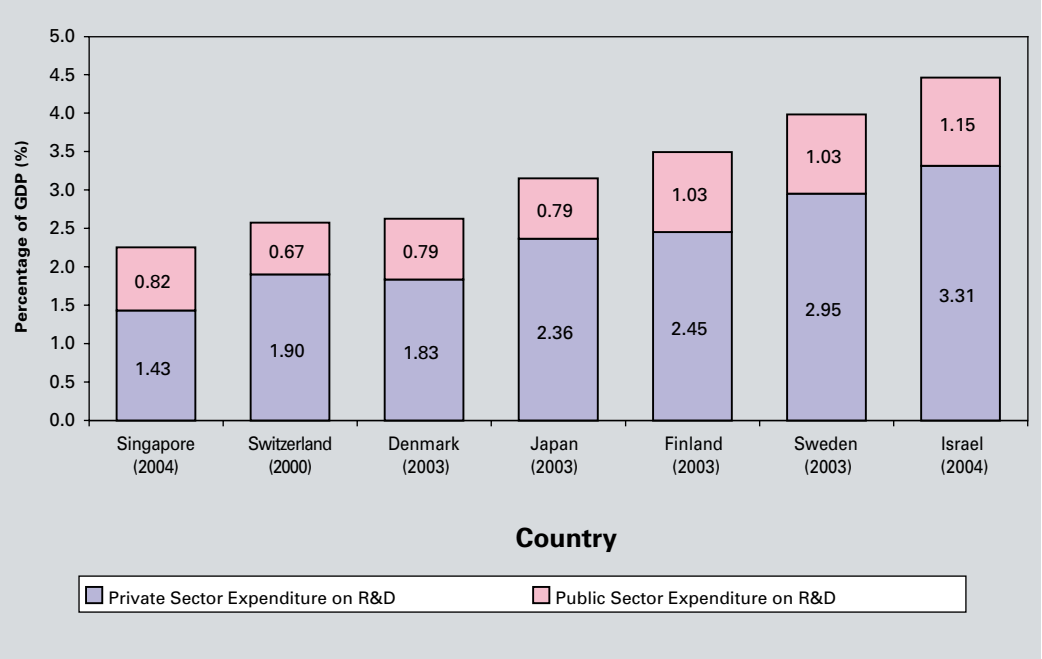
ENCOURAGING MORE PRIVATE SECTOR R&D

Singapore must continue to intensify efforts to promote private sector R&D. This is one of the major thrusts for the next 5 years under the S&T Plan 2010.

Under the S&T Plan 2010, a target has been set for two-thirds of GERD to be performed by the private sector over the longer term. Top innovative economies, such as Sweden and Finland (Fig 7-2), already achieve private sector spending of over 2% GDP and over two-thirds of GERD.

One of the major thrusts for the next 5 years under the S&T Plan 2010 is to encourage more private sector R&D. Indeed, private companies are better placed to decide which areas of R&D to invest in, and to align R&D investments with economic opportunities.

Fig 7-2: Private & Public Sector Expenditure on R&D



Source: OECD Main Science and Technology Indicators (2005)

STRATEGIES TO RAISE THE LEVEL OF PRIVATE SECTOR R&D

• Anchor R&D Investments and Activities

Multinationals and large local enterprises will continue to be the key performers of private sector R&D activities in Singapore. Going forward, the aim is to anchor more flagship R&D projects and attract multinational companies (MNCs) to locate more corporate R&D activities in Singapore. Greater efforts will be also put in to help Singapore local companies to upgrade and develop depth through R&D capabilities, in order to stay competitive in the next 5 years and beyond.

EDB will work closely with A*STAR RIs and the universities to promote R&D investments, so as to better engage companies at the technology level. The promotion effort would be supported by a combination of incentives and assistance schemes, as well as R&D support.

Incentive and Assistance Schemes

The Research Incentive Scheme for Companies (RISC), established in 1993, has been a key industry and capability development tool for anchoring and building R&D capabilities in Singapore. Through a co-funding mechanism, RISC grants help to attract R&D investments in Singapore e.g. R&D centres, particularly in areas of economic importance to Singapore. RISC also supports R&D projects that result in the increased hiring and training of RSEs. Through RISC, local enterprises enhance their capabilities to

better enable them to compete in the global market or to build sustainable R&D and manufacturing activities in Singapore.

Over the past 5 years, every dollar of RISC grant has attracted several dollars in additional R&D investment by the private sector.

In addition to RISC, there are other assistance schemes which incentivise companies to engage in innovation-based activities e.g. innovation grants, additional tax deductions on R&D related costs.

- **Build R&D Capabilities**

A*STAR RIs

A*STAR and its RIs play a key role in strengthening Singapore's industrial capabilities and enhancing industrial competitiveness. It supports EDB's investment promotion role by helping to stimulate, support and enhance the growth of competitive clusters of industrial innovation, and to anchor their activities in Singapore.

The A*STAR RIs have developed core competencies that support Singapore's key industry clusters. A*STAR also actively builds linkages across the RIs, industry, and the university sector, and leverages on international collaborations to develop a full spectrum of R&D activities.

A*STAR will continue to expand and strengthen collaborations and linkages between public sector R&D and industry through direct support for industrial innovation activities, and by sharing R&D human capital and resources with industry. A*STAR seeks to establish a robust research environment and infrastructure that serves to support Singapore local companies and anchor MNC R&D activities in Singapore.

A*STAR contributes towards public-private partnerships to spur more private sector R&D in the following ways:

• **Direct support for industrial innovation** – Either by partnering firms to undertake research, development, and design activities, or by assisting companies in bringing prototypes to production or adopting new technology,

leading to long-term collaborative relationships with companies, and deepening of their economic presence in Singapore;

• **Provision/sharing of R&D/technical facilities and services to the industry** – This reduces capital investment that companies have to make to conduct R&D activities, and allow economies of scale to be exploited to lower operating costs of doing R&D in Singapore. Through the cohabitation of public and industry R&D, it also facilitates the inter-mingling of R&D personnel, exchange of expertise and ideas, building of both formal and informal linkages, as well as encourages the flow of R&D talent from the RIs to industry;

• **Industrial Consortium** – formation of task forces by multiple RIs and companies to address broad industry-wide issues and opportunities; and

• **Commercialisation of Technology (COT)** – Identify cutting-edge technologies from A*STAR RIs and undertake development risks to bring them to a stage that is easily commercialised by industry.

Private Laboratories

Private laboratories are a key infrastructure that can support private sector R&D growth over the longer term. Such laboratories will enhance Singapore's R&D capabilities, add to the diversity of R&D sources, and provide an alternate means for companies to conduct R&D here. These laboratories can also provide services such as contract research, consulting, technology transfer via IP licensing and spin-off companies, and technology commercialisation projects.

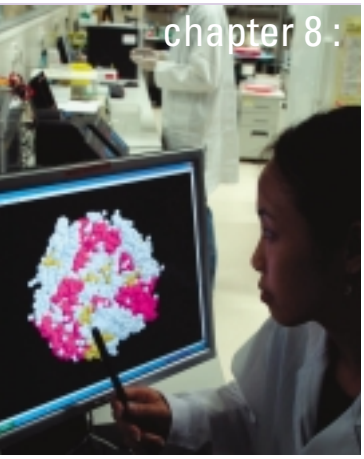
• Diversify Sources of R&D Funding

We need to promote a greater diversity of R&D funding to encourage more private sector R&D. Singapore should continue

work to gradually increase the research funding coming from non-profit organizations as well as private foundations. These funds play an important role in funding R&D whose commercialisation potential may be uncertain, such as basic research or very specialised areas of R&D.

• Encourage Innovation in SMEs

SMEs are a critical component of the enterprise ecosystem. A strong cluster of innovative enterprises will help to stimulate a culture of creativity and experimentation; and to support and hence attract higher value-added industries and R&D activities. Strengthening technology innovation in SMEs will thus be another key thrust to encourage more private sector R&D.



chapter 8 :

STRENGTHENING TECHNOLOGICAL INNOVATION CAPABILITIES IN SMEs

Enterprises create value by converting ideas into commercial reality. They are a key player in the innovation system, helping to turn knowledge and research into new products, services and processes. Indeed, enterprises lie at the core of successful innovation.

This chapter outlines the framework for building technology innovation capabilities in our local enterprises, with focus on small and medium enterprises (SMEs), to better enable them to contribute to the innovation system.

SMEs in Singapore – as in most other countries – occupy an important position in the enterprise ecosystem. They make up 99% of all enterprises, and contribute 47% of GDP and 23% of manufacturing exports. More importantly, they account for a significant 62% of employment.

TECHNOLOGY INNOVATION IN SMES

SMEs are well aware of the need to leverage on technology to thrive in a competitive knowledge-based economy. In the 2004 SME Development Survey conducted by DP Information Network, 1 out of every 3 SMEs in Singapore identified the need to keep up with new technology as a key factor for business growth.

SMEs, because of their small size and less entrenched modus operandi, hold great potential as a source of creativity and innovation. In the US, 4 out of every 10 highly innovative firms are small firms.

Indeed, technology innovation can provide a powerful platform from which SMEs launch into the competitive economic landscape of the 21st century.

Many SMEs, however, lack the know-how and capability to absorb and deploy new technologies. Most are either technology followers or technology-indifferent, with only a minority possessing the technological foundation and skilled personnel to take advantage of technology. We need to help SMEs bridge the gap, and better position them to take advantage of opportunities in new markets that come about from changing global trends.

EXISTING INITIATIVES ADDRESSING TECHNOLOGY INNOVATION IN SMES

Over the years, we have introduced a range of programmes to help enterprises undertake technology innovation. In 2003, we launched the GET-UP Programme which pulls together various existing assistance programmes to provide a customized solution for enterprises. GET-Up provides three broad areas of assistance: technical assistance and manpower support; financial incentives and assistance; and overseas market development.

Official Launch of the **GET-Up Initiative** in 2003

- **Technical assistance and manpower assistance programmes**

– **Operation and Technology Roadmapping (OTR)** which aims to enable companies to develop Technology Roadmaps aligned to their mid-term business goals and strategies.

– **Technology for Enterprise Capability Upgrading (T-Up)** which enables local enterprises to access the R&D talent in the RIs to help them build in-house R&D capabilities and culture; and forge collaborations between the local enterprises and RIs for technology transfer.

– **Technical Advisory Support (TA)** which aims to provide a bridge between the in-depth technical advice needed by companies and the expertise available in the RIs.

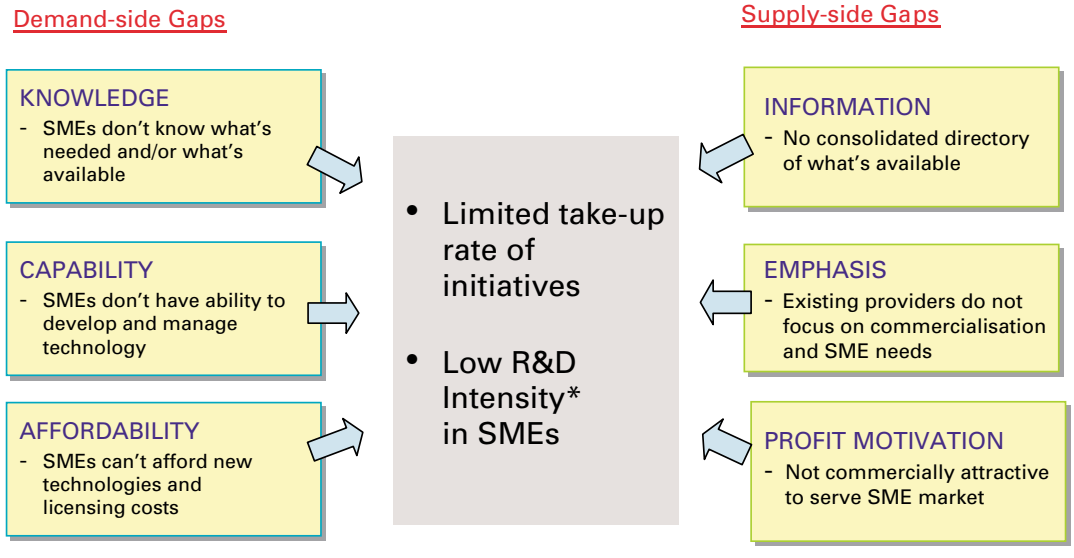
- **Financial assistance schemes**

– **Innovation Development Scheme (IDS)** which encourages and assists Singapore-registered companies and organisations to engage in and develop capabilities in the innovation of products, processes, applications and services.

– **Local Enterprise Technical Assistance Scheme (LETAS)** which supports generic upgrading projects for SMEs by defraying the cost of consultancy service for the implementation of IT projects, quality management systems and OTR.

– **Local Enterprise Finance Scheme (LEFS)**, which is a fixed interest rate financing programme designed to encourage and assist local enterprises to upgrade, strengthen and expand their operations.

Fig 8-1: Gaps in Technology Innovation



Note: "R&D Intensity is defined as R&D spending as a percentage of Value Added".

GAPS IN TECHNOLOGY INNOVATION

While much has been done to help enterprises, more can be done. Fig 8-1 shows some of the reasons cited by SMEs and service providers on the difficulties encountered in technology innovation. It is clear that there is a need to:

- Help SMEs understand their technology needs;
- Help SMEs gain access to technology and related information;
- Help SMEs source for relevant technologies both locally and globally;
- Encourage technology innovation in SMEs; and
- Provide incentives for technology innovation in SMEs.

TECHNOLOGY INNOVATION FRAMEWORK FOR SMES

SPRING has developed an SME Technology Innovation Framework to address the demand and supply gaps. There are three key strategies under this framework.

- **Catalyse Technology Innovation Projects in SMEs**

This promotional role will be undertaken at the general SME community level, as well as the more specific industry and enterprise levels; with a focus on helping SMEs address their technology gaps through technology advisory and matching services, drawing on technologies and partners both locally and overseas.

SMEs will be encouraged to undertake technology innovation projects, in particular with knowledge institutions such as polytechnics.

- **Build Technology Innovation Capabilities in SMEs**

The aim is to help SMEs build up their technology innovation capabilities through the secondment of expert manpower from research institutes and other knowledge institutions and providers to SMEs as well as the training of employees in SMEs. The long-term goal is to invigorate enterprises by helping them develop indigenous innovation capabilities, and expand their capacity for innovation.

- **Develop Technology Support Infrastructure for SMEs**

SPRING will work with RIs and polytechnics to set up relevant technology laboratories & services to support SMEs in key verticals (either by expanding the capacity of existing infrastructure or creating new infrastructure). This will create a favourable support environment for SMEs to undertake technology innovation.

SMEs will continue to make important contributions to the economy as we transit to a reasearch-and innovation-intensive environment. We will need to strengthen the transfer of technology and expertise from public research agencies to the enterprise sector and to deepen capabilities in enterprises to benefit from such initiatives. This will help to realize one of the key thrusts of the national R&D strategic framework; viz., to strengthen the nexus between R&D and industry.

SPRING, will focus more attention on promoting technology innovation, and developing the requisite technology innovation and innovation support capabilities.

SPRING will take a market-driven approach towards assistance: The technology solution identified should be driven by the SMEs' business agenda and assistance provided only in areas where there is market failure. There must also be co-investment by SMEs to ensure ownership.

SPRING will also leverage on existing capabilities, institutions, and infrastructure via partnerships with various technology service providers such as A*STAR RIs and the polytechnics, SMEs and industry associations.

SPRING will work through industry associations as Technology Co-Facilitators to reach out to SMEs, identify their needs, and help implement technology upgrading programmes.

For a start, SPRING will focus on strategic clusters with significant growth potential for SMEs, for example Precision Engineering, Transport Engineering, Logistics, Environmental Engineering and Food.

INCREASING COMMERCIALISATION OF PUBLIC RESEARCH – IP POLICIES

Singapore has put in place a reliable and robust intellectual property (IP) framework that offers protection for created knowledge and provides an equitable framework in which this knowledge can be leveraged commercially. The framework constitutes a key infrastructure underpinning innovation and business growth in a knowledge-based economy. It will promote the growth of R&D activities and the commercialisation of their results.

As part of Singapore's plan to become an IP hub, efforts have been made to strengthen IP legislation and the enforcement mechanism; foster greater IP awareness and capability development; and raise Singapore's profile in the international IP regime. The Intellectual Property Office of Singapore (IPOS) was established in April 2001 as the leading government agency to spearhead these efforts. The IP Academy was launched in January 2003 to deepen and broaden Singapore's knowledge and capabilities in IP protection, exploitation, and management.

The success of these efforts is reflected by Singapore's climb up the international rankings in patent and copyright protection, as well as the per capita number of patents in force (Fig 9-1). An Asian Intelligence Report by the Political Economic Risk Consultancy (PERC) in 2004 ranked Singapore tops in terms of IP rights protection amongst 12 Asian countries.

Singapore's excellent IP regime has helped it to attract significant new investment in the biomedical sciences sector, in particular in the pharmaceutical industry. The biomedical sciences sector in Singapore is one of the fastest growing sectors, contributing substantially to the growth in exports.

The strong IP regime has also contributed to efforts to promote Singapore as an R&D hub.

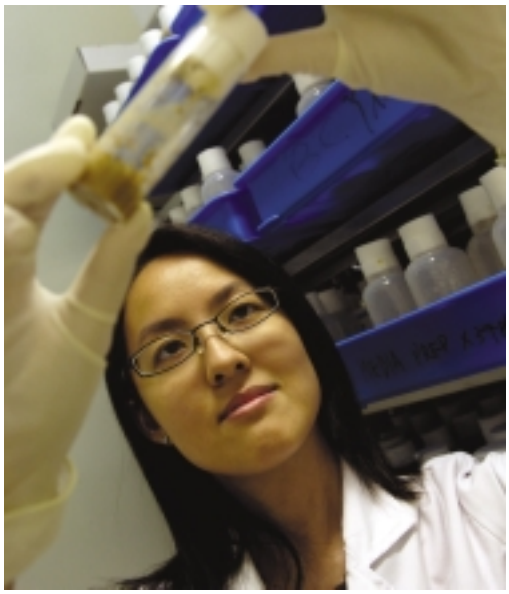
Singapore's strategy to become an IP hub also involves strengthening the link between IP creation and exploitation.

Public research is an important source of new discoveries, ideas and innovation. These can be taken to the market to generate new jobs and create value and wealth for Singapore's economy. In both the A*STAR RIs and the universities and polytechnics, commercialisation of research results is regarded as a core

Fig 9-1: Singapore's International Ranking in the IP Field

Year	2001	2002	2003	2004	2005
Patent & Copyright Protection	#14	#13	#14	#7	#7
No. of Patents in Force per 100,000 inhabitants	#17	#13	#14	#9	#4

Source: IMD World Competitiveness Yearbook 2005



activity alongside the research activities. Our funding models recognise the risks and the time horizons it may take to achieve significant successes in commercialisation.

To optimise the economic impact of the IP created from publicly-funded research, clear policies and structures have been put in place to manage IP effectively. Efforts at commercialisation will also take account of the availability of industry receptors to absorb and exploit new technologies.

IP POLICIES

• Collaborations

R&D is rarely done in isolation. In particular, R&D partnerships between public research organisations and industry are a key feature of an innovation system. Clear and robust guidelines and policies on the ownership, use and exploitation of IP generated in R&D collaborations have been put in place to facilitate such partnerships.

For public research organisations, the guiding principle for the management and commercialisation of IP is to ensure the full exploitation of research results. In particular, they aim to ensure that the IP remains available for further use and exploitation, including when partnering with different collaborators in the future.

• Incentive Policy

Measures have been put in place to incentivise researchers to commercialise their research, through policies that allow them to share in the financial returns. This recognises that the researchers have a significant role in determining the commercialisation pathways, and may not

KEY ISSUES OF IP OWNERSHIP IN COLLABORATIONS BETWEEN PUBLIC RESEARCH ORGANISATIONS AND INDUSTRY

The key consideration in IP agreements arising from collaborations is the right for the PROs to use and exploit the IP, even when partnering other collaborators in future research. Ownership is not necessary to guarantee these rights, but is an effective solution in practice.

Generally, these objectives can be achieved by arrangements where either joint ownership is provided for or the industry partner owns the IP, while allowing the PRO freedom to use the IP for research and development. The PRO should also have a share of the revenue generated by the industry partner (where the industry partner commercializes the IP). However, for the reasons stated below, these are not the most expedient solutions and PRO ownership of the IP is preferred.

In the case of joint ownership, clear rules must be prescribed upfront on the management of IP protection and sharing of costs, particularly with regard to patents. Also, rights must be defined for dealing with the potential asymmetry of advantages accruing to commercial organizations who can exploit the technology themselves whereas PROs can only commercialize through licensing. Verification and monitoring of the industry partners' obligations may be costly and difficult. Potential problems could also arise when a PRO needs to create a bundle of IP based on licenses from different industry collaborators, and when IP is owned by different parties. In such cases, fragmentation of IP ownership becomes an impediment to effective exploitation.

In collaborations and sponsored research, the basic premise in deciding the assignment of commercialisation rights should be to assign the rights to whichever party can best achieve it. The sponsoring agencies should receive a fair share of the revenue from commercialisation.

ENABLING INFRASTRUCTURE FOR EFFECTIVE IP MANAGEMENT AND COMMERCIALISATION

Appropriate structures and processes need to be in place at the PROs to encourage the valorisation of research. A clear mandate from the management is necessary and appropriate performance indicators relating to commercialization must be established to ensure focus. Research at PROs should cover technology validation and proof-of-concept activities that would bring the technology closer to the market and increase its likelihood of commercialization.

- **IP Management and Processes**

PROs should demonstrate their commitment by investing in proper commercialization management systems. PROs should have in place an organizational structure for commercialization of IP that allows for timely decision-making, appropriate risk management process, and flexibility in market approach. Employment, reward, assessment, and recognition systems have to be designed to provide incentives for researchers to encourage them to engage in commercialization activity.

Technology and Competitive Intelligence (TICI) should be undertaken to analyse the strength of the PRO's IPs and their market potential. In particular, PROs need to pay more attention to portfolio building so as to enhance the success of bringing to market technologies with good commercial potential. Commercialization as well as incubation and spin-off management teams must also actively bring budding technologies to the companies to facilitate their commercialization.

- **Technology Managers**

Technology transfer offices must be able to hire staff with sufficient expertise as well as outsource certain activities to specialists as the need arises. Efforts by the IP Academy, IPOS, as well as Exploit Technologies, in providing training for IP professionals must continue.

- **Availability of Early Stage Funding**

The venture capital (VC) environment in Singapore is unlike that of the Silicon Valley or Boston-Cambridge. In Singapore, there are limited investments by VCs into seed-stage companies, with most VC funds focusing on later-stage companies, typically when they are already generating revenue.

The limited funding available at the pre-seed and seed rounds generally discourages potential entrepreneurs from spinning-off companies out of PROs, unless there are alternative sources of funds that allows them a sufficient runway to achieve milestones of significance (e.g. pre-clinical proof of concept) to attract early stage VC funds. PROs could have a role in this.

always be interested in spinning off companies. One of the significant models in North America, which has also been adopted by A*STAR, allocates one-third of net proceeds to the researcher, one-third to the researcher's department, and the remaining one-third to the institution or its commercialisation arm.

SUPPORTING INSTITUTIONS

Effective IP management and commercialisation must be supported by an experienced and well-trained base of technology transfer expertise, and informed by robust Technology and Competitive Intelligence (TICI).

In addition, the availability of early stage funding for new technologies is critical to bridge the gap between the laboratory and commercial exploitation. For instance, EDB has initiated the Start-up EnterprisE Development Scheme (SEEDS) which provides equity funding to start-ups at the early seed stage. SEEDS has supported 148 start-ups in the last 4 years.

A*STAR established its commercialisation arm, Exploit Technologies in 2002, to integrate the IP management and commercialisation efforts of the A*STAR RIs. The commercialisation professionals at Exploit Technologies provide the base of technology transfer expertise to drive A*STAR's commercialisation efforts. Exploit Technologies actively markets A*STAR's IP to industry, negotiates licenses and helps to ensure smooth technology transfer to Singapore industry.

Extensive efforts are being undertaken by the IP Academy, IPOS and Exploit Technologies to train technology transfer

specialists and IP managers, as well as to raise the level of awareness of IP and technology transfer issues amongst researchers. These efforts will continue over the next 5 years.

Exploit Technologies has implemented two key initiatives to help bridge the early stage funding gap for new technologies.

- Commercialisation of Technology (COT) Fund – Promising technologies from A*STAR RIs are developed into a prototype or more commercially ready state, which can then be taken up by companies. This reduces the risk to companies of taking up new technologies. Companies can license these technologies and introduce products to the market more quickly.

- Incubation and Spin-off Management (ISM) – New companies may be incubated when the technology is disruptive or there are no existing companies that are able to effectively exploit the technology. Exploit Technologies will work with the researcher on the business plan, help raise funds from angel investors or seed funds, and may inject capital into the company for equity.

ENTERPRISE RECEPTORS

A critical factor for effective exploitation of research results is a strong base of enterprises which have the capabilities to further develop and exploit new technologies. Efforts to promote awareness of new technologies emerging from public research and the benefits of technology upgrading and licensing amongst local enterprises will continue.

Exploit Technologies' promotional efforts will continue to include company visits

and publicity mechanisms using the mass media and participation in trade shows and exhibitions. The technologies that are available for licensing are offered on Exploit Technologies' website. New offerings are also disseminated to companies through quarterly mailers

Exploit Technologies regards technology licensing as a key means to help upgrade Singapore local companies, and strengthen their competitive advantage. It has flexible licensing terms to cater to the differing needs and circumstances of licensees. For example, MNCs may prefer to pay a lump sum upfront rather than running royalties, while SMEs may prefer to pay royalties matched to their revenue stream. Exploit Technologies has built in sufficient flexibility to provide for the waiver or deferment of the up-front payments and minimum royalties.

R&D INFRASTRUCTURE

WORLD-CLASS RESEARCH INFRASTRUCTURE

Singapore has made significant progress in creating an attractive environment with high quality facilities to support research and technology activities.

In addition to the facilities and infrastructure located at the public RIs, universities, and hospital clusters, we have embarked on major development projects, such as the Biopolis and the Fusionpolis, to enhance the research environment in Singapore.

The aim is to create a "plug and play" environment that will make it easy for foreign companies to locate R&D operations in Singapore, and for Singapore Local Comapanies to kick-start or expand their R&D activities.

With good infrastructure support, Singapore hopes to build up a dynamic and vibrant environment for R&D, and position itself as the R&D gateway to Asia, through which companies can access the attractive markets in the region.

PHYSICAL INFRASTRUCTURE

Media Preparation, a core service provided at the **Biopolis Shared Facilities**

Fusionpolis will be a cradle for knowledge convergence, where next generation applications are incubated and test-bedded, and a magnet for MNCs, start-ups, and venture companies seeking new technologies.

Artist Impression of the ***FUSIONPOLIS***

• Biopolis

The Biopolis is the centre of biomedical research in Singapore. It was conceived as the cornerstone of a broader vision to build up the biomedical sciences industry in Singapore. At the Biopolis, public sector and private sector research are co-located. The Biopolis Shared Facilities and the Biological Resource Centre provide scientific equipment, services and resources catering to the full spectrum of R&D activities and graduate training.

• Fusionpolis

The Fusionpolis is being developed as the focal point for the physical sciences and engineering clusters, a parallel to the Biopolis for the biomedical sciences. The Fusionpolis will house public research institutions, technologies, products, applications and services, and showcase state-of-the-art prototypes.

Phase I of the Fusionpolis will focus on the Infocomms and Media (ICM) cluster.

It is due to be completed in 2007. Phase II will bring in the complementary strengths and capabilities in materials, devices and related technologies, including manufacturing and nanoscale technologies.

The Fusionpolis will be a cradle for knowledge convergence, where next generation applications are incubated and test-bedded. It will be a magnet for MNCs, start-ups, and venture companies seeking new technologies.

• Singapore Tissue Network

The Singapore Tissue Network (STN) is the national tissue and DNA repository. Established through an initiative from the BMRC, Ministry of Health and Genome Institute of Singapore in March 2002, the STN is the national repository for clinicians in Singapore to archive tissue, sera and DNA samples of both normal and disease origins for research purposes.

These samples are collected by the STN with proper informed consent and using confidential, ethical processes. The samples will be made available for researchers seeking to advance biomedical sciences and healthcare while maintaining the donors' rights to privacy and confidentiality.

STN's goals are to develop a novel and internationally recognized national repository to facilitate the conduct of the highest quality translational and population research, and to develop an infrastructure that will support worldwide academic and commercial collaborators and investments in Singapore's biomedical sciences initiatives.

NGPP comprises of heterogeneous compute resources connected together via 1 Gbps lines. Today, nearly 500 CPUs are linked to NGPP. The NGPP Hub has connectivity to the US, Japan and Korea.

• National Grid

The National Grid Pilot Platform (NGPP) is the initial phase of a cyber-infrastructure which allows users to tap on a wider pool of distributed resources for collaboration and problem-solving. NGPP aims to enable the sharing of computing resources in Singapore in a secure, reliable and efficient manner by authenticated users. Its uses may span R&D, education, commerce, entertainment, national security and other new applications. NGPP forms the base of a strategic technology platform that promises to transform the way we work, and ultimately improve the economic and technological competitiveness of Singapore.

OPTIMIZING USE OF R&D FACILITIES

Mechanisms have been established to ensure the optimal usage of public R&D facilities at our research institutes, universities and polytechnics.

A*STAR has put in place R&D facility and equipment management systems to promote greater sharing across the RIs. This will also be extended to the universities, polytechnics and industry collaborators. In addition, A*STAR RIs make available to industry specific high-cost, low-intensity usage facilities and equipment that would not otherwise be readily available to companies.

SOFT INFRASTRUCTURE

• Bioethics Advisory Committee

In December 2000, the Government established the Bioethics Advisory Committee (BAC) to address the potential ethical, legal and social issues arising from biomedical sciences research in Singapore.

The Committee is charged to ensure that Singapore's decisions regarding the biomedical sciences and its research are based on good science and high ethical and legal standards. It actively gathers information and views from international and local communities and makes its recommendations to the Steering Committee on Life Sciences (SCLS).

• National Advisory Committee for Laboratory Animal Research

The National Advisory Committee for Laboratory Animal Research (NACLAR) was set up to establish national guidelines for the proper treatment and use of animals for scientific purposes, while taking into consideration the relevant scientific, ethical and legal issues. NACLAR makes its recommendations to the SCLS accordingly. It comprises members drawn from academia, research organizations and the Agri-Food and Veterinary Authority of Singapore (AVA), as well as legal and ethics specialists.

NACLAR is composed of three subcommittees, each looking into specific aspects of the national guidelines, namely (i) general guidelines on animal care and use for scientific purposes based on ethical, legal and scientific considerations; (ii) institutional animal care and use committees; and (iii) training of personnel involved in the care and use of animals for scientific purposes.

NACLAR released the "Guidelines in the Care and Use of Animals for Scientific Purposes" in October 2004. In conjunction with the release of the NACLAR Guidelines, it was also announced that institutions which use animals must be licensed under the AVA's Animals and Birds (Care and Use of Animals for Scientific Purposes) Rules, which came into effect on 15 November 2004.

MAJOR R&D FACILITIES AT THE UNIVERSITIES

Apart from the RIs, our universities also have a wide range of research facilities and equipment, mainly used for teaching and basic research. For instance, NUS hosts the Singapore Synchrotron Light Source (SSLS), the Centre for Remote Imaging, Sensing and Processing (CRISP), as well as the Centre for Ion Beam Applications (CIBA). NTU hosts specialised infrastructure, such as the Microfabrication Facility, the Facility for Advanced Characterization, Testing and Simulation, the NTU Life Sciences Core Instrumentation Centre and the Animal House.

chapter 11 :

BUDGET AND TARGETS

EXPENDITURE ON R&D

To drive the transformation of Singapore to a research and innovation-driven economy, the Government will set aside a budget of $13.55 billion to promote public and private R&D (excluding the defence sector) over the next 5 years.

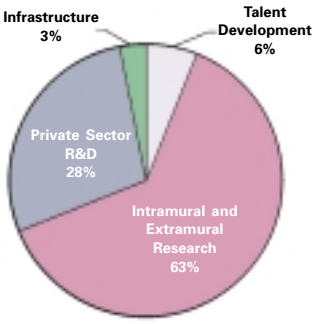
$5 billion will go to the National Research Foundation (NRF) to fund new growth areas and strategic programmes; $1.05 billion to academic, investigator-led research under the Ministry of Education (MOE); $7.5 billion to promote economic-oriented R&D and related investment promotion activities under the Ministry of Trade and Industry (MTI).

S&T Plan 2010

The $7.5 billion allocated to MTI will support the S&T Plan 2010 for the period FY2006 to 2010.

Of the $7.5b budget, about $0.45 billion or 6% will be set aside for developing and managing talent through various A*STAR scholarship and fellowship grants.

Fig 11-1: Breakdown of S&T2010 Budget



About $4.7 billion or 63% will be allocated for research activities carried out by both A*STAR RIs and extramural community such as universities, hospitals and disease centres. The funding would go towards deepening RIs' existing research capabilities, fostering inter-disciplinary synergies through inter-RI collaboration, and supporting extramural research that complements and strengthens RIs' capabilities along strategic themes. The funding would also support pre-commercialisation activities such as early stage funding to support worthy innovations.

$2.1 billion or 28% of the budget would be used to promote private sector R&D. EDB will continue to promote the growth of high value-add advanced manufacturing clusters and the establishment of corporate R&D centres in Singapore.

Another $0.25 billion or 3% would be spent on research infrastructure to support research activities, including the Biopolis and Fusionpolis.

NATIONAL R&D TARGETS

At the national level, the following R&D targets have been set:

- **To increase Gross Expenditure on R&D (GERD) to 3% of GDP** within the next five years, from the 2004 level of 2.25%. The aim is to close the gap in R&D investments with innovation leaders such as Sweden, Finland, and Japan. (See Fig 11-2 for international comparisons)

Fig 11-2: GERD as a % of GDP

Country	GERD/GDP (%)	Year
Sweden	3.98	2003
Finland	3.49	2003
Japan	3.15	2003
US	2.68	2003
Korea	2.63	2003
Denmark	2.62	2003
Switzerland	2.57	2000
Singapore	2.25	2004
Netherlands	1.84	2003

Source: OECD Main Science and Technology Indicators (2005)

- **To increase private sector's share of GERD to two-thirds** over the longer term, from the 2004 level of 64%. (See Fig 11-3 for international comparisons.)

Fig 11-3: BERD as a % of GERD

Country	BERD as % of GDP	BERD/ GERD (%)	Year
Sweden	2.95	74.1	2003
Finland	2.45	70.2	2003
Japan	2.36	75.0	2003
Korea	2.00	76.0	2003
Switzerland	1.90	73.9	2000
US	1.88	70.1	2004
Denmark	1.83	69.8	2003
Singapore	1.43	63.8	2004
Netherlands	1.06	57.6	2003

Source: OECD Main Science and Technology Indicators (2005)

- **To increase the research manpower to support our R&D thrusts and the higher level of R&D activities.** The aim is to catch up with countries like Sweden and Japan to ensure an adequate supply of manpower See Fig 11-4 for international comparisons.

Fig 11-4: Number of researchers (Full Time Equivalent) per 10k labour force

Country	FTE per 10k labour force	Year
Finland	159	2003
Sweden	106	2003
Japan	101	2003
Singapore	98*	2004
US	91	2002
Denmark	90	2003
Korea	66	2003
Switzerland	62	2000
Netherlands	45	2003

* In 2004, there were 87 RSEs per 10k labour force. To allow for international comparison, "researchers" (FTE) is used instead of "RSEs". "Researchers" includes degree and non-degree R&D personnel, and post-graduate students, while "RSEs" includes only degree R&D personnel.

Source: OECD Main Science and Technology Indicators (2005)

Agency Level R&D Targets

At the agency level, the following R&D targets have been set for A*STAR and EDB over the next five years from 2006 to 2010:

Fig 11-5: A*STAR indicators

Indicators for A*STAR	Projected (2001-05)	Target (2006-10)
Human Capital Development		
1. Number of PhD students trained and graduated	215	220
2. Number of RI staff spun out to locally-based industry as RSEs	706	835
Intellectual Capital Development		
3. Number of primary patent applications	850	1,100
4. Number of papers published (in science citation and engineering index journals)	5,727	7,940
Industrial Capital Development		
5. Number of projects with industry	952	1,120
6. Industry funding ($m)	143	197

Fig 11-6: EDB indicators

Indicators for EDB	Actual (FY01-05)	Target (FY06-10)
1. Total Research Investment (TRI)	$8.5 bil ($1.7 bil p.a.)	$9-10 bil ($1.8-2 bil p.a.)
2. No. of large R&D projects (defined as projects >= $50 mil TRI)	40	45
3. No. of RSE positions created	6,449	7,500

COMPOSITION OF S&T2010 COMMITTEE

Prof Tan Chorh Chuan
Provost
National University of Singapore
and
Deputy Chairman
A*STAR

Prof Chong Tow Chong
Executive Director
Science & Engineering Research Council
A*STAR

Assoc Prof Kong Hwai Loong
Executive Director
Biomedical Research Council
A*STAR
[to April 2005]

Assoc Prof Lam Kong Peng
Acting Executive Director
Biomedical Research Council
A*STAR
[from April 2005]

Mr Ng Wai Choong
Deputy Secretary (Industry)
Ministry of Trade and Industry

Mr Laurence Lien
Director (Economic Programmes)
Ministry of Finance

Mr Ko Kheng Hwa
Managing Director
Economic Development Board

Mr Tan Chek Ming
Assistant Managing Director (Cluster Development)
Economic Development Board
[alternate member]

Mr Loh Khum Yean
Chief Executive
Standards, Productivity and Innovation Board

Mr Boon Swan Foo
Managing Director
A*STAR

Mr Teoh Yong Sea
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FORESIGHT AND TECHNOLOGY SCANS

A key component of the S&T planning process was the Technology Foresight and Scan to identify driver applications and disruptive technologies over a 10-15 year horizon and develop roadmaps that will guide science & engineering research to 2010. Technology Scan Panels were set up for each area, jointly led by chairpersons from the universities, the RIs and government agencies, in consultation with local and international technical advisors. The RI Executive Directors and chairpersons of these Panels were members of a collective Foresight Committee, which had the task of identifying, in consultation with visionaries, overarching "themes" or key problems which will direct the Tech Scan and Roadmapping effort. SERC set up thirteen such Panels in 2004. Their compositions are as follows:

Exploiting Nanotechnologies

Chairpersons:
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Mr Koh Wee Leong, Economic Development Board (EDB)
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Mr Kenneth Low, Exploit Technologies (ETPL)
Mr Tim Harper, Cientifica
Mr Chin Sai Kong, SERC

Information Storage

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Semiconductors

Chairperson:
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Dr Shi Luping, DSI
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Dr Wei Jun, SIMTech
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Asst. Prof Yeo Yee Chia, NUS
Asst. Prof Wang Hong, NTU
Ms Serena Teo, EDB
Mr Gong Xuesong, ETPL
Ms Ng Puay Hua, ETPL
Mr Low Joon Kiat, SERC

Advancing Science through the Grid

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Information Management

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Mr Leong Mun Kew, I²R
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Mr Alvin Kam, I²R
Mr Yau Wei Yun, I²R
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Harnessing Broadband

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Niche Opportunities in Manufacturing

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Frontier in Chemicals

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Ms Tan Le-Shon, A*STAR

Others Panels

A*STAR MNC Panel – A*STAR engaged industry in discussions on the key developments, trends and issues that bore on public policies and programmes in the area of science, technology and innovation. The panel members are:

1) Mr Jen Kwong Hwa, Managing Director, Micro Semiconductor Asia Pte Ltd
2) Mr Atsushi Kawai, Managing Director, Oki Techno Centre (Singapore) Pte Ltd
3) Mr Mourad Mankarios, Chairman and CEO, Philips Electronics Singapore Pte Ltd
4) Mr Jeffrey Tan, President, Motorola Electronics Pte Ltd
5) Mr Thomas Frischmuth, Managing Director, Siemens Pte Ltd
6) Mr Kay Das, Director R&D Asia Pacific, STMicroelectronics Asia Pacific Pte Ltd
7) Mr Lim Shao Bin, Director for Information Solution Systems, Sony Electronics Asia Pacific Pte Ltd
8) Mr Goh Ah Bee, Managing Director, Leica Instruments Singapore Pte Ltd
9) Mr Haruki Yoshiura, Managing Director, Mitsui Phenol Singapore Pte Ltd

S&T Infrastructure Panel – The Panel deliberated on how public R&D infrastructure could be better shared by Singapore's research community. Composition of the panel is as follows:

1) Prof Jackie Ying, Executive Director, IBN (Chairperson)
2) Prof Lee Soo Ying, Dean, School of Physical and Mathematical Sciences, NTU
3) A/Prof Subodh Mhaisalkar, Vice Dean of Research, School of Materials Engineering, NTU
4) Prof Lim Hock, Director, Temasek Laboratories, NUS
5) A/Prof Ren Ee Chee, Deputy Director, GIS; and Director, BSF
6) A/Prof Victor Wong, Deputy Director, BSF
7) Dr Lee Loke Chong, Deputy Director, SIMTech
8) A/Prof Alfred Huan, Laboratory Manager, IMRE
9) Dr Narayan Balasubramanian, Laboratory Head of SPT, IME
10) Mr William Lau, Director, Directorate of R&D, DSTA
11) Dr Tan Geok Leng, Chief Technology Officer, IDA

12) Dr Madesh Choolani, Consultant and Assistant Professor, Department of Obstetrics & Gynaecology NUS (representing National Healthcare Group)
13) Prof Malcolm Paterson, Scientific Director, Singapore Health Services

RI-University Panel – The Panel deliberated on the key issue of building collaborative partnerships between the Universities and the A*STAR RIs. The panel members are:

1) Prof Barry Halliwell, Executive Director, NUS Graduate School of Integrative Sciences and Engineering, NUS
2) Prof Lim Hock, Deputy Director, Office of Research, NUS
3) Prof Chew Yong Tian, Deputy Director, Office of Research, Department of Mechanical Engineering, NUS
4) Prof Tony Woo, Vice President of Research, NTU
5) A/Prof Subodh Mhaisalkar, Vice Dean of Research, School of Materials Engineering, NTU
6) Ms Rachel Foo, Senior Finance Executive, Higher Education, MOE
7) Mr Timothy Sebastian, Director, A*GA, A*STAR
8) Dr Andre Wan, Director, BMRC, A*STAR
9) Dr Rajendran Thampuran, Acting Director, SERC, A*STAR
10) Dr Lim Juay Yong, Deputy Director, BMRC, A*STAR

ABBREVIATIONS

A*GA	A*STAR Graduate Academy
A*STAR	Agency for Science, Technology and Research
BERD	Business Expenditure on Research and Development
BMRC	Biomedical Research Council
CAGR	Cumulative Average Growth Rate
EDB	Economic Development Board
ETPL	Exploit Technologies Private Limited
GDP	Gross Domestic Product
GERD	Gross Expenditure on Research and Development
IES	International Enterprise Singapore
IP	Intellectual Property
KPI	Key Performance Indicator
MCRD	Ministerial Committee for Research and Development
NRF	National Research Foundation
NTP	National Technology Plan
NSTP	National Science and Technology Plan
OECD	Organization for Economic Co-operation and Development
PRO	Public Research Organization
R&D	Research and Development
RI	Research Institute
RIEC	Research, Innovation and Enterprise Council
RISC	Research Incentive Scheme for Companies
RSE	Research Scientist and Engineer
S&T	Science and Technology
SERC	Science & Engineering Research Council
SPRING	Standards, Productivity and Innovation Board

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