S –10

DBJ REPORT

Fostering Research & Development and Technopreneurship in Singapore

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Development Bank of Japan
Representative Office in Singapore

Preface

Research and Development (R&D) sector is becoming increasingly important to the long-term economic growth of Singapore. With the New Economy already setting in, there is a need to continuously harness information by using technology innovatively, maximise efficiency and minimise cost and find solutions creatively, and implement them efficiently.

The characteristics of a knowledge economy are parallel to that of the New Economy, that is using technology as an enabler, in increasingly creative ways such as expanding in e-commerce, which is transacting over the Internet.

The report you are going to read is but highlights of what is going on in Singapore's young yet promising R&D sector.

R&D is carried out in government funded Research Institutes and Centres, Universities, Polytechnics and other private Research Centres set up by foreign multinational corporations located here. Emphasis is placed on government funded research centres collaborating with industries, foreign universities and research centres, to build economically relevant technology, with incentives implemented around this purpose. This with the view of leveraging on each other's strength and developing technology that is of practical use to the current needs of technology-related industry.

The purpose of this report is to give the reader a simple yet comprehensive overview of how the R&D sector is being built up since 1990 by the Singapore government.

Statistics and examples given are chosen by the author on the basis of interest and should not be used as a generalisation. Information is by no means complete and suggestions and conclusions drawn are based on the then available information.

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Entrepreneurial Spirit within the R&D Industry in Singapore

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The Success of Kent Ridge Digital Lab

Established a little more than 2 years ago, in April 1998, Kent Ridge Digital Lab (KRDL), pronounced as ‘cradle’, has earned itself a place in the international arena as an innovative lab in Asia, successfully spawning multiple high technology start-ups in high growth new markets.

To date, they have produced a portfolio of more than 15 start-ups, with prominent names like BuzzCity, MediaRing.com, Horizon and Thirdvoice. They have also been active in collaborating with industries in projects

and joint ventures, being able to quickly and effectively commercialise the technology developed by their researchers.

KRDL, formed in April 1998, is a national applied research and development organisation, founded through a merger of the Information Technology Institute (ITI) and the Institute of System Science (ISS). It is 65% funded by the National Science and Technology Board, with the remaining funds from other projects through collaborations.

Located at the edge of the lush, leafy campus of the National University of Singapore, KRDL has earned itself a name in the world of Internet incubators, switching focus from doing traditional research to hatching start-ups, turning it into a capitalist tool. It is a place for the creative, adventurous young to commercialise their ideas, by researching on relevant technology in the infocomms industry, and commercialising them, creating wealth.

KRDL is riding its success on the wave of the infocomms, a wave happening not only in Singapore but around the world, as telecommunications and IT takes on centre stage in this New Economy. As the telecommunications, finance, media and other sectors begin to be deregulated by the Singapore Government, KRDL can certainly take advantage of these newly created opportunities.

The Singapore Government has been aggressive in further developing the country into a Knowledge-Based Economy (KBE), one that is competitive in the global economy. To remain competitive, the Government placed tremendous efforts to promote R&D and technopreneurship in Singapore. We will soon see why and how in the pages to come.

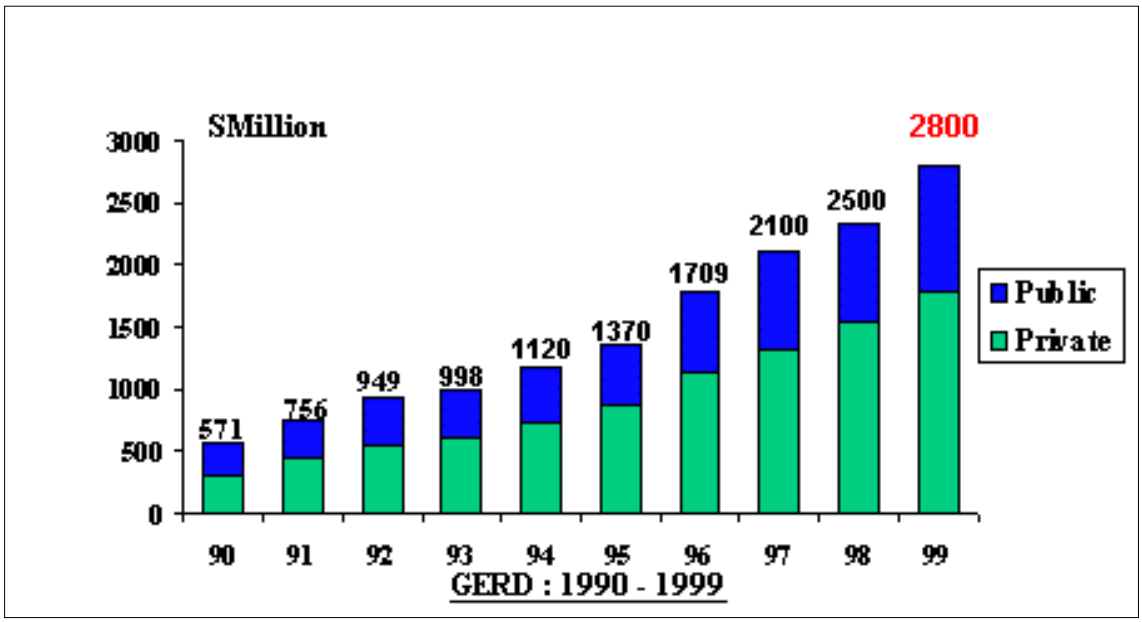
Overview of the R&D scene

In this section, we examine the leading indicators of 1999's results of preliminary key statistics on Singapore's R&D scene.

Gross Expenditure on R&D (GERD)

R&D Expenditure grew in the midst of the Asian economic crisis of 97/98. With the economic recovery in 1999, led by the strong rebound in manufacturing, private sector expenditure on R&D grew even more strongly, reaching $1.79 b in 1999. This is in an increase of 17% over the previous year. The public sector, in particular the Research Institutes and Centres (RICs) and the tertiary institutes, also increased their R&D expenditure last year by 5% to reach S$1,005 million. As a result, Gross Expenditure on R&D (GERD) grew to S$2.80 billion, up 12% from 1998. Consequently, the ratio of GERD/GDP increased to 1.94%, up from 1.76% in 1998 (see figure 1).

Figure 1: Gross Expenditure on R&D (1990-1999)

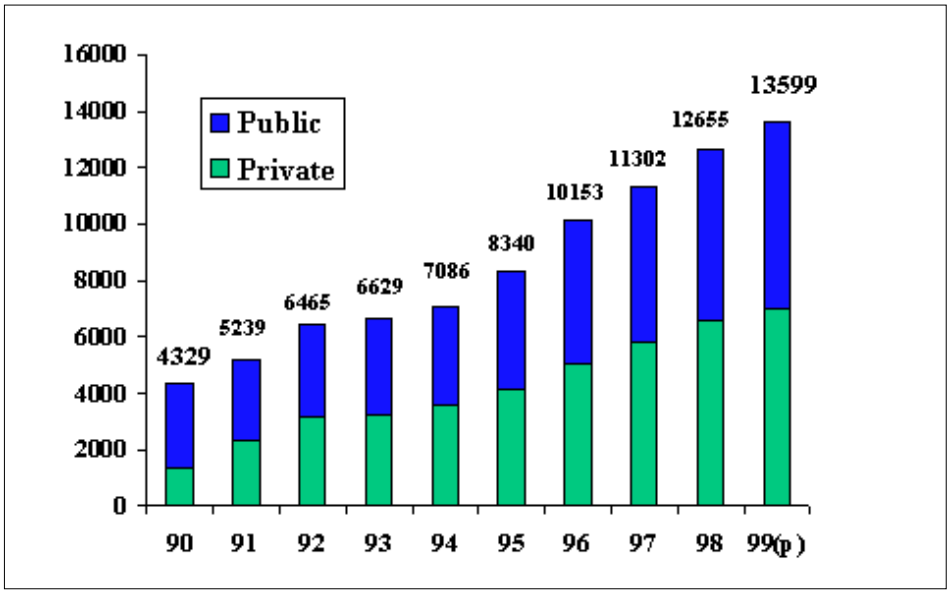


Source: NSTB

Research Scientists and Engineers (RSEs)

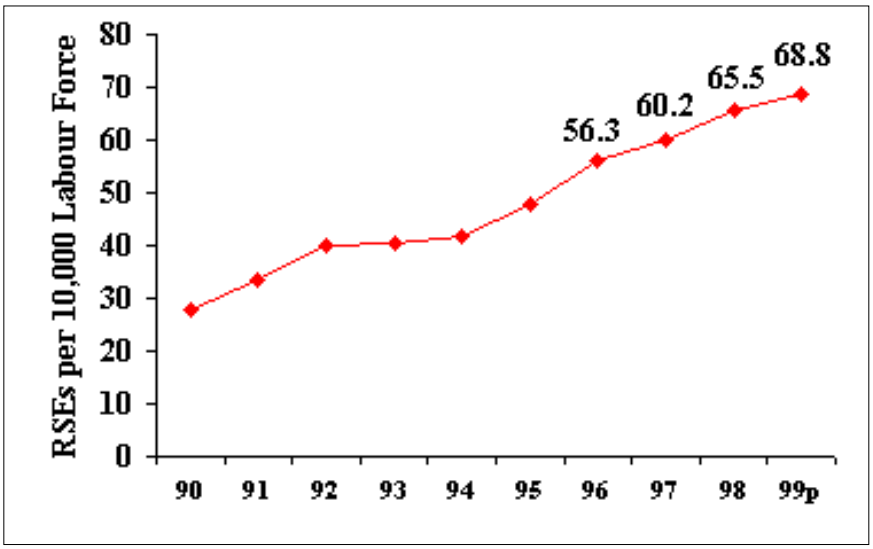
The number of RSEs continued to grow, reaching an estimated 13,599 RSEs in 1999, an increase of 7.5% from 1998. As a result, RSEs per 10,000 labour force increased to 68.8. This is higher than the target for year 2000 set forth in the National Science and Technology Plan 2000 of 65 RSEs per 10,000 labour force. We should therefore be on track to reach the Year 2005 target of 90 RSEs per 10,000 labour force (see figure 2 and 3).

Figure 2: Number of RSEs (1990-1999)



Source: NSTB

Figure 3: RSEs per 10,000 Labour Force (1990 1999)



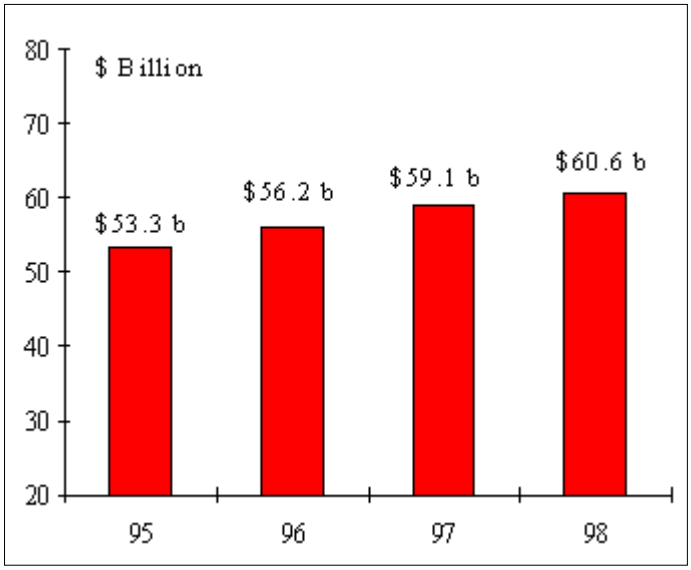
Source: NSTB

Volume of High-Tech Exports

High-tech industries enjoyed good returns from their R&D investments. Singapore's volume of high-tech exports grew to S$60.6b in 1998, up 2.5% from 1997 (see figure 4). It had grown at an average rate of 14% annually since 1990.

The share of high-tech exports as a percentage of total Non-Oil Domestic Exports increased correspondingly to 66% in 1998 compared to 65% in 1997.

Figure 4: Volume of High-Tech Exports (1995-1998)



Source: NSTB

Value-Added per Worker of R&D Companies

Companies performing R&D are contributing more value to our economy. The value-added per worker of R&D companies is higher than the industry average, ranging from 147% higher for companies in the Electronics cluster to 250% higher for companies in the IT & Services cluster.

R&D companies in other clusters also registered a higher value-added per worker than their industry average, namely Engineering (157% higher), Life Sciences (177%) and Chemicals (192% higher) see table 1.

Table 1: Value Added per worker of R&D Companies vs. Industry Averages 1996

Industry Cluster	*VA per Worker ($) of R&D Companies*	*VA per Worker ($) Industry Average*	*Variance*
IT & Services	274,500	109,800	250%
Chemicals	242,900	126,700	192%
Life Sciences	106,400	60,000	177%
Engineering	79,100	50,300	157%
Electronics	144,500	98,700	147%

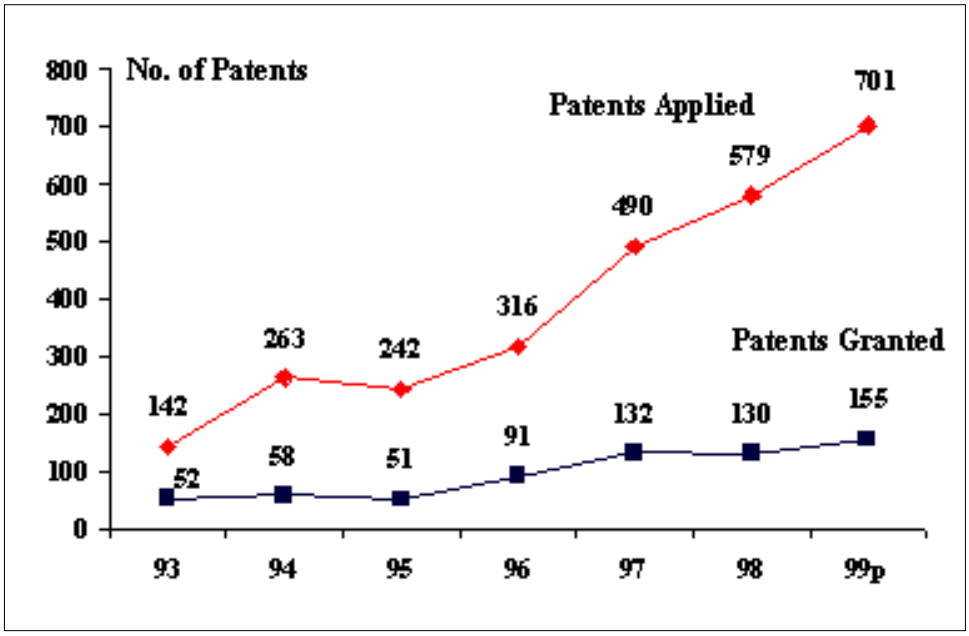
Source: NSTB

Patents

Patenting activities continue to intensify in 1999, indicating a healthy level of commercialisation. The number of patents applied reached 701 in 1999, up 21% from 1998, while the number of patents awarded grew to 155, up 19% from a year ago (see figure 5).

The National Patent Information Centre was active in helping technopreneurs with enquiries and searchers. The Centre held two clinics on intellectual property rights to full attendance. A CD-ROM on ‘Patent Information What you should know’ was released in 1999 to promote awareness on intellectual property issues.

Figure 5: Number of Patents Applied and Granted (1993-1999)



Source: NSTB

Singapore Government's Commitment to R&D and Technopreneurship

Singapore's economy in the 80's has depended heavily on manufacturing, services, and has built good supporting infrastructure like telecommunications, utilities and port services. But in order to remain competitive, there is a need to move to an innovation phase of development. This has to be done by mastering science and technology, to undertake research and development of international standard.

Therefore, 1991 marks the beginning of a series of National Technology Plans the Singapore Government undertakes to spearhead R&D.

The National Science and Technology Board

NSTB (www.nstb.gov.sg), formed in January 1991, is a statutory Board under the Ministry of Trade and Industry, along other Boards like

Economic Development Board (EDB), Trade Development Board (TDB) and Singapore Tourism Board (STB). All Statutory Boards work close under their Ministry, implementing policies, programmes and incentives that go in line with one another, allowing each Board to move alongside with the Ministry towards the same goal.

Spearheading Singapore into the New Economy is a collective goal by the Singapore government. Industry 21 of EDB, Tourism 21 of STB, Trade 21 of TDB, all bring together a package of policies that leverage on one another, bringing a unified result, which is sustainable growth for Singapore in the New Economy.

NSTB has a mission of spearheading industry-driven R&D, promoting and strengthening Singapore's technology infrastructure, and promoting and developing technopreneurial environment in Singapore.

Building technology infrastructure involves developing research capabilities in research institutes and centres, universities, polytechnics and government-funded institutions, which have economic relevance and which will lead to the commercial exploitation of technology and innovation.

A thriving technopreneurial sector will lead to a vibrant and thriving sector of high growth technology-oriented companies, where its key growth will be intellectual properties.

Industry-Driven R&D

Upon recognising the importance of technology to economic upgrading, the National Technology Plan (NTP) was drawn up in 1991 to spearhead R&D, with the purpose of applying science and technology for economic growth.

The focus is on " industry-driven" R&D, which means those research that will contribute towards enhancing the competitiveness of Singapore. Industry-driven R&D is narrowly defined with these characteristics. Firstly, it is motivated by the possibility of direct commercialisation and corporate profits now or in the future. Second, the main driving force is the objective of producing proprietary and saleable products. Third, R&D tends to be done most successfully by the companies themselves

The private sector must undertake the bulk of R&D activities, as the best measure of gauging its success, is when profit-seeking organisations are willing to commit funds and resources towards it. The government is simply playing a pro-active role by facilitating, supporting and promoting these efforts.

Research is directed towards economic upgrading, producing results that eventually enhance Singapore's competitiveness. Target areas of excellence are carefully selected in niches that are relevant to Singapore's strengths. The Government will work in collaboration with industry; research institutes will complement industries' efforts in working towards a common end.

National Technology Plan drawn up in 1991

NTP was the first of the series of 5-year plans by NSTB to spearhead industry-driven R&D in Singapore. It is a blueprint in which the Government will follow and targets to achieve 'to develop Singapore into a centre of excellence in selected fields of science and technology so as to enhance our competitiveness in the industrial and services sectors'.

Recommendations

a) A $2 billion R&D fund to support industry-driven R&D over the next 5 years;

b) Provision of grants and fiscal incentives to encourage more R&D by the private sector;
c) Assistance in developing and recruiting R&D manpower;
d) Support and funding for research centres and institutes that can train the manpower or provide the technological support to enable companies to undertake the R&D; and
e) Assistance for commercialisation and infrastructural support.

Targets to be achieved by 1995

a) Total national expenditure on R&D to reach 2% of GDP by 1995;
b) A minimum 50% private sector share of total R&D expenditure; a working target of 50:50 distribution between public and private sector expenditures on R&D; and
c) A ratio of number of scientists and engineers engaged in R&D activities of 40 per 10,000 labour force by 1995.

Strategy for NSTB

NSTB leads by being the promoter and facilitator or R&D by:

a) Encouraging companies here to undertake more R&D activities through various financial and fiscal incentives;
b) Identify the need for enabling resources to build a long-term sustainable advantage in such R&D, particularly iin respect of manpower and technology; and
c) Based on the needs identified, support and fund centres or institutes that can train the manpower or provide the technological support to enable companies to undertake their R&D.

Key Initiatives

These target and strategies can be achieved by using these initaitives:

a) The Government committing $2 billion over the next 5 years;
b) Leading in manpower development;
c) Providing incentives and assistance to the private sector;
d) Supporting commercialisation; and

e) Developing technology infrastructure.

Table 2: 5-Year Public Sector Budget for R&D

Programme	*1991-95 ($million)*
Technology Programmes	806
Key strategic thrusts in technology, Ad-Hoc projects	556
Research and Development Assistance Scheme	80
Manpower Development	158
Technology Infrastructure	45
Science Park Development	355
TOTAL	2,000

Source: National Technology Plan 1991

9 key technology areas are that are most relevant to Singapore's economic growth are being selected, so as to develop these core competencies. They are Information Technology; Microelectronics; Electronics Systems; Manufacturing Technology; Materials Technology; Energy, Water, Environment & Resources; Biotechnology; Food & Agrotechnology; and Medical Science.

National Science and Technology Plan (NSTP) 1996 to 2000

NSTP aims to further the objective of promoting economically relevant scientific and technological development in Singapore. It builds upon the experiences and achievements resulting from the first plan, the NTP.

The NSTP charts the vision, objectives and strategy for Singapore's technological development over the next 5-15 years. It identifies key initiatives to address the challenges that face Singapore's development in science and technology. This framework will provide a comprehensive approach in addressing key issues pertaining to the development of a strong science and technology base in Singapore.

The objective to attain is by the year 2000, in industry clusters where there is already a significant competitive and technological edge, Singapore should aim to achieve leadership or near-leadership in the key technologies supporting these clusters.

Review of targets of the National Technology Plan 1991

From 1991-1994, the GERD grew by a compound annual growth rate of 16% from $757 million to $1,175 million. However, because of the high nominal annual GDP growth rate of 12% over that period, the GERD/GDP ratio only increased by 3.5% pa to reach 1.12% in 1994.

The other 2 targets were exceeded. As of 1994, the number of RSEs per 10,000 workers reached 41.9. The number of RSEs grew by 12% pa from 5,218 in 1991 to reach 7,086 in 1994. Private sector contribution towards national GERD has reached 62.7% in 1994. This shows that the private sector is the major contributor to R&D investments.

New targets for NSTP

The NSTP aims to achieve the following objectives:

1. Overcome bottlenecks that could hinder the development of Singapore science and technology capabilities from growing further;
2. Develop strong technological capabilities in fields that will support Singapore's strategic industry clusters and high growth sectors. The intention is both to root MNCs as well as to enable local SMEs to grow and compete internationally.
3. Extend the outreach of Singapore science and technology capabilities so that it will impact a broader spectrum of the economy. The intention is to enable as many companies and industry sectors to benefit from innovators and developments in science and technology as possible. This will include non-manufacturing sectors as well as industries that are not technology-intensive.
4. Encourage companies to undertake industry-relevant R&D. The intent is to encourage companies, even individuals, to invest in R&D and

translate its outputs into commercial gain. The Government will continue to make R&D and innovation assistance schemes available, facilitate networking between industry and R&D set-ups, as well as to encourage and facilitate technopreneurs to build technological start-up companies.

National Technology Strategy

Technology development may be broadly divided into 3 tiers: short, medium and long term development.

Tier 1: The first tier comprises the development, innovation/adaptation and acquisition of near term technologies. The time-to-market for technologies in this tier varies for different technologies. This ranges from 1-3 years for electronics, information technology and telecommunications, 5-8 years for biopharmaceuticals. It is expected that industry will spearhead developments in this tier to make innovative improvements to the present generation of products and services, as well as to develop the next generation of products and services.

Over the next 5-10 years, Singapore as a nation will focus most of its scientific and technological efforts in this tier of technologies. Some 70% of the government's total resources for science and technology will be directed at developing capabilities in this tier. This will comprise investments made through various government agencies like NSTB, EDB and PSB. This focus will serve to rapidly raise the broad-based level of technological competence of Singapore's industries.

Tiers 2 and 3: Singapore will, at the same time, deepen its long-term technological capabilities and engage in medium and longer-term technology development. This is necessary in order to anchor the competitive position of its key industry clusters as well as foster the growth of emerging high value-added clusters.

In order to be world class in a few key technological areas in the long term, it is imperative that Singapore develops depth in strategic areas of research, which demonstrates medium to long-term economic relevance. Development of such capabilities cannot be left alone, as industry tends to focus on short to medium term goals.

It is thus important that Singapore invests strategically and selectively in medium term technology development as well as in long term strategic research. These R&D efforts should be carried out in the research institutes and universities over a 5-10 year period or longer. NSTB will be the lead government agency in driving medium and long-term technology development, with some 40% of its resources invested in the second and third tier.

The private sector contributed much to the development and success of R&D sector

The private sector was the determining factor in growing the R&D industry, while government agencies play the facilitative role. Private sector GERD (see figure 1) always accounted for at least 50% of total expenditure for R&D. The rate of increase in R&D expenditure by the private sector has been the fastest in comparison to other sectors (see figure 6).

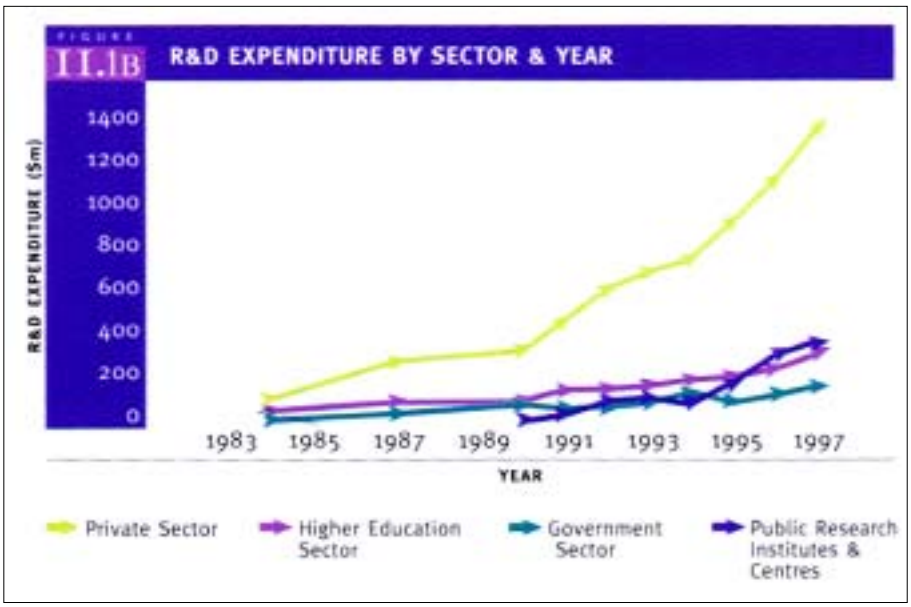


Figure 6: R&D Expenditure by sector 1983 - 1997

Source: National Survey of R&D in Singapore 1997

6 key thrusts

To implement these plans, NSTB has structured itself to work on 6 key thrusts, which are aligned to R&D and technopreneurship development.

1. Strengthening the technology infrastructure;
2. Developing a conducive environment;
3. Growing technopreneurial business;
4. Promoting finance and investment;
5. Developing manpower for R&D and technopreneurship; and
6. Establishing international linkages

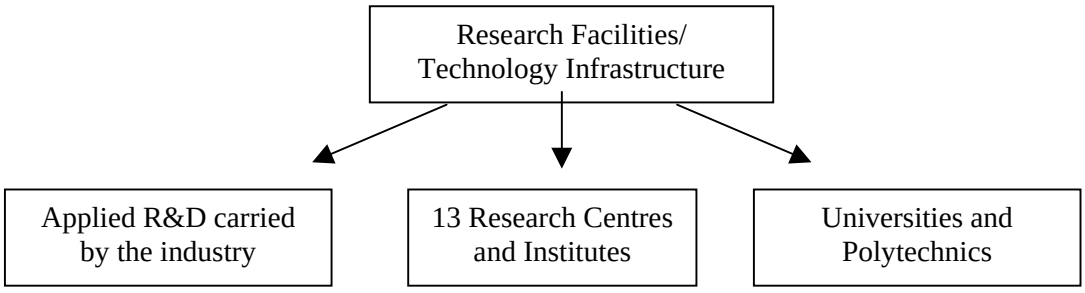
We shall elaborate on these in the next 6 sections.

Thrust 1: Technology Infrastructure

Singapore's technology infrastructure comprises the 13 research institutes and centres (RICs), the two universities, and four

polytechnics, which collectively provide the advanced scientific and technological resources and expertise to help local industries position their business and enhance their global competitiveness (see figure 7).

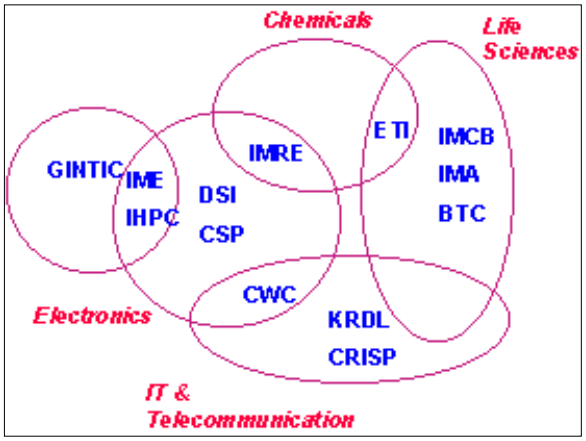
Figure 7: R&D Facilities in Singapore



13 Research Centres and Institutes

RICs serve as a bridge between research carried out in the universities and polytechnics and applied R&D carried out by the private sector, with funding from NSTB in economically relevant projects. The 13 RICs support industries clusters marked out in the NSTP, ranging from electronics, chemicals, life sciences, IT and telecommunications (see figure 8).

Figure 8: 13 RICs to support key industry clusters



Source: NSTB

1. Bioprocessing Technology Centre (BTC)
2. Centre for Remote Imaging, Sensing and Processing (CRISP)
3. Centre for Signal Processing (CSP)
4. Centre for Wireless Communications (CWC)
5. Data Storage Institute (DSI)
6. Environmental Technology Institute (ETI)
7. Gintic Institute of Manufacturing Technology (Gintic)
8. Institute of Materials Research & Engineering (IMRE)
9. Institute of Microelectronics (IME)
10. Institute of Molecular Agrobiology (IMA)
11. Institute of Molecular & Cell Biology (IMCB)
12. Kent Ridge Digital Labs (KRDL)
13. Institute of High Performance Computing (IHPC)

NSTB collaborates with local universities and polytechnics

Under the NSTP, the local universities play a central role in producing well-trained R&D manpower. Developing these research areas are modelled from countries with established research systems, like the US. Research in the universities is restructured to be centred around laboratories, such as in the case of Stanford University, which will enable research undertaken in the universities to have greater impact and achieve world class excellence. By the year 2000, a target of 12-15 top-class university research centres will be built in the two universities.

Various programmes are initiated by NSTB to partner with the National University of Singapore, Nanyang Technological University, the country's only 2 universities, and 4 other polytechnics, under the University R&D Programme and Strategic Research Programme (SRP), co-funding research that are done in these institutions.

Tables 3 and 4 shows NSTB's investment in R&D for the RICs and tertiary institutions.

Table 3: Public Research Institutes & Centres Investment in R&D

Expenditure on:		Remarks:
R&D	S$350.5 m	14.1% of GERD
R&D Manpower[1]	S$144.4 m	41.2% of public RICs R&D expenditure
Capital	S$99.5 m	28.4% of public RICs R&D expenditure
Manpower:		
R&D Manpower	2,240	11.8% of total number of R&D manpower
Number of RSEs[2]	1,636	12.9% of total number of RSEs
Researchers[3]	1,682	11.3% of total number of researchers
No. of PhD Degree RSEs	644	39.4% of RSEs in public RICs

Source: National Survey of R&D in Singapore, 1998

Table 4: Higher Education (Universities and Polytechnics) Sector Investment in R&D

Expenditure on:		**Remarks:**
R&D	S$277.7 m	13.2% of GERD

[1] Manpower include all personnel, which comprise of researchers, technicians and staff supporting R&D work, irrespective of their qualifications.

[2] RSEs are personnel who hold formal university qualifications and are principally employed in a research capacity. RSEs also include managers and administrators engaged in the planning and management of the research.

[3] Researchers are RSEs plus personnel who are principally employed in a research capacity though without formal university qualifications.

R&D Manpower	S$193.5 m	69.7% of higher edn R&D expenditure
Capital	S$58.6 m	21.1% of higher edn R&D expenditure
Manpower:		
R&D Manpower	4,051	23.5% of total number of R&D manpower
Researchers	3,179	23.8% of total number of researchers
Number of RSEs	3,159	28.0% of total number of RSEs
No. of PhD Degree RSEs	1,455	46.1% of RSEs in higher edn

Source: National Survey of R&D in Singapore, 1997

Thrust 2: Making Singapore a Conducive Environment for R&D

Nurturing a conducive environment requires both the hard physical infrastructure and soft infrastructure. The Science Park, located at Buona Vista is developed as a focal point science and technology related technopreneurial activities. Soft infrastructure includes pro-enterprise government rules, regulations and policies that can create a supportive business environment.

Science Park

The 50-hectare Singapore Science Park (http://www.sciencepark.com.sg), in which the second and final phase being fully developed by this year, provides a focal point for R&D and innovation in Singapore and the region. The science park, consisting of the 30 hectare Science Park 1 and 20 hectare Science Park 2, has full facilities and amenities, creating a vibrant and conducive environment for R&D, as well as facilitating formal and informal interaction between industry, academic and research groups in the Park.

Table 5: Science Park facts

Infrastructure	*Description*
No. of tenants	Approximately 200
Total no. of staff	Approximately 7000
Developer	Arcasia Land Pte Ltd
Facilities	Land and buildings, specialised units for lease
Technology Support Services	Legal, Accounting and Financial Management, Management Consultancy, Venture Capital, IT

	support and maintenance
Amenities	Amenity Centre with auditorium and exhibition halls, and recreational facilities
Activities available	Business, social and fitness activities

Source: Science Park

Located in the south-western side of Singapore, close most of the tertiary institutions, RICs and industrial parks, the south-west of Singapore makes up the technology corridor of the country where there is a high concentration of knowledge-based industries (see figure 9).

Figure 9: Technology corridor in the south west of Singapore

Source: Science Park

The Science Park, which is expected to be worth S$5 billion, with investments coming from both the private and public sector, presents these benefits:

1. Position Singapore for high-tech activities

This Hub demonstrates Singapore's commitment by providing the necessary infrastructure to meet the needs of R&D companies and personnel.

2. Create a focal point for R&D and high-tech activities
   This will enhance the visibility and image of these activities, thereby attracting both local and foreign talent.

3. Develop and Innovation Milieu
   The Hub will provide an environment where business interactions, technology exchanges and networking can flourish to provide a breeding ground for innovation and technopreneurship.

Thrust 3: Empowering Potential Technopreneurs

Technopreneurship 21 (T21)

T21 is an initiative involving high-level government and private sector efforts to prepare and lay the foundation for the successful development of a technopreneurship sector in Singapore, which is the cornerstone of Singapore's plans to build a knowledge economy. The Technopreneurship 21 Ministerial Committee provides the impetus to this drive.

The initiative, covers four areas critical for the technology sector to flourish. They are education, facilities, regulations and financing. Within each of these 4 areas are a complex array of policies, like revamping the educational system in schools and tertiary institutions, creating a intellectually stimulating environment for technopreneurs,

relaxing rules to remove obstacles to technopreneurship, and attracting venture capital, through funding programmes.

NSTB empowers technopreneurs by business matchmaking, providing infrastructure, financing, incubation support, venture capital and promotes and develops Singapore as an R&D hub of Asia.

The US$1 billion Technopreneurship Investment Fund (TIF), a government funded capital set up in April 1999, and various tax incentives for venture capital funds and venture capital fund management companies, are but 2 examples.

Venture investment support for Start-ups (VISS)

VISS is a program to directly co-invest into early stage promising and strategic companies that are based or linked to Singapore. It is a three-fold aim to play a catalytic role in drawing investments into earlier stage start-up companies, to draw in start-up companies that are strategic in nature to Singapore, and to develop an environment that will bring forth a critical mass of promising start-up companies in the early stage.

NSTB co-invests with the private sector. With every $2 of private investment the start-up acquires, NSTB funds an additional $1, with a maximum of S$500,000. NSTB will not become the largest shareholder in the company (see table 6 and figure 10).

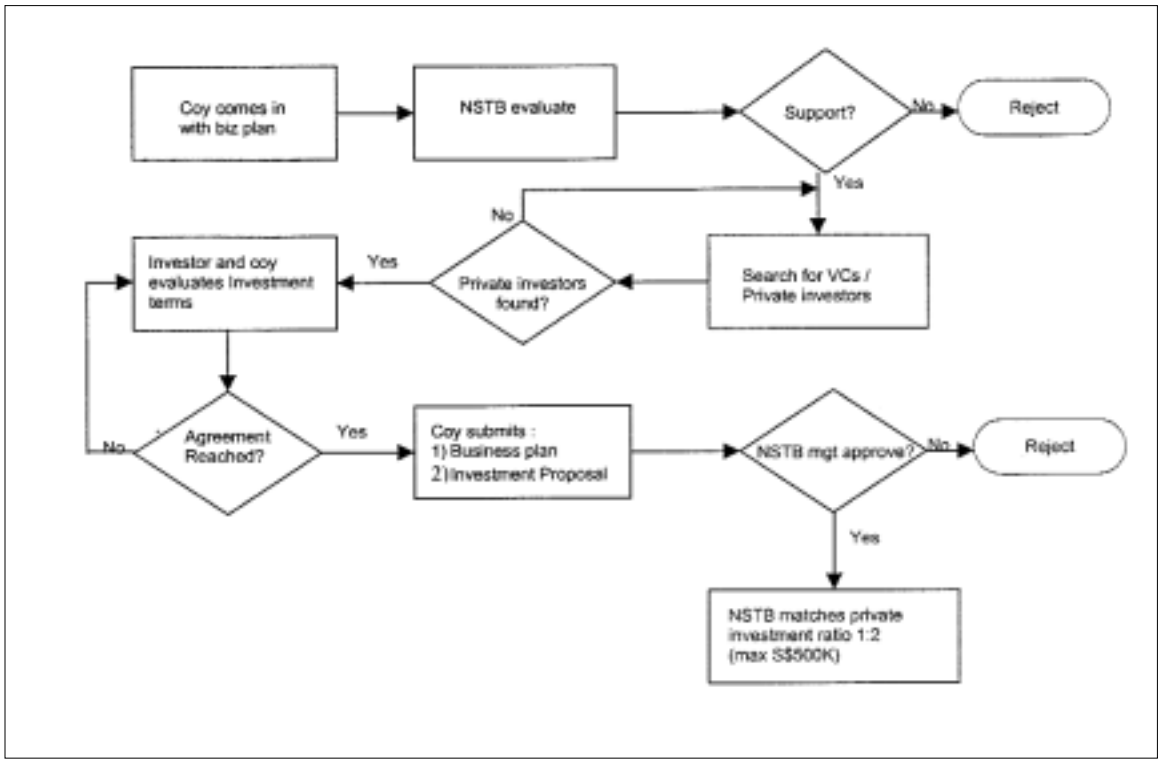
Table 6: Details of VISS programme

Eligible investment	▪ In the seed and early stage of company development ▪ Have a presence or agree to set up one in Singapore

	▪ In a fast-growing technology sector
Eligible investors	▪ VCs, Corporate, Business Angels, Family, Friends
Due diligence by	▪ Both NSTB and private investors
Funding principles	▪ Co-investment scheme (S1 VISS investment for every $2 private investment ▪ Maximum of S$500 K per investment
Benefits to private investors	▪ Risk is reduced with the co-investment scheme
Benefits to technopreneurs	▪ Funding opportunity ▪ Access to private investor's expertise in management and business network

Source: NSTB

Figure 10: Flowchart of decision making by NSTB



Source: NSTB

www.techsingapore.com.sg

This website is developed by the NSTB, and it provides a one-stop portal dedicated to promoting high-tech technopreneurial activities in Singapore.

It has valuable resources and acts as a springboard for both technopreneurs and investors.

Services provided on the website include:

1) Match investors seeking high-tech investment with technopreneurs or budding technopreneurs of high growth potential
2) Deliver the latest news on the happenings and upcoming events in the world of entrepreneurs and investors
3) Offer guidance through its start-up procedures and library of frequently-asked questions and
4) Provide technopreneurs the opportunity to pose questions to industry experts.

Figure 11: www.techsingapore.com.sg

Thrust 4: Bringing in Venture Capital

Venture capital (VC), by helping to finance small and medium sized but rapidly growing companies which do not have access to conventional capital markets, contributes to the economic development process. It is a pillar in supporting industry development and entrepreneurship and a key catalyst in developing Singapore into a knowledge-based economy.

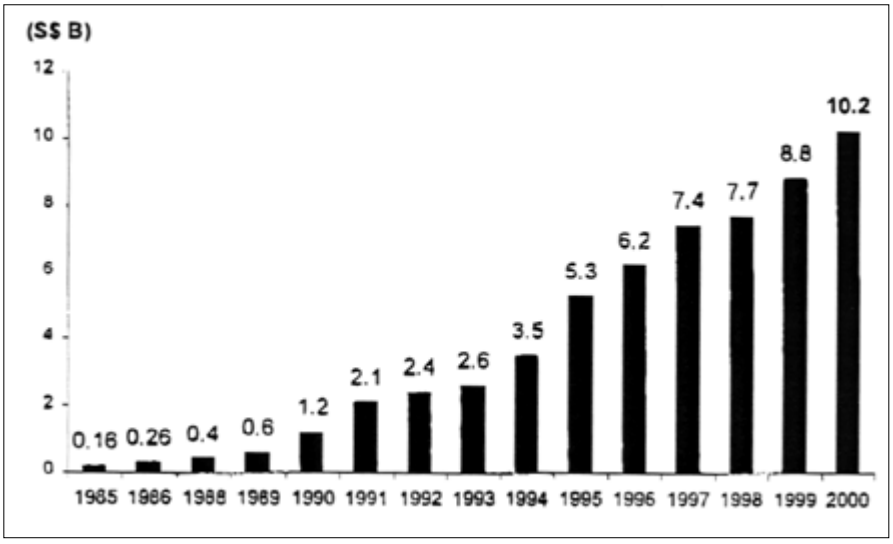
Since 1985, EDB has tailored tax incentives, through various forms of full or partial tax exemptions, to accelerate the formation of more venture capital funds and fund management companies. As at 1999, about a third ($3 billion) of the VC industry have been incentivised by EDB,

with a significant portion of these dedicated to Singapore-related projects.

EDB and NSTB have conducted a joint survey to track the investment and fund raising activities of VC in 1999, with the following selected results.

1) Singapore now manages a cumulative total of $10.2 billion in VC funds as at end 1999. The VC industry raised $1.4 billion last year, a growth of 16% from 1998 or $300 million more than the $1.1 billion raised in 1998 (see figure 12). There is strong participation of both MNC and Singapore companies in the VC industry. There are currently 90 fund management groups here, employing more than 370 investment professionals.

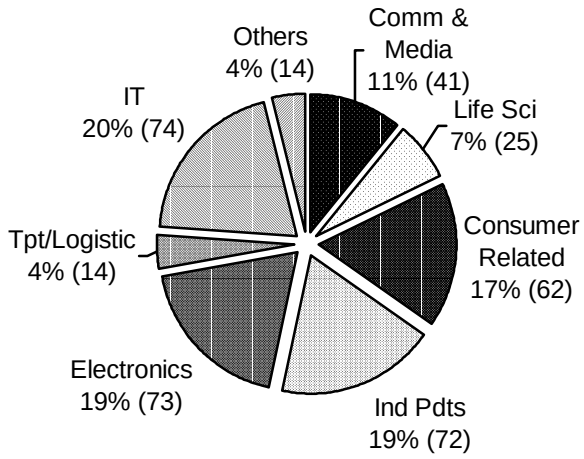
Figure 12: Growth of Singapore VC industry -cumulative funds under management



2) As at 1999, there were at least 375 VC-funded companies in Singapore, which is an increase 65 from 310 in 1998. Of these 375 VC-funded companies, 31% are companies in Infocomms (IT and communications &

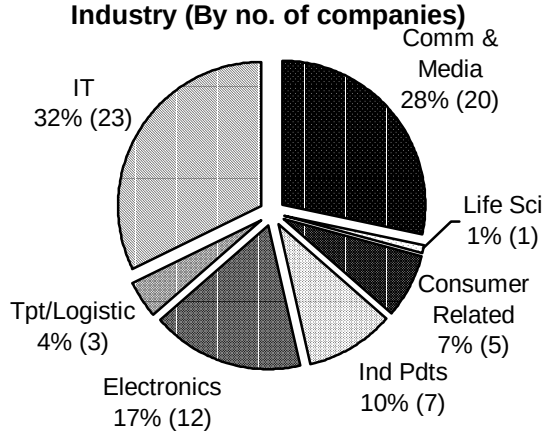
media), signs showing that the Infocomms is the most promising among venture capitalists. About a third of these companies were funded during their early and seed stage (see figure 13).

Figure 13: VC Funded Companies in Singapore by Industry (By no. of companies)



3) Technology-related deals dominate the industry. They accounted for more than half of all investments in 1999. 71 Singapore companies were funded in 1999, of which 43 were in the infocomms sector, chalking up more than half of the investments in Singapore (see figure 14).

Figure 14: 1999 Singapore Companies by Industry (By no. of companies)



Thrust 5: Manpower Development

NSTB's all round approach in fostering R&D and technopreneurship includes developing of skills and talents that will meet the challenges of the New Economy the organisation is steering Singapore towards. They have a 4-fold approach towards manpower development that includes *training, recruitment, recognition and promoting science and technology.*

Training

NSTB works with the industry, universities and the RICs to identify training needs and develop training courses to meet industry demands. The *Manpower Upgrading for Science and Technology (MUST) Programme* aims to help companies to acquire and build up capabilities and know-how in R&D and technopreneurship activities through post graduate studies.

The MUST programme consists of two components, training attachment where it supports the training attachment of qualified employees to local and overseas companies and institutions; and a study grant, supporting the upgrading of industry researchers and scientists through postgraduate degrees at local and overseas universities.

Recruitment

NSTB facilities in attracting foreign talent into Singapore as well as attracting local talents into the science and technology field, through various programmes like *Post-graduate Training Programme, Foreign Researchers Recruitment Programme, Temasek Professorship Programme and Employment Pass and Housing assistance.*

The number of foreign talents in the science and technology field have increased in these recent years, as NSTB gradually relaxes rules and criteria for eligibility to work or study in Singapore.

Recognition

Awards have been given out by annually by NSTB during the annual TechMonth to recognise individuals and companies who have contributed to science and technology in Singapore.

1. *Technology Achievement Award*

   The most widely acclaimed award given by NSTB, the technology achievement award is a national award that recognises locally based companies, which have successfully exploited R&D for their business competitiveness to raise their stature and attract new investments and contributed significantly to the economic output of Singapore.

   This award was established by NSTB, EDB, Arthur Andersen Business Consulting (AABC) and The Straits Times, Singapore's most widely read newspaper.

   Companies that make it to this award will be recognised as part of an elite group. They can use the award logo on their corporate collateral to identify themselves as one of the outstanding award winners in Singapore. The local media will also lend publicity to this award. And profiles Technology Achievement Award winners in the course of the year.

2. *National Science Award*

This award recognises research scientists and engineers in Singapore who have made outstanding contributions in basic research in the fields of science, engineering and medicine.

3. *National Technology Award*
   This award is given to researchers and scientists in the country who have contributed to applied R&D resulting in industrial applications, such as improving key industrial processes, or using emerging technology to develop new or improved industrial products with potential for commercialisation.

4. *National Science and Technology Medal*
   The award recognises individuals who have made contributions to Singapore's development through the promotion and management of R&D, ranging from the management of R&D resources to the training and development of R&D professionals.

5. *Young Scientist Award*
   This award is given to young researchers below the age of 34 who are actively engaged in R&D activities in Singapore and who have shown great potential to be world-class research in their fields of expertise.

Thrust 6: International Collaboration

NSTB forges and strengthens bilateral relations and multilateral relations through a comprehensive networking programme, in order for local companies to explore and develop further areas of growth.

Joint Ventures

Shanghai Zhong Xin Technology Co. Ltd
This is a US$1.2 million joint Singapore-China technology investment company that is based in Shanghai. It aims at promoting the development and commercialisation of innovations arising from the research results in the PRC universities, governmental laboratories and other research institutes.

Through Zhong Xin, companies and research organisations in Singapore can tap into Chinese technologies with potential for commercial development.

Singapore-Israel Industrial R&D Fund (SIIRD)
This joint Singapore-Israel R&D support fund aims at promoting, facilitating and supporting joint industrial R&D projects between Singapore and Israeli high-tech companies that would lead to successful commercialisation.

SIIRD organises matchmaking opportunities between Singapore and Israeli high-tech companies. Its support also includes funding up to 50 percent of the eligible R&D costs of approved joint R&D projects.

Other programmes
Other methods in fostering international ties include participating in regional for a through ASEAN Committee on Science and Technology, and APEC Working Group on Industrial Science and Technology.

Some countries, which NSTB has established linkages with, include Canada, China, Israel, Japan and the US.

Success begets success at KRDL

The factor that contributed to the success of KRDL (www.krdl.org.sg), is its ability to transfer market-ready technologies to industry rather than to 'hog them'. It is the largest lab in Singapore comprising more than 350 staff working on projects in info-communications, learning, knowledge, ubiquity, bio-medical and transportation areas.

KRDL has carved a niche role for itself, acting as an extension of companies' R&D resources and a supplier of leading edge technologies. With the pool of market-ready technologies in KRDL industry can either license the technologies or invest in start-ups based on these technologies.

Thus its ability to quickly and effectively commercialise the technology developed by their researchers by working hand in hand with industry is KRDL's greatest asset as well as a key to its success.

Market sensitive, enterprising, outward looking organisation

KRDL keeps the industry informed of emerging technologies from within the Labs as well as collect valuable feedback from their partners on specific industry trends, with the objective of allowing industry to drive research programs rather than developing technologies that no one needs.

Their business development unit is a robust bridge between KRDL's technical team and the markets, with the mission of spearheading the commercialisation of KRDL's technologies. It has forged alliances with companies like Microsoft, Apple, HP Labs, Ericsson, Motorola and Sun

among others, collaborates with universities worldwide, as well as partnered in a joint venture with Horizon and Silk Route Group.

The multi-disciplinary New Initiatives department involves researchers with diverse background, who keeps track on the frontier technologies in all the industry segments, so as to enable KRDL to make more intelligent or autonomous devices, that are likely to mature in the next 3 5 years.

KRDL has worked with several international and Singapore-based venture capitalists, corporate investors and angel investors to incubate new ventures, and this is what the Bridging Units does: to build a network of relationships and accumulate experience with the goal of creating new start-ups now being encapsulated in KRDL's incubator.

The Bridging Units work on developing business models, validating business models in conjunction with lead customers, attracting new members with complementary business and technical skills to round off the founding team, keeping technology development apace with changes in business models and writing of business plans. KRDL has more than 18 spin-off companies since its establishment in 1998 (see table 7).

Table 7: KRDL's Spin-off companies

Spin-off company	*Function*
AsiaRain Automated Translations www.asiarain.com.sg	Specialises in high volume Asian technical translations, software and web localisation
AsiaWorks www.asiaworks.com.sg	Supplier of language- based enabling technologies for Asian language markets
Buzzcity www.buzzcity.com	Free smart email alert service
Clarity Systems Pte Ltd www.clarity.com.sg	Specialist in decision support systems offering planning, scheduling and resource allocation systems
CommonTown www.commontown.com	An Internet application linking people through a Virtual Online Community
EcQuaria Technologies www.ecquaria.com	Internet software company, developing and providing customised Internet services to businesses

Horizon.iExpress.com www.horizon.com.sg	Provides broadband multimedia applications targeting schools, governments and MNCs
KrisTech	Joint venture with Malkin and Singapore Bio-Innovations. A heterogeneous data retreival system for Bio-Informatics
MediaRing.com www.mediaring.com	Offers Voice Communication services on the web
Mindmaker Pte Ltd www.mindmaker.com	Provides AI-enabled development platforms for developers and applications for home users
Mustard Technology www.mustardtech.com	Offers database search technology to allow large companies to quickly find names of their customers or products in a database
PixAround.com Pte Ltd www.pixaround.com	Provides integrated solution that takes web pages beyond passive viewing graphical and flat images
PrivateExpress.com www.privateexpress.com	Provides private digital courier service
Singalab www.singalab.com.sg	Offers software services and development in the areas of Data Management & Business Intelligence, Enterprise Applications Integration and e-commerce
Star+Globe Technologies www.starglobe.com	Provider of multilingual software and solutions
Third Voice www.thirdvoice.com	Allows Internet surfers to post notes that fuses their own ideas with web content to any page on the web
Transparity www.transparity.com	Delivers security solutions and services at low cost and convenience
Vivid Technology Pte Ltd www.vivid.com.sg	Source for Data and Tele-Communication solution that enables multimedia exchange over the Internet and Intranet

Source: Kent Ridge Digital Lab

Table 8: Timeline of KRDL

Date	***Description***
01 Apr 98	KRDL incorporated through the merger of ISS and ITI
27 Apr 98	KRDL and PICAS (Picture Archival System) signing ceremony
07 Jul 98	KRDL holds it first IT Market Day – a showcase of KRDL technologies
11 Jul 98	Launch of eduMALL
29 Sep 98	Agreement signed between KRDL and Land Transport Authority on KRDL's Integrated Transport Management System
10 Nov 98	Ericsson, Centre for Wireless Communications and KRDL Collaboration

	Press Conference
16-20 Nov 98	KRDL participated in COMDEX in Las Vegas, USA
24-27 Nov 98	5th Pacific Rim International Conference on Artificial Intelligence and 1st RoboCup'98 (jointly organised with National University of Singapore
27 Jan 99	Agreement signed with SENTO / HP Bristol Labs, on Secure Virtual Private Networks over the Extranet
31 Mar 99	Launch of Advanced Interactive Media Centre (AIMC), a tripartite relationship between KRDL, National Computer Board and industry partners
12 Apr 99	Launch of SpeechQuotes, Asia's First Speech Activated Stock Quote System – World's First in Mandarin. Jointly launched by KRDL, Stock Exchange of Singapore and SpeechWorks
12 May 99	Launch of Java Resource Centre (JRC)
25 Aug 99	KRDL and Asiasoft in licensing agreement for KRDL's Formaster, a form processing system using character recognition technology
4-9 Sep 99	Machine Translation Summit '99
17 Sep 99	KRDL and Group Sense Ltd in partnership for Advanced OCR Technologies for bilingual Chinese/English character recognition
17 Sep 99	Launch of eduPAD
07 Oct 99	KRDL launched its first book on Competitive Intelligence called "Charting Your Course in the Digital Age – An IT Perspective" with a public seminar
1-4 Nov 99	ACM Conference 99 on Computer and Communication Security
15 Nov 99	KRDL and Horizon.com signed MOU to form JV company Horizon.iExpress.com
01 Feb 00	IPAS MOU signing

Source: Kent Ridge Digital Lab

From incubation to start-up

Assuming, John has an idea. He can approach KRDL and make a presentation about his ideas and business model. The panel from KRDL will decide on whether to take in the idea or not. If they approve on the proposed idea, KRDL will provide John with the funding, team up with him in research, to be completed within a certain time frame. Upon which John can leave

KRDL to start up his own company, with KRDL having an equity stake in the start up firm.

As such, KRDL's job is done. KRDL comes up with the technology, John commercialises it. There is much autonomy given to John on how he wants to run his company. John looks for his own manpower, designs his marketing strategy, and forms his own alliances.

Thus, KRDL is constantly recruiting people like John to join, come up with a technology that is economically relevant and commercialise it either by selling the technology to a company to use, or begin a new company harnessing this technology.

A unique KRDL

Good people play a large part in the success of KRDL. It has earned a brand name for itself as a place of innovation and flexibility. This has further attracted capable people into its management and R&D team. KRDL is involved in many projects and if given a choice, would focus on their quality rather than quantity.

The organisation's willingness to invest in people, focusing on teamwork, freedom to dare and err and passion for technology will bring the young research centre to greater heights.

A Promising Future for Horizon.Com

As the world heads towards a new global economy, there is a growing trend that is observable in many other countries and that is the proliferation of dot com companies. Without exception, dot com startups are sprouting up like mushrooms in Singapore. Many of these dot coms come and go but one dot com company stands out from the rest Horizon.Com Ltd. Horizon.Com is a success story that stems from the fact that the company is actually turning decent profits from its commercialisation of its R&D efforts.

Since its restructuring in July 1999 into three business groups namely *e-Learning, e-Business,* and *e-Ventures*, the company has achieved a healthy group turnover of S$23.1 million for 1999, an increase of about 18% over the previous year. The e-Business group recorded a turnover of $11.1 million, an increase of S$0.2 million compared to 1998 whereas the e-Learning group achieved a turnover of S$12.0 million, an increase of S$3.3 million compared to 1998. It has the distinction of being the First dot com company that managed to go for a Singapore listing in 2000.

From its 3 core business, Horizon.Com has developed various proprietary application software and tested and proven e-business solutions.

e-Learning group

One of Horizon.Com's business focus is on e-Learning. In 1995, there was a low utilization of IT as an educational tool in schools throughout Singapore. Horizon.Com targeted this niche and set up a subsidiary-

Horizon Educom in 1995. It has now grown to offer a wide range of broadband technology and services to educate students and throughout Singapore and the region. Broadband surfers can log on to Horizon's educational channels at its Horizon BBand (another subsidiary) portal to try out new software or pay to use the software if they so desire.

The e-learning group is in the business of providing educational products and services to four main market segments: K-12, Post secondary, Corporations with e-learning requirements and the Home/Consumer.

The types of products include education software in the form of cd-rom and web-sites, computer peripherals that aids in learning such as data-loggers and e-books, and courseware in enhancing the process of teaching and learning using IT.

The types of services include comprehensive consultancy in the area of using IT in education. They offer consultancy to businesses or institutions wishing to either adopt a single technology solution, or an entire suite of solutions that can include Web Portals or integrated mobile computer devices or palm-held computers and training of users in the use of new technologies and change management.

As such, they are now the market leader in providing e-learning solutions and content to customers that includes the Ministry of Education, IDA and National Library Board.

Horizon.Com has won tenders and projects that have impacted the course of learning and teaching. Horizon.Com's e-Learning solutions have been implemented throughout the nation. Two excellent examples are AITP, where we trained all 10,000 teachers in the Primary Schools and SCHIPS, where they introduced innovative IT-enhanced teaching-learning methodologies in the curriculum of primary three and four students. Horizon.Com is also the main supplier of dataloggers and educational software to all 360 primary and secondary schools in Singapore.

Horizon.Com has also researched and developed a proven online curriculum for primary schools known as Horizon JESI (Young Journalist, Young Explorer, Young Scientist and Young Indiana). In addition, Horizon Educom has pioneered technologies such as Knowledge Builder Framework (KBF) that organises content and information such that it enables users to find information efficiently and easily. Another technology that Horizon has pioneered, School Groupware Resource Planning (SGRP) helps to manage access to educational resources and supports the exchange of information between teachers and school administrators. These technologies have also been used in secondary schools in the teaching of subjects such as Biology, Chemistry, Physics and General Science.

Online streaming technology

The Group has successfully launched its proprietary Internet enabling tool, Horizon iExpress, an R&D development between Horizon.Com and Kent Ridge Digital Labs. It is a software distributing technology that allows the on-line streaming of software through the Internet thus minimising the need for physical manufacturing, sales and delivery. This technology is used in conjunction with Horizon.Com's initiatives to introduce education and edutainment broadband content to the global community.

Horizon.Com is one of only 4 companies in the world to provide Online Streaming application technology. Horizon.Com has harnessed the power of this technology in the educational sector where there are few competitors therefore there exists tremendous growth opportunities for Horizon.

e-Business and e-Ventures group

As part of its push to be at the forefront of application technology, Horizon.Com has developed a globally scalable application tool, Horizon

SPAWN (Strategic Procurement Advanced Workflow Network). It is a e-procurement solution suitable for use by the construction, building administration and state management companies. This application tool has also been adapted for use by townships, town councils, housing estates and similar communities.

Since its listing in January, Horizon.Com has also entered into an agreement with Hong Kong's Pacific Convergence Corporation (PCC), a subsidiary of Pacific Century Cyberworks for the promotion and distribution of its products and services through PCC's broadband Internet infrastructure.

Under this agreement, PCC will market Horizon.Com's Internet and broadband based content and services as part of its overall content feed to local cable operators. These operators are franchised by PCC to act as service hubs in the regions covered by the AsiaSat III satellite footprint. PCC will also host Horizon.Com's servers in its Primary Network Operations Centre (PNOC). These arrangements are based on a revenue sharing model and Horizon.Com will pay to PCC a small share of its revenue derived from the sale of its content sold through PCC's network.

In addition, Horizon.Com will purchase air time from PCC for the broadcast and distribution of advertisements of Horizon.Com's products on PCC network. In return, PCC will incorporate Horizon.Com's proprietary broadband streaming and messaging technology into its infrastructure for the purpose of distributing Horizon's content.

Horizon.Com has recently entered into a joint venture agreement with ProcureNet, a pioneer and leading provider of end-to-end eProcurement solutions, to establish ProcureNet Asia Pacific (PNAP). This joint venture company will deliver eProcurement solutions to the Asia Pacific markets. Horizon.Com has since partnered with Singapore Power and KS

Tech to deliver eProcurement services to the utilities, oil and gas markets in Asia Pacific.

Having gained a foothold in the Singapore market, Horizon.Com intends to expand aggressively into the Asia Pacific market. It has already made a foray into the Taiwan, Hong Kong and Indonesia market through strategic alliances and plans to aim for the other Asian countries in its next expansion move.

Horizon.Com and 1-Net Singapore have formed a Consortium to service the broadband market in Taiwan. The consortium has been commissioned by Taiwan's Shin Kong Group to carry out studies to evaluate and propose Shin Kong's entry into Taiwan's broadband market, which is inclusive of infrastructure, content, distribution and management.

As part of its regional expansion, Horizon's subsidiary, Horizon iTech was appointed by Indonesian PT Rekasiscom Widya (Reka) to build, operate and manage a broadband service to deliver the Group's content and services in Indonesia that will serve 200 universities over a 5 year period.

Horizon.Com has also acquired a 40% stake in SMP.Com Pte Ltd, the Number One Mobile Commerce ("M-Commerce) solutions provider for the insurance industry in the Asia Pacific. SMP's current flagship product WinQuote is, to the best of its knowledge, **the world's first palmtop-based m-commerce solution** for the life insurance industry. WinQuote enables insurance professionals to access product and client information on the move; dynamically configure insurance products on the fly; capture clients' digital signature on the spot; and submit policy applications for underwriting anytime, anywhere. SMP's current technology partners include Hewlett Packard, Psion and Microsoft. This is in line with Horizon's strategy to take up equity positions in companies synergistic to Horizon's business model and which have a solid business, and proven revenue and profitability.

Horizon.Com and Singapore Power's e-commerce subsidiary, SP E-Services have signed a 65/35 joint venture agreement to develop and operate a town portal, canTown.com.sg (canTown), for the various townships in Singapore. The expected transaction volume for the first year when all the 13 Town Councils participate in canTown is between S$16 to S$20 million.

The canTown portal will provide a 24-hour online service to all residents. Services available range from an amenities search, to on-line and real-time booking and payment of town facilities. Residents can find out about the latest events and happenings in the town through the portal. Information such as HDB upgrading programmes and Town Council services can also be easily obtained.

In a nutshell, Horizon.Com is a company that is worth looking at. This dot com company boasts of numerous factors that point to its imminent growth in the broadband services arena.

Conclusions

The last decade has proved to be a fruitful one for the R&D and technopreneurship sector. Singapore has achieved recognition as an R&D hub in Asia, attracting multinational corporations to set up their R&D offices here. The country continues aiming towards the status of a first league developed country in the 21st century. The key success factor for this goal to become a reality is the ability of the economy to restructure and upgrade its industry and business clusters. This will enable the economy to sustain high value-added manufacturing and service activities.

There are however a few challenges ahead:
1) Meeting the demand for manpower.

Most firms are responding to the coming Information Age, and are gearing themselves to compete in the Internet realm. This calls for an acute shortage of manpower, especially in the IT sectors.

2) Making it conducive for industry to undertake R&D.
   Singapore is competing with other Asian countries in the sector. General cost of doing business here is rising. Therefore, there is a need to compete in other terms like establishing leadership in key technology areas Singapore has a competitive advantage in.

3) Strengthening technological capability.
   Singapore's technological capability still lags behind countries in the US, Europe and Japan. It is a constant challenge for Singapore to bridge this gap, especially in such a time when technologies get obsolete quickly.

4) Fostering technology innovation and commercialisation
   People and environment are 2 critical factors supporting technopreneurial culture. Development of the Science Park can provide an environment for idea generation and innovation, but it is only a prerequisite. How people respond will depend on the possible rewards.

   There also represents an acute bottleneck between technology development and the translation of technology into commercial benefits. These factors have to be dealt with to ensure investments in R&D will reap the corresponding benefits.

Singapore has come through the Asian Crisis better than most Asian countries, and will continue to promote this sector, and anticipate, identify and clear hurdles that hinder R&D and technopreneurship.

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