DEVELOPMENT OF UNIVERSITY - INDUSTRY PARTNERSHIPS FOR THE PROMOTION OF INNOVATION AND TRANSFER OF TECHNOLOGY: SINGAPORE

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PROMOTION OF INNOVATION AND TRANSFER OF TECHNOLOGY: SINGAPORE

A Singapore country paper by

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ABSTRACT

Technology transfer and collaboration with industry are central to the evolving role of the National University of Singapore and the Nanyang Technological University towards realising value in research and technology development. Measures to foster university-industry research collaboration, technology development, and a culture of entrepreneurship are described. We highlight some specific initiatives and role played by the two universities in close cooperation with government and industry in their quest to contribute to innovation and the development of Singapore's future industries.
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1. INTRODUCTION

Singapore is an island state of about 685.4 sq km. comprising one main island and a number of islets scattered off its north-eastern and southern coasts. It has a total population of 4.1 million, of which the resident population of Singapore citizens and permanent residents is 3.32 million. It is strategically located at the heart of the economically booming South East Asian region and is a gateway to the vibrant Asia-Pacific. To remain economically competitive, its industry is committed to continue to add value to manufacturing and services, increase productivity and creativity, and entrepreneurial development.

The key factor to economic growth has been the availability of a highly educated and productive workforce within a supportive environment that promotes innovation and enterprise. Over the last 10 years, the government has created a pro-business environment for entrepreneurship to sprout and flourish. This includes instituting policy and regulations, setting up the infrastructure, reviewing government rules and regulations which may have become outmoded in today's business environment, enhancing intellectual property protection, improving business access to financing, training manpower and encouraging more creativity, innovation and entrepreneurship in the education sector. This development of entrepreneurial technology driven businesses is a key component of Singapore's economic strategy in the 21st century.

2. POLICY FRAMEWORK, FOR UNIVERSITY-INDUSTRY PARTNERSHIPS

In order to become a competitive knowledge based economy, Singapore has set in place a dynamic and supportive IP infrastructure to encourage IP creation, ownership, protection and exploitation. Singapore is in full compliance with the World Trade Organisation's Trade-Related Aspects of Intellectual Property Rights Agreement. It has top rankings in terms of IP protection, and was accorded the 'Best IPR Protection in Asia' by the Political and Economic Risk Consultancy (PERC) since 1997, and the 'Top Country in Asia for IP protection' by both the World Economic Forum and the Institute of Management Development. It is also a member of major IP-related conventions and organizations such as the World Intellectual Property Organisation, the Paris Convention, the Berne Convention, the Madrid Protocol, the Budapest Treaty and the Patent Co-operation Treaty.

The Intellectual Property Office of Singapore (IPOS) under the Ministry of Law is the government body that provides the infrastructure, platform and environment for creation, protection and exploitation of IP in Singapore. IPOS develops, reviews and administers IP laws in Singapore to ensure a sound IP legal infrastructure that is conducive to trade and investment. It pro-actively carries out activities to promote awareness of IP rights in Singapore.

The Ministry of Trade and Industry (MTI) is the key driver of economic development in Singapore. It has the triple objective of developing Singapore into a globalised knowledge economy, a creative and entrepreneurial nation, and a diversified economy powered by the twin engines of manufacturing and services, where vibrant Singapore companies complement MNCs and new start-ups coexist with traditional businesses exploiting new and innovative ideas. Two key government agencies under MTI's
purview are the Economic Development Board (EDB), which is responsible for driving Singapore's economic growth into the next millennium, and the Agency for Science Technology and Research (A*STAR). A*STAR is the key agency supporting scientific research and nurturing world-class scientific talent for a vibrant knowledge-based Singapore.

Since the early '80s, the government has encouraged university-industry relationships through its incentives and research and development funding schemes. A Research and Development Assistance Scheme (RDAS) introduced in 1981 is aimed at stimulating industry R&D by providing part funding to companies' approved R&D projects. The grant enables companies to pursue R&D in collaboration with the universities and government research institutes and centres thereby availing themselves of existing facilities and expertise. One major element of the scheme at that time has been the training of skilled R&D manpower for industry.

In supporting and funding research, the government has not sought to own or manage the intellectual property generated. Therefore, there was overriding law to govern university-industry interactions. IP management and University-Industry relations is governed by the universities own policy, strategies and best practices. Mechanisms have been established and fine-tuned over time for staff and students to adapt to and take an active part in entrepreneurial development and in promoting technology transfer and commercialisation.

3. **EXTENT OF UNIVERSITY-INDUSTRY PARTNERSHIPS**

3.1 **Participating Universities**

The National University of Singapore (NUS) and the Nanyang Technological University (NTU) are public universities. A third University, the Singapore Management University (SMU), opened its doors to students in August 2000. The SMU is a government-funded privately managed university offering a broad-based business curriculum modeled after that of the Wharton School of the University of Pennsylvania. An open university degree programme established in 1992 and managed by the Singapore Institute of Management awards the degree of the Open University of the United Kingdom. The above tertiary institutions come under the Ministry of Education.

NUS has a full-time enrolment of about 32,000 comprising some 23,000 undergraduate and 9000 postgraduate students. It has 8 schools/faculties, an academic staff strength of 2055 and another 1151 research staff. In 2004 NUS produced some 6066 graduates and 2699 postgraduates in the major disciplines of engineering, science, medicine, business administration, architecture and building and estate management, law, arts and social sciences, and dentistry.

NTU has a full-time student population exceeding 24,000, which includes some 7400 postgraduates. It has nearly 1400 academic and 652 research staff members. In 2004 some 4238 graduated in the major disciplines of engineering, applied science, accountancy, mass communications, and education. Of these, about 1189 were for higher degrees.
Together, the two universities represent the single most important talent pool and source of highly trained manpower for the nation. NUS and NTU have consistently produced well-trained graduates with the requisite fundamentals, practical skills and entrepreneurial spirit much sought after by industry and business. Being a major resource and producer of research output, there is recognition of the universities’ social responsibility to translate the outcomes of research for commercialisation and application. Both universities have been drawn into a succession of initiatives aimed at capitalising such supposed opportunities latent in their research laboratories to:

(i) disseminate new and useful knowledge resulting from University research,
(ii) license technology to industry in order to promote the development of inventions towards practical applications,
(iii) provide a source of income from the University’s investment in R&D to support further research, with a share of the income going to the inventor, and
(iv) ensure that technology transfer obligations of the University towards a research sponsor are met.

The universities employ a range of activities such as collaborative research and development, staff consultancy, seminars and specialist training courses, industrial attachment programmes, technology licensing and commercialisation, formation of spin-off companies, and venture development. Through these various modes of collaboration, the universities build on existing relationships to forge closer and longer-term strategic alliances with industry for mutual benefit.

3.2 Administrative and Organisational Set-up for Managing University Industry Partnerships

NUS and NTU have taken steps to enhance infrastructure and mechanisms to facilitate university-industry interaction with technology transfer being central to the research process. NUS and NTU have dedicated technology transfer offices known as the Industry and Technology Relations Office (INTRO) and the Innovation and Technology Transfer Office (ITTO), respectively. Indeed, both NUS and NTU, have mature and well-structured set of guidelines relating to collaboration with industry.

The first University-industry technology transfer operations in Singapore began with the formation of INTRO in August 1992. INTRO deals with the entire range of research collaboration, IP management and technology transfer activities. INTRO is now part of a larger NUS Enterprise Cluster (ETP) alongside the University’s Academic and Corporate Clusters. ETP consists of seven other units dealing with entrepreneurship, consulting, continuing education, incubators, overseas colleges and the university press. A separate unit called NUS Venture Support is responsible for nurturing start-ups. Grants and funding for research not sourced from industry collaboration is handled by a separate Office of Research within the Academic Cluster.

Similarly, as part of NTU's efforts to nurture an entrepreneurial community within the University, ITTO was established on 18 March 2000. ITTO aims to promote innovation and transfer of NTU’s intellectual capital for industry’s use through licensing and new venture creation, leading to equitable benefits for students, staff members and the University. ITTO ensures the protection of the IP through a seamless process for
disclosures, evaluation and assessment of inventions and patent applications. It also provides the support systems for an entrepreneurial ecosystem by networking NTU’s research community to work more closely with the industry.

ITTO supports the Schools and various Research Centres in technopreneurship development and training by providing resources to aid the research on and teaching of entrepreneurial-related subjects. Together with its Nanyang Technopreneurship Centre (NTC), ITTO manages an integrated system that promotes an entrepreneurial culture by developing innovations, planting the seeds for new ventures, preparing entrepreneurs through technopreneurship education and providing the infrastructure to perpetuate and support new start-ups and ventures.

3.3 IP Policy and Ownership of IP

Under NUS rules relating to inventions and innovations and other works instituted since 1991, all rights to inventions developed by a staff member as part of his duties or contract of employment, or through the course of his participation in a research project funded through or by NUS, belong to NUS. This is with the exception of inventions arising from externally funded research covered by agreements containing intellectual property provisions. In return for the rights to the invention, the inventor will receive a portion of the royalties and fees received by the University on exploitation of the invention.

A policy on Intellectual Property and Technology Transfer was put in place in 1998 to provide guidelines to NTU's higher degree students and staff members on intellectual property protection and management, new venture creation and sharing of benefits. The Policy spells out the rights and obligations of inventors and the circumstances under which IP developed by staff member belong to the University.

Both NUS and NTU have clear rules and management processes that deal with IP. INTRO first produced a comprehensive set of technology transfer guidelines in 1994 in a publication entitled "A Guide to Patenting, Technology Transfer and Research Collaboration with Industry".

3.4 Royalties

INTRO is flexible in negotiating royalty arrangements for licensing of NUS technology. In return for the rights to the invention at NUS, the inventor will receive a portion of the royalties and fees received by NUS on exploitation of the invention. Up to September 2000, under the NUS rules relating to inventions and IP, NUS offered a generous royalty split, with two thirds of net royalty accruing to the inventor, without limit. Following a change in the rules in September 2000, royalties received by NUS, net of costs, are to be divided as follows: 50% to the inventor(s), 30% to the department and 20% to the university. Direct costs of intellectual property protection and administrative charges of not more than 15% of the royalty received are recoverable by NUS. The royalty sharing formula ensures that not only NUS and the inventor benefit but also the environment that fosters the research.
At NTU, net royalties, fees and other benefits generated by commercial exploitation of IP are shared as follows:

<table>
<thead>
<tr>
<th>Net royalties, fees and other benefits</th>
<th>Inventor(s) (%)</th>
<th>University (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) of the first $500,000 or part received</td>
<td>75</td>
<td>25</td>
</tr>
<tr>
<td>(b) of the next $1 million or part received</td>
<td>55</td>
<td>45</td>
</tr>
<tr>
<td>(c) in excess of $1.5 million</td>
<td>35</td>
<td>65</td>
</tr>
</tbody>
</table>

Where NTU decides not to retain the IPR for patenting, licensing or other forms of commercial exploitation, the inventor(s) may request for the right to pursue IP protection and commercial exploitation on their own. However, the inventor(s) are required to share any royalties, fees and benefits in the following manner.

<table>
<thead>
<tr>
<th>Net royalties, fees and other benefits</th>
<th>Inventor(s) (%)</th>
<th>University (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a) of the first $500,000 or part received</td>
<td>85</td>
<td>15</td>
</tr>
<tr>
<td>(b) of the next $1 million or part received</td>
<td>75</td>
<td>25</td>
</tr>
<tr>
<td>(c) in excess of $1.5 million</td>
<td>65</td>
<td>35</td>
</tr>
</tbody>
</table>

NTU defines net royalties, fees and benefits as gross income less determinable expenses whether incurred by NTU or the staff member on his own account, including but not limited to, patent filing, legal fees, marketing and licensing costs, administrative expenses and fixed overhead costs and other expenses necessary incurred for patenting and licensing the invention. NTU will share a proportion of net royalties, fees and benefits with the relevant schools where the invention originated from in a proportion that it deems fit.

The Universities will not normally seek protection for inventions which are not commercially attractive, even if the invention is intellectually meritorious, unless there are special requirements. In cases where the NUS does not wish to file for a patent and there are no other terms and conditions governing the invention, the rights to the invention normally revert to the investigators.

### 3.5 Key Statistics

Since its inception in 1992, INTRO has received about 600 invention disclosures mainly in the fields of physical sciences and engineering, life sciences and information technology. It has facilitated the filing of more than 500 patents, of which 140 have been granted. Some 107 technologies have been licensed. Between 1998 and 2002, nearly $1 million from royalties were generated from the licensing of such IP. In 2001 and 2002, 136 research collaboration agreements were signed with a total project value of over $42 million. It has forged over 800 partnerships through research collaboration, project agreements and MOUs.

The research funding for FY 2001 almost doubled that of the year before; a reflection of the emphasis funding organisations placed on the work being conducted at NUS and its research institutes and centres. The number of new and ongoing projects grew to 1,969, of which two thirds were in the areas of medicine, science, engineering and computing. In FY 2003, NUS is engaged in some 1841 research projects, many of
which are collaborative projects with private companies, government bodies, academic and research institutions and international agencies. A substantial number of its collaborators are overseas.

During the year 2001/2002 at NTU, a total of 103 collaborative projects with industry, 161 projects with other government bodies and another 253 projects with other universities and research organisations were in progress with a total funding of $44 million from external sources. In addition, 31 patents were filed by staff and 3 spin-off companies were formed by NTU staff. A major thrust of NTU’s research strategy is to concentrate on multi-disciplinary research, in order to optimise on the pooling of resources and to foster synergy and cross fertilisation of research. Twenty six interschool research centres have been established. These programmes resulted in over 3500 research papers in international and local journals and conferences.

Figure 1 shows that over a ten year period from 1995 to 2004, the 2 Universities filed a total of 1052 patents and had 229 patents granted.
4. NATURE OF UNIVERSITY-INDUSTRY PARTNERSHIPS

The universities employ a range of activities in their interaction with industry. These include collaborative research and development, staff consultancy, seminars and specialist training courses, industrial attachment programmes, technology licensing and commercialisation, formation of spin-off companies, and venture development. Through these various modes of collaboration, the universities build on existing relationships to forge closer and longer-term strategic alliances with industry for mutual benefit.

4.1 Modes of Research Collaboration

Depending on the motivation and the needs, each collaboration arrangement is tailored to meet the specific needs of both sides. Generally, collaboration can take any of the forms described below.

4.1.1 Unrestricted Grants-in-Aid

Grants-in-aid are normally provided by a research sponsor for an individual researcher or group of researchers where the research activities have the following general characteristics:
(i) no specific result is required or expected by the sponsor,
(ii) no rights to inventions or other intellectual property accrue to the sponsor,
(iii) no restriction on publication of results,
(iv) no information confidential to the sponsor will be accepted, and
(v) no overhead overheads charged by the University.

4.1.2 Collaborative Research and Development Agreements

In many instances of research collaboration, projects are undertaken on a shared cost basis with the following characteristics:
(i) job scope defined jointly by the company and the University,
(ii) specific expected result or development defined,
(iii) ownership of inventions, software, biological materials, know-how, trade secrets or other IP vests in the University,
(iv) company can be granted an option on a first refusal basis to a royalty-bearing licence (exclusive or non-exclusive) to commercially exploit IP or research results in specifically defined areas,
(v) publications may be temporarily restricted (within clearly defined limits) to protect commercial interests,
(vi) confidential information provided by the company will be protected by the University to the best of its ability (with clear definition of what constitutes confidential information and the conditions under which it remains confidential), and
(vii) standard University overhead charges apply.
4.1.3 Research and Development Contracts

Research contracts are not usually undertaken as the Universities are not works for hire. Consideration for any such projects will be at full costs with the following conditions:
(i) work to be done defined by the company,
(ii) specific result or development expected,
(iii) IP and research results will be offered to the sponsor on a first refusal basis,
(iv) publications may be temporarily restricted (within clearly defined limits) to protect commercial interests,
(v) confidential information provided by the company will be protected by the University to the best of its ability, and
(vi) project charged at full costs including standard University overhead charges.

4.1.4 Memorandum of Understanding

An MOU is an umbrella arrangement defining the terms and conditions governing the overall management and conduct of joint activities between the university and industry. It is used when the collaborating party has an interest in projects over a wider discipline (normally applicable to government ministries and statutory boards). Terms governing joint projects under the MOU are defined individually and separately in accordance with the guidelines covering cooperative R&D agreements.

4.1.5 Consulting

Academic staff members consult for the private and public sectors on a routine basis. Consulting is considered a private arrangement between the company and the individual staff member, where the staff member has to abide by the following rules:
(i) no use of University space, equipment, facilities without University approval,
(ii) no involvement of non-academic staff during normal working hours,
(iii) no involvement of students, and
(iv) no use of the University name (e.g. University letterhead, University name on report).

IP generated in a consulting arrangement is a private matter between the consultant and the client. However, normally consulting is based on the use of existing knowledge of the staff member and no new IP is expected to be generated.

4.1.6 Tangible Research Property/Biological Material Transfer Agreements

In instances where the University needs to transfer biological materials, the following rules will apply:
(i) materials (including all progeny/derivatives) delivered by the University is owned by the university,
(ii) for research purposes only, no licence implied,
(iii) all inventions made with materials provided by the university shall be disclosed to the university with due acknowledgments in any publications that may arise,
(iv) no warranty of suitability for use, and
(v) the university assumes no liability.
4.1.7 Confidentiality/Non-Disclosure Agreements

When information of a confidential nature is required to be transferred to a third party for evaluation, the transfer is covered by a confidentiality/Non-disclosure agreement.

In general, all IP developed by the Universities in collaborative activities, whatever the mode of collaboration, remain the property of the Universities. The collaborating party is:
- offered the right of first refusal to file a patent and utilise the technology developed on agreed terms and conditions.
- often given the equal right to determine the final disposition of the research results especially if the company also participates in the research activities and contributes to the intellectual outputs.

This is to give the Universities the title to the IP and the powers of enforcement. Under the rules pertaining to IP ownership, all IP generated through the course of a staff members employment at the Universities, belong to the respective Universities.

However, the Universities are not rigidly bound in its negotiations with companies on this issue depending on the circumstances surrounding each collaboration and the leverage it has on the deal. For collaboration with statutory boards and government ministries who do not intend to exploit commercially the results at the end of the project, the Universities prefer to own the intellectual property rights and to grant the relevant bodies a non-exclusive non-royalty bearing licence for their own internal use. However, the Universities will accommodate the reasonable expectations and rights of all partners.

If a company sponsors research at the universities, the usual position adopted by NUS and NTU is that it will retain ownership of all IP that it develops or creates. The company will have a first right to obtain either a non-exclusive or exclusive fee-based licence to use the resulting IP commercially. Such licence will be negotiated on commercial terms. An exclusive licence may not however be available if a key platform technology is involved.

Generally, the universities will consider joint ownership of the resulting IP if the company will be contributing its background IP to the project and will also be involved in creating or developing the IP together with university researchers. The company must also be contributing significantly to the total project costs. In this case, the company will have a non-exclusive royalty-free right to commercially exploit the resulting IP but will be required to account to the universities a percentage of any licensing revenue it receives should it license the resulting IP to third parties. The company will also have the first right to negotiate a royalty-bearing licence to exclusively commercialise the resulting IP.

NTU does consider sole ownership of IP by the company but only on a case-by-case basis and if the following criteria is first met:
- The project is focused mainly on product development or improvements to the company’s existing products or services.
• The project has unambiguous known objectives and the company lays down a defined way of performing the study.

• Only the company’s background IP is involved. The project does not require the use of any existing NTU IP but only the expertise and know-how of NTU’s researchers.

The company will also be required to bear the full cost of the project to be carried out at NTU. The company’s ownership of resulting IP will however be limited to the company’s stated field of application.

4.2 Status of R&D Collaboration with Industry

Research undertaken in collaboration with industry, government bodies and other organisations (local and overseas) represents a significant percentage of the universities’ overall research effort. Strong encouragement is given to such collaboration as it represents a major avenue for technology transfer, rejuvenation of research and improvement to the curriculum.

According to the annual National R&D Survey conducted by the Agency for Science, Technology and Research (A*STAR), in 2003, a total of 617 private sector enterprises reported that they performed R&D. These companies expended $2081 million on R&D representing 60.8% of total expenditure on R&D. Of these:

• 304 (49%) were in manufacturing industries
• 299 (48%) in service industries
• 14 (2%) in the primary industries and construction.

Many private sector companies undertaking R & D are already collaborating with NUS or NTU and strong links are being maintained with this group of companies. Also on the priority list are major small- and medium-sized enterprises considered most likely to initiate R & D activities.

NUS is also situated next to the Singapore Science Park and the latest 200ha epicentre One-North. The Singapore Science Park is Asia’s most prestigious research and development and technology hub. It was set up under a government initiative in 1980 to provide infrastructure for R&D to flourish in Singapore. Today, the Science Park community comprises over 300 multinational companies, local companies and national research institutes.

One-North is the government’s latest initiative to develop an exciting place of vision and inspiration, where it is possible to live, work and play and be inspired by leading scientists, researchers and technoprenuers around the world. Located in One-North is the Biopolis, a state-of-the art biomedical research complex of seven buildings that houses the five Biomedical Research Council (BMRC) research institutes of A*STAR, and R&D laboratories of pharmaceutical and biotechnology companies all within close proximity of one another so as to promote greater collaboration.

The 5 BMRC research institutes develops core capabilities in niche research areas to support key industry clusters in biomedical sciences and collaborate with the
universities in research and R&D manpower development. The Institutes under BMRC are:

- BioInformatics Institute
- Bioprocessing Technology Institute
- Genome Institute of Singapore
- Institute of Molecular and Cell Biology
- Institute for Bioengineering and Nanotechnology

A*STAR is building a diverse community of local and foreign researchers, and has already attracted some of the best and brightest minds from the US, Europe, Australia and Asia to build a critical mass of researchers that will contribute to IP generation. Its science and engineering research institutes actively collaborate with the universities. They are:

- Institute for Infocomm Research
- Institute of Chemical and Engineering Sciences
- Institute of High Performance Computing
- Institute of Materials Research and Engineering
- Institute of Microelectronics
- Singapore Institute of Manufacturing Technology

The universities regularly organise visits to companies to gather information about their R&D activities, their technology and training needs and to explore opportunities for collaboration. Regular seminars are also organised on campus targeting industry participation. The Faculty of Engineering at NUS, the largest collaborator with industry, has collaborative arrangements with all the national research institutes and centers, 25 government agencies and statutory boards, over 200 local companies and more than 250 overseas companies, institutions and universities.

Much of the recent collaboration is in multidisciplinary areas involving scientists and engineers from overseas institutions such as the Institute of Environmental Medicine, Karolinska Institute, Sweden; Georgia Institute of Technology, University of Waterloo, National Aeronautical and Space Administration (NASA), Technical University of Denmark, Stanford University and Hong Kong University of Science and Technology. Collaborators hail from across Faculties e.g Medicine, Engineering, Sciences and the Arts. Some examples of such research activities are:

- Roche Diagnostics and John Hopkins Singapore to develop new tests for early detection of tropical diseases endemic in Asia e.g. dengue fever.
- Georgia Institute of Technology and Penn State University to develop an interactive, automated fixture design and analysis system for manufacturing, on the web.
- University of Toronto to develop an integrated membrane process for microbial control and water reclamation.
- Swiss Federal Institute of Technology (EPF-Lausanne) to develop a robotic micro-assembly of scaffold/cell constructs for tissue engineering.
- Institute of Microelectronics and Georgia Institute of Technology to develop nano-interconnection designs, test and burn-in technologies for nano-wafer level packaging.
Other collaborators from the Universities include:

- Technical University Eindhoven. Collaborator in setting up the NUS-TU/e Design Technology Institute to offer a Master of Technological Design degree.
- Johns Hopkins University. Collaborator in Johns Hopkins Singapore. DJHS targets its research to advances in immunology, virology, cancer biology and experimental therapeutics.
- Joint Laboratory with Centre National de la Recherche Scientifique (CNRS) to develop a 3D full-featured orthognathic surgical simulator with NUS' Dentistry Department.
- Massachusetts Institute of Technology in the Singapore - MIT Alliance to offer innovative engineering education and undertake research collaboration.
- Georgia Institute of Technology. Collaborator in The Logistics Institute - Asia Pacific (TLI-AP) to provide advanced studies in modern manufacturing, warehousing and logistics.
- Helsinki University of Technology. Collaboration with School of Computing’s Collaborative Technology Lab.
- Stanford University. Collaboration in NUS’ first overseas college in Silicon Valley.
- University of Pennsylvania. Partner of second NUS overseas college in Bio Valley.
- University of Wuppertal. Collaboration with NUS Engineering Faculty’s Center for Integrated Circuit and Failure Analysis.

Research Institutes and Centres such as:

- Advanced Institute of Science and Technology (China)
- Centre National de la Recherche Scientifique (France)
- China Research Institute of Radiowave Propagation
- Chinese Academy of Sciences (China)
- Institute of Beijing (China)
- Institute of Industrial Science (Japan)
- Institute of Microelectronics (China)
- Institute of Semiconductor (China)
- International Center for Advanced Internet Research iCAIR (Chicago, USA)
- Laboratorie d’ Automatique de Grenoble (France)
- Laboratoire de Physiologie de la Perception et de l’ Action (LPPA), CNRS - College de France
- National Research Council (Canada)

Industry Partners, such as:

- Sumitomo Chemical Co Ltd. Corrosion studies.
- Chartered Semiconductor Manufacturing. Advanced CMOS process Technology.
- Stem Cell Technologies Pte Ltd. Cure for diabetes through adult stem cells.
• Agilent – Thermal management of electronics cooling
• Chartered Semiconductor Manufacturing - Tunneling Current Microscopy for Imaging Defects in Thin SiO2 Films, Hot carrier reliability studies
• Defence Science Technology Agency – wearable computing and mixed reality
• Ericsson Cyberlab – Open Source Software Lab
• IBM - Product LifeCycle Management and Internet-based Collaborative Product Commerce.

International Project Sponsors
Some organizations who have sponsored research and other activities include:
• Asia Pacific Foundation, Canada
• Asian Development Bank (ADB)
• AT&T Global Foundation
• BMW Herbert Quandt Foundation
• British Council
• Canadian International Development Agency (CIDA), Canada
• DCE Consultants, The Netherlands
• Foundation for Advanced Studies in International Development (FASID), Japan
• Global Catalyst Partners
• Hans-Seidel Foundation, Germany
• IDE/JETRO, Japan
• IDRC, Canada
• Institute for Posts and Telecommunications Policy (IPTP), Japan
• INTERMAN, ILO
• Japan Institute for Science & Technology Cooperation (JISTEC)
• Korea National Computerization Agency (KNCA)
• Nomura Research Institute, Japan
• Sasakawa Peace Foundation (SPF), Japan
• UN/WIDER, Helsinki, Finland
• UNESCAP, Bangkok, Thailand
• UNIDO
• World Bank
• World Intellectual Property Organization (WIPO)

Some notable NTU Memoranda of Understanding and research projects with industry and academic communities, both local and overseas, are listed below:

Overseas Industry
• British Gas Asia Pacific Pte Ltd, in natural gas reforming with optimised hydrogen-rich reformate.
• AMR Technologies Inc., Canada, in Processing Optimisation for nanostructured rare earth materials.
• Institute of Mechanical Systems Engineering, National Institute of Advanced Industrial Science & Technology, Japan, in micro-machining technology for advanced materials.

Overseas Institutions/Agencies
• Institute of Metal Physics, National Academy of Sciences of the Ukraine, in study of smart materials and their applications.
Korea National Computerisation Agency, (Chungnam National University, InfoCom Engineering Department), in "IPv6-Based High Performance Multimedia Conferencing over the APH Testbed" Project.

Moscow Aviation Institute (State Technical University), Russia, on research of Electromagnetic Wave Scattering from Moving Bodies and Development of Programme Complexes for Scattered Field Computer Simulation.

University of Oxford, Department of Engineering Science, UK, on nanostructured materials, advanced processing of materials, advanced materials characterization, advanced materials modelling, prediction of material failure, surface engineering and tribology.

Local Industry

- Motorola Electronics Pte Ltd, in Plastic Housing Crack Prediction.
- Shimadzu (Asia Pacific) Pte Ltd, in XPS study of nanocomposite thin films.
- Silicon Graphics Pte Ltd, on joint establishment of Centre for Supercomputing and Visualisation.
- Sumitomo Electric Industries Ltd (SEI) and VS Electronics Pte Ltd (SEI's subsidiary), in the development of Optical Packages.

Local Institutions/Government Agencies

- Singapore Police Force, Criminal Investigation Department, on joint research in fields of forensic interests.
- Singapore Productivity and Innovation Board, SPRING Singapore, in development of metrological capabilities and measurement standards in Singapore.

5. COMMERCIALISATION OF RESEARCH RESULTS

University inventions and research results form a reservoir of intellectual property that industry can tap into. Where technologies have immediate commercial value to industry, the universities seek out industry partners for technology licensing or development. Technology licensing represents one of the more direct technology transfer mechanisms available to companies seeking to exploit university intellectual property. NUS employs a variety of means to publicise its technology availability. Technologies and intellectual property are selectively sent to companies for evaluation and are placed in a "technology offer" database on the internet. It currently oversees a portfolio of 250 NUS technologies for licensing.

NUS has local and foreign licencees mainly for intellectual property in the fields of engineering, medicine and science. Experience at NUS shows that licensing often has spin-offs leading to further research collaboration and funding and staff consulting.
While companies can seek exclusive licences to exploit intellectual property and software, NUS favours those arrangements where companies are prepared to sponsor continuing research on campus. Royalties derived from licences are used to support further research and are shared with inventors to provide incentives for further research and innovation.

Concurrent with the patent decision process, and for non-patentable inventions, INTRO will market and, if successful, begin licence negotiations with the potential licensee. The commitment, wholehearted support and enthusiasm of the inventor throughout the technology commercialisation process will be a critical factor for successful licensing.

5.1 Technology Licensing

The University strongly supports the application and commercialisation of all its inventions and technology by industry for public use and benefit. The main vehicle for the transfer of technology to industry is through licensing. Licensing is also the main source of financial return for the University's investment in R&D. The exploitation of University technology can either be achieved through independent development by the company or through a collaborative effort between the University and the company.

Licensing involves an agreement that gives a licensee the legal right to use University technology or IP. It also involves identifying and negotiating licences with companies that can demonstrate the capabilities and resources sufficient to take a technology from the university bench-scale level through a prototype demonstration to full production. A licensing activity may begin any time after disclosure and is not delayed to allow a patent to issue.

5.2 Technology Licensing Process

The University maintains a licensing programme which is available to all staff inventors. INTRO's standard operating procedures for technology licensing and commercialisation involve the following steps.

1. On receipt of an invention disclosure, INTRO with the help of the inventor makes an evaluation of the invention for the level of protection needed, technical feasibility, novelty, potential applications and possible markets. A preliminary licensing strategy will be developed depending on the invention. In addition, the University will consider a staff inventor's proposal to exploit his or her own invention.

2. All disclosures accepted by INTRO are entered into the intellectual property database. A general description of the invention indicating the advantages and performance criteria, and a broad outline of how it works and how the performance criteria are achieved, is normally written-up in the form of Technology Offer Sheets. Such offer sheets also indicate the status of the technology, i.e., if they are available for licensing or for further collaborative work.
3. As part of the development process of the licensing strategy as much information and feedback as possible are sought on market risks from various sources such as potential licensees and venture capital firms. Before divulging any information of significant importance to industry, the industry partner must execute a Confidentiality Agreement with the University. This is to protect patent rights if no public disclosure of invention has occurred, or if the patent filing date has not been awarded.

4. Information on technology that have intellectual property protection are sent selectively to companies on the INTRO network.

5. Concurrent with the patent decision process, and for non-patentable inventions, INTRO will market and, if successful, begin licence negotiations with the potential licensee. The commitment, wholehearted support and enthusiasm of the inventor throughout the technology commercialisation process will be a critical factor for successful licensing.

6. Companies likely to be interested are approached and are given an opportunity to evaluate the invention. If the company shows strong interest, a business plan is requested. The business plan is subject to negotiations and, if acceptable to both parties, will form the basis of the licence proposal and royalty arrangement. Revenues to universities can be in the form or fees (upfront and annual), royalties, and equity. Royalty rates range from 1 to 20% depending on the technology. Higher rates are often adopted for software, where the variable costs of production are minimal.

7. Technology transfer can also be handled through the form of an option agreement between the interested company and the University. This written agreement serves as a guarantee to the interested company that for a designated period of time (usually six months) the invention will not be offered to other companies who may have an interest in it. The option agreement gives the company time to consider the potential of the technology within the company's corporate strategy. If there is more than one potential licensee, it is a philosophical mandate of the University to try to support local commercial exploitation and application of the technology wherever possible. The inventor will also be consulted on the suitability of a particular licensee.

8. If successful, the signing of a licence agreement is the beginning of a long term relationship. The licensee's performance is monitored for the duration of the licence. Most licence agreements require the licensee to submit annual financial statements and progress reports. All royalty payments are collected by NUS and distributed according to the terms of the IP Policy (see 3.4). It is often necessary to re-evaluate a licensing relationship to adapt to the changed circumstances or to take into account new situations. Either NUS or the licensee can request an amendment to the licence agreement at any time during its life.

Most licenses arising from collaborative research are technology licences, comprising tangibles and intangibles such as know-how, processes, techniques, algorithms, data, etc, as opposed to IP licences where patents, copyrights, trademarks or designs are involved. A combination of both is also common. Technologies and IP are always
licensed and never assigned so that the right to use the technologies and IP for teaching and further research are always retained.

Technology transfer can be accompanied by physical documents (e.g manuals, specifications, and designs), or software, prototypes and models, as the case may be. Proprietary information that is not patented is disclosed on a strict need to know basis under the obligation of confidence. If training or other knowledge transfer is needed, the staff inventor/collaborator concerned, can be engaged on a consultancy basis. If successful, the signing of a licence agreement is the beginning of a long term relationship.

5.3 Key University IP Licensing Terms

The main thrust of a licence agreement is to transfer technology in a manner that produces a desired application and a financial return. However, in doing so, the University will ensure that all licensing agreements limit the liability that it undertakes.

(i) Improvements and Foreground IP

The University must be careful to leave itself free to find future sponsors for its research. "Improvements" which may be made at the University, subsequent to the licence, will not necessarily be part of the licence. However, the University usually requires that it be entitled to use foreground IP and information (developed in the course of modifications, improvements or further research by the licensor) for the purposes of teaching and further research.

(ii) No Warranty of Fitness for Use

Almost without exception, technologies are licensed on an as-it basis, but without warranties on fitness for use. This is because the invention is usually in a very embryonic state and its fitness for use is a matter of conjecture. The University does not have the resources to thoroughly assess the market nor to study the practical uses and limitations of the technology. The royalty rate payable is usually a reflection of the risk that the licensee is taking, as well as the lack of any warranty by the University.

(iii) A Limited Transfer of "know-how" Clause

Sometimes there may be a need for "know-how" to be transferred in addition to the patent rights. As such technology transfer may require the cooperation of the inventors, it may be included in the licence "to the extent practical". The licensee may is usually advised to make a separate consulting agreement with the inventor to provide such know-how.

(iv) The Indemnification Clause

The University requires licensees to broadly indemnify the University against any product liability actions which may arise from the licence, including the costs of defending the suits. This is because the University has very little control on how the licensee develops, uses and markets the technology.
(v) Responsibility for IP and Enforcement Rights

The licensee is usually required to indemnify the university from all claims and damages arising from the use of the licensed technology. It is also the responsibility of the licensee not to infringe any third party IP rights and to inform the University if any infringement is suspected. This will enable the University to work with the licensee on the appropriate plan of action against any such infringement.

5.4 New High Technology Companies and Venture Development

Staff members are permitted to set up companies to enable the commercial exploitation of their inventions/technologies. While licensing remains a primary avenue for technology transfer and application, it is not always possible to find a suitable licensee even when market demand for the technology is evident. When this happens, and when staff members strongly believe that their personal involvement is needed to enhance the chances of commercial success, the route of establishing a start-up company is then taken.

In such a development, staff entrepreneurs are allowed to be directors of companies whose activities include the commercial exploitation of the invention of the staff member. Besides managing the business, staff entrepreneurs are also expected to be involved in providing scientific and technical expertise to the start-up. The level of their involvement in any new venture would always be subject to that staff member being able to fulfil his research, teaching and administrative duties. In the event that a member of staff wishes to dedicate more time to his spin-off company, he can negotiate for leave of absence or part-time employment. Each case will be assessed on its own merits. The objective is to create an environment which will encourage budding entrepreneurs to explore the idea of starting their own business without taking undue career risks.

Staff entrepreneurs wishing to commercialise technology would need access to intellectual property rights relating to the technology. Under current University rules, such intellectual property belongs to the University as employers. When the University is satisfied that the creation of a start-up is an appropriate route, the appropriate licensing arrangement will be drawn up between NUS and the start-up company. Start-ups are treated at arms length and key licensing terms are applicable. Appropriate licensing arrangements will be drawn up between NUS and the spin-off company even if the staff member is the inventor. The standard licensing agreements will define amongst other items the following:

(i) the IP to be made available e.g. patents, know-how, drawings etc.
(ii) the term of the licence;
(iii) the licence fee, royalties and terms of payment, including possibilities of converting such payment into equity;
(iv) the extent of the licence e.g. exclusive or non-exclusive, the territory in which it can be exploited and the specific applications of the IP;
(v) the scale of effort that will be put in to exploit the IP;
(vi) the references that can/cannot be made to the university in marketing.
(vii) a disclaimer by the University of all liabilities arising from the use of the results; and
(vi) the responsibilities and obligations of both parties in treatment of new IP.

In January 1995, NUS incorporated the NUS Technology Holdings Private Limited, (NUSH), to seed and take equity in new high-technology companies arising from university research. Drawing upon funds then made available under the Commercialisation Grant Scheme (CGS), NUSH provides early stage support to such approved new spin-offs thus helping to lower the barriers to successful exploitation and application of university inventions and research. Starting-up is further facilitated by the formation of NUS Venture Support (NVS) in December 2002 aimed at developing a venture support ecosystem to cover not only staff by also students and alumni. In January 2003, an NUS Venture Support Fund was created to seed start-ups. Of the 40 applications received, 16 were presented to an awards committee (comprising venture capitalists, angels and entrepreneurs) and 5 received funding of between S$150K to S$300K.

Of the current 90 start-ups, NUSH holds equity in 48 companies which were created mainly out of research conducted in the faculties of engineering, science and medicine. The companies represent an interesting mix of technology businesses having high potential for growth locally and internationally. Major criteria used in approving the spin-off company formation include: (i) presence of market demand but no ready licensee or immediate technology supplier, (ii) personal involvement of enthusiastic staff members themselves in providing advice and consultancy so as to enhance the chances of commercial success, and (iii) willingness of staff members who are the inventors and technology creators to invest their own personal funds in the new entities thereby sharing the risks with the university.

Approval of the start-ups is based on the strength of the business plan and potential future growth of the new companies. Once formed, the companies hope to continue collaborating with the university in R&D and seek to license future research results and intellectual property. The goal is to facilitate another 120 start-ups in the next 5 years so that some of them may develop into significant global companies.

Two examples of licenses for recent start-ups at NUS are:

- Mikrotools Pte Ltd – Miniature machine tool for manufacturing of micro, high precision components.
- Avant Werz Pte Ltd – Intelligent web-based information management system.
- Protherapeutics Pte Ltd - Research and experimental development in life sciences and other natural sciences

Similarly, in April 1995, NTU created NTU Ventures Pte Ltd to invest in and promote commercialisation of research by its staff, again drawing on funds allocated under the CGS. Its first start-up was seeded in 1996 and by 2001, more than 20 companies have been set up with industrial partners to commercialise staff research. These companies attracted $80 million in external funding.

As the spirit of enterprise gains momentum, active commercialisation and application of research will inevitably sharpen the universities' strategic research focus and update teaching curricula. Entrepreneurially-minded staff members are encouraged to
contribute actively to the growth of technology start-ups. Such involvement by university staff will further facilitate the diffusion of ideas to industry and allow staff members to deepen their knowledge of industry and keep abreast of economic and technological developments. In the long-term, this will help the universities become more adaptive and engender a culture of entrepreneurship in academia.

5.5 Student Start-ups

In 2004, an Entrepreneurial Talent Development Fund (ETDF) was initiated by the Economic Development Board to provide funding to Institutes of Higher Learning (IHL) to support their Student Venture Programmes. Full time and part-time students of IHLs (except part-time students under the continuing education programme) regardless of nationality are eligible. Alumni members of IHLs who have graduated within a year from their date of application are eligible if their business venture are initiated or conceived during the time that they were students of the IHLs. The ETDF acts as a co-investment fund. For every S$3 invested from ETDF, the IHL and the student must make a co-investment of $1 each. The maximum investment to each student venture from the ETDF is S$50,000. Using the ETDF, NUS seeded 9 student companies over the six month period from November 2004, in the form of convertible loans. NUS expects to seed 20 such companies a year, up to 100 in the 5 year life span of the ETDF.

5.6 Innovation Centres, Incubators, and Technogarage

At NUS, three incubators, one at the university level and one each at the Faculty of Engineering and School of Computing, that can accommodate 35 to 40 incubatees, have been established. The NUS Business Incubator located at its Kent Ridge Campus, provides physical infrastructure and office support, as well as access to a wide network of professional resources, which includes mentors, advisors and consultants. Since overseas market validation is a key prerequisite to securing significant external funding, an Enterprise Centre was established in Silicon Valley in 2003 to facilitate entry of NUS start-ups into the US markets. The Centre also facilitates beta testing, fund raising and business networking opportunities. A Centre in Shanghai is being planned.

To encourage local and locally-based enterprises to carry out their R&D activities on campus where expertise of NTU staff and facilities are readily available and where students could be involved in such activities, the NTU has set-up an Innovation Centre. The Centre facilitates R&D activities by matching industry's needs with expertise of NTU staff. Collaborators are given access to advanced facilities and can engage students in R&D projects. Over the years, more than 60 tenants in different R&D fields such as materials, biotechnology, product development and information technology have collaborated with the University through the Innovation Centre since its inception in 1987. At present some 20 firms have set up their units at the Innovation Centre for research and development work. Besides R&D, the Innovation Centre also aims to encourage innovations and entrepreneurship by providing technology incubation facilities at a nominal rate to organisations and offers assistance to University staff members in the commercialisation of their research results.
Technopreneurs working at NUS’s Incubation Centres and NTU’s Innovation Centre enjoy strategic proximity to faculty expertise and ready access to state-of-the-art facilities and laboratories at nominal rates.

In line with the University's quest to motivate its students to take the lead in the technopreneurship drive and to nurture a future generation of technopreneurs, the Innovation Centre also provides NTU students with incubation units at a TechnoGarage for them to create and develop their innovations to commercial fruition. Mentorship and financial assistance programmes are made available for the aspiring student entrepreneurs. TechnoGarage consists of 6 rooms, size ranging from 13 to 20 sqm each. All rooms are equipped with air-conditioning, lighting, furniture and necessary facilities. Users pay nominal monthly maintenance charges.

To assist the students in starting a new enterprise, ITTO sees a need to provide a good mentorship programme that comprises members of NTU teaching staff, NTU Alumni and the private sector to provide advice and guidance to the students. Through the programme, students can avoid pitfalls that may unnecessarily delay the development process, get first hand pragmatic solutions to problems, moral support and encouragement. Areas of mentorship provided include:

- Assessing the business concept.
- Writing of business plan.
- Contribution of knowledge in engineering, business development, marketing and finance.
- Linking-up with venture capitalists.
- Linking up with potential customers.
- Starting and running the business.

6. SOURCES OF FUNDING

A wide range of financing options are available across the different stages of the business cycle. These options cover research and development grants, seed funding, patent assistance, loans and government financing schemes. These options are complimented by an ample and growing pool of venture capital and private equity funding available in Singapore. In addition, various tax incentives are available.

6.1 Academic Research

BMRC extends funding support to research that generates knowledge and capabilities vital to Singapore's vision of becoming a premier centre for biomedical research and development. Four types of grants available for research programs ranging from basic to clinical research are:

- **Project Grants** - seed funding for young and promising investigators, who are at the early stage of their career, to engage in research for up to 3 years.
- **Program Grants** - funding for an extensive program of research by established investigators for up to 5 years, in the first instance.
- **Co-operative Grants** - funding interdisciplinary collaborative research involving two or more groups for 5 years, in the first instance. The collaboration should
focus on a common theme and leverage on current strengths of each individual research group

- Core Competence Grants - funding for a cohesive research unit where investigators engage in research that develops and/or strengthens capabilities in areas that the Council considers of strategic importance. Funding will be for 5 years, in the first instance.

The SERC Funding Scheme for Public Sector R&D Projects covers 100% funding of direct costs for science and engineering projects for 3 years. The SERC Funding Scheme for Strategic Research Programme provides 100% funding of direct costs for science and engineering projects from universities, research institutes and centres. Projects must have a value of more than $500,000 but less then 3 million over 3 years.

These funds are available to researchers in Singapore's public sector who are not employees of A*STAR-funded research institutes. Research at the Universities is also supported by the Ministry of Education through its Academic Research Fund.

6.2 Industry R&D

To help companies strengthen capabilities through R&D in Singapore, the EDB extends R&D grants to startups, local enterprises and large global companies.

- The Research Incentive Scheme for Companies (RISC) provides partial grant support for qualifying costs resulting from R&D projects. The scheme aims to encourage companies to develop R&D capabilities in strategic technology areas, and support the company in increasing its industrial competitiveness over the long term.

- The Innovation Development Scheme (IDS) is designed to encourage and assist companies to develop capabilities in the innovation of products, applications and services.

- The Biomedical Sciences Proof of Concept (BMS POC) scheme provides seed funding to support the development of early ideas that are patentable and could lead to the formation of new startups or licensing deals with biomedical sciences companies.

6.3. Seed Funding for Start-ups

Generally, funding for start-ups is a major issue. Venture capitalists with the necessary funds are highly focused on business opportunities rather than the early stages of the innovation cycle.

Seed funding for start-ups are available from the Start-up Enterprise Development Scheme (SEEDS) of EDB. SEEDS offers dollar-for-dollar equity matching for early stage start-ups. To qualify, businesses must have a substantial innovative or intellectual content, high growth potential and scalability for the international market. EDB matches every dollar raised by a startup from third-party investors up to a maximum of S$300,000. Third party investors are required to invest a minimum of
S$75,000 each. Under this scheme, both SEEDS Capital and the third party investors will take equity stakes in the investee company in proportion to their investments. To date, successful SEEDS applicants span a wide spectrum of industries, including IT, biotechnology, electronics and e-commerce, media & communications, and nanotechnology.

Given the recent government emphasis on biomedical research and development, EDB through Bio*One Capital, a subsidiary of Singapore EDB Investments Pte Ltd, administers the Biomedical Sciences Innovate ‘N’ Create Scheme (BMS INC). The BMS INC scheme provides seed and early stage funding to support local biomedical start-ups to foster the biomedical sciences entrepreneurial environment in Singapore. Investments are between S$250,000 to S$2,000,000 in the form of equity or convertible loans.

Some other sources of government funds for start-ups are:

- Technology Incubator Programme (A*STAR), which covers 85% of R&D costs or up to $300,000 per year for 2 years
- Venture Investment Support for Start-ups (VISS) – a SGD $50m co-investment program that directly co-invests into early stage promising and strategic companies that are based or linked to Singapore. Start-ups in any industry are eligible for a matching dollar for every two dollars of private investment, up to $500,000.

The National University of Singapore has its own complementary NUS Venture Support Fund, which provides seed funding of up to $300,000 in the form of convertible loan or redeemable preference shares. It recently established a Technology-to-Market Fund (T2M) with an initial $200,000. T2M aims to provide modest but critical support to selected technologies arising from research projects that need further development in order to be commercially viable.

SPRING Singapore manages two funding schemes for startups:

(i) The Micro Loan Program, which is a fixed interest rate financing programme for startup and small enterprises, particularly those that are asset-light and knowledge-intensive. Enterprises can use the loan to establish new businesses, modernise and automate operations, expand existing businesses, and augment working capital needs.

(ii) The Loan Insurance Scheme, which offers loans that suit the risk profile of the borrowers, with the interest rate based on the startup’s credit assessment.

### 6.4 Patent Assistance

EDB administers the Patent Application Fund Plus to encourage innovation, awareness and commercialization of IP. It helps defray the cost of patenting, up to a cap of S$30,000, and is available to all Singapore-based small and medium enterprises.
6.5 Venture Capital

More than 150 VCs of local and international VC fund management groups are located in Singapore managing some S$16 billion worth of funds. These funds are invested globally across all industry sectors with a substantial amount directed to biomedical industries. EDB hosts a DEALS Portal which aims to match companies seeking venture funding to Singapore’s venture capital community. One can register and upload one’s business plan at the DEALS Portal and the Portal will automatically match and direct the business plan to the appropriate VCs in Singapore.

The Government has also invested in venture funding. Its Technopreneurship Investment Fund (TIF) is a US$1 billion venture capital fund-of-funds that assists Singapore-based institutions to participate in the local venture capital industry. The Fund is managed by TIF Ventures (TIFV) a corporatised entity wholly owned by T21 Holdings under EDB. The charter of the company is to manage funds of funds and associated activities with emphasis on harnessing new technology and value-add business building capabilities.

7. CONFLICT OF INTEREST

In University-Industry interactions, a member of staff is considered to have entered into a situation of potential conflict of interest if, in discharging his/her duties or in dealings with industry, the best interest of the University could be compromised in the personal interest of the staff member.

Various situations relating to technology transfer interactions with industry present the possibility for staff members to make money and this potential for making money can bias their objectivity. Other potential situations of conflict of interest include staff members acting as spokesmen of university spin-off companies, collaborative arrangements between the University and its spin-offs, purchase of equipment from its spin-off companies, and supervision of students.

The success of university-industry interactions leading to technology transfer and commercialisation of University technology is contingent on the close involvement of staff members in the research, invention disclosure and, finally, the technology transfer process. While it is in the interest of Universities to foster entrepreneurial spirit in its faculty staff members and promote active university-industry relations, it recognises the importance for staff members to avoid actual or apparent conflict of interest between their obligations to their university and their outside interests. As a rule, a clear demarcation of both effort and incentive relating to faculty duties from those activities associated with personal enterprise would minimise conflict.

Some current practices and potential conflict of interest situations and their recommended guidelines to assist members of staff of NUS are described below.

7.1 Involvement in Start-ups Companies and Technology Commercialisation

Where a staff member has a financial interest in a company which is developing his/her technology or when a staff member is involved with a company holding a
licence on his/her technology, the following situations which are perceived to be in conflict should be avoided:

(i) Misuse of students by using them as "cheap labour" doing product development for the financial benefit of the staff member. In cases where a staff member supervises final-year projects and postgraduate students, this includes shifting thesis topics towards commercial development or even biasing of grades.

(ii) Transmitting to the company information that is not made generally available. This includes withholding or reducing publications after transferring technology to the company, or failing to attend to industry visitors from competing companies.

(iii) Undertaking or changing the orientation of research (whether supported by university funds or external grants) to serve the research, product development or other needs of the company.

(iv) Utilising University resources, e.g., laboratory facilities and clerical and service support, for the activities of the company without permission and proper agreements.

(v) Purchasing of major equipment, instruments, materials, or other items for University research from the company in which the staff member has an interest without disclosure of such interest.

(vi) Funding by the company of research projects related to the licensed technology with supervision by the staff member without disclosure of such arrangements.

Other types of financial attachments between a staff member and a company that could create the above concerns include: consulting, equity ownership, royalty interest, or family ties to someone financially attached to the company. A staff member has the responsibility of informing the University administration of the potential conflict situations and address how the issues of conflict of interest are to be managed.
Some examples of possible conflict situations and the policy guidelines are listed below:

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<th>Conflict Situations</th>
<th>Policy and Guidelines</th>
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<tr>
<td>(i) Misuse of students.</td>
<td>Staff inventors must avoid directing students into research activities which serve their own personal interests at the expense of scholarly achievement. Supervisors of such staff inventors can decide if co-supervisors who have no direct interests in the spin-off company should be appointed or create a group of two or three peers to advise the inventor on issues related to conflicts and to meet regularly with the inventor to evaluate the appropriateness of on- and off-campus activity.</td>
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<td>(ii) Transmission of privileged information.</td>
<td>Care should be taken to ensure that cooperative agreements with external organisations do not contain unacceptable limitations on open publication. Limited delays in publication may be acceptable to accommodate explorations of patentability or sponsor's utilisation of research results for a new product or process. Such arrangements may not be considered if they impede the progress of students toward their degrees.</td>
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<td>(iii) Undertaking or changing the orientation of the staff member's University research to serve the research or other needs of the company.</td>
<td>There should be differentiation between the work undertaken by a staff member for a company and the work undertaken for the University involving expertise for which the staff member is employed. In general, work with scholarly content should be performed as part of University duties, eg., research with scholarly, publishable content vs. refinement of a specific process or product or service-oriented tasks, etc.</td>
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<td>(vi) Utilisation of University resources for the activities of a spin-off company.</td>
<td>The utilisation of University resources, on-campus (laboratory facilities, clerical and service staff support, etc.), for the activities of a start-up company should be cleared and documented with the University administration. Arrangements should be covered in a Letter of Understanding which spells out the extent and rules governing usage of facilities, including the cost to the company of such use. In principle, start-ups should not have access to university facilities beyond that available to other similarly qualified companies. The involvement of University students and staff, off-campus, in spin-off company activities should be undertaken with caution. Safeguards must be instituted on a case-by-case basis to ensure that the performance of University duties and the scholarly mission of the university are not compromised. The above policy also applies in relation to involvement with any company other than a university spin-off.</td>
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(v) Purchase of major equipment, materials, or other items from a company in which the staff member has an interest without disclosure of such interest.

A staff member who has a direct interest in a company that has dealings with the University should bring this to the attention of relevant University administrators. These staff members should not be asked to perform administrative duties which may place them in a position of possible conflict of interest.

In addition, where a staff member or his research team is required to draw up specifications for equipment procurement that may result in the purchase of equipment from his/her company, an independent committee should review the specifications.

(vi) Funding of research projects by a start-up company

If a staff member owns equity in a company that has a licence to a University invention, the company can fund research at the University related to the invention on a case-by-case basis. This is to avoid the university becoming a development arm of the company. This also helps guard against misuse of students in the event that the research is driven by the interests of a biased sponsor.

(vii) Supervision of student projects and thesis work.

If a staff member owns equity in a spin-off company, the staff member shall not act as academic supervisor or examiner of students’ projects and thesis work where such work is the result or form the basis of collaboration between the University and the company.

(viii) Lack of understanding of rules and acceptable behaviour of staff inventors and those engaged in technology transfer activities.

To overcome the problem of managing conflicts, rules are available to assist department heads to advise staff members. To minimise potential problems and facilitate collaboration, the mode of operation between the company and NUS for each cooperative activity should be set forth in a specific agreement approved by the University.

Staff members are advised not to act as spokesman of the company to avoid any misconception with regard to their first loyalty.

8. SUCCESS FACTORS IN UNIVERSITY-INDUSTRY PARTNERSHIPS

A major success factor in university-industry partnership is the willingness and ability to collaborate in R&D in areas of mutual interest. Such partnerships are usually forged through long-standing interactions. Research undertaken in collaboration with industry, government bodies and other organisations (local and overseas) represents a significant percentage of the universities' overall research effort. Strong encouragement is given to such collaboration as it represents a major avenue for technology transfer, rejuvenation of research and improvement to the curriculum.

The experience at the universities indicates that collaborating organisations benefit from establishing formal links with academics and students. Such interactions allow
companies to scout for talent and recruit fresh graduates. Collaboration also raises the specialist skills level of company staff engaged in the research activities. Companies are also aware that collaboration with the universities allow for substantial cost savings. This is particularly beneficial to SMEs when they tap into the universities' wide ranging expertise and facilities in project execution and project design. With MNCs, research collaboration with universities provides opportunities for resource sharing and optimisation. As MNCs normally possess in-house expertise and information to define the project deliverables and time-frame, collaboration allows them to tap into the universities' talent pool to "jump-start" research projects of local or regional interest.

The universities on their part benefit from research collaboration with industry as it provides opportunities to extend their academic research capability downstream towards commercialisation and application. Through collaboration, academics stand a better chance of obtaining proprietary information or product or process data crucial to the proof of the method and analysis which would otherwise remain mere academic exercises. These joint R&D initiatives also offer real-world training and exposure to students and better prepare them to meet the needs of industry. Research collaboration brings in funds to support incremental research manpower and create opportunities for universities to derive revenues from the successful commercialisation of research results subsequently. Thus, universities can adopt a longer-term view towards developing a successful research collaboration framework. To support a long-term fruitful partnership with industry in research and technology commercialisation universities will need to develop a strong commercial focus and entrepreneurial approach in the management of IP. Universities will need clear policy on university-industry partnership. Well formulated mechanisms and incentives will enable active participation of faculty and engender a culture of entrepreneurship among staff and students.

In encouraging University-industry interaction, a major stumbling block to improving the management and commercialization of IP has been the lack of IP capability across the innovation process. Given the wide and varied skill sets required across the entire business cycle, the need for experienced people in IP protection and technology transfer and commercialization will be critical. Especially relevant is the perceived shortage of qualified manpower to take technology to the market. This is a significant gap especially in start-ups as the manpower profile of any would-be start-up is an important factor that financiers look for when evaluating possible investment. Therefore, manpower development will be an important area of focus.

9. RECOMMENDATIONS FOR IMPROVING THE USE OF IP IN PROMOTING UNIVERSITY-INDUSTRY PARTNERSHIPS SO AS TO IMPROVE THE COMPETITIVENESS OF INDUSTRY, ESPECIALLY SMES.

Concerted efforts are being made to strengthen R&D collaboration among universities research institutes and industry and the strong partnerships are vital to the creation of a knowledge economy. The management of IP is central to the scheme of university-industry collaboration.
University-industry collaboration in Singapore has had several positive impacts. Academia and industry benefit from the formal interaction to achieve a better understanding of the opportunities and constraints and to develop a rewarding working relationship. This has led to more collaborative projects thus better use of resources and faster commercialisation and application of research results. By interacting with industry, academics gain credibility and confidence in their teaching, especially in fields where technological advancements are rapid and the market exerts a strong "pull" factor on university research direction. Our universities' involvement in seeding start-up companies has generated further interest in academia and the public on the usefulness of university research. It demonstrates how important it is to have active staff intervention and teamwork in order to ensure success in the commercialisation effort.

The quest for knowledge in academia has begun to bridge the need to serve for the public good. Opportunities are there for our universities to harness their basic strengths in the fundamentals to fuel many downstream endeavours which will have rewarding economic spin-offs. All the more important is the ability to cooperate synergistically with industry and government so as to derive optimum results. As universities seek to achieve excellence in teaching and research, university-industry collaboration will have to evolve into a culture within a supportive environment that is responsive and adaptive.

Among the institutions that practise IP management and have established mechanisms for collaboration with industry, there remain long standing difficulties that needed to be overcome. Industry still has strong perceptions on ownership of IP as sponsors of university research. Technology development at the company subsequent to the licensing of the IP still poses certain difficulties. Within the institutions, perceptions on working with industry for monetary gains are still not too well regarded. Academics still regard university research's main beneficiaries are the students. Moreover, by nature of the profession, academics are largely driven to publish their research results believing that that would be in their best interests. The situation at the government research institutes is quite different. While researchers do publish they do not teach and are hired to do research of economic relevance. However, recent efforts by A*STAR to nurture the life sciences have shifted attention quite strongly to the need for upstream research.

Generally, the main obstacle to IP protection is the cost, especially if no returns are immediately foreseeable. The lack of appreciation and understanding by both management and inventors of the IP process, legal issues and the lack of quality local patent agents in some areas all add to the eventual prohibitive costs. However, the fact that these associated costs are only a fraction of the potential huge resources needed to bring any technology to market is usually not appreciated due to the long term nature of the IP process.

SMEs in Singapore conduct mostly developmental work. The main barriers that hinder technology transfer are lack of funding, lack of expertise, company's resistance to new technology, avoidance of uncertainty and proprietary concerns. SMEs are usually concerned with the immediate benefits they could derive from the new technology, rather than the time and the effort that would be needed to implement it. They are influenced more by factors outside their companies rather than factors within their
companies when deciding to upgrade their technology. As for the research performed by SMEs, not much increase and change in their R&D activities can be expected. This is despite the fact that it is imperative for SMEs to be more involved in R&D in order to meet future challenges resulting from increased international competition.

It appears that the universities and research institutes and centres will have an important role to play to assist these SMEs in their technology upgrading and guide them in developing their own research capability so that they can better meet future challenges.

The Economic Development Board (EDB) has several programmes such as Locally-based Enterprise Advancement Programme (LEAP) and Local Industry Upgrading Programme (LIUP), which help smaller companies collaborate with multinationals, larger local enterprises and other organisations. It also manages a one-stop portal for technology start-ups and enterprises, providing relevant information, latest news & developments and links to potential markets and partners in Singapore at http://www.techsingapore.com.sg. Other avenues for help to commercialise and market products or services are business associations like the Singapore Business Federation and the Singapore Confederation of Industries which represent and promote the business interests of Singapore enterprises. They help plug into Singapore's business networks via their seminars and events, and their trade partnerships and business matching efforts.

The above changes reflect the response of the Universities to the changing environment in which universities conduct their research and the use of the technology transfer process as a means of supporting the growth of mutually supportive relationship with industry partners and the local economy.