

Singapore and the Nanyang Technological University—A young country with a young university on the move

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Singapore is a unique environment for research and one that has become a global phenomenon and model for a country truly embracing the concept of the knowledge-based economy. Over the first 10 years of the 21st century, Singapore has advanced into the “Ivy League” of research by a sustained and high investment in research both in government research institutes, notably those of the Agency for Science, Technology, and Research (A*Star), and in the university sector. Unusually, for a country with its population of approximately 4.5 million, there are only four universities in Singapore (with one only very recently established) with two of these being very major and successful institutions, of which Nanyang Technological University (NTU) is one. It is a relatively young university still undergoing rapid evolution and development, yet has consistently been ranked among the top 100 universities worldwide. In the most established ranking system for universities (that of the Quacquarelli Symonds World University Rankings), there are no younger universities in the top 100 category.

It was originally founded in 1955 as a privately funded university (Nanyang University) teaching in Chinese and was the only such institution outside China and Taiwan. It aimed at serving the Chinese diaspora in South East Asia and it still retains strong links in China itself. Nanyang University was merged with the University of Singapore in 1980 to form the National University of Singapore (NUS)—the other major tertiary level institution—and in 1981, it was reformed as the Nanyang Technological Institute with the objective of providing training and education of engineering manpower and with the medium of instruction being English, the language of government and business in Singapore. It became a fully fledged university with its own charter in 1991. Since then, NTU has moved consistently and rapidly into the top echelon of high performing research intensive universities, especially during the 2000s (Fig. 1).

Over the recent past, it has become a much more comprehensive university but still with engineering at its core and, indeed, engineering in all its guises remains two-thirds of the institution. As such, it is probably the world’s largest engineering-based institution on a single campus. Its route toward enlarging its portfolio started with the addition of the Nanyang Business School, now the top rated school in Singapore and also considered one of the best schools in the

Asia-Pacific region. More recently, the addition of the College of Science, although new, is developing rapidly with a very international faculty, and the College of Humanities, Arts, and Social Sciences with a School of Art, Design, and Media (housed in one of the university’s many iconic buildings, see Fig. 2), Singapore’s only school of journalism, have added greatly to the educational and research opportunities at the university and provided the basis for a complex web of interdisciplinary activities. NTU includes the National Institute of Education (NIE), responsible for the education and training of all of Singapore’s school teachers at all levels, and the Rajaratnam School of Strategic and International Studies (RSIS), a graduate school and think-tank concentrating on security and, again, very highly regarded both in the region and globally. The move toward a more comprehensive institution will be completed following Prime Minister Lee’s announcement (August 2010) that NTU has been entrusted with a new medical school, a joint venture offering a joint qualification with Imperial College London, which has also developed a medical school on what is a predominantly engineering base. Imperial College is now the largest medical school and hospital administrator within the British university medical system.

NTU has also gained ground in other areas as we host two out of the five nationally awarded and prestigious Research Centres of Excellence (RCEs)—the Earth Observatory of Singapore (EOS) and the Singapore Centre for Environmental Life Sciences and Engineering (SCELSE). The university is also a partner in one of the other RCEs—Mechanobiology—hosted at the NUS.

The RCE scheme itself has promoted the rapid evolution of Singapore into the upper ranks in the world “league” of research in selected areas. For example, in 2007, top level Earth sciences hardly existed in the region, but by attracting world-leading researchers such as Kerry Sieh from California Institute of Technology (Caltech) (Fig. 3), Paul Tapponnier from Institut de Physique du Globe de Paris, and Chris Newhall from the U.S. Geological Survey (a “dream team” of tectonicists and volcanologists), together with more than \$200 million in funding for EOS, we have leap-frogged into the premier league of Earth science research and embedded these new disciplines within the university in establishing a new division of Earth and environmental sciences.



FIG. 1. (Color online) Chinese Heritage Center.

The RCE scheme itself is very competitive and awards are made only after a rigorous international peer review and, in terms of both rigor and funding scale, the RCE scheme is well above the “noise level” of the normal research grant system.

The second RCE hosted at NTU, SCELSE, brings world-leading experts Staffan Kjelleberg and Yehuda Cohen, together with Stephan Schuster, to form one of the world’s top research centers in the emerging area of microbial biofilms (Fig. 3). It is also creating a new and exciting interdisciplinary activity across microbiology, systems biology, environmental genomics, and a range of expertise in engineering and environmental biotechnology to provide an unparalleled research platform for understanding and delivering management required for water and environmental sustainability. SCELSE aims to be an international leading hub for the interface between microbial life sciences and environmental and water engineering.

These considerable research investments are excellent examples of the dedicated political vision of the Singaporean government in its pursuit of economic advancement and well being through research. It also shows its determination to take rapid although considered action rather than the European propensity for seemingly endless discussion and planning.

NTU is now moving rapidly to organize its strategic research on an interdisciplinary basis through the creation of five key, priority research areas around which activities can concentrate (Fig. 4).

Overall, NTU sees its research as based on a “planetary system” of activities built around a core of engineering. The five key areas are



FIG. 2. (Color online) NTU’s iconic building housing the School of Art, Design, and Media.



(a)



(b)

FIG. 3. (Color online) Two leaders of the NTU–RCEs: (a) Kerry Sieh (EOS) and (b) Staffan Kjelleberg (SCELSE).

- (1) sustainability research
- (2) medicine and healthcare
- (3) “new media” research—interactive digital media
- (4) China and Asian studies, which we are calling “the new silk road”
- (5) application of new technologies and industrial research collaboration

At the same time, the university has created a number of pan-university research institutes and related activities to provide a coordinating focus for interdisciplinarity, all of which form the basis for our “assault” of these peaks. In terms of sustainability, there are major inputs from the Nanyang Environment and Water Research Institute (NEWRI).

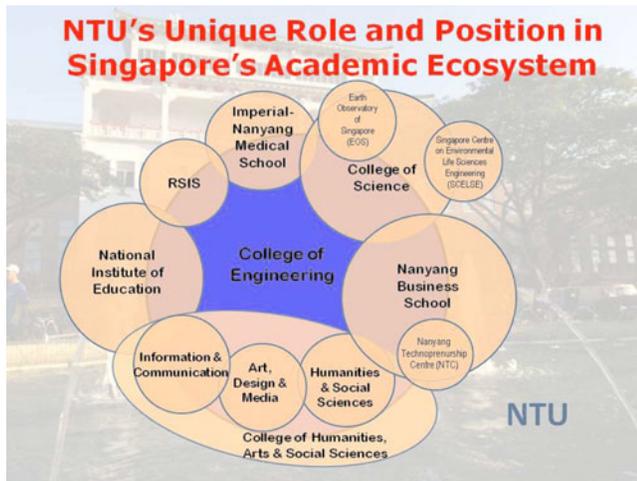


FIG. 4. (Color online) NTU's unique role and position in Singapore's academic ecosystem.

We have recognized the huge potential for research in this area in which Singapore and NTU aim to become a world leader. NEWRI operates through a series of interlinked centers and industrial and international partnerships. The first center is in partnership with the Danish hydrological institute with the support of the Environment and Water Industry Development Council of Singapore. The second center is the Singapore Membrane Technology Centre, which spearheads Singapore's research efforts in fundamental and applied membrane technology. The third research center is the Residues and Resource Reclamation Centre, which has the aim of developing technologies on waste minimization, conversion of residues into resources, contaminated environment remediation, and other related fields. NEWRI has been able to raise more than \$200 million in external funding to address these key strategic needs in Singapore.

The second pan-university effort is based on the Energy Research Institute at NTU (ERIAN), which embraces a wide range of energy-related research, especially in fuel cells, energy storage, and photovoltaics. Again, ERIAN is working through a series of partnerships with public agencies in Singapore and with international industrial leaders including Rolls-Royce, Robert Bosch, and Vestas, to name but a few. More recently, through an active collaboration with the Technische Universität, Munich (TUM), NTU is working on the complex issues of electromobility. The two RCEs also make important contributions in this area. In addition, we have an Institute of Catastrophic Risk Management, which spans engineering, science, and business studies and is a key player joining advanced research with an understanding of risk, especially for the insurance sector.

One of the most important developments of recent years is the building of a new commercial CleanTech Park immediately adjacent to the NTU campus. In this way, we expect to have both NEWRI and ERIAN as core tenants of the park, thus creating the environment necessary for the translation of

research into innovation—one of the aims of our innovation initiatives.

Medicine and healthcare builds on the new Medical School and the development of a dynamic link between medicine and engineering, but also with the addition of a Business School involvement to promote research into advanced health economics and health management, an area in which the general practitioners will increasingly need to be equipped as leaders of health teams. This initiative also builds on the relatively new School of Biological Sciences, with its very international staff working in a range of important health areas such as malaria and dengue fever. It also provides a high level research base through the recruitment of top scientists from renowned institutions such as the Karolinska Institutet, Stockholm. This activity is in the area of structural biology based on x-ray spectroscopy and high resolution NMR and working especially in the area of membrane proteins—the targets for new advanced drugs. Another exciting development in the life sciences relevant to the medical initiative is that of Bo Liedberg, from Linköping University, Sweden, who has been at the forefront of the development of the detection system used in the Biacore technology (the gold standard for studies of biospecific interactions). He is directing a new biosensor activity The Centre for Biomimetic Sensor Science (CBSS) at NTU focusing on the development of portable sensors for remote (on site) detection of infectious diseases and microbial toxins. This activity involves also scientists from the Austrian Institute of Technology, Vienna, under the leadership of Wolfgang Knoll, the Institute for Materials Science and Engineering, and the Defence Science Organisation National Laboratories in Singapore.

The new media initiative is a truly interdisciplinary initiative and is a unique opportunity to combine engineering with interactive digital media and industrial design expertise within the university's Institute of Media Innovation (IMI). Again, our approach is not only one of encouraging interdisciplinarity through a university-wide institute, but is also based on external partnerships with other leading universities in this area and with other internationally renowned institutes, much of which are supported by Singapore's Media Development Authority. One of these is a unique collaboration between NTU and the Fraunhofer Institute from Germany, which has established a laboratory on campus, the first such development by Fraunhofer. A particular aspect of new media is through linking our NIE, an autonomous part of NTU, which provides Singapore with its teacher training at all levels, with the IMI in the promotion of interactive digital media for educational uses—possibly one of the most significant areas for commercial development in the future.

While many universities across the world want to and are endeavoring to develop links with China, NTU is in the fortunate position of being able to build on its original Chinese legacy and is already well positioned within China. In other words, NTU is already “in” China. We are also building on several very successful educational programs—the so-called

Mayors Programme, which provide business and administration education at the masters level for provincial officials from China. We have an annual convocation in China and the creation of active alumni associations in the country. In parallel, and underpinning these programs, is an ongoing research activity in Chinese language and literature. However, we believe that we should not only promote the development of NTU in China but also build on the very strong links that we have with other Asian countries, including India and in the Middle East and other parts of west Asia, beyond Singapore's immediate Association of Southeast Asian Nations region in which NTU is well embedded.

A major concern of the Singaporean government is to translate research into intellectual property and hence into the development of the Singaporean economy. There is a general problem in this regard within Singapore with its generally risk-averse culture.¹ NTU is committed to contributing to the solution of this national problem and is moving forward rapidly in striving for innovation and technology transfer. We need to ensure that the results of our research and development are used for the benefit of Singaporean society. First, the university encourages both staff and students to take an entrepreneurial stance toward their research discoveries in terms of patenting and spin-offs. Second, it develops research collaboration with industry, attracting major technologically based multinational corporations to its campus, the establishment of joint research projects, and the shared supervision and support of Ph.D. students—in other words, using “technology transfer through people.” This embeds major industrial partners within the university, both metaphorically and literally, as several have on-campus facilities, making our collaboration particularly intimate (Fig. 5). The list of such partners is both lengthy and impressive and includes, for example, Rolls-Royce (which has an Advanced Technology Centre on campus), Robert Bosch GmbH, EADS, Infineon, Nitto Denko Corporation, ST Kinetics, Siemens, Sembcorp Industries, THALES, CBSS and Vestas. Through the link with TUM in the electromobility project, we now also have links with Audi.

NTU sees itself very much as an international university in many ways. First, it has a student population from many parts of the world, especially at the postgraduate level, and its faculty and research staff are very international and far more so than most institutions in Europe and North America coming from 67 countries. We have bilateral links with a range of leading universities in Asia, Europe, and North America in terms of research collaboration and also in student and educational exchange, many of which have been formalized into joint degree programs. One strategy has been our development of joint Ph.D. programs with top universities worldwide starting with Imperial College London (the first such arrangement for that institution anywhere in the world) and now extending to other universities in the UK (University of Southampton and University of Warwick), Austria (Austrian Institute of Technology with the Universität für Bodenkultur—University of Natural Resources, Vi-



(a)



(b)

FIG. 5. (Color online) (a) Research TechnoPlaza, which houses many of NTU's prestige industrial and international partners. (b) The skylight-lit circular void with glass lifts.

enna), France (ParisTech—the consortium of 12 Grandes Ecoles in Paris and the Université de Technologie de Troyes), Germany (Technical University of Munich), Israel (Technion—Israel Institute of Technology), Sweden (Karolinska Institutet), and the U.S.A. (Carnegie Mellon University and Columbia University). This is an innovative ap-

proach to research training using the mutual strengths of NTU and its partners to offer advanced research training. This is coupled with the creation of interdisciplinary graduate schools within the university so that postgraduate training at NTU is becoming a very attractive option for bright students both from Singapore and elsewhere.

Through the Global Alliance of Technological Universities (GLOBALTECH), which comprises the California Institute of Technology (Caltech) (U.S.A.), ETH Zürich (Switzerland), the Georgia Institute of Technology (U.S.A.), Imperial College London (UK), the Indian Institute of Technology Bombay (India), Shanghai Jiaotong University (China), and ourselves, we have established a group of leading institutions which can, through the leadership of the NTU President, Dr. Su Guaning, as chair of the Alliance, can speak with one voice on key issues of world concern and can promote wide-ranging exchange and collaboration from a common technological base.

We also host a *Unité Mixte Internationale* with the Centre National de la Recherche Scientifique (CNRS) of France, which is a unique arrangement for CNRS involving a university (NTU) with a major research institute as well as having an industrial partner in THALES, which has been based at NTU for some time. The Fraunhofer's presence on campus in the interactive digital media initiative is also the first for that organization in Asia.

This international vision has been an important part of NTU's development and the university was the driving force behind and hosts the European Union Centre in Singapore, which is a collaborative venture between NTU, NUS, and the European Commission in the area of policy research and expert advice.

NTU has a recruitment strategy to attract the brightest brains to the university at all levels. At the undergraduate level, we see an increasing quality of students coming to NTU from the wider Asia region, while at the Ph.D. level, NTU is very active in recruiting students from around the world including Europe, the U.S.A., and the Middle East in addition to our traditional recruiting grounds of Malaysia, Indonesia, China, and India.

We have been especially successful in recruiting young postdoctoral faculty in the highly competitive National Foundation Research Fellowships, which is akin to the elite young investigators program operated by the European Research Council Starting Grants for Young Scientists initiative. Of the 30 successful young investigators recruited so far, more than half have chosen NTU, above other Singaporean institutions, as the place to hold their awards. One of these is A/Professor Christos Panagopoulos, who was at the Cavendish Laboratory, Cambridge University, UK, and a former European Young Investigator (EURYI) award holder, who focuses on condensed matter systems with spontaneous tendencies toward complex electronic pattern formation at a range of temperatures especially close to absolute zero. He is quoted as saying "I had a choice between top 10 schools in the UK, Europe, and U.S.A. until I realised the potential at NTU." A second such EURYI awardee and National Re-

search Foundation fellow, Professor Hilmi Volkan Demir, from Stanford University and Bilkent University, Turkey, said, "There is a lot of encouragement for scientific excellence, innovation, and entrepreneurship at NTU. This creates a good ecosystem which allows for us to work together." A comparable scheme run by the university itself is the Nanyang Assistant Professorships and, again, this is highly competitive and both schemes provide substantial start-up grants as part of the awards. NTU has also recruited more senior faculty to augment its expertise and to nucleate new research activity and groups.

To support the research intensity of the university and the academic "stars" that have joined the institution, NTU has also taken a strategic view with regard to the provision of research infrastructure in order to best utilize its resources in this regard. One significant addition to its well resourced research laboratories, including one on structural genomics, is the establishment of a High Performance Computing Centre to provide the data handling and modeling capacity so necessary in all disciplines and is one of the highest-powered of such facilities in Asia. Professor Rudy Marcus, California Institute of Technology (USA), the Nobel chemistry prize winner for electron transfer, is a senior visiting professor at NTU and is quoted as saying that NTU had a fantastic campus and research infrastructure, especially in the provision of laboratories and facilities.

Apart from the university structure, NTU has established an Institute of Advanced Studies (IAS) to develop forefront activities in a variety of areas including complexity. IAS is also a focal point in attracting Nobel prize winners and researchers of similar standing to Singapore and especially to NTU. A sample of the activities of IAS include the first ever meeting held outside France of the celebrated Les Houches Physics Summer School, a symposium on complexity to celebrate the 80th birthday of John Holland, the originator of the theory of genetic algorithms, and a symposium in honor of Murray Gell-Mann, a distinguished Nobel laureate for his work on elementary particles.

In common with many universities, NTU is also becoming a multicampus operation. The main campus for NTU as a residential university is the Yunnan Garden Campus in the west of the island of Singapore in a superb green and tropical setting and which has been chosen to serve as the Olympic Village for the first ever Youth Olympic Games in 2010. Apart from the Medical School to be located at the Novena Campus in central Singapore, NTU also has a base at One North with its own base, but more importantly establishing research laboratories within A*Star at its Biopolis center.

In summary, building from its historic base in the Chinese community of South East Asia and later as a center for advanced engineering training, NTU has advanced into the top echelons of world universities. Now a research intensive and highly competitive institution with a wide international perspective, NTU probably represents most closely the ambitions and success of Singapore itself in the 21st century—the century of Asia. With its strategic vision, NTU has set its

sights high and intends to emerge into the top circle of the world's leading academic institutions.

APPENDIX: ABOUT NTU

- (1) Established in its present form in 1991 with roots in Nanyang University (founded in 1955 and the only Chinese-medium university outside China), it is now one of the world's largest engineering-based universities.
- (2) Based on a large residential campus (the Yunnan Garden Campus) of over 200 ha plus subsidiary campus sites at One North.
- (3) The youngest institution ranked in the top 1% of world's universities.
- (4) Highly ranked Nanyang Business School and the RSIS.
- (5) Includes the world-renowned NIE.
- (6) With 23 043 undergraduates and 10 044 graduate students of whom 3031 are research students from 73 countries.
- (7) With 3094 faculty and research staff from 67 countries.
- (8) Leading member of the Global Alliance of Technological Universities.
- (9) Hosts two Research Centres of Excellence—the Earth Observatory of Singapore and the SCELSE.
- (10) Pan-university institutes include NEWRI, IMI, and ERIAN.
- (11) Total revenue (2008–2009) is \$S 1 173 000 000.
- (12) Joint Ph.D. programs with Imperial College (London), University of Southampton and University of Warwick (UK), Technion (Haifa, Israel), Technical University of Munich (Germany), Karolinska Institutet (Stockholm, Sweden), KAIST (Korea), ParisTech and the University of Troyes (France), Carnegie Mellon University and Columbia University (U.S.A.), and Austrian Institute of Technology with the Universität für Bodenkultur—University of Natural Resources (Vienna, Austria).

¹B. Andersson, T. Mayer, and J. Nadison, *University Research for Innovation*, Glion Colloquium Series, edited by L. E. Weber and J. J. Duderstadt (2010).