issues & events

Singapore applies itself to science

Despite its small size, the Lion City has become an influential exemplar of investing in science to promote industry.

At a ceremony held last September at the Ritz-Carlton hotel in Singapore, the country's president, S. R. Nathan, handed out the 2010 President's Science and Technology Awards. The top award, the president's medal, went to Chong Tow Chong, an administrator whose resumé encapsulates Singapore's achievements and ambitions in science and technology.

From 1995 to 2010 Chong held leadership positions at the Data Storage Institute, which conducts basic and applied research in close collaboration with Seagate, Fujitsu, and other disk manufacturers. Half the world's disk drives are already made in Singapore. Looking to the future, Chong helped persuade those companies to set up R&D laboratories in addition to their factories.

While he was executive director of the Science and Engineering Research Council, Chong oversaw the five-year plans of 2005 and 2010. Those plans included investing in new and promising areas, such as nanotechnology and molecular electronics, and establishing Fusionopolis, a technology hub for interdisciplinary research in the physical sciences.

Chong's current job is provost of the country's fourth and newest university, the Singapore University of Technology and Design. Founded in 2009, SUTD aims to complement the strong science and technology departments in established universities with a school whose students can conceive of and design commercially successful products.

Singapore occupies 704 square kilometers, roughly the same as the area enclosed by the Capital Beltway around Washington, DC. Its population, at 5 million, and its gross domestic product (GDP) per capita, at $43 000, are about the same as Colorado's. In such a small rich country, implementing the plans that Chong and his associates, past and present, have drawn up is easier than it would be in a larger country.

What makes Singapore stand out from other countries, big or small, is the devotion and assiduousness with which it plans for its future prosperity. In science and technology, the focus on prosperity has entailed an emphasis on applied, rather than basic, research and on forging strong, mutually beneficial ties with local and foreign companies.

Other countries, notably China, look to Singapore as a model for technology-led development. Indeed, the Chinese Academy of Sciences' recently unveiled blueprint for becoming an economic superpower, Innovation 2020, called for a Singapore-like emphasis on translating research into marketable technologies.

Singapore is not neglecting basic research. Last year, the country's researchers published 41 papers in the *Nature* family of journals, up from 26 in 2009. Among Asian countries, only Japan, China, and South Korea published more papers in those journals in 2010. Only China had a percentage increase as large as Singapore's.

Past and present

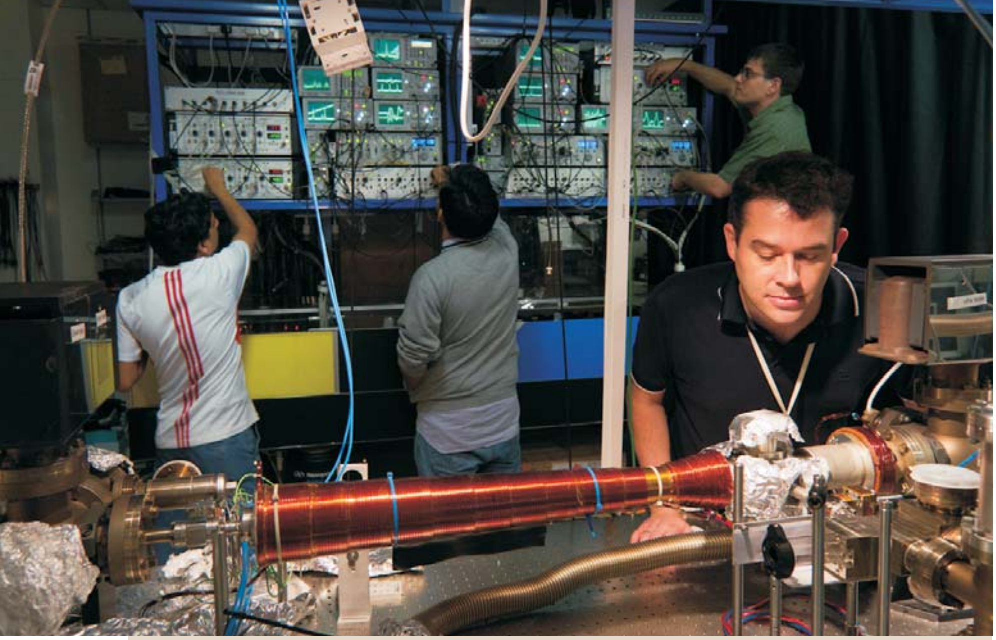
The modern history of Singapore began in 1819 when Stamford Raffles of Britain's East India Co landed on the lightly inhabited island, envisioned it as a thriving, tax-free port, and arranged its purchase from the local Malay leader. Raffles's vision became a reality that endured for almost 150 years.

Singapore became independent of Britain in 1963 when it formed the new country of Malaysia with Malaya, Sabah, and Sarawak. Two years later, Singapore seceded. The country's leaders soon realized that the laissez-faire capitalism that had sustained a colony since 1819 would not, by itself, safeguard the future of a tiny independent country devoid of natural resources.

Out of necessity Singapore began transforming its economy. To commerce and trade, its traditional strengths, it added manufacturing—first textiles, then shipbuilding and oil refining—all the while maintaining low taxation, the rule of law, and an environment hospitable to foreign investment.

In the late 1970s, Singapore embarked on a second industrial revolution to become what it is today: a technology-

Fusionopolis consists of two towers, Connexis and Symbiosis, which house R&D labs, high-tech companies, and government agencies. Located in the One-North business park, Fusionopolis is close to the Singapore Science Park, an international business school, a research hospital, and Biopolis, a new R&D campus devoted to biological sciences.



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The Centre for Quantum Technologies is among the research groups at the National University of Singapore. Here, Kai Dieckmann inspects part of an experiment for studying ultracold mixtures of fermionic and bosonic atoms. Behind Dieckmann are members of his group, Kanhaiya Pandey (left), Tarun Johri (center), and Johannes Gambari.

intensive economy. In support of that initiative, Singapore's two main universities, the University of Singapore and Nanyang University, merged in 1980 to form the National University of Singapore (NUS). A year later, Nanyang Technical Institute, the forerunner of Nanyang Technological University, was founded.

Today, Singapore's science and technology enterprise has features that resemble its counterparts in other rich countries. The physics department at NUS, for example, has research groups in quantum information, nanoscale physics, functional materials, biophysics, and complex systems. Individual researchers also work in financial physics, cosmology, and other theoretical areas.

Singapore competes vigorously and successfully to attract international talent to all important sectors of the economy, including science and technology. It also strives to retain its homegrown talent. Among Singapore's rich-country peers, only the US and Switzerland have lower rates of brain drain.

The Centre for Quantum Technologies at NUS exemplifies Singapore's emphasis on cultivating talent. Now in its fourth year, the center is led by Artur Ekert, who was recruited from Oxford University. Its mix of international and Singaporean staff conducts research that encompasses quantum information theory, cold-atom condensates, and the fabrication of quantum devices.

Industrial research

Among the physicists who received awards last September from Singapore's president was a team led by Patrick Lo Guo-Qiang. Lo and his colleagues Yu Mingbin, Ang Kah Wee, and Liow Tsung-Yang work at the Institute of Microelectronics (IME), where they developed their award-winning silicon-based electro-optical modulator.

The IME modulator was conceived not only to convert electrical signals rapidly and efficiently into photonic signals, but also to be compatible with two industrial technologies already in use: avalanche photodetectors and CMOS fabrication. To make their device even more attractive to industry, Lo and his team declined to submit a patent.

Like a university lab, IME publishes its research in *Applied Physics Letters* and other academic journals. But unlike university labs, IME has the equipment and infrastructure to fabricate silicon wafers 200 mm in diameter, which, until recently, was the industrial state of the art. Among the world's research institutes, only Belgium's IMEC has comparable chip-making capability.

Aligning infrastructure with the needs of industry is evident at another of Singapore's research institutes, the Institute for Chemical and Engineering Sciences (ICES). Located amid oil refineries and chemical plants on an offshore island, ICES conducts research on catalysis, synthesis, and biotechnology on industrially relevant scales of mass and volume that are beyond the reach of university labs.

IME and ICES are among the 22 research institutes operated by A*STAR, the Agency for Science, Technology, and Research. An arm of the Ministry of Trade and Industry, A*STAR was founded in 1991 to raise Singapore's level of science and technology.

In 2010 the Singapore government spent S$13.9 billion (US$11.4 billion) on R&D. The Research, Innovation and Enterprise Council, which funds Singapore's main basic research agency, the National Research Foundation, received 37%. A*STAR received 39%. The remainder was divided among the funding arms of the education and health ministries.

In its spending on R&D, Singapore compares itself to other small, R&D-intensive countries such as Finland and South Korea. Singapore invests just under 3% of its GDP in R&D, which is less than Finland's 3.7% and South Korea's 3.4%. The comparison looks more favorable to Singapore when you take into account the relative size of its public sector. Government spending amounts to 17% of Singapore's GDP but 30% of South Korea's and 50% of Finland's.

Besides investing directly in R&D, Singapore strives to attract corporate R&D. The portfolio of companies that have set up labs and research centers in the country includes Japan's Nitto Denko Corp (materials), France's Thales Group (defense), Switzerland's Novartis International AG (pharmaceuticals), Britain's Rolls-Royce PLC (aerospace), and California's Hewlett Packard (electronics).

To cultivate homegrown technology companies, A*STAR collaborates with three other government agencies to run GET-UP, a program that pays for A*STAR researchers to work in small- and medium-sized companies for up to two years. As of April, 296 researchers had been placed in 183 companies.

Local companies are also being spun off from NUS, Nanyang Technological University, and, to a lesser extent, from A*STAR. Founded by NTU engineer Adrian Yeo Piah Song, Membrane Instruments and Technology PTE makes devices that remotely sense the health of membranes that filter water in treatment plants. Since 2002 more than 30 spin-offs have launched.

For the 21st century, Singapore aims to complement its technology-intensive industries with innovative, knowledge-based ones. Meeting that goal will depend as much on its people as on its investment. Starting in 1995, the Trends in International Mathematics and Science Study has assessed 13-year-olds around the world every four years. Apart from 1999, when it came second to Taiwan in science, and 2007, when it came second to Taiwan in math, Singapore has always taken first place.

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