cience Business Office Fea

SINGAPORE'S SCIENCE BET

Singapore has fast become a significant biomedical hub. But can it maintain the momentum? **By Gunjan Sinha**

n a quiet room, two men stare wide-eyed at a television on the distant wall—cars race around a track. The men, wired with electrodes, appear to be playing a video game, although there are no joysticks to be seen. Tap one of them on the shoulder, however, and a car will stop moving.

This is no ordinary video game and these are no ordinary men. They are scientists at the Singapore Institute for Infocomm Research, part of the Agency for Science Technology and Research (A*STAR), and they are developing a tool that can potentially help children and adults with attention deficit hyperactivity disorder learn how to focus. The research project is just one example of the "cross-cutting, interdisciplinary research going on at A*STAR," says **Charles Zukoski**, chair of A*STAR's Scientific Engineering Research Council (SERC). Indeed, at a time when the term "interdisciplinary research" has become the mantra of good science policy, A*STAR is embracing the idea with gusto.

The video game research project is taking place in Singapore's Fusionopolis—a new 120,000 square-meter, two-tower complex that houses research labs, serviced apartments, a fitness club, a swimming pool, shops, and even a movie theater. Opened last fall, Fusionopolis aims to bring research scientists, engineers, and technology experts from A*STAR and those from the private sector together under one roof. The idea is to spur interdisciplinary research that is commercially viable.

Fusionopolis sits adjacent to Biopolis, a seven-building research facility opened five years ago that is A*STAR's primary home. Over a decade ago the Singapore government declared science and technology to be an essential pillar of the country's economy. With no natural resources and facing tough competition from neighboring countries for foreign investment, the government implemented a plan to capitalize on its most valuable asset: human knowledge. Both Fusionopolis and Biopolis represent that commitment.

Certainly the goal of a knowledge-based economy isn't unique to Singapore. The European Union, for one, identified the same goal as part of its Lisbon strategy in 2000. And yet A*STAR, with its roughly 2,250 scientists, has created global buzz. Its advisory board reads like a list of scientific who's who. World-renowned scientists are known to drop by from time to time just to see the place or give a lecture. As one indicator of success, the number of scientific papers produced at the Institute of Molecular and Cell Biology (IMCB), an A*STAR institute, jumped from 82 in 2000 to 165 in 2006, according to Thomson Scientific. And the rate of scientific citations rivals those of institutions with longer histories.

Why has Singapore been so successful in such a short time? "It is the ability to focus and plan for the future," says Zukoski. Singapore has set up a mechanism to bring in talent from around the world and send local talent abroad to get educated, he explains. These Singaporeans often return to Singapore, drawn by modern facilities, continued »



66 It is the ability to focus and plan for the future.**99**

Charles Zukoski, chair of A*STAR's Scientific Engineering Research Council (SERC)

UPCOMING FEATURES

Careers in Drug Safety/Toxicology — March 13 Green Science Jobs — April 3 The Road to Diversity in Science: Are We There Yet? — April 24

Focus on Singapore

"As the nature of scientific research changes, there is more need for scientists to work together for a common goal." —Sir George Radda



good funding opportunities, and the chance to work with renowned scientists.

Singapore has already spent S\$12 billion (Singapore dollars) and has committed to an additional S\$13.55 billion (US\$9.16 billion) from 2006 through 2010—to transform the city-state into a public and private research and development hotspot. Whether this will translate into economic growth over the long term is still uncertain. But most experts agree that if current indicators are a measure of long-term success, then Singapore is right on track.

Betting on Science and Technology

Seven years ago, Singapore folded its existing national research labs into what is now known as A*STAR. The agency consists of two primary research organizations, the Biomedical Research Council (BMRC) and SERC, each of which is further broken down into seven institutes.

Although A*STAR is often compared to the US National Institutes of Health in terms of organization, the agency is much more goal-oriented. In addition to its research institutes, A*STAR also has two other arms—the Graduate Academy and a division called Exploit Technologies. The academy manages and promotes scholarships in the sciences to support foreign students in Singapore and Singaporean students abroad. The Exploit Technologies arm manages any intellectual property created by the research institutes and facilitates the transfer of technology from the research institutes to industry. A*STAR is funded by the ministry of trade and industry and, as such, its goal is to grow the economy.

"We sit between universities and industries," Zukoski explains. "Either we discover the new stuff that we need to solve a problem or we harvest the basic research from the universities. We can also seed universities to do that research. We then work on it, harden it, and either pass it on or launch a startup company."

For example, Fusionopolis scientists are developing a heart monitor that can communicate with a cell phone. The cell phone can continuously record signals from the monitor and alert the wearer and a health care professional of a problem. Such a project links scientists who design computer hard drives, build algorithms, understand wireless technology, and engineer heart monitors. Scientists are also collaborating with doctors at the university hospital. Such expertise is normally scattered across research institutes, says Zukoski; Fusionopolis brings all that expertise together in one place.

To ensure that such goal-oriented interdisciplinary research takes place, groups of collaborators will work toward solving specific problems rather than pursuing disparate research projects. Moreover, they will focus in four specific areas: energy technology, aerospace, health care, and future living. And the public spaces at Fusionopolis serve as test beds for innovations. A retail store in the complex, for example, will test Asia's first intelligent shopping cart that can automatically locate items in the store.

Last year, A*STAR launched a landmark aerospace research program involving industry scientists at Boeing, EADS, Pratt and Whitney, and Rolls-Royce. These industry giants signed on to collaborate with A*STAR's scientists on research covering inspection and testing, manufacturing, advanced materials, and computational modeling. One collaborative project, for example, seeks to develop lasers that can tool lightweight composite materials, used today in many airplane and automobile parts. But such material is prone to damage during trimming and drilling. Lasers would eliminate such wear and tear and might speed up manufacturing because they can be automated.

Another project will try to develop nondestructive testing and inspection techniques for airplanes. Current protocols involve dismantling and reassemblimg aircraft components, which is laborious and time-consuming. Portable, nondestructive tests to inspect airplane parts would save both time and money.

New Opportunities

Fusionopolis represents an entirely new model of a way that research and development can be done. "There aren't models like this in the United States," says Zukoski, who was head of the Department of Chemical Engineering and vice chancellor of research at the University of Illinois until October 2008, when he moved to Singapore to head SERC. "One of the attractions here was to work under this type of system," he adds.

Other scientists have been lured to A*STAR for similar reasons. "As the nature of scientific research changes, there is more need for scientists to work together for a common goal," says **Sir George Radda**, deputy chair of the Singapore Bioimaging Consortium (SBIC) at the BMRC. Radda was a pioneer in the use of NMR spectroscopy to study tissue metabolites during the 1970s and 1980s. He also chaired the United Kingdom's Medical Research Council between 1996 and 2004, and was head of the departments of Physiology, Anatomy, and Genetics at Oxford University. He has always tried to bring together the physical and engineering scientists with biomedical researchers, he says. But Singapore represents a unique opportunity to form synergies. "Given the strengths and proximity of the SERC research institutes and the BMRC research institutes as well **continued** "

Focus on Singapore

as the universities and hospitals, I very much hope to be able to contribute to promoting such interactions in Singapore."

Seasoned scientists aren't the only ones being drawn in; A*STAR is attracting promising young talent, too. A few years ago, **Leonid Krivisky** applied to A*STAR for a young investigatorship award. The award offered him his own lab and US\$500,000 each year for three years. The 29-year-old physicist wrote a proposal to study how photoreceptors in the eye respond to quantum light, which has applications in designing artificial intelligence systems. He landed the award and started assembling his lab just last fall. "I couldn't pass up the opportunity," he says.

Biomedicine Takes Off

To be sure, research such as Krivisky's can take years to turn into commercially viable technology, but the government understands this risk. Meanwhile, economic indicators suggest that the biomedical industry is thriving. Biomedical sciences manufacturing output expanded fourfold from S\$6.3 billion (US\$4.2 billion) in 2000 to S\$24 billion (US\$15.9 billion) in 2007, at a compounded annual growth rate of 21 percent, far surpassing the industry's global growth rate. Private spending on biomedical research and development in 2005 reached 35 percent of the nation's total research and development spending, up from 28.5 percent in 2001. And in 2007 alone, the biomedical science sector hired more than 12,500 people and accounted for 5 percent of Singapore's gross domestic product, according to Singapore's Economic Development Board (EDB).

That biomedical companies find Singapore an attractive place to set up shop is nothing new. Biomedical manufacturing has been thriving since the mid 1980s, when the EDB put several measures in place to lure industry. Companies that, for example, are the first to manufacture a novel drug or medical device in Singapore may be eligible to receive "pioneer" status and pay no tax on any income earned from that drug or device. EDB also offers a number of research and development grants that can subsidize up to 50 percent of a company's capital expenditure, depending on what type of skills and expertise it is planning to bring into Singapore.

The incentives have been "very successful," says **Jiu Lim**, CEO of Merlin MD in Singapore who formerly worked for the private equity arm of the EDB. Not only are all the major pharmaceutical companies represented in Singapore, but within the past three years Genentech, GlaxoSmithKline, Lonza, and Novartis announced decisions to build a total of five major continued »



Featured Participants

Agency for Science Technology and Research (A*STAR) www.a-star.edu.sg

Bio One Capital www.bio1capital.com

Biopolis www.a-star.edu.sg/biopolis/9-Biopolis

Economic Development Board (EDB) of Singapore www.sedb.com

Eli Lilly www.lilly.com

Fusionopolis www.fusionopolis.a-star.edu.sg

Genentech www.gene.com

GlaxoSmithKline www.gsk.com Lonza www.lonza.com

Institute of Molecular and Cell Biology (IMCB) www.imcb.a-star.edu.sg

Merck www.merck.com

Merlin MD www.merlinmedical.com

Novartis Institute for Tropical Diseases www.novartis.com/research/nitd

Singapore Bioimaging Consortium (SBIC) www.sbic.a-star.edu.sg

Singapore's National Neuroscience Institute www.nni.com.sg

Straits Times www.straitstimes.com

Wyeth Pharmaceuticals www.wyeth.com

Focus on Singapore

"I couldn't pass up the opportunity." —Leonid Krivisky



biologics manufacturing facilities amounting to a US\$1.5 billion investment. The facilities will be located in Tuas Biomedical Park that is already home to manufacturing facilities owned by Merck, Pfizer, and Wyeth, amongst others.

But even without economic incentives, Lim thinks that Singapore will continue to attract private investment. "Initially, the economic incentives were probably the primary driving force," says Lim. "Subsequently, as we started churning out our own engineers and scientists, the quality of the people here certainly became a draw." There are other factors, too. Singapore's location in Asia at a mid point between India and China, for example, places it between the two biggest markets in the East. "Singapore also plays by the rules," says Lim. "Here the rule of law prevails and that's important." This includes intellectual property laws.

As a testament, Lim points to the fact that there is a new wave of private investment from the biomedical industry, and the money isn't only being spent on manufacturing facilities, but also on research and development centers. Some recent additions include: in 2007 GlaxoSmithKline opened a US\$13 million medicinal chemistry outfit at Biopolis that doubled the company's research staff in Singapore; Eli Lilly's Singapore Center for Drug Discovery plans to boost its drug-discovery efforts, in part, by tripling its research and development staff to 150 within three years; the Novartis Institute for Tropical Diseases has grown to a staff of over one hundred researchers and supporting staff since its inception in 2002.

Success Not Guaranteed

But critics, such as **Lee Wei Ling**, head of Singapore's National Neuroscience Institute, have argued that to transform the economy into one that that is truly knowledge-based, scientific talent must come from within. Right now, roughly 75 percent of the 500 or so Ph.D.-level Biopolis researchers, for example, are foreign born.

Lee has also questioned A*STAR's research program which, in an opinion piece she wrote in Singapore's *Straits Times* newspaper in 2006, she criticized as being too broad.

But whether a research program is too broad or too narrow

depends on your point of view, counters Lim. "Some people believe in blue sky research while others think that research isn't worth doing unless you have an objective. What is the right balance? That's a matter of opinion."

As for the ratio of foreign scientists to native Singaporeans, A*STAR, for example, is aiming for a 50–50 balance. Through its graduate academy, Singapore plans to send abroad and fund some one thousand students to earn undergraduate and graduate degrees at top foreign universities by 2015. And the presence of high caliber scientists in Singapore will provide incentives for them to return, say advocates of the program.

Economists at the World Bank have also expressed cynicism that Singapore's investment in biomedical science will pay off, arguing that the best measure of success is when home-grown companies begin turning profits and start filing for initial public offerings. Even more discouraging: apart from Bio One Capital, the private equity arm of the EDB, which has some US\$800 million in private equity to invest globally in startups, venture capital is nonexistent.

Like Europeans, Singaporeans tend to be more risk averse than say Americans, says Lim, which is why Singapore may lag in startups and attracting venture capital. Even the bright minds at A*STAR are finding it challenging to get their scientists to think big. "We are truly idea-limited, not money-limited," says Zukoski. "Here you have the capacity to do really bold things. The management's challenge is to get talented staff to think that way."

Part of the solution, says Zukoski, is to reinvent management structure. Right now SERC leaders are spending a lot of time thinking through how the institute can best integrate research programs to foster collaboration and innovation, he says. Interdisciplinary research has been the focus of many universities. But the SERC model will be more efficient. Unlike universities that have a primary mission of educating, A*STAR's goal is economic.

"In academia, we bemoan our lack of ability of do interdisciplinary research. But we certainly wouldn't consider changing the management structure of the university to enable interdisciplinary research," says Zukoski. "In SERC we are changing our structure. We can have people working on teams. We can set up compensation and evaluation schemes. And we can change the way problems are selected."

The goal is lofty, he concedes. "But the thing that needs to be recognized is that A*STAR is not a university. We will hire academics and we will publish in top scientific journals, but we don't have that educational mission. It's all part of an exciting experiment. Not everyone would want to bet on our side. But it's certainly an experiment worth watching."

Gunjan Sinha is a freelance writer living in Berlin, Germany.

DOI: 10.1126/science.opms.r0900067