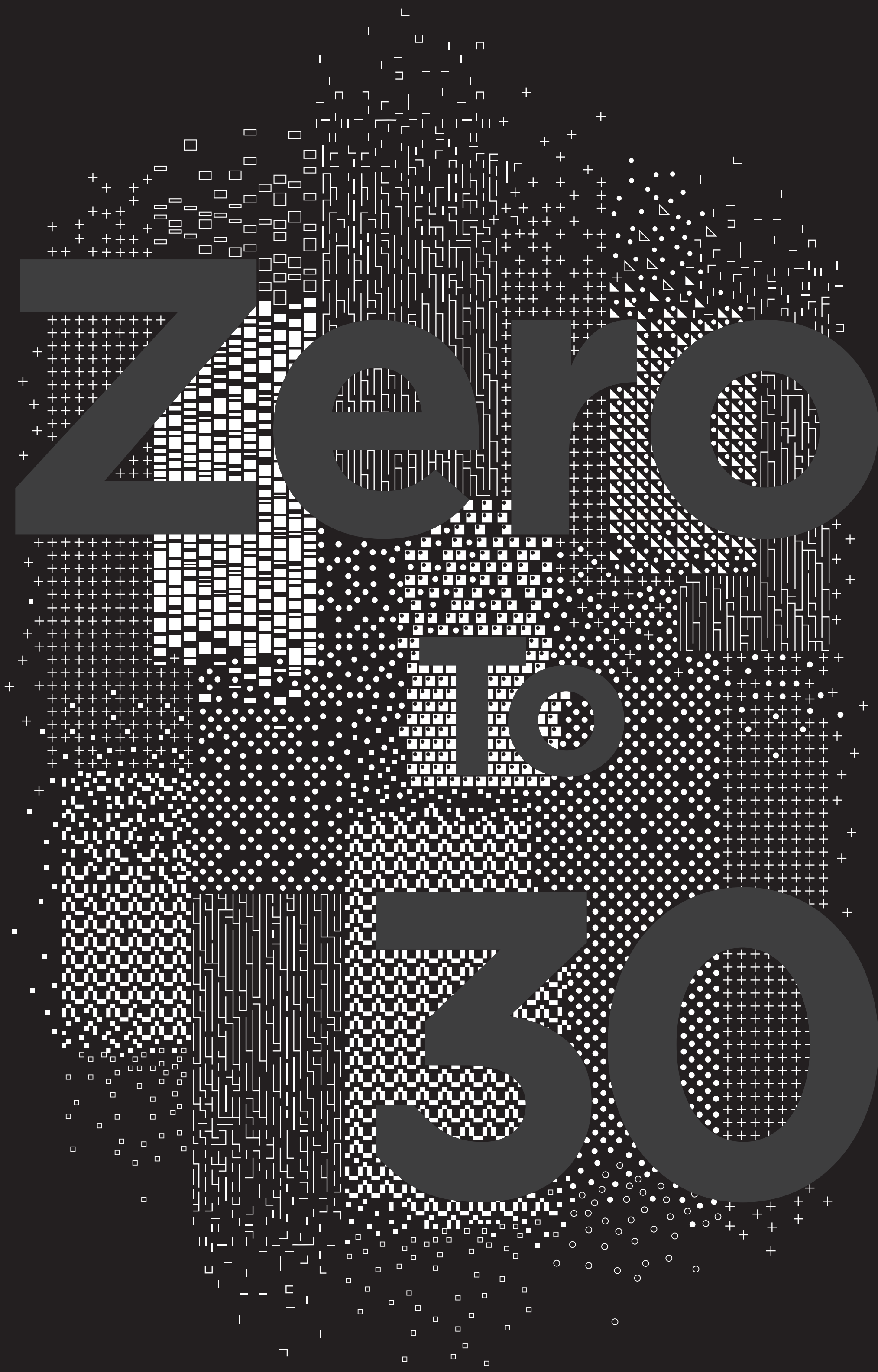
Zero To 30



SINGAPORE'S SUPERCOMPUTING JOURNEY

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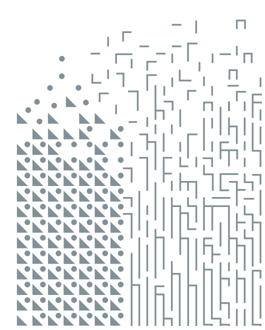

The cover design is
conceived from the idea
that data + compute power
deliver powerful insights
that can be used to solve
the challenges facing science,
society and business.

Zero to 30

SINGAPORE'S SUPERCOMPUTING JOURNEY

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Zero To 30
Singapore's
Supercomputing
Journey

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Technology is a foundation of Singapore's ambition to be a competitive, liveable and sustainable nation into the future. Technology is strategic. It underpins the economy, promotes productivity and supports job creation.

Today, Singapore is a prosperous technology hub in the heart of Southeast Asia, among the world's fastest growing regions. The Global Innovation Index ranks the country as the fifth most innovative in the world. It has also been ranked at the top globally for technology readiness in the next five years by the Economist Intelligence Unit. These are among the many accolades the Republic has received for its innovation and technological capabilities.

Singapore embarked on a national infocomm technology (ICT) strategy more than 30 years ago, with the first seeds planted in 1981. Supported today by a fast and dense broadband infrastructure, ICT has given the economy a competitive boost. Supercomputing is another vital component of the country's ICT strategy. It has played a major role in advancing technology and innovation here. Over the past 30 years, the government has invested in supercomputing that researchers and industry alike have been able to tap in order to solve complex scientific problems in engineering, life sciences, defence, medicine, genomics and advanced manufacturing.

As Singapore enters the digital era, even more computing power will be needed. High performance computing (HPC) can tackle problems that have billions and billions of data points that cannot otherwise be tackled meaningfully on smaller machines. Used imaginatively, HPC can eliminate the need for costly experimentation. This is particularly important for the nation, given that we are a small country with limited resources.

In 2016, Singapore's supercomputing crown jewel was unveiled. Aspire 1, with 1Petaflop of processing speed, became the fastest supercomputer in the country. It gave the Republic's HPC a big boost, and has already begun to transform research and industrial activity in Singapore. Aspire 1 also adds credibility to the nation's position as a technology and research hub.

Today, the Republic's vision for technology is centred on the Smart Nation initiative. Supercomputing will play a vital role in supporting the Smart Nation of Singapore as it moves into a brave new world of artificial intelligence, big data/data analytics, advanced manufacturing, life sciences and so on.

As in the past and always with an eye to the future, the National Supercomputing Centre (NSCC) Singapore that hosts Aspire 1 aims to collaborate with researchers and industry users to exploit supercomputing for innovation in the country's strategic industries, and to position Singapore as a global technology hub.

In commissioning this book, Zero To 30, the NSCC hopes to explain to a general audience the significance of supercomputing to Singapore's future, and to celebrate the many people who contributed to building the supercomputing capability in the country. Their efforts in overcoming technology challenges, clearing bureaucratic roadblocks and promoting supercomputing in the country are an inspiration to all of us who believe that our future lies in the imaginative and innovative use of technology.

HIGH PERFORMANCE COMPUTING (HPC) CAN TACKLE PROBLEMS THAT HAVE BILLIONS AND BILLIONS OF DATA POINTS THAT CANNOT OTHERWISE BE TACKLED MEANINGFULLY ON SMALLER MACHINES.

30 years in evolution is only a blink of an eye. For society, a period of 30 years marks a generation where children are born, grow up, become adults and begin to have offspring of their own. So it is with Singapore's supercomputing development.

In the three decades

between 1988 and 2018, supercomputing "grew" from a small centre where the technology was seeded, nurtured and primed to support the Republic's move into the digital economy. In one generation, supercomputing has grown to three public sector agencies dedicated to industry collaboration and supporting national research projects.

The supercomputing community in Singapore has over a few thousand professionals, including computational scientists and engineers working mostly in research and tertiary institutions and a sprinkling employed in manufacturing, engineering and other firms. Supercomputing is powerfully quiet, touching lives and solving complex engineering problems.

This book documents the peaks and valleys of this journey. It explains why a small country like Singapore – where resources are limited – uses technology to further its economic agenda. The supercomputing agencies, especially the Institute of High Performance Computing (IHPC), collaborate with many multinational corporations – which have investments in Singapore – to crack their engineering or scientific problems. For example, Rolls-Royce engineers in Singapore wanted to benchmark the performance of several supercomputers in order to select the right system to invest in. In the public sector, the technology is used by urban planners to model and analyse real-time road usage to gain insights for the mapping of a more efficient transportation system. Supercomputing systems also help meteorologists get a better understanding of the impact of rising sea levels and temperatures. The technology's applications are countless; from building "greener" buildings and autonomous vehicles to designing better robots for healthcare and precision medical systems, the list is infinite.

IHPC scientists and engineers have solved many complex engineering problems to the delight of their MNC customers. For some of the scientists and engineers, they have obtained recognition when they publish their work in peer-reviewed journals.

However, the public knows little of it although many supercomputing activities impact lives, the environment and work. Through this technology, for example, people get more reliable weather forecasts, more energy-efficient buildings and better-designed jet engines.

Consistent with Singapore's development, it was the early pioneers of infocomm technology led by retired top civil servant Philip Yeo[1], who as Chairman of the National Computer Board, grasped the significance of supercomputing and had the wherewithal in 1988 to get the resources, including capital, to set up a private company to offer high performance computing services. It was considered a frontier technology that would impact innovation and economic development and, hence, it became part and parcel of the early computerisation plans for the country.

Policies the early pioneers laid down have become tenets that continue to hold strong 30 years later. The tenets are that, where possible, expensive technology resources must be shared among the public and private sectors and big and small organisations. Technology must also support Singapore's economic strategy and help create jobs.

Hence, supercomputing resources were set up as time-sharing systems available and accessible to both government researchers and industry. They provide a solid reason in Singapore's efforts to attract research and development activities because the supercomputing agencies can collaborate with them to solve their engineering challenges. At the same time, this effort also creates higher value jobs in R&D for Singaporeans.

More than 30 years ago, physicists created their theories, then validated them via simulation and modelling on supercomputing systems. Today, scientists and researchers feed voluminous data into such systems to discern trends before coming up with new theories. Supercomputing technologies are being intertwined with big data/data analytics and artificial intelligence and its related areas of machine learning and deep learning.

In the next few years, supercomputing will play a key role helping industries in their digital transformation journey as Singapore steps up its Smart Nation programme and its Future Economy initiative. Supercomputing is also the frontier technology supporting key national research initiatives under Singapore's national R&D effort called the Research, Innovation and Enterprise (RIE) 2020 programme.

WHAT IS SUPERCOMPUTING?

Prior to 1988, there were no supercomputing systems in Singapore. From zero base, Singapore has invested easily over S$400 million[2] in several supercomputing systems in universities, research institutions and at the National Supercomputing Centre (NSCC) Singapore. The Republic has joined the ranks of the petascale community, namely, the global supercomputing community offering a computer's processing speed that is greater than one petaflop or the ability of a computer to do one quadrillion floating point operations per second. Such tremendous computing power can, for example, allow a person to play a very, very ultra high-definition game in 4K while simultaneously live-streaming it and, at the same time, also do two other things such as video-editing and astrophysical simulation.

According to website Techopedia[3], supercomputing "brings together several technologies such as computer architecture, algorithms, programs and electronics, and system software under a single canopy to solve advanced problems effectively and quickly. A highly efficient supercomputing system requires a high bandwidth, low-latency network to connect multiple nodes and clusters."

Put simply, supercomputing is a combination of high-end processing capability and storage capacity. It is a strategic game-changing technology, standing at the forefront of scientific discovery and commercial innovations. In Singapore, the technology is used to solve complex engineering solutions that demand intensive computational work.

Under RIE 2020, supercomputing systems are used in cross-disciplinary areas to:

- simulate and model sea waves and currents for marine and offshore structures;
- provide individually tailored medical treatments and procedures to patients, based on their detailed genetic, molecular and clinical profiles;
- better understand Asian genomics data to accelerate precision medicine and clinical applications for Asian patients; and
- contribute to high bandwidth, low latency, transcontinental data transfer gateway.

Foreign observers say that Singapore has achieved much in the past 30 years, able to showcase lighthouse projects as part of the work for multinational corporations (MNCs). More still needs to be done. The good news is that the government is willing to invest in the future. However, some supercomputing systems have reached the end of their lifespans and need upgrading. While Singapore is not in a supercomputing arms race – installing the biggest and fastest systems – bigger machines with increased capacity are needed to solve ever more complex problems such as big urban challenges.

The book hopes to pick out the trends, including the lessons learnt in the past generation. It will also look forward to a new generation of applications aided by supercomputing. Doctors and researchers may be able to unlock the secret to delivering personalised medicine, climate scientists may better understand climate change and engineers may be able to put autonomous vehicles on the road safely.

The applications are immense and the benefits bountiful. Is Singapore ready for the challenge?

THE EARLY YEARS

SUPERCOMPUTERS IN THIS ERA

NEC SX-1A

NEC SX-2A

ACC

Set up in 1988, the Advanced Computation Centre (ACC) was Singapore's first supercomputing bureau, offering supercomputing resources to public sector agencies as well as private enterprises.

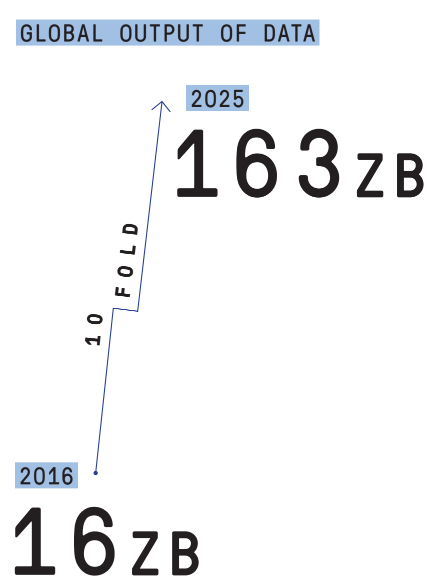
Weather forecasting impacts the lives of many people. It helps airline pilots to anticipate the weather en route to their destinations. Weather forecasting also helps travellers prepare for what to expect and how to dress appropriately. The forecast informs people to stay in for lunch rather than walk out to the food centre – or at least take along an umbrella.

Whether it is "Rain Today" or "Sunny 32°C", real-time weather forecasting requires powerful computing resources to issue predictions before the thunderstorm or other weather events actually occur. Meteorological Service Singapore (MSS) collects and processes about 40 million observations daily from satellites and the Earth's surface as well as upper air measurements to provide these forecasts. It is a computationally demanding job requiring the use of high performance computing (HPC) or supercomputing. That is the reason for MSS to be one of the earliest users of supercomputing in Singapore.

MSS Director-General Wong Chin Ling[4] said: "With a more powerful supercomputer, we can process data faster, get the analysis out quickly, then get the warnings out speedily and much earlier too."

"The whole process of assimilating observations and producing a forecast for the next week and over the whole globe should not take more than one hour," said Dr Erländ Kallèn, Director of the Centre for Climate Research Singapore.[2] "This requires a computing capability that is available only from the most powerful machines on the market."

Forecasting the weather has evolved with supercomputing but there are still limitations of which computing power is a key factor. Twenty years ago, MSS could not forecast the North-East Monsoon surge a few days in advance. The supercomputing simulation at that time was just not sophisticated enough. Contrast it to today where the technology's capabilities can predict several days ahead when the rains brought by this monsoon will occur.



WHY DOES SUPERCOMPUTING MATTER?

It matters because it is needed to process the zillions of data points collected. In 2016, research figures from International Data Corporation showed the global output of data was about 16ZB. By 2025, it will explode 10-fold to 163ZB. Governments and organisations need to make sense of this voluminous data so as to respond appropriately. Only powerful high performance computers are able to execute the mammoth and rapid computations to cope with this ever increasing amount of data. Technology played its part with the availability of super speed commodity microprocessors like GPUs which made supercomputing more accessible and affordable.

SINGAPORE'S SUPERCOMPUTING JOURNEY

Government identifies supercomputing as an important resource.

MID-1980s

Supercomputing has become a strategic tool for science, industry and society. It lets governments better understand and respond to urban challenges of congestion, transportation and healthcare. It allows scientists to design and simulate the effects of new drugs and offers health agencies a way to control epidemics. There are countless applications in engineering and manufacturing from building more energy-efficient buildings to making safer cars and planes.

Singapore is no different. Just as it understood the impact of infocomm technology (ICT) more than 30 years ago, it also recognised the relevance of supercomputing to the country. The story has almost simultaneous starting points, one of which begins at the National University of Singapore (NUS).

In the 1980s, researchers at the NUS were running out of computing power. The Hewlett Packard 3000 minicomputer met their demands but they were ramping up their research. The HP minicomputer was upgraded to an IBM mainframe 3031, which also ran out of steam after two years. Researchers wanted to look at the data as the mainframe was crunching them. But it did not have sufficient memory to cope with this interactive use. It could not even achieve a 99.5 per cent uptime, crashing twice a week.

Naturally, the researchers were unhappy. Around 1986, Dr Thio Hoe Tong,[3] then Director of NUS Computer Centre, proposed a comprehensive IT resource plan to upgrade the university's computing infrastructure. Comprising hardware, software and networking, the plan was worth about S$64 million, a large sum to spend on computing in those days. A portion of the budget was for a supercomputer to meet the research computing demands.

Meanwhile, the government had identified supercomputing as an important resource for the country. A technical team was put together to study the feasibility of starting a supercomputing centre in 1986. Among its members were Tan Chee Kiow[4] then Deputy Director of the NUS Computer Centre and Secretary to the Technical Committee and Philip Yeo, then Chairman of the National Computer Board (NCB) and Permanent Secretary (Defence). Other members included representatives from the Ministry of Defence (Mindef).

SUPERCOMPUTING PIONEER
Tan Chee Kiow supported the technical committee for the procurement of Singapore's first supercomputer.
PHOTO COURTESY OF NSRC

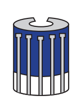
Mindef had problems to solve in the 1980s. One was to simulate the impact of an armament on land. Intensive computational power which was needed to do this was then not available in Singapore.

To examine the potential use of new technology, a study trip was necessary. In 1987, Yeo[5] went to the United States on an Eisenhower Fellowship for 11 weeks. Among other activities, he visited five supercomputing centres where he learnt about high performance computing and their applications in engineering design and 3D rendering. The centres he visited included the San Diego Supercomputer Centre at the University of California San Diego and the National Centre for Supercomputing Applications at the University of Illinois at Urbana-Champaign. He found out that these centres received financial support from the US organisation, Defence Advanced Research Projects Agency, or Darpa.

Singapore could follow the same model, he believed. The Republic had a strong manufacturing base which could use high performance computational resources for engineering simulation and modelling, he reasoned. It would also be of use to other industries such as defence and manufacturing.

COST OF PROCESSING POWER OVER YEARS

CRAY-2 SUPERCOMPUTER



1985
244 MHZ
US DOLLARS
>$30 mil

2012
800 MHZ
US DOLLARS
<$1,000

APPLE IPHONE 5

Supercomputers in the 1980s could cost beyond US$10 million for processing power that is so much lower than the smartphone in your pocket. The Apple iPhone 5[6], for example, cost less than US$1,000 in 2012 and boasted a CPU speed of 800MHz, compared with the US$32 million Cray-2 supercomputer launched in 1985, which had a CPU speed of 244MHZ.

Generally, supercomputers were huge machines often taking up thousands of square feet of floor space. They were large and some required gas cooling, which needed special facilities to be built.

To Yeo, a university would not be able to afford a supercomputer, much as researchers needed it. Engineers at Singapore's Mindef

Technical team set up to study feasibility of starting supercomputing centre.
1986

Chairman of National Computer Board Philip Yeo proposes government-funded facility to provide shared computing resources.
1987

also needed supercomputing for modelling among other things such as war games and weapons design. Supercomputing, too, would help to improve manufacturing and engineering capability for Singapore industry. Mindef could afford the supercomputers but the equipment would have to be housed within defence properties with restricted access. This means that the resources would be inaccessible to the private sector.

He strongly believed that, for a small country like Singapore, expensive technological resources should be available to anyone who needs them. He unravelled the dilemma by setting up a new organisation that would own the supercomputing resources and make it available to both the private and public sectors.

As Mindef's Permanent Secretary, Yeo also oversaw the defence technology companies. From Computer Engineering Services, which provided engineering services to Mindef, he spun out a new subsidiary called Advanced Computation Centre (ACC) with an initial investment of S$40 million. This private company offered time-sharing service for supercomputing resources which was the most cost effective way to service the computational requirements of the scientific, engineering and commercial sectors in Singapore. Organisations could "book" computational time to run their projects.

ACC was launched in 1988[7], by the late Minister of State for Education and Chairman of the Committee for National Computerisation Dr Tay Eng Soon, who described ACC as a national resource to "encourage new research activities in areas which were previously constrained by the lack of computing power". Potential users then would be the universities and government bodies like the Meteorological Service as well as private-sector users.

ACC WAS LAUNCHED IN 1988, BY THE LATE MINISTER OF STATE FOR EDUCATION AND CHAIRMAN OF THE COMMITTEE FOR NATIONAL COMPUTERISATION DR TAY ENG SOON

At the launch, then NCB General Manager Lim Swee Say[8] said the ACC would provide an additional incentive to offshore companies who had very high computational needs to invest in Singapore. "The establishment of the centre is consistent with the goal of exploiting IT for economic development".

The ACC was equipped with a supercomputer the NEC SX-1A and a mainframe with supercomputing power, the IBM 3090 Model 200E with a VF vector processor. The NEC system was rated at 665 Megaflops in vector performance and 167 Megaflops in scalar performance. The IBM system has a rating of 240 Megaflops in vector performance and 32 Mips in scalar performance.

SKILLS DEVELOPMENT
ICT pioneer Noel Hon (right), who was then Managing Director, NEC Singapore, developed an initiative to provide training on supercomputing skills.
PHOTO COURTESY OF NSRC

The world in the mid-1980s was still feeling the after-effects of World War II.[9] Between 1947 and 1991, there was a state of geopolitical tension between the United States and the Soviet Union called the Cold War. Japan, reeling from the consequences of WWII, had adopted a pacifist constitution. While Japanese computer firms like NEC, Toshiba, Hitachi and Fujitsu were the supercomputer leaders then, they took great pains to ensure that the machines they sold to other countries would not be used for war-like purposes such as atomic energy development. They also had to follow the rules set out by CoCom, the Coordinating Committee for Multilateral Export Controls, which put an arms embargo on Comecon (the Communist countries of the Eastern Bloc in Europe) region. The rules prescribed products that were not to be sold because they could be used for military purposes.

Noel Hon, then Managing Director of NEC Singapore, recalled: "The Japanese were more interested in the adherence to their ethics and pacifist constitution. NEC was keen on the sale but not going out of the way to get it. NEC was prepared to forgo the business. This was my difficulty. Business was business, but we had to adhere to rules." The sale required an export licence from the Japanese government. The Singapore government also had to sign an end-user agreement, giving the assurance that the machines would not be used for military purposes and that, afterwards, they would not be sold to Communist countries. Users also had to be approved. This is a policy that is still followed today.[10]

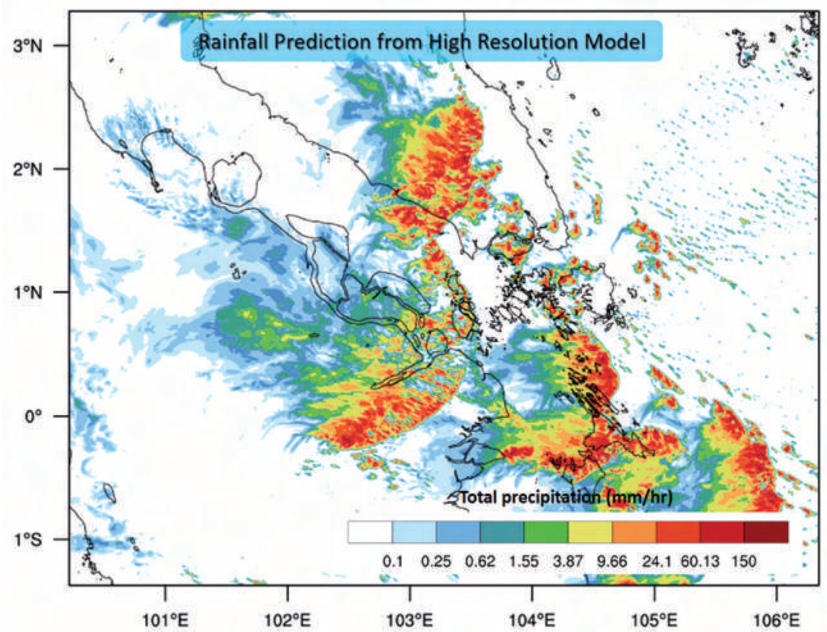
So Hon's first hurdle to the sale was to complete all the paperwork required from the Japanese and Singapore governments. Then came the benchmarking. Earlier in 1962, when Singapore's Central Provident Fund Board[11] bought its first IBM mainframe, all the software was tested in Sydney, Australia, because Singapore lacked a mainframe. Similarly, Hon ran all the supercomputer benchmarks in Japan because there was no supercomputer in the Republic. NEC had to provide the benchmark to selected software and show the statistics such as clock time and number of CPUs used to run a research cycle to the tender technical committee. NEC also had to demonstrate multiple computing capability including the computer's ability to be linked to different brands of computers. By 1987, the benchmarks were completed and the ACC was opened in 1988.

Yeo sets up Advanced Computation Centre (ACC) with initial S$40 million investment.
1988

The sale mattered to Hon. But of greater importance was that the supercomputers would be used to drive Singapore's economy. "I thought more of it. I wanted to do something for Singapore on a larger level. We made the project more than just the sale of hardware. We also provided training." This benefited local ICT professionals as they were trained to use the computational tools.

The NEC SX-1A was shipped by sea from Japan to the Republic. It was installed in ACC's office in the Singapore Science Park. The machine filled up a big room. Water plumbing was required for cooling, so was a reinforced floor since the machine weighed several tonnes. It was installed with the arithmetic unit, CPU, tapes, disks and laser printers. It would be five years later when Singapore upgraded the machine to another NEC supercomputer, the SX-2A.

The MSS was a pioneer user.[12] It collected weather information such as rainfall, temperature and wind to support its provision of weather forecasting services to the public and various other user sectors. There was no supercomputer in Singapore prior to 1988, so it relied on model forecast information from centres such as the UK Met Office. When the NEC SX-1A was installed, the MSS used it to model atmospheric conditions to predict the weather.



MORE ACCURATE WEATHER PREDICTION
A computational modelling of weather systems around Singapore.
PHOTO COURTESY OF MSS

The motivation to use supercomputers for Numerical Weather Prediction (NWP) began in the 1950s. Given the high level of resources required to run NWP models, Singapore did not have this capability until the late 1980s. Then in 1993, MSS began hosting the Asean Specialised Meteorological Centre, a regional collaborative effort to enhance the capability of Met Services in the Asean region. MSS Director-General Wong said the need for Singapore to have the ability to run NWP models became a top priority. "It motivated us. We're the first in Southeast Asia to run NWP models."

SUPERCOMPUTING CAPABILITIES
Sun Microsystems provided computers with supercomputing capabilities that were used in the universities in the 1990s.
PHOTO COURTESY OF NSRC

Prior to the setting up of ACC, Singapore organisations had no supercomputing facilities. Like others elsewhere, they had installed mostly minicomputers from IBM, Hewlett Packard and Digital Equipment Corporation and engineering workstations from Silicon Graphics and Sun Microsystems. Financial institutions and the public sector usually had mainframes.

Researchers at NUS and, soon after, Nanyang Technological University, the MSS and the public sector agencies were the early users of ACC services. As their own requirements grew, and when the prices of supercomputers fell, they supplemented the ACC offerings with their own installations. Supercomputing compute power is dependent on the research project. The more complex the research, the greater the computational power needed.

Unlike the public sector, especially the Ministry of Defence, businesses were not quite ready for supercomputing. In the 1980s and 1990s, only the very large organisations had computers. It was still early days of computing for Singapore. The national computerisation effort began in 1981 was driven by the civil service in the hope that the private sector would follow suit. The mass PC industry was just beginning. It was de rigueur to have fax machines in every office than a PC.

The ACC thus had a tough time attracting industry users. The company morphed into a new organisation called the National Supercomputing Research Centre (NSRC) ▪

THE MOTIVATION TO USE SUPERCOMPUTERS FOR NUMERICAL WEATHER PREDICTION (NWP) BEGAN IN THE 1950S.

NEC SX-1A arrives from Japan, installed in ACC's office in the Singapore Science Park.

13 JANUARY 1998

SUPERCOMPUTERS IN THIS ERA

- NEC SX-3/11
- CRAY RESEARCH T94

THE BUILDING YEARS

NSRC

The National Supercomputing Research Centre (NSRC) was set up in 1992 to support academic, scientific and industry users with their supercomputing needs.

Singapore's early experiences in computer simulations arose from defence technologies. In the early 1990s, the Singapore Navy needed special ships. Called mine counter-measure vessels, these ships would sweep the sea lanes around the Republic for unexploded underwater devices. Naval mines pose a significant threat not only to the navy but civilian shipping as well. They had to be built in such a way to resist the shock from underwater explosions.

An external consultant engaged to test the special ship's proposed design via computer modelling and simulation made a recommendation. However, the Singapore Navy wanted more simulations. Professor Lui Pao Chuen[1], then Singapore's Chief Defence Scientist was in a bind. The initial project had taken two years. More simulations would consume more time and incur additional cost. If only there was a local expert who could do the modelling and simulation. Better still if a Singapore-based researcher could undertake the modelling and simulations. It would be the best solution because it would be good for Singapore to develop its own expertise.

Prof Lui had his answer in Professor Lam Khin Yong who was lecturing and undertaking research at the NUS. Prof Lam was involved in simulation projects for the Public Works Department (now known as CPG Corporation). In 1991, he was a principal investigator on a project to model the effectiveness of civil-defence shelter doors. Having served reservist duty in the Republic of Singapore Navy, he recognised the need for vessels to better withstand shock. He began to do computational modelling to simulate field conditions.

PROFESSOR LAM KHIN YONG JOINED NUS IN 1985 AFTER COMPLETING HIS DOCTORATE AT THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY. HE WAS APPOINTED PROFESSOR, DEPARTMENT OF MECHANICAL ENGINEERING, NUS, IN 1999.

A collaboration to study underwater shock research was born. In 1993, Prof Lam received a S$3.13 million grant, one of the biggest at the time, from the Naval Logistics Department and DSO National Laboratories to set up the underwater shock laboratory at NUS.[2] The grant money let him buy a minicomputer which was used to model shock waves and the resulting bubbles travelling through water, such as from underwater mine explosions, analysing their interaction with the surroundings. The research helped the Navy design naval vessels that could better withstand underwater shock. Five years later, his team became the first led by a university academic to win the Defence Technology Prize, from the Ministry of Defence for its work.

Said Prof Lui: "Work at the Defence Science Organisation is classified. But computer models are not classified. So we can tap the intellectual capacity of scientists and researchers in the public sector to work with Mindef engineers for a win-win situation." This cooperation was the beginning of continuous collaboration between government agencies and the private sector on supercomputing needs. Prof Lam would go on to play a key role in Singapore's supercomputing development.

With S$3.13 million grant, Prof Lam Khin Yong buys minicomputers for modelling underwater mine explosions.

1993

SUPERCOMPUTER RESOURCE CENTRE ENVISIONED

Industry collaboration was a key mission of the National Supercomputing Research Centre (NSRC) which was originally conceived as a resource centre. Set up in 1993, its expanded remit included undertaking research to solve industry problems. The Centre was first announced in 1990, coming close on the heels of the Advanced Computation Centre (ACC), Singapore's first supercomputing bureau set up in 1988 which focused only on resource sharing. In the early days of the ACC, the government had already recognised that cost, access and the lack of expertise hampered local industry's usage of this new tech resource. Few people could afford the use of or tap supercomputing technology. Even fewer had the expertise to use it.

To redress the situation, the late Dr Tay Eng Soon, who was then Chairman of the Committee on National Computerisation (CNC), endorsed a proposal by the NCB and NUS to set up the NSRC.[3] Funding was a S$9.27 million grant from NUS, and the National Science and Technology Board (NSTB), the precursor of Agency for Science, Technology and Research (A*STAR).

Towards the end of 1992, the ACC wound down. Its supercomputers and equipment were handed over to the NSRC which came into being in January 1993. Tan Chee Kiow, then Deputy Director of the NUS Computer Centre was appointed the first NSRC Executive Director. Overseeing the NSRC was a management board chaired by ICT pioneer Lim Swee Say, who was then Deputy Managing Director (International) of the Economic Development Board. Ko Kheng Hwa, then NCB's Chief Executive, helmed the advisory committee to provide the operational guidance.

LIM SWEE SAY LEFT THE CIVIL SERVICE TO JOIN POLITICS. HE HELMED MANY MINISTRIES. HIS LAST POST WAS MINISTER FOR MANPOWER 2015-2018.

Located in The Rutherford, a building in the Singapore Science Park, the NSRC had about 20 staff who were excited by the concept of supercomputing, its capabilities and applications. Many of its research scientists were from China. A pioneer staff member, Evelyn Lau, recalled the excitement of seeing the machines moving into the building. "They came in crates and were lifted to the machine room where the supercomputers were assembled."[4] A fire suppression system called the FM200 was installed.

The team was closely knit. Staff would bring their families for durian parties held in the vacant space – allocated for NSRC's expansion – next to the building. Tan who often worked late would have a special visitor, husband Dr Tan Boon Wan. "The office was in a quiet, secluded corner of the Science Park. I wanted to keep her company, until she finished work," he said.[5]

DURIAN PARTY
The NSRC team was small, had good camaraderie and worked closely together.
PHOTO COURTESY OF NSRC

To the detractors in the ICT community, there was scepticism about the NSRC. Did Singapore bite off more than it could chew? NSRC was to support academic, research and industry needs. Academics would know about the technology, not enterprises and industry. Singapore in the 1990s had no serious industry research projects that would need supercomputing power to model and simulate aircraft design, or undertake a blueprint for a new drug.

It was the government which had the foresight. Singapore was transitioning from labour-intensive to high-value work of which computing resources would be a key enabler. Hence its willingness to invest in supercomputing, way ahead of Asian countries including China.

NSRC put out several initiatives to ramp up industry interest. Tan strengthened NSRC's infrastructure, adding a new supercomputer NEC SX-3/11 to its hardware through a donation by NEC.[6] Collaborations with foreign companies for technology were inked. American firm Smith Barney Shearson adapted its neural network to help local financial institutions to more accurately predict market trends using supercomputers. Silicon Graphics set up a visualisation laboratory, providing high-end technical workstations and visualisation software to enable local industry to undertake molecular simulations for the design of pharmaceutical and petrochemical products.

NSRC WORKED WITH FOREIGN COMPANIES TO HELP LOCAL ENTERPRISES DEPLOY SUPERCOMPUTING CAPABILITIES.

To promote supercomputing, Tan introduced a conference series. Besides promoting the technology, the conference also served as a platform for the supercomputing community to discuss issues and exchange ideas. The inaugural conference, held in 1994, was opened by then Education Minister Lee Yock Suan. For better internal and external communications, NSRC also published a newsletter called Teraflops. Tan, who served two years at NSRC between 1993 and 1995 was awarded a Public Administration Medal (Bronze) for her contributions to Singapore's supercomputing journey.

ACC hands over supercomputers to newly formed NSRC, which has Tan Chee Kiow as its first Executive Director.

1993

HPC CONFERENCE 1994
Lee Yock Suan (second from right), previously Minister for Trade and Industry in 1994, opened the conference.
PHOTO COURTESY OF NSRC

POWERFUL SUPERCOMPUTER
NSRC's hardware resources were enhanced in 1994 with a more powerful machine, the NEC SX-3/11.
PHOTO COURTESY OF NSRC

ONE FOR THE ALBUM
William Hale (seated with tie), Executive Director, NSRC, with employees.
PHOTO COURTESY OF NSRC

FAMILY DAY
At NSRC with infants and toddlers in tow.
PHOTO COURTESY OF NSRC

Successive NSRC leadership continued with industry outreach. William Hale, NSRC's second Executive Director between 1995 and 1996, allowed students from Nanyang Polytechnic's computer animation diploma course to use its supercomputers.

An animation production house called 25 Frames used NSRC to successfully create a Fresh & White toothpaste commercial featuring polar bears. To encourage and facilitate the ease of use of supercomputing resources, users could access supercomputing systems remotely. While public broadband was not available in the mid-1990s, users could connect to NSRC using a university broadband network called Technet, via leased lines or through dial-up telephone lines. For those who preferred to work at NSRC premises, special rooms were set aside for them. For companies doing confidential work, there were terminals that accepted removable hard disks. Usage rates were also priced affordably – starting from S$80 an hour – for using the supercomputers. In the US it would be US$500 an hour.

DR KAHANER VISITS NSRC
Dr David Kahaner (left), who chaired IHPC's advisory council from 1998 to 2002, with Prof Lam Khin Yong (centre) during a visit to NSRC.
PHOTO COURTESY OF NSRC

These initiatives caught the attention of businesses. Many companies sent their staff to explore the use of supercomputers in IC design, electronics and data mining.[7]

A competition to garner interest in applying supercomputing technology to solve problems was held. Introduced in 1996, CrayQuest encouraged industrial and academic researchers to submit their work demonstrating the benefits of supercomputing in different economic sectors. A leading supercomputer vendor Cray Research sponsored the prizes for winners including total cash prize of about S$27,000.

Still, the early traction was with government agencies. The Maritime and Port Authority of Singapore worked with the NSRC and NUS to jointly develop numerical models of the marine environment. They would be used, among other things, to conduct studies for port planning and development, water quality of the marine environment and the prediction of dispersal of oil spillage in port waters. The Labour Ministry's Department of Health undertook a study to predict the level of chemical exposure hazards in factories with the NSRC.

The public sector saw the need to have its own supercomputing facility. By 1995, there were already 10 to 12 supercomputers in the Republic.[8] That year, IBM sold and installed another two supercomputers worth S$3.6 million to the NSRC and Central Provident Fund Board. The more powerful machine IBM SP2 went to NSRC to support R&D projects in electronic design automation, computational chemistry and financial market evaluation. Over at the CPF Board, the low-entry machine boosted its data management functions.

ARRIVAL OF NEW SUPERCOMPUTERS
NSRC Executive Director William Hale welcomes new supercomputers with NSRC staff Chua Kong Sian.
PHOTO COURTESY OF NSRC

One big user of supercomputing then was Prof Lam of NUS who was doing modelling and simulations in his underwater shock lab set up to, among other things, undertake Mindef projects. In 1994, he convinced the university to establish a Centre for Computational Mechanics where he obtained more work in the area of computational fluid dynamics. While the lab had its own Convex supercomputer, it needed extra computational power in addition to NSRC resources.

Singapore's most powerful supercomputer came in 1996 when NSRC bought the Cray Research T94 machine. The acquisition yet again demonstrated the government's commitment to provide world-class resources and facilities to meet industry's needs and to ensure that high-tech and higher value-added operations would replace lower-value and labour-intensive activities. It would be a strategy the government used for its high-tech and R&D investments.

IBM sells two more supercomputers worth S$3.6 million to the NSRC and CPF Board. The more powerful machine SP2 went to NSRC to support R&D projects.

1995

COMPUTATIONAL SCIENCE DEGREE AND NUS

When the ACC and NSRC were set up, the academic researchers tapped the supercomputing resources for research into various topics including computational fluid dynamics, computational mechanics and civil engineering.

Theoretical physicist Professor Lai Choy Heng[9] picked up programming and computing on his own, like other NUS researchers did to support their own research computational needs. The effort was time consuming. What if there were specialist engineers who could help them run the computation? He recalled that at that time the subject of computational science was becoming popular in the US but it was only available at graduate level. It would be nice for Singapore to have a similar programme. However, an undergraduate course would be sufficient for Singapore.

Prof Lai said: "The bunch of us at NUS, physicists, engineers and other researchers, looked at our landscape and the kind of computational intensive investigations we needed. We concluded that we and the industry didn't need PhDs in computational science. There was no need to follow the US to introduce a graduate programme. A good structured undergraduate training in physics, other sciences and computer science would be sufficient." Such a course would also promote wider use of supercomputing.

Discussions led to the introduction in the early 1990s of a degree programme in Computational Science with Chemistry/Mathematics/Physics offered by the Science Faculty. Prof Lai was one of the lecturers. The aim was to equip students with computing and a science domain. So students learnt computing including coding in different languages like assembly and machine languages. They also studied chemistry, maths or physics. Response to the programme was good.[10] Each cohort numbered 100 students. Each student was equipped with the latest workstations from the likes of Sun Microsystems, Digital Equipment Corporation and Hewlett Packard. Turned out that for several years, the NSRC was staffed by many of these graduates. In 1997, a computational science department was set up, a confirmation of the fact that the course contributed to the scientific community.

IN 1997, A COMPUTATIONAL SCIENCE DEPARTMENT WAS SET UP, A CONFIRMATION OF THE FACT THAT THE COURSE CONTRIBUTED TO THE SCIENTIFIC COMMUNITY.

However, interest in computational science declined and the course came to an end in the mid-2000s. Students found the course too demanding, having to study a science subject and computing, both of which were rigorous disciplines.

Research using supercomputing continued for the lecturers who started tinkering around with HPC clusters. These are groups of high-end workstations clustered and networked together to get high computational power. HPC clustering was in its infancy and was tough to do. The researchers turned to clustering because they found the NEC supercomputer at NSRC difficult to use. This issue was alleviated when the NUS Computer Centre set up its own supercomputing facility in 1995. ICT staff at the NUS Computer Centre, now called NUS IT, helped to match the right computational software with the research data that needed crunching, so as to optimise the operations and speed up the simulations.[11]

Helping to build up the NUS expertise was Tan Chee Chiang, who currently heads research in computing at NUS IT. A civil engineering graduate, he had done post-graduate work in computer modelling and simulation on the effect of rain on surface run-off and water flow in the drains. Already familiar with supercomputing, he was tasked to support researchers using NSRC when he joined NUS Computer Centre in 1993. He helped them run their computations, optimising the code for parallel processing and speed up the simulations. Researchers were mainly from the engineering department with projects in computational fluid dynamics to study the impact of water and air flow; civil engineering projects to study the effects of surface run-off and reservoir outflow; and computational mechanics which modelled engines, metal structures and strengths.

CONSOLIDATION

ICT industry veteran Lim Soon Hock, who had become Chairman of NSRC's advisory committee in 1995, was dead against fragmenting supercomputing resources[12] in Singapore. NUS had its own facility. NTU was rumoured to be setting up one. The Centre for Computational Mechanics also had its

Cray Research T94, Singapore's most powerful supercomputer arrives at NSRC in 1996.
1996

Prof Lam's team wins the Ministry of Defence's Defence Technology Prize.
1996

own supercomputer. Lim believed that for Singapore to develop complex software and simulation for engineering and financial problems, there needs to be scale.

"The government had foresight to invest in supercomputing, way before anyone else in the region, way before China did. For a small country like Singapore, why would you need several centres with crunching machines?

"The right thing to do is to concentrate all the hardware and capability in one centre," said Lim.

"It was not about investment in hardware. The real challenge was to be able to develop software applications for industry to use supercomputing. So you need to bring people from NUS, NTU, Mindef, all those with engineering and technical capabilities under one roof to do this."

Together with Peter Boek, who joined the NSRC as Executive Director in 1996, they pushed for a merger between the Centre for Computational Mechanics and NSRC. At that time, the NSRC's joint stakeholders were NUS and NSTB, both of whom needed to be convinced of the merger.

"It didn't make sense to me that there would be two centres providing supercomputing resources," said Boek.[13] Besides, he had too many bosses. He used the NUS personnel department to recruit and reported to the deputy vice-chancellor (a position now known as deputy president) of NUS. He also reported to NSTB and to Lim. It was not the best structure.

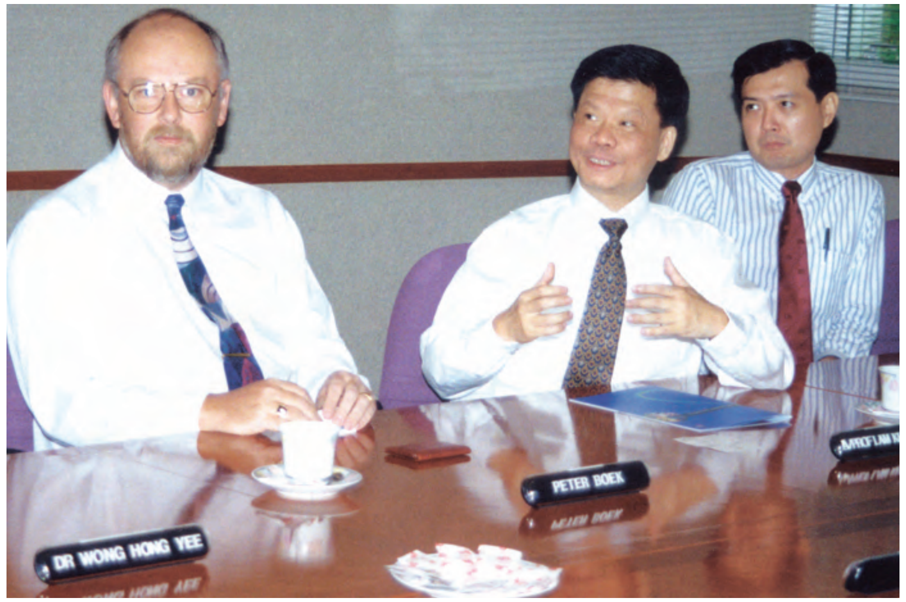
"WE SET UP A MODEL WHERE OUR RESEARCHERS WORKING ON PURE RESEARCH CAN USE OUR FACILITIES AND WITHOUT BEING CHARGED. BUT IF A COMPANY CAME TO US TO SOLVE A PROBLEM, WE WOULD CHARGE FOR MANPOWER AND COMPUTING RESOURCES. IT WORKED OUT QUITE WELL."
– PETER BOEK, NSRC EXECUTIVE DIRECTOR

Boek was suited for the job as he understood sales and marketing. Prior to NSRC, he was Asian head of Cray Research tasked with selling supercomputers to countries in the region. He also understood how simulations work, so it was fairly easy for him to target organisations that were doing research and likely to use heavy computing resources. He also reorganised NSRC to position it better for sales and marketing because not enough was done to establish a customer base with industry. He set up units to focus on different sectors. For example, he put Dr Kurichi Kumar, who became a stalwart in Singapore's supercomputing community, to manage a unit focused on getting business from the petroleum sector.

"We set up a model where our researchers working on pure research can use our facilities and without being charged. But if a company came to us to solve a problem, we would charge for manpower and computing resources. It worked out quite well."

By 1998, the merger was successful. The Institute of High Performance Computing (IHPC) came into being with the merger of NSRC and the Centre for Computational Mechanics. Prof Lam was the Founding Director with Boek his assistant tasked with integrating the two organisations.

Prof Lam was a hands-on scientist and a manager. He was also entrepreneurial. Together with Lim, who was experienced in sales and marketing, they successfully inked contracts with many companies to collaborate with IHPC, starting the golden years of supercomputing in Singapore ■



IHPC FORMED
Prof Lam Khin Yong (second from right) led IHPC in 1998 when it was formed. Peter Boek (first from left) joined him from NSRC.
PHOTO COURTESY OF NSRC

NSRC and the Centre for Computational Mechanics merge to form Institute of High Performance Computing (IHPC).
1 APRIL 1998

SUPERCOMPUTERS IN THIS ERA

- IBM SP2 SUPERCOMPUTER
- CONVEX C3440

THE BOOM YEARS

IHPC

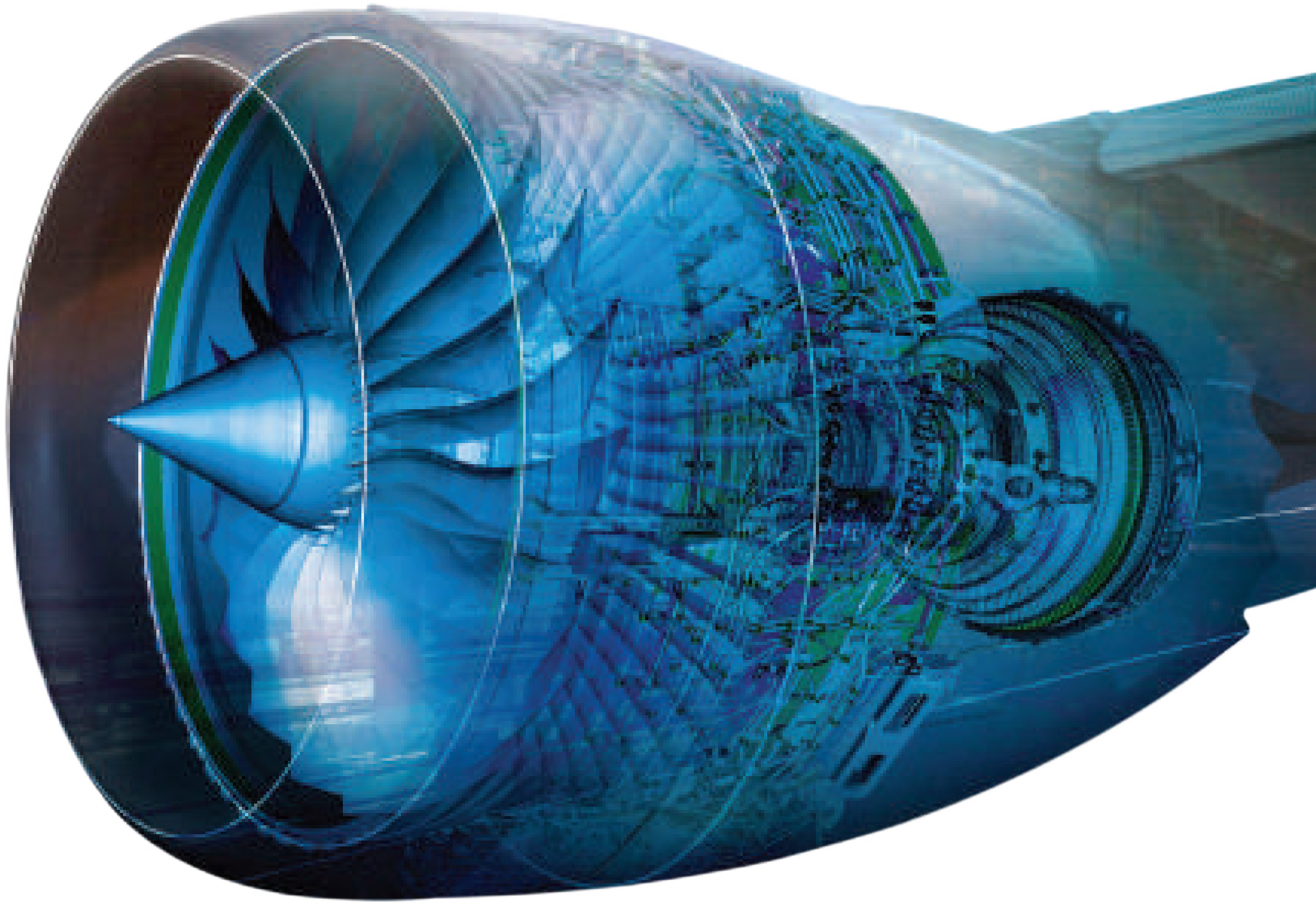
Institute of High Performance Computing (IHPC) is an applied research lab, developing new tools and supercomputing-based solutions in collaboration with organisations including businesses.

Rolls-Royce, famous for its luxury cars, is also well known as the world-class jet-engine manufacturer, with major customers such as Airbus and Boeing. Its latest jet engines power the new Airbus 350 family of planes. To design new jet engines, it uses computer modelling and simulation software. In the early 2000s, its Singapore office wanted to have a better understanding of the performance of these software on different high performance computing architectures.

The Institute of High Performance Computing (IHPC) had a variety of supercomputers which could benchmark the software performance, helping the company identify the right supercomputing architecture to invest in. Without the benchmarks, Rolls-Royce Singapore might have picked the wrong architecture, wasting investment and prolonging product development time.

Rolls-Royce Singapore was a satisfied customer, returning for subsequent projects. One improved the performance of its computational fluid dynamics (CFD) simulation code on the IBM Power series supercomputers, significantly shortening the design cycle time. Another project automated the analysis of CFD results engineers used to highlight errors. Manual inspections took hours because of the massive amount of data generated. Applying physics and machine-learning methods, IHPC automated this process improving the accuracy of the inspection and shortening the turnaround time, letting the engineers focus on other crucial aspects of design.

ROLLS-ROYCE JET ENGINE
PHOTO COURTESY OF ROLLS-ROYCE



IHPC helps Rolls-Royce in Singapore identify right supercomputing architecture to invest in.

EARLY 2000s

Success with Rolls-Royce projects generated greater visibility for IHPC, highlighting the capability of supercomputing to support enterprises' engineering as well as design and product-development processes. It triggered many organisations to approach IHPC for intensive computational needs. This was the reason Singapore's Defence Science and Technology Agency (DSTA) used IHPC resources during the development of the Bionix armoured infantry fighting vehicle. The institute developed the Bionix Virtual Prototyping System, a special 3D virtual reality and advanced visualisation software to help DSTA design the correct ergonomics for this vehicle.[1]

The software enabled users to "walk through" the Bionix during virtual driving operations, giving DSTA the insights into how users could interact with the devices and equipment in the vehicle. Product design review was greatly enhanced as it could be reviewed in real time. The system also provided a simulation model for training operators and maintenance engineers.

Founded on 1 April 1998, the IHPC is the result of a merger between the Centre for Computational Mechanics and the National Supercomputing Research Centre (NSRC). It was set up jointly by the NUS and the National Science and Technology Board (the predecessor of A*STAR), which also provided the funding. The intent was for IHPC to centralise all Singapore's supercomputing resources under one roof.[2] While it initially prevented fragmentation of these resources,[3] this concept faded as the local tertiary institutions and various organisations installed supercomputing systems as, among other reasons, they became more affordable. Supercomputer clusters, made up of high-end workstations which used commodity processors, were cheaper than supercomputers, which often cost over S$1 million.

The institute's mission is to enhance Singapore's global competitiveness by promoting the use of supercomputing among local and multinational companies. It created higher-valued jobs for Singaporeans, lifted local industry capability and added economic value via collaborations with multinational corporations. IHPC is in applied research, developing new tools for industry and international collaborations.

IN THE FIRST YEAR
IHPC SCIENTIFIC STAFF

SUPERVISED
13 PHD CANDIDATES

ORGANISED
21 CONFERENCES & SEMINARS

PUBLISHED
90 PAPERS IN SCIENTIFIC JOURNALS

TRAINED
250 RESEARCH SCIENTISTS & ENGINEERS

A GOOD PAIRING

A two-in-one leadership combo in the early years of the IHPC laid the foundation for its success. Lim Soon Hock, as Chairman of NSRC Board and later IHPC Board, was a veteran ICT professional, battle-hardened in the highly competitive PC market. He led Compaq Computer Asia-Pacific and China operations, building it into a billion-dollar business in the region. He was conversant with sales and marketing. Prof Lam Khin Yong was an academic researcher and a visionary setting out the technological directions for the IHPC. To further hone his entrepreneurial and commercial skills, Lim sent him to Harvard's Advanced Management Course so that he could better manage IHPC as a commercial entity.

COMPAQ COMPUTER, FOUNDED IN 1982, WAS ACQUIRED BY HEWLETT PACKARD IN 2002

Their business acumen set them apart from the previous leadership at Advanced Computation Centre – the first supercomputing agency in Singapore set up in 1988 – and National Supercomputing Research Centre, whose leaders were less familiar with the marketing and the business worlds.

IHPC had about 120 computational scientists and engineers, who came from around the globe, including many from leading universities in the world. Its report card for the first 12 months in 2000/2001 was sterling.[4] Industry collaboration climbed to 69, much more than its target of 10. These were initiated with more than 40 multinational and local corporations including Yeow Hwa Engineering, PSA Singapore, Defence Science Organisation and Molex Singapore. These corporations contributed a total of S$2.65 million for their collaboration with IHPC.

In that first year, IHPC scientific staff supervised 13 PhD candidates and trained 250 research scientists and engineers in short courses and seminars. About 90 papers were published in scientific journals. It also organised 21 conferences and seminars. Among the joint R&D programmes with foreign universities and research institutes were Texas A&M University, US; University of Reading, UK; Engineering Systems International, France; and US Naval Postgraduate School. It also set up three centres, namely, Advanced Numerical Engineering Simulations with the NTU, financial engineering and advanced computations in engineering science with NUS and the Interactive Visual Simulation Lab with ST Training and Simulation, which supplied the Singapore Science Centre with an advanced virtual reality (VR) facility.

APRIL 2003
National Grid Office set up to coordinate the formation of national grid computing infrastructure to support growing demand for computing resources.

2006
Seiko Instruments sets up R&D facility in Singapore in collaboration with IHPC to focus on fuel cell development.

Both Lim and Prof Lam set up IHPC to solve potential customers' problems, a strategy to "hide" the complexities of supercomputing technology so as not to scare away potential customers. "What we did was to understand the problems companies were facing and offer our solutions using our researchers' expertise. That's how we managed to get so many customers,"[5] said Lim.

PROF LAM KHIN YONG
Set up IHPC to solve potential customers' problems.
PHOTO COURTESY OF NTU

New technologies which supported industry collaboration were also introduced. One was Singapore's first VR facility called CAVE (Cave Automatic Virtual Environment). This is an immersive system that became the standard for rear projection-based virtual reality systems. Co-invented by Tom De Fanti, a pioneer graphics researcher, CAVE was introduced to IHPC by Professor Tan Tin Wee, who had been involved with Internet development and advance research networking in Singapore and Asia since the 1990s. Prof Tan is currently Chief Executive of NSCC.

The CAVE attracted a lot of industry partners, including property developer Far East Organization, which was revamping the iconic Fullerton Building – which housed the General Post Office and government agencies such as the Inland Revenue Authority of Singapore and the Economic Development Board – into a five-star hotel. Using the 3D virtualisation facility, Far East architects created and rendered virtual 3D models of the building's interior before selecting the optimum design.[6]

Other key industry undertakings in the early years included:

- Data mining for customer segmentation for the insurance industry;
- Modelling of the Buangkok MRT station for fire safety;
- Detecting prostate cancer via a specially developed artificial intelligence software which analysed hair samples, helping researchers identify those suffering from the disease; and
- Improving Land Rover communications system by using computer-aided simulation and visualisation to analyse the electromagnetic activity; identifying potential problems from the outset and minimising the need for costly, time-consuming redesign and retrofitting.

IHPC and Hewlett Packard collaborated to offer computing capabilities in a shared-services delivery model.

2006

CRAY SUPERCOMPUTER COMMISSIONED
In 1996, then Minister for Trade and Industry Yeo Cheow Tong (fourth from right) officiated at the commissioning of the Cray Supercomputer at NSRC. Lim Soon Hock (second from right) NSRC Chairman and Teo Ming Kian then Chairman of National Science and Technology Board (first from left) were also present.
PHOTO COURTESY OF NSRC

VIRTUAL REALITY EXPERIENCE
General (retired) Alexander Haig tried the 3D facility called CAVE at IHPC during his visit there in 1999. He was shown the facility by Prof Lam Khin Yong, Executive Director of NSRC (first from right).
PHOTO COURTESY OF IHPC

A scientific advisory board is set up to benchmark IHPC's activities and improve its work.

2006

The IHPC's store of multi-vendor supercomputing platforms was integral to its research efforts and industry collaborations because it ensured relevance across a broad range of fields and disciplines. It also constantly evaluated new computing paradigms and continuously upgraded resources to keep up with the latest developments. Towards the end of 2000, its hardware included Cray T94, IBM SP2 supercomputer, Convex C3440 and NEC SX3 (which it managed for Met Service Singapore) and high-end work-stations from Silicon Graphics, Hewlett Packard and Sun Microsystems.

Dr David Kahaner, who chaired IHPC's advisory council from 1998 to 2002, attributed IHPC's accomplishments to Lim's and Prof Lam's leadership. They were pro-business and marketing oriented leading to increased work with industry. "The people at IHPC were very good at engineering and understanding and solving the problems of organisations."[7]

UNDER LIM'S AND PROF LAM'S LEADERSHIP FROM 1998 TO 2001, IHPC WAS ONE OF THE RESEARCH INSTITUTIONS WITH THE HIGHEST INDUSTRY INCOME. BY THE TIME THE DUO LEFT IN 2001, IHPC WAS ON A STRONG FOOTING.

Under Lim's and Prof Lam's leadership from 1998 to 2001, IHPC was one of the research institutions with the highest industry income. By the time the duo left in 2001, IHPC was on a strong footing. It had already chalked up many achievements including reaching out to local enterprises to improve their competitiveness. It had increased industry revenue for the institute and it had many repeat customers. It introduced and encouraged long-term adoption of supercomputing-based virtual product development and business intelligence. There was also ongoing international collaboration on the research front.

DEVELOPING SUPERCOMPUTING

Successive leaders built upon IHPC's mission. Singapore was in the high-tech, knowledge-based economy from the 2000s. Supercomputing meant high-tech which fit into Singapore's economic blueprint. Because of Singapore's early adoption of supercomputing, computational skills became pervasive in the engineering and science curriculum of the local universities.

This early investment has resulted in a supercomputing community, said Dr Raj Thampuran, A*STAR's Managing Director.[8] About a third of A*STAR's 5,200 engineers and scientists would use supercomputing in some way. The researchers, engineers and scientists in the community are using supercomputing to go into the brave new area of modelling and simulation, which he described as the "third pillar of scientific discovery, a companion to theory and experiment".[9]

DR RAJ THAMPURAN
Researchers and scientists are using supercomputing as a way for scientific discovery.
PHOTO COURTESY OF A*STAR

On the significance of supercomputing, he said: "Modelling and simulation creates digital metaphors of the real world. If you've the right algorithm and maths and computing resources you could really emulate systems with a high degree of fidelity."

No innovation is done today without some modelling and simulation work. Previously, modelling followed theory – not so today. Scientific discovery can be had by crunching the vast amount of data available today. Modelling and simulation have almost replaced theory, added Dr Thampuran.

Significantly, research collaborations with local and foreign companies and universities continued. They included:

- An R&D facility set up in 2005 by Japanese company Seiko Instruments, its first outside of Japan and focused on the development of fuel cells;
- In 2006, IHPC and Hewlett Packard set up the world's first shared-services platform lab to offer computing capabilities in a shared-services delivery model;
- A series of joint labs were set up with NTU to foster scientific research in 2008, of which one focused on nanoelectronics and plasmonics, the study of the interaction between electromagnetic field and free electrons in a metal;
- In 2008, IHPC inked a three-year S$3.4 million research programme with the Maritime and Port Authority to spearhead the use of computational science and engineering in the maritime industry via private-public research partnerships;
- Lloyd's Register set up a Group Technology Centre in 2012, of which one initiative was a joint lab to co-develop applications and solutions in the marine and offshore sectors;[10]
- In 2012, an agreement was inked with the International Centre for Applied Mechanics at Xi'an Jiaotong University to foster research collaboration; and
- IHPC was one of two A*STAR RIs in 2015 to undertake research work with Singapore's transport operator SMRT to improve station equipment and operations.[11]

A*CRC inherits 10 small HPC clusters totalling 10 TFlops, considered quite powerful in 2007.

2007

A scientific advisory board was also set up in 2006. Comprising prominent scientists they would visit IHPC biennially to review its work and provide feedback. This was a way to benchmark the institute's activities and improve its work. The current board is chaired by Professor William Curtin of the Laboratory for Multiscale Mechanics Modeling, Switzerland.

Currently, its more than 200 scientists and researchers contribute to supercomputing research, publishing an average of 250 papers every year in scientific journals. Conferences and workshops were held for IHPC to share its expertise and show its industry capabilities. There was also HPC Quest, a competition to promote high performance computing among industry users and students. HPC Quest was originally started as Cray Quest in NSRC for students but was later expanded to include industry. Student outreach was a major initiative which included science fiction writing competitions, computer visualisation camps and student attachment programmes.

PROF LAWRENCE WONG, NUS
Speaking at an HPC Quest event, a competition to promote high performance computing among industry users and students.
PHOTO COURTESY OF IHPC

A new home beckoned in 2008. IHPC moved to a spanking new building called Fusionopolis in the leafy science suburb of One-North. Occupying four floors, the move was opportune for the institute to enhance existing facilities. Its capabilities in visualisation, for example, were refreshed with a new simulation chamber where researchers and industry could work on simulating various 3D scenarios.

A*STAR COMPUTATIONAL RESOURCE CENTRE (A*CRC)

Set up in 2007, A*CRC is the research enabler, providing supercomputing services only to A*STAR's research institutions, which number over 20. It was formed from the hardware teams of two organisations, namely, the high performance computing unit of IHPC and the systems, storage, network and data centre team of BII (Bioinformatics Institute). Centralising the supercomputing resources for A*STAR would be more efficient. Dr Thampuran, who initiated the formation of A*CRC, believed that it was more efficient to pool resources rather than have separate teams.

The hardware team members had advanced computational skills and could develop state-of-the-art solutions in diverse areas to meet researchers' demands. Equipped with many supercomputing systems, it is a hardware facility for computational research. A*CRC offers compute resources on multiple operating systems and a comprehensive range of third-party software for various applications.

A*CRC had inherited several supercomputing clusters totalling 10 Teraflops, considered quite powerful in 2007. Project submissions for A*CRC computation services were made more straightforward.

IHPC moves to Fusionopolis in One-North. A new simulation chamber was also set up in the new office.
2008

Dr Marek T Michalewicz[12], A*CRC Senior Director then, replaced five different online queuing systems for project submission with one online scheduler. Dr Michalewicz was part of A*CRC's senior leadership which was led by Dr Thampuran, who was also Executive Director of IHPC at that time. Among A*CRC activities were a supercomputing conference and special bootcamps for undergraduates here who were specifically trained to participate in international supercomputing competitions. The first time a student team was entered for an international competition was in 2013. These competitions held in China, the US or Europe required months of preparation. Students, usually computer science and engineering undergraduates, were given intensive training. Among other things, they learn supercomputing technology, how to build a supercomputer-like system using commodity electronic parts and run specific supercomputing software on them.

Specifications differ for each competition but generally the students must build their own supercomputer which must not exceed 3 kilowatts of power. The machine must pass specific benchmarks and run stated software. During the competition, the machine must repeat the benchmarks and its ability to run the specified software. The team must also successfully run a mystery scientific challenge. In 2017, the NTU team trained by A*CRC took the top honours in the annual highly competitive Student Cluster Competition at the supercomputing conference SC17 in Denver, US.

A DEMONSTRATION IN 2014, DURING THE SUPERCOMPUTING CONFERENCE SC14, SUCCESSFULLY SHOWCASED INFINICORTEX RUNNING AT A HIGH BANDWIDTH OF 100GBPS LINKING SINGAPORE'S SUPERCOMPUTER TO ANOTHER IN NEW ORLEANS WHERE THE CONFERENCE WAS HELD.

Another feather in Singapore's supercomputing cap was the landmark InfiniCortex project, which extended the global range of the InfiniBand communications protocol. InfiniBand is widely used in supercomputers to interconnect its processors and feature very high throughput and low latency. The InfiniCortex project used long range InfiniBand to interconnect supercomputers across the globe to Singapore. It is a scientific network, not to be mistaken for another Internet network. Until recently, the use of InfiniBand was restricted to the boundaries of a data centre or a supercomputer facility, where the machines were not more than 30 metres to 40 metres apart. A demonstration in 2014, during the supercomputing conference SC14, successfully showcased IC running at a high bandwidth of 100Gbps linking Singapore's supercomputer to another in New Orleans where the conference was held. This demonstration was undertaken together with Obsidian Strategics, Tata Communications and Rutgers University.

Several joint labs were set up with NTU to foster scientific research.
2008

INFINICORTEX WINS AWARD

Led by Prof Tan Tin Wee (first from left), the A*CRC team won a Gold award from the Ministry of Trade and Industry in 2015. Lim Hng Kiang, then Minister for Trade and Industry (fifth from left) presented the award.

PHOTO COURTESY OF A*CRC

The project was later expanded to include other national and regional education networks in Europe and the US. IC provides a level of concurrent supercomputing that can support exascale computing, which is the next level in supercomputing.

IC made Singapore relevant to the world supercomputing community, said Dr Michalewicz. "It was the combined effort of many researchers in Singapore and in the world. In Singapore it was Prof Tan who persuaded researchers and different organisations to back the project." Dr Michalewicz and Prof Tan's efforts were recognised by A*STAR, winning one of three innovation awards the agency gave out in 2015. Prof Tan was given a Gold Award by the Ministry of Trade and Industry for leading the project. SingAREN (Singapore Advanced Research and Education Network) benefited from its participation in the IC project. It signed research collaborations with well-known research agencies in the US such as Oak Ridge National Laboratory.

Moving on, the A*CRC's current challenge is its ageing "iron".[14] Four of its five supercomputing systems have reached their end-of-life or end-of-support stages. Plans are in the pipeline to refresh them. A*CRC CEO Tay Kheng Tiong's[15] intention is to build an integrated platform with different architectures and operating systems that are interoperable to serve the varying needs of A*STAR researchers in the engineering and biomedical fields.

What is clear is that rising demand for A*CRC services has led Tay to consider other ways of increasing supercomputing capacity. One is a supercomputing network. Another option under consideration is to link to other supercomputing centres in the world to give local researchers opportunity to access large computation capacity.

To ensure that researchers find it convenient and easy to access A*CRC's services, Tay is building an intelligent software supported by artificial intelligence to allow what he described as "seamless supercomputing at your fingertips". This software will allow any A*STAR researcher to submit scientific computing jobs from their smart devices, be it laptops or mobile phones.

The AI component will have deep learning capabilities to make the computing more efficient. The software will get progressively better as it learns from the researchers' usage patterns, training itself to offer better computational configurations. As an example, if a researcher has submitted computational jobs that require the compute power of 100 CPUs, the software will "observe" and learn. The next time it may offer the researcher 90 CPUs or even 110 CPUs so as to run the computation more efficiently.

As the software's developer, Tay has filed a technology disclosure with Exploit Technologies, the commercialisation arm of A*STAR. This means that it is a new program which has potential to be commercialised.

TECHNICAL RESOURCES USED IN SINGAPORE

60% DEFENCE R&D

36% LIFE SCIENCES

4% PHYSICAL SCIENCE & DIGITAL MEDIA

GRID COMPUTING

In 2003, a national initiative began to aggregate, virtualise and share the technical computing resources available in universities and research institutions (RIs). They became part of a national grid computing infrastructure. IHPC was one of five key participants; the others were NUS, NTU, Genome Institute of Singapore (GIS) and Bioinformatics Institute (BII). In grid computing, each computer's resources in these organisations are part of the network which can be shared with other linked computers. Grids are a special type of distributed computing where a super virtual computer comprising many networked computers performs very large tasks akin to a supercomputer system. It is often used as a form of parallel computing to solve a single large task in computationally intensive scientific, mathematical or academic problems.

Coordinating the grid effort was a National Grid Office set up in April 2003[16] under A*STAR. A national grid steering committee was also set up, chaired by career civil servant Peter Ho, who was, at that time, Permanent Secretary for Defence. Dr Sydney Brenner, who heads A*STAR's Biomedical Research Council was the Vice-Chairman. This 20-member committee was drawn from government agencies who were the potential users of grid computing as well as owners of large computational resources in Singapore. The late Dr Cheong Beng Teck, who was Director of Mindef's CIO Office, was appointed the Director with Dr Lee Hing Yan as his deputy.[17]

The grid was to facilitate the seamless use of an integrated cyber infrastructure in a secure, effective and efficient manner to advance scientific, engineering and biomedical R&D. The longer term goal was to transform the Singapore economy using grid. Its formation was timely because Singapore was attracting high-value R&D investments in areas like biotechnology and pharmaceuticals which would need the computation resources.

Besides, technical computing resources were also expensive. Virtualising and sharing them would lead to higher usage. Organisations would not have to spend as much on supercomputing systems. A survey conducted around 2002 to 2003 found that organisations could each have savings of

IHPC signs three-year research programme with Maritime and Port Authority on the use of computational science and engineering in the maritime industry.

2008

between 20 per cent and 30 per cent over five years if grid computing was adopted.[18] Without a grid infrastructure, RIs and universities would spend nearly S$30 million to buy supercomputing systems compared with less than S$20 million if they were part of a grid infrastructure.

Under the National Grid Pilot Platform (NGPP), two pilot grid projects were rolled out to explore the possibility of linking all the supercomputing resources in Singapore, letting users submit their computational jobs through an online scheduler. One finding between April 2005 and June 2006 highlighted that 60 per cent of the resources were used by defence R&D, 36 per cent by life sciences, with the remainder by physical science and digital media industries.[19]

The pilots demonstrated that the grid concept was workable. However, due to the heterogeneous nature of the hardware, many issues had to be addressed.[20] The HPC clusters and supercomputers were of different brands and ran different operating systems. Some software could run on a few machines, others needed to be modified. The biggest impediment was licensing. The supercomputing software was licensed to the RIs and universities, not to other users hooked up to the grid network. Commercial software at that time was not ready for pay-per-use. While the RIs and universities bought into the grid computing concept, there was an underlying tension. They had bought their own supercomputing systems. Centralising the supercomputing resources meant taking away parts of their budgets. Perhaps, this was not socially acceptable.

THE PROBLEMS OF THE GRID COMPUTING PLATFORM WERE NOT INSURMOUNTABLE BUT THE GRID IDEA FADED, OVERTAKEN BY THE ARRIVAL OF CLOUD COMPUTING.

From the pilots, it was clear the resource-poor researchers were very willing to make use of the grid resources – although the grid tools were far from production quality – but the resource owners were not so willing to share, said Dr Lee.

"So there was a disparity. There might be situations where computational resources sit idle but not made available on grid pilot platform when there were users seeking computational resources to run their work." The solution was to let the organisations buy their own computational resources "on condition that they had to be made available to a larger community of users", he added.

Initially, the national grid was meant for the research and academic communities. However, in 2007, it expanded its focus to industry where the challenges were different. Commercial software was much more expensive and the pay-per-use scheme made more sense. In 2010, the NGO was transferred from A*STAR to the Infocomm Development Authority (the predecessor of Infocomm and Media Development Authority).

The problems of the grid computing platform were not insurmountable but the grid idea faded, overtaken by the arrival of cloud computing. Once it was clear to the government that cloud computing was no hype or fad, the grid gave way to the National Cloud Computing Office and the grid participants reverted to using their own resources for themselves.

AVOIDING OBSOLESCENCE

At A*STAR, the chief concern was a supercomputer strategy that made sense for Singapore. There was awareness that computing technology developed at a torrid place. Moore's Law, which states that the number of transistors on a chip doubles every year while the costs are halved, drives computing development. Investments in hardware can rapidly become obsolete.

So why not combine financial resources to invest in a much larger centralised supercomputing system?

This thinking came about when NUS and NTU were deciding to upgrade their supercomputing systems around 2012. At the same time, Singapore geared up its R&D and innovation agenda. About S$19 billion was budgeted for the latest five-year research and innovation plan from 2016 to 2020. Looking at this situation then, it would be useful for the Republic to invest in a larger supercomputer facility to support national research initiatives as well as academia and local industry.

The A*STAR leadership successfully persuaded the two universities to agree to invest in a petascale computing facility which would list Singapore among the top 500 largest supercomputers in the world. Other stakeholders were A*STAR and Singapore University of Technology and Design (SUTD). A*STAR conceived the plan, successfully getting the government to co-invest in such a facility.

Called the National Supercomputing Centre (NSCC) Singapore, it would push the innovation envelope, letting the scientific community to do research and topics they want to work on ▪

Lloyd's Register sets up a Group Technology Centre, part of collaboration with IHPC.

2012

SUPERCOMPUTERS IN THIS ERA

- CRAY J90
- CRAY XC-30
- FUJITSU PRIMERGY CX2550/2570

THE PETASCALE ERA

ACRC

The A*STAR Computational Resource Centre (A*CRC) provides the A*STAR research community with high performance computational resources. As A*STAR's supercomputing technical arm, it manages several high-end HPC clusters and data storage resources.

The universities were among the public-sector agencies that had their own supercomputing resources. NUS was a supercomputing pioneer, providing the initial thought leadership as well as usage and talent for this technology to advance in Singapore. The university's 30-year journey began in 1986 when Dr Thio Hoe Tong[1], then Director of NUS Computer Centre, included supercomputing facilities as part of the university's ICT masterplan.

THE FIRST TERAFLOP SCALE PC GRID IN THE REGION WAS QUICKLY ACHIEVED

2005

1 TFLOPS

COMPUTING POWER RAPIDLY EXPANDED WITHIN A SHORT TIME

2003

FIRST PC SUPERCOMPUTING GRID RUNNING AT

593 GFLOPS

2000

COMPAQ ALPHA SERVERS CAPABLE OF

52 GFLOPS

However, when the masterplan was implemented, supercomputing was excluded. From 1988, when NUS researchers needed high-end computational resources, they were re-directed to the supercomputing bureau Advanced Computation Centre[2], which was set up that year, and then later to the NSRC, which took over ACC's work in 1992.

NUS staff went over to the NSRC to help kickstart it. Tan Chee Kiow, who was with the NUS Computer Centre, became NSRC's first Executive Director. Another was Evelyn Lau, then an Administrative Assistant with NUS. At the NSRC, she managed administration and human resource activities, continuing in the same capacity later at IHPC. "There were about 40 of us, many from NUS," said Lau, who left IHPC for church work[3].

Researchers from NUS were among the biggest group of users at NSRC. However, not all were able to use the NSRC resources. Some researchers needed their own computational resources to push for certain research projects. Others with no access to supercomputing facilities were unable to continue with their research.

Gradually, over the past 30 years, the NUS expanded its supercomputing resources to meet the rise of complex computational projects, especially with the establishment of several research centres and institutes in NUS.

With growing demand, NUS set up its in-house resources called Supercomputing and Visualisation Unit (SVU) at the NUS Computer Centre (now called NUS IT). Among the SVU's first machines was the Cray J90 2.4 Gflops vector supercomputer and the SGI Onyx visualisation system.[4] In 2000, when the HPC cluster concept emerged, it was an early user, deploying a system based on Compaq Alpha servers capable of 52 Gflops. In 2003, it introduced the first PC supercomputing grid running at about 593 Gflops, which was soon expanded beyond 1 Tflops, making it the first Teraflop scale PC grid in the region.

With the rise of big data analytics and deep learning developments in the past few years, there had been an increase in supercomputing demand for data-centric research that would need, among other things, more computational power from GPU and other accelerators.[5]

Currently, the number of supercomputing users at NUS is about 1,500, up from fewer than 100 in 1995. Between 300 and 400 users each year are trained in supercomputing through workshops and seminars. Common application software used includes Matlab, Abaqus and Fluent[6].

Other universities in the Republic also have their in-house supercomputing resources. All are based on cost-recovery model, meaning that the researchers have to pay to use the resources.

By the 21st century, Singapore's ambition is to be an innovation-driven economy. This and supercomputing demand aggregation and centralisation of such resources were the key reasons for the establishment of the National Supercomputing Centre (NSCC) Singapore in 2015. By then, many companies had already benefited from supercomputing technologies. The majority collaborated with the IHPC to solve their complex computation problems. They include:

1. DESIGNING BUILDINGS

PIONEER SUPERCOMPUTING USER
DP Architects was an early user of supercomputing technology. Its specialist arm called the DP Sustainable Design (DPSD) comprises architects, environmental engineers and building analysts.
PHOTO COURTESY OF DP ARCHITECTS

At DP Architects (DPA), supercomputing use in computational fluid dynamics (CFD), augmented reality/virtual reality and building information modelling (BIM) have influenced the way its architects, engineers and ESD analysts design new buildings.[7] A leading Singapore architecture firm with 10 architecture-related specialist companies under one roof, DP is embracing computational design as a standard operating procedure. Technology helps architects make informed decisions, provides them with more design options and gives them a better understanding of the consequences of their designs, said Chan Hui Min, Director at DP Architects.[8]

Benefits of supercomputing include quick modelling of environmental conditions. An environmental response to wind and angle of sun, for example, can be computed by the firm's specialist arm, DP Sustainable Design to suggest ideas for energy-efficient buildings.

DP first used an early virtual reality (VR) software in 2000 when it refurbished the iconic General Post Office into the Fullerton Hotel.[9] The VR software in a special user lab called the CAVE allowed architects and designers to "enter" the Fullerton Hotel lobby to visualise colour schemes on the walls and furniture. It collaborated with the developers (Far East Organization) and IHPC on this project. A current project is Singapore University of Technology and Design where the firm used CFD for environmental design. The CFD techniques were used to ensure that the space would be well ventilated with comfortable wind velocities. The edges of the building were also rounded to prevent winds from creating uncomfortable eddies.

DPA installed its own supercomputing system around 2016, upgrading it in 2017 to a Dell system cluster with 172 cores. Working together with its specialist groups, APIs (application programming interfaces) are also written to help connect software used in current workflows to the high performance computing system.

InfiniCortex (IC) is demonstrated running at 100Gbps during SC14 in New Orleans.
2014

2. IMPROVING WEATHER FORECASTS

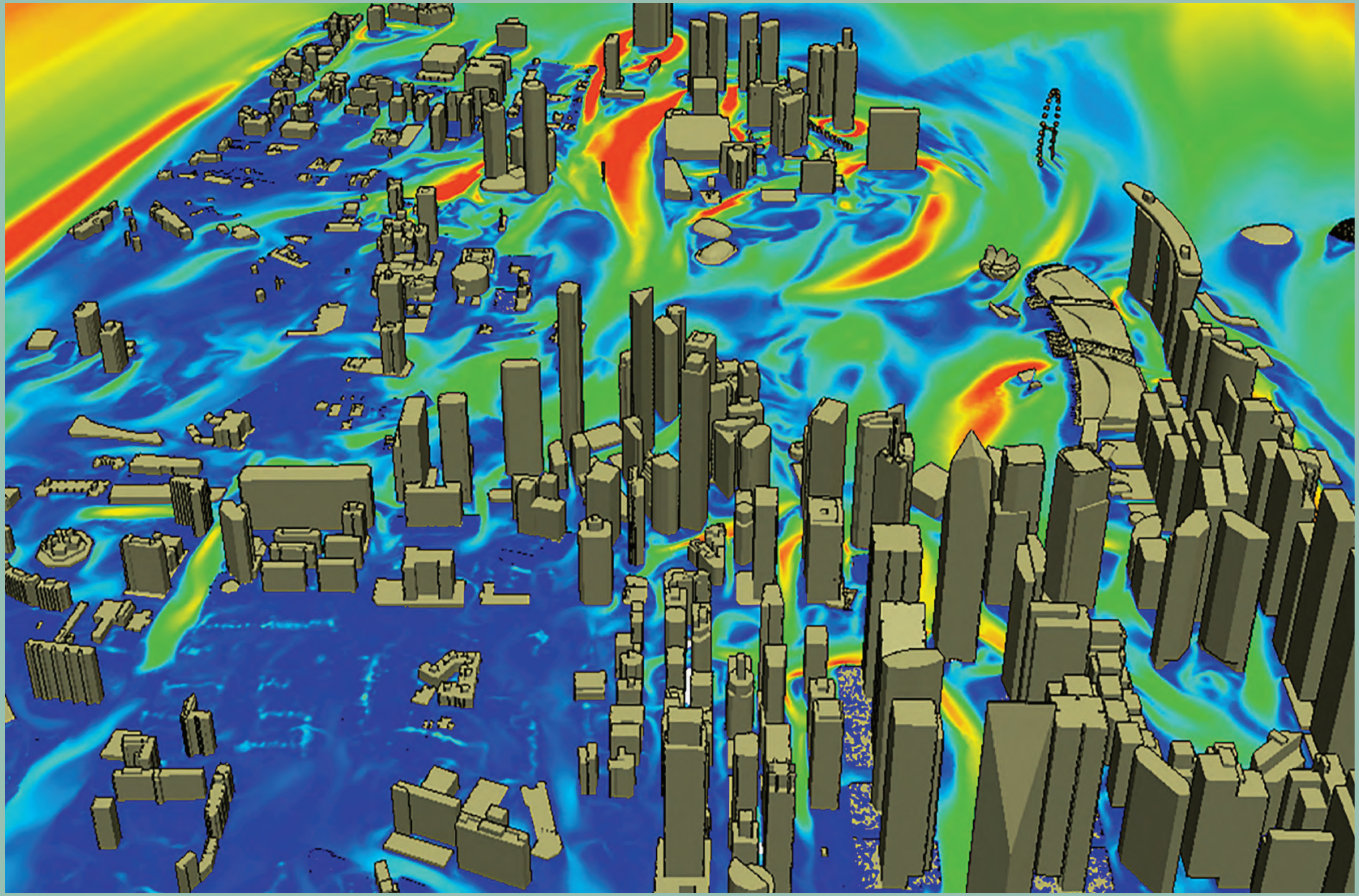
Behind the scenes of each weather forecast are supercomputers which crunch billions of weather data points – including temperature, humidity and wind direction and speed – to give reliable forecasts. Will the haze blow Singapore's way again? Will it rain during Chinese New Year, when the younger members of the community visit their elders to pay their respects?

Supercomputers at Meteorological Service Singapore (MSS) provide these forecasts so that people and businesses are better prepared for the haze, tropical storms or other weather events which can impact daily lives or people's livelihood.

MSS has used various supercomputers over the past 30 years to provide weather forecasts. It used different models of the NEC supercomputers. In 2014, it installed a Cray XC-30 machine with peak performance of 55 Tflops and the supercomputer has been upgraded in 2018 with new processors to a performance level of about 200 Tflops. In the early days, its modelling capabilities were restricted because the supercomputer power was restricted. In the 1990s, its supercomputers were running computer models of horizontal spatial resolution of 50km to 100km. Today, the models can focus on areas below 2km spatial resolution. The machines can also measure up to 40 levels of atmospheric layers, compared with just 10 to 20 years ago, the higher spatial resolution results in more detailed simulation of weather systems. Two decades ago, MSS could only predict the prolonged rain of the north-east monsoon surge a day or two in advance. With the progress in models and data processing, a monsoon surge can now be predicted several days in advance.[10]

CAPABILITIES OF SUPERCOMPUTERS AT METEOROLOGICAL SERVICE SINGAPORE

1990s	2018
AREA OF FORECAST **50-100 KM WIDE**	PINPOINT AN AREA OF **1.5 KM WIDE**
LEVELS OF ATMOSPHERIC LAYERS **5 LEVELS**	UP TO **40 LEVELS**
PREDICTION LEAD TIME OF NORTH-EAST MONSOON SURGE **1 TO 2 DAYS**	FORECAST AHEAD, **SEVERAL DAYS IN ADVANCE**



HOW IS THE WEATHER?

Benefits of supercomputing systems include quick modelling of environmental conditions, as illustrated in this screenshot of the software rendering. Data on wind, angle of sun and number of rain days, for example, can be computed to suggest ideas for energy-efficient buildings.

PHOTO COURTESY OF IHPC

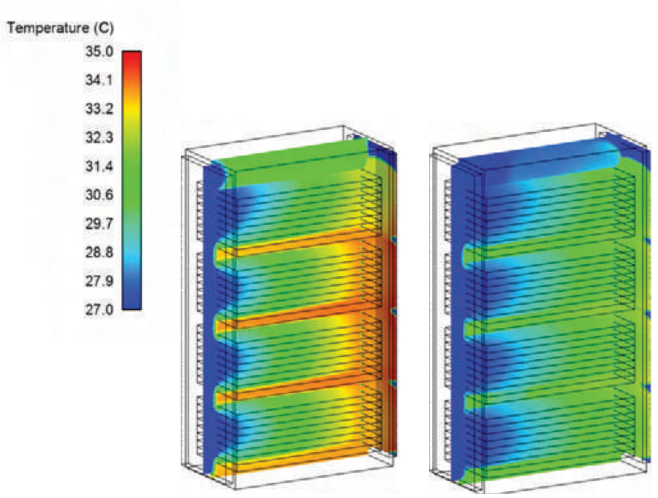
3. GREENHOUSE EMISSION

Local data centre equipment company ERS Industries used CFD to study the flow of air in and around the racks of servers in a data centre. This resulted in solutions that ensured the maximum amount of air flow and the best cooling conditions for a data centre layout at a minimum fan and air-conditioning operating cost. Through collaboration with IHPC, ERS is the first and only Singapore-based rack manufacturer for the data centre industry to use CFD simulations in the design process and verify CFD-assisted design upon deployment.

Based on its solution, ERS expanded its services to solve challenging thermal-fluid problems associated with designing new products, including hot/cold containments, exhaust chimneys and inlet louvres.

4. DEEP-TUNNEL SEWERAGE SYSTEM

In the late 2000s, the Public Utilities Board (PUB) embarked on a S$2.7 billion deep-tunnel system to move waste water and other effluents underground to water-treatment plants. The flow of liquids in the 48km tunnels meant the moving of an enormous amount of liquids, resulting in massive calculations[11], letting engineers design the right tunnels. Using modelling and simulation, the engineers were able to understand the effluent flow to ensure building accuracy. The project was successfully completed in 2008.



BEST COOLING CONDITIONS
Through collaboration with IHPC, ERS Industries is the first and only Singapore-based rack manufacturer for the data centre industry to use CFD simulations in the design process and verify CFD-assisted design upon deployment.
PHOTO COURTESY OF IHPC

PETASCALE COMPUTING

While supercomputing technology gained recognition, the landscape from a national level appeared fragmented. For a small country with limited resources, policymakers once again decided that it was better to centralise expensive resources for better sharing.

A*STAR TOOK THE LEAD TO CONVINCE THE TWO UNIVERSITIES THAT CO-INVESTING WITH THE GOVERNMENT FOR A SHARED FACILITY WOULD BE A WIN-WIN SITUATION FOR ALL PARTIES.

By the late 1990s and early 2000s, several organisations like the Bioinformatics Institute had their own supercomputing initiatives. They bought and deployed their own systems. Supercomputing consultant Nebojsa Novakovic,[12] who has worked closely with the various supercomputing agencies in the past 20 years, observed that there was little sharing of resources among them. Each had its own budget and was protective of its resources and facilities.

Efforts to bring the resources together began with the hiving-off of the ICT hardware teams – including resources such as storage and networking – at IHPC and BII to set up A*STAR Computational Resource Centre (A*CRC) in 2007. That provided some centralisation and sharing of resources. But the computing power was still not enough.

Around 2008, NUS and NTU looked into upgrading their supercomputing systems. This spurred discussion that the universities should combine efforts to build a more powerful supercomputing facility. Resources could then be shared. Besides, Singapore's supercomputing systems then were in the 100 Tflops range. Policymakers recognised that this computational capacity was not enough for Singapore, which was moving towards an innovation-based digital-driven economy.

A*STAR took the lead to convince the two universities that co-investing with the government for a shared facility would be a win-win situation for all parties.[13] With a bigger pot of money, a more powerful system, hopefully in the petascale ambit, could be deployed and shared among the different parties.

A*STAR Chairman Lim Chuan Poh[14] recognised that, in some classes of research, the speed of computational solution is critical, which means that a much more powerful system is needed. But it would not be sufficient for such a supercomputing facility, he emphasised, to show only higher speed but to also demonstrate meaningful outcomes and impact for Singapore. "The value of supercomputers (is) to push the envelope, to do the research and work on the topics we identify."

Dr Raj Thampuran[15], A*STAR's Managing Director, put it succinctly: "We've an economic agenda for our supercomputing strategy, that is offer access to supercomputing resources to the private sector in Singapore so

LIM CHUAN POH
Supercomputing must push the research envelope especially on the topics Singapore has identified.
PHOTO COURTESY OF A*STAR

that they can do the high-value computer modelling and simulation work to improve its competitive advantage. In the process, the multinationals who have invested in Singapore would be encouraged to use the facilities, which could bring new types of activities here and create jobs locally."

Supercomputing would be treated as a utility like water and electricity. It would be a workhorse opening access to as many users as possible. There would be no heroic supercomputing here like nuclear fission. Instead, supercomputing would be tailor-made to suit the Republic's strategy in applied science and solve industry challenges. The remaining issue then was to decide on the right size of petascale computing facility and an upgrade path to avoid technological obsolescence. This was the continuation of a strategy that started in 1988, when the supercomputing strategy was first proposed. This strategy will prevail for many more years.

PROFESSOR TAN TIN WEE
Founding Chief Executive, National Supercomputing Centre (NSCC) Singapore and member of Internet Hall of fame.
PHOTO COURTESY OF NSCC

While this discussion continued in the government, the leadership at the A*STAR Computational Resource Centre and IHPC were drawing up plans for such a facility. Prof Tan, who became Chairman of A*CRC in 2011, was roped in as part of the project for the National Supercomputer Centre, (NSCC) Singapore. Prof Tan is a biochemist with tech savviness honed from years of being involved in the early days of Internet development in Singapore, first at NUS, then at the Asian level TCP/IP networking community. For his work in multi-lingual Internet domain name system, he was inducted into the Internet Hall of Fame in 2012. As plans progressed, he became the director-designate for the National Supercomputing Centre (NSCC) Singapore.

Finally, the NSCC was approved and it was established in 2015 with Prof Tan as the Chief Executive. Its stakeholders are A*STAR, NUS, NTU and SUTD. Its budget over three years was S$98 million. The government put in the bulk of the money with the remaining coming from the other stakeholders.

ASPIRE 1

A pro-tem committee chaired by Dr Raj Thampuran, A*STAR Managing Director, was set up in 2013 to look into procuring Singapore's first supercomputer. After investigations and study trips overseas, NSCC decided on the Fujitsu Primergy CX2550/2570, an HPC cluster. Called Advanced Supercomputer for Petascale Innovation Research and Enterprise or Aspire 1, it was unveiled in 2016. To facilitate usage, NSCC rolled out high-speed networks to the three universities so that researchers there could remotely access Aspire 1. Via SingAREN (Singapore Advanced Research and Education Network), a fast-speed national research and education network, it is linked to the global scientific community.

In designing Aspire 1, the aim was to enable speedy communications between the millions of data points. The bottleneck is getting the data transferred between the CPU and the memory. This is an ongoing challenge resolved by ensuring very fast networks like InfiniCortex in the data centre.

The 1 Pflop HPC cluster is based on Fujitsu's x86 architecture series called Primergy, comprising about 1,288 nodes and about 31,000 cores. The system has 13 PB storage with an input/output burst rate of 500 GB per second and a total memory of 229 TB. When it was launched, Aspire 1 was ranked 93rd most powerful supercomputer in the Top500 list released in June 2016 and the highest ranked system in Southeast Asia. As a comparison, Aspire 1 is about one-tenth the processing power of the Japanese K supercomputer located at the Riken Advanced Institute for Computational Science, Kobe, Japan. In 2018 Aspire 1 was beefed up with six units of Nvidia DGX-1 systems comprising 48 units of Nvidia V100 GPUs. As ASPIRE 1 was designed and installed before the current Artificial Intelligence (AI) wave hit the supercomputing community, theses GPUs therefore provided ASPIRE 1 with greatly enhanced capabilities for AI workloads.

It fell on Tay Kheng Tiong, previously the CIO of NTU, to implement Aspire 1. He co-chaired the implementation committee together with Prof Tan, Chief Executive of NSCC. Both were members of the pro-tem committee. Tay's implementation strategy was based on a basic principle: efficiently deliver supercomputing services to scientists and researchers.

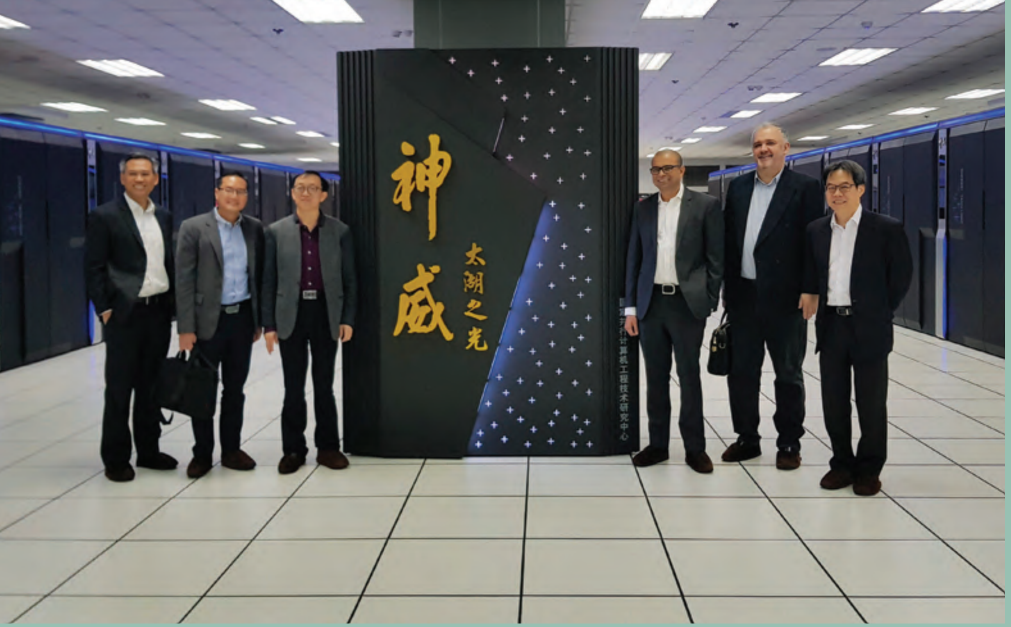
"It was not about building a new facility. I focused on the 4Ps of service delivery – people, process, products and partners. There must be people with the skills to deploy the supercomputer, the correct process must be taken to roll out services, the product must offer relevant solutions and the partner which is Fujitsu, must work as a team with us," said Tay, Executive Director of A*CRC.

Among the challenges Tay faced was that the supercomputer was housed on the 17th floor of Fusionopolis. The committee had to ensure that the floor could handle the giant weight of the Fujitsu system. Supercomputers also need lots of electricity. Consuming about 1 megawatt a day, special electrical cables had to be trunked up to the 17th floor.

The other challenge was the warm water cooling system for Aspire 1, a first in Asia. Data centres require air-conditioning because all microprocessors generate heat. However, Aspire 1 is cooled by warm water and this substantially reduced its cooling bill.

Dr Marek T Michalewicz organises Supercomputing Frontier, a supercomputing conference which is now called SCAsia.
2015

Ministry of Trade and Industry gives Prof Tan Tin Wee and his team from A*CRC the Gold Award for leading the InfiniCortex project.
2015



DEEPENING COOPERATION BETWEEN SINGAPORE AND WUXI SUPERCOMPUTING CENTRE
Dr Janil Puthucheary, Senior Minister of State, Ministry of Communications & Information and Ministry of Transport (third from right) led Singapore team to visit Wuxi and discuss further collaboration.
PHOTO COURTESY OF MINISTRY OF COMMUNICATIONS & INFORMATION

COMMISSIONING OF ASPIRE 1
NSCC steering committee Chairman Peter Ho (right) officiated at the launch of Singapore's first petascale supercomputing system in 2016. Prof Tan Tin Wee (left) is NSCC's Chief Executive.
PHOTO COURTESY OF NSCC

INAUGURAL HPC-AI COMPETITION
George Loh (left), Director, Programmes, National Research Foundation, in a discussion with Charlie Foo (third from right), Vice-President and General Manager of Asia Pacific and Japan, Mellanox, Prof Tan Tin Wee (first from right), Chief Executive, NSCC.
PHOTO COURTESY OF NSCC

NSCC's Technical Director Stephen Wong explained: "All the microprocessors don't need to be cooled to 20°C. Instead, they can operate at 60°C to 70°C. Hot water is circulated directly to the CPUs in place of conventional cooling. To maintain the water temperature at 40°C to 45°C, water is pumped to a dry cooler system above the data centre. There ambient air cools the water which is then fed back to circulate in the data centre."

Through this warm water cooling system, the power usage effectiveness (PUE) is 1.3 – which means that, for every dollar NSCC spends on the IT load, 30 cents is spent on cooling. This is much better than the government target of a 1.6 power ratio.[16]

In the past three years, demand for Aspire 1 has been off the charts with demand outstripping its capacity. Wong said the machines are already running throughout the day with a high percentage of CPU cycle used. Protein folding, he added, is the highest workload among all the science and engineering computations submitted. Demand is much greater than available resources can provide.

The NSCC also supports key national initiatives in precision medicine, genomics and offshore and marine research. IHPC tops the user leader board. In apportioning demand, NUS, NTU and SUTD researchers have priority because they are the key stakeholders in NSCC. Others have to join the queue. Key applications pulling at the resources include the modelling and simulating of oil rigs to be used at sea and micro climate environments in Singapore. Some juggling in schedule and provisioning of resources are needed on a daily basis to ensure everyone gets a fair and equitable share.

> IN THE PAST THREE YEARS, DEMAND FOR ASPIRE 1 HAS BEEN OFF THE CHARTS WITH DEMAND OUTSTRIPPING ITS CAPACITY. WONG SAID THE MACHINES ARE ALREADY RUNNING THROUGHOUT THE DAY WITH A HIGH PERCENTAGE OF CPU USED.

To help those users who are in the queue but need to get the supercomputing resources quickly, Wong's team is trying to buy computation time from commercial cloud vendors such as Amazon Web Services and Microsoft Azure unit. "We are trying to establish collaborations with other bigger cloud operators where they can rent or sell supercomputing resources to us."

These collaborations will be for research workloads that are amenable to cloud architecture like life science projects which do not need fast network ccommunications between processors. AI research requires more computational power. It is like throwing data into a black box, with each data point able to influence each other. Hence greater computing crunching power is needed to process the data.[17]

OUTREACH ACTIVITIES

Apart from enabling users to solve scientific and technological problems, NSCC also undertakes outreach activities. Annually, it holds a supercomputing conference called SCAsia, which gathers global thought leaders to discuss key supercomputing and related issues here. In 2018, there were 800 participants from 24 countries. It also holds events and workshops to allow members of the supercomputing community to network and share expertise. It also held in 2018, an inaugural Asia-Pacific HPC-AI competition which was won by China's Tsinghua University team. Participants were given problem statements, such as simulating the speed of a weather forecasting application, to solve.

TOMORROW'S HPC PROFESSIONALS
Participants of the first HPC-AI competition come from the Asia-Pacific region.
PHOTO COURTESY OF NSCC

The outreach activities include collaboration and information exchange with the overseas supercomputing centres. One such collaboration was inked during a recent visit to the National Supercomputing Centre in Wuxi, China, which built the world's fastest supercomputer with 10 million cores compared to 31,000 cores in Aspire I. The Singapore team, led by Dr Janil Puthucheary, Senior Minister of State (Ministry of Communications & Information and Ministry of Transport), witnessed the signing of the collaboration for technology development among three parties, namely, the Wuxi National Supercomputing Centre, the Infocomm and Media Development Authority and NSCC.

For Dr Puthucheary[18], the Wuxi visit threw up an interesting observation on talent and manpower development. These two issues are crucial considerations for future supercomputing advancement in Singapore and overseas. Demand for supercomputing is increasing, experts are urgently needed to support such activities. Dr Puthucheary remarked that both Wuxi centre and NSCC would need to inspire students to study supercomputing-related disciplines.

LESSONS FROM HISTORY

A centralised shared supercomputing facility that is the NSCC looks much like how the NSRC operated when it was set up in 1992. Is the NSCC a duplicate of the NSRC?

In 1988, when Singapore initiated its supercomputing strategy, it was too ahead of the technology adoption curve. Big users were the government, namely, defence, just like in the US. Besides, the early supercomputers were not powerful enough for massively complex computation work. Users were also lacking. Local companies circa 1990s were not sophisticated technology users. Multinational corporations depended on their own supercomputing facilities back in their headquarters in the US and Europe.

There was also the absence of a supercomputing talent stack needed to ensure that research projects hum along without hiccups. Scientists, the domain experts in biology, chemistry and other sciences, are a critical part of the stack. They work closely with computational scientists, who are the supercomputing experts, and code optimisers, who know which software to use for the appropriate computation. They also know how to program, optimise the code and undertake the computer modelling. Then there are the infrastructural professionals, the ICT folks, who look after the supercomputing systems. Parallelling this is the business development team to corral in the customers.

IN 1998,WHEN SINGAPORE INITIATED ITS SUPERCOMPUTING STRATEGY, IT WAS TOO AHEAD OF THE TECHNOLOGY ADOPTION CURVE. BIG USERS WERE THE GOVERNMENT, NAMELY, DEFENCE, JUST LIKE IN THE US.

At the NSRC, it was missing parts of this stack. It had the machines and many users were scientists from NUS and NTU but there were few industry customers. It had the technical team to provide support. The challenge was that the scientists from the universities just used the NSRC, it did not contribute any scientific knowledge. And NSRC had only a few supercomputing experts.

The NSCC has a more complete supercomputing stack. It has a group of ready users, namely, stakeholders whose scientists use up most of its computation resources, a business development capability to look for new customers and an in-house technical support which is backed up by additional resources from Fujitsu. Users are also more technologically savvy and it helps that organisations understand that technology is the key driver for tomorrow's success. The only factor it lacks is scientists but, because a major stakeholder is A*STAR, it has closer affiliation to the scientific community.

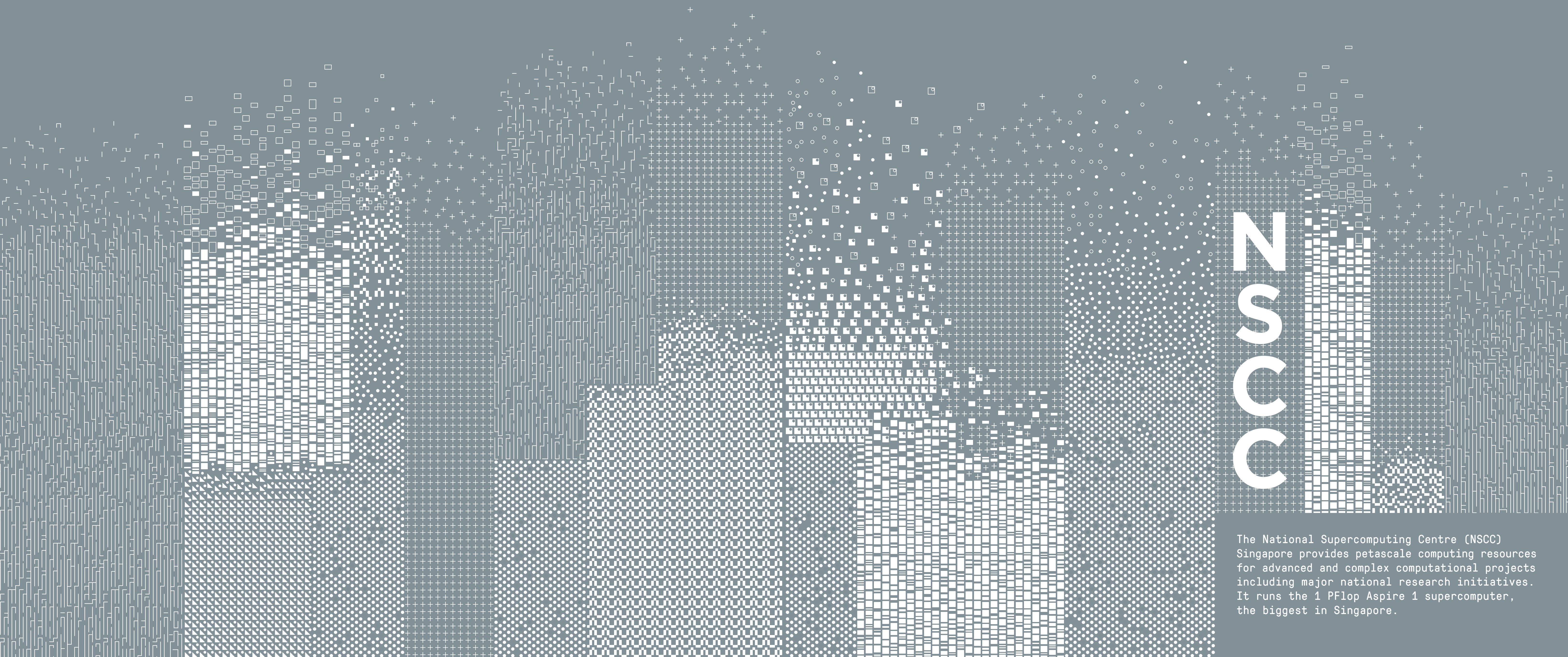
Ultimately, whether the NSRC model is repeated in NSCC is not the issue. Organisational dynamics aside, the crucial thread in this discussion must be that similar ideas need to be tweaked and improved so that lessons from history can light a path to the future.

One aspect shines through: There is a lot of heart and ambition among the leadership teams, as well as staff, some of whom have long been associated with the supercomputing agencies, to encourage advancement of the technology and its use at the NSCC and, for that matter, in all the related agencies. They do not equal success but they push the journey along much faster. Persistence always pays ▪

NTU team wins annual Student Cluster Competition at supercomputing conference in Denver, US.
2015

5 CHAPTER

THE FUTURE



The National Supercomputing Centre (NSCC) Singapore provides petascale computing resources for advanced and complex computational projects including major national research initiatives. It runs the 1 PFlop Aspire 1 supercomputer, the biggest in Singapore.

The three-decade story of Singapore's supercomputing journey set out in the previous chapters was viewed mostly through the lens of policy makers, ICT pioneers, researchers and scientists and industry executives involved in the development of this field.

The key players in this development, which also involves the establishment of the NSCC, include the National Research Foundation, A*STAR and the local universities. That the government played a fundamental role as masterplanner was to be expected as it was about capability development during this period.

With NSCC 1, which is its first three-year phase, at its end, a new proposal and strategy are due soon. At the time of writing, the plan for an improved supercomputing facility, let's call it NSCC 2, has not been finalised. Definitely, it will include funding for a better performing supercomputer facility. As in the case of all projects in Singapore, funding will be based on the potential uses and benefits rather than the goal of simply deploying a high performance computing system that is among the fastest in the world.

THE CASE FOR NSCC 2

A quick revisit on the discussion for NSCC 2 leadership-class petascale computing facility.

Adoption of supercomputing has risen over the last three decades. Users include the public and private sectors, enterprises and the scientific community. At IHPC, there is more demand for industry work than the institute can cope. These are good signs that would lead to greater adoption of supercomputing technology, said seasoned ICT Executive Dr Simon See of Nvidia.[1] The rise of AI, machine learning and deep learning will further hasten the use of supercomputing as voluminous data needs intensive computation power.

Supercomputing applications are countless and growing in science, medicine, engineering and other fields. They are used to improve products, reduce production costs and decrease the time it takes to develop new items. With the technology, architects can build more energy-efficient buildings while engineers can design better and safer cars and planes. Scientists use supercomputing capabilities to design new drugs and simulate its side effects faster, safer and more efficiently. Providing a roadmap for further petascale computing will facilitate further research to solve complex problems and, more importantly, attract talent to Singapore.

Over and above all, petascale computing is vital for cyber defence. Singapore is a prime target for cyber criminals, gangs, hacktivists and even state actors. Between April 2015 and June 2016, Singapore came under 16

VIPS VISIT NSCC

NSCC hosted Cabinet ministers and senior civil servants in 2018. The visitors included Deputy Prime Minister Teo Chee Hean and Finance Minister Heng Swee Keat (fifth and sixth from left, respectively), and Prof Low Teck Seng, Chief Executive Officer, National Research Foundation and Yong Ying-I, Permanent Secretary, Public Service Division (second and third from left, respectively). Representing the hosts were A*STAR Chairman Lim Chuan Poh (fourth from left) and NSCC Chief Executive Prof Tan Tin Wee (extreme right).

PHOTO COURTESY OF NSCC

ASPIRE 1

Southeast Asia's biggest supercomputer, Aspire 1 boasts a unique cooling system which makes use of warm water to cool its microprocessors.

PHOTO COURTESY OF NSCC

TOP SUPERCOMPUTERS IN THE WORLD - JUNE 2018

#1
UNITED STATES, SUMMIT
122 PFLOPS

#2
CHINA, SUNWAY TAIHULIGHT
93 PFLOPS

#11
SOUTH KOREA, NURION
13.9 PFLOPS

#29
SAUDI ARABIA, SHAHEEN II
5.53 PFLOPS

#50
JAPAN, SORA-MA
3.1 PFLOPS

waves of malware and phishing attacks.[2] The latest attack in July 2018 was on healthcare provider SingHealth which saw the personal information of 1.5 million patients stolen by cyber attackers.[3]

In this current age of ballooning network traffic and increasing file sizes, organisations face a daunting task of being able to detect cyber intrusions almost instantly before damage can be done. The major challenge is to derive relevant security data from massive databases, which are continuously receiving data flows, even during attacks. Timely, effective scrutiny needs advanced analytic power that only supercomputing systems can provide. The technology can also be used for modelling and simulating cyber attacks and defence scenarios.

Supercomputing can support Smart Nation initiatives which seek to use digital innovation to provide citizens with good jobs and an exceptional quality of life. One area is anticipatory governance. Singapore is good at responding reactively and quickly to problems raised by citizens, said Dr Goh Eng Lim, a seasoned supercomputing Executive with Hewlett Packard Enterprises.[4] Public-sector agencies can use the predictive analysis made possible by supercomputers to anticipate problems and the needs of its citizens.

A leadership-class supercomputing facility will be a step up beyond the 1 Petaflop of Aspire 1, the fastest supercomputer in Singapore. In the listing of top supercomputers in the world, the US and Chinese installations mostly lined up the top 20 global supercomputing systems. Summit, a 122 Petaflop machine installed at Oak Ridge National Laboratory in the US is currently the fastest supercomputer in the world followed by Sunway TaihuLight at the National Supercomputing Center in Wuxi, China, with a 93 Petaflop machine.[5]

After that the performance varies. At 11th position is Nurion, a 13.9 Petaflop system at the Korea Institute of Science and Technology Information, South Korea; 29th is Shaheen II a 5.53 Petaflop machine at the King Abdullah University of Science and Technology, Saudi Arabia; 50th position is Sora-Ma, a 3.1 Petaflop machine at the Japan Aerospace eXploration Agency. As of this writing, NSCC Aspire 1 is ranked 264th in the Top500.[6]

Singapore supercomputing deployment needs to be comparable to the rest of the world, said Dr Janil Puthucheary, Senior Minister of State, Ministry of Communications and Information.[7] There will always be a need for more computational power but what is sufficient, he asked.

DR JANIL PUTHUCHEARY
SENIOR MINISTER
OF STATE
"Singapore supercomputing deployment needs to be up there with the rest of the world".
PHOTO COURTESY OF MINISTRY OF COMMUNICATIONS & INFORMATION

A balance is needed, he stressed, between significant improvement in computational power and capacity to meet future projects and demand.

It would be advantageous if NSCC 2 can be among the top 50 in the world. Singapore is not in an "arms race" for supercomputing performance so it should not take on American and the Chinese supercomputing deployments in the top 10 positions. But industry observers believe Singapore could easily step up with a new supercomputing deployment system that would rank it anywhere between 11th and 50th in the Top500 supercomputing listing. This would make the world sit up and take notice, giving Singapore credibility and a voice in the world supercomputing community.

Professor Lawrence Wong of NUS[8], who has been involved in networking for many years, said such a ranking would mean a supercomputing facility with sufficient power and performance, with a little bit of buffer, for future projects.

As a more computationally powerful system is envisaged for NSCC 2, existing data centres which are connected to it may not be conducive. They may not have enough electrical power or space. On the other hand, with today's supercomputers getting smaller and lighter, the footprint will be smaller which makes housing it in a high-rise building more probable.

Despite this sense that Singapore is still "young" in supercomputing, the country has earned a good reputation for its high performance computing journey, said Dr Kahaner, Chairman of IHPC's advisory board from 1998 to 2000.

The country has developed a deep understanding of the supercomputing software needed to run engineering applications. It also is becoming known for its ability to help organisations resolve industry challenges using supercomputing, added Dr Kahaner who was last in Singapore in 2017 to attend a supercomputing event.

BHAG NEEDED

NSCC 2 needs BHAGs – big hairy audacious goals – to create a greater impact in the supercomputing community in Singapore and beyond.

One comes to mind. Why not commercialise the InfiniCortex (IC)? Conceived at the A*CRC, it extended the global range of the InfiniBand communications protocol. A*CRC has successfully demonstrated it running at a high bandwidth of 100Gbps linking Singapore's supercomputer to another in New Orleans during the supercomputing conference SC14 held in that city.

This technology, however, is collecting dust, left unused. As a BHAG, IC can be used to link key data centres in Singapore creating a supercomputing cloud and grid network. Data centre resources can be shared, provisioned out as and when needed. Lag would be forgotten, users will welcome a world of high data throughput and low latency. Once it is used here, it can be exported to other countries as well. More, it could be used to connect all supercomputers here to regional systems, hence creating an uber supercomputing network.

Another option under consideration is to build on the experimental success of InfiniCortex to establish production links to other supercomputing centres in the world to give local researchers the opportunity to access the largest supercomputing resources.

COMMERCIALISING IC WOULD BE A FEATHER IN THE CAP FOR SINGAPORE'S SUPERCOMPUTING CAPABILITY. THE CHALLENGE IS TO FIND A COMPANY THAT CAN "PRODUCTISE" IT.

Commercialising IC would be a feather in the cap for Singapore's supercomputing capability. The challenge is to find a company that can "productise" it. There are local companies with product development and marketing experience that can do this.

The second BHAG is also about creating new supercomputing solutions. Exploit a more powerful NSCC 2 for predictive work. For example how to deal with haze. Wouldn't it be nice if a supercomputer in Singapore can reduce the haze via computer modelling and simulation? Said Dr Goh: "Can we find out that if all the buildings are built this way, trees planted that way, haze can be re-directed or dispersed? Computer modelling and simulation may also show that 80 per cent of citizens will experience 40 per cent less haze if urban planning followed this model."

The skills gained from doing this is exportable, said Dr Goh. Some Asian cities suffer from air pollution, others from sand storms. They would be interested in the Singapore expertise to help them manage their environments. Hence at the national level, pre-emptive initiative requires the public sector to "own their compute power and simulation to answer all the what ifs".

The new technology that is gradually creeping to the surface is the third BHAG for NSCC 2 to pursue: quantum computing.

Quantum computing is completely a new form of computing, with capabilities and power far greater than that from the abacus to a modern-day supercomputer, and with performance gains in the billion-fold realm and beyond.[9] Just like 30 years ago, Singapore entered the supercomputing technology when it was still developing, it has to do the same with quantum computing. How can NSCC 2 play a role in quantum computing? For a start, it could collaborate with the Centre of Quantum Computing at the NUS to see how supercomputers can leverage on the new technology.

Another option under consideration is to build on the experimental success of InfiniCortex to establish production links to other supercomputing centres in the world to give local researchers opportunity to access the largest supercomputing resources.

TALENT CHALLENGE

As in all ICT fields, talent for supercomputing skills are lacking. Supercomputing needs computational scientists who understand computing and science domains so that they can apply the best algorithm to run the computation. Fujitsu, which supplied Aspire 1, found it difficult to find local expertise capable of operating a petaflop computing infrastructure.[10] Ultimately, it deployed a team from Fujitsu Japan for installation while support at that time was provided by a six-man local team comprising foreigners except for one Singaporean. NSCC now has its own technical group supported by Fujitsu's team.

> SUPERCOMPUTING NEEDS COMPUTATIONAL SCIENTISTS WHO UNDERSTAND COMPUTING AND SCIENCE DOMAINS SO THAT THEY CAN APPLY THE BEST ALGORITHM TO RUN THE COMPUTATION.

Dr Goh urges that it is important to get computational scientists because the technology is a multi-disciplinary field. Biologists, physicists and other researchers have different ways of investigating scientific theses. In civil engineering for example, the investigations revolve around fluid dynamics like wind flow. In fintech, the problems are about analysing data. Because of the multi-disciplinary nature of various domains, there are not enough experts with a background in both the domain-specific knowledge and the supercomputing computational approaches that need to be taken.

It is time to re-start the computational science course that ran from the 1990s to the early 2000s at NUS.

There are now appreciable demands for supercomputing as research in the deep tech and science such as material simulation, ocean-basin studies, advanced simulation of aerodynamics are making demands on supercomputing. Looking into the future, developing talent should be a key role for NSCC.

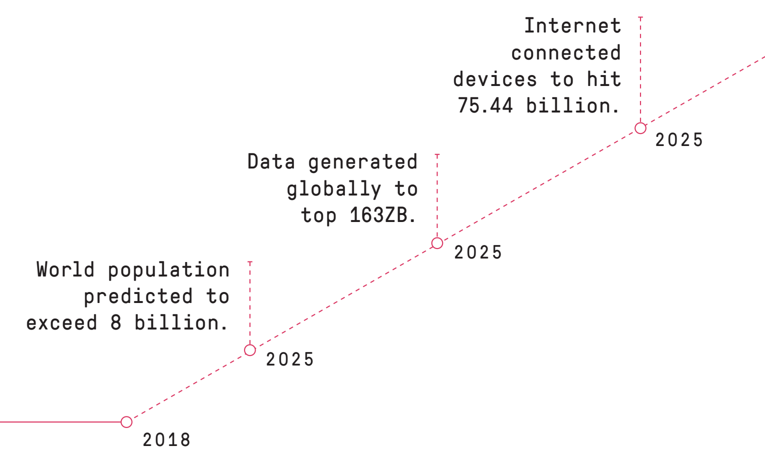
NSCC TEAM
Led by Chief Executive Prof Tan Tin Wee (front row, fifth from right), NSCC is driven by a passion to advance supercomputing in industry, business and education.
PHOTO COURTESY OF NSCC

THE NEXT 30 YEARS

Singapore is leading in supercomputing in the region because of early and sustained leadership in computing, a strong set of mission drivers, outstanding higher educational system and strong support from agencies. It is set to play a larger role in advancing supercomputing capabilities in Asean.

A*CRC CEO Tay Kheng Tiong is chairing a task force for Asean high performance computing. It is conceived to be a shared facility for Asean's 10 member states linked by mesh network set up in the region. A facility will be set up with its own supercomputers. However, discussions are in early stage and no decision has been made on where the facility will be based.

Asean leadership in supercomputing will add to Singapore's lead in this area. But its leadership-class petascale computing facility, that is, NSCC 2, will bolster Singapore's reputation as the technology hub in Asean. The Republic will be where the region's diverse data intensive workflows are stored, computed and distributed at the highest performance in terms of scale, throughput and data analytics ▪



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AGENCIES

- ADVANCED COMPUTATION CENTRE (ACC)
- NATIONAL SUPERCOMPUTING RESEARCH CENTRE (NSRC)
- INSTITUTE OF HIGH PERFORMANCE COMPUTING (IHPC)
- A*STAR COMPUTATIONAL RESEARCH CENTRE (A*CRC)
- NATIONAL SUPERCOMPUTING CENTRE (NSCC) SINGAPORE

1988-1992
ADVANCED COMPUTATION CENTRE (ACC)

1988-1992
Chew Chan Yong,
Director

1993-1997
NATIONAL SUPERCOMPUTING RESEARCH CENTRE (NSRC)

1993-1994
Tan Chee Kiow,
Executive Director

1994-1996
William Hale,
Executive Director

1996-1998
Peter Boek,
Executive Director

1998-CURRENT
INSTITUTE OF HIGH PERFORMANCE COMPUTING (IHPC)

1998-2003
Prof Lam Khin Yong,
Executive Director

2003-2006
Associate Prof
Lee Heow Pueh,
Executive Director
(Acting)

2006-2010
Dr Raj Thampuran,
Executive Director

2010-2012
Dr David Srolovitz,
Executive Director

2012-2018
Prof Alfred Huan,
Executive Director

2018-CURRENT
Dr Lim Keng Hui,
Executive Director

2010-CURRENT
A*STAR COMPUTATIONAL RESEARCH CENTRE (A*CRC)

2007-2009
Dr Raj Thampuran,
Executive Director

2009-2016
Dr Marek Michalewicz,
Chief Executive Officer

2017-CURRENT
Tay Kheng Tiong,
CEO

2015-CURRENT
NATIONAL SUPERCOMPUTING CENTRE (NSCC) SINGAPORE

2015-CURRENT
Prof Tan Tin Wee,
Chief Executive

1988 1993 1994 1996 1998 2003 2006 2007 2009 2010 2012 2015 2017 2018

ADVANCED COMPUTATION CENTRE (ACC)
Singapore's first bureau offering supercomputing services to the public and private sectors. Set up as a private company in 1988, it is a pioneer in the government's journey in supercomputing

ASPIRE 1
Advanced Supercomputer for Petascale Innovation Research and Enterprise is the name of Singapore's first 1 Petaflop supercomputer.

A*CRC
The A*STAR Computational Research Centre provides high performance computing resources for all of A*STAR research institutes, which number more than 20. It was formed in 2007 with the hiving off of the ICT hardware offices including the storage and networking units of two agencies, namely, the Bioinformatics Institute (BII) and the Institute of High Performance Computation (IHPC).

A*STAR
Agency for Science, Technology and Research is a Singapore statutory board, tasked with scientific discovery and technological innovation to drive economic growth and create jobs for the country. It also nurtures and develops talent for Singapore's research institutes and industry as well as the wider research community.

CCM
Centre for Computational Mechanics was set up at NUS in 1994 to undertake computer modelling and simulation research in applied science and engineering. It was involved in research and undertook industry projects.

CFD
Computational fluid dynamics is the use of applied mathematics, physics and computational software to visualise gas or liquid flows and the way they affect objects as they flow past.

CNC
Committee on National Computerisation was set up by the Singapore government in 1980 to chart Singapore's computerisation strategy.

CORES
A core is the processing unit that receives instructions and performs calculations, or actions, based on those instructions. A set of instructions can allow a software program to perform a specific function.

DSTA
Defence Science and Technology Agency is a statutory board under the Ministry of Defence responsible for harnessing science and technology to meet the defence and national security needs of Singapore. It also provides technological and engineering support.

GPU
The graphics processing unit is specially designed to handle intensive graphics-rendering tasks. It accelerates processing so that instructions can be completed faster.

GRID COMPUTING
Grid computing is the use of widely distributed computer resources to crunch a large number of files. Grid computers are different from supercomputer systems in that in grid computers, they each have a node to perform specific task or application.

HIGH PERFORMANCE COMPUTING (HPC) CLUSTER
A high performance computing cluster is a group of high-end servers networked together to be used to crunch a lot of data. It is more complex than a simple desktop computer and is used for advanced computational needs.

IHPC
The Institute of High Performance Computing came into being in 1998 with the merger of the NSRC and the Centre for Computational Mechanics. It was formed to undertake applied research in supercomputing so as to help industry better solve problems that need bigger compute power.

MSS
Meteorological Service Singapore is the national authority on the weather and climate. A key responsibility is the provision of round-the-clock weather forecasts, warnings, monitoring and assessment for critical sectors such as civil aviation, military, maritime, private or public agencies and the general public.

NCB
The National Computer Board was set up in 1981 to drive Singapore's computerisation strategy and to develop the Republic as a regional centre for computer software development and services. It was tasked with three functions, namely, to computerise the Civil Service, coordinate computer education and training and to develop and promote the computer services industry.

NSRC
The National Supercomputing Research Centre is a shared supercomputing research centre offering services to the public and private sectors. Set up in 1992, its primary aim was to help industry with their complex computational problems.

NSTB National Science and Technology Board is the predecessor of A*STAR.

NUS Founded in 1905, the National University of Singapore is the oldest tertiary institution in Singapore as well as the largest in the country in terms of student enrolment and curriculum offered. It is a comprehensive research university with an entrepreneurial dimension, offering a wide range of disciplines, including the sciences, medicine and dentistry, law, arts and social sciences, engineering, business and computing in both undergraduate and postgraduate education. The NUS name is the result of the merger in August 1980 of the University of Singapore (1962) and Nanyang University (1955), after the main local university had existed under different incarnations such as the University of Malaya (1949) and Raffles College (1928) and King Edward VII Medical School (1913) and King Edward VII College of Medicine (1921).

NTU A research-intensive public university, Nanyang Technological University has undergraduate and postgraduate students in engineering, business, science, and humanities, arts and social sciences. Founded in 1991, its Lee Kong Chian School of Medicine was established jointly with Imperial College London. NTU hosts two national research centres of excellence, namely, the Earth Observatory of Singapore (EOS) and Singapore Centre for Environmental Life Sciences Engineering (SCELSE). Both of which tackle important questions in environmental sustainability and public health.

SUPER-COMPUTERS A supercomputer is a very large and expensive computer with tens of thousands of processors. Each supercomputer costs multi-millions of dollars. Because of its architecture, it is able to crunch voluminous data quickly.

SUTD Officially inaugurated by President Tony Tan Keng Yam in May 2012, the Singapore University of Technology and Design is a leading research-intensive global university focused on technology and all facets of technology-based design. Its aim is to educate technically grounded leaders who are steeped in the fundamentals of mathematics, science and technology, and are creative and entrepreneurial.

SVU Supercomputing and Visualisation Unit of the NUS offers modelling and rendering services based on supercomputing technologies.

I am appreciative of the support I have received from NSCC, in particular Professor Tan Tin Wee, Chief Executive; Jerry Lim, Deputy Director; and Barry Lo, Senior Officer. I am grateful to the policy makers, ICT and supercomputing professionals who readily agreed to be interviewed for this book. Altogether I interviewed dozens of policy makers, business leaders and ICT professionals, to get their stories and views on Singapore's supercomputer journey. Most are based in Singapore and a handful overseas. I would also like to thank the various agencies who have aided with providing information and images for this book.

Below are some of the people interviewed in alphabetical order.

Grace Chng

■

Professor Alfred Huan
2012-2018
Executive Director,
Institute of High
Performance Computing

■

Andrew Underwood
High Performance Computing and
Artificial Intelligence Leader,
Dell EMC

■

Craig Stires
Head of Analytics, AI, and Big Data
Asia Pacific at Amazon Web Services

■

Dr David Kahaner
1998-2002
Chairman, Advisory Council
Institute of High
Performance Computing

1992-current
Founding Director of ATIP
(Asian Technology
Information Program)

■

Evelyn Lau
1998-2009
Head, Administration,
Institute of High
Performance Computing

1994-1998
Executive, Administration,
National Supercomputing
Research Centre

■

Dr Goh Eng Lim
Vice-President & Chief
Technology Officer,
Hewlett Packard Enterprise

■

Dr Janil Puthucheary
Minister of State,
Ministry of Communications &
Information and Ministry of Transport

■

Jerry Lim
2015-present
Deputy Director Corporate Services,
National Supercomputing Centre
(NSCC) Singapore

1998-2015
Deputy Director Corporate Services,
Institute of High
Performance Computing

1994-1998
Executive,
National Supercomputing
Research Centre

■

Dr Kurichi Kumar
2018-present
Head of Technology,
Rolls-Royce Singapore

■
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