NANYANG TECHNOLOGICAL UNIVERSITY SINGAPORE

PUSHING FRONTIERS

FROM BENCH TO MARKET

RESEARCH MEETS BUSINESS TO TAKE ON GLOBAL CHALLENGES

TRANSFORMATIONAL SYNERGIES

Bringing ideas to life, together

SAFEGUARDING INNOVATION

Why intellectual property matters

PUTTING RESEARCH TO WORK

Applying ideas to benefit society

ISSUE 23
2024

NANYANG TECHNOLOGICAL UNIVERSITY SINGAPORE

DRIVING A VIBRANT ECOSYSTEM FOR ENTREPRENEURSHIP

A research-intensive university, Nanyang Technological University, Singapore (NTU Singapore) accelerates the development of solutions to humanity's greatest challenges.

Various innovation drivers in NTU come together to turn the University's inventions into practical applications that promote Singapore's growth and improve societal well-being.

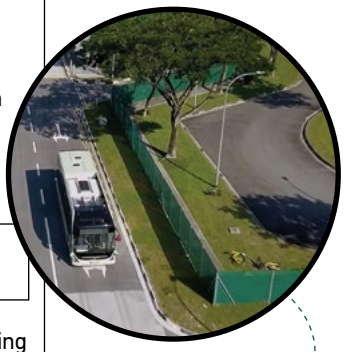
Sparking the entrepreneurial spirit

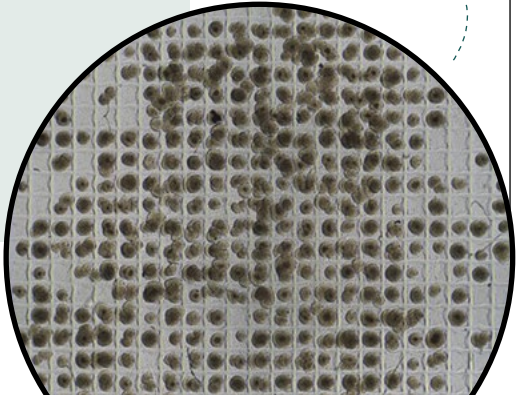
The **NTU Entrepreneurship Academy** nurtures a culture of inventive thinking and entrepreneurship in undergraduates and graduates. Its academic programmes, student engagement activities and overseas entrepreneurship programmes equip students and working professionals with skills to start their own ventures.

Paving enterprising pathways

NTUitive helps budding entrepreneurs turn their next big idea into reality. The innovation and enterprise company of NTU manages the University's intellectual property and facilitates the commercialisation of research.

To find out more about innovation and entrepreneurship initiatives at NTU, visit **ntu.edu.sg/innovates**





Stories in this issue can also be found at *ntu.sg/research-hub*

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We welcome your ideas, views and contributions. Email us at pushingfrontiers@ntu.edu.sg

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TRANSFORMING THE WORLD WITH IMPACTFUL IDEAS

As a comprehensive research-intensive university with roots in training engineers for Singapore, NTU is focused on solving real-world problems. Translational research is one of its unique selling points – NTU is the birthplace of many innovations aimed at addressing global challenges.

This issue of *Pushing Frontiers* highlights the multitude of translational research outcomes from NTU, which encompass the science, technology, engineering and mathematics fields as well as the social sciences and humanities domains.

We shine the spotlight on NTU researchers' novel solutions to what ails us, from wound-healing patches created from discarded frog skin to a tool that helps companies assess workplace safety.

Industry partnerships are essential in bringing our inventions to market; corporations offer a wealth of knowledge and resources that complement our deep research expertise. Our distinguished record of industry collaborations is testament to the University's commitment to addressing market and societal needs through research. We work with established names in the business and help them find answers to their pain points, via corporate laboratories, joint laboratories and larger multi-party tie-ups.

In this issue, NTU researchers-turned-entrepreneurs share valuable insights from their experience, providing a window into the origins of spinoffs and what is needed to take research out of the lab. Their stories reflect how the University helps budding companies get to where they are now.

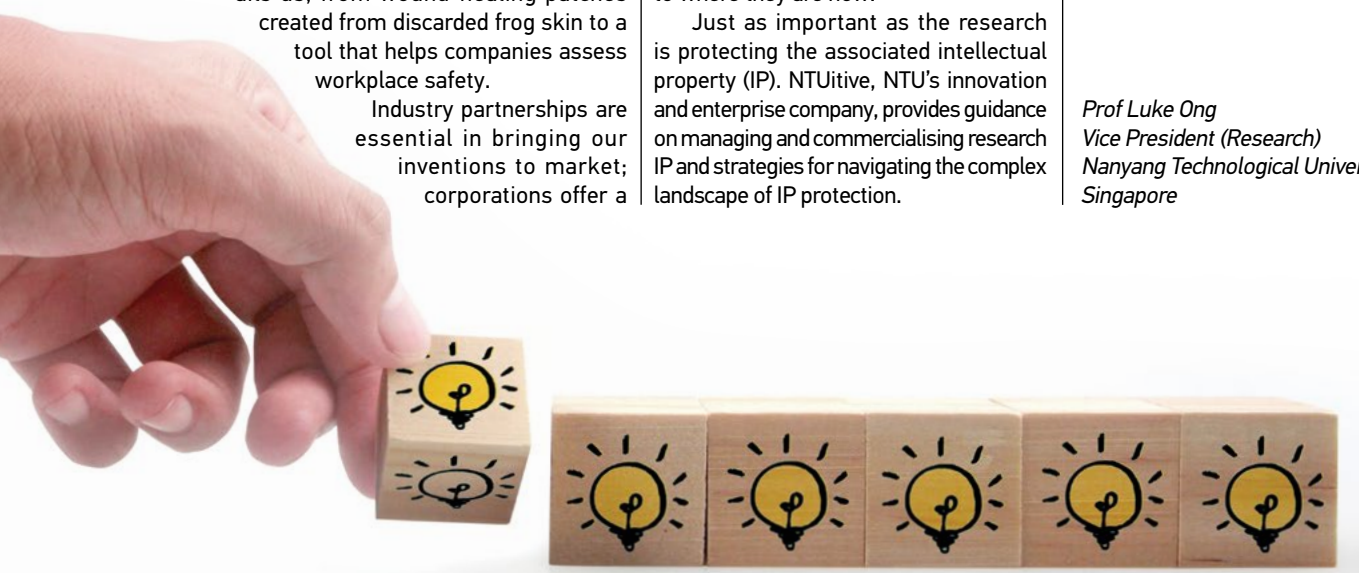
Just as important as the research is protecting the associated intellectual property (IP). NTUitive, NTU's innovation and enterprise company, provides guidance on managing and commercialising research IP and strategies for navigating the complex landscape of IP protection.

Working with my NTU colleagues to bring you *Pushing Frontiers* has been a great pleasure and honour.

From 1 May 2024, I will embark on new roles as Vice President (AI and Digital Economy) and Dean of NTU's new College of Computing and Data Science. Renowned gastroenterologist and former Health Minister of the Netherlands, Prof Ernst Kuipers, will succeed me as Vice President (Research). I wish Prof Kuipers the very best in driving NTU's research aspirations and taking the University's research efforts to its next stage of development.

I am optimistic that NTU's research will continue to provide vital solutions to the needs of our time.

Prof Luke Ong
Vice President (Research)
Nanyang Technological University
Singapore



SUSTAINABLE SYMPHONY

Geothermal energy potential in Singapore

Geothermal heat below the surface could be a new consistent source of clean energy for Singapore, according to a groundbreaking study.

Exploratory work by researchers from NTU, TUMCREATE and infrastructure consultancy Surbana Jurong revealed the country's significant geothermal resource. TUMCREATE is a joint research programme between the University and Germany's Technische Universität München.

The research team discovered that rocks 1.1 km underground at a site near a hot spring in Singapore's Sembawang town had temperatures ranging from 60 to 90 degrees Celsius.

The team – co-led by NTU's Prof Alessandro Romagnoli, Co-Director of the Surbana Jurong-NTU Corporate Laboratory, and TUMCREATE Principal Scientist Dr Tobias Massier – estimated that at depths of 4 to 5 km or deeper, the geothermal site could have a temperature of 200 degrees Celsius. Such high temperatures could be useful for applications such as district cooling.

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Funding surge for water research

Water and environmental research and innovation at NTU's Nanyang Environment and Water Research Institute (NEWRI) has received a S$92 million (US$69 million) funding boost.

The investment supports projects such as a novel test using lab-grown human cells to identify new, potentially hazardous chemical compounds in treated water. This new test could substitute animal tests done in many countries, says Prof Shane Snyder, NEWRI's Executive Director.

The funding boost is from the National Research Foundation, a Singapore agency that sets the country's direction for research and development, and other organisations.

This grant will help draw in an additional industry funding of S$23 million (US$17 million) for NEWRI, bringing the total water research investment to S$115 million (US$86 million) by 2026.

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Global, interdisciplinary programme to tackle climate change

NTU has launched an interdisciplinary programme to address climate change issues, such as the impact of heat and air pollution on human health.

With research done in Singapore and Southeast Asia, the new S$50 million (US$37 million) Climate Transformation Programme is hosted by the University's Earth Observatory of Singapore (EOS) and co-funded by Singapore's Ministry of Education.

The programme brings together researchers from different disciplines at NTU, other Singapore autonomous universities and research centres across the world. Prof Benjamin Horton, the programme's Lead Principal Investigator and EOS' Director, stresses the importance of interdisciplinary research in studies on global warming as little is known about how climate change would affect many areas.

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Better cardiovascular care

How can people be empowered to better manage chronic conditions and live healthier lives while reducing their medical expenses?

Could health coaching powered by artificial intelligence (AI) help patients tackle cardiovascular diseases linked to high blood cholesterol?

These are some objectives for an AI, digital health and human potential project led by NTU's Assoc Prof Andy Ho from the School of Social Sciences, together with Assoc Prof Andy Khong from the School of Electrical and Electronic Engineering. Both hold joint appointments at the University's Lee Kong Chian School of Medicine.

Their project comes under Singapore's Cardiovascular Disease National Collaborative Enterprise, which aims to improve Singaporeans' heart health and establish the country as a global leader in cardiovascular research.

COASTAL SCIENCE

HISTORY REVEALS A HIDDEN DISASTER AT SHARK BAY

Shark Bay on the central Western Australian coast is home to the Earth's largest seagrass beds and one of the biggest dugong populations. A UNESCO World Heritage site, the bay also supports the livelihoods of its community.

But the risks of highly damaging tropical cyclones at Shark Bay are understudied, likely because it lies on the margins of cyclone impact and cyclones rarely occur there.

To better understand how such storms affect land use planning, emergency management and environmental management, a team of researchers modelled a powerful tropical cyclone that struck Shark Bay in 1921 using detailed data from historical records.

Led by Prof Adam Switzer from the Asian School of the Environment, who is also a principal investigator at NTU's Earth Observatory of Singapore, the team developed a new framework that assessed factors like data accuracy and impartiality to quantify the quality of the records.

By reconstructing the 1921 event, the researchers narrowed the combination of cyclone parameters that led to the impacts observed in the records, such as the sea level rise during the cyclone and the discovery of sharks and fish up to nine kilometres inland.

The results suggest that the 1921 cyclone caused the sea level at Shark Bay's Denham town to rise by three metres, which was higher than previously thought. This implies that a repeat of the event would have devastating socio-economic consequences, as a storm surge exceeding two metres at Denham now would likely flood critical infrastructure and cripple regional tourism.

Read more about the study "The utility of historical records for hazard analysis in an area of marginal cyclone influence" in Communications Earth & Environment *(2023), DOI: 10.1038/s43247-023-00844-z.*

Prof Adam Switzer examining historic documents that were used to estimate the size of the 1921 tropical cyclone that struck Shark Bay. Credit: Earth Observatory of Singapore.

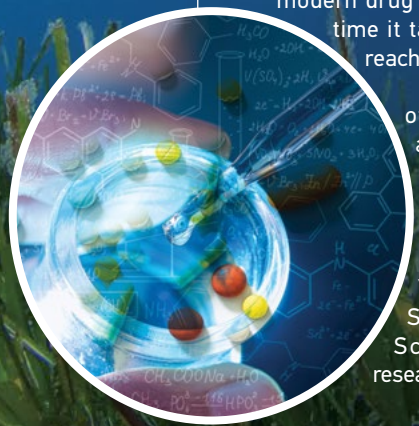
DRUG DISCOVERY

MAKING VIRTUAL DRUG SCREENING MORE EFFICIENT

On average, it takes 10 years or longer for a new drug to be tested and approved. This long road of drug development is also littered with many failed drug candidates – an estimated 9 in 10 drugs fail during clinical trials.

Computational models capable of predicting the properties of a drug based on its molecular structure have expedited modern drug discovery and the time it takes for a drug to reach the market.

Joining the ranks of these models is an industry game-changing computer-aided drug design method developed by Assoc Prof Mu Yuguang of NTU's School of Biological Sciences and his research team.



Using a type of machine learning called graph convolutional networks, the artificial intelligence-powered model can simultaneously predict several properties of a drug, such as absorption, distribution, metabolism, excretion and toxicity.

Compared to existing methods, the new model is 100 times faster at screening drug molecules with minimal computational costs. It can also be run on a personal computer.

"Our all-in-one method removes the need for multiple specialised models to predict how a drug will function in the body, which could make the drug discovery process more efficient," says Assoc Prof Mu.

Read more about the innovation in "Application of variational graph encoders as an effective generalist algorithm in computer-aided drug design", published in Nature Machine Intelligence *(2023), DOI: 10.1038/s42256-023-00683-9.*

OPTICS

LIGHTING THE FUTURE OF QUANTUM PHOTONICS

Nonlinear optics is essential for many technological advancements, from material analysis to quantum computing. One process associated with nonlinear optics is second-harmonic generation (SHG), or frequency doubling. SHG occurs when the interaction between an incoming wave of light and a material with nonlinear optical properties generates another wave with twice the frequency.

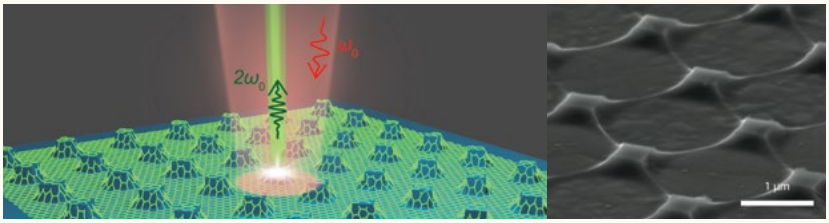
Graphene, which is only one atom thick, holds great promise for the development of miniature photonic nonlinear devices. However, the symmetrical arrangement of its atoms inhibits SHG.

To break the symmetry, researchers co-led by Assoc Prof Nam Donguk and PhD student Lu Kunze of NTU's School of Electrical and Electronic Engineering fabricated an array of nanometre-sized pillars of graphene. They then applied a non-uniform strain to the edges of the nanopillars and observed a never-before-seen type of SHG in graphene.

The novel SHG was 30% stronger than the SHG observed in hexagonal boron nitride, a material commonly used in optics and photonics applications. At ultra-low temperatures close to absolute zero, the novel SHG was also almost 50 times stronger than at room temperature.

According to Assoc Prof Nam, this discovery opens new opportunities for graphene to be used in innovations like quantum photonics devices.

The breakthrough was reported in "Strong second-harmonic generation by sublattice polarization in non-uniformly strained monolayer graphene", published in Nature Communications *(2023), DOI: 10.1038/s41467-023-38344-5.*



Left: A light wave with twice the frequency of the incoming wave is generated when the graphene nanopillars are strained. Right: Scanning electron microscopy image of the graphene nanopillars. Credit: NTU.

QUANTUM MATERIALS

A QUANTUM LEAP IN CREATING EXOTIC MATERIALS

Strong interactions between subatomic particles like electrons occur when they are at a specific energy level known as the van Hove singularity. These interactions give rise to unusual properties in quantum materials, such as superconductivity at high temperatures, potentially ushering in exciting technologies of tomorrow.

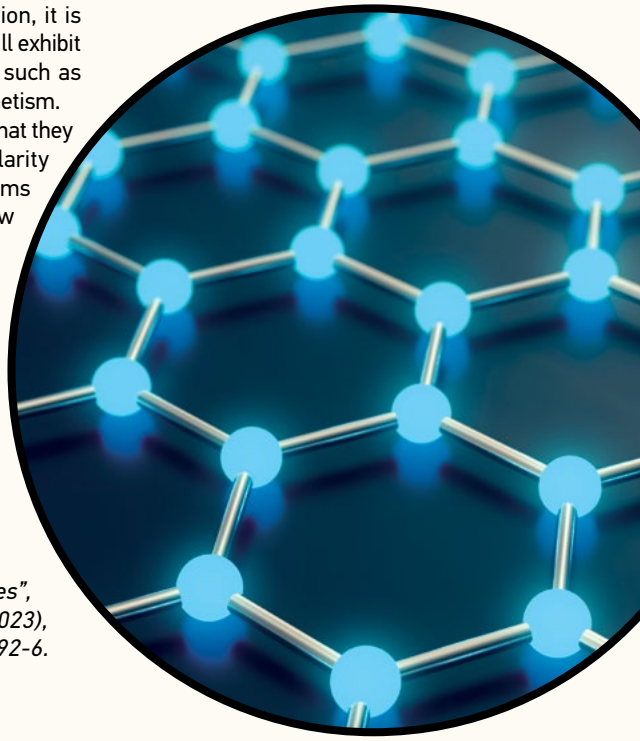
Research suggests topological materials that allow electrons to flow only on their surface to be promising quantum materials. However, the quantum properties of these materials remain relatively unexplored.

A study co-led by Nanyang Asst Prof Chang Guoqing of NTU's School of Physical and Mathematical Sciences identified two types of van Hove singularities in the topological materials rhodium monosilicide (RhSi) and cobalt monosilicide (CoSi). They found that the van Hove singularities are near the Fermi level – the highest energy level that an electron can occupy at absolute zero temperature. In this situation, it is highly likely that the materials will exhibit desirable quantum properties, such as superconductivity and ferromagnetism.

The researchers also found that they could tune the van Hove singularity energy levels by adding metal atoms to the materials, creating new avenues for engineering quantum materials with novel properties.

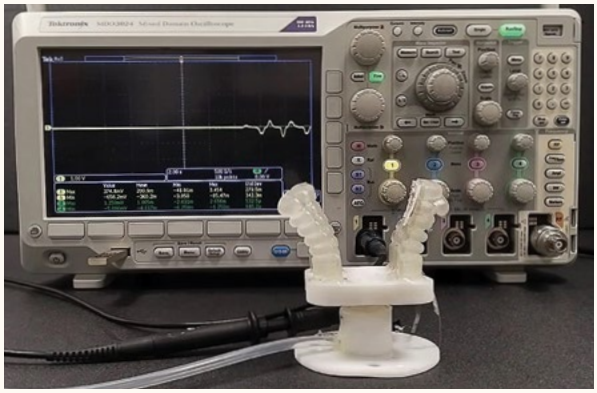
"Our findings open the door to discovering more quantum materials with unique characteristics, which could fuel breakthroughs in fields ranging from computation to energy," says Asst Prof Chang.

The research was reported in "Tunable topologically driven Fermi arc van Hove singularities", published in Nature Physics *(2023), DOI: 10.1038/s41567-022-01892-6.*



MATERIALS SCIENCE

STRETCHING ENERGY-HARVESTING LIMITS



The scientists attached their energy-harvesting patch to a soft gripping finger to determine if the patch was able to produce different voltages when the finger was bent at different angles. Credit: Wiley-VCH.

Thin films made of piezoelectric polymers can generate electricity when pressed or stretched, becoming ideal energy-harvesting materials to power wearable electronic devices sustainably.

However, the low stretchability of certain piezoelectric polymers like polyvinylidene difluoride (PVDF) limits their electricity-producing capability.

In a breakthrough study, scientists led by Prof Lee Pooi See, Vice President (International Engagement) from NTU's School of Materials Science and Engineering, addressed this problem with 3D-printed auxetic structures – structures with repeating weave-like patterns.

The resarch team layered their 3D-printed auxetic structures made of urethane diacrylate – often used as a protective coating for electronic devices – over a thin film of PVDF and gold electrodes to create an energy-harvesting patch.

The auxetic structures form a dome-shaped curve when bent, enabling the PVDF to stretch more than usual. This allows the material to produce electricity when the thin patch is bent. The team's experiments showed that the bent patch produced a voltage 8.3 times higher than a patch without auxetic structures.

Applying the innovative patch to different body joints that bend, like the elbow and ankle, the team found that the patch produced different voltages when bent at different angles. This finding opens avenues for developing self-powered devices for soft robotics sensing and medical diagnostics to monitor a person's joint motion and gait.

Find out more about the research "3D printed auxetic structure-assisted piezoelectric energy harvesting and sensing" in Advanced Energy Materials *(2023), DOI: 10.1002/aenm.202301159.*

COMMUNICATION STUDIES

SIGNING ONLINE PETITIONS DAMPENS DONATIONS

Would people who sign online petitions to support a social cause they feel is important later walk the talk and donate to it?

This is unlikely to happen, according to new research by Assoc Prof Kim Nuri, Assoc Prof Kim Hye Kyung and final-year students from NTU's Wee Kim Wee School of Communication and Information. People who engage in small acts of token support online – or clicktivism – were reportedly less likely to donate to a cause than those who did not sign any petition.

In the study, 190 college students in Singapore were asked to rank their support for three social causes: elderly care, mental health awareness and reducing plastic waste. For their participation, each student received S$10 (US$7.56).

Some participants were then randomly invited to sign an online petition for their first-ranked social cause, such as advocating a charge for plastic bags in supermarkets.

All participants were later asked how much of their S$10 incentive they would donate to their top cause.

The study found that participants who signed an online petition were half as likely to donate to their cause than those who did not sign a petition. This is consistent with the moral self-licensing theory, which states that people might act in morally questionable ways later if they have already performed a good deed.

Based on their findings, the researchers suggest that it might be more effective to get people to donate before asking them to share online their act of donating with others.

Details of the study "The moral license of a click: How social observability and impression management tendencies moderate the effects of online clicktivism on donation behaviour" can be found in New Media & Society *(2023), DOI: 10.1177/14614448231153971.*

AI AND ENTREPRENEURSHIP

NEGATIVE VISUALS SPUR CROWDFUNDING

Crowdfunding videos usually depict smiling entrepreneurs pitching their products to potential funders, encouraging them to support their ventures. But could negative emotions in videos – conveyed by scenes with or without people – be more effective at drawing the audience's attention and raising more funds?

Now, a recent study reports that videos with visuals evoking negative emotions performed seven to eight times better at attracting funding.

In the research headed by Assoc Prof Marilyn Ang Uy and NTU Entrepreneurship Academy Director Prof Foo Maw Der – both from NTU's Nanyang Business School – the researchers analysed nearly 3,200 pitch videos from crowdfunding platform Indiegogo using machine learning tools.

They observed that videos evoking negative emotions received more funding compared to positive clips featuring human expressions, such as cheerful people, and those without discernible human faces, such as the sun rising.

The researchers believe that this could be due to negative emotions bringing problems to the attention of potential backers, which motivated them to remedy the situation by supporting the project.

The study also found that negative feelings conveyed through human faces had a stronger impact if they were presented in the first half of the crowdfunding pitch video instead of the second half.

Surprisingly, if negative sentiments were presented without human presence, the impact was stronger in the second half of the video and not the first. This suggests the value of reiterating the problem later in the pitch video using non-human elements.

Details of the study were reported in "Visual totality of rewards-based crowdfunding pitch videos: Disentangling the impact of peak negative affective visual expression on funding outcomes", published in Journal of Business Venturing *(2023), DOI: 10.1016/j.jbusvent.2023.106318.*

RESPIRATORY HEALTH

BETTER SCREENING FOR FUNGAL RISKS IN LUNG DISEASE

Chronic obstructive pulmonary disease (COPD) is a lung disease that restricts the airway, making it harder to breathe. Certain patients with COPD become sensitised to allergens in the environment, such as fungal particles, which can worsen their condition.

Currently, "crude" and natural allergens extracted directly from fungi are used in the clinic to identify sensitised patients who have developed an immune response to fungal particles. This practice has come under scrutiny due partly to concerns that such allergens are not specific enough to pinpoint all at-risk patients.

The researchers compared allergens from *Aspergillus fumigatus* (pictured in petri dishes) with those from other fungi. Credit: LKCMedicine.

While artificial "recombinant" allergens could theoretically overcome this limitation, most remain untested. A study led by Assoc Prof Sanjay Haresh Chotirmall, Vice Dean (Research) at NTU's Lee Kong Chian School of Medicine, shed more light on this issue.

The researchers tested 35 fungal allergens, both naturally occurring and artificial, on about 600 COPD patients from Singapore, Malaysia and Hong Kong.

They discovered that patients sensitive to allergens from *Aspergillus fumigatus* – found commonly in the air and soil – experienced flare-ups more frequently compared to other fungal allergens.

The study also found that many COPD patients not sensitised to natural *Aspergillus fumigatus* allergens were actually sensitive to several artificial variations. The finding suggests that these recombinant allergens could be a more accurate screening tool at identifying at-risk patients than the natural, crude allergen approach.

Read about the research "Sensitisation to recombinant Aspergillus fumigatus *allergens and clinical outcomes in COPD" in* European Respiratory Journal *(2023), DOI: 10.1183/13993003.00507-2022.*

BUSINESS

IDENTIFYING COMMERCIAL OPPORTUNITIES

Entrepreneurs on the lookout for new business ideas can actively create business opportunities for themselves by combining existing resources on hand, such as assets, people and available technologies, in innovative ways.

For example, a company with a fleet of vehicles originally meant to be rented out to customers could use these assets for an unintended purpose, such as to raise additional capital.

This is among several recommendations in a new book titled *Identifying Business Opportunities Through Innovation*.

Written by Prof Boh Wai Fong, Vice President (Lifelong Learning and Alumni Engagement) from NTU's Nanyang Business School, and Dr Thara Ravindran, a Research Fellow at the School, the book serves as a guide to finding and executing business ideas and navigating the hurdles that emerge.

Another key advice from the book for entrepreneurs to heed is to plan ahead by identifying emerging trends. For example, the next generation of consumers will have different needs and expectations, opening up new demands for businesses to fulfil.

The book collates the lessons and insights gleaned from more than 500 interviews conducted over five years on various aspects of developing and running an enterprise. These findings have also been published in reports and papers, and discussed and shared with practising entrepreneurs in classrooms over the last decade.

The book Identifying Business Opportunities Through Innovation *is published by World Scientific (2023).*

The book offers recommendations on finding and executing business ideas. Credit: World Scientific.

SUSTAINABILITY

SATISFYING THE WORLD'S APPETITE WITHOUT HEATING UP THE GLOBE

The global food system is a significant contributor to greenhouse gas emissions, a major cause of climate change and global warming. A considerable proportion of the emissions comes from food loss and waste, though the exact impact size is not known.

To estimate emissions from lost and wasted food, Asst Prof Fei Xunchang of NTU's School of Civil and Environmental Engineering co-led a study that tracked the emissions of various types of food at different stages of their life cycles, including transportation, sale, consumption and disposal.

Analysing the food supply data of 164 countries from 2001 to 2017, the researchers examined emissions across 54 food commodities belonging to four categories: cereals and pulses; meat and animal products; vegetables and fruits; and root and oil crops.

They found that lost and wasted food accounted for about half of the global food system's total emissions in 2017, an amount equivalent to 9.3 billion metric tons of carbon dioxide. Almost three quarters of emissions that occurred during the supply-chain phase came from lost meat and animal products.

The researchers also found that food waste treated with advanced techniques, such as anaerobic digestion and composting, generated fewer emissions in developed countries than waste disposed of in landfills.

"Our study shows that factors such as eating habits, technological interventions and socioeconomic aspects impact greenhouse gas emissions from lost and wasted food," says Asst Prof Fei. "Reducing meat production in some areas, while switching from landfills to advanced waste treatment techniques in others could make the food system more sustainable."

The study "Cradle-to-grave emissions from food loss and waste represent half of total greenhouse gas emissions from food systems" was published in Nature Food *(2023), DOI: 10.1038/s43016-023-00710-3.*

MEDICAL DEVICES

TREATMENT FOR DIABETES INSPIRED BY A SNACK

More than half a billion people worldwide live with diabetes, a chronic condition where a person's blood sugar levels are higher than normal.

Insulin injections or pumps are commonly used to manage the blood glucose levels of patients with insulin-dependent diabetes. However, taking too much insulin or administering it at the wrong time can lead to dangerously low blood glucose levels in patients.

A device inspired by a breakfast favourite may someday be used to treat diabetes without the side effects associated with insulin injections. Resembling a waffle, the innovation traps and delivers pancreatic cells that secrete insulin in response to blood glucose levels.

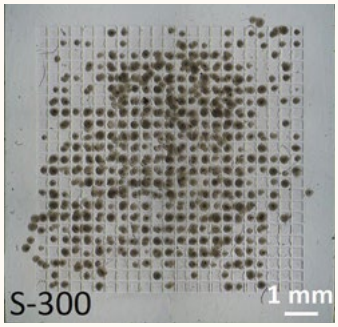
It is the brainchild of a research team led by Asst Prof Dang Thuy Tram of NTU's School of Chemistry, Chemical Engineering and Biotechnology.

The device was constructed by creating square-shaped wells in a gelatin-based material. The team then added a mixture containing spherical clumps of islet cells – pancreatic cells that produce insulin – and alginate to the wells, with one cell cluster fitting into one well. Alginate, a seaweed-derived natural polymer, shields the cells from being attacked by the immune system when the device is implanted in the body.

To enhance the survival of islet cells, the device was also seeded with cells with the potential to develop into blood vessels that deliver nutrients and oxygen.

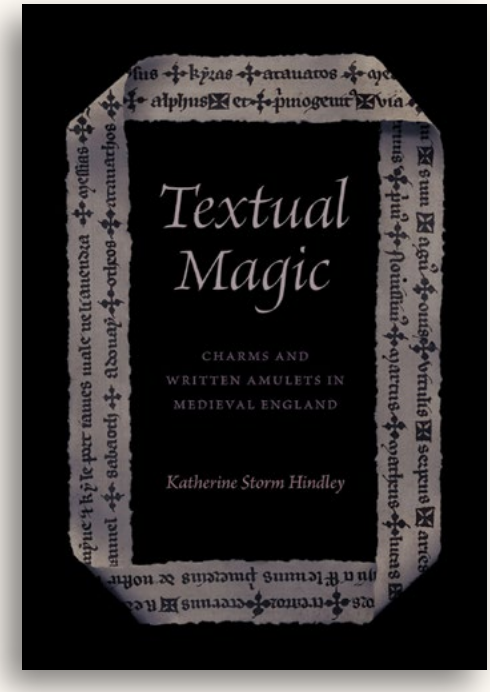
The researchers found that the device was effective at restoring and maintaining normal blood glucose levels when transplanted into diabetic mice. It also performed better than similar devices. The research team is now working on bringing their invention to the clinic.

The invention was featured in "Waffle-inspired hydrogel-based macrodevice for spatially controlled distribution of encapsulated therapeutic microtissues and pro-angiogenic endothelial cells", published in Bioengineering & Translational Medicine, *DOI: 10.1002/btm2.10495. btm2.10495.*



Like blueberries on a piece of waffle, clusters of cells fit into the square cells of the device. Credit: NTU.

ENGLISH



A GUIDE TO MAGIC IN THE MIDDLE AGES

Before the age of modern medicine or science, residents of medieval Europe (c. 500 – 1500 CE) used spoken or written charms to fend off danger and cure illnesses.

In her book, *Textual Magic: Charms and Written Amulets in Medieval England*, Asst Prof Katherine Hindley of NTU's School of Humanities introduces the various charms that were part and parcel of life in medieval England.

Drawing on a collection of over 1,000 charms, Asst Prof Hindley examines the relationships between language, belief and power. The variety of written charms and spoken incantations used to address different conditions, from bleeding to fever, illustrates the pervasive influence of charms on medieval society.

Through these examples and their uses in everyday life, Asst Prof Hindley highlights the perceived power of words in changing the world. Her analysis also reveals the effect of shifting cultural landscapes on the use of charms to heal and protect, shedding light on this fascinating aspect of medieval culture.

The book introduces readers to the various charms used in medieval England. Credit: The University of Chicago Press.

Textual Magic: Charms and Written Amulets in Medieval England *is published by The University of Chicago Press (2023).*

FROM BENCH TO MARKET

RESEARCH MEETS BUSINESS TO TAKE ON GLOBAL CHALLENGES

From partnering its homegrown unicorn to working with industry giants, NTU is creating value through innovation and entrepreneurship.

Many have wondered if eating a local delicacy – frog porridge – sparked the development of a wound-healing collagen product made from bullfrog skin in Singapore.

"But the leap from porridge to science wasn't how it happened," says Assoc Prof Dalton Tay, one of the developers of the innovation from NTU's School of Materials Science and Engineering.

Instead, the researchers had been looking for an eco-friendly source of collagen from Singapore when their search led them to discarded bullfrog skins from farms near their laboratories.

Together with Assoc Prof Tan Nguan Soon from the University's Lee Kong Chian School of Medicine, Assoc Prof Tay is upcycling the skins to create clinical-grade collagen patches that can accelerate the healing of chronic wounds.

NTU's innovation and enterprise company, NTUitive, exclusively licensed the patented technology to local medtech firm Cuprina Wound Care Solutions in 2022. NTUitive comes under the NTU Innovation and Enterprise (NTU I&E) initiative, which seeks to nurture entrepreneurs by mentoring and supporting students, faculty and alumni looking to turn their ideas into market-ready products.

After setting up a lab to scale up its commercial production, Cuprina is now planning clinical trials at local hospitals.

"Licensing allows us to focus on innovation and scientific advancement while leveraging the business acumen and market presence of established companies like Cuprina," says Assoc Prof Tay.

Developing wound healing patches made of amphibian skin is one example of how NTU scientists are creating game-changing solutions to real-world problems.

In fact, the United Kingdom-based global information services provider Clarivate listed NTU as the No. 7 research organisation globally for the greatest number of research papers referenced by the inventions of Clarivate's top 100 global innovators.

Says Prof Louis Phee, Vice President (Innovation and Entrepreneurship) : "We've set up an ecosystem where NTU students, graduates and faculty members with guts and ideas can create an innovation and spin off a company from it, while being supported by the University."

LEAP, LICENSE, LAUNCH

While Assoc Prof Tay and Assoc Prof Tan chose to license their technology, other NTU scientists have dived into entrepreneurship.

Dr Shi Xu, former Associate Professor at NTU's School of Electrical and Electronic Engineering (EEE), is a pioneer in Singapore's deep-tech startup ecosystem. In 1999, he founded Nanofilm Technologies International (NTI), which provides advanced nanomaterial solutions using vacuum coating technologies and processes that Dr Shi invented and patented during his tenure at NTU.

Since spinning off from NTU, Nanofilm has become the first local deep-tech unicorn to be listed on the Singapore Exchange. It continues to expand into growing areas in nanotechnology to keep up with market demand.

The company has presence in Europe, China, Vietnam and Japan, and is constructing a 44,000-sqm mega plant in Vietnam.

In 2023, Nanofilm and NTU launched the NTI-NTU Corporate Lab, a multimillion-dollar facility supported by Singapore's public sector that brings industry together with academia to develop next-generation nanotechnology solutions.

Reflecting on his technopreneurial journey, Dr Shi explains that scientists face common challenges when turning their research into a business: "Scientists often dive too deeply into research and may miss the sweet spot for commercialisation."

"We've set up an ecosystem where NTU students, graduates and faculty members with guts and ideas can create an innovation and spin off a company from it, while being supported by the University."

Prof Louis Phee
NTU's Vice President (Innovation and Entrepreneurship)

Dr Shi emphasises the importance of being commercially savvy and having skills in areas such as effective business structuring and people management.

Finding harmony between science and business is not a one-person job, as seen in the partnership between Assoc Prof Darren Sun from NTU's School of Civil and Environmental Engineering and Mr Wong Ann Chai, formerly an adjunct professor at NTU's Nanyang Business School.

Assoc Prof Sun has decades of research expertise in nanomaterials and, as an esteemed International Water Association Fellow, he was interested in using advanced additive manufacturing to produce membranes. Meanwhile, Mr Wong has prior experience as a banker helping companies raise capital and go public.

In 2013, this meeting of minds birthed Nanosun, a spinoff that uses 3D-printed nanomaterials to manufacture cutting-edge membranes for water treatment and renewable energy applications.

"NTUitive was instrumental in our growth in the early years by providing an incubator and competencies as well as helping us access grants," says Mr Wong, Nanosun's Managing Director.

"The company-on-campus concept enables intensive exchange and close cooperation between our employees and doctoral candidates and students from NTU on future-oriented research projects."

Dr Alvin Wong
Schaeffler's Head of Digital Transformation Asia/Pacific and Deputy Director of the Schaeffler Hub for Advanced Research at NTU

"We've learnt a lot from NTU and it's time for us to see how we can do more."

Starting with microfiltration and ultrafiltration flat sheet membranes, Nanosun has deployed water treatment solutions in Singapore, Indonesia, China and Taiwan, particularly for industrial wastewater treatment. The spinoff has secured million-dollar contracts, bagged awards and established its presence in the Asia Pacific.

INNOVATING WITH INDUSTRY

Speed is key to staying competitive in translational research, and leveraging the expertise of an industry partner could be helpful. NTU's industry partnerships with major corporations, such as Continental, Schaeffler and HP, seamlessly bridge this bench-to-industry gap.

"We assess the complementary resources and capabilities each party brings to the table to ensure a collaboration that can eventually bring about impact to the research and development ecosystem," says Prof Lam Khin Yong, NTU's Vice President (Industry).

By working with industry, NTU researchers are attuned to real-world pain points. Applying their findings back in the lab, they enhance the impact and relevance of their research by crafting solutions that address market needs.

For instance, technology company Continental and NTU formed a corporate lab in 2019 that receives support through the National Research Foundation, an agency that sets Singapore's direction for research and development.

"The lab's research contributes to Continental's strategy in developing new products and services in artificial intelligence (AI), future mobility, cyber security, wireless technologies and more," says Dr David Woon, Director (Academic Liaison) at Continental and Co-Director of the Continental-NTU Corporate Lab.

The lab is working with public transport operator Go-Ahead Singapore to enhance the driving safety management systems of Go-Ahead's buses. In the tie-up, NTU researchers built an AI model that predicts potential accidents and alerts fleet operators to abnormal driving patterns that indicate a heightened chance of accidents.

In 2023, the lab started piloting the system on 10 Go-Ahead buses and collected driving data to refine their AI model and enable more accurate predictions.

Partnerships with industry also lead to research that enhances the quality of education, resulting in training that can benefit industry, says NTU's Prof Lam Kwok Yan, Associate Vice President (Strategy and Partnerships).

For instance, a joint lab between Mastercard and NTU not only conducts cyber security research, but also offers relevant skills training and education programmes to better equip students for future careers in cyber security and digital trust and further research in these areas.

"This builds a talent pipeline with critical research and operational skills that are in short supply in industry," adds Prof Lam, who co-leads the Mastercard-NTU joint lab.

At a joint lab between automotive and industrial components supplier Schaeffler and NTU, scientists and students work with Schaeffler employees to develop insights from application-driven research projects that flow directly into the development of new products and technological solutions.

"The company-on-campus concept enables intensive exchange and close cooperation between our employees and doctoral candidates and students from NTU on future-oriented research projects," says Dr Alvin Wong, Head of Digital Transformation Asia/Pacific at Schaeffler and Deputy Director of the joint lab called the Schaeffler Hub for Advanced Research (SHARE) at NTU.

The lab focuses on expanding the state of advanced innovation and technology in areas like robotics and Industry 4.0. It also plans to venture into professional service robotics. To date, it has over 40 invention disclosures, with 17 patents awarded.

One success story is the Dual EXtendable (DEX) autonomous mobile robot designed to work with shopfloor employees to boost productivity in industrial settings. DEX can communicate with different robots, recognise speech and gestures, and avoid obstacles, including moving ones.

BUILDING TOOLS FOR SOCIETAL GOOD

Multi-institutional collaborations involving academics, policymakers and industry players bring together diverse expertise and perspectives. Through this, research findings can be translated to benefit industry and the broader community.

Prof Theng Yin Leng and Dr Vered Seidmann from NTU's Wee Kim Wee School of Communication and Information gained these insights from working with the Workplace Safety and Health Institute at Singapore's Ministry of Manpower and the Republic's Workplace Safety and Health Council (WSHC).

Together with Dr Seidmann and six co-investigators from the School, Prof Theng spearheaded the creation of a digital tool that measures a company's level of workplace safety and provides recommendations for improvement.

The tool has now been launched by WSHC as a free online company-administered assessment platform called iOwnWSH, as part of Singapore's goal to foster a no-blame culture and a mindset that workplace accidents are preventable.

"The tool is particularly useful for high-risk industries such as construction, logistics and transportation, marine, services and manufacturing. Being a free tool, it would also benefit small and medium-sized enterprises that often have limited budgets for their safety department," says Dr Seidmann.

Gamified solutions, such as pictorial card games featuring common workplace hazards and good practices, were also created. The researchers are working to advance these solutions further and intend to partner companies from high-risk industries to test them.

"We realised that it's important to use pictures when communicating workplace safety and health ownership. With our gamified solutions, we want to turn routine safety briefings into something fun and easy to understand," adds Prof Theng.

Another assessment tool resulting from a multi-institutional tie-up is the Singapore Ability Scales (SAS). A collaboration between NTU, the National Institute of Education (NIE) at the University, Singapore's Ministry of Education (MOE) and test publisher GL Assessments, SAS is a commercially available psychometric tool administered to students to comprehensively evaluate the cognitive abilities important for learning and educational development.

NIE's Prof Kenneth Poon explains that tests developed in other countries are not tailored to Singapore's context and norms, impeding the accurate assessment of children's cognitive abilities.

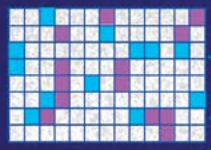
Together with MOE's Adjunct Assoc Prof Mariam Aljunied, Prof Poon and his NIE team adapted the British Ability Scales by modifying the item instructions, stimuli and scoring rules for Singapore's context. They also conducted the test with 2,000 local children and youths to create an appropriate benchmarking sample for performance comparison.

SAS provides key information to facilitate school placement decisions for children with special educational needs in Singapore. "We now have a test that gives results we are confident in, which is very important when we advise parents on how best to support their children," says Prof Poon. "At least a quarter of psychologists in Singapore have also been trained to administer this test."

MOVERS AND SHAKERS

Translational research is driven by passionate people who bring innovative ideas to life. To groom forward-thinking talent, NTU seeds the entrepreneurship spirit in students.

"My co-founders and I were students of a Minor in Entrepreneurship course offered at the NTU Entrepreneurship Academy (NTUpreneur) during our undergraduate studies," recounts Dr Rex Tan, Chief Technology Officer of Aevice Health, an NTU spinoff that develops medical devices to monitor patients with respiratory diseases. "That experience certainly helped us appreciate entrepreneurship in a structured way."



The company invented AeviceMD, a smart wearable stethoscope that continuously analyses chest sounds to monitor vital signs and detect early signs of worsening respiratory disease.

During his PhD studies at NTU's EEE, Dr Tan witnessed NTUitive helping research groups spin off technologies. Both he and Aevice Health co-founder Mr Adrian Ang later experienced this when NTUitive provided advice and linked them up with industry stakeholders from the start of their entrepreneurial journey.

Aevice Health has secured regulatory approval for AeviceMD in Singapore and the United States, and continues to grow its pipeline of commercial and pilot partners locally and internationally. Looking ahead, Dr Tan sees NTU as a launchpad for projecting Singapore medtech innovation globally.

Another pair of NTU graduates who spun off a company from the University are VFlowTech co-founders Dr Avishek Kumar and Dr Arjun Bhattarai. Their spinoff develops vanadium flow batteries for large-scale and long-term storage of renewable energy like solar energy.

Since its 2018 inception, VFlowTech has raised US$13 million (S$17.3 million). Its PowerCube technology was deployed to provide sustainable electricity to Singapore's Pulau Ubin island. PowerCube has also been deployed in several Asia-Pacific countries and Africa.

NTU I&E is also working to encourage more students, graduates and faculty members to dare to dream the startup dream. It does this through NTUpreneur, which aims to cultivate an entrepreneurial mindset in the NTU community.

Says Prof Phee, who leads NTU I&E: "Unlike other places where you're short of ideas or technology, we are full of them at NTU. We're trying to nudge people to try out entrepreneurship and translate these ideas to the next level as an enterprise."

TRANSFORMATIONAL SYNERGIES

BRINGING IDEAS TO LIFE, TOGETHER

Through partnerships, NTU helps industries accelerate research translation.

Pests are the bane of the horticulture, landscape and agriculture sector, destroying about 20 to 40% of global production yearly. One effective way to tackle this problem is by detecting pest infestations early.

To this end, a laboratory set up by NTU, Singtel – led by its digital and technology services unit, NCS – and the National Research Foundation Singapore presents an innovative solution.

Leveraging machine learning, researchers at the Singtel Cognitive and Artificial Intelligence Lab for Enterprises (SCALE@NTU) devised a sensor using radio waves called millimetre waves (mmWave) to detect insect pests on plants without the need for manual inspection. This transforms the labour-intensive process of pest detection into something automated, data-driven and non-invasive.

The innovation has piqued the interest of a branch in Singapore's lead agency for greenery and biodiversity conservation, the National Parks Board (NParks). The agency's Plant Science and Health branch is working with the lab to refine the prototype and test it in the field.

"NParks' Plant Science and Health branch is keen to explore this advanced technology for pest detection. The utilisation of mmWave radar technology presents a significant commercial opportunity in horticulture and agriculture, offering a sustainable solution for pest management," says Prof Cong Gao, Co-Director at SCALE@NTU.

SCALE@NTU is an example of a successful academia-industry tie-up based at NTU. Collaborations like this help research breakthroughs find the light of day in real-world applications, while companies and governments tap into the University's vast resources for their innovation needs.

To date, NTU has over 250 industry partners. SCALE@NTU is one of about 20 corporate and joint labs involving major companies and the University, set up right on the campus where the action is.

Such cooperation stands to benefit both industry and academia, according to Prof Lam Khin Yong, NTU's Vice President (Industry). Prof Lam heads the University's Vice President (Industry) Office (VPIO), which was formed to accelerate bench-to-industry applications.

"Building strong strategic partnerships with key industry players will not only contribute to innovation and the commercialisation of basic research, but also enrich the academic and industrial experience for our students and researchers," says Prof Lam.

Offering multiple models for different parties to cooperate, NTU aims to enable its public agency and industry partners to hit the ground running when innovating alongside researchers. How these models work depend on the needs of the industry, and can run the gamut from one-to-one unions and tripartite-level corporate labs to multi-party tie-ups, large consortiums and flagship programmes involving overseas organisations.

For instance, SCALE@NTU is a corporate lab established to help drive Singapore's digitalisation strategy in becoming a smart nation. Its various research projects, from enhanced search-and-rescue localisation technology to intelligent transportation systems, are anchored on cutting-edge artificial intelligence to address key issues across sectors.

"Synergising the domain expertise of NCS with NTU's research strengths, we've achieved remarkable outcomes, including training 280 researchers and students, filing 82 technology

disclosures and completing 16 technology transfers," says Prof Ong Yew Soon, Co-Director at SCALE@NTU. "Our fruitful collaboration exemplifies an effective public-private partnership."

SCALE@NTU's latest research in pest detection is spearheaded by Dr Muhammad Faeyz Karim and Assoc Prof Arokiaswami Alphones of NTU's School of Electrical and Electronic Engineering. The potential benefits it presents are manifold – the solution can improve plant quality and crop yield, contribute to the urban greening of Singapore and the nation's "30 by 30" goal of being self-reliant in food production, and address labour shortage in the horticulture and agriculture sector.

Says Dr Karim, who is preparing the technology for commercial use: "Its real-time nature could provide early warnings of pest outbreaks, allowing farmers to take timely action and reduce losses."

A BOON FOR THE INDUSTRY

Industry players like infrastructure consultancy Surbana Jurong have found working together with NTU on research valuable. For example, to address the need for clean energy, the Surbana Jurong-NTU Corporate Lab developed a cryo-polygeneration project.

The project involves converting liquefied natural gas (LNG) back to gas, a process that releases "cold energy". The gas can then be used for applications like generating electricity, while the cold energy is not wasted but instead harnessed for various industry cooling needs, including refrigeration and deep freezing.

This alliance pairs NTU's world-class research capabilities with Surbana Jurong's global industry experience in the urban and infrastructure sectors to develop solutions for complex urban and industrial challenges.

"As global temperatures continue to rise, the tropical hot weather that we face in Singapore will only get worse. Leveraging the circular economy concept, our lab saw the potential of repurposing waste cold energy to provide clean and efficient cooling to residential districts and for industrial applications," explains Prof Alessandro Romagnoli, Co-Director of the Surbana Jurong-NTU Corporate Lab.

With cryo-polygeneration, the researchers seek to use the waste cold energy generated during LNG regasification as a cooling mechanism and to capture carbon – trapping harmful greenhouse gases emitted during industrial processes, such as in industrial parks.

According to Mr Tan Wooi Leong, Surbana Jurong's Senior Executive Director, Energy, producing cold energy for carbon capture is expensive, so the cryo-polygeneration project presents a sustainable alternative that optimises waste cold energy.

Mr Tan is confident of the project's commercial viability. "The design, plant process and all other packages of the project are completed. We are already looking at implementing it across our other projects worldwide. The knowledge that we've gathered through the corporate lab has allowed us to navigate these overseas projects quite easily," he says.

Another example of the synergy between NTU and the industry in accelerating research translation is the joint work between battery maker Durapower and the University's Energy Research Institute @ NTU (ERI@N), both of which share similar goals towards developing innovative energy solutions.

"We believe in value creation. Our partnership with NTU is an extension of our company's readiness to adopt new technology through ongoing market engagement, and research and development," says Mr Kelvin Lim, Durapower's CEO. "NTU offers research expertise, while we provide industry-focused insights, mass production capabilities and global sales channels."

According to Prof Madhavi Srinivasan, Executive Director of ERI@N, both parties have complementary expertise and interest in advancing sustainable battery research. There has been good progress since the start of the tie-up. The team has created a novel solution that utilises digital twin and cloud technologies to offer accurate, real-time condition monitoring of lithium-ion batteries for up to five years. This patent-pending innovation developed by ERI@N Cluster Director Asst Prof Hung Dinh Nguyen is expected to extend the lifespan of batteries by over 50% and, in turn, significantly reduce carbon emissions. It is currently being tested at NTU's Smart Campus.

"Our partnership with NTU is an extension of our company's readiness to adopt new technology through ongoing market engagement, and research and development."

Mr Kelvin Lim
Durapower's CEO

"The humid, high temperatures of tropical Singapore pose unique challenges to battery performance, so testing and understanding the operational state of batteries at the individual component and system levels is important," explains Prof Madhavi.

BUILDING A COMMUNITY

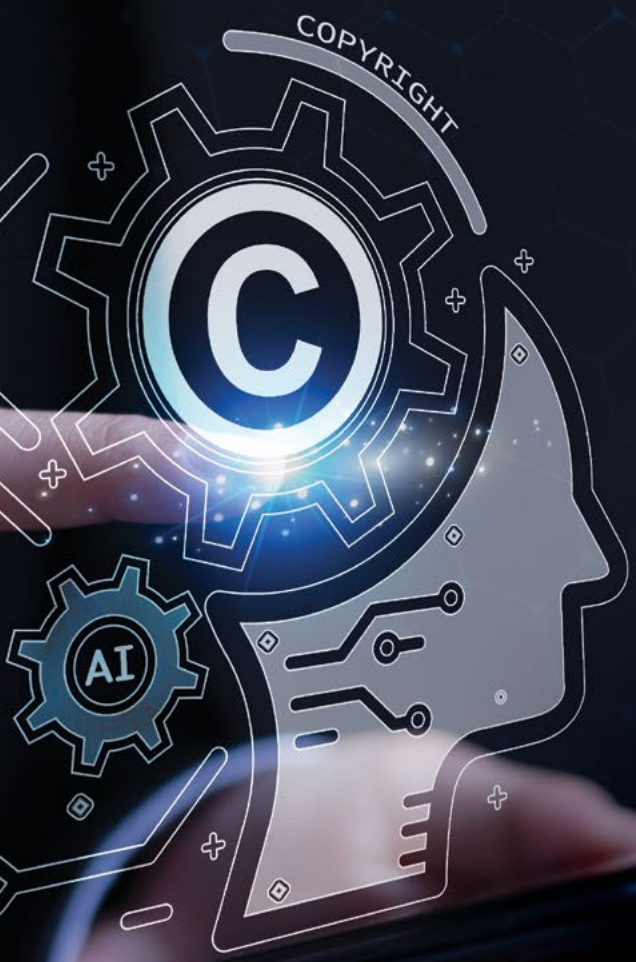
As industry problems become more complex and involve more stakeholders, NTU is pivoting to multi-party collaborations that leverage the expertise and strengths of each party from academia and industry. One example is its ongoing research in liquid organic hydrogen carriers – compounds used for storing and transporting hydrogen as renewable energy. This is a joint effort with the National University of Singapore and several companies across Singapore and Japan.

VPIO's Prof Lam says: "We foresee such collaborative models will become the norm as industries become increasingly interconnected and global challenges require more interdisciplinary solutions."

SAFEGUARDING INNOVATION

WHY INTELLECTUAL PROPERTY MATTERS

Protecting a researcher's rights to the outcomes and activities stemming from scientific studies is paramount but often neglected.



In a Louisville-headquartered company, there is a cabinet with two combination locks kept behind a vault and a triple-locked door. Lying in this cabinet are 11 vials of herbs and spices as well as a yellowed, handwritten note describing one of the most well-guarded secrets of all time: KFC's original recipe.

Recipes are prized as trade secrets in the food sector. Trade secrets and patents are types of intellectual property (IP) available in other sectors as well, such as search engine algorithms and patented drugs derived from research innovations.

By turning an idea or invention into IP that is legally protected and owned, using it will require authorisation from the IP owner. For scientists, understanding their IP rights is fundamental, especially when their research is translated into practical applications.

To support translational research at NTU, the University's innovation and enterprise company – NTUitive – is committed to helping NTU scientists protect their discoveries and launch them from the lab to the marketplace.

MANAGING IP

"IP management is important because it allows inventors to legally protect the potential value of their discoveries and inventions," says Mr David Toh, CEO of NTUitive. "This protection encourages inventors to invest time and effort into research and innovation, knowing that they have legal protection to safeguard their IP."

Overseeing and managing NTU's IP assets, NTUitive supports the University's mission of developing an innovative ecosystem that fosters entrepreneurship and facilitates research commercialisation. It aids in evaluating technology disclosures from NTU researchers to ensure that they align with statutory patentability requirements before determining the most suitable mode and strategy for filing IP protection.

NTUitive also teams up with external parties to oversee the drafting, prosecution and maintenance of the patents in both local and international settings. It works closely with researchers throughout the process, educating them on the nuances of IP protection and dispelling common misconceptions.

Ms Christina Gee, Director of IP Management at NTUitive, says that many researchers assume that securing a patent is instant upon filing. In fact, patent filing is a lengthy and iterative procedure that can span two to seven years, depending on the nature of the technologies involved.

She encourages researchers to cultivate an awareness for spotting potential IP early in their projects. "To bring the benefits of their discoveries to the public, learning about IP rights would be the first essential step," she says.

Securing IP rights ensures inventors are recognised for their ideas and hard work, while protecting their work from unauthorised use by others. IP holders, whether of a patent or other forms, are granted exclusive rights to control the use of their invention.

This can help facilitate collaboration, where industry partnerships can be formed, and licensing opportunities, where licenses can be granted to industry to bring the ideas to market. Patents also help spur innovation as they will

"To bring the benefits of their discoveries to the public, learning about IP rights would be the first essential step."

Ms Christina Gee
NTUitive's Director of IP Management

subsequently be published, allowing others the opportunity to build on them.

In the complex landscape of IP protection, NTUitive offers researchers guidance on formulating cost-effective strategies and navigating revisions to IP filing, making sure there is room for products to potentially evolve over time.

NTU spinoffs, such as medical devices company Articares, have benefitted from NTUitive's IP assistance. Articares is known for its flagship product H-Man – an intelligent and portable robot that provides stroke patients with minimally supervised, at-home arm rehabilitation.

According to Articares CEO Dr Asif Hussain, NTUitive's support started as early as 2013 when research behind H-Man began, and continued until the company was spun off in 2017.

"NTUitive played a crucial role in guiding us through the complexities of IP planning. With limited knowledge in this domain, understanding how to protect our innovations effectively was a daunting task," he says. "Their expertise proved invaluable as they educated us on the nuances of IP protection and also helped us discern which aspects to prioritise, particularly considering the associated high costs."

Articares relies on cutting-edge hardware and artificial intelligence technologies, so safeguarding its IP assets has been crucial.

"Our collaboration with NTUitive was not just transactional – the insights acquired became an integral part of our company's DNA. We were not just recipients of advice, but active participants in the process of fortifying our IP, which contributed significantly to our subsequent successes," adds Dr Asif.

In the last 14 years, NTU has amassed over 5,000 technology inventions/disclosures and licensed out nearly 1,000 technologies. In 2022 alone, the University reported 518 technology inventions/disclosures, of which over 140 have been licensed – surpassing their figures from five years ago by 40%.

TAKING CONCEPTS TO INDUSTRY

IP protection is just one part of the research translation equation. After securing IP, commercialisation typically takes two pathways. The most common approach is to license out IP assets. In this instance, NTUitive leads the negotiation of license agreements to ensure financial and other benefits for NTU and its inventors.

Alternatively, NTU inventors can opt to establish a company like Articares. According to Dr Manish Sinha, NTUitive's Director of Venture Building, establishing spinoffs can be a learning curve for scientists. This is why NTUitive offers diverse training programmes, such as the Lean LaunchPad bootcamp to assist inventors in developing business acumen.

"The process for creating spinoffs is non-linear and a long haul, but can be highly rewarding," says Dr Sinha, who also emphasises the importance of identifying customer needs and staying abreast of international competition in building successful businesses.

Every project often begins with NTUitive identifying potential spinoffs based on market opportunities and the IP's technological edge, followed by improving the IP's market viability. NTUitive's non-dilutive proof-of-concept and proof-of- value grants, which provide sizeable capital allocations of about S$250,000 (US$188,000) and S$500,000 (US$376,000) per project, serve as substantial aid for IP commercialisation.

The company further leverages its entrepreneurial ecosystem by connecting inventors with mentors, industry players, and strategic and financial investors aligned with the execution of their ideas.

In under a decade, NTUitive has successfully incubated 330 startups and deep-tech spinoffs. The collective value of 70 of these deep-tech spinoffs – where NTUitive has current holdings – surpasses S$820 million (US$616 million), as determined by their latest funding valuations.

A CONTINUOUS JOURNEY

While spinoffs initially emerge from IP developed through research, this only marks the beginning of their journey. To remain competitive, ventures should continually develop new IP assets. NTUitive facilitates new IP creation with proof-of-concept grants and equity-linked funding.

Scientists, often the founding members of spinoffs, are also encouraged to maintain close ties with their ventures and continue to develop new IP. Integrating new technologies into spinoffs hones their technological advantage in the market.

Dr Sinha cites Articares as a prime example of how the continuous collaboration between CEO Dr Asif and co-founder Assoc Prof Domenico Campolo of NTU's School of Mechanical and Aerospace Engineering has been fruitful for the company. He believes their joint efforts in developing future IP would strengthen Articares in the realm of intelligent robotics and patient care.

The NTUitive team is optimistic and energised for what lies ahead. Dr Sinha highlights that their goals have always extended beyond financial terms: "It's on us to bring innovation from NTU to the global map and make an impact."

For NTUitive CEO Mr Toh, he defines his team's purpose as two-fold, saying: "Our activities are intended to translate research outcomes into societal and economic benefits and, at the same time, help make innovation and entrepreneurship a defining feature of NTU's brand of education."

Biology meets engineering to tackle chronic conditions

Combining biomaterials, drug delivery and cell therapies to solve complex medical challenges

By Dang Thuy Tram and members of the Dang Group

Asst Prof Dang Thuy Tram of NTU's School of Chemistry, Chemical Engineering and Biotechnology designs innovative medical devices and drug delivery systems to treat chronic conditions ranging from arthritis to diabetes.

Read more about the innovations in Acta Biomaterialia *(2020), DOI: 10.1016/j.actbio.2020.09.026; Inflammation-responsive anti-inflammatory hydrogels (2021) (WO 2021/112772 A1), World Intellectual Property Organisation; and Therapeutic hydrogel device (2020) (WO 2020/204829 A1), World Intellectual Property Organisation.*

Thanks to advancements in medical science, we are living longer than ever before. However, this boon is counterbalanced by the prevalence of chronic conditions. Globally, approximately half of all adults are affected by at least one chronic condition, a statistic that rises to almost 90% among the elderly.

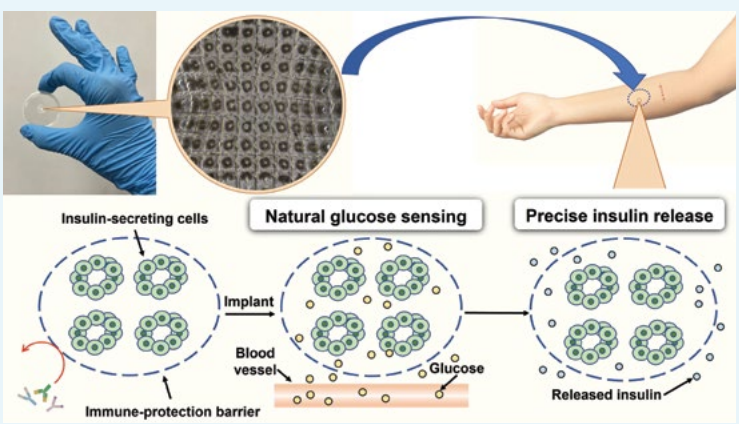
Conditions such as diabetes and arthritis can lead to severe complications, considerably impairing quality of life. By leveraging our collective expertise in tissue engineering, biomaterials and human physiology, my research group is pioneering approaches for chronic disease management.

NEEDLE-FREE SOLUTIONS FOR DIABETES CARE

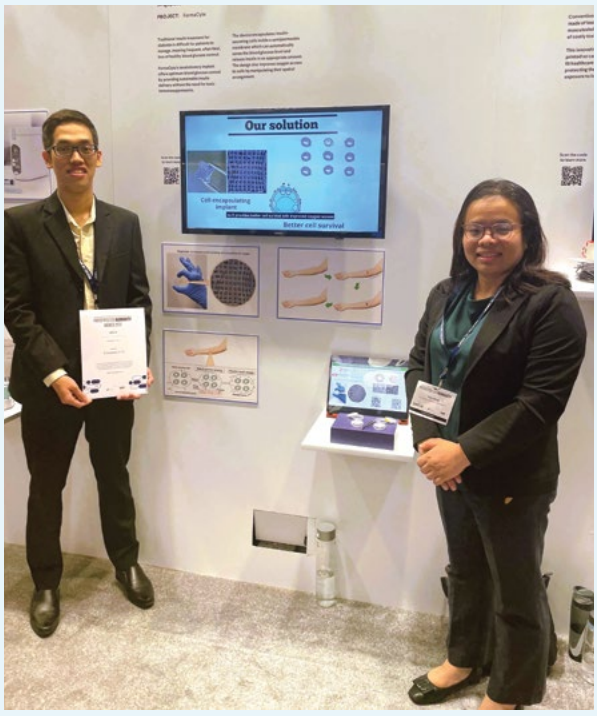
Individuals with Type 1 diabetes or insulin-dependent Type 2 diabetes often rely on regular insulin injections or insulin pumps to maintain their blood glucose at healthy levels.

Such methods, however, do not emulate the body's natural insulin production perfectly, leading to a substantial proportion of patients experiencing dangerously low blood glucose episodes. Moreover, insulin therapy requires patients to meticulously manage their insulin levels and adhere to stringent dietary and exercise regimes, which can impair their quality of life.

Our team has developed a novel implant that houses insulin-secreting cells, either isolated from the pancreas of healthy donors, or derived from stem cells. Designed to be implanted under patients' skin, the device senses blood glucose concentrations and secretes the right amount of insulin in response, providing precise glucose regulation without the need for regular injections.



Cells in the implant release insulin in response to glucose levels in the blood, removing the need for regular insulin injections to regulate blood glucose levels. Credit: Dang Thuy Tram.



NTU PhD student Nam Tran (left) and Asst Prof Dang Thuy Tram with the award-winning insulin-secreting prototype device at the 2022 Prototypes for Humanity showcase. Credit: Dang Thuy Tram.

The cells within the implant are encapsulated in a special hydrogel, a soft, water-based material that protects the cells from immune system attacks. The advantage of this is that patients may not need to take daily immunosuppressants, avoiding adverse side effects associated with the drugs. Additionally, the implant's design facilitates optimal cellular oxygen uptake, which is crucial for the implanted cells to survive and thrive.

Our prototype implant has been shown to be effective at normalising blood glucose levels in mouse models of diabetes. We are currently exploring a more sophisticated prototype for potential human trials.

This technology, currently under patent application, has garnered national and international accolades. It triumphed in the healthcare category at the 2022 Prototypes for Humanity programme, which recognises the top 100 global innovations with societal benefits. Our technology also placed second at the 2022 China-ASEAN Innovation and Entrepreneurship Competition, the 2021 MIT Club of Singapore 15k Competition and the 2021 Society for Biomaterials Business Plan Competition.

RESPONSIVE DRUG DELIVERY FOR ARTHRITIS PAIN RELIEF

Arthritis, a condition that causes joint pain, swelling and stiffness, is a debilitating disease especially prevalent in the elderly. Treatment typically involves anti-inflammatory medications to alleviate symptoms and pain.

Finding the "sweet spot" in medication dosage for arthritis is crucial, as high doses can cause side effects, while low doses might not be sufficient to be effective.

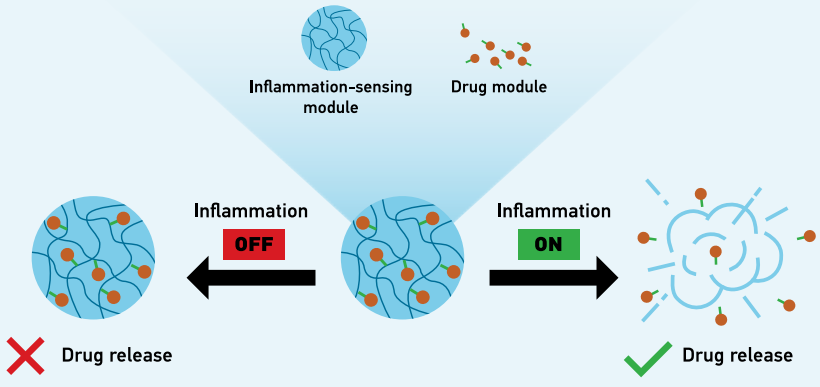
To address these issues, we have engineered a novel drug delivery system that is activated by inflammation. Our device dispenses a precise dose of anti-inflammatory medication, specifically targeting the inflamed tissues.

This unique inflammation-responsive system comprises a special hydrogel that releases drugs in the presence of inflammatory enzymes, allowing for a more targeted and effective treatment for arthritis.

In mouse models of chronic inflammation, our system has shown promise, being effective, safe and non-toxic. Current evaluations are underway in rat models of arthritis and we are working with our clinical partners in a local hospital to evaluate our hydrogel in human joint fluid, in preparation for future clinical trials.

This patent-pending invention has received several awards and was a finalist in national and international entrepreneurship competitions, including taking the third prize at the 2022 Society for Biomaterials Business Plan Competition.

There is tremendous potential in integrating biology with engineering to address chronic diseases, and our team is excited about converting innovations at the bench into clinical solutions, with the ultimate aim of enhancing human health and well-being.



In response to inflammation, drugs are released from the hydrogel to relieve arthritis symptoms. Credit: Dang Thuy Tram.

Understanding infants' mental skills

New AI and sensor tools to measure development

By Victoria Leong, Domenico Campolo and Jonathan Ong

Prof Victoria Leong from NTU's School of Social Sciences (SSS) is Deputy Director of the Cambridge-NTU Centre for Lifelong Learning and Individualised Cognition (CLIC). The developmental cognitive neuroscientist also leads the Baby-LINC Lab at NTU, with an affiliated research team at the University of Cambridge. She studies parent-child neural processes that support social learning and the development of early executive function skills and creativity.

Assoc Prof Domenico Campolo from NTU's School of Mechanical and Aerospace Engineering is the Director of the Robotics Research Centre and co-founder of Articares, an NTU spinoff that specialises in rehabilitation and assistive robotics. His research includes human-machine physical interactions and motor control in humans and robots with applications in industry and healthcare.

Jonathan Ong is a Master's student at SSS, supervised by Assoc Prof Leong. His research interests include understanding how parent-child biobehavioural processes support social learning in both humans and rodents.

Details of this research can be found in Sensors *(2023), DOI: 10.3390/s23052709;* Policy Insights from the Behavioral and Brain Sciences *(2022), DOI: 10.1177/23727322211068020;* Sensors *(2020), DOI: 10.3390/s20205781; and* The British Journal of Psychiatry *(2019), DOI: 10.1192/bjp.2019.73.*

From the first months of life, the social environment – particularly interactions between parent and child – plays a fundamental role in shaping the developing brain and mental faculties. Social behaviours, such as hugs, eye contact, smiling and engaging in conversations, help children cultivate their executive functions as they grow.

These cognitive control skills – including memory, self-regulation and mental flexibility – are crucial for the child to develop focus and the ability to plan actions, and lay the foundation for future academic achievement along with enduring health and well-being.

However, the development of these executive functions may be affected in certain neurodevelopmental conditions, such as autism spectrum disorder and attention-deficit/hyperactivity disorder. These conditions often influence social behaviours in the child and can both impact and be impacted by the quality of early social interactions. Recognising and addressing these challenges at an early stage can significantly mitigate their lifelong impact.

Presently, clinical screening tools are generally only applicable for children aged two and older, which overlooks a critical window for early intervention during infancy. We are pioneers in developing advanced sensor technologies and computational tools for clinical use in the early identification of neurodevelopmental risks.

TRANSFORMING CHILD DEVELOPMENT ASSESSMENTS

A methodological breakthrough is "artificial intelligence (AI) neural sociometrics", a computational technique predicting infant cognition based on multimodal profiles of parent-child social interaction.

By leveraging cutting-edge sensor technologies, we capture and analyse patterns and dynamics of parent-infant interaction: synchrony in pose and movement, shared gaze, emotional expression, vocal turn-taking – when individuals take turns to speak – and neurophysiological measurements of the parent and child's brainwaves and heart rate.

Our approach to these measurements is minimally intrusive, occurring during natural play interactions between children and their parents. With ongoing advancements in signal processing, it may soon be feasible to collect rich biobehavioural data in more familiar settings, such as homes or pre-schools.

To facilitate this, we are developing "smart toys" that are embedded with motion sensors similar to those in smartphones, including an inertial measurement unit

A mother and her child share a moment of eye contact and joint attention while sensors capture their brain and behavioural patterns (image used with specific parental consent). Credit: Baby-LINC Lab.

and a barometer. Designed to elicit natural play, these toys simultaneously measure the child's interactions with them, quantifying the direction and speed of toy movement and the applied pressure. The collected data provides a detailed sequence of toy interactions, revealing patterns from which we can infer aspects of infant cognition and learning through specialised AI algorithms.

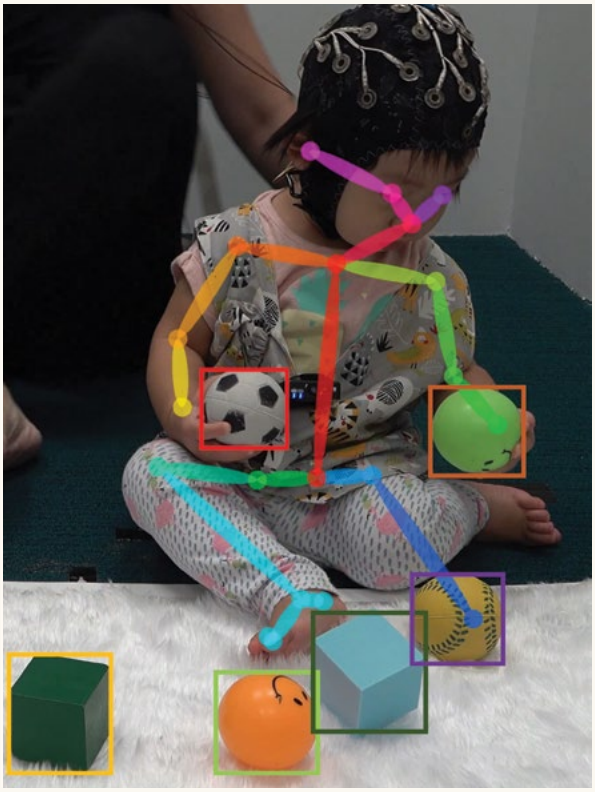
These smart toys, coupled with AI sociometrics technologies, could represent a significant leap forward in early childhood assessment – offering an objective, reliable and scalable method to gather data about a child's developing mental skills, even during infancy.

A NEW PARADIGM FOR CHILD DEVELOPMENTAL SCREENING

Imagine a future where routine 10-minute visits to a child development clinic evolve into interactive play sessions. Families enter a sensor-equipped playroom, where small, unobtrusive sensors and cameras capture brain activity, heart rates, gestures, facial expressions and speech. Toys fitted with eye-tracking and touch sensors provide real-time data on the child's attention and interaction patterns.

A psychologist observes and guides these interactions, extracting meaningful social responses for analysis. High-performance computers equipped with AI algorithms then scrutinise this data, offering real-time feedback on the child's cognitive development.

The time and resources required for such sociometric screening could eventually become comparable to that of a standard newborn hearing test, a nearly universal practice. If achieved, this would facilitate the routine use of sociometric screening as part of a child's developmental journey, informing the timely allocation of healthcare resources and intervention. Early and timely action could fundamentally alter the developmental trajectory of children, setting them on a course towards lifelong cognitive health and mental well-being.



Trained AI algorithms predict the child's pose and interactions with toys in near real-time (image used with specific parental consent). Credit: Baby-LINC Lab.

Coating technology beats the heat

Fire protection for timber without hiding wood grain

By Aravind Dasari and Dean Seah

Assoc Prof Aravind Dasari is Associate Chair (Academic) at NTU's School of Materials Science and Engineering (MSE). His research interests include designing and developing polymer composites, nanocomposites and coatings that can be used in the construction and building sector, electrical and electronic industries, and the renewable energy sector.

Dr Dean Seah is a research fellow at MSE. He studies, among other things, chemical and physical material properties of polymers with and without flame-retardant additives, and seeks to find real-life applications for them.

Details of the research can be found in Polymer Testing *(2023), DOI: 10.1016/j.polymertesting.2022.107893;* Construction and Building Materials *(2023), DOI: 10.1016/j.conbuildmat.2023.132633;* International Journal of Adhesion and Adhesives *(2022), DOI: 10.1016/j.ijadhadh.2022.103185; and* Progress in Organic Coatings *(2021), DOI: 10.1016/j.porgcoat.2020.105985.*

Creating materials that can withstand fire or prevent it from spreading quickly is incredibly important in industries where keeping people safe is a top priority. Imagine the materials used to construct the buildings where we work and live in: they should be made of strong, fire-resistant and flame-retardant materials that retain their integrity in the event of a fire.

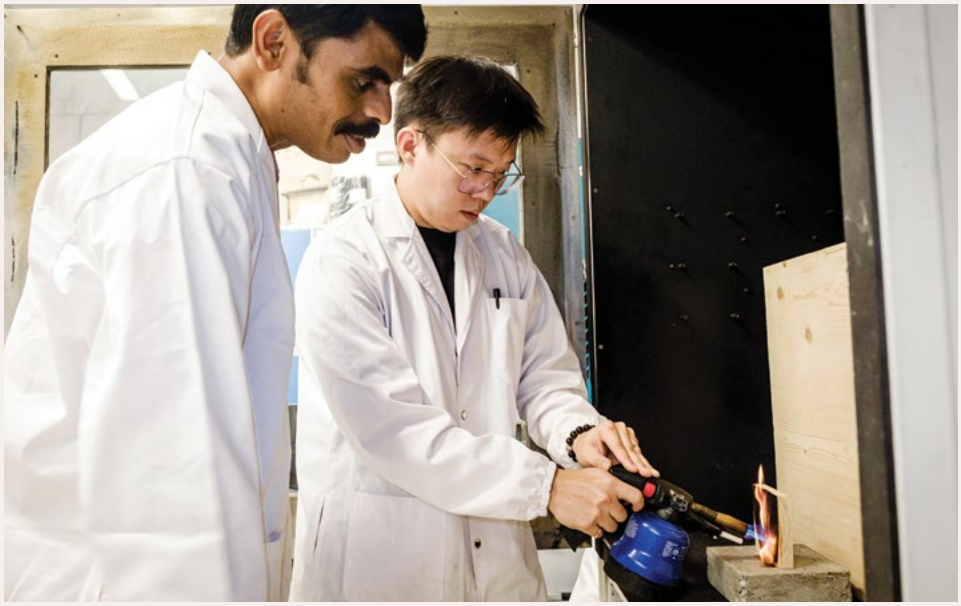
Most research in the field of material flammability focuses on the qualities of the materials themselves, such as how well they can withstand heat and how long they take to burn. Nonetheless, for a multitude of fire-protection material applications, as in construction, marine and offshore industries, the requisite fire-performance parameters differ significantly, necessitating large-scale testing which is conventionally both time-consuming and resource-intensive.

As a result, many questions have been raised on the validity of the thermal and flammability tests done using academic approaches to predict how well fire-protection materials perform in real-world scenarios.

Our team distinguishes itself by rigorously investigating the combustion behaviour of materials and systems across varying scales – from individual materials to components and entire structures – in close collaboration with industrial partners and regulatory bodies. In this way, we are able to overcome substantial barriers in the transition from research to commercial viability.

We have successfully designed and engineered flame-retardant polymers, composites, foams and a plethora of coatings, including one called "FiroShield". Additionally, we have pioneered core materials for aluminium composite panels, natural fibre-based panels and geopolymer composites with inherent fire retardant and resistant properties.

When exposed to fire, wood not coated with the invisible coating (left) gets burnt and damaged, unlike wood protected by the novel coating's char (right). Credit: NTU.



Assoc Prof Aravind Dasari (left) and Dr Dean Seah from NTU's School of Materials Science and Engineering exposing wood without their coating to a flame. Credit: NTU.

Our scientific discoveries have not only been featured in peer-reviewed publications, but have also led to numerous technology disclosures, a significant number of which has been commercialised through licensing agreements with corporate entities.

ULTRA-THIN FIRE PROTECTION

One notable technology disclosure, facilitated through NTU's innovation and enterprise company NTUitive, concerns the licensing of a transparent fire-retardant coating developed by our team.

This innovative coating is designed to shield mass engineered timber, a construction material garnering increasing interest due to its potential to expedite construction timelines by up to 35% through offsite prefabrication.

The natural wood grain of mass engineered timber contributes to its aesthetic appeal. When sourced from sustainably managed forests, buildings constructed from this timber variant have the potential to exhibit a reduced, or even negative, carbon footprint, in comparison to those constructed using steel or concrete.

Nonetheless, given timber's inherent flammability, protective measures are imperative. Current practices involve encasing the timber in gypsum or magnesia fire-retardant panels or applying fire-retardant coatings – both of which obscure the timber's natural wood grain.

Our research endeavoured to surmount this limitation, culminating in the development of a transparent fire-retardant coating that maintains the visible natural aesthetic of mass engineered timber while safeguarding it against fire.

Upon exposure to fire, the coating undergoes a chemical reaction, causing it to expand over 30-fold in thickness and forming a char layer that insulates the timber beneath from the flames.

This versatile coating is also applicable to other engineered wood-based products used in the building and construction sector, be it for architectural structures or internal linings, decking and flooring.

LAB TO MARKET SUCCESS

In partnership with Venturer Timberwork, a Singapore-based mass engineered timber design and build firm, our research has addressed numerous industrial challenges.

Our coating was tested against industry standard fire classification protocols and we eschewed the use of halogen-containing additives, known for producing toxic emissions upon combustion.

Experimental comparisons between wood treated with our coating and untreated specimens revealed a pronounced reduction in heat release rates and flame spread inhibition with minimal smoke produced.

Even a coating of minuscule thickness, comparable to a strand of human hair, achieved excellent ratings under European fire reaction standards for building materials, alongside fulfilling an International Organisation for Standardisation benchmark for product ignitability.

Venturer Timberwork has obtained exclusive rights to this innovation and has pursued further testing, obtaining regulatory approval for its application in several construction projects in Singapore. They have also partnered with Japan's Kajima Technical Research Institute to adapt the coating for Japan's mass timber building market.

A crucial factor in the scalability of the NTU-developed coating lies in its amenability to factory application, a feasibility rendered by its robust epoxy-based formulation, which distinguishes it from other water-based alternatives. Among the manufacturers interested in adopting this factory-applied coating is the Versowood Group, Finland's leading private sawn timber producer and processor.

PURPOSEFUL INNOVATION

NTU's new President, Prof Ho Teck Hua, shares how NTU is fuelling translational research to solve industry pain points and push knowledge frontiers

Research builds new knowledge that advances society and addresses some of its most pertinent issues. Applying knowledge from research to tackle humanity's greatest challenges is a key aspect of NTU's mission as a global, research-intensive university founded on science and technology.

The University needs a systematic way to encourage such research, as well as strike a balance between discovering new knowledge and finding practical applications, says NTU President Prof Ho Teck Hua.

Prof Ho was appointed as the University's fifth President in April 2023 and also honoured as a Distinguished University Professor, the highest academic honour bestowed on eminent NTU faculty members with extraordinary scholarly achievement.

An acclaimed expert in behavioural economics, data science and management science, he is also the Founding Executive Chairman of AI Singapore, a national research and development programme, and President of the Academy of Engineering, Singapore.

In this interview, Prof Ho outlines NTU's vision for translational research and why ideas are its most valuable assets.

Q Why is translational research important to the University?

A Research translation is in our DNA. NTU is, by design, a practical and technological university that creates solutions to change the world.

We began by producing practising engineers. Now, we're producing not only graduates in many disciplines but also ideas that make a difference.

This is integral to our vision and mission to be a great global university founded on science and technology that nurtures leaders and creates societal impact through interdisciplinary education and research.

Q How is translational research crucial for Singapore?

A For small countries like Singapore, research translation is important because our enterprise ecosystem is not as vibrant as that in larger countries. We don't have as many big companies capable of turning research into innovations, so we must figure out a more systematic and purposeful way.

Through translational research, there is economic impact when companies use our research to create products, jobs and exports for Singapore. Besides financial returns, translational research can also improve life in other ways, such as helping us find answers in the fight against pandemics and enabling people to be healthier.

Q How is the University encouraging research translation?

A We fuel research translation to create societal impact in four ways. First, we work with world-class industry partners on research, including companies as diverse as Rolls-Royce and HP. They tell us their pain points, and we address them by providing technical expertise as well as new and relevant research ideas. So, our research serves as an economic engine that helps businesses develop better products and solutions.

We now have over 250 industry partners and about 20 corporate laboratories and joint laboratories with industry on research.

Second, we conduct research that we believe will be useful to the world, and license intellectual property (IP) from our research to companies. Businesses can then use the IP to improve their goods and services and address problems they face.

We have over 5,000 invention and technology disclosures from the past 14 years. Among these, about 20% of the technologies have been licensed.

The University's third approach to research translation is to cultivate our own startup ecosystem, where we support the creation of enterprises that tap into our IP to develop products and services for a global market.

In the past decade, we have incubated 70 companies spun out from NTU's research, from biomedical innovations to water treatment solutions. Several spinoffs have been publicly listed or acquired too.

For instance, CelePixel, which designs high-speed imaging sensors for autonomous electric vehicles and robots, was spun out from NTU in 2016 and acquired by OmniVision for S$100 million (US$134 million) in 2019.

Lastly, we build on NTU's contingent research capabilities that can be leveraged to find solutions during crises such as the COVID-19 pandemic. To develop these capabilities, we support our researchers in honing their skills and expertise through challenging research problems.

Q What is NTU doing to improve its work with industry partners and licensing its research IP?

A For our industry collaborations, we want to improve the quality of the research projects done with our partners to address not only their immediate and short-term problems, but also their longer-term and more ambitious challenges.

Besides just applying our research knowledge to solve issues, we strive to make new discoveries and push the knowledge frontier at the same time – achieving a balance between the two is important.

To facilitate the licensing of NTU's research, we are simplifying our IP framework and making the IP application process easier for companies by dramatically cutting application times from months to weeks.

This will be done through a common online IP platform that we're developing with the National University of Singapore (NUS). The platform is part of a recently launched S$75 million (US$56 million) programme by NTU, NUS and Singapore's global investment company, Temasek.

Under the new platform, IP licensing fees will also be deferred to lower barriers to encourage companies to experiment with our IP for free. They pay licensing fees only after they start making a certain amount of revenue.

Additionally, we want to better promote NTU's IP, so that more organisations can tap on our ideas to deal with their pain points.

In the coming year, we are developing a systematic way to group relevant IP together and market it as a bundle, while also offering consulting services to guide companies in translating the IP.

Our goal is to increase the proportion of technologies we license from one in five now to one in two in the future.

Q How does NTU intend to grow its startup ecosystem and foster unicorn companies?

A Every year, we invest in 15 deep-tech startups spun out from the University's research on significant scientific advances or engineering innovations. So far, we have one unicorn (a private startup valued at over S$1.34 billion or US$1 billion), the nanotechnology solutions company Nanofilm Technologies International.

We have an ambitious plan to double the number of NTU deep-tech spinoffs from 15 to 30 annually by 2026. Through careful curation and support, we hope to increase the probability of producing unicorns.

Three ingredients are necessary to foster the birth of the next unicorn: technical expertise, venture building experience and funding. The recent S$75 million (US$56 million) programme launched by Temasek, NTU and NUS aims to bring these factors together and accelerate the creation of successful deep-tech startups from research at NTU and NUS.

The initiative will focus on companies possessing technologies with the potential to address large problems in a market that is worth over S$50 billion (US$37 billion).

NTU and NUS will provide "experts on demand" to help companies overcome

"Research translation is in our DNA. NTU is, by design, a practical and technological university that creates solutions to change the world."

technical barriers in bringing these technologies to market.

Temasek will offer venture building guidance and provide managerial talent to run startups. For instance, the chief executive officer of the NTU spinoff Amperesand, whose technology could enable more efficient charging of electric vehicles, was brought in with Temasek's help.

Joint funding from Temasek, NTU and NUS will also support the startups financially.

Q Why is it important for the University to build contingent research capabilities?

A Recent advancements in generative artificial intelligence (AI) include chatbots like ChatGPT that are poised to fundamentally change the way we learn and interact with machines, as they make a huge wealth of knowledge accessible to us.

However, AI chatbots are influenced by biases in the data fed to them. This makes them less effective at making sense of cultural norms and nuances that they are not trained on, such as language varieties unique to specific countries.

NTU can leverage its strong contingent capabilities in AI research to develop generative AI innovations tailored to languages used in Southeast Asia.

This would not be possible if the University did not already have such research competencies on hand.

Other up-and-coming, game-changing fields where NTU has demonstrable prowess are photonics and quantum science.

Our Photonics Institute is a world-class centre in photonics technology research. The University's Quantum Science and Engineering Centre is also the first of its kind in Singapore, developing devices and technologies powered by quantum science and training skilled talent for quantum engineering.

We will continue to explore emerging contingent capabilities on which to build our strengths.

Q How does NTU balance the pursuit of intellectual curiosity and research commercialisation?

A NTU always focuses on research with high intellectual value. Within this category, we have research with high intellectual value and high translational value (applied research), and research with high intellectual value and uncertain translational value (curiosity-driven research).

Applied research can lead to immediate impactful outcomes for society.

Curiosity-driven research advances our understanding of the world, even if its applications and translational value may not be apparent yet.

We believe in striking a balance between applied research and curiosity-driven research at the University.

Q What skills and mindset should a researcher have, and how can NTU attract the best research talent?

A We want our researchers to embrace a culture of pursuing research that tackles the biggest, most difficult and most intellectually challenging problems.

Researchers should stay curious about their fields of study while addressing the biggest limitations that the world faces, such as land scarcity issues and bottlenecks in human productivity.

They should strive to come up with solutions to challenging problems and push the frontiers of human development in meaningful ways.

To produce outstanding results from research, NTU must continue to nurture an open, creative and encouraging environment that empowers our researchers. Our infrastructure, resources, shared facilities and mentorship from colleagues are also crucial to supporting our researchers in their endeavours.

PUTTING RESEARCH TO WORK

APPLYING IDEAS TO BENEFIT SOCIETY

Translating research into useful applications and even viable businesses requires quality research and effective partnerships. *Pushing Frontiers* speaks with four NTU research leaders on what it means to develop solutions that address global issues and meet industry needs.

Translational research goes beyond merely conducting research with practical applications – the research needs to be at a level that can create intellectual property (IP), such as patents, with societal impact and strong market potential.

NTU strives to achieve this through its work with more than 250 industry partners. One reason for the successes that the University has enjoyed lies in how it works with industry, says Prof Lam Khin Yong, NTU's Vice President (Industry).

"We work hand in hand with industry partners on research from Day One," explains Prof Lam, who is from NTU's School of Mechanical and Aerospace Engineering. "This is very useful because companies have deep market knowledge and can provide inputs that help guide scientific research towards outcomes that can be commercialised to benefit society."

When NTU works with industry, each research project is led from the start by an NTU professor and a company scientist or engineer, he adds. This is especially so for NTU-industry alliances in the form of corporate labs co-funded by government agencies and businesses, and joint research labs funded by companies.

NTU has around 20 corporate and joint labs on campus with many leading businesses such as Continental, Delta Electronics, Mastercard, Rolls-Royce, Singtel and SP Group.

Research tie-ups between academia and industry benefit both parties, emphasises Prof Lam, who is in charge of overseeing and driving NTU's partnerships with industry.

"Industry partners are able to access world-class expertise to develop processes, products and services that add value to them," he says. "This also means companies can tap trained student researchers at the undergraduate and graduate levels, whom they can hire after graduation to continue research and development with the firms."

NTU's strengths in research are well recognised. According to the US News and World Report global university rankings for 2022 to 2023, NTU ranked first worldwide in five areas of research: condensed matter physics, energy and fuels, materials science, nanoscience and nanotechnology, and physical chemistry.

The same rankings also placed the University second globally in the fields of artificial intelligence, electrical and electronic engineering, and engineering.

One industry player that has benefitted from partnering NTU is British engineering giant Rolls-Royce. The company applied research from the Rolls-Royce@NTU Corporate Lab, housed within NTU, to help design and develop future power and propulsion systems and improve manufacturing operations in Singapore and other Rolls-Royce sites elsewhere.

The lab was the result of a relationship between Singapore and Rolls-Royce that Prof Lam helped to nurture for decades since his days in the late 1990s as the Founding Executive Director of the Institute of High Performance Computing at Singapore's Agency for Science, Technology and Research.

Another beneficiary of research unions between NTU and industry is students; they stand to gain valuable research and development training, and mentorship. "Such experiences are important for students to thrive in a world now shaped by technological innovations that are moving at a rapid pace," says Prof Lam.

Besides corporate and joint labs, NTU is also working collectively as a consortium with multiple parties – more than just a single corporation or government agency – that share a common mission and purpose to address complex challenges and drive innovation.

The approach draws on the strengths of each party in the consortium, from academia to industry. "This allows us to pool resources, knowledge and capabilities to accelerate the development and application of cutting-edge solutions," says Prof Lam.

This was the case for the world's first testbed launched in Singapore to develop and test innovative and sustainable cooling technologies for data centres in the tropics.

Dubbed the Sustainable Tropical Data Centre Testbed, it involves researchers led by NTU and the National University of Singapore working with many industry partners, from CBRE and Intel, to Ascenix and Keppel Data Centres.

NTU works with industry on other testbeds too, and its campus is a living lab to test new technologies. According to Prof Lam, these testbeds assess the practical implications of research in controlled but real environments, ensuring the technologies can be applied on a broader level and scaled up.

The University's Energy Research Institute @ NTU, for instance, is working with its partners on testbeds to shore up Singapore's clean energy and sustainability capabilities. Its collaboration with the country's National Environment Agency aims to test how well different sources of renewable energy can work under the Renewable Energy Integration Demonstrator-Singapore project, which helps power a facility on Singapore's only landfill.

Beyond Singapore, Prof Lam says that NTU is cultivating long-term tie-ups with overseas companies, universities, research institutes and public agencies for research, education and development initiatives.

Recently, the University established the Indonesia-NTU Singapore Institute of Research for Sustainability and Innovation with Indonesia's Ministry of Education, Culture, Research and Technology, as well as four top universities in the country. The institute seeks to address climate change and sustainable development.

For research projects like these and many others with industry, Prof Lam stresses that "the ingredient for success is always teamwork". Students, research staff and faculty members from across disciplines are usually involved to lend their varied expertise and perspectives to help projects get across the finish line, he adds.

Prof Lam's efforts to foster close academia-industry collaborations were recognised in 2018 with the Singapore President's Science and Technology Medal. Earlier, in 2017, he was made a knight in the Legion of Honour, the highest national award bestowed by the French government.

"By combining NTU's strengths in science and technology with the high-quality resources of leading companies in the world, we can accelerate innovation and research to solve global challenges," says Prof Lam.

Prof Lam Khin Yong

Industry rainmaking

Credit: NTU.

Prof Louis Phee

Innovation and entrepreneurship

Credit: NTU.

In the decade-plus since co-founding his first spinoff, Prof Louis Phee has grown familiar with the ups and downs that come with starting a business venture. Taking the plunge from research to industry demands considerable time, effort and capital, with its fair share of risks.

The prospect of embarking on entrepreneurship is understandably intimidating for many people in Singapore who can be fairly risk averse.

Nevertheless, compared with the early stages of his own entrepreneurial journey, Prof Phee – who is currently Vice President (Innovation and Entrepreneurship) at NTU – has witnessed a shift in the next generation of innovators.

"Young people are willing to take more risks now. They understand that being young has its advantages and are willing to take their chances," says the entrepreneur, who co-founded the medical devices companies EndoMaster and EndoPil in 2011 and 2019, respectively.

"And I want to create an ecosystem where people can take more risks, help one another and, as OneNTU, push up more startups," adds Prof Phee, referring to the OneNTU collective spirit embraced by the University's community.

This vision underpins an initiative he is driving to bolster innovation and entrepreneurship at NTU. One idea is the development of new academic credentials in innovation to lower the barriers to entrepreneurship. In the proposed education programme, students will engage with relevant academic coursework. But instead of just submitting a thesis, they will also establish a business on the back of an innovation.

"You would be pursuing a programme that involves starting up a company at the same time," says Prof Phee. "Even if your company fails, you'd still have learnt from your startup experience and have academic credentials too."

The details of the programme are under development, with NTU seeking funding, potentially earmarked for scholarships.

Should the programme come to fruition, it could contribute to the University's ambition of doubling the number of deep-tech firms from 15 annually now to 30 by 2026. Such companies spin out from NTU's research on significant scientific advances or engineering innovations.

"The hope is that if you have more good startups that can be invested in, there's a higher chance of having another 'unicorn' in the long run," says Prof Phee. He is alluding to NTU's first unicorn, Nanofilm Technologies International, a deep-tech spinoff incorporated in 1999 and publicly listed in Singapore in 2020. Unicorns are private startups valued at over US$1 billion (S$1.34 billion).

To encourage and nudge students to think out of the box and be more entrepreneurial, NTU has instituted courses and programmes. For example, all new undergraduates are introduced to concepts of entrepreneurship in the Interdisciplinary Collaborative Core curriculum. Successful entrepreneurs are also invited by the University to mentor and share insights with students.

Prof Phee has a particular interest in cultivating doctoral students and postdoctoral graduates. "Given enough resources and training, they can take NTU's research outcomes, including the research-based intellectual property they create, and translate them," he explains.

He also emphasises the lesson that successful ventures often require collaborative efforts, rather than solitary endeavours. This is one of the most important things Prof Phee learnt from bringing research to market.

"Many company founders think they know everything. The truth is, as one person, you know very little," he says. "For a company to succeed, you need people from very different disciplines to come together."

For instance, as an engineer from NTU's School of Mechanical and Aerospace Engineering, Prof Phee has the know-how to develop the technology behind his companies' surgical robot and weight-management device. But marketing them is another matter and requires people from other fields with the relevant experience on board, he explains.

This interdisciplinary tenet is reflected in activities under his innovation and entrepreneurship effort. It includes hackathons and competitions at NTU, where students from varied academic backgrounds – such as business, engineering and medicine – are encouraged to team up and complement one another to tackle challenges.

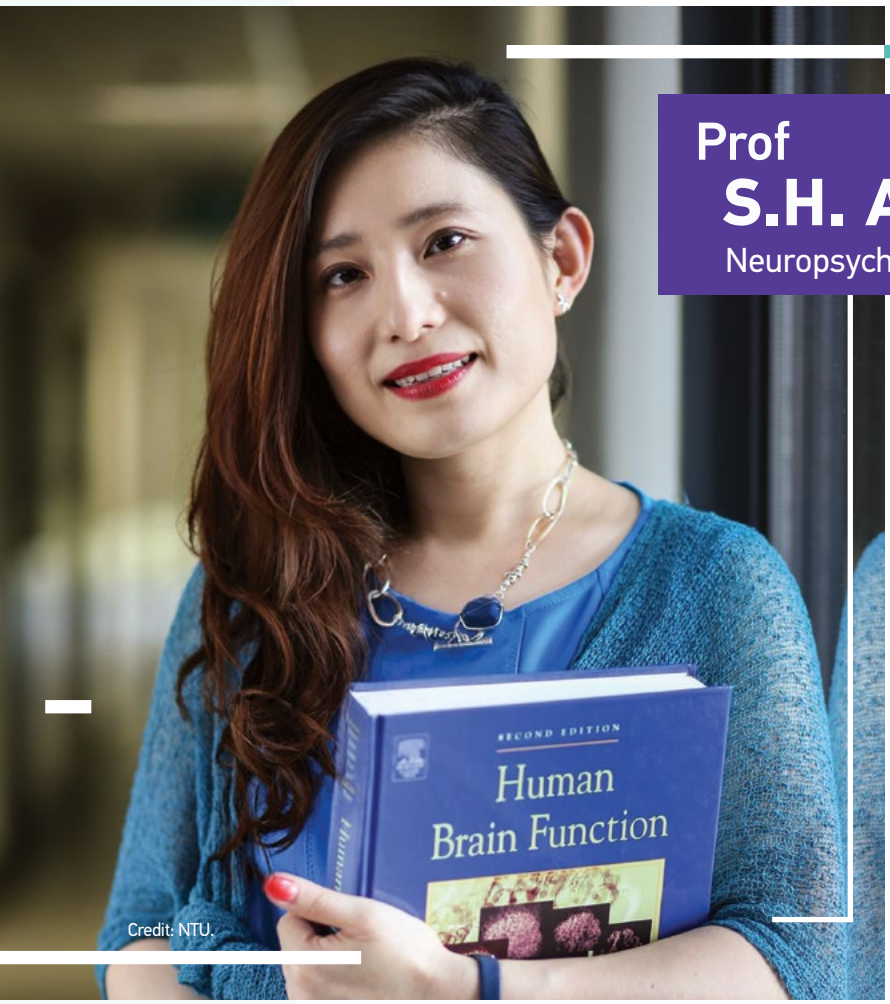
To further promote collaboration between students and even companies, and provide room for them to tinker and experiment, Prof Phee wants to create more dedicated, easily recognisable spaces to cultivate startups on campus. This would be NTU's own take on the United States' renowned Kendall Square innovation hub that is closely linked to the Massachusetts Institute of Technology.

"Such spaces are important because they can draw like-minded people to come together to generate more ideas," says Prof Phee.

At the same time, he acknowledges that entrepreneurship cannot be forced and overly curated: "A lot of it is serendipity. And we should give people room for this to happen."

Beyond becoming vibrant places for startups to congregate, Prof Phee aspires for these university spaces to also celebrate and elevate successful NTU-originated companies and their founders as beacons of inspiration for others to follow.

"These founders are heroes who dare to dream and start their own homegrown companies," he says. "These companies are the future of Singapore's economy and we need more like them."



Credit: NTU.

Prof S.H. Annabel Chen

Neuropsychology and the science of learning

Our brain plays a vital role in how we perceive and interact with the world. Can we harness the brain's ability to change and adapt to enhance learning or to treat conditions like mental health issues?

This is one of the questions that Prof S.H. Annabel Chen of NTU's School of Social Sciences explores in her research at the Clinical Brain Lab. The clinical neuropsychologist is interested in how brain networks influence our thinking and behaviour, and how we can use this knowledge to make our brains work better.

Her earlier study at Stanford University challenged the traditional view that a part of the brain known as the cerebellum is only involved in movement. Through functional magnetic resonance imaging and transcranial magnetic stimulation, she found that the cerebellum is also important for higher cognitive functions like working memory.

This discovery has been employed to understand conditions such as chronic alcoholism, schizophrenia and obsessive-compulsive disorder. Now, Prof Chen is studying the role of the cerebellum in language, especially reading, to improve intervention strategies for reading difficulties, such as dyslexia.

Her team at the Clinical Brain Lab is also exploring how our brains change as we age, particularly in Asian populations. Her research suggests that combining physical and mental exercises can boost cognition in older adults.

Together with colleagues at the National Institute of Education (NIE) in NTU, Prof Chen studied the benefits of a square stepping exercise on cognition and well-being in the elderly. She also partnered investigators in the Philippines to improve the thinking abilities of older adults exhibiting mild cognitive impairment through dance, with evidence from neuroimaging.

In the last several years, Prof Chen has been involved in the national Science of Learning initiative. Currently, she is Director of the Centre for Research and Development in Learning (CRADLE) at NTU, a pan-university research centre that supports interdisciplinary research across the University to transform learning in higher education.

Applying science of learning concepts to education, the CRADLE team is examining the brain networks involved in biliteracy. The team has shown that working memory is linked to reading, which presents significant implications for teaching and learning.

In a project funded by Singapore's Ministry of Education, Prof Chen is also studying how brain networks are involved in the development of reading, mathematics and working memory skills. The goal is to identify and help students who may be struggling in these areas.

Prof Chen is also a co-director of NTU's Centre for Lifelong Learning and Individualised Cognition, which hosts international collaborations with the University of Cambridge to examine how cognitive flexibility can be enhanced to optimise learning and develop educational and real-life applications.

To make cognitive neuroscience findings accessible to educators, Prof Chen is working with colleagues at NIE and developers of the BrainMap project at the University of Texas Health Science Centre to develop visualisation tools for various brain functions and networks.

More recently, Prof Chen has ventured into the interdisciplinary field of social neuroscience. She aims to unravel the brain processes underlying deception, cognitive biases and the perception of real and fake information.

"A critical understanding of how the brain is involved in thinking and behaviour is important for optimising its function. I look forward to pushing the frontiers of what we know about this remarkable organ," says Prof Chen.

Prof Chen Xiaodong wants to expand the physician's toolkit for disease diagnosis.

He and his research team at NTU came up with an electronic glove equipped with sensitive, flexible pressure sensors that can differentiate between healthy and diseased body features.

The innovation could revolutionise patient examinations and help doctors treat patients more effectively. It is also an important step towards the development of medical robots.

Prof Chen's expertise spans diverse futuristic applications of soft materials, ranging from flexible devices to innovations in carbon capture. In particular, he wants to harness soft materials to create flexible electronics for the next generation of medical devices.

The prolific inventor, with over 50 patents under his belt, advocates that softness embodies strength, viewing it as resilience rather than a weakness.

"Unlike rigid materials that break under extreme stress, soft materials are stable even when stressed as they are flexible and stretchable," says Prof Chen, who is President's Chair in Materials Science and Engineering at NTU.

"Soft materials open the door to a multitude of possible healthcare applications, such as soft surgical robots and wearable sensors for continuous health monitoring."

Prof Chen is also Deputy Director of NTU's Institute for Digital Molecular Analytics and Science, a research centre dedicated to advancing the science of analysing biological molecules.

One of his ongoing projects involves a data-centric approach for the objective evaluation of complex scents. This project was awarded the Agency for Science, Technology and Research RIE2025 Manufacturing, Trade and Connectivity Programmatic Fund, which supports research that has the potential to create significant impact for Singapore. Prof Chen's project aims to bridge a gap in mass scent evaluation and can be applied to several areas, such as food and environmental analysis.

Prof Chen has published over 380 papers in top-tier journals. He also serves on several editorial advisory boards while helming prestigious scientific journal *ACS Nano* as Editor-in-Chief.

To translate technology from his research endeavours, Prof Chen actively collaborates with industry partners and institutions. Together with multinational consumer goods corporation Procter & Gamble, he and his team developed a sensor for testing product textures.

He has also garnered many accolades for his research, including the Dan Maydan Prize in Nanoscience and Nanotechnology in 2023 for his breakthrough contributions to novel nanomaterials and nanodevices, especially for flexible electronics, nano-bio and cyber-human interfaces, and alternative energy applications. He is the first Asia-based recipient of this prestigious prize.

In the same year, Prof Chen received the Kabiller Young Investigator Award conferred by Northwestern University's International Institute for Nanotechnology. He was recognised for his groundbreaking achievements in creating devices such as soft composite materials, biosensors and neural interfaces, which hold transformative implications for nanoscience and nanomedicine.

Besides heralding future healthcare innovations, Prof Chen is exploring the potential uses of soft materials for capturing atmospheric carbon dioxide to tackle global warming.

"I am motivated by the prospect of making a positive impact in the world through my research, and I aspire to continuously deliver innovative solutions at the interface of human and machine that benefit our society," says Prof Chen.

Credit: NTU.

Prof
Chen Xiaodong
Soft materials

EXPLORING SUSTAINABILITY AND THE IMPACT OF AI

Climate change is a looming crisis that NTU researchers are actively addressing.

A three-part documentary series titled *Our World to Change* by NTU and Singapore broadcaster Mediacorp gives a first-hand look at how the University is championing sustainability and advocating change through its wide-ranging initiatives.

From scientists on an Antarctica expedition studying rising sea levels linked to global warming, to researchers solving waste management problems by turning trash into treasure, the documentary sheds light on the critical research and novel solutions from NTU to save the planet.

The series premiered in July 2023 and was produced under Mediacorp's news network CNA, in support of the Singapore Green Plan 2030 that charts the country's way towards a sustainable future.

To test driverless technologies, such as self-driving electric buses, NTU has a track at its Centre of Excellence for Testing and Research of Autonomous Vehicles – NTU, as seen in *Our World to Change*, a documentary highlighting NTU's sustainability efforts. Credit: NTU.

What are the ethical considerations when using artificial intelligence (AI) chatbots like ChatGPT in research? How do we ensure compliance with research integrity policies?

These were some of the issues discussed at the Research Integrity Conference, organised by NTU, the National University of Singapore and Singapore's Agency for Science, Technology and Research.

The event, held in May 2023, examined how research integrity can be maintained when managing research data, especially with the advent of AI. It also delved into the way researchers leverage AI, which could be a double-edged sword when not used properly.

Other conference topics covered include why people share data and how this enabled governments and healthcare institutions to respond to global pandemics, such as detecting new variants of the COVID-19 virus.

AI is set to transform the healthcare sector in profound ways. To discuss how it will shape the future of medicine and healthcare, the medical and engineering colleges at NTU, together with Singapore's National Healthcare Group, held the inaugural International Conference on Artificial Intelligence in Medicine in August 2023.

The three-day meeting at NTU's Novena campus drew attendees ranging from clinicians and scientists to engineers and AI experts. They explored the impact of AI on medicine and healthcare, including the ways it could change the delivery of medical education and practice, and data privacy concerns arising from its use.

Singapore's Manpower Minister Dr Tan See Leng (left) and Prof Joseph Sung, NTU's Senior Vice President (Health and Life Sciences) and Dean of the Lee Kong Chian School of Medicine (second from left), at an exhibition held at the conference. Credit: LKCMedicine.

In May 2023, a renowned data symposium regularly hosted at the United States' Massachusetts Institute of Technology was brought to the Asia-Pacific for the first time in cooperation with NTU's Nanyang Business School.

Held in the University's main Yunnan Garden campus, the Chief Data Officer and Information Quality Asia-Pacific Symposium provided a platform for data leaders from academia, government and industry to look into pressing data topics, such as data governance and ethics in analytics, machine learning and AI.

The original Chief Data Officer and Information Quality Symposium, which had its 17th edition in 2023 in the US, is one of the most important data events globally where attendees exchange innovative ideas and best practices as well as advocate the role of chief data officer in organisations.

[COMING YOUR WAY]

1 NTU has inked new partnerships with two of Vietnam's leading public universities – **Vietnam National University**, **Hanoi**, and **Vietnam National University**, **Ho Chi Minh City** – to work on research in sustainable development, climate change and air traffic management. The tie-ups will enable faculty and students to share expertise through exchange programmes, and to harness best practices in research areas of joint interest.

NTU's Vice President (Industry), Prof Lam Khin Yong, signed the Memoranda of Understanding for the partnerships, witnessed by Singapore Prime Minister Mr Lee Hsien Loong and Vietnam Prime Minister Mr Pham Minh Chinh. Also present were Singapore Education Minister Mr Chan Chun Sing and Vietnam Minister of Education and Training Mr Nguyen Kim Son.

NTU's Vice President (Industry), Prof Lam Khin Yong (third from left), exchanging the Memoranda of Understanding with Prof Nguyen Minh Tam, Vice Chancellor of Vietnam National University, Ho Chi Minh City. Credit: Vietnam National University, Hanoi.

2 A new **CyberSG R&D Programme Office** has been launched to strengthen Singapore's cyber security capabilities. The first research programme of its kind in the region, it taps into expertise at local universities and research institutes to position Singapore as the global forerunner of cyber security R&D and adoption.

Hosted by NTU's School of Computer Science and Engineering and funded by the National Cybersecurity R&D Programme, under Singapore's Research, Innovation and Enterprise 2025 plan, the S$62 million (US$46.3 million) initiative leverages the University's strength in artificial intelligence, strong industrial links and network of collaborators to address current challenges, and to safeguard against future cyber security threats for the nation.

3 NTU, the National University of Singapore (NUS) and ExxonMobil signed the **Singapore Energy Consortium (SEC) membership agreement** in October 2023, ahead of the Singapore Energy Centre (SgEC) taking a new form as SEC. The SgEC was founded in 2018 by NTU and NUS, with ExxonMobil as the first founding industry partner. The partners are committed to advancing energy research and innovation in Singapore.

4 NTU and Delta Electronics are ramping up robotics research with a new corporate lab. The S$24 million (US$17.9 million) **Delta-NTU Corporate Laboratory for Advanced Robotics**, supported under Singapore's Research, Innovation and Enterprise 2025 plan, will develop next-generation technologies to overcome the challenges of labour shortage in the manufacturing and intralogistics industries.

The launch of the joint lab was attended by Mr Alvin Tan, Singapore Minister of State for the Ministry of Trade and Industry; Mr Yancey Hai, Delta Electronics Chairman; and Dr Chiueh Tzi-Cker, General Director, Delta Research Centre.

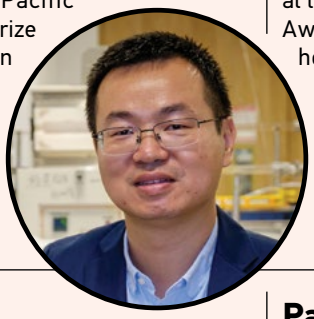
5 NTU, **NUS** and **Temasek** have embarked on a joint S$75 million (US$56.3 million) pilot programme to accelerate the creation of successful deep-tech startups from the pipeline of research at NTU and NUS. Both universities will also develop a common intellectual property (IP) licensing framework to expedite the IP licensing process, bringing emerging technologies to market.

(From left) NTU President Prof Ho Teck Hua, NUS President Prof Tan Eng Chye and Mr Russell Tham, Head, Emerging Technologies and Joint Head, Enterprise Development Group (Singapore) of Temasek, sealing the collaboration to develop a powerful innovation ecosystem to support Singapore's establishment of a strong knowledge economy. Credit: NTU.

[THE HONOUR ROLL]

APEC science prize

For his work in semiconductor manufacturing and developing a cost-effective and sustainable material for green hydrogen energy, **Prof Liu Zheng** of NTU's School of Materials Science and Engineering was honoured with the 2023 Asia-Pacific Economic Cooperation (APEC) Science Prize for Innovation, Research and Education (ASPIRE). He is the first Singapore winner of the award, which recognises young scientists for their research and scholarly publications as well as collaboration with other scientists from the 21 APEC member economies.



Furthering quantum science

Nanyang Asst Prof Chang Guoqing of NTU's School of Physical and Mathematical Sciences won the Young Scientist Award at the President's Science and Technology Awards 2023, Singapore's highest honours for research scientists and engineers who have made outstanding contributions to the nation's research and development landscape. The accolade recognises his pioneering achievements in topological quantum semimetals – materials with unique electronic properties – that have opened new avenues in quantum materials and photonics.

Innovator under 35

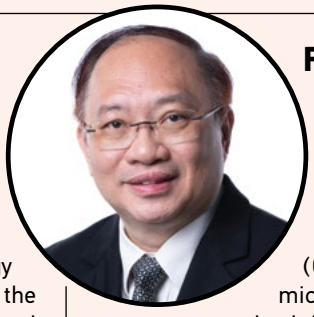
Nanyang Asst Prof Hortense Le Ferrand of NTU's School of Mechanical and Aerospace Engineering was named in the MIT Technology Review's Innovators under 35 Europe 2023 list for her innovations in 3D printing. For her work in creating bioinspired materials and structures for a more sustainable world, she was also awarded the Scientific Achievement Award at the Nature Awards for Inspiring Women in Science 2023, organised in partnership with Estée Lauder Companies.

Page-turning design

From thousands of submissions, the Tridea Project book by **Asst Prof Lisa Winstanley** of NTU's School of Art, Design and Media was named one of the best 100 entries for 2022 by design publication *Creative Quarterly: The Journal of Art and Design*. The book was previously selected as one of the winners for best graphic design in a quarterly competition by *Creative Quarterly*. It also won the Red Dot Design Award and the A' Design Award in the print and published media design category.

Volcanic impact

Assoc Prof Susanna Jenkins of the Asian School of the Environment and the Earth Observatory of Singapore at NTU was one of three recipients of the Wager Medal from the International Association of Volcanology and Chemistry of the Earth's Interior in 2023. The medal, awarded to mid-career scientists, recognises her substantial contributions to volcanology.

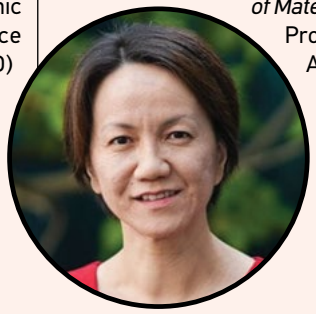


Front-line technologist

In recognition of his research contributions in gallium nitride (GaN) monolithic microwave integrated circuit (MMIC) technologies for defence applications, **Prof Ng Geok Ing** of NTU's School of Electrical and Electronic Engineering was awarded the Defence Technology Prize 2023 Individual (R&D) Award by Singapore's Ministry of Defence (MINDEF). The Defence Technology Prize is MINDEF's most prestigious award presented annually for significant contributions towards enhancing Singapore's defence capabilities.

New editor-in-chief

Prof Ling Xing Yi of NTU's School of Chemistry, Chemical Engineering and Biotechnology has been appointed Editor-in-Chief of the ACS Applied Materials portfolio comprising eight journals focused on materials, interfacial processes and their applications. She has also served as an editorial advisory board member for ACS journals *Analytical Chemistry* and *Chemistry of Materials*. Since 2019, Prof Ling has been Associate Editor of *Nanoscale* and *Nanoscale Advances*.



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- INTELLIGENT TRANSPORTATION
- SMART CITY TECHNOLOGY
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For more information, contact info.vpio@ntu.edu.sg

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Application

Applications for NAP can be submitted throughout the year. Applicants are welcome to send their CVs and other supporting documents to **nanyangprofessorship@ntu.edu.sg**.

For more information

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