A*STAR RESEARCH

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I&E: Innovation and Enterprise
RO: Research Office

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The Agency for Science, Technology and Research (A*STAR) is Singapore's lead government agency dedicated to fostering world-class scientific research and talent for a vibrant knowledge-based economy.

A*STAR actively nurtures public-sector research and development in biomedical sciences, physical sciences and engineering, and spurs growth in Singapore's key economic clusters by providing human, intellectual and industrial capital to our partners in industry and the healthcare sector.

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A*STAR Bioinformatics Institute (A*STAR BII)
A*STAR Bioprocessing Technology Institute (A*STAR BTI)
A*STAR Genome Institute of Singapore (A*STAR GIS)
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Experimental Drug Development Centre (EDDC)
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MedTech Catapult
National Semiconductor Translation and Innovation Centre (NSTIC)
National Supercomputing Centre (NSCC) Singapore
Nucleic Acid Therapeutics Initiative (NATi)
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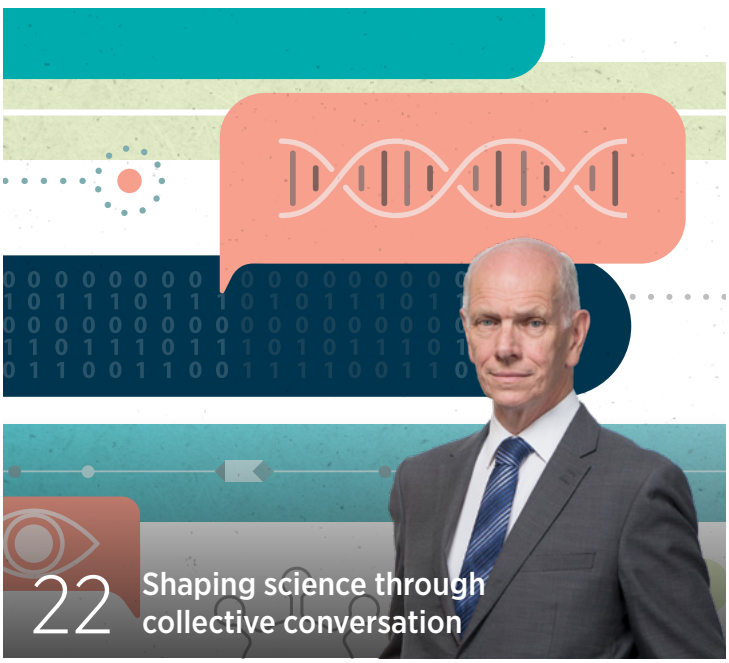

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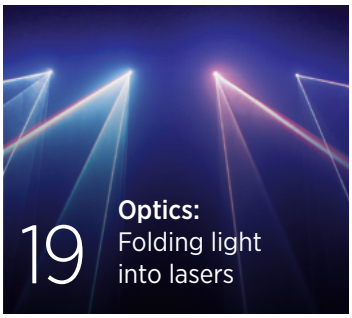

EDITORIAL NOTES

Singapore sits today at several turning points: a population now classified as a super-aged society; an energy crisis from geopolitical upheaval in the Middle East; a year of record-breaking heat and rainfall linked to a changing climate; and a trillion-dollar revolution in artificial intelligence. In an ever more turbulent world, strong investments in research, innovation and enterprise (RIE) are foundational not just to a nation's economy, but to its sustainable future.

In this issue's cover story, 'RIE2030: Turning the page (p. 08)', we review A*STAR's role within the new national five-year plan to develop Singapore as a knowledge-based, innovation-driven society. Through its support for grand interdisciplinary programmes; groundbreaking R&D in critical fields; and translational pathways that enable world-class innovation, A*STAR aims to bolster needle-moving impact across the nation's strategic RIE priorities.

This issue also commemorates the outstanding contributions of Sir John O'Reilly as he steps down from his role as Chairman of A*STAR's Science and Engineering Research Council. In our first feature, 'Shaping science through collective conversation (p. 22)', Sir John shares insights from his 15-year tenure in leadership at A*STAR, highlighting his efforts in surfacing promising ideas, fostering dialogue and harnessing collective wisdom to advance impactful science.

A key part of creating impact is bridging research and real-world deployment, driven by individuals with a passion for both science and entrepreneurship. In this issue's second feature, 'Seeing beyond the surface (p. 28)', Rachel Sim reflects on her journey from A*STAR National Science Scholar to scientist and startup founder, blending optical imaging and translational medicine to bring microscopic insights closer to clinical application.

This issue also highlights innovations and scientific insights from A*STAR's diverse research institutes and their partners, from novel mRNA vaccine platforms to sustainable urban planning models. More on these are covered in 'Vaccine packages signed, sealed, delivered (p. 04)'; 'Street smarts for roadside chargers (p. 34)'; and other stories throughout.

To stay updated on the latest developments in A*STAR research, visit **research.a-star.edu.sg.** You can also follow us on X/Twitter at **@astar_research**, LinkedIn at **A*STAR Research** and Telegram at **A*STAR Research.**

On the cover
A sheet of paper cut and folded outwards reveals a new page in Singapore's research, innovation and enterprise story, focusing on key fields: semiconductors, healthy ageing, climate adaptation and artificial intelligence.

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BIOMATERIALS

Vaccine packages signed, sealed, delivered

A*STAR researchers develop a smarter delivery system for mRNA vaccines that boosts their targeting abilities and biological safety.

No letter is useful until it safely reaches its intended recipient. This idea is critical in mRNA vaccines, where disease-fighting instructions for the immune system are 'written' in fragile strands of mRNA. When these messages reach the right cells, they can have a powerful impact, as demonstrated by the global success of COVID-19 mRNA vaccines. However, just as letters can be lost in transit, mRNA vaccines can also be damaged en route or delivered to the wrong place.

To protect these delicate instructions, most mRNA vaccines today are 'packaged' in lipid nanoparticles (LNPs) coated with polyethylene glycol (PEG). Like plastic wrap shielding a paper package from damp, PEG helps LNPs stay stable in the bloodstream—but it can also cause complications.

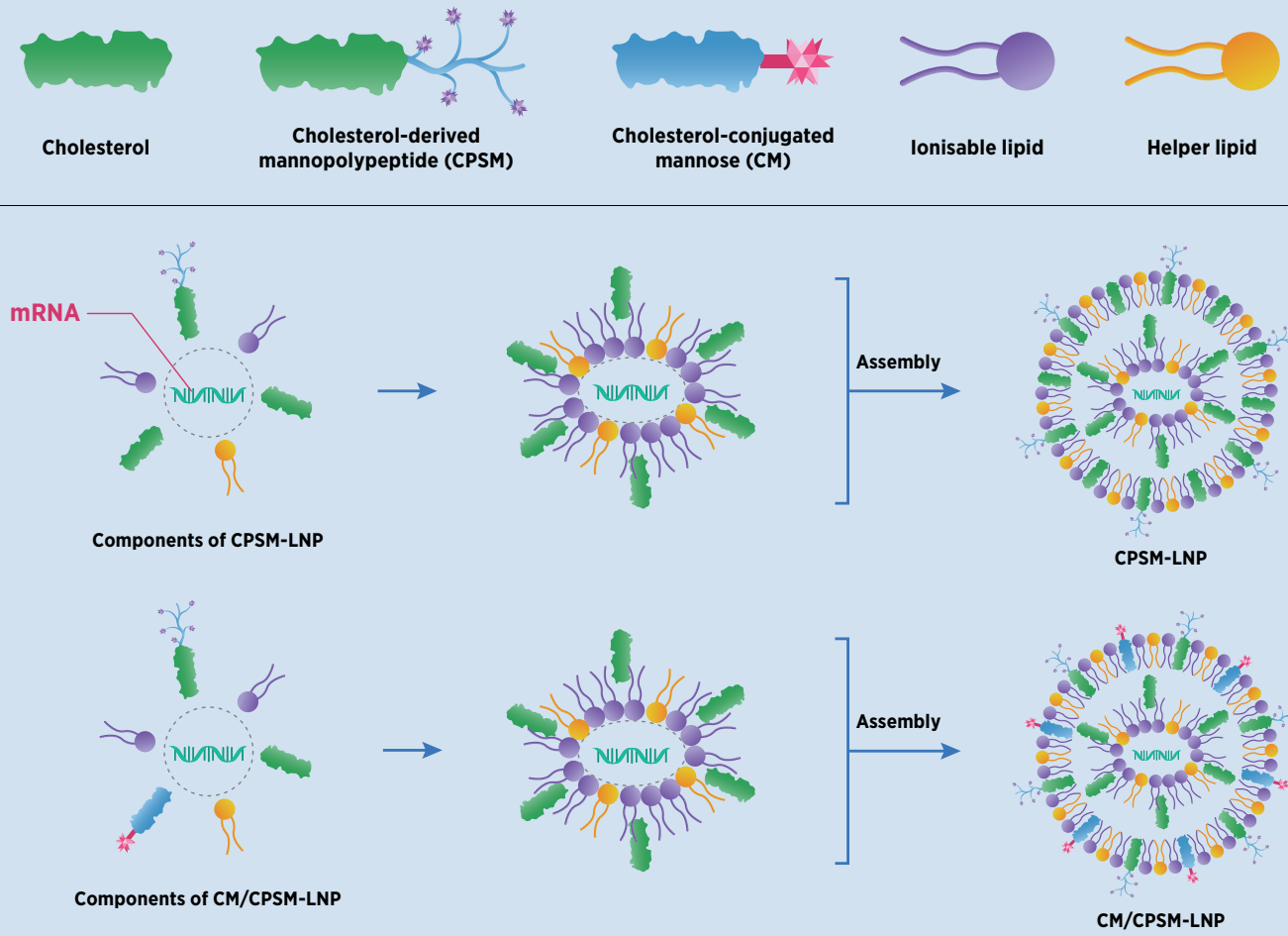
"While effective, PEG doesn't break down easily and can sometimes trigger unwanted immune reactions," said Yi Yan Yang, a Distinguished Principal Scientist at the A*STAR Bioprocessing Technology Institute (A*STAR BTI). "With repeated doses, the body may begin to recognise PEG as foreign, reducing vaccine effectiveness. PEGylated LNPs can also lack precise targeting."

Seeking a better solution, Yang recently led a team of A*STAR BTI and A*STAR Institute of Molecular and Cell Biology (A*STAR IMCB) researchers in a rethink of LNP design. "We wanted to build a smarter vaccine delivery vehicle: one that the body recognises, immune cells welcome, and mRNA can rely on to deliver its message where it matters most," said Yang.

The team tested two innovative tweaks to LNPs. First, they replaced PEG coatings with biodegradable polypeptides, made from the same building blocks as natural proteins. "Polypeptides are more body-friendly, and can be broken down and cleared once LNPs deliver their cargo," said Yang. "This reduces the risk of unwanted immune reactions from repeated dosing, which is crucial for vaccines that require boosters."

"We wanted to build a smarter vaccine delivery vehicle: one that the body recognises, immune cells welcome, and mRNA can rely on to deliver its message where it matters most."

Photo credit: Wirestock / Freepik



Schematic illustration of LNP formulations using biodegradable cholesterol-derived mannopolypeptides (CM) and cholesterol-conjugated mannose (CM) for targeted and efficient mRNA delivery into the body. (Adapted from Zeng *et al.* 2025)

Second, they added biological address labels onto LNPs: molecules of mannose sugars, which guide LNPs toward antigen-presenting cells (APCs). Acting as the immune system's teachers, APCs are central to vaccines; they process vaccine antigens and present them to other immune cells, triggering strong and long-lasting immune responses.

When tested in mice, the team's systems behaved very differently from standard PEGylated LNPs, selectively travelling to the lymph nodes with very little accumulation in the liver. "Seeing our nanoparticles naturally home in on lymph nodes was both surprising and exciting," said Jinyue Zeng, a Senior Scientist at A*STAR BTI. "They're the immune system's command centres, where APCs gather to initiate immune responses."

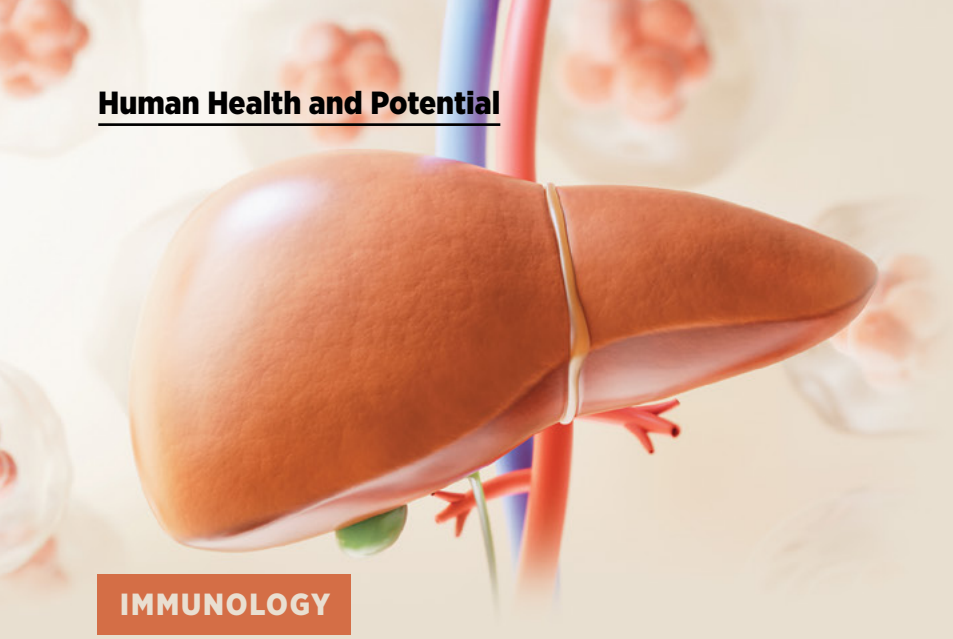
The team noted that this precise targeting could not only enhance mRNA vaccines for infectious diseases, but also cancer vaccines, where accurately directing immune responses is critical.

Looking ahead, the team has proactively designed their technology with manufacturing in mind. "The polypeptide lipids in our system are inherently scalable, and their synthesis follows a well-established process that can be adapted to large-scale production," Yang added. ★

Researchers
Yi Yan Yang, Jinyue Zeng and Shonya Lingesh,
A*STAR BTI

IN BRIEF
A biodegradable, mannose-tagged lipid nanoparticle system selectively redirects mRNA vaccines to lymph nodes, enhancing immune targeting while reducing off-target accumulation.

1. Zeng, J.-Y., Lingesh, S., Krishnan, N.B., Loong, B.S.Y., Liu, M., *et al.* Cholesterol-derived mannosylated polypeptide-formed lipid nanoparticles for efficient in vivo mRNA delivery. *Small Methods* **9** (6), e2401712 (2025).



IMMUNOLOGY

Releasing the brakes on liver cancer treatment

An established drug for high blood pressure could potentially be repurposed as a more affordable treatment for liver cancer.

Imagine driving a car with the accelerator and brakes pressed at the same time. This futile attempt to keep the car moving is akin to how cancer-killing T cells struggle to mount an immune response under suppression from tumours like hepatocellular carcinoma (HCC). While immunotherapies can empower T cells to attack tumours again, in HCC, the liver itself steps on the brakes even during immunotherapy treatment, greatly reducing its efficacy.

"Even without any tumours, the liver is a uniquely immunosuppressive organ," said Rong En Tay, a Group Leader at the A*STAR Singapore Immunology Network (A*STAR SIgN). "When tumour-driven immunosuppression enters the picture, these become formidable twin obstacles that T cells have to overcome before they can eliminate the cancer."

However, current immunotherapies against HCC have largely yet to address the liver's intrinsic immunosuppressive environment as they were primarily developed to treat other cancer types. In addition to their limited effectiveness, these treatments, especially when used in combination, remain expensive and inaccessible for many patients.

To search for a compound that might address the issue, Tay and co-first-author Charmaine Ho teamed up with researchers from A*STAR SIgN; the A*STAR Infectious Diseases Labs (A*STAR IDL); Nanyang Technology University, Singapore; National University of Singapore; and National Cancer Centre Singapore.

They first screened a library of existing drugs to identify ones that could boost T cell responses. Compared to developing new treatments from scratch, repurposing drugs already used against other diseases offers the benefit of facing fewer regulatory and logistical hurdles before reaching the clinical trial stage, explained Tay. From this screen, an anti-hypertension drug called ketanserin emerged as a promising candidate.

When cytotoxic T cells were treated with ketanserin, they became more potent killers of liver cancer cells. Ketanserin inhibits a receptor protein known as 5-HT_{2A}. To confirm ketanserin's activity against 5-HT_{2A} as the decisive factor, the team found that genetically disrupting the 5-HT_{2A} receptor in T cells similarly boosted their ability to eliminate HCC cells.

Importantly, in mice with aggressive liver tumours, treatment with ketanserin led to significantly longer survival compared to untreated mice. Moreover, this effect was comparable to the survival benefit achieved with a clinically approved combination therapy. "Ketanserin treatment may have the potential to benefit patients with HCC as much as combination immunotherapies, which are far more costly," said Tay.

The team's findings also pointed to 5-HT_{2A}'s role in suppressing immune activity in the liver. Applying ketanserin releases these immune 'brakes', allowing immunotherapies to work their magic.

Looking ahead, the team aims to continue leveraging their knowledge of liver immunobiology to guide cancer drug discovery and development. They are also working on advancing 5-HT_{2A}-based therapeutics towards the clinic.

"We are looking for like-minded clinical and industry partners who share our vision to develop more efficacious and cost-effective therapeutics for HCC," said Tay. ★

Researcher
Rong En Tay,
A*STAR SIgN

IN BRIEF
By inhibiting the 5-HT_{2A} receptor, the anti-hypertension drug ketanserin could be repurposed to help tame the liver's immunosuppressive environment, enabling T cells to better target tumours.

1. Tay, R.E., Ho, C.M., Ang, N.D.Z., Tay, H.C., Lopez, D.Z., *et al.* Serotonin receptor 5-HT_{2A} as a potential target for HCC immunotherapy. *Journal for ImmunoTherapy of Cancer* **13** (6), e011088 (2025).

Photo credit: Vinkf / Freepik

NEUROMETABOLISM

Back to the basics of hunger circuits

Comparing hypothalamic networks in zebrafish and mice reveals evolutionarily conserved neuronal pathways that regulate appetite across vertebrates.

Regulating how much to eat based on hunger levels is essential for animal survival. A deep brain region called the hypothalamus plays a central role in controlling these feeding behaviours.

By mapping the neural pathways in this region as it manifests in different species, researchers like Caroline Wee aim to identify appetite-regulating mechanisms that have stood the test of time across vertebrate evolution.

"We know that if something is important in biology, it will be very well-conserved through evolution," explained Wee, a Principal Scientist at the A*STAR Institute of Molecular and Cell Biology (A*STAR IMCB). "While the mouse hypothalamus is tiny relative to other brain regions, the fish hypothalamus occupies up to half of the brain, showing its importance in regulating basic functions."

In a recent study funded by the A*STAR Brain-Body Initiative and the National Research Foundation Fellowship, a team of A*STAR researchers and collaborators from Dartmouth University, US, compared the hypothalamic networks of fish and mouse models.

Led by A*STAR IMCB Scientist Vindhya Chaganty, the study team included Wee; Sarah Luo, A*STAR IMCB Principal Scientist; Wei Leong Chew, A*STAR Genome Institute of Singapore (A*STAR GIS) Associate Director; and Anand Andiappan, A*STAR Skin Research Labs (A*STAR SRL) and A*STAR Singapore Immunology Network (A*STAR SIgN) Principal Scientist.

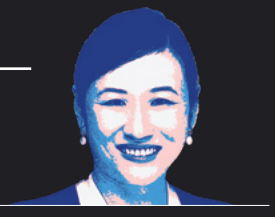
Using an advanced single-cell RNA sequencing technique called Act-seq, the researchers captured both the diversity and activity patterns of neurons in the zebrafish hypothalamus, focusing on the lateral hypothalamus, a region known to be involved in appetite control. They then used computational algorithms to align these zebrafish brain cell profiles with existing mouse hypothalamus datasets, revealing both shared and species-specific neuron types.

This comparison revealed that many overlapping cell clusters were inhibitory neurons, highlighting their potential importance across species. Among them, one group stood out: neurons that express growth hormone (GH) receptors while also releasing tachykinin, a neurochemical linked to feeding behaviour. The team found that these neurons are most strongly activated during hunger-driven feeding frenzies among zebrafish. Moreover, brief exposure to human GH was sufficient to activate these neurons and boost food intake in otherwise satiated zebrafish.

Previously, ghrelin was the only identified hunger-promoting hormone. This study suggests that GH—typically known to regulate growth and metabolism over longer time scales of development—may also function as a fast-acting appetite signal, helping the body keep pace with changing energy demands.

"GH may be the new kid on the block for integrating metabolic needs with appetite control," Wee said. "We are the first to identify an evolutionarily conserved hypothalamic cell type that could potentially mediate GH's effects on appetite."

In future studies, Wee and colleagues hope to better understand how and when this GH-responsive circuit contributes to hunger cues, and to identify the nutrients and biochemical interactions influencing its activity. ★



Researcher
Caroline Wee,
A*STAR IMCB

IN BRIEF
Act-seq single-cell RNA sequencing of the zebrafish hypothalamus identifies conserved appetite-regulating neuronal clusters shared with mice, including growth hormone-responsive cells that link hunger to energy needs.

1. Chaganty, V., Cheng, R.-K., Shen, K., Na, Z., Doblado, G.Y., *et al.* Comparative transcriptomics of lateral hypothalamic cell types reveals conserved growth hormone-tachykinin dynamics in feeding. *Molecular Metabolism* **102**, 102251 (2025).

Photo credit: Nikolett Emmert / Unsplash

RIE2030: TURNING THE PAGE

As a new five-year phase of Research, Innovation and Enterprise takes off across the nation, A*STAR leaders present the strategic throughlines and shifts through which the agency will advance national priorities in health, economy, sustainability and future technologies.

Change is inevitable. As the 21st century advances, Singapore faces a wave of unprecedented challenges driven by rapid shifts across its economy and society: from an increasingly erratic climate to an ageing urban population; from new industrial sectors to the artificial intelligence (AI) revolution. To not only adapt but thrive, Research, Innovation and Enterprise (RIE) remain fundamental to the country's future.

"RIE is a cornerstone of Singapore's strategy to develop a knowledge-based and innovation-driven economy and society," said John Lim, Chief Executive Officer of the National Research Foundation (NRF) Singapore.

Commenced in April 2026, Singapore's recently announced RIE2030 Plan is structured to achieve consequential impact through large interdisciplinary, national-level initiatives, as well as major domain-level programmes. The five-year plan will also continue to actively support foundational research; maintain globally competitive research capabilities and talent; and strengthen Singapore's position as a global technology startup node.

"We are fortunate to be able to build from a position of strength, with Singapore internationally recognised as a leading RIE centre," said John Lim. "We must continue our efforts to advance Singapore as a great place for world-class research and scientific discovery; to turn ideas and inventions into impact; and to attract and nurture RIE talent. Our efforts are guided by a clear focus to create new economic possibilities and growth for Singapore, and to drive positive societal impact for Singapore and beyond."

As Singapore's strategic innovation engine, A*STAR is gearing up for RIE2030 across its vertical domains and horizontal enablers, with efforts encompassing talent recruitment, interdisciplinary R&D initiatives and wider ecosystem collaboration.

"We need the best people working together across institutions and sectors for Singapore to have its best chances at excelling globally, being attractive as a strategic partner, and creating even greater impact," said Chorh Chuan Tan, A*STAR Chairman.

A*STAR Chief Executive Officer Kian Teik Beh emphasised the importance of moving beyond pushing technology to letting real-world needs pull science forward, aligning with national strategic priorities. "A*STAR must deepen the pathways that carry research through to real-world application, ensuring that our work translates into tangible outcomes across healthcare, industry and society," said Beh.

STRONG FOUNDATIONS, NEW DIRECTIONS

RIE2030 will sustain fundamental elements of RIE2025, including a committed investment of about one percent of Singapore's GDP, amounting to S$37 billion. It will also maintain RIE2025's four vertical domains—Manufacturing, Trade and Connectivity (MTC); Human Health and Potential (HHP); Urban Solutions and Sustainability (USS); and Smart Nation and Digital Economy (SNDE)—with Academic Research and Talent as the key horizontal enablers.

New to RIE2030 are RIE Flagships and RIE Grand Challenges: national interdisciplinary programmes that respectively aim to advance the economy in key sectors such as semiconductors, and to pull through coordinated research to address national strategic challenges such as healthy ageing and decarbonisation.

"We intend to implement actively managed programmes at sufficient scale and intensity to drive greater impact, compared to smaller, potentially disparate programmes that could be individually meaningful but have less collective impact," said John Lim.

A second priority area is to build well-coordinated, cutting-edge Data-AI-Compute (DAC) capabilities to accelerate and boost research and innovation. Directed by comprehensive national AI, research data and compute strategies, DAC capabilities will be a key enabler of both national-level initiatives and domain-level major programmes in RIE2030 and beyond.

A third shift is the deeper integration of Innovation and Enterprise (I&E) into each domain rather than as a separate third horizontal, enabling end-to-end, sector-specific I&E strategies to be developed for each domain. At A*STAR, robust venture building frameworks such as the Entrepreneur Partners Program (EPP) and Venture Atelier Partners (VAP) will pair differentiated intellectual property (IP) with experienced entrepreneurs, providing structured pathways to advance technologies and develop global deep tech spinoffs.

"The NRF will continue to support early-stage research translation efforts across all fields and sectors, while the Ministry of Trade and Industry (MTI) will administer schemes to support enterprise innovation activities and scaling," said John Lim.

As Singapore's leading public sector R&D agency, A*STAR will play a significant role across RIE2030. The following sections feature leadership insights on the agency's strategic directions for RIE2030's four vertical domains and Talent horizontal.

DOMAIN: MANUFACTURING, TRADE AND CONNECTIVITY

Under RIE2030, A*STAR's MTC portfolio will prioritise strategic sectors of high economic importance, such as semiconductors, advanced manufacturing and connectivity, with resources aligned to create clearer pathways to adoption and impact, according to Keng Hui Lim, Assistant Chief Executive of A*STAR's Science and Engineering Research Council (SERC).

"A*STAR will place a stronger emphasis on deep collaborations with Quality Partners (QPs): both multinational companies (MNCs) and promising growth companies that will adopt, scale and invest further in Singapore," Keng Hui Lim added. "In parallel,

RIE FLAGSHIP 1: SEMICONDUCTORS

Singapore's semiconductor industry accounted for an estimated 10 percent of global chip production, six percent of national GDP and 35,000 jobs in 2025, according to the Singapore Economic Development Board (EDB).

Co-led by A*STAR and EDB, and working with autonomous institutes of higher learning (IHLs), the Semiconductor RIE Flagship programme aims to strengthen Singapore's strategic importance as an R&D node in the global semiconductor supply chain, deepening its capabilities in high-impact technology areas and growing globally competitive local companies and deep tech startups.

"With AI, high-performance computing (HPC) and electrification placing greater pressure on how chips handle data, power and heat, Singapore's strongest opportunities lie in areas where semiconductor performance increasingly depends on system integration and data movement rather than transistor scaling alone," said Yeo. "Rather than replicate the logic scaling race of the largest semiconductor manufacturers, we can harness our strengths in integration and translational R&D."

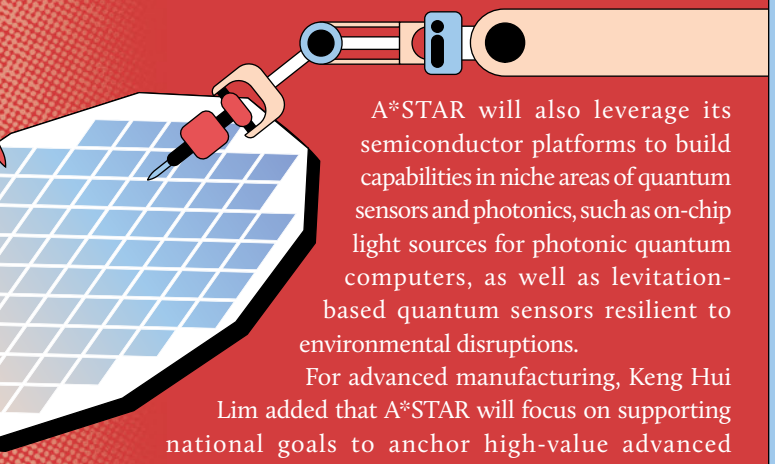
The Flagship will create a broader national structure that aligns research institutes, infrastructure and industry partnerships under shared priorities and delivery milestones. "A*STAR plays a central driving role in this, giving Singapore more room to organise capabilities and engage additional partners as industry needs evolve," Yeo added.

Research institutes such as the A*STAR Institute of Microelectronics (A*STAR IME) and A*STAR Institute of Materials Research and Engineering (A*STAR IMRE) will anchor A*STAR's core research and engineering capabilities, while NSTIC will serve as a national translation platform to bring those capabilities into industry-facing development and deployment.

we will continue to support and uplift small and medium enterprises (SMEs) through defined pathways—including tech adoption, supply chain integration and capability uplift—while maintaining the flexibility to seize emerging opportunities from scientific breakthroughs."

In the semiconductors sector, A*STAR's work will be anchored by RIE2030's first RIE Flagship, as well as the National Semiconductor Translation and Innovation Centre (NSTIC), with a strong focus on heterogeneous integration and silicon photonics. *(see inset: "RIE Flagship 1")*

"Our work on piezoelectric microelectromechanical systems (PiezoMEMS), flat optics, gallium nitride-based radio frequency (RF GaN), power electronics, and RF and cryogenic integrated circuit design will also support emerging application areas ranging from next-generation communications and sensing systems to electrification and advanced computing," said Yee Chia Yeo, Deputy Chief Executive of A*STAR Innovation and Enterprise (I&E).



A*STAR will also leverage its semiconductor platforms to build capabilities in niche areas of quantum sensors and photonics, such as on-chip light sources for photonic quantum computers, as well as levitation-based quantum sensors resilient to environmental disruptions.

For advanced manufacturing, Keng Hui Lim added that A*STAR will focus on supporting national goals to anchor high-value advanced manufacturing locally while positioning Singapore as a manufacturing innovation hub for Southeast Asia.

"We will build on the agency's track record of measurable productivity and value-added impact, and mobilise whole-of-agency capabilities to drive shopfloor productivity, strengthen local supply chains, co-develop new products with companies, and begin regionalising efforts," said Keng Hui Lim.

In the connectivity sector, A*STAR's Hub of the Future (HOTF) central framework aims to support Singapore as a global air, sea and land transport and logistics hub through innovation for efficiency, sustainability and resilience, working in close partnership with public agencies and industry players.

"A*STAR will raise ambitions for needle-moving real-world outcomes while continuing to sustain strong scientific excellence in MTC," said Keng Hui Lim. "We will build on what worked in RIE2025: strong translational capabilities, ecosystem partnerships and solutions that address industry needs."

MTC IN RIE 2030: A*STAR HIGHLIGHTS

Semiconductors

- **RIE Flagship:** National programme to unite ecosystem capabilities in heterogenous integration, silicon photonics and other critical semiconductor technologies, expanding high-value research and manufacturing.
- **NSTIC:** A*STAR-hosted national platform in flat optics and advanced photonics R&D, in partnership with IHLs.

Advanced Manufacturing

- **Joint Labs with QPs:** Paired with SME-MNC supply chain integration efforts to uplift factories and strengthen local ecosystem capabilities; and to support local SMEs to become product owners and venture into high-value markets globally.
- **Sectoral AI Centre of Excellence for Manufacturing (AIMfg):** National centre driving manufacturing plant rejuvenation and digital/AI transformation.
- **Deeper IHL partnerships:** To strengthen longer term, low translational readiness level (TRL) manufacturing research capabilities and sustain breakthrough innovation.
- **Embodied AI (EAI) and robotics:** To augment workforces in physically demanding and highly complex tasks, focused on advanced manufacturing, airport and seaport operations.

Connectivity / Hub of the Future (HOTF)

- **Maritime:** Doubling down on AI-enabled outcomes for just-in-time, fuel-efficient operations, including vessel near-miss detection and arrival time estimation tools. Advancing deployment and licensing to maritime operators and companies.
- **Land:** Scale up trials of CRUISE intelligent traffic management system; industry collaboration for potential overseas export and deployment.
- **Aviation:** Development of total airport management platform for new operating concept trials; supporting Changi Airport in operational growth paradigms without commensurate manpower increases.

DOMAIN: HUMAN HEALTH AND POTENTIAL

Precision population health, the optimisation of lifelong human potential, and biomedtech and biomanufacturing form the key thrusts of RIE2030's HHP domain, which includes the first RIE Grand Challenge: maximising healthy and successful longevity. (*see inset: "RIE Grand Challenge 1"*)

"A*STAR's RIE2030 HHP strategy is distinguished by a sharper alignment to population-level impact and life-course optimisation, broadening our focus beyond disease management," said Lisa Ooi, Assistant Chief Executive of A*STAR's Biomedical Research Council (BMRC). "A strengthened Precision Health Strategy will build on RIE2025's translational foundations, focused on extending healthspan across our population."

Leveraging A*STAR's core strengths in biomedical sciences, multi-omics, data science and AI, the agency will work closely with longitudinal Asian cohorts and national initiatives to develop large-scale multimodal datasets anchored in Singapore's population, supported by secure data environments and trusted governance frameworks.

"By integrating biological, behavioural and environmental data at scale, A*STAR aims to generate actionable insights that inform preventive strategies, refine risk-prediction tools, and guide targeted interventions tailored to Asian populations," Ooi added.

High-value therapeutics are another priority area under RIE2030. A*STAR will adopt a portfolio-based therapeutics strategy, organised around priority disease areas and intervention modalities.

"In the near term, we will harvest existing programmes and catalyse spinoff generation through differentiated assets and venture capital (VC)-investible data packages. Over a five-year horizon, we will develop capabilities and programmes with clear sightlines toward generating future substrates for globally investible assets and platforms," said Ooi. "A portion of our portfolio remains dedicated to novel technologies, biology and mechanisms that seed future therapeutics."

A*STAR will also continue to emphasise medtech, having significantly contributed to the sector's growth since 2010 by generating over 40 spinoff companies valued at over S$1 billion, building global partnerships, and seeding national initiatives to meet translation and talent gaps, such as the Diagnostics Development Hub (DxD Hub), MedTech Catapult (MC) and Singapore Biodesign (SB).

"Looking ahead, A*STAR will anchor Singapore as a leading global medtech ecosystem by creating a flywheel of value creation through a sustainable 'Build-to-Buy' model that creates high-value substrates that are attractive to VC groups, Venture Builders and QPs," said Irene Cheong, Assistant Chief Executive of A*STAR I&E.

Cheong added that A*STAR will expand DxD Hub and MC as commercialisation engines by enhancing their venture acceleration, market access and clinical evidence generation capabilities. This will enable groups working with them to reach significant valuation uplifts, drive adoption and revenue generation, and bring faster benefits to patients. A coordinated financing continuum with a clear commercial end-in-mind will also be established through these initiatives, pulling upstream RIE grants through to government-linked financing for strong commercial and patient outcomes.

"We will also double down on Tier-1 QPs for outsized value creation and value capture, particularly for AI and digital transformation needs," said Cheong.

Beyond these areas, A*STAR will also contribute to broader national priorities, including the bioeconomy and pandemic preparedness. "We will continue to advance capabilities in biotechnology, synthetic biology and biomanufacturing that support economic diversification, resource resilience and new industrial value chains," said Ooi. "We will also strengthen capabilities in pandemic preparedness, including vaccines, pathogen surveillance and scalable manufacturing, to enable rapid national response in close collaboration with public agencies and healthcare partners."

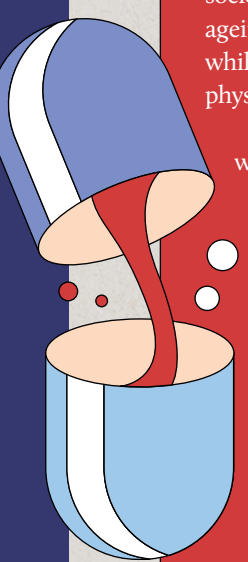
RIE GRAND CHALLENGE 1:

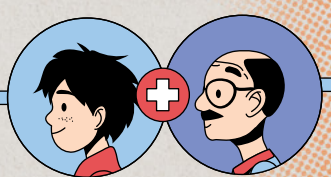
MAXIMISING HEALTHY AND SUCCESSFUL LONGEVITY

As of 2026, Singapore has become a super-aged society, with more than 20 percent of its population being 65 years or older. "This programme aims to generate research insights for developing targeted interventions—both health and socio-environmental—that support healthy and successful ageing by supporting brain health and physical function while slowing the onset and progression of cognitive and physical decline," said John Lim.

To support efforts in this area, Lisa Ooi noted the agency will catalyse industry partnerships and pilot AI-enabled screening and risk stratification tools in the near term. A*STAR will also deepen existing collaborations with ministries, agencies and healthcare clusters to validate and scale up preventive interventions, aligned with national health strategies and care delivery systems.

"Over the long term, our ambition is to position Singapore as a trusted translational research ecosystem for population-scale preventive health and healthy longevity, shifting healthcare policy and practice while attracting high-value industry partnerships," said Ooi.





HHP IN RIE 2030: A*STAR HIGHLIGHTS

Precision population health

- **RIE Grand Challenge 1:** Coordinated research for targeted preventive interventions, evidence-based policy and practice, and deployment-ready solutions for a healthy and successful ageing population.
- **Asian longitudinal cohorts:** Greater integration and deployment of insights on determinants of Asian health, performance and mental well-being from early development (GUSTO, S-PRESTO, SG-LEADS, iAdore) and life-course studies (SLAS, SCHS), in collaboration with the National Precision Medicine (NPM) Programme.
- **TRUST[1] platform:** A connected and secure HHP data ecosystem linking research and longitudinal real-world clinical datasets. Hosted at A*STAR and managed in close partnership with the Biomedical Data Hub and National Cohorts Office.

Therapeutics

- **National translational platforms:** Bridging discovery and partnership-ready asset creation via the Singapore Therapeutics Development Review (STDR), Experimental Drug Development Centre (EDDC) and Nucleic Acid Therapeutics Initiative (NATi).

Medtech

- **MedTech Innovation Development and Acceleration Scheme (MIDAS):** Competitive grants enabling DxD Hub and MC to direct upstream R&D, strengthening early-stage pipelines.
- **National commercialisation engines:** Venture acceleration, market access and productisation-focused support via DxD Hub and MC, helping diagnostics, digital health, medtech devices and life science tools reach markets faster with clinician adoption for patient benefits.
- **Ecosystem development:** Dedicated innovation talent programmes via SB, and active public-private partnership facilitation between QPs, clinical groups and researchers via the Biomedical Sciences Industry Partnership Office (BMSIPO).

BioMedtech

- **HHP MISSION:** Mission-driven translation model, shifting from individual principal investigator-driven projects to coordinated challenge-led programmes that target industry-relevant bottlenecks.

DOMAIN: SMART NATION AND DIGITAL ECONOMY

To support Singapore's National AI Strategy 2.0 and National Quantum Strategy, AI and quantum capabilities will be the primary drivers of A*STAR's SNDE efforts for RIE2030. "The shift towards AI is particularly critical as Singapore positions itself as a global AI leader and aims to harness AI's strategic advantages through coherent solution deployments," said Keng Hui Lim.

At A*STAR, a key SNDE hub will be a new Compute Intelligence R&D Institute[2] that consolidates the A*STAR Institute of High Performance Computing (A*STAR IHPC) and A*STAR Institute for Infocomm Research (A*STAR I²R). Keng Hui Lim noted that the organisational shift will better connect foundational compute and AI capabilities with real sector outcomes, harnessing deep collaborations with domain experts in manufacturing, materials science, healthcare and others.

SPOTLIGHT: DATA-AI-COMPUTE (DAC)

RIE2030 aims to develop DAC capabilities under the following strategic umbrellas:

- **Data: National Research Data Strategy** to enable expeditious and safe access to deidentified government and strategic publicly funded research datasets; enhance and scale TRUST; and expand TRUST to support non-health research data.
- **AI: AI for Science**[3] and **Applied AI** initiatives under the **National Artificial Intelligence R&D (NAIRD) Plan** to act as amplifiers to accelerate and boost research and innovation, leveraging outcomes from specific workstreams to build peaks of basic AI research excellence.
- **Compute: National Research Compute Strategy** under development to map how to leverage and build leading capabilities in classical HPC, hybrid computing and quantum computing.

[1]TRUST: Trusted Research and Real World-Data Utilisation and Sharing Tech

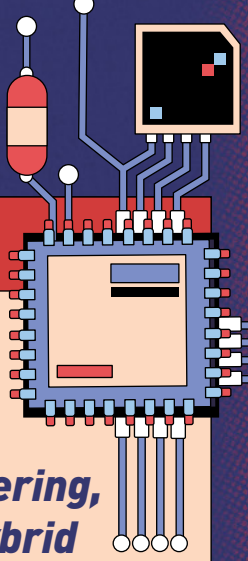
[2] Name to be announced later in the year

[3] Announced in Oct 2024, the S$120M AI for Science initiative focuses on the development and adoption of AI methods and tools that are transferable across multiple domains of science, to enhance research productivity and advance scientific discovery.

"By bringing A*STAR's DAC capabilities under one roof, the new institute will form the bedrock of our RIE2030 aspirations in advanced intelligence and computing so as to deliver impact at speed and scale," said Keng Hui Lim. "It will accelerate the development of digital workflows and reusable digital assets, enabling same-day intelligence, first-time-right impact, and safe and trustworthy deployment in key sectors, all while strengthening platforms for our broader DAC ambitions."

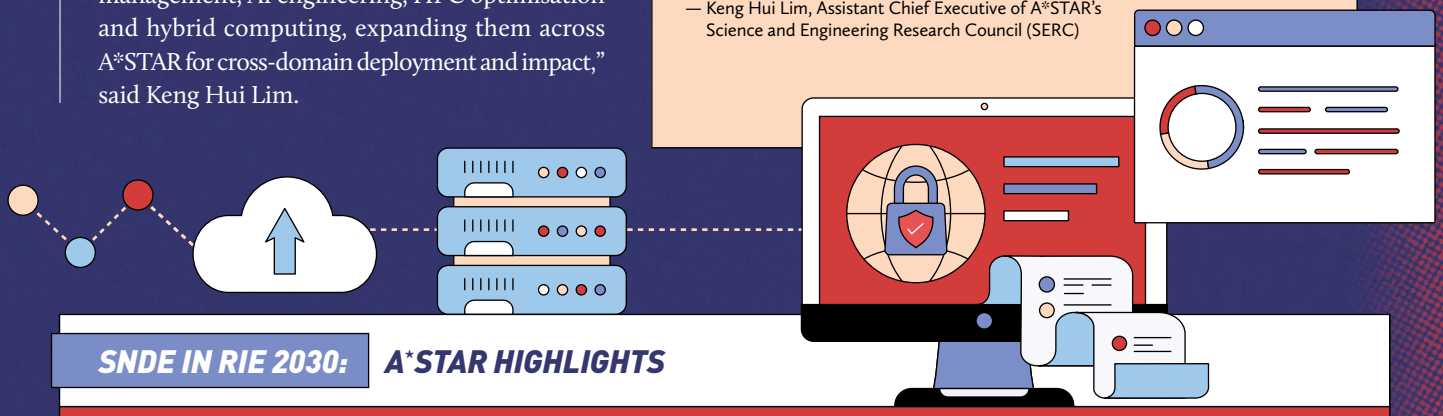
The agency will also maintain its core strengths in digital intelligence and computing with domain expertise (AI-for-X) for key sectors such as advanced manufacturing, semiconductors, connectivity and digital services.

"We aim to deepen our capabilities in data management, AI engineering, HPC optimisation and hybrid computing, expanding them across A*STAR for cross-domain deployment and impact," said Keng Hui Lim.



"We aim to deepen our capabilities in data management, AI engineering, HPC optimisation and hybrid computing, expanding them across A*STAR for cross-domain deployment and impact."

— Keng Hui Lim, Assistant Chief Executive of A*STAR's Science and Engineering Research Council (SERC)



SNDE IN RIE 2030: A*STAR HIGHLIGHTS

Hybrid quantum-classical computing

- **Advanced R&D:** Development of cross-cutting capabilities and technology platforms by the National Quantum Computing Hub (NQCH) co-led by the new Compute-Intelligence R&D Institute at A*STAR, as part of the National Quantum Strategy.
- **Use-case development:** Drug discovery, financial optimisation, logistics and other potential high-impact use cases in collaboration with companies.

AI for Science

- **Acceleration of scientific discovery:** Advanced computing technologies such as generative AI, autonomous experimental labs, AI surrogate models and HPC acceleration for materials science and other fields, providing horizontal functions across A*STAR.

Digital trust and security

- **Safe and trustworthy systems:** Development and deployment of tools to prevent, detect and mitigate harmful online content through the Centre for Advanced Technologies in Online Safety (CATOS).

National LLM development and digital services

- **MERaLiOn LLM programme:** Advancement to global leadership in open-source conversational AI for Southeast Asian languages and in human-AI interaction. Next phase to broaden capabilities and industry engagement in visual intelligence, expressive speech generation and agentic AI.

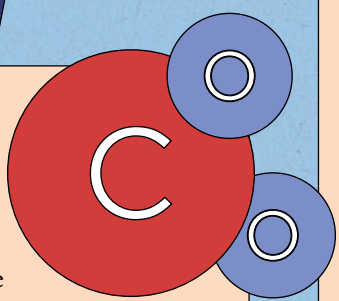
DOMAIN: URBAN SOLUTIONS AND SUSTAINABILITY

As a small yet densely urbanised island nation with limited natural resources, Singapore faces rising sea levels, extreme weather and other sustainability challenges posed by climate change. As such, USS in RIE2030 will focus on advancing decarbonisation, strengthening climate resilience, and building a sustainable and liveable Singapore.

"A*STAR will maintain its interdisciplinary strengths—particularly in AI and autonomous experimental labs; techno-economic analysis (TEA) and life cycle assessment (LCA); and process engineering and scale-up—to guide technology selection, R&D investment and pilot deployment in this domain," said Keng Hui Lim.

With RIE2030's second RIE Grand Challenge placing the spotlight on decarbonisation, A*STAR efforts under USS will focus on supporting national emissions reduction targets and the transition of key industrial ecosystems (*see inset: "RIE Grand Challenge 2"*)

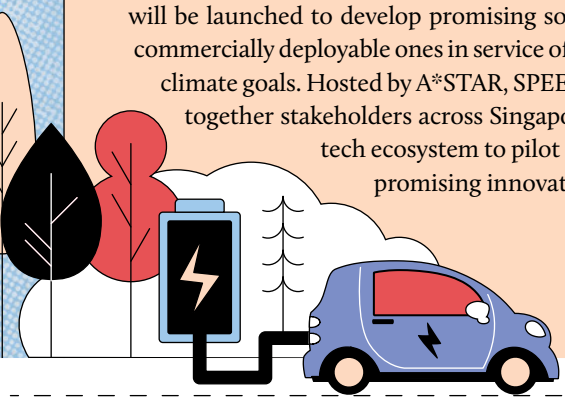
RIE GRAND CHALLENGE 2: DECARBONISATION



In 2020, Singapore ratified a United Nations climate pledge to achieve net zero greenhouse gas (GHG) emissions by 2050. To help the nation meet its climate commitments, the Decarbonisation RIE Grand Challenge (DGC) will support research, innovation and translation efforts in low-carbon energy generation and industrial process decarbonisation.

Led by MTI, the S$800 million programme will focus on potential technologies to decarbonise industrial and power sectors at scale, as these areas account for over 80 percent of Singapore's GHG emissions.

Under DGC, the Singapore Pilots for Energy and Enterprise Decarbonisation (SPEED) programme will be launched to develop promising solutions into commercially deployable ones in service of Singapore's climate goals. Hosted by A*STAR, SPEED will bring together stakeholders across Singapore's climate tech ecosystem to pilot and support promising innovations.

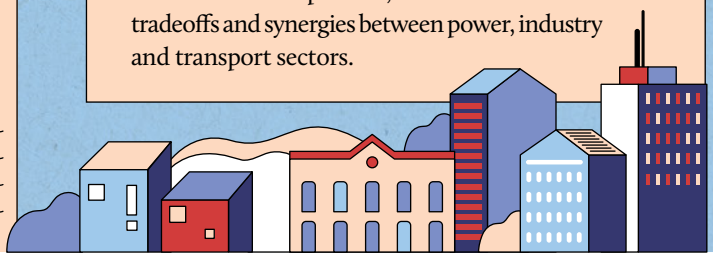


"A*STAR's decarbonisation thrust for RIE2030 will target CO_2 abatement through R&D pilots spanning carbon capture and utilisation, alternative energy carriers, low-carbon hydrogen and industrial safety standards," added Keng Hui Lim. "Our overall approach is framed as a technology-industry-public sector collaboration model which will catalyse robust value chains and downstream adoption of technological solutions."

USS IN RIE 2030: A*STAR HIGHLIGHTS

Decarbonisation

- **RIE Grand Challenge 2:** Coordinated research for power and industry decarbonisation, and scaling up promising technologies that address Singapore's national imperative (SPEED programme).
- **CO_2 capture and utilisation:** Exploring solutions such as conversion and mineralisation of incinerated ash waste into alternative building materials, in collaboration with power generation and waste management companies.
- **Low-carbon hydrogen:** Development of low-cost, low-carbon hydrogen production technologies (e.g., methane cracking, ammonia cracking) for power generation. Catalysed through platforms such as the ExxonMobil-Nanyang Technological University-A*STAR Corporate Laboratory.
- **Industrial safety measures and standards development:** Partnerships with relevant agencies and companies to create comprehensive guidelines and rigorous standards for large-scale handling of alternative energy carriers such as ammonia.
- **Process engineering and technology scale-up:** Upcoming Low-Carbon Technology Translational Testbed (LCT^3) on Jurong Island to offer cost-effective modular testbeds for emerging low-carbon technologies. LCT^3 is based at the A*STAR Institute of Sustainability for Chemicals, Energy and Environment (A*STAR $ISCE^2$).
- **Modelling and simulation:** Centre for Energy and Emissions Modelling (CE2M), National Climate Change Secretariat, other government agencies and IHLs to collaborate on integrated modelling to inform decarbonisation policies, and assess net zero tradeoffs and synergies between power, industry and transport sectors.



HORIZONTAL: TALENT

Good science and great talent underpin an RIE ecosystem at any scale. As such, RIE2030's Talent horizontal aims to grow a strong and diverse talent base in research, translation and innovation, as well as nurture tomorrow's leaders in these areas.

"A*STAR's talent strategy critically serves not just the agency, but Singapore as a whole," said Andy Hor, A*STAR Deputy Chief Executive (Research). "It must consider not only those who remain in research, but those who develop other skillsets and interests over time, moving into management, entrepreneurship, industry, IHLs or the public sector. It must also consider how talents will fit in with, and contribute to, future national strategic needs."

Hor added that A*STAR will continue to invest in and develop a strong local talent core enriched by top global talents; recruit across a wide spectrum of fields including life sciences, physical and natural sciences, engineering and computer science; and seek quality talent with established track records or outstanding potential.

"For RIE2030, there will be a sharper focus on priority R&D areas such as AI, semiconductors, biomedtech and decarbonisation," said Hor. "We're also increasing our investment in innovation and entrepreneurial talent to incentivise and support startups and spinoffs; and mounting stronger recruitment efforts for bilingual talents with interest in research, entrepreneurship and programme management."

Hor added that research is a key pillar in RIE2030, but not the only one. A*STAR will encourage local and global talents to consider their work in deeper and longer timeframes, aiming to support RIE2030's entire value chain, which also includes its innovation and enterprise mandates.

"Research talents must subscribe to the innovation spirit, aiming for meaningful impact on societies, systems or communities," said Hor. "Enterprise is also fundamental, as its growth depends on talent that can help industries address future challenges and move into new products, services and businesses." ★

TALENT IN RIE2030: A*STAR HIGHLIGHTS

Renewed focus on:

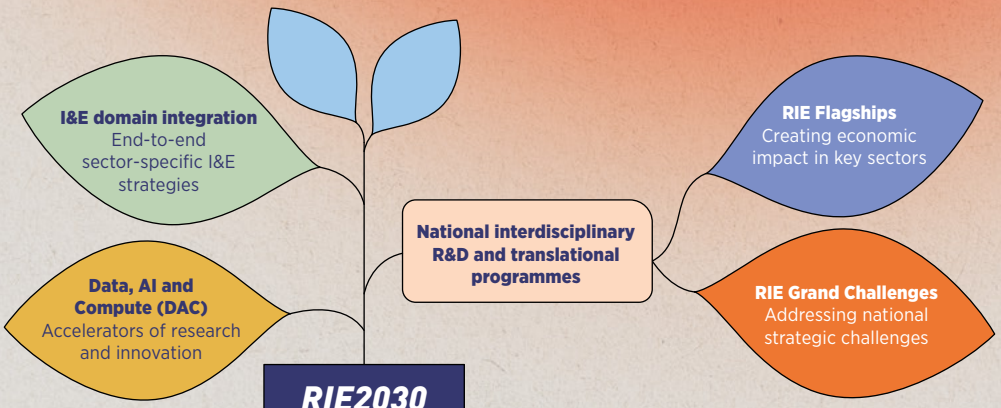
- **NRF Fellowships and Investigatorships:** Leveraging ecosystem RIE talent development programmes to support independent research by early to mid-career researchers in A*STAR; and high-impact, high-risk research by A*STAR's research leaders.
- **A*STAR Scholarships:** Continuing a 25-year track record of developing top local talents at A*STAR institutes, and supporting their exploration of wider RIE ecosystem opportunities.
- **Global talent scouting:** Harnessing A*STAR's global network of universities, research institutions and organisations to bring talents in basic science, translation and industry into Singapore's local ecosystem.

New programmes:

- **NRF Postdoctoral Award:** Enables the recruitment of high-potential young talents to conduct independent postdoctoral research while preparing for longer-term appointments.
- **A*STAR Early Career Researcher (ECR) Overseas Exchange Fellowship:** Two-way avenue for ECRs from Singapore and abroad to join leading international research environments, so as to develop capabilities, facilitate collaborations, understand global benchmarks and keep abreast of global developments in strategic RIE areas. Currently in the pipeline.
- **Singapore-Southeast Asia Fellowship (S-SEAF):** National scheme to promote regional talent mobility and capability development, enabling inbound and outbound postdoctoral researcher exchange between Singapore and ASEAN countries. Coordinated by A*STAR from 2026 onward.
- **A*STAR Entrepreneurial Investigatorship (EI):** Kickstarts entrepreneurial researchers who aim to lead novel, high-impact translational projects, with tailored support for innovation, venture building and commercialisation.

AT A GLANCE:

From RIE2025 to RIE2030



RIE2030

Foundations

Objectives: economic and social impact; future security
Investment: ~1% GDP (RIE2025: S$28 billion; RIE2030: S$37 billion)
Vertical domains: MTC, HHP USS, SNDE
Horizontal enablers: Academic Research, Talent

Strategic Shifts

- **Beyond pushing technology** → Letting real-world needs pull R&D forward
- **Beyond great science** → Building globally investible deep tech startups (EPP, VAP)
- **Breaking down silos** → Enabling breakthrough team science

A*STAR in RIE2030

Manufacturing, Trade and Connectivity

Strategic directions

- Deep QP collaborations
- SME upliftment

Semiconductors
National translational platforms (NSTICs); heterogenous integration and silicon photonics; next-gen communications technologies

Flagship 1: Semiconductors

Advanced Manufacturing
Joint Labs with QPs; AI for Manufacturing (AIMfg); Embodied AI

Connectivity (HOTF)
AI-enabled port operations; intelligent land traffic management (CRUISE); total airport management systems

Health and Human Potential

Strategic directions

- Asian population-level impact, life-course optimisation
- Portfolio-based therapeutics
- Last-mile translational support

Precision population health
Longitudinal cohort integration (GUSTO, S-PRESTO, SCHS, NPM, etc); national HHP data ecosystem (TRUST)

Grand Challenge 1: Maximising Healthy and Successful Longevity

Therapeutics
- Translational platforms (STDR, EDDC, NATi)

Medtech
- Competitive grants (MIDAS)
- Commercialisation engines (DxD Hub, Medtech Catapult)
- Ecosystem development (SB, BMSIPO)

BioMedtech
- Mission-driven models (HHP Mission)

Urban Solutions and Sustainability

Strategic directions

- Maintain strengths in AI, digital chemistry, TEA, LCA
- Ecosystem partnerships for cross-sector adoption

CO_2 capture and utilisation
Conversion technologies in power, waste management

Low-carbon hydrogen
Low-cost production tech for power generation

Industrial safety
Large-scale handling of alternative energy carriers

Process engineering, tech scale-up (LCT3)
Cost-effective testbeds for low-carbon technologies

Modelling and simulation
Assessing sectoral net zero synergies (CE2M)

Grand Challenge 2: Decarbonisation

Smart Nation and Digital Economy

Strategic directions

- New Compute-Intelligence R&D Institute at A*STAR
- Advance AI, quantum capabilities
- Same-Day Intelligence, First-Time-Right digital adoption

DAC

Hybrid quantum-classical computing
Advanced R&D, use-case development

AI for Science
Advanced computing for scientific discovery (generative AI, HPC, autonomous labs)

Digital trust and security
Harmful online content mitigation (CATOS)

National LLM (MERaLiON)
Leading conversational AI for Southeast Asian languages

Talent Horizontal

Strategic directions

- Priority R&D areas
- Innovation and entrepreneurial talent
- Multi-skilled expertise

Programmes

- NRF Postdoctoral Award
- S-SEAF
- A*STAR EI
- A*STAR ECR Overseas Exchange Fellowship
- NRF Fellowships, Investigatorships
- A*STAR Scholarships

SOCIAL SCIENCES

Two weeks off for fatherhood gains

Two Singapore-based studies of young families reveal how paternity leave nurtures stronger family bonds and enhances early childhood development.

In the joyous, chaotic weeks that follow a baby's arrival, many fathers want to play an active role but often feel constrained by cultural norms and workplace demands—pressures that can be especially strong in Asian societies. Now, researchers are starting to uncover how at least two weeks of dedicated 'dad time' at home can shape family routines and support child development, positioning paternity leave as far more than just a workplace perk.

"Currently, many fathers in Singapore hesitate to take paternity leave, especially those in lower-income or manual roles," said Jean Yeung, Director of Social Sciences at the A*STAR Institute for Human Development and Potential (A*STAR IHDP). "Qualitative research suggests that they fear being penalised or replaced at work, or struggle with perceptions of childcare as 'women's work'. However, paternity leave is critical because it helps fathers bond with their children and strengthens couples' relationships."

In the first study of its kind in the world, Yeung and former A*STAR IHDP Scientist, Nanxun Li, provided quantitative evidence hinting at the long-term effects of paternity leave on family relationships and early childhood development. They drew on data from the Singapore Longitudinal Early Development Study (SG-LEADS): a nationally representative project which followed the socioemotional, cognitive and health trajectories of children in Singapore across two surveys in 2018 and 2021.

Yeung and Li tracked how varying durations of paternity leave affected academic and behavioural outcomes in 3,895 children below seven years old living in two-parent households where mothers were primary caregivers.

"Overall, we found fathers who took a minimum of two weeks' paternity leave were more involved in childcare, formed closer father-child bonds and enhanced family dynamics—meaning there were reduced conflicts between family members, while mothers were more satisfied in their marriages and less stressed about child raising," Yeung explained. "Among the mediators of children's outcomes, family dynamics emerged as the strongest predictor of fewer behavioural problems, while also showing a positive relationship with verbal development."

Improved father-child bonds were also closely linked to stronger behavioural and cognitive outcomes, both of which were measured when the target child was between three and eight years old. Yeung posited that children with engaged fathers had the benefits of richer conversations and play activities that encouraged curiosity, problem-solving and confidence, laying the foundations for learning.

In contrast, a single week's paternity leave had no observable positive impacts. "One week could be too short for fathers to build routines, learn new childcare skills and coordinate with mothers," said Yeung.

Yeung added that these findings indicate how paternity leave should be seen as a social investment not just for individual families, but also for employers, communities and countries. "Raising a child isn't just a private family matter, but a shared national responsibility, as strong families and healthy child development help build a stronger, more productive and more cohesive society in the long run," Yeung concluded. ★

Researcher
Jean Yeung,
A*STAR IHDP

IN BRIEF
Data from SG-LEADS, a longitudinal study of Singaporean families, shows two or more weeks' paternity leave strengthens family dynamics and father-child relationships, correlating with reduced childhood behavioural issues and improved cognitive outcomes.

1. Li, N. and Yeung, W.-J.J. Paternity leave-taking and early childhood development: A longitudinal analysis in Singapore. *Journal of Marriage and Family* **87** (5), 1841–1864 (2025).

2. Yeung, W.-J.J. and Li, N. Paternity leave, family dynamics, and children's behavior in Singapore. *Journal of Marriage and Family* **85** (2), 580–602 (2023).

Photo credit: Sergio Capuzzimati / Unsplash

OPTICS

Folding light into lasers

A new nanoscale laser uses optical origami to balance trapping and releasing light, paving the way for efficient integrated photonics.

Stand between two mirrors that face each other, and you'll see your reflection multiplied countless times. Engineers use a similar optics trick to create lasers. In every laser is an optical cavity: an enclosed structure with mirror-like internal surfaces. Filled with gain materials (or light amplifiers), such cavities trap light waves (photons) and bounce them back and forth, aligning them into similar spatial patterns (modes) and amplifying their power. At a certain level of amplification, known as a lasing threshold, these photons pierce through one end of the cavity, creating the focused light cone we call a laser beam.

Yet, designing a good laser takes a balancing act. The better an optical cavity is at trapping light, the less initial power it needs to emit a beam. However, a cavity that's too good at its job might emit weaker beams, as photons fail to escape it.

"The main challenge in optical cavity design is creating a balance between confining light and extracting a useful amount of it," said Matthew Chua, a Scientist at the A*STAR Institute of Materials Research and Engineering (A*STAR IMRE).

A*STAR IMRE Principal Scientist Arseniy Kuznetsov added that nanoscale lasers present added hurdles. While these tiny devices make attractive platforms for both free-space and on-chip optical communication—which might drive next-generation computers—some key components can be easily degraded or heat-damaged when power is pumped into the system. These components include quantum dots: nanocrystals that act as potent gain materials. Hence, low lasing thresholds are critical for such devices.

To address the challenge of nanoscale lasing, Chua, Kuznetsov and A*STAR IMRE colleagues, including Senior Scientist Lu Ding, teamed up with Hilmi Volkan Demir and colleagues from Nanyang Technological University, Singapore, as well as Dalian Polytechnic University, China. Together, they recently trialled a novel nanophotonic cavity design using an effect in periodic structure known as "Brillouin Zone Folding (BZF)."

In such an optical cavity, trapped photons couple to guided modes, while still being emitted in the device's light cone. The team fabricated a device consisting of a titanium oxide metasurface with a pegboard-like array of identical nanoscale cylinders embedded in a homogeneous medium of hydrogen silsesquioxane. They then spread a gain medium of quantum dots over the metasurface.

The team found that despite the array's finite extent, the distributed feedback from their test structure's periodic design was sufficient to promote lasing. Then, for every 2x2 group of cylinders, they enlarged one cylinder's diameter.

"The initial structure was carefully spaced out to create photons with appropriate guided modes on the edges of the array's Brillouin Zone," said Ding. "The slightly larger cylinder then introduced a perturbation to the pattern of guided modes, which helped 'fold' them into the emitted light cone. Controlling the perturbation's magnitude allowed us to control the balance between trapped and extracted light."

"Controlling the perturbation's magnitude allows us to control the balance between trapped and extracted light."

Put to the test, the team's device demonstrated very low effective lasing thresholds of approximately 4.08 μJ/cm^2. "This demonstrates the high efficiency enabled by the BZF approach," noted Ding.

Having validated BZF's potential in low-threshold nanoscale lasing, the researchers are studying alternative designs with other BZF concepts and laser types. "With careful cavity design, this BZF-based system may offer an alternative route toward low-threshold, vertically emitting lasers compatible with sensitive gain materials," said Chua. ★

Researchers
Matthew Chua, Lu Ding and Arseniy Kuznetsov, A*STAR IMRE

IN BRIEF
Using Brillouin Zone Folding, a nanoscale optical cavity design with quantum dot gain media achieves very low lasing thresholds, supporting the future development of lasers with similarly sensitive gain materials.

1. Chua, M.R., Ding, L., Liang, X., Dabard, C., Wang, W., *et al.* Lasing from Brillouin Zone folding guided resonances. *ACS Nano* **19** (39), 34677–34685 (2025).

Photo credit: Artem Bryzgalov / Unsplash

TRANSPORTATION

Forecasting the rain(out) from next-gen fuels

A simplified model helps predict the liquid fraction of accidental low-carbon fuel leaks at maritime facilities, supporting safer handling and operational design.

While electric cars are now an everyday sight on land, electric ships may take longer to ply the oceans, as the world's ports and vessels are still built around the storage, supply and use of liquid fuels. To help cut carbon emissions in the interim, the shipping industry is exploring alternative lower-carbon fuels such as liquefied natural gas (LNG), ammonia and methanol, which can be adapted to existing infrastructure for maritime refuelling (bunkering).

However, these fuels have their own unique safety challenges. "Unlike most conventional fuels, alternative fuels are typically gaseous under atmospheric conditions," said Vinh-Tan Nguyen, an A*STAR Institute of High Performance Computing (A*STAR IHPC) Senior Principal Scientist. "For efficient storage and transport, they're stored under high pressures and low temperatures that keep them in a liquified state. This means when accidental leaks occur, they can release rapidly expanding gas plumes; sometimes highly flammable and sometimes toxic, endangering a wide area."

Not all ejected fuel immediately vaporises during a leak. The liquid portion, known as rainout, could play a crucial role in understanding a leak's overall severity. To help with bunkering safety protocols for alternative fuels, Nguyen, A*STAR IHPC Scientist Raymond Quek and A*STAR IHPC colleagues have been developing a fluid dynamics model to rapidly estimate rainout fractions from leaks as they happen.

"Rainout refers to the mass of fuel ejected as liquid from a leak. The presence of rainout means that the mass of fuel ejected as gas is reduced, making the resulting hazardous plume smaller and less concentrated," said Quek. "Therefore, quantifying rainout allows a more accurate estimate of the facility area affected by the plume, which helps with the efficient designation of safety zones."

Quantifying rainout can be challenging given the variable infrastructure and operating conditions in bunkering facilities. Leaks also involve complex, fast-changing processes and depend on detailed parameters that are often unknown or unavailable. As such, most existing models for rainout estimation are either too complicated, data-intensive or uncertain for rapid safety assessments.

To solve these issues, Nguyen, Quek and A*STAR IHPC colleagues teamed up with the A*STAR National Metrology Centre (A*STAR NMC) and maritime engineering company Seatrium (formerly known as Sembcorp Marine) to create a simplified rainout estimation model that requires only minimal inputs, including storage pressure, ambient temperature and basic fluid properties.

"We were motivated to create a universal model that is transparent, easily understood and applicable to a wide range of alternative fuels," said Quek, the study's first author. "By avoiding complex and abstract calculations, the model can be easily used by port workers and engineers. This is especially useful if a quick estimate is urgently required in the event of a leak."

The team validated their model against published results for hydrogen, LNG, ammonia and butane leaks, and found that it demonstrated reliable order-of-magnitude predictions for rainout across a wide range of fuels and leak conditions.

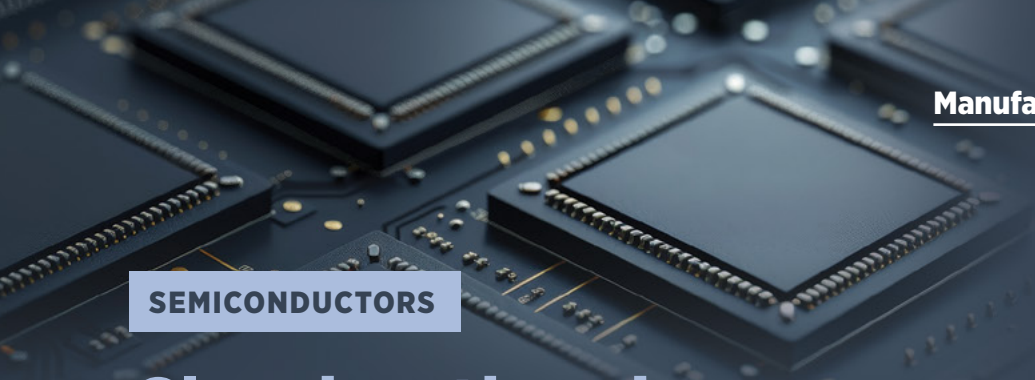
"This model could enable more accurate plume sizing, which would help improve facility design, mitigation planning and operational decision-making at ports handling alternative fuels," said Nguyen. ★

Researchers
Vinh-Tan Nguyen and Raymond Quek, A*STAR IHPC

IN BRIEF
A simplified fluid dynamics model uses storage pressure, ambient temperature and basic fluid properties to estimate rainout from cryogenic fuel leaks at maritime bunkering facilities, enabling improved plume sizing, facility design and rapid operational decision-making.

1. Quek, R., Nguyen, V.-T., Raghavan, V., Kang, C.W., He, Z., *et al*. A simplified model for rainout estimation for two phase releases of alternative liquified fuels. *Journal of Loss Prevention in the Process Industries* **97**, 105693 (2025).

Photo credit: Shutterdin / Freepik



SEMICONDUCTORS

Clearing the air on semiconductor performance

Researchers uncover an unlikely culprit behind the mysterious underperformance of novel 2D semiconductors: oxygen.

For decades, silicon has been the industry's material of choice for the billions of tiny on-off switches that power our computers. To pack more power into smaller devices, developers are shrinking these switches towards the atomic scale. But when silicon approaches its physical limits, defects at the semiconductor's surface begin to impede electron flow and waste energy.

Two-dimensional transition metal dichalcogenides (2D TMDs) are widely considered leading candidates to replace silicon. Their ultra-thin, atom-thick structure allows for faster electron flow and minimal power loss, promising a future of more energy-efficient electronics—at least in theory. In practice, however, 2D TMD devices have consistently fallen short of their predicted performance.

"It has been a persistent mystery in the field," said Aaron Lau, Pillar Director at the A*STAR Quantum Innovation Centre (A*STAR Q.InC) and Johnson Goh, a Senior Principal Scientist at the A*STAR Institute of Materials Research and Engineering (A*STAR IMRE). "For over two decades, the performance of these materials in the laboratory has consistently lagged behind what theory predicted."

Lau, Goh and colleagues at A*STAR Q.InC and A*STAR IMRE suspected that environmental factors might be responsible, even though previous studies had largely assumed that TMDs were stable under ambient conditions. Together with Yee Sin Ang and colleagues at the Singapore University of Technology and Design, the researchers investigated whether non-dissociative chemisorption—where oxygen molecules bind strongly to a material's surface—could explain the performance gap.

To catch the culprit, they developed a rigorous oxygen-free fabrication method for TMDs, handling the materials within carefully controlled environments to prevent any contact with the atmosphere. The difference was staggering: TMDs produced via the oxygen-free route outperformed those exposed to air by more than tenfold. These results showed that the TMDs' persistent underperformance was not due to flaws in the underlying physics, but rather to environmental contamination.

"If we want the best-performing 2D chips, we must maintain strict environmental hygiene."

"The biggest surprise was just how extensive and permanent the effect of oxygen exposure actually was," said Goh, adding that even brief exposure to air allows oxygen molecules to attach to microscopic surface imperfections in TMDs. "This was not just a surface stain we could wipe off; it's an irreversible process that alters the material's electronic properties."

While the researchers built a specialised facility to minimise oxygen exposure during fabrication, they emphasised that controlling the manufacturing environment is an engineering challenge the semiconductor industry must address. "Our work can provide an instruction manual for the industry. If we want the best-performing 2D chips, we must maintain strict environmental hygiene," Lau said.

The team now hopes to harness the unique physics of these 2D materials to develop new devices, aiming to improve both power and control in next-generation quantum technologies. ★

Researchers
Chit Siong Aaron Lau, A*STAR Q.Inc and A*STAR IMRE and Kuan Eng Johnson Goh, A*STAR IMRE

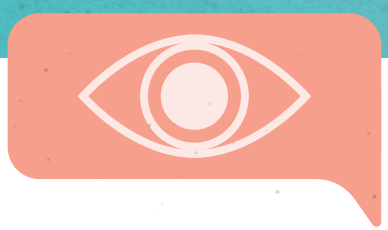
IN BRIEF
An oxygen-free fabrication method promises to close the gap between theory and reality for the fabrication of 2D transition metal dichalcogenides, paving the way for more energy-efficient electronics.

1. Mukherjee, S., Wang, S., Venkatakrishnarao, D., Tarn, Y., Talha-Dean, T., *et al.* Toward phonon-limited transport in two-dimensional transition metal dichalcogenides by oxygen-free fabrication. *ACS Nano* **19** (9), 9327–9339 (2025).

Photo credit: rajahanan5048 / Freepik

SHAPING SCIENCE THROUGH COLLECTIVE CONVERSATION

After 15 years of shaping A*STAR's approach to research, innovation and enterprise in the physical sciences and engineering, Sir John O'Reilly highlights the importance of surfacing promising ideas, fostering dialogue and harnessing collective wisdom for impactful science.



Since 2010, Singapore has made substantial investments in its scientific and technological capabilities through successive Research, Innovation and Enterprise (RIE) five-year masterplans. These have driven progressive transformations across the nation's research and development (R&D) landscape, including at A*STAR, where the complementary expertise of its diverse research institutes (RIs) has increasingly converged on strategic initiatives that translate groundbreaking science into impactful innovation.

Behind such bold moves are world-class leaders whose insights have helped shape the agency's approach to RIE. Among them is Sir John O'Reilly, who over the past 15 years progressed from member to Chair of A*STAR's Science and Engineering Research Council (SERC)—later retitled Chairman of the Science and Engineering Advisory Council. He also served on the A*STAR Board.

Tapping on years of industrial and academic experience, as well as numerous scientific advisory roles at an international level, O'Reilly's tenure has been defined by cultivating dialogue that underpinned pivotal initiatives, including accelerating R&D collaborations with multinational engineering companies; fostering new synergies between SERC and the Biomedical Research Council (BMRC) and advancing cross-disciplinary programmes.

In this interview with *A*STAR Research*, O'Reilly reflects on the highlights of his tenure, his philosophy as a scientific advisor, and the key R&D areas that will keep Singapore and A*STAR globally competitive in the years ahead.

Q: WHAT FIRST DREW YOU TO A SCIENTIFIC ADVISORY ROLE? WHAT SHAPED YOUR APPROACH TO IT?

With a background spanning industry, government laboratories and academia, I was invited to serve as a committee member of the UK Research Council, which shaped policy and research funding for my field—that is, communications engineering. Through this role, I met senior figures across the sector and found myself being approached by other organisations, such as the European Commission's Research and Development in Advanced Communications Technologies in Europe (RACE) programme. These experiences were professionally stimulating and significantly broadened my perspective.

In 2001, I was appointed Chief Executive of the Engineering and Physical Sciences Research Council (EPSRC), the UK body responsible for research policy and funding in those fields. There, I also served as the national representative for annual meetings between leaders of science funding organisations from across Europe and with the G7 countries.

This period highlighted the need for diverse approaches to supporting research, alongside a consistent focus on excellence. It also underscored the value of selectively identifying promising emergent areas for focused intervention—what I refer to as 'sensing weak signals'. As Chairman of A*STAR's SERC, I sometimes described this as 'stirring the miso soup': bringing ideas to the surface to stimulate discussion and consideration.

> **"Credit for successful outcomes belongs to the collective and not the individual."**
>
> — Sir John O'Reilly, A*STAR SERC Chairman

Q: HOW HAS SINGAPORE'S R&D ECOSYSTEM EVOLVED OVER YOUR 15-YEAR TENURE AS SERC CHAIRMAN?

My interactions with Singapore predate my time with A*STAR. Prompted in part by connections with Singaporean students at my university in the UK, I visited several RIs and institutions of higher education in Singapore. I also engaged with Singtel through my work with British Telecommunications Plc.

In the early 2000s, I visited more frequently through my roles at EPSRC and as President of the UK's then-Institution of Electrical Engineers, now the Institution of Engineering and Technology (IET).

At that time, growing R&D was high on the agenda in Singapore. With companies such as Rolls-Royce establishing a local presence, the UK actively fostered stronger engagement with Singapore. I became involved in both the Rolls-Royce collaboration and the development of the initial 10-year UK-Singapore Partners in Science initiative, and was privileged to attend its signing ceremony at the Istana in 2004.

Since then, I have certainly seen progression in the ecosystem. Universities that once focused primarily on teaching have become research-intensive institutions of international standing, integrating education with world-class RIE. A*STAR has also experienced change; RIs that operated largely independently were encouraged to collaborate, and a competitive element was introduced into what had previously been largely dedicated funding to individual RIs. While challenging to implement, this shift represented an important step forward.

When we were developing the European Research Council (ERC), we'd noted informally that its acronym also stood for Excellence in Research through Competition—the competition for support between the best, most promising and potentially impactful research ideas. Of course, achieving the right balance between stability and agility is not easy, but it is essential. The ecosystem is strongest when it supports both individual research and collaborative pursuits that bring together complementary expertise across institutions in priority areas.

Q: WHAT ARE SOME ACHIEVEMENTS OF YOUR TENURE THAT YOU ARE MOST PROUD OF?

There is one aspect of my role I wish to emphasise. I see it not so much as 'advising' *per se*, but as stimulating discussion—surfacing promising topics for consideration and bringing collective wisdom to bear on key issues. As such, credit for successful outcomes belongs to the collective and not the individual; I've been privileged to interact with very able and dedicated individuals in A*STAR in this capacity.

I would also like to be clear that no individual has a monopoly on what is 'right' in science and R&D policy. However, international experience across a broad span of science and RIE actions may bring a distinctive perspective, and prompt one to raise topics worthy of consideration that might otherwise not get attention.

To illustrate: early in my tenure, I observed limited interaction between SERC and BMRC RIs. I suggested that A*STAR could be particularly well-positioned in medical fields such as bioelectronics by drawing on the complementary research strengths of both councils. While I don't claim that my recommendation was the principal driver, I was pleased to see subsequent cross-council developments in medical technologies.

In another instance, drawing on insights from the EPSRC's e-Science programme and my chairmanship of the Physical Sciences Search Committee for the Körber European Science Prize, I proposed that combining data science, materials theory and machine learning offered the possibility of *in silico* design of new materials with predefined properties. It was fulfilling to see this concept—reiterated in the report from our international review of materials research in SERC—lead to international visits and collaborations that contributed to accelerated materials development at A*STAR.

Q: HOW CAN SINGAPORE AND A*STAR STAY GLOBALLY COMPETITIVE IN SCIENCE AND TECHNOLOGY?

Manufacturing—an important pillar of Singapore's economy—was significantly impacted by the COVID-19 pandemic, declining from around 20 percent of GDP pre-pandemic to 17 percent today. Supporting its recovery remains a national priority.

In this context, I have highlighted several forward-looking R&D actions that I see as important for maintaining and growing foreign direct investment in manufacturing and further developing local manufacturing enterprises—including startup ventures—enabling them to compete globally. These include emergent developments in integrated metrology that could contribute to sustainable manufacturing; advanced developments in neuromorphic vision and tactile sensing; and Manufacturing-as-a-Service initiatives.

Of course, there is artificial intelligence and all that it brings. One particularly important area is the development of sixth-generation (6G) mobile telecommunications (telecoms) standards. This may come as a surprise, as local telecoms companies typically acquire equipment from leading international suppliers based elsewhere, resulting in limited industry demand for Singapore-based telecoms R&D. However, 6G—the next generation of mobile telecoms—is so much more than that; I see it as a potentially pervasive technological development and a source of novel enterprise opportunities.

Sir John O'Reilly
Former Chairman
Science and
Engineering
Research Council
(SERC), A*STAR

Q: WHAT ARE YOU LOOKING FORWARD TO IN YOUR FUTURE ENDEAVOURS?

I can't imagine not being involved with the world of science and engineering research. I have continuing links with universities where I've previously worked or had advisory roles; I also chair the search and selection panel for the annual IET A. F. Harvey Engineering Research Prize, a global research award.

I am also pleased to continue my association with A*STAR by chairing the review panels for the ongoing Manufacturing, Trade and Connectivity (MTC) 2025 Industry Alignment Fund pre-positioning and programmatic projects. I would particularly commend my colleagues in the Office of Grant Administration for how they have established and currently operate this initiative. Expert reviewers can provide early stage constructive feedback on collaborative proposals, allowing project teams to refine their work in response. This support greatly benefits both the final proposal and ongoing project monitoring and management, enhancing the contributions of all parties towards RIE in Singapore.

On a personal note, I'm looking forward to spending time with my family—including my two beautiful granddaughters—which is an endless source of great pleasure. We also have a relatively large garden that I hope to devote more time to; that is, as and when the UK weather allows! ★

CYBERSECURITY

Encrypted but not invisible

The internet's latest privacy upgrades hide your data, but the patterns they leave behind can still reveal where you browse.

If someone wanted to track a letter without opening it, they could follow the postman's route to learn more about its sender and recipient. In a similar way, cyberattackers can infer online activity by observing how data packets move across networks, even when the content itself is encrypted. To guard against such web fingerprinting, today's internet architecture carries various privacy protocols, with QUIC emerging as a key foundation.

QUIC not only enables faster connections but also encrypts communication between a user's device and a server, hiding the content of data exchanges from anyone observing the network in between. It supports both the Domain Name System (DNS) that converts web URLs into machine-readable addresses, as well as HTTP/3, which facilitates packet exchange and loading webpage content.

Initial tests suggested such encryption could protect privacy, but many of these either ran on older protocols before QUIC or did not incorporate HTTP/3 traffic. This prompted researchers at the A*STAR Institute for Infocomm Research (A*STAR I²R) to ask whether the data exchange patterns visible to a passive observer still carry enough distinctive characteristics to enable the same website identification possible with older protocols.

Led by A*STAR I²R Senior Principal Scientist Dinil Mon Divakaran and Senior Scientist Levente Csikor, the team collaborated with researchers from the National University of Singapore to simulate web fingerprinting attacks powered by artificial intelligence (AI). They developed an AI-based transformer model that analysed encrypted internet traffic, training it on 500 QUIC-enabled websites while using traces from over 74,000 additional websites to evaluate its performance in realistic browsing scenarios.

Their experiments revealed that when filtering on encrypted DNS traffic alone, the first 200 packets were enough to capture the complete DNS exchange in nearly all website visits. These packets already carried the unique characteristics of DNS requests that help reveal which website was visited. By analysing these DNS packets alone, the transformer model could correctly identify 70 percent of monitored websites at 90 percent precision.

"Modern websites trigger a characteristic sequence of DNS lookups, ranging from the domain itself to analytics and ads. Together, the patterns form a very distinctive web 'signature' that still broadcasts its identity, as our experiments have shown," said Csikor.

When combining DNS-over-QUIC with HTTP/3 web traffic, the model's performance improved further to approximately 80 percent recall at 90 percent precision. By contrast, an older deep learning approach achieved less than 10 percent recall at the same precision, highlighting how transformers' ability to weigh relationships across the entire packet sequence allows for spotting patterns that previous models missed.

The findings further show that traditional defences such as packet padding, which adds extra data to disguise traffic patterns, are ineffective against modern AI-based attacks trained on the latest QUIC protocols.

"We need defences that scramble the relationships between packets so that AI models can't tell which one matters, much like adding white noise to a conversation to confuse a speech recogniser," said Divakaran.

"Ultimately, users must become more privacy-conscious by using privacy-enhancing tools like Tor or VPNs to make any eavesdropping attacks more difficult to execute," he added.

While websites' fingerprinting signatures remain difficult to mask, the team has released their dataset and tools publicly to enable the broader community to build on their work and develop stronger defences against emerging privacy threats. ★

Researchers
Levente Csikor and Dinil Mon Divakaran, A*STAR I²R

IN BRIEF
Transformer models can exploit the traffic patterns of encrypted DNS-over-QUIC and HTTP/3 protocols to identify which websites a user visits, showing that encryption alone is not enough to protect browsing privacy.

1. Csikor, L., Lian, Z., Zhang, H., Lakshmanan, N. and Divakaran, D.M. DNS-over-QUIC and HTTP/3 in the era of transformers: The new internet privacy battle. *IEEE Communications Magazine* **63** (11), 114–120 (2025).

Photo credit: Rob Wingate/ Unsplash

ARTIFICIAL INTELLIGENCE

When AI plays to learn

A new framework to train artificial intelligence models draws on concepts from game theory to improve their stability and performance.

"The generator tries to create realistic images, while the discriminator tries to spot the fakes. They keep improving their tactics until neither can easily win."

If you were shown two photos side by side, could you tell which one was generated by artificial intelligence (AI) and which was real? A few years ago, that would have been easy; today, much less so. Deep learning (DL) models—a subtype of AI—have become remarkably adept at creating realistic images by repeatedly playing, and learning from, similar games of 'spotting the fake'.

Known as Generative Adversarial Networks (GANs), this class of AI training methods involves two neural networks locked in competition: a generator and a discriminator. "The generator tries to create realistic images, while the discriminator tries to spot the fakes," explained Aye Phyu Phyu Aung, a Scientist at the A*STAR Institute for Infocomm Research (A*STAR I²R). "They keep improving their tactics until neither can easily win."

However, GANs may run into issues of mode collapse, where the generator and discriminator become trapped in a narrow set of strategies. The result is subpar, repetitive outputs that make for an ineffective training regime for DL models.

To mitigate this, Aung and A*STAR I²R colleagues, including Senior Scientist J. Senthilnath and former Senior Principal Scientist Xiaoli Li, teamed up with collaborators from Nanyang Technological University, Singapore; Singapore Management University; KTH Royal Institute of Technology, Sweden; and University of Nebraska-Lincoln, US. As generator/discriminator pairs act like opponents in a game, the researchers believed that adopting game theory principles could be the key to improving GANs.

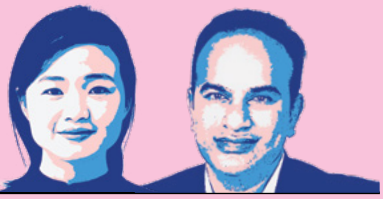
One such concept, the Double Oracle (DO) algorithm, starts with a smaller version of the fake-spotting game instead of determining the best strategies for the whole game from the get-go. "DO solves a small restricted game, asks each player's best response to find a better strategy, adds those strategies, and repeats until no improvement is possible," said Aung.

The team further complemented DO with Neural Architecture Search (NAS), melding them into a framework dubbed DONAS. Scouring through a variety of player architectures, NAS identifies those that best match the optimal strategies determined by DO—much like selecting athletes with skillsets and playstyles that align with a coach's tactical vision.

Tests revealed that DONAS effectively enhanced a GAN's performance, making it more robust against mode collapse. "We were able to get vastly different models, generating samples of diverse features and patterns," said Aung. "Moreover, the trained models could create realistic images resembling those in a given dataset, outperforming other GAN approaches across several benchmarks."

The team also observed similar improvements when they applied DONAS to another framework, which uses classifier/attacker pairs rather than generator/discriminator to analyse imaging datasets. Aung and colleagues have since continued to develop more robust and effective AI training frameworks, including a recently patented GAN-based module. ★

Photo credit: Freepik



Researchers

Aye Phyu Phyu Aung and J. Senthilnath, A*STAR I²R

IN BRIEF

Integrating the Double Oracle Algorithm and Neural Architecture Search into deep learning frameworks enables diverse outputs during training, leading to models that can produce more realistic images.

1. Aung, A.P.P., Wang, X., Wang, R., Chan, H., An, B., *et al.* Double oracle neural architecture search for game theoretic deep learning models. *IEEE Transactions on Image Processing* **34**, 2463–2472 (2025).

SEEING BEYOND THE SURFACE

Rachel Sim develops imaging platforms that bring microscopic insights into the operating theatre, helping surgeons make more informed decisions in real time.

A fresh pair of eyes can often spark new insights. In the lab, different perspectives can inspire new ways to tackle age-old problems. In the clinic, a second opinion can bring clarity to complex diagnoses.

For Rachel Sim, the question is whether entirely new ways of seeing disease could help doctors make better decisions during surgery.

These cross-consultations are common—and often necessary—such as when surgeons send tissue samples to pathologists for analysis. There, definitive clinical diagnoses emerge from careful microscopic examination of tissue organisation, cell morphology and disease-related protein markers.

While these histological evaluations are essential after surgery, Sim, a Scientist at the A*STAR Institute of Molecular and Cell Biology (A*STAR IMCB) and co-founder of medtech startup Ocellivision, believes similar information could also guide surgeons while an operation is still underway.

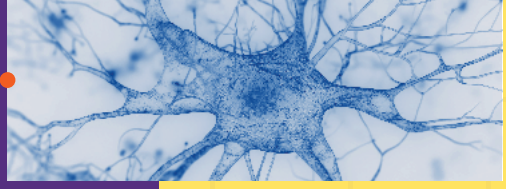
Also an A*STAR National Science Scholarship recipient, Sim's background in medicinal chemistry led her towards understanding the workings of fluorescent probes. A powerful tool in modern microscopy, these probes are simultaneously precision targeting devices and flashing neon signs; they latch onto target molecules and light up at specific wavelengths, allowing scientists to visualise molecules and cells across time and space.

In this feature, Sim shares how such probes and novel imaging systems could bring fresh insights during critical surgeries, and reflects on her journey navigating the space between academia and Singapore's startup ecosystem.

Q: HOW DID YOUR SCIENTIFIC JOURNEY LEAD YOU TO YOUR CURRENT RESEARCH?

I have long been fascinated by the relationship between molecular structure and biological function. During my undergraduate training in medicinal chemistry, I was drawn to the idea that small molecules could influence biological systems in precise and powerful ways. Over time, my interests expanded beyond therapeutics to explore how these molecules could also serve as diagnostic tools to visualise and interrogate biology.

This curiosity eventually led me into fluorescence imaging and microscopy. I became increasingly interested in how chemistry and optical technologies could be combined to create new ways of 'seeing' disease.



For many cancers and neurodegenerative disorders, pathology remains the gold standard for diagnosis, yet there is often a gap between what is seen during surgery and what can be confirmed histologically. I found myself asking: can we bring microscopic-level information closer to the point of care?

Today, my research at A*STAR IMCB and Ocellivision is driven by the vision to transform how diseases are detected and characterised by building novel imaging platforms that bridge the molecular and clinical worlds.

Q: HOW DID A*STAR'S NATIONAL SCIENCE SCHOLARSHIP SUPPORT YOUR DEVELOPMENT?

The scholarship provided me with the opportunity to pursue interdisciplinary training at world-class institutions while being exposed to diverse research environments and scientific cultures. In addition to broadening my perspective, the experience also helped me build a strong network of collaborators and mentors who continue to influence my work today.

Importantly, being an A*STAR scholar meant I was embedded within the agency's research ecosystem early in my career. I benefited greatly from the guidance of senior researchers and from engaging with multidisciplinary teams that actively encouraged translational thinking. This environment shaped how I approach science—not as isolated discoveries, but as components of a larger innovation pipeline that can translate research into clinical or industrial applications.

Upon returning to A*STAR after completing my PhD degree, I was also given the opportunity to design and lead my own research projects. This allowed me to grow not only as a scientist but also as a leader, with a stronger focus on translating discoveries into solutions that have real-world impact. That experience further reinforced my interest in bridging fundamental research with clinical and technological applications.

Rachel Sim
Scientist
A*STAR Institute of Molecular and Cell Biology (A*STAR IMCB)

Q: HOW MIGHT YOUR INTERDISCIPLINARY RESEARCH AT A*STAR LEAD TO CLINICAL IMPACT?

My work sits at the intersection of chemical probe development, optical imaging and translational medicine. At A*STAR IMCB, we focus on developing molecular imaging platforms that combine fluorescent probes with optical systems to generate actionable biological insights.

For example, our team recently generated fluorescent probes to detect pathological protein aggregates in neurodegenerative diseases. By combining chemical design with biological validation, we demonstrated selective detection of disease-associated aggregates in both brain and intestinal tissues. Such molecular tools could expand our understanding of disease progression and potentially enable earlier detection strategies.

Meanwhile, we are also developing high-resolution imaging systems for cancer surgery by integrating optics engineering, probe chemistry and biological validation. Developing these platforms requires close collaboration with partners across multiple disciplines—from the chemists designing the probes, to the engineers building the optical systems, to the clinicians helping to evaluate how these tools might work in surgical settings.

Our imaging system aims to deliver histology-like information in real time during operations, potentially supporting surgical decision-making. We also work closely with our clinical partners to evaluate prototypes on patient tissues, which keeps our work grounded in real-world needs.

Q: WHAT DO YOU HOPE TO ACHIEVE THROUGH OCELLIVISION?

Ocellivision was founded on a simple but powerful observation: while pathology provides definitive diagnosis, it is often separated in time and space from the surgical procedure itself. Surgeons frequently make critical decisions without comprehensive access to microscopic-level information at the point of care.

Our team saw an opportunity to bridge this gap by developing an imaging platform that provides high-resolution, histology-like information during surgery. This real-time tissue assessment, we hope, can ultimately improve patient outcomes. More broadly, our ambition is not just to make incremental improvements, but to rethink how tissue assessment can happen intraoperatively: bringing microscopic insights directly into the operating theatre.

Through Ocellivision, we are translating years of research in optical imaging and probe development into a clinically deployable system. We aspire to build a company that remains rooted in scientific rigour while being responsive to clinical needs. Beyond product development, our goal is to contribute to a broader ecosystem in Singapore where deep science can evolve into impactful medical technologies.

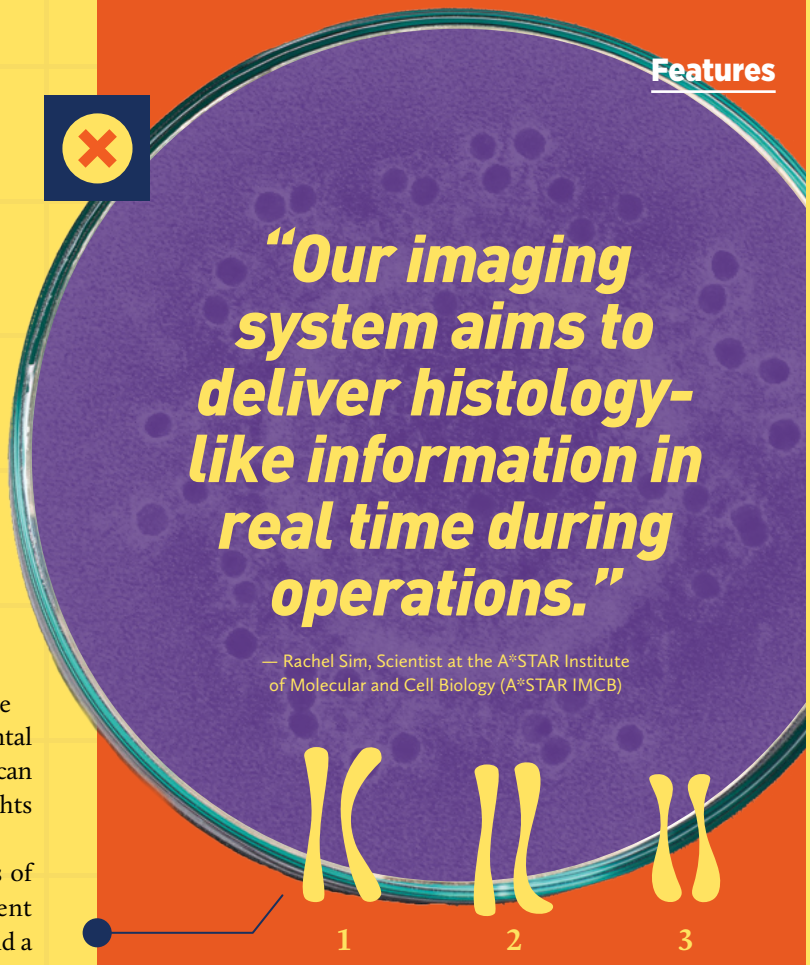
Q: WHAT IS LIFE LIKE AS A MEDTECH STARTUP FOUNDER?

In academia, the focus is on discovery and validation. As a founder, however, one must also consider regulatory strategy, manufacturing, finances and personnel development. The guiding question shifts from 'Is this scientifically interesting?' to 'Can this solve a defined problem in a sustainable way?'

As we move closer to translating research into a product, the scope of considerations expands significantly. We must think about regulatory strategy, manufacturing pathways, reimbursement frameworks, fundraising and team building—all while ensuring that the science remains robust and clinically relevant.

While Singapore offers strong institutional support and access to translational grants, medtech development is inherently complex and timelines are long. Resilience and perseverance are essential, particularly when navigating the technical, regulatory and financial challenges that come with bringing new medical technologies to the clinic.

That said, it has been an incredibly meaningful journey thanks to the multidisciplinary team of engineers, clinicians and scientists that we work with. Despite the challenges, our team remains united by a shared mission. Seeing our science move closer to real-world application makes the effort deeply gratifying.



Q: WHAT ADVICE WOULD YOU LIKE TO SHARE FOR ASPIRING SCIENTIFIC ENTREPRENEURS?

First, engage end users early. Whether in healthcare or other fields, understanding real-world workflows and constraints is critical. Technologies developed with these real-world needs in mind are far more likely to be adopted and have lasting impact.

Second, be adaptable. Many new discoveries and setbacks will arise along the way. Amid these challenges, the ability to respond constructively to change and pivot when necessary is essential.

Most importantly, enjoy the journey! ★

GREEN ENERGY

Unlocking ruthenium's structural secrets

A closer look at a popular catalyst for green fuels and chemicals reveals the hidden relationships between its atomic-level structure and catalytic performance.

Ruthenium might sound like a material from science fiction, but it's found in a surprising range of everyday items, from electronic chips to fountain pen nibs. In its oxidised form, ruthenium's unique properties could also make it a potent electrocatalyst in the oxygen evolution reaction (OER), a key step in the water splitting (electrolysis) process for making green fuels and chemicals.

However, various studies have shown that ruthenium oxide (RuO_2) catalysts don't always perform consistently. When tasked with boosting the OER in the acidic conditions typical of many industrial water electrolysers, some RuO_2 samples stay stable throughout repeated use, while others rapidly dissolve.

"Although many research papers refer to 'RuO_2 catalysts,' these materials can look very different at the atomic level," said Jiajian Gao, a Senior Scientist at the A*STAR Institute of Sustainability for Chemicals, Energy and Environment (A*STAR ISCE²). "Some are amorphous, meaning their atoms are arranged loosely like a pile of stones; others are crystalline, meaning their atoms are packed neatly like bricks in a wall."

To figure out how these structural differences can affect RuO_2's catalytic performance, Gao and A*STAR ISCE² colleagues worked with researchers from National Yang Ming Chiao Tung University, Taiwan, in a systematic side-by-side comparison of several commercial RuO_2 catalysts in acidic OER electrolysis.

The team used cyclic voltammetry, hydrogen peroxide (H_2O_2) probes, *in situ* spectroscopy and other techniques to examine the catalysts' structures, catalytic performance activity and stability. They also observed minute changes to the catalysts as they operated, such as the way amorphous RuO_2 dissolved almost instantly under voltage.

"Using an ultra-sensitive microbalance, we confirmed that it was amorphous RuO_2's inherent structural instability, and not electrochemical degradation, that was causing it to disappear before producing any meaningful oxygen," said Gao.

The researchers also tested catalysts created by heating (calcining) RuO_2 at different temperatures, revealing that samples calcined at 300–400 °C hit a performance 'sweet spot' of high activity and reasonable stability.

"We used H_2O_2 as a test molecule that mimics a key step in the OER; if a catalyst can handle H_2O_2 well, it often means it has the right surface chemistry to promote the OER efficiently," said Gao. "When we tested our catalyst series with H_2O_2, we found that the 300–400 °C samples reacted at lower voltages and with faster kinetics."

Mass-tracking tools and *in situ* spectroscopy measurements revealed why this was the case: moderately calcined samples had just enough crystallinity to remain stable, but were still 'open' enough at their surface to interact effectively with reaction intermediates. In contrast, highly crystalline catalysts calcined at 700 °C showed excellent stability but weaker intermediate adsorption, limiting their activity.

Gao noted that future strategies for fine-tuning RuO_2 could include doping the material with other elements or designing nanostructures that use each ruthenium atom more efficiently. "Overall, we now have a reliable benchmark that helps judge whether new ruthenium-based catalysts are true improvements in both activity and durability," said Gao. ★

"When we tested our catalyst series with hydrogen peroxide, we found that the 300–400 °C samples reacted with it at lower voltages and with faster kinetics."

Researcher
Jiajian Gao,
A*STAR ISCE²

IN BRIEF
Advanced *in situ* molecular characterisation techniques reveal how structural differences affect the performance and stability of ruthenium oxide electrocatalysts during the oxygen evolution reaction, providing new optimisation insights.

1. Chen, M., Tan, S.X., Cheng, S., Chen, Y.-Y, Hsu, Y.-H., *et al.* Revisiting the ruthenium oxide-based water oxidation catalysts in acidic media: From amorphous to crystalline. *Nano Energy* **137**, 110800 (2025).

Photo credit: Shutterdin / Freepik

FOOD SCIENCE

Layer by layer: building realistic meat alternatives

A*STAR researchers take a layered approach to create fibrous alternative meat products that mimic the sensory profiles of the real deal.

Rather than being sliced and stacked, what if the meat alternatives of the future emerged from droplets in motion? A technique called rolling droplet interfacial polyelectrolyte complexation (RD-IPC) could bring us closer to that reality.

Pioneered by researchers from the A*STAR Singapore Institute of Food and Biotechnology Innovation (A*STAR SIFBI), A*STAR Institute of Molecular and Cell Biology (A*STAR IMCB), and the former A*STAR Institute of Bioengineering and Bioimaging (A*STAR IBB), RD-IPC involves edible, oppositely charged biopolymer droplets. As these droplets fall and interact, the resulting fibres resemble the aligned structure of animal muscle tissue, effectively emulating the texture of meat.

Apart from texture, convincingly matching the flavour and appearance of animal meat is key to enhancing the consumer appeal of alternative meat products. While the original RD-IPC method showed promising results, issues of scalability quickly became apparent.

"When the RD-IPC technique was first developed, the fibres were drawn by gravity, making it quite a slow process," said Andrew Wan, a Senior Principal Scientist at A*STAR SIFBI.

To achieve the high throughput required for commercialisation, the A*STAR SIFBI team devised a roll-on collection method, which simultaneously draws and collects the fibres from RD-IPC on a rotating drum. Beyond speed, this approach also allows more precise control over where to place different nutrients in a product.

"With every rotation of the drum, new fibres are deposited on previously laid ones, building up a meaty construct layer by layer with various nutrients targeted to specific layers," said Wan.

To better mimic pork belly, for example, the researchers deposited alternating layers of fat and protein into their meat analogues. This produced a sensory profile that not only differed substantially from protein-only versions, but also delivered a distinct texture compared to products made by simply mixing the nutrients together.

Moreover, roll-on-based RD-IPC is compatible with both plant-based ingredients and cultivated cells, serving as a flexible technology for producing hybrid alternative meat products. After testing various combinations of fat and cultivated pork cells, the team observed that such hybrid structures may be the key to emulating animal meat flavour profiles.

"It enables the production of realistic, fibrous, whole-cut and structured meat alternatives," said Wan. "We believe that our current method is potentially more cost-effective, has a smaller environmental footprint and is amenable to scale-up and commercialisation."

With a patent now granted for their technology, the researchers are continuing to refine the sensory qualities of their meat analogues, aiming to bring them closer to their natural counterparts. ★

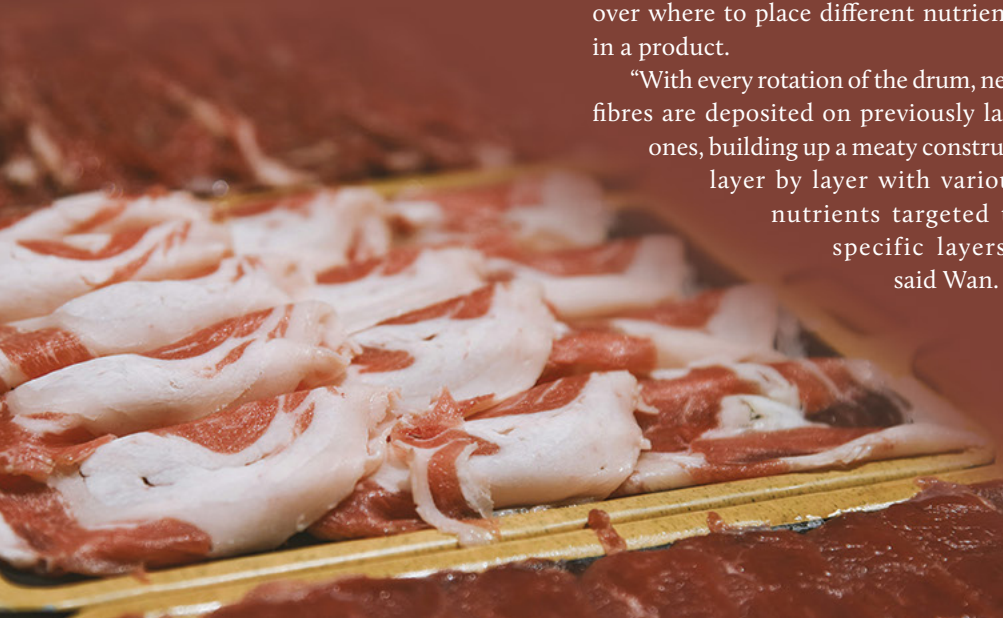


Photo credit: Luna Wang / Unsplash

Researcher
Andrew Wan, A*STAR SIFBI

IN BRIEF
A novel rolling technique deposits biopolymer fibres into a multi-layered meat analogue with highly specific nutrient compositions and realistic sensory profiles, offering a scalable platform for producing hybrid meat alternatives.

1. Du, C., Choy, K.K.L., Chew, L.J.M., Antipina, M.N., Chng, V.J.Y., *et al.* Nutritionally enhanced fibrous scaffolds by rolling droplet-interfacial polyelectrolyte complexation (RD-IPC). *Journal of Food Engineering* **357**, 111627 (2023).

2. Chng, V.J.Y., Chan, G., Lim, P.Y., Loh, H.X., Loo, L.S.W., *et al.* Layered structuring of nutritional components in meat analogues by rolling droplet-interfacial polyelectrolyte complexation (RD-IPC). *Food Research International* **221**, 117173 (2025).

TRANSPORTATION

Street smarts for roadside chargers

Harnessing street view images, a new deep learning model could aid urban planners in expanding city-wide electric vehicle charging infrastructure.

As the world shifts toward sustainable transportation, electric vehicles (EVs) have become a common sight on city streets. However, the EV boom poses a conundrum for city planners and EV adopters alike: while it takes just minutes to refill a fuel tank, it can take hours to top up a set of batteries.

"As EV charging takes time, drivers in dense urban areas can struggle to locate available parking lots—especially during peak hours or busy hotspots—forcing them to drive longer distances to access charging," explained Rui Zhu, a Senior Scientist at the A*STAR Institute of High Performance Computing (A*STAR IHPC). "A spike in charging demand can also challenge power grid stability."

Roadside charging piles offer a compact alternative to chargers found in dedicated carparks, as they can be placed on small streets and therefore more widely distributed across a city. However, it can be difficult to identify optimal locations for charging piles, as EVs need to be able to park beside them for hours without disrupting traffic flows or power grid capacity.

"It is imperative for urban planners to estimate charging demands at city-scale to optimise the locations, quantity and power demand of roadside chargers," Zhu added.

Faced with this challenge, Zhu teamed up with researchers from the National University of Singapore and institutes in China, developing an integrated deep learning (DL) model that estimates city-wide roadside charging capacity and potential sites for new chargers. Tapping into Geographical Information Science (GIScience) data, DL-enhanced street view images (SVIs) and 3D geometry projections, the model aims to effectively simulate real-world geospatial surveys for urban planning.

"Our ultimate goal is to provide a city-scale dataset of island-wide outdoor parking stalls, along with prospective locations for photovoltaic-powered electric vehicle charging bays."

"SVIs are an essential source of rich, city-wide information on roads and streets," said Zhu. "Through DL-based visual detection and urban landscape understanding, we can harness SVIs to identify and suggest suitable roadside EV charging locations."

Photo credit: Ernest Ojeh / Unsplash

The team's three-module framework first identifies roads in government-authorised parking zones (APZs). The model then analyses SVIs collected from these zones to detect objects in the surrounding landscape—such as trees, sidewalks and buildings—which help determine a neighbourhood's function, whether residential, commercial or otherwise, and pinpoint streets suitable for roadside charging.

Finally, the model transforms the flat 2D SVIs into 3D geometry, enabling estimates of available roadside parking areas at each location, as well as potential charging capacity based on existing EV charging records.

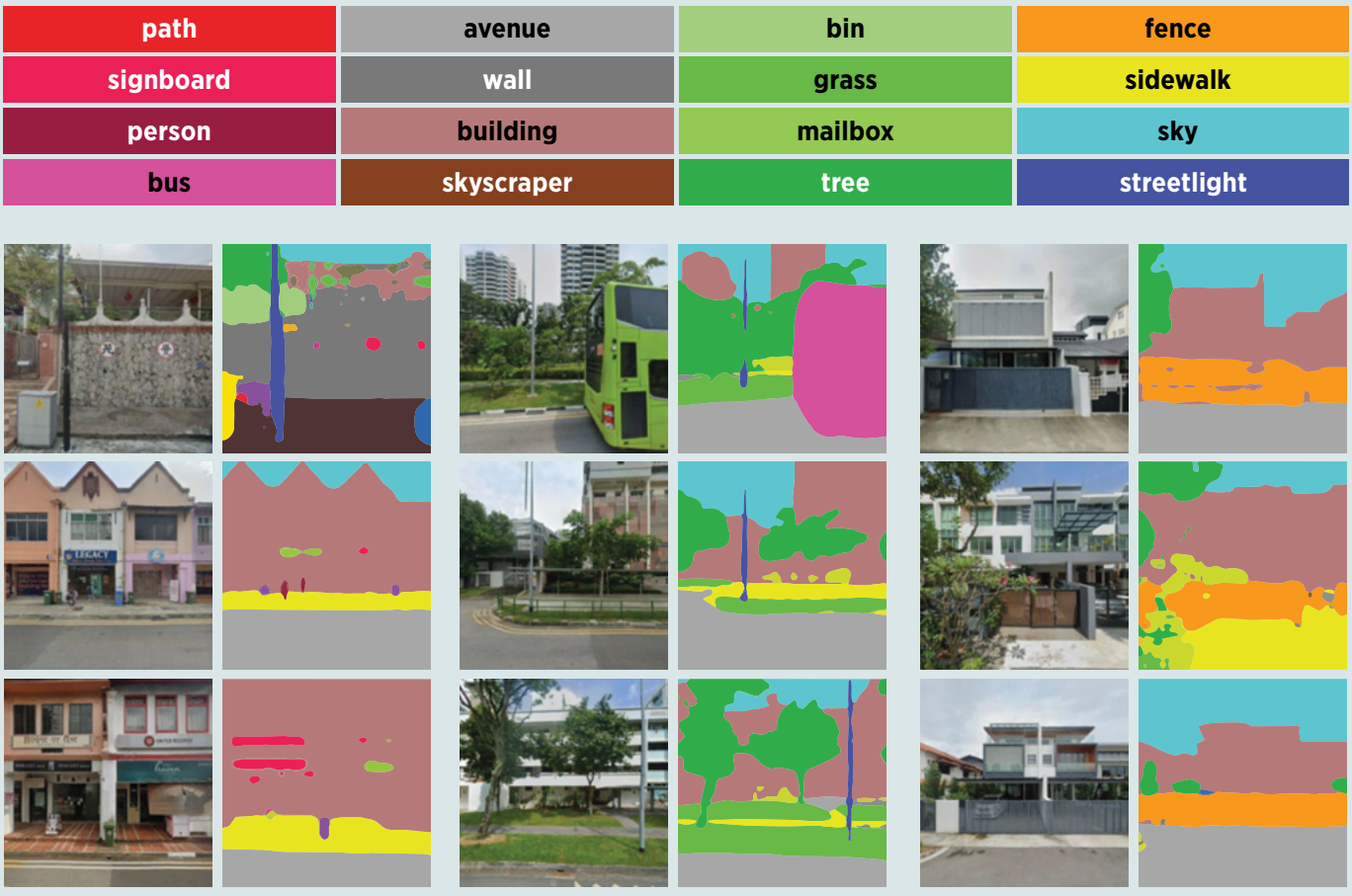
By testing their model using more than 55,000 SVIs collected across Singapore's APZs, the team identified 54,812 potential roadside parking stalls spanning 6,761 commercial and residential locations.

"We foresee that this framework can help guide policy regulations to expand EV parking and charging capacity," said Zhu. "Our ultimate goal is to provide a city-scale dataset of island-wide outdoor parking stalls, along with prospective locations for photovoltaic (PV)-powered EV charging bays." ★

Researcher
Rui Zhu,
A*STAR IHPC

IN BRIEF
A deep learning-augmented, street-view-image data mining and analytic framework identifies optimal roadside charging locations for electric vehicles in urban areas based on geospatial statistics.

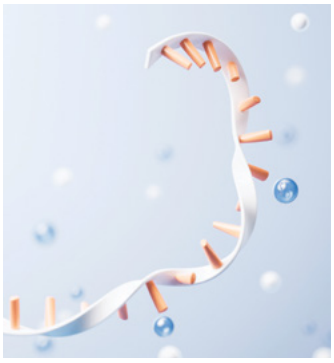
1. Pu, Y., Zhu, R., Wang, S., You, L., Zhong, T., *et al.* City-scale roadside electric vehicle parking and charging capacity: A deep learning augmented street-view-image data mining and analytic framework. *Applied Energy* **389**, 125795 (2025).



A sample of street view images taken in various urban functional zones in Singapore, segmented by the team's integrated deep learning model. (Adapted from Pu *et al.* 2025)

SNEAK PEEK

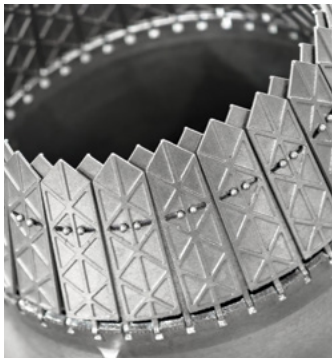
A brief look at upcoming research highlights in the next issue of A*STAR Research



AI IN GENOMICS

PREDICTING PURPOSE IN UNSEEN SHAPES

The largest RNA language model to date helps researchers uncover the hidden roles played by non-coding RNA sequences in our cells.



ADVANCED MANUFACTURING

WHEN LITTLE THINGS ADD UP TO FLAWS

A comprehensive study reveals how tiny differences in process settings can affect the structure and performance of 3D-printed titanium alloys.

ARTIFICIAL INTELLIGENCE

SHARPENING SHEARS FOR AI PRUNING

Inspired by classical signal processing techniques, a new approach to fine-tuning AI models helps reduce irrelevant computing while maintaining performance.

GREEN ENERGY

CRACKING METHANE'S CARBON PROBLEM

An in-depth investigation of how graphene catalysts split methane molecules offers a cleaner route to hydrogen fuel production with near-zero CO_2 emissions.

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