
SPIRIT
OF
INNOVATION
ST Engineering

Spirit of Innovation

ENGINEERING OUR FUTURE

Message from Vincent Chong

Group President & CEO

As a technology, defence and engineering Group, ST Engineering's corporate purpose is to harness technology and innovation to enable a more secure and sustainable world. To do that well, we continuously enhance our capabilities in technology and engineering to solve real-world problems and improve lives.

This booklet features some of our noteworthy innovations as well as the talent and promise of our employees. By being tenacious, capable and cooperative, our teams have produced amazing assets and solutions that create value and help make the world a better place to live in.

Problems and challenges that need solving will keep surfacing as the world advances which plays to our strengths as we apply technology and innovation to solve them. From 5G, the Internet of Things (IoT), cloud computing, cybersecurity, Artificial Intelligence (AI), opportunities to optimise resources and energy consumption via technology and digitalisation for greater sustainability will abound.

We at ST Engineering are determined to remain at the forefront of innovating for a greater purpose. We are strengthening our competencies for engineering excellence as captains of our industry. In addition, our door is always open for partnerships and co-creation because innovation cannot happen in silos. Such collaborations are needed for a robust ecosystem of open sharing and innovation. Most importantly, it will further our quest for a more secure and sustainable world for all.

VINCENT CHONG

Message from Ravinder Singh

Group Chief Operating Officer
(Technology & Innovation)
President, Defence & Public Security

Innovation is about solving problems, improving lives, and progressively nudging the world into a better place. At ST Engineering, we want to build technology and innovation that make a positive impact. Hence, we have been building a culture of innovation across the Group.

We also establish partnerships to co-create new capabilities and strengthen our products and solutions. One such initiative is Research Translation @ ST Engineering which we launched in late 2021. Under this collaborative model, we work closely with academic researchers to undertake impactful translational research that meets fast-evolving market needs and customer demands. Further, we partner government agencies, start-ups, and other businesses on strategic ventures.

The booklet contains innovation stories from ST Engineering, some inspired from within, while others developed in partnership, and all of which underscore one truth. That is, with collective wisdom, we can fuel innovation and create a more equitable and sustainable future.

RAVINDER SINGH

Contents

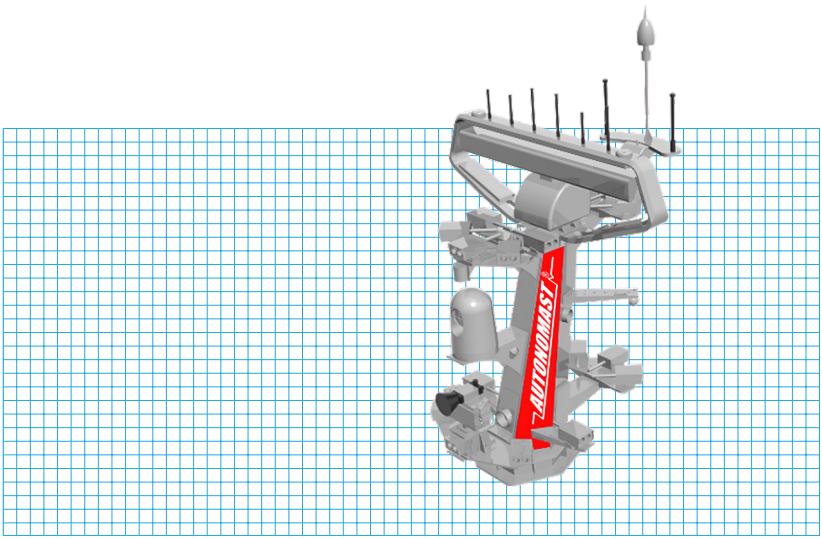
Transforming Ships into Autonomous Vessels

The AUTONOMAST system has made unmanned maritime robotics a reality and is changing the way navies and commercial shipping operate around the world.

The compact AUTONOMAST, with a footprint no larger than a seat's width, is more than meets the eye. Once "bolted" on, it can unman any vessel and provide propulsion control, agile and effortless.

The project, seeded by Andrew Yue and led by Germaine Ee, was initiated by the Ministry of Home Affairs in 2016 for its Unmanned Surface Vessel (USV) programmes. Crewless craft can be significantly safer and maximise operational endurance, but were a costly proposal.

> Today, the AUTONOMAST has proven both its effectiveness and affordability. It can be rigged up in under eight weeks, requiring much less downtime than the several months previous technology required.



Armed with an arsenal of perception sensors including camera arrays, navigation radars, Inertial Measurement Unit (IMU), Global Positioning System (GPS), steerable search lights and more, it allows a vessel to self-pilot from one point to another autonomously. Manoeuvring intelligence ensures collisions are avoided, while mesh Wi-Fi, LTE and aggregated satellite communications ensure on-shore command centres always have control.

The technology is densely packed in the form of a vessel mast, a modular set-up that also allows it to be built outside a factory setting. Installation is quick, practical and economical—factors that have fast-tracked its adoption in the international market.

The AUTONOMAST is now established as part of the Singapore Police Coast Guard's equipage and is also used in the Singapore Civil Defence Marine Command's FireFighting (FiFi) USV. It has also been installed in MITSUI ocean-going vessels and adopted by the Australia Defence Science and Technology Group's Mine Countermeasures USV FSD, amid a host of other local and overseas programmes.

Developing Unmanned Surface Vessels (USVs)

USV Programme Lead Huang WeiQi and Lead Engineer Pang Loo Twang share the story of ST Engineering's foray into USV development.

Our USV development journey started in 2008, in alignment with the Republic of Singapore Navy (RSN)'s vision to create an Unmanned Mine Countermeasure (MCM) naval force. Prioritising safety, efficiency and sustainability in dangerous maritime missions led us to engineer our first 9-metre experimental USV platform, capable of basic autonomy in waypoint navigation.

> Two MCM USV demonstrators for mine detection and disposal followed. Leveraging our strength in payload integration, we also developed a Force Protection USV demonstrator in 2010, which integrated a remote weapon system with a 7.62mm general-purpose machine gun.

Testing our USVs in Singapore waters—among the busiest in the world—meant operating at high speeds and in close proximity to the heavy shipping traffic. Traditional sensors would be inadequate, so the USV team worked to enhance the perception and decision-making capabilities of the vessels. These efforts led to the birth of a highly effective Collision Detection Collision Avoidance (CDCA) feature, boasting human-like discretion. It consolidates input from radar, day and night optical cameras as well as commercial shipping automatic

information systems, while applying the Convention on the International Regulations for Preventing Collision at Sea (COLREGS) rules. Success in the Singapore straits meant exceptional navigational safety for our seafarers is assured.

> The full-scale MCM USVs had been delivered to the RSN. Driven to further unman maritime operations, our team has since developed the 24/7 operational Maritime Security (MARSEC) USV.

We have also expanded into the Public Safety and Security sector with a policing USV for the Singapore Police Coast Guard, and a fire-fighting USV for the Singapore Civil Defence Marina Division.

Wi Fi

CES INNOVATION AWARDS 2022 HONOREE

COMMON CRITERIA pending

Keeping Cyberspace Secure with WiZ-Knight

In the face of pandemic restrictions on working at the office, the world's first and smallest wireless encryptor was developed in record time.

COVID-19 fundamentally changed traditional workplace practices. Overnight, organisations converted to hybrid work arrangements with a blend of in-office and work-from-home (WFH) operations. With telecommuting came new challenges for cyber defenders—could employees securely access sensitive information without compromising company systems? VPN connections between office servers and remote computers could be hacked and disabled, as the available software VPN solutions then were not designed to protect such use.

During the crisis, ST Engineering's deep expertise came to the fore. Cybersecurity specialists in firmware, hardware, systems and testing, crypto, mechanical and production departments pulled together to resolve the issue speedily. Their goal was to re-engineer the conventional 1U server-sized encryptor deployed at the back-end as a lightweight, portable device for individual users.

WiZ-Knight contained innovative new security architecture, with cutting-edge hardware and an ergonomic design, becoming the smallest wireless encryptor in the world. Through it, WFH users has since been able to access a secure wireless VPN connection to the office with confidence.

> The 5G-ready device has won contracts from the Singapore government, as well as commercial enterprises overseas. The WIZ-Knight solution stands to be a game-changer in meeting customer demands for a lightweight encryptor that can be deployed anywhere.

The Bronco Family: Our Home-grown All-Terrain Armoured Carriers*

From first-generation to the latest spin-offs, the Broncos have proven their worth and made Singapore a well-regarded name in the military world.

Land military forces around the world have a constant need for tracked articulated, all-terrain amphibious carriers for personnel and equipment. Whether in snow or bog, these vehicles have to be flexible and rugged enough to get their loads through.

In the past, the Singapore Armed Forces (SAF) relied on the BV206 developed by Hägglunds (now part of BAE Systems Platforms & Services). By the late 1990s, it became clear that the aging BV206s, unable to handle heavier payloads or offer crew protection from advanced kinetic munitions against armoured vehicles, would need to be replaced.

* This story is extracted from ST Engineering's publication entitled 'The Bronco Legacy: 20 Years of Engineering Excellence' (2019).

ST Engineering's Land Systems was called upon to design a carrier we could now call our own. Bronco 1 entered into service in 2001, a lighter-weight vehicle, built by a pioneering team. Indigenous solutions and continuous testing and improvements by a tenacious team answered operational needs.

L-R: Lim Chun Seng, Thum Chow Wah, and Sim Young Fong served in Afghanistan with our Warthog

Subsequently, a Bronco 2 variant called the Warthog was customised for the British Army, for deployment in Afghanistan. Among the specifications, the UK military required high mobility and enhanced crew protection against improvised explosive devices (IEDs). Despite the short turnaround time, the fleet of Warthogs was delivered as promised, accompanied by Field Service Representatives Thum Chow Wah, Lim Chun Seng and Sim Young Fong. Living and working in harsh conditions near the war zone, they not only kept the Warthogs operational, but also collated critical information for the design team back in Singapore. As it turned out, the British Army's Warthogs encountered 30 IED attacks in battle—but kept their crews safe.

Bronco 3 was a variant developed in response to evolving demands for high arctic mobility, modular payloads and more protection features. It is also light enough to be air-lifted into operation, reducing response time.

> Our Bronco family's business impact is still growing. Bronco 1 continues to be valued as a logistic workhorse by the SAF. The Warthog's war record has placed ST Engineering's Land Systems on the world map as a credible defence player and a partner of choice. Bronco 3 is proving to be on target as a next-gen carrier, having successfully completed US Army trials in Alaska.

The Bronco family also created a spin-off, the ExtremV. Conceived with civilian-agency users in mind, it can be used in disaster relief, firefighting and exploration operations. To keep costs low for the target market, ExtremV employs commercial off-the-shelf (COTS) technology. Procured by Japan's Fire and Disaster Management Agency and renamed Red Salamander, it was the only vehicle that could access disaster areas affected by landslides. A newer generation of ExtremV has since been used by the Fire Fighting Department of the German Army in swampy terrain.

Throughout the chronicles of the Bronco, many heroes of innovation have surfaced. Business leaders, managers, engineers, technicians and more are all part of this success story, and as much to be celebrated as their creations.

All Fired Up for the 40mm Family of Ordnances*

* This story is extracted from ST Engineering's publication entitled 'Redefining Firepower: Singapore's Large Calibre Weapon Systems' (2022).

An anticipated demand for 40mm ammunition proved prescient, and ST Engineering's Advanced Material Engineering (AME) arm has not looked back since.

In the late 1980s, the SAF's ammunitions requirement was partly supported by ordnance products created by AME. Most were manufactured under license, or based upon technical data package transfers. Many of AME's articles were also sold internationally. As militaries modernised, some product lines became obsolete; others, like the 40mm, saw demand shoot up.

In the 1990s, AME began to develop products at a higher level of technology, incorporating in-house innovation. One of these was the world's first 40mm ammunition with patented mechanical self-destruct (SD) fuses that promised zero duds. Designed, qualified and manufactured in Singapore, the product found a ready market in Europe, where cold weather would often leave many duds among the rounds countries there previously used.

Poster showing ordnance products manufactured in in the 1980s. The 40mm range represents only a small set of AME's vast offerings.

The small success spurred more innovation back in AME. As the century turned, the 40mm engineering team started building electronics into its designs. Focusing efforts on developing rounds with electronics that could survive gun launches unlocked a new range of ordnances with better features. The 40mm Airburst rounds, 40mm All-terrain SD (self destruct) rounds and 40mm Soldier Parachute Aerial reconnaissance camera system are all the result of the team's labour, and these ordnances, too, found success globally.

In recent years, with the easy availability of various low-cost commercial technologies, a new threat surfaced and began to proliferate—unmanned aircraft systems (UAS). Even as security forces everywhere scrambled for solutions, AME was ahead of the game and refactored its 40mm Airburst—in record time, the team proudly relates—to come up with the 40mm Counter-UAS round.

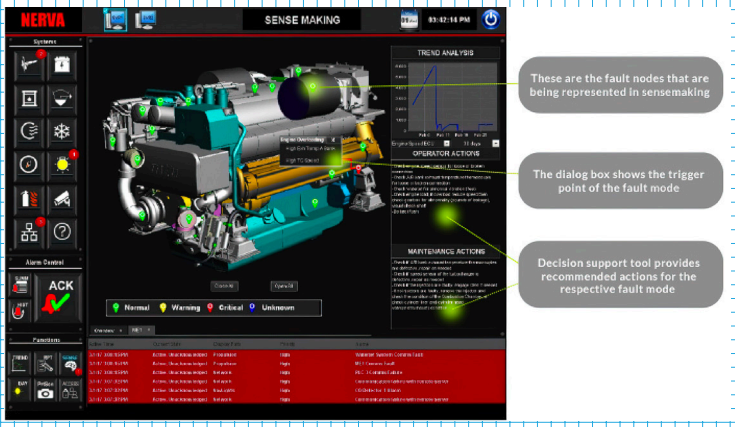
> Over decades, AME has had its vision affirmed, and it remains consistent in its strategy to grow its line-up of 40mm grenades. Today, thanks to the talent, teamwork and grit of the design and manufacturing teams, there is a 40mm variant to suit any customer need.

Getting on course with NERVA Ship Management System & Sensemaking (SMS²)

NERVA Ship Management System and Sensemaking System (SMS²) is an ST Engineering product that integrates predictive maintenance into the Ship Management System.

What use is a ship if it's not ready to sail? ST Engineering's NERVA SMS² employs data analytics and machine learning to keep commercial and naval fleets afloat.

The key to ensuring a high availability of commercial vessels or the operational readiness of naval fleets is a disciplined regime of preventive maintenance for ship systems, equipment and machinery. But sudden faults can throw a spanner in the works, leading to unplanned downtime.



One of the projects for NERVA SMS² is to provide early warning of any potential failure of the marine diesel engine at least 2 hours ahead of impending failure.

Enter the Marine entity of ST Engineering with NERVA SMS, making it the first shipbuilder to be awarded the American Bureau of Shipping's Certificate of Design Assessment. The highly capable NERVA system boasts easy and efficient operations, along with configurable modules and intelligent decision support. In integrating predictive maintenance into a centralised control and monitoring platform, the Sensemaking system further reduces downtime and maintenance costs.

Leading the project was Yue Siew Peng, a recent arrival at the Marine entity of ST Engineering bringing with her new and innovative ideas. Helping her establish NERVA SMS² in the new era of digitalisation, her team of electrical and electronic engineers was, however, lacking expertise in marine equipment. Targeting industry-approved Commercial-Off-The-Shelf (COTS) equipment for predictive maintenance required Marine Systems colleagues from the Engineering Design Centre to come alongside.

> The alliance has proven successful. One initiative has been a potential-failure detection system which can provide a two-hour early-warning window for customers to take action, significantly minimising the impact on operations.

For now, Siew Peng continues to drive enhanced sensemaking capabilities through collaborations with institutes of higher learning, domain experts and data analytics partners.

Yue Siew Peng
Project Team Lead

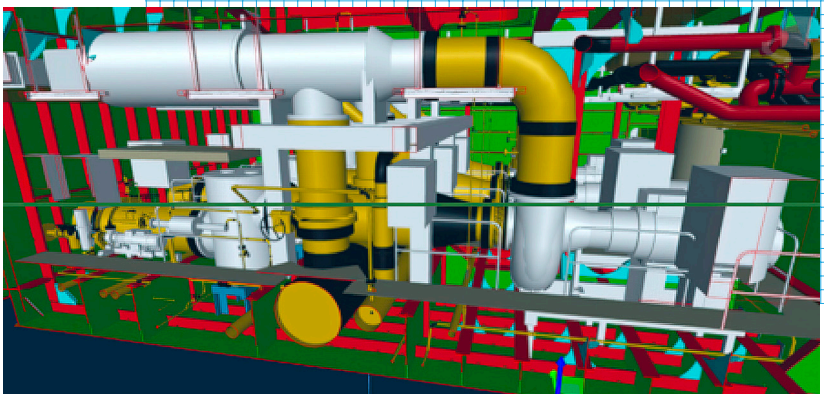
Siew Peng joined Marine in 2021 and brought with her new and innovative ideas to lead NERVA SMS² into the new era of digitalisation, enhancing it with data analytics and machine learning. She is currently driving the Sensemaking capabilities through the collaboration with IHLs, domain experts and data analytic partners.

3D Modelling Helps Optimise a Floating Power Plant

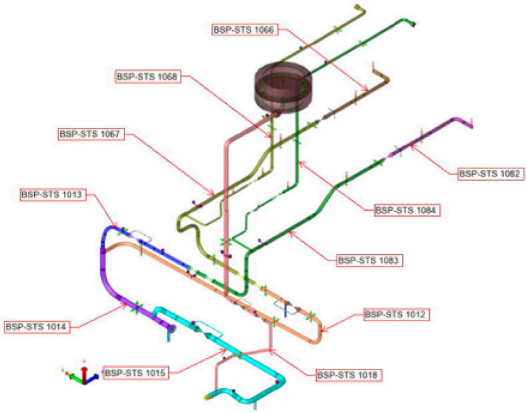
A contract to build a floating power plant becomes more challenging with a higher output requirement and smaller footprint than usual.

In the Dominican Republic, and as a small country with limited space, it is unable to support the infrastructure of a land-based power plant to ease its woes. A solution was therefore to construct a 147MW floating power plant, a venture which the Marine entity of ST Engineering partnered with Siemens to undertake. The Estrella Del Mar III (EDM III) would allow customers to tap into a clean, reliable and affordable electricity source, while conserving precious land.

However, on board the EDM III, space constraints also surfaced. Unlike typical floating power plants, this needed to be more compact, but with a larger power generation capability.



Project Lead Engineer Nick Xiao Yao was unfazed. With his team, a decision was made to digitalise the entire design process. Multiple software programmes were pooled to provide full 3D modelling as well as stress analysis and optimisation solutions.



Being able to visualise how the EDM III would look and operate greatly facilitated discussions with the customers, too. While the software got all the equipment and pipes on board to be fitted for optimal compactness and safety, customers were able to provide timely feedback to ensure the design suited their needs effectively.

The worldwide market for floating power plants was valued at approximately USD 1.0 billion in 2020, with an expected compound annual growth rate (CAGR) of 9.5 per cent. This project has given ST Engineering a foothold in the marine environmental business sector—anticipated to define the marine and offshore industry in the next three decades—especially in the floating power plant market.

Nick Xiao Yao
Project Leading Engineer

Nick joined Marine in 2010 and led this project from start to finish. Throughout this project, he was able to not only meet the expectations of his customers but to go above and beyond, through the incorporation of innovative solutions and with the close collaboration of his team members.

DroNet – Giving Drone Applications a Lift

Singapore's first unmanned aircraft system (UAS) to employ flights Beyond Visual Line of Sight (BVLOS) enables city-wide deliveries, site inspections, security surveys and more.

As unmanned technologies became more accessible and civil aviation regulations on commercial UAS relaxed, ST Engineering's Aerospace division capitalised on the opportunity. DroNet was conceptualised in 2017 with a vision to bring safe and unique capabilities to the market, which at the time consisted mainly of hobbyists.

Designing DroNet for the commercial market took into account potential customer needs including minimising manpower, time and hazards while maximising data and insights for decision making. However, drones were then generally able to operate only over sanitised areas and within visual lines of sight; getting approval to conduct BVLOS operations would thus become the team's key focus for development.

With 20 years of experience in developing UAS for the defence market, confidence was high. But creating DroNet required significant changes and new skills from the team.

Led by Zhang Yu (Design Leader on DroNet's redundancy flight control system), Guang Ye (Design Leader for FCS and GCS software development), programme manager Teo Kee Huat and product manager Lim Wen Rong took it in their stride. Where C-sharp programming had been the norm, the team was now learning to set up web-based applications and integrate controls using Robotic Operating Systems, to align with the dominant use of tablets and mobile devices in the consumer market. Polymer materials replaced the de facto aluminium the team was used to working with on manned aircraft, so 3D printing and injection moulding capabilities were brought in. New Standard Operation Procedures (SOPs) had to be written to guide practices, for safety and consistency. "Most importantly," the team says, "we had to throw our traditional work processes and mindsets out of the window in order to accelerate product development and be competitive in the industry."

> DroNet became operational within two short years. And in 2019, the robust system safety of the DroNet won the first BVLOS permit in Singapore.

In 2020, the first extensive trials with the government's Home Team Science and Technology Agency (HTX) saw over 600 successful sorties within six months. Subsequent contracts from the Public Utilities Board and the Singapore Land Authority followed. In 2022, another significant milestone was reached—the granting of the Medium Risk BVLOS permit to fly over populated areas.

Today, our UAS are seamlessly integrated with the Group Engineering Centre's AI platform to provide near-real time access to live video streams and analysed data on IoT-based architecture. Customers enjoy a full suite of services with DroNet, from the state-of-the-art drones to the all-weather DroPort for storage, control operations at DroHub and advanced real-time analytics with DroConnect.

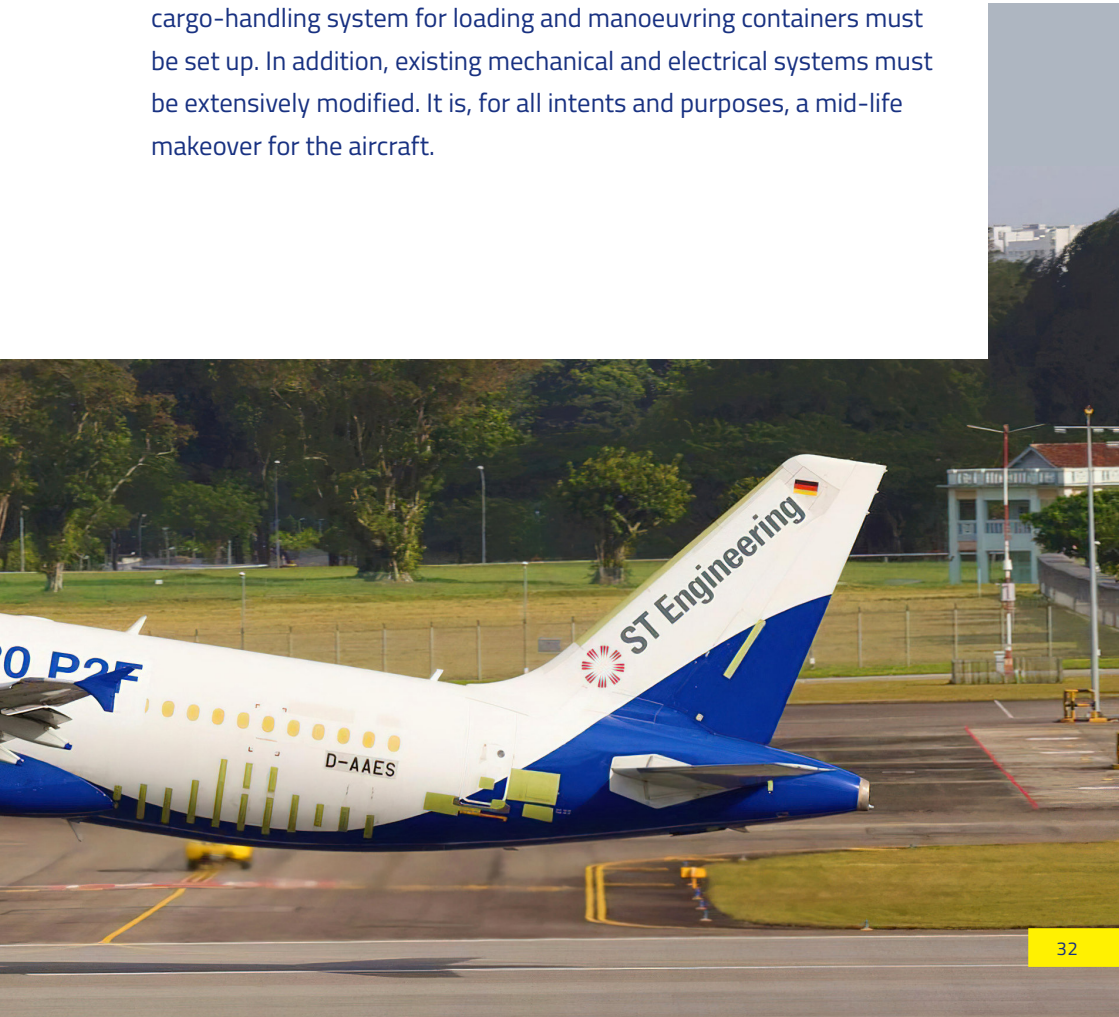
The team has a slew of upgrades in the pipeline—there is scope for continued growth for years to come.

From Passenger-to-Freighter Aircraft – New Life for the Airbus

A ground-breaking Passenger-to-Freighter (P2F) conversion programme has made the A320, A321 and A330 Airbus planes a synergised family representing the next generation of highly fuel-efficient, first-in-class freighters.

The A320/A321/A330 Passenger-to-Freighter (P2F) conversion programme, first launched in 2012, is a collaboration between ST Engineering, Airbus and Elbe Flugzeugwerke (EFW). Recycling retired passenger aircraft offers operators a more excellent modern cost-effective and greener alternative as they replace the ageing classics.

But the conversion process is a complex overhaul. Beyond removing seats, and storage bins and covering passenger windows, reinforced flooring and new sidewalls are required. A main-deck cargo door and 9G rigid barrier to protect the cockpit need to be installed; and a cargo-handling system for loading and manoeuvring containers must be set up. In addition, existing mechanical and electrical systems must be extensively modified. It is, for all intents and purposes, a mid-life makeover for the aircraft.



This engineering feat has only been made possible through the constant innovation and inspired design-thinking by our in-house design engineers and highly specialised analytical teams within the Cabin Interior & Engineering Services (CIES) group. Technical Manager Jim Tan has been a key enabler, overseeing the entire development, implementation and maintenance of the P2F conversion solution. He shared how despite various critical challenges, "the team managed to ingeniously resolve all associated technical considerations".

Jim Tan
Technical Manager

> Indeed, a high level of creativity was seen in the effort to fully maximise the A320/A321P2F main-deck payload volume. To accommodate one additional full container unit, a bold concept was adopted to re-skin the existing passenger door and develop a new, complex crew-entry door.

This provided the A320/A321P2F with an industry-leading payload capacity plus a high (85%) stowage efficiency that competing P2F products have been unable to match. All this was achieved while sustaining financial viability.

These converted freighters are now the only ones in the narrow-body segment worldwide to feature digital fly-by-wire technology, along with enhanced volume efficiency and the ability to accommodate both bulk cargo and containerised freight in their belly holds. As for the A330P2F, it offers unprecedented efficiency, with ideal volume and payload in the wide-body freighter segment. Meanwhile, additional conversion lines have been set up in China, the USA and Germany, which will ramp up global conversion capacity to more than 60 conversion slots per year by 2024.

Thanks to the thinker-engineers of the Commercial Aerospace arm, ST Engineering continues to set new standards in usability, efficiency, economics and loading flexibility that are so crucial for our freight operator customers.

Smart MRO: Maintenance, Repair and Overhaul Goes Digital

ST Engineering continuously invests in and incorporates smart technologies into our Maintenance, Repair and Overhaul (MRO) work to serve our customers better.

MRO is joining Industry 4.0. The Commercial Aerospace business area of ST Engineering is digitally enabling our workforce, making us more efficient as we add value for our customers. Transforming our hangars on four strategic fronts are digitalisation, automation, additive manufacturing and data analytics.

Championed by the Innovation & Continuous Improvement Department, inventive ideas have come alive in areas as wide ranging as inspection, predictive maintenance algorithms, additive manufacturing processes as well as design and aviation-specific robotics. Such as in-house development has made every member of the Smart MRO team a star, but we have also collaborated closely with research institutes and institutions of higher learning, and partnered with vendors to generate our solutions.

We exploited new technologies to advantage our customers. Whether it is integrated customer portals or robotics boosting productivity, end-to-end digital MRO workflows or certified additive manufactured parts for aviation applications, performance is getting better. Data analytics allow predictive maintenance to provide accurate insights on aircraft reliability and availability. Operational flexibility is enhanced. We are also cost competitive.

Making our MRO solutions and processes smarter also helps to optimise our use of resources and we are ready to expand capacity. After all, working smart brings the business to new heights.

Smart Junctions, Smooth Traffic

AI powers modern traffic junctions in our Smart City solution to day-to-day road vexations.

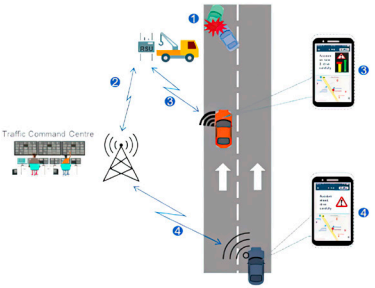
Congestion. Fuel wastage. Greenhouse gas emissions—road users want to wish these all away. Commuters often point to the ubiquitous traffic junction as a pain point, the long-established light system being less than ideal. The current fixed-phase timing it operates on works independently of traffic conditions and patterns, and calls for optimisation.

In 2018, ST Engineering's Urban Solutions business area answered the call with its first steps towards creating a smart digital junction. The technology was ripe, with video cameras and LIDAR sensors available; there was better connectivity with dynamic short-range communications; and 4G LTE and 5G infrastructure were in place. Big data and predictive analytics were also familiar tools.

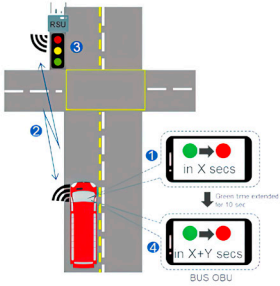
The way forward was clear for Yeo Khiaw Ming, Chua Ka Yi, Dr Zhou and Phil Gould from the Mobility Road team, and Allan Pang and Lee Choon Hong from the URS Technology Office. Describing the work as "challenging but most fulfilling", the team has since made good with a Central Management System that offers a full suite of capabilities for monitoring and managing all traffic controllers at each junction within a city's road network.

The cross-functional team from the URS Technology Office, L-R: Phil Gould, Yeo Khiaw Ming, Chua Ka Yi, Leong Royston, and Dr Zhou.

SMART DIGITAL JUNCTIONS



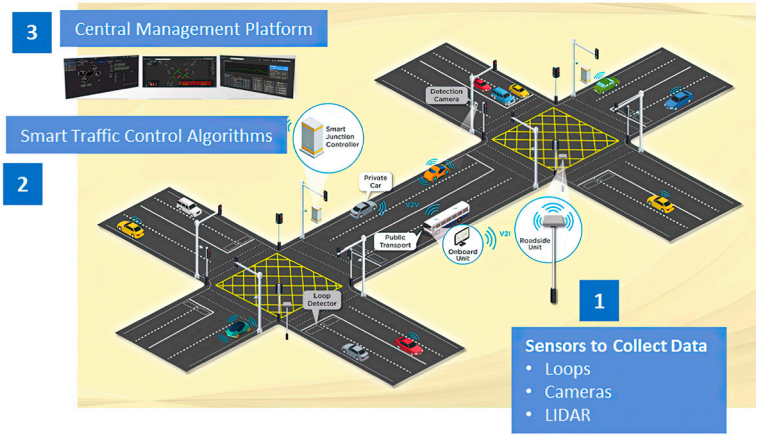
Use Case 1: Traffic Incident Alert



Use Case 2: Smart Digital Junction for Signal Priority

With traffic prediction comes timely information for motorists. Up-to-the-minute reports on road and weather conditions aid in congestion mitigation strategies. Operator-friendly interfaces employ an advanced traffic control algorithm that reduces manual intervention and potential human error. AI and big data analytics are leveraged upon to make the smart junction self-learning and able to achieve optimum traffic control. Traffic pattern recognition and real-time adaptation further enabled quick responses to unplanned incidents. The mechanism clears the way for emergency priority and right-of-way for ambulances, police vehicles and fire trucks.

SMART TRAFFIC MANAGEMENT



The smart digital junction is people- and city-centric, bringing a better travel experience and shorter travel times. It leads to fuel efficiency and fewer emissions. It is also scalable to adapt to changing junction networks and nodes in a dynamic city. It is, the team explains, a future-ready solution.

Benchmarking studies on countries with advanced intelligent traffic systems have referenced vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I), and even vehicle-to-everything (V2X) solutions. With our smart digital junction, Singapore joins Austria, China, Germany, Japan, the Netherlands, Spain, South Korea and the US in the surge towards intelligent traffic deployments.

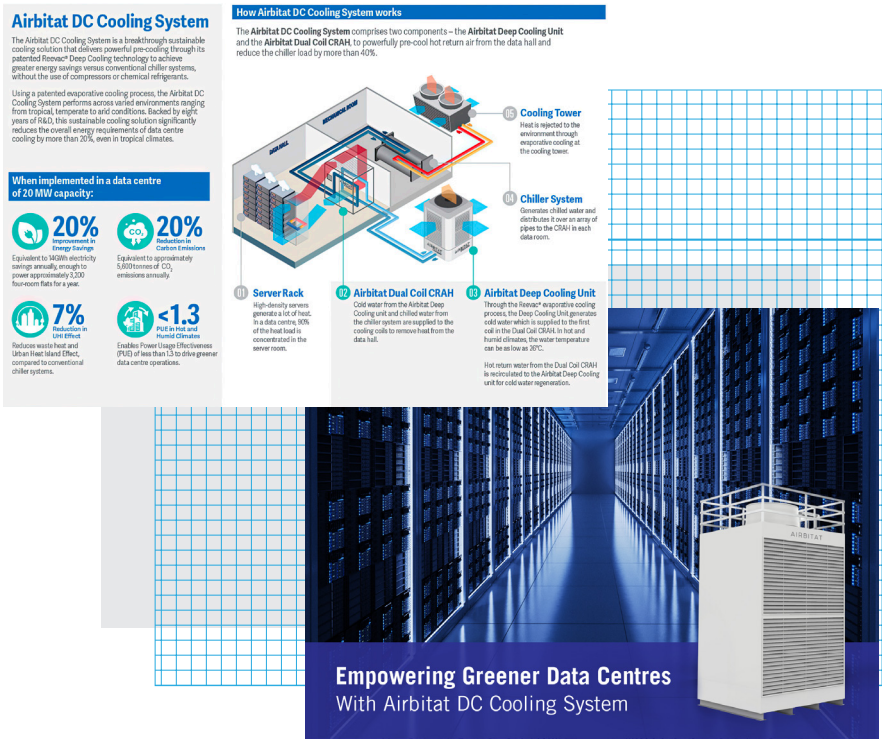
Rethinking Cooling for Data Centres – the Airbitat Goes Green

Re-engineering data centre chiller systems for Singapore's hot and humid environment results in a sustainable deep cooling solution for greener operations.

Cooling for data centres is energy-intensive, consuming up to 40 per cent of the energy a data centre might use. Their chiller systems also release excessive heat waste into the environment. This contributes to the urban heat island (UHI) effect, making the data industry unsustainable amid a growing demand for data centres. It is a problem all the more pronounced in tropical climes such as in Singapore.

The engineering team from Urban Environment Solutions (UES), Sustainable Cooling, tells of the dire need for greener technology as climate change action ramps up globally. In the drive towards sustainable cooling in data centres, countries have increasingly turned to indirect evaporative cooling (IEC) systems for pre-cooling. While effective in temperate climates, IECs success is limited in the tropics. Under the high heat and high humidity conditions here, not only is water evaporation limited, but the water generated is not sufficiently cold to offset the chiller heat load efficiently.

The challenge prompted the UES team to relook the Airbitat, their previously designed, now well-established cooling system. They found a different angle—focusing on cold water generation instead of cold air generation. Leveraging eight years of R&D on their patented Reevac® Deep Cooling technology and extensive field experience, the engineers—Li Fuyun, Hillary Yap, Andy Liu and Huang Yujun—were able to accelerate product development, coming up with the Airbitat DC Cooling System within 12 months.



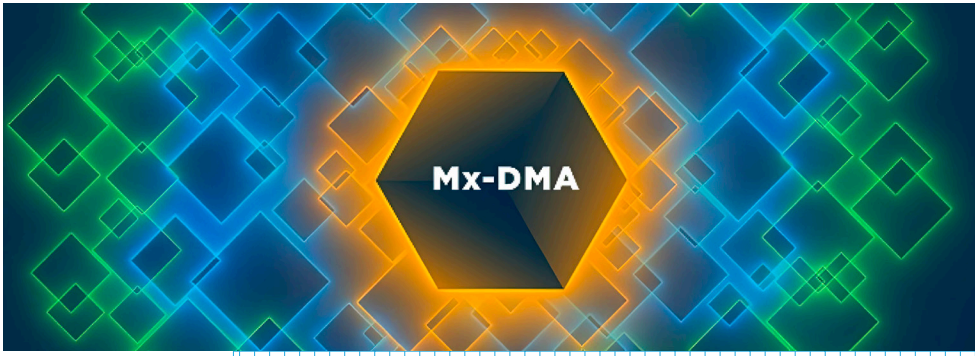
Today, a new Deep Cooling Unit couples with a mould-breaking Dual Coil Computer Room Air Handler (CRAH) to form the Airbitat DC Cooling System. Smart controls detect ambient psychrometric conditions and automatically adjust cooling modes in real-time for consistent energy-efficient cooling. Additionally, a modular design and ability to scale on demand accommodate different data centre cooling requirements as well as structural and layout constraints, allowing for easy integration in both greenfield and brownfield developments.

> Working in tandem with existing chiller systems, the Airbitat DC Cooling System enables data centres to reach a targeted Power Usage Effectiveness (PUE) of below 1.3 – representing energy savings of more than 20 per cent over conventional chiller systems alone. It also provides a 20 per cent reduction in carbon emissions and a 7 per cent drop in the UHI Effect, making it more environmentally friendly.

UES Head Gareth Tang says, "We believe that the Airbitat DC Cooling System can help the industry address its most critical challenge today and support its growth in a more sustainable manner."

Combining the Best of Satellite Waveforms: the Mx-DMA MRC

Teamwork, patience and determination bear fruit with award-winning developments in multi-access waveforms.



Legacy satellite platforms are typically based on either one of two return technologies: Multi-Frequency Time-Division Multiple Access (MF-TDMA) or Single Channel Per Carrier (SCPC). Service providers have always had to make a choice between one or the other, each having its own advantages and disadvantages. MF-TDMA has limited transmission efficiency and once the investment in the hub infrastructure and terminals is made, the cost of the satellite bandwidth remains the major recurring cost driver. Dynamic SCPC is an interesting and efficient technology, but any change in network design has a serious impact on the network itself. Services need to be reshuffled, creating significant traffic interruptions.

In 2014, iDirect, the Satellite Communications entity of ST Engineering, resolved the "SCPC versus MF-TDMA" dilemma by combining the best of both worlds in the patented Mx-DMA—a revolution in the satcom sector that won the team a Stellar award for Best Ground Segment Technology at VSAT Global 2016. It followed this up with the Mx-DMA MRC (Multi Resolution Coding), which offers unprecedented service agility, extending the availability of Mx-DMA to very large networks,

and lowering the total cost of ownership. Now, service providers can cover every use case imaginable in a single return link without making trade-offs between speed, efficiency, scale or cost. This breakthrough was recognised in 2022 with the Teleport Technology of the Year Award from the World Teleport Association.

For the people behind the innovation, who call themselves Team Comet, their work is more than a job. It is a calling, they say, which has seen them grow as the Mx-DMA family has evolved. Today, some 25 engineers make up the force.

> Their journey has not been easy. There is the challenge of orchestrating a multitude of transmissions to a satellite to prevent overlapping, which would cause interferences. To achieve this, the Mx-DMA MRC is designed to dynamically allocate resources and provide the fastest reaction time to changing user demand, ensuring all users have the bandwidth they need. The operation is seamless as no data is lost.

> Team Comet has added mass scalability to the feat, allowing the highest throughput per user and the ability to simultaneously accommodate many thousands of users with very different use patterns and bandwidth demands, on the same platform.

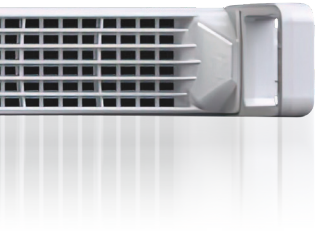
Leading satellite broadband operator Kacific was an early adopter of the technology. The Mx-DMA MRC's self-optimising capabilities have allowed Kacific to simplify network planning and do without pre-configuration. Kacific now delivers the most reliable 3G and 4G connectivity solution in the vast Asia-Pacific region, at affordable price points and with rapid return speeds on small consumer-type Very Small Aperture Terminals (VSAT) terminals. Says Cyril Annarella, Chief Operating Officer at Kacific Broadband Satellites Group, "Whether in suburban, rural or fringe and remote areas, we help businesses, governments and communities fully participate in the digital world."

Introducing Satcom's Fastest Satellite Modem: the **MDM5010**

ST Engineering's iDirect scores another industry first with a new class of modem for the most demanding requirements.

Some service providers want the fastest dedicated Single Channel Per Carrier (SCPC) links. Some desire versatile shared networks for a mix of users. But some demand both. In the trailblazing MDM5010 multi-mode satellite modem by iDirect, they have the solution.

Developed to plug the gap, the MDM5010 features an SCPC standalone mode at 1.6 Gbps of point-to-point speed and up to 1.2 Gbps in VSAT (Very Small Aperture Terminal) mode, both in a single piece of hardware. This makes it the first modem in the world to offer service providers a choice of mode (SCPC or VSAT) for a myriad of use cases.



iDirect's earlier MDM6000 standalone SCPC modem had been a success, but it had reached the limits of its capabilities even as customer demands became more exacting. Instead of opting for a successor to the 6000 series, the team hatched the idea of a line rate modem on its existing 5000 series hardware.

Over the many years developing their VSAT modem portfolio, the team has also curated best practices with a clear perspective on ease of configuration and operation. Also, well-developed is the tight collaboration between hardware and software members in the team, led by industry veteran Dave Suffys, Product Manager, Satellite IP Modems.

Just a year and a half in the making, the industry's fastest SCPC point-to-point modem, catering to both VSAT and SCPC requirements, debuted. Customers can now run a VSAT network with a mix of services ranging from 'bursty' to very high-rate traffic in VSAT mode. If a very high-rate circuit in the VSAT network continuously takes away too much bandwidth, it is now easy to offload it to its own dedicated SCPC circuit without having to swap out the remote terminal. This cuts the complexity of storing, configuring and operating multiple modem types, and allows service providers to adapt seamlessly to the end-customer's needs.

> The MDM5010 makes life much easier for our customers. As a single modem that covers all applications with the guarantee of the highest performance, it can find employment far and wide, from maritime vessels and large enterprise customers to cellular backhaul connectivity and broadcasting services.

Already, it has seen 100+ Mbps links being deployed in cellular backhauling with large trunks, bringing 4G networks to remote locations. This demand is expected to increase by at least a factor of ten with 5G networks.

ABOUT ST ENGINEERING iDIRECT

COMPANY OVERVIEW

ST Engineering iDirect is a strategic technology partner to the world's top satellite operators and service providers. It delivers advanced satellite ground capabilities that enable customers to accelerate business growth.

Throughout its 40+ year history, ST Engineering iDirect has been a driving force in unlocking the promise of satellite communications. The company played a key role in the development of the first Digital Video Broadcasting standards in the 1980s, and was later behind the first enterprise class service platform that enabled the transition to High Throughput Satellite architectures, becoming the technology partner for major satellite operators such as Eutelsat, Inmarsat, Intelsat, SES, Telenor and Yahsat, as well as leading service providers such as Marlink, Panasonic and Speedcast.

Today, ST Engineering iDirect is a global ground segment market share leader in mobility, government and broadcast markets, with centres of excellence in the US, Europe and Asia.

CAPABILITIES, PRODUCTS AND SERVICES

The company's business model is fully focused on technology and service innovation, with a portfolio that represents the industry's de-facto standard in performance, efficiency and reliability to support the profitable growth and success of the world's leading satellite operators, service providers, mobile operators, system integrators and equipment makers.

ST Engineering iDirect is pioneering a cloud-based satellite ground infrastructure platform that enables multi-orbit, multi-access technology services in a converged telco environment driven by the best business cases and market strategy. Its model for ground infrastructure is fully digitised and virtualised, based on open standards, and orchestrates dynamically configured space resources with real-time demand on the ground. It advances key aspects of a satellite network from more powerful waveforms and more intelligent bandwidth allocation to more capable remotes. It transforms satellite service delivery to be perfectly seamless, significantly more economical, infinitely scalable, and can deliver the required data rate and functionality for any possible application that satellite connectivity can support.

ST Engineering iDirect is leading the industry adoption of the 5G mobile standard, achieving major testing milestones in the integration of satellite services within the end-to-end converged network.

The Hunter Armoured Fighting Vehicle – A big leap in capabilities through digitisation*

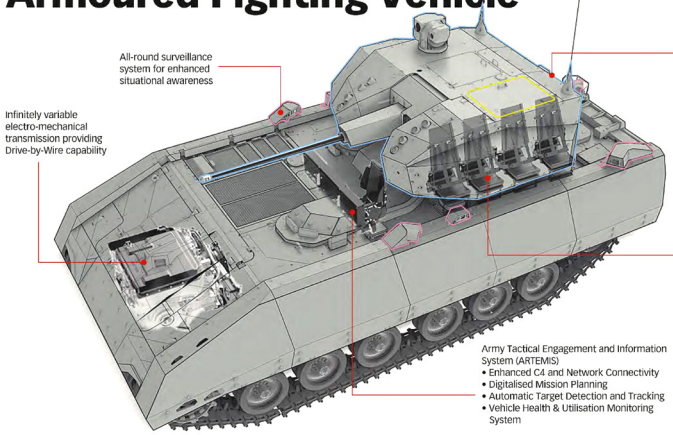
Developed for the Singapore Army, the Hunter is the latest from a lineage of locally developed armoured fighting vehicles (AFVs) by ST Engineering which includes the Bionix, Bronco and Terrex, as well as several variants of these models.

*This story is drawn from material featured in the following media reports: "Bionix to Hunter – the Evolution of a Singapore-made Armoured Fighting Vehicle," The Straits Times, 19 June 2019; and Charmaine Ng and Lim Min Zhang, "Team behind next-gen Hunter Armoured Fighting Vehicle bags defence tech prize," The Straits Times, 25 October 2019.

It is a testament of Singapore's stellar heritage in defence engineering capabilities, one that stretches back more than a decade with a bold vision – to develop a land combat vehicle that offers the same level of situational awareness as the cockpit of a fighter jet.

In line with the design guidelines from the Defence Science and Technology Agency (DSTA), the Hunter is designed for growth, through an open and modular Vehicle Electronic Architecture (VEA) which helps to reduce integration risks and facilitate future technology insertions. The Hunter's Remote Controlled Weapon Station (RCWS) is integrated with the VEA to leverage on the full potential of a digitisation platform. Through the VEA, the AFV will be able to integrate with unmanned platforms in the future to gather reconnaissance and surveillance information.

Bionix to Hunter –
the Evolution of a Singapore-made Armoured Fighting Vehicle



HUNTER AFV IN NUMBERS

MORE THAN 1,000,000 MAN-HOURS from conceptualisation to design, test and build

60,000+ KILOMETRES OF CUMULATIVE MILEAGE TO DATE

1,400+ PARTS PER VEHICLE PRODUCED IN SINGAPORE

1,000+ METRES OF WIRING PER VEHICLE

100+ SMEs with workforce of more than 2000

5 VARIANTS IN THE FAMILY

1 VISION To build an advanced digitalised fighting platform for the future battlefield

Another key feature of the Hunter is its communications capabilities. Compared with older AFVs, it has been enhanced with a system architecture that is not just modular to enable easier upgrades, but also fully accommodates both hardware and software systems. As such, the Army Tactical Engagement, and Information System (ARTEMIS) deployed on the Hunter, comprising vehicle, weapon, and communications controls, is no longer a standalone subsystem within any one vehicle, but one that has acquired the capabilities to link up with other vehicles as well as battlefield command with improved connectivity.

The Hunter also features drive-by-wire technology, where both driver and vehicle commander can switch roles without leaving their seats. In addition, the Hunter also employs a closed-hatch system which offers better safety especially in urban environments. A closed-hatch operation is one in which the crew can view their surroundings onscreen with an all-camera system without the need for the vehicle commander to look out of the turret and potentially be exposed to sniper fire.

Engineers on the Hunter programme at work.

To meet the requirements of a fully digitised platform, the Land System Vetronics and Software Team worked very closely with DSTA, Digital System and dedicated local SMEs to identify requirements, ideate possible solutions, build prototypes, evaluate, test, and produce the final product. Functional and workflow testing were made simpler, faster, and more complete with the introduction of System Integration Laboratory Testing (SILT), which reduces vehicle integration risks significantly. Safety is always of paramount importance, and this required the design engineers to fully understand the operations of the entire digitised system and its corresponding safety considerations.

> The Hunter programme involved more than 100 local SMEs, with a workforce of about 2,000 people, producing more than 1,400 parts in each vehicle. ST Engineering took the lead to develop a robust local defence ecosystem. which will continue to offer both the breadth and depth of technology and engineering capabilities for the manufacturing and production of the Group's advanced solutions.

The team responsible for the Hunter programme, comprising members from ST Engineering, DSTA and the Army, were recognised for their engineering achievements in developing the AFV at the Defence Technology Prize Award Ceremony in October 2019.

Pervasive Connectivity Yields a Smart Crane, Smart Yard System

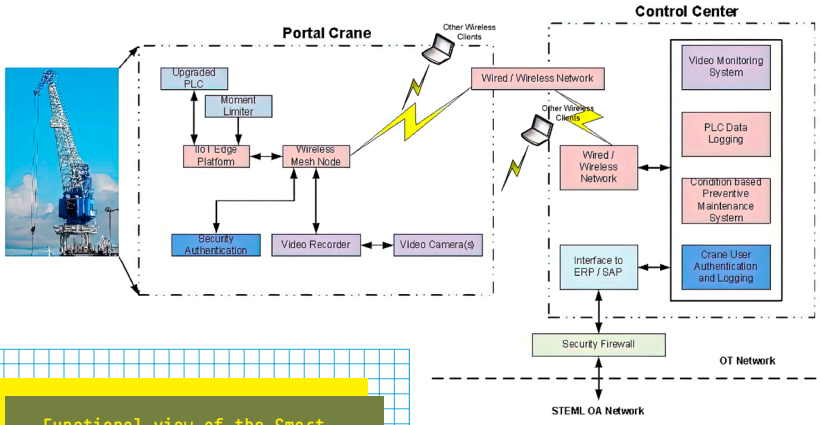
A partnership with A*STAR's Institute for Infocomm Research (I^2R) makes for efficient crane operations at the shipyard.

Shipyards often face difficulties in authenticating, monitoring and logging access to crane operator cabins, but a joint project between ST Engineering and I^2R has shown the way forward. Not only that, but their work has brought docks up to speed with Industry 4.0, across diverse operations.

RESEARCH TRANSLATION
@ ST ENGINEERING

Pervasive wireless connectivity was the goal right from the team's formation in 2019. Coming together under the 'Research Translation@ ST Engineering' umbrella, it took advantage of commercial off-the-shelf wireless access points, enhancing them with A*STAR's custom IP to reduce latency and increase the robustness of the connectivity. No longer are wireless signals blocked, reflected back or inaccessible in the crowded dock environment.

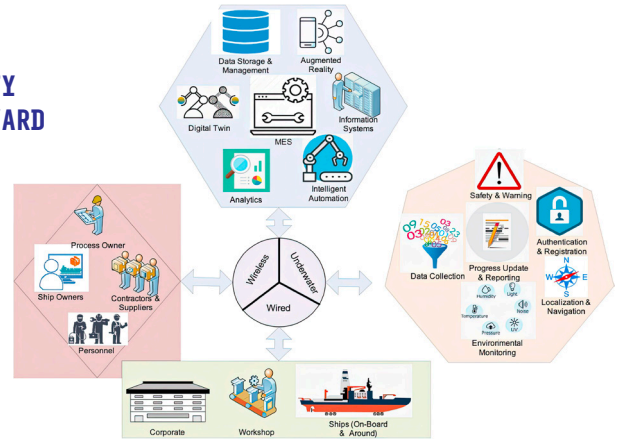
SYSTEM FUNCTIONAL VIEW



Functional view of the Smart Crane Monitoring System

Across the shipyard, options for more IIoT applications—and even greater efficiency—are now open. The monitoring and tracking of machines, materials and staff are possible on the platform. A further improvement has come with the utilisation of machine learning (ML) to generate maintenance insights. Captured PLC data from the cranes was used to train the ML model, which determines individual sub-system usage of the cranes and classifies them accordingly. A preventive maintenance programme based on this information has since reduced down-time at the shipyard.

PERVASIVE CONNECTIVITY FOR SMART YARD



ST Engineering Marine started pursuing the smart yard concept in 2019 in line with Industry 4.0 concepts. Innovation and digitalisation of the shipyard operation process has optimised cost effectiveness, efficiency and productivity.

HaLow, a low power long range Wi-Fi standard, is the long range wireless backbone.

Dr Syed Naveen Altaf Ahmed, Principal Investigator for I²R, called this a "meaningful collaboration" which has effectively addressed operational challenges. The solutions from the team, which includes ST Engineering Marine's leaders Tan Kok Kong and Adikari Mudiyanselage Nihal Dharma Sri Adikari, have allowed shipyards to perform real-time monitoring, logging and analysis. Man-hours are saved, with equipment status, operation records and video footage all made available at the control centre. Shipyards are now smart yards.

Dr Syed Naveen Altaf Ahmed, Principal Investigator of the Smart Crane Monitoring System, Institute for Infocomm Research (I2R), A*STAR.

Says Professor Tan Sze Wee, Assistant Chief Executive, Innovation & Enterprise, A*STAR, "We're proud to have been part of ST Engineering's innovation journey… co-creating more opportunities that will uplift Singapore's ecosystem."

left
Tan Kok Kong
Engineering Project Lead

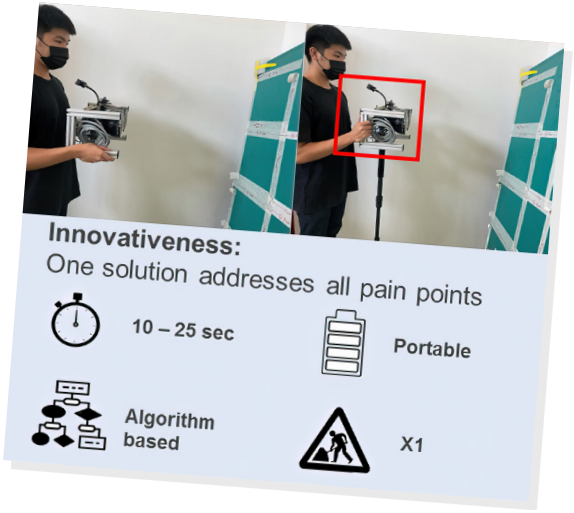
right
Adikari Mudiyanselage Nihal Dharma Sri Adikari
Engineering Project Lead

"Through this project we were able to achieve operational excellence with pervasive connectivity, tracking, live feed and data analytics."

Integrated Infra-Red Thermography for Rudder Repairs Takes Off

New technology from A*STAR and ST Engineering leads to a new way of working and soaring efficiency for the aircraft maintenance, repair and overhaul (MRO) sector.

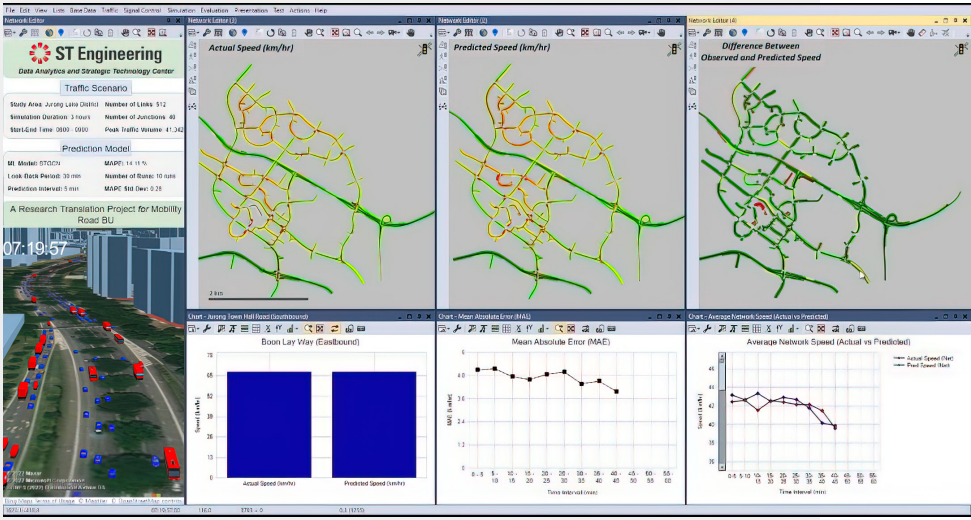
Two persons working at height, wielding a thermal camera and an air heater in a painstaking operation—this is how routine inspections for water ingress in aircraft rudders are traditionally performed. The process is critical when it comes to ensuring the structural integrity of an aircraft. If any water is detected, follow-up repairs can be immediately carried out. But first, an ultrasonic test is required to confirm the suspected anomalies are indeed water, not resin. In an industry facing manpower constraints, this process is a significant stress on resources.



Dr Andrew Ngo, Division Director (Composites and Structural), Institute of Materials Research and Engineering, A*STAR, Principal Investigator for the Infra-Red Thermography (IRT) for Water/Resin Differentiation project

Transforming this time-consuming and labour-intensive job is an integrated active infrared thermography (IRT) system developed by ST Engineering with A*STAR's Institute of Materials Research and Engineering. In its first phase of development, the portable system immediately halved the manpower required, by capturing indicators of water ingress in the carbon fibre reinforced polymers (CFRP) panels without the need for a heat gun. In the project's second phase, an algorithm that is able to automatically distinguish between water and resin further slashed man-hours by eliminating the ultrasound test as well.

Principal Investigator Dr Andrew Ngo, Division Director (Composites and Structural) at A*STAR, notes the economic impact of the project. Not only has productivity more than doubled for such inspections, but there is great potential for the new technology and its applications as well, once licenced.



Smoothing Urban Traffic Flows

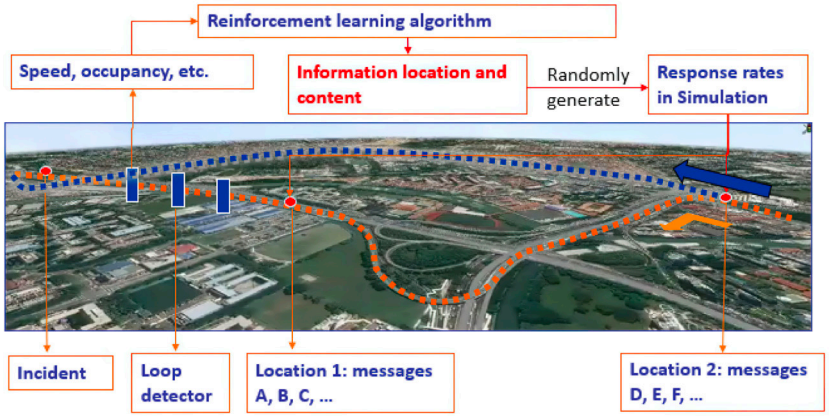
It takes a wide array of strategies making full use of data analytics and artificial intelligence to provide a smooth commute. This calls for the skills of an equally extensive multi-disciplinary task force – one spanning several faculties of the National University of Singapore (NUS) and ST Engineering.

Urban traffic flow is a function of multiple static and dynamic factors. Real-time as well as predicted traffic information, along with a pro-active traffic system that is able to diffuse congestion and mitigate disruptions, can offer commuters a seamless road experience.

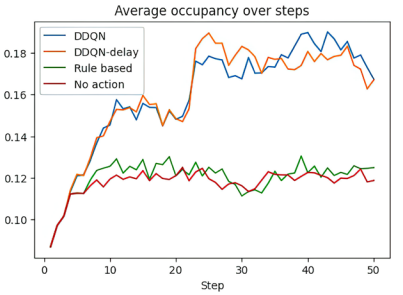
> Taking an innovative data-driven approach were teams from NUS' Civil and Environmental Engineering, Industrial Systems Engineering and Management, and Mechanical Engineering schools. ST Engineering's Data Analytics Strategic Technology Centre (DA STC) then bridged the collaboration with the Mobility Road team, for a high-fidelity traffic simulation model that is as robust as it is scalable and portable.

Reinforcement machine learning models predict traffic conditions, which helps road users to plan trips efficiently—especially important for freight transporters trying to reduce costs. In the event of a traffic incident, in-depth insights into the performance of road networks and automated guidance strategies can shorten the response time by transport agencies. The potential for the Traffic State Prediction module has even received international recognition, with plans on the cards for trials in commercial projects abroad.

A framework for effective traffic signal control was also developed to optimise the passage of traffic. Real-time data, collected over 5G from roadside sensors and cameras, is fed into a centralised controller which dynamically coordinates the traffic signal timing at multiple intersections. Fluctuations in traffic flows at various times are thus smoothed. Together with the traffic information and incident regulation modules, well-managed traffic is on its way to becoming a reality.

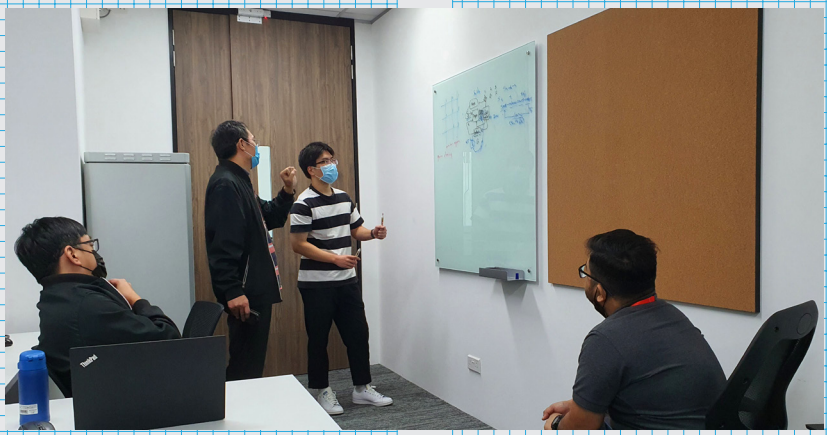


An illustration of the proposed reinforcement learning-based approach for traffic diffusion and dissemination strategy.



An illustration of the average occupancy over multiple time steps.

An illustration of the average queue delay over multiple time steps.




Data Generation Progress
Stage 0
Stage 1

Opportunities Ahead for eVTOL Aircraft

ST Engineering is providing the thrust to Singapore's ambitions in the global race to develop electric vertical take-off and landing (eVTOL) technologies and advanced air mobility (AAM).

When it comes to unmanned aircraft systems (UAS), ST Engineering has set its sights on middle-mile logistics for heavy-lift cargo. The transport of these massive loads presents an opportunity worth evaluating, even as advancements in drone technology and worldwide regulations for commercial applications have climbed in the past four years or so. Having conducted market and feasibility studies, the time is ripe for venturing into this new business.

Coming on as a valuable partner is Nanyang Technological University (NTU), whose aspirations to position Singapore in the lead are strongly aligned with ours. The plan: to validate new knowledge and innovations from researchers and industry partners with a customised aircraft. The joint team is developing deep expertise in core eVTOL aircraft technologies—some which are yet to be realised in Singapore.

From electric propulsion to light weight structure and materials; advanced composite manufacturing processes to autonomous control; and from systems engineering and integration to aircraft vehicle design, the team has its work cut out for them. Eliminating development risks while building capability for product sustainability is part of the process, made easier by leveraging on ST Engineering's matured DroNet flight operating system for drones.

The ambitious eVTOL Technology Demonstrator on a 1/5th scale aimed to fly with up to 150kg of cargo. The team will eventually be working towards registering a fully-developed 5-seater, 3,175kg eVTOL with the European Union Aviation Safety Agency (EASA) by 2030.

Stay tuned as the team explores potential growth in the passenger eVTOL space.

Intelligent and Adaptive OT Cybersecurity

System fault or cyber threat? An intelligent solution works around the constraints of a secure Operational Technology (OT) environment to boost cybersecurity in critical infrastructure.

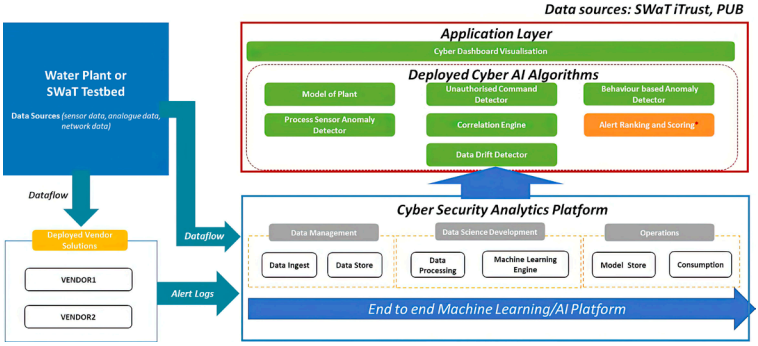
ST Engineering's growing OT cybersecurity business offers solutions and services to a wide variety of clients. Among them are water distribution and water treatment plants, whose critical OT/IT infrastructure require careful monitoring. However, not being connected to the internet as part of the cybersecurity arrangement means machine learning systems cannot be easily trained to improve detection accuracy. In addition, standard OT cybersecurity solutions are unable to determine whether detected anomalies are actual cyber threats or merely system errors.

Linking up with Prof Chen Binbin and his Information Systems Technology and Design team at the Singapore University of Technology and Design (SUTD), our own Dr Andrew Yoong and Ivan Lee from the Group Engineering Centre and Cybersecurity have taken on the challenge. Their partnership is a seasoned one, having collaborated previously in the National Research Foundation-seeded cybersecurity Corporate Laboratory initiative.

Supported by the Cyber Security Agency of Singapore (CSA) and PUB, this new project aims to build an intelligent system that is able to piece together the output of various sensors and anomaly detectors in an OT plant, and present a comprehensive situational picture. A cyber security analytics platform will then deploy this system in a secure OT environment. The difference will be in its ability to adapt, learn and become more accurate as operational data and user feedback is absorbed. Users will be able to differentiate system faults from potential cyber alerts, helping OT plant operators to detect cyber-attacks early and prevent any catastrophic impact.

With the success of this project in sight, plans are already in place to adapt the solution for other critical infrastructure, as it is easily extended to include new detectors.

ADAPTIVE AND INTELLIGENT CYBER MONITORING SOLUTION FOR OT (WITH SUTD)



ST Engineering has a growing Operational Technology (OT) cybersecurity business vertical, with solutions that cater to services from monitoring OT/IT infrastructure to the detection of anomalies in water distribution and water treatment plants.

Network Connectivity Over Singapore Waters

Autonomous tugs and remote pilotage improve port efficiency, but a lack of connectivity hampers operations. A private Open Radio Access Network (O-RAN) is ST Engineering's answer.

The waters of Singapore's ports are busy, and facilitating the work is a fleet of autonomous tugs and remote pilotage operations. However, these suffer from critical disruptions in communications with the control centre, caused by insufficient network coverage, low data rates and high latency. Uninterrupted network connectivity is necessary for the real-time streaming of the tugs' video signals, as well as for remote pilotage. Currently, public networks are unable to provide the much needed coverage due to their own business considerations.

Compounding the problem is heavy vessel traffic in the port environment, adding severe interference and pockets of blind spots over the sea passage. An earlier study conducted by ST Engineering and MPA had only confirmed the great challenge in maintaining highly reliable and continuous connectivity in the stretch of water from Marina South to Pasir Panjang Terminal.

To Singapore University of Technology and Design (SUTD) Professor Tony Quek, the solution was clear-cut: an Open-RAN 5G private network deployed across the harbour, optimised to meet the requirements of the autonomous tugs and remote pilotage. Adapted 5G terminals would also need to be installed on board the autonomous tugs and remote-piloted vessels. A fix did not exist, but a research team was organised at the university to develop one, working closely with ST Engineering's team of 5G Engineers. This coalition would leverage SUTD's AI and the national Future Communications Research & Development programmes, while also taking advantage of ST Engineering's vast 5G project experience across use cases in defence, public safety and more.

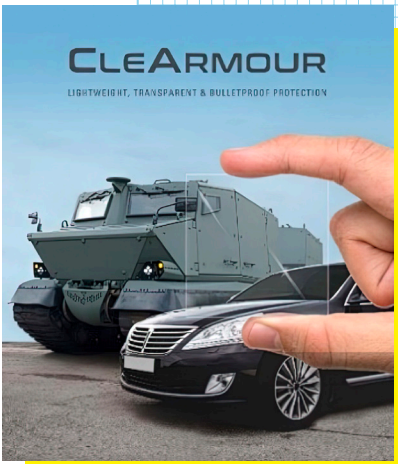
If successful, this new end-to-end solution they are devising will significantly transform maritime operations in Singapore, establishing the country as a global leader in the sector. The deployment of a highly reliable, high quality-of-service 5G network over Singapore Port waters will go a long way to support our national economy and maritime aspirations in the years ahead.

Professor Tony Quek

Novel Methods in Transparent Ceramics Manufacture

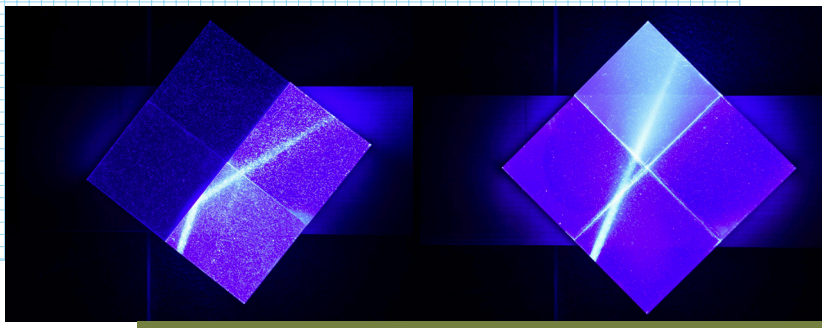
Researchers shatter current limitations on how transparent ceramics are made and used.

Glass is only as hard as ordinary sand. It falls short of expectations when it comes to chemical, scratch and impact resistance, and cannot bear the loads expected in some high performance applications. Transparent ceramics are excellent replacements for glass-based protective systems, but their manufacture requires conditions of high heat and high pressure that affect both production throughput and costs. Expensive tooling and processing also limit the range of sizes available for industrial use.



Transparent ceramics are excellent replacements for glass-based protective systems, but their manufacturing requires conditions of high heat and high pressures that affect the production throughput and production costs.

While transparent ceramics have had early successes in niche areas such as laser gain media, their full potential has yet to be realised in large-scale engineering applications. When used as substitutes for traditional materials in transparent windows, various challenges become clear. The understanding of how such materials perform still lags, and industry standards are lacking. But there was a breakthrough when researchers at ST Engineering and the National University of Singapore joined forces.



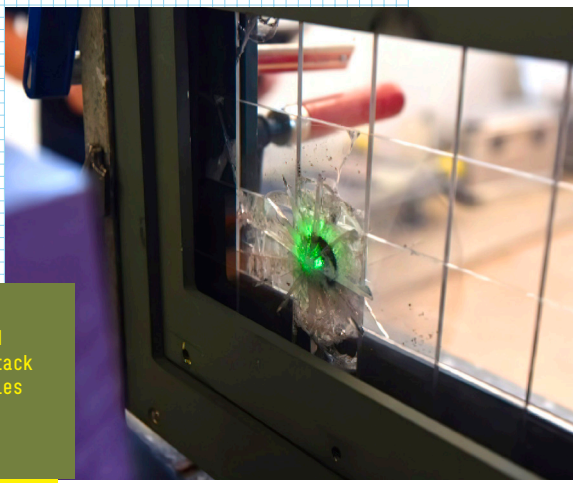
Control sample without optical coupling (left); full optical coupling achieved through the novel bonding method developed (right).

The team from ST Engineering comprised Dr Jeremy Koh (Principal Material Scientist), Eric Lim (Product Chief Engineer), Douglas Chong (Lead Chemist), and Dr Tan Sheng Cai (Product Director), who were tireless in their experimentation work. Together with Prof John Wang (Research Collaborator & Technical Consultant) from the National University of Singapore, they were able to modify the very tight compositional chemistries of the material to arrive at a unique formulation allowing transparent magnesium aluminate spinel to be formed at significantly lower pressures.

They also developed an approach to scale production for large format applications, centring on how the material could be joined. This resulted in a novel bonding method which conserved both the

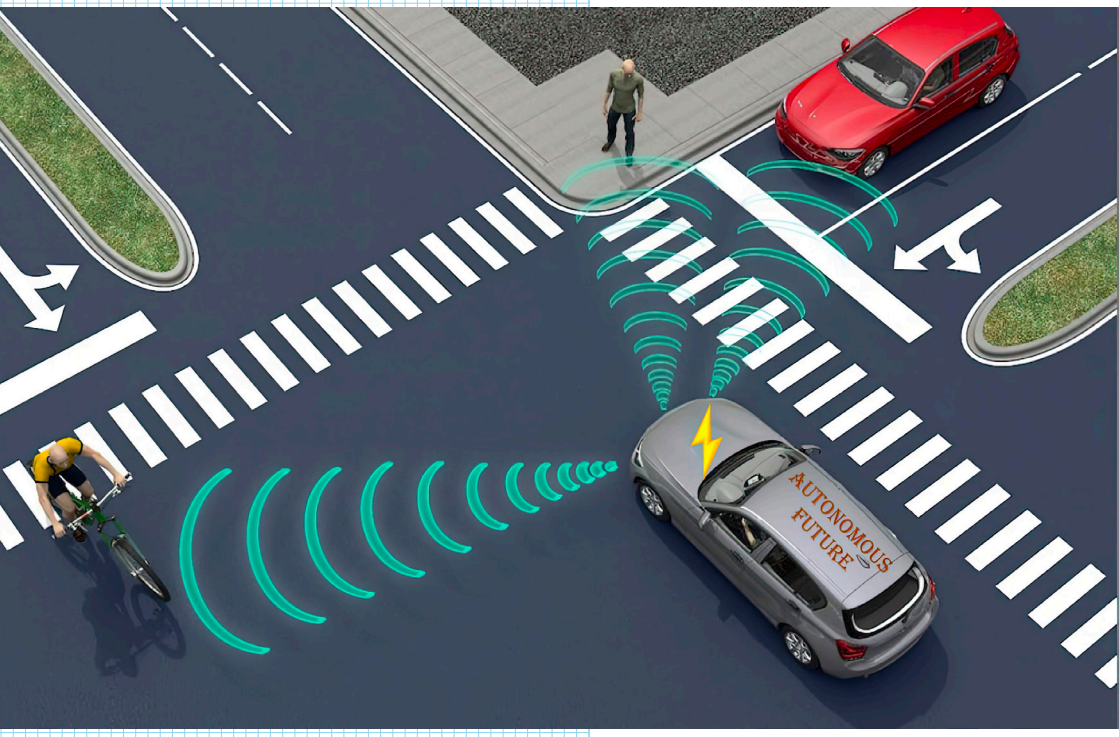
mechanical and optical properties of the material. A fully functional transparent protective window system the team fabricated proved to be superior to conventional armour glass—while being produced at a lower energy cost and higher throughput.

This project has pushed the boundary of applications for synthetic magnesium aluminate spinel. Already, such systems have been incorporated into a variety of products for multiple dual-use functions. The lowered barrier of technology adoption now ushers in the use of high-performance transparent ceramics across a sweep of high-value protective applications.



Excellent residual visibility achieved through superior crack arrestment properties of CleArmour protective windows

Moving Forward with AI in Transport Technology



Vehicles with automated driving (AD) capabilities represent the future of transport, but can they handle a mixed traffic environment safely? Artificial intelligence (AI) techniques pave the way.

Prof Wang Dan Wei is an expert in multi-modal perception, autonomous driving and 3D digital twinning. From his base at the School of Electrical and Electronic Engineering in Nanyang Technological University (NTU), Prof Wang says, "The next phase of NTU-ST Engineering collaboration will drive autonomous systems technologies to new heights."

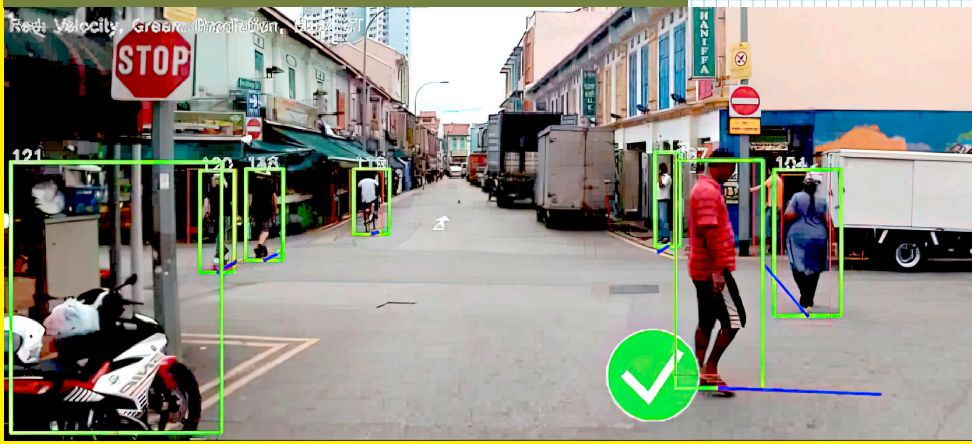
Professor Wang Dan Wei

Beyond the transition from fossil fuels to greener and quieter electrical batteries, Prof Wang envisions a sustainable transport ecosystem that includes electric vehicles fitted with AD technology. He is working in tandem with Dr Alok Prakash, Head of Research and Collaborations at ST Engineering's Autonomous Solutions division, to see the vision through. Their cooperation is part of a well-established partnership between the two organisations, combining NTU's deep research capabilities with ST Engineering's longstanding track record of successful real-world translation and deployment.

Even as Prof Wang and Dr Prakash are working to introduce AD transport, they are mindful of how autonomous vehicles must learn to co-exist with other road users, including driver-operated vehicles, cyclists and pedestrians. Enabling AD vehicles to safely navigate among them entails developing a slew of supporting technologies. From real-time environment perception in all weather and illumination conditions to understanding and predicting the intentions and trajectories of other road users, intelligent models need to be developed and matured.

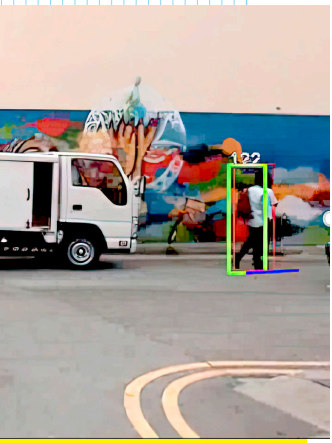
PREDICTING TRAJECTORIES OF PEDESTRIANS

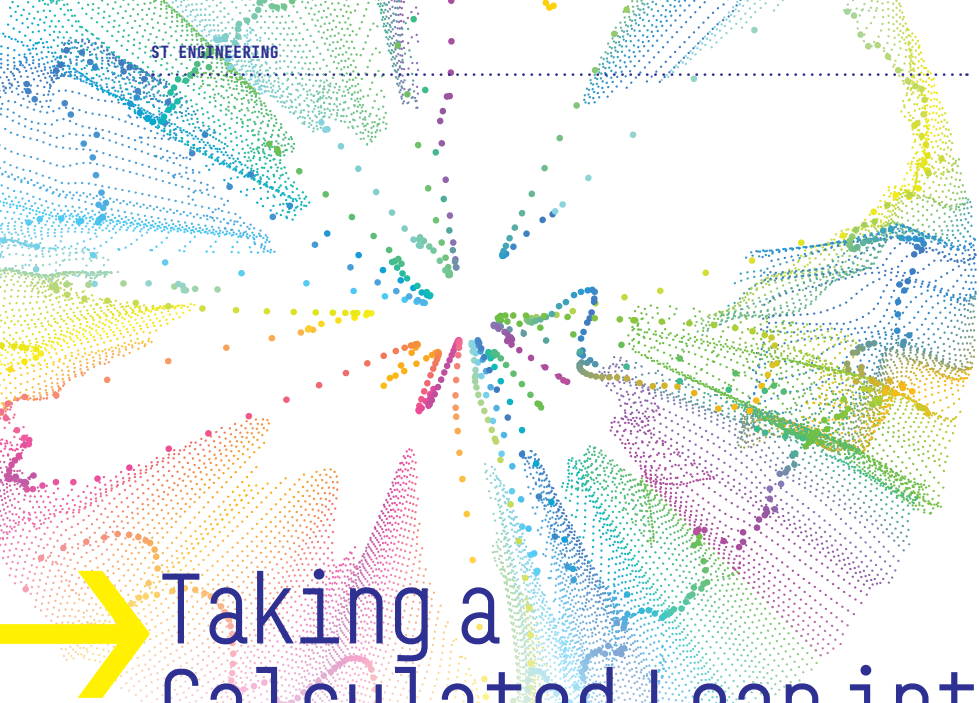
While current state-of-the-art systems can effectively perceive their environments during broad daylight, innovative Artificial Intelligence (AI) and Deep Learning (DL) based technologies will be developed to improve the perception capabilities during rainy and dimly lit conditions.



AI and Deep Learning will come into play, as will lidars, cameras and radars. Novel hardware and software optimisations will be explored in the quest to meet the real-world requirements of AD systems. At the same time, there are strict power, size and weight budgets, so as to avoid reducing the primary task of the vehicle, which is to ferry commuters. Real-life trials will be undertaken to ensure the efficiency as well as the safety of the proposed technologies prior to a wider deployment.

Dr Prakash is looking forward to bringing out a world-class product. Autonomous vehicles with home-grown AD technology will one day navigate our roads without compromising safety, and commuters can be comfortable and confident.





Taking a Calculated Leap into Quantum Technology

ST Engineering joins the Centre for Quantum Technologies in the exciting race to develop the next big thing using quantum science.

It is one of the most promising technologies to emerge in recent years, drawing deep investments from governments worldwide. Quantum technology sees active research across the globe, with top universities, tech giants and start-ups equally pushing the boundaries in search of a breakthrough. The next generation of quantum computers, networks and sensors are expected to be highly disruptive.

Singapore has allocated national funds to R&D in quantum technology since 2007. The Centre for Quantum Technologies (CQT), which is hosted at the National University of Singapore (NUS), brings together physicists, computer scientists and engineers to explore its potential. Over the past year, ST Engineering has established a close partnership with CQT, joining our engineering capabilities with CQT's deep scientific know-how in various collaborations. Now, the partnership is set to strengthen with the participation of Professor José Ignacio Latorre, Director of CQT at NUS' Department of Physics.

José Ignacio Latorre was appointed Director of the Centre for Quantum Technologies in July 2020. He is also Professor in the National University of Singapore's Department of Physics.

On the cards is the building of real-world applications that exploit quantum technology. The development of Quantum Key Distribution (QKD) capabilities for advanced cybersecurity is ongoing, while new areas of research include quantum sensing for detection and navigation, and quantum computing hardware and software. As ST Engineering leverages and extends our in-house competencies in control electronics, photonics, software and systems integration to quantum engineering, we are, at the same time, developing indigenous capabilities and local talent in this futuristic field. Our doing so supports Singapore's national quantum strategy, towards a robust quantum ecosystem.

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